Honeywell

4803
Precision FotoFiber Sensor

User's Manual

6510020314

4803 Precision FotoFiber

October, 2009

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Introduction

The purpose of this manual is to provide an introduction to the operation, setup and use of the Honeywell Surface Fiber Orientation Sensor. The 4803 Precision FotoFiber Sensor has been designed to be used with Da Vinci systems. The features of this sensor can be fully utilized with RAE 5 or newer systems.

Audience

This manual is intended for use by engineers or process engineers and assumes that the reader has some knowledge of the operation of a paper machine and a basic understanding of mechanical, electrical and computer software concepts.

About This Manual

This manual contains the following chapters:

Chapter 1, **Introduction to Fiber Orientation in Paper and Board**, describes what is paper fiber orientation, how the papermaking process can affect it, and how to rectify some fiber orientation problems.

Chapter 2, **FotoFiber Structure and Operating Principle,** gives an overview of the FotoFiber fiber orientation sensor structure and its operating principle.

Chapter 3, **Da Vinci FotoFiber Software,** describes communication functions between the FotoFiber sensor and the Da Vinci system, as well as the Da Vinci operator interface.

Chapter 4, **Detailed FotoFiber Structure,** gives an overview of the sensor's internal structure – electronics, pneumatics and software – and describes sensor hardware configuration.

Chapter 5, **Installation**, describes physically installing and removing the sensor, and related post-installation configuration of the Da Vinci server and the MSS.

Chapter 6, **Maintenance**, describes the standard procedures used to keep the sensor in good working order and to perform field repairs and updates.

Chapter 7, **Troubleshooting**, gives a number of approaches to diagnosing and solving problems which might arise.

Chapter 8, **Appendices**, contains additional related material.

Related Reading

The following documents contain related reading material.

Honeywell p/n	Document Title / Description
N/A	

Conventions

The following conventions are used in this manual:

ATTENTION	Text may appear in uppercase or lowercase except as specified in these conventions.

`Boldface`	Boldface characters in this special type indicate your input.
`Special Type`	Characters in this special type that are not boldfaced indicate system prompts, responses, messages, or characters that appear on displays, keypads, or as menu selections.
Italics	In a command line or error message, words and numbers shown in italics represent filenames, words, or numbers that can vary; for example, filename represents any filename. In text, words shown in italics are manual titles, key terms, notes, cautions, or warnings.
Boldface	Boldface characters in this special type indicate button names, button menus, fields on a display, parameters, or commands that must be entered exactly as they appear.
lowercase	In an error message, words in lowercase are filenames or words that can vary. In a command line, words in lowercase indicate variable input.
Type	Type means to type the text on a keypad or keyboard.
Press	Press means to press a key or a button.
`[ENTER]` or **`[RETURN]`**	**`[ENTER]`** is the key you press to enter characters or commands into the system, or to accept a default option. In a command line, square brackets are included; for example: **`SXDEF 1 [ENTER]`**
`[CTRL]`	**`[CTRL]`** is the key you press simultaneously with another key. This key is called different names on different systems; for example, **`[CONTROL]`**, or **`[CTL]`**.
`[KEY-1]-KEY-2`	Connected keys indicate that you must press the keys simultaneously; for example, **`[CTRL]-C`**.
Click	Click means to position the mouse pointer on an item, then quickly depress and release the mouse button. This action highlights or “selects,” the item clicked.

Double-click	Double-click means to position the mouse pointer on an item, and then click the item twice in rapid succession. This action selects the item “double-clicked.”
Drag X	Drag X means to move the mouse pointer to X, then press the mouse button and hold it down, while keeping the button down, move the mouse pointer.
Press X	Press X means to move the mouse pointer to the X button, then press the mouse button and hold it down.
ATTENTION	The attention icon appears beside a note box containing information that is important.
CAUTION	The caution icon appears beside a note box containing information that cautions you about potential equipment or material damage.
WARNING	The warning icon appears beside a note box containing information that warns you about potential bodily harm or catastrophic equipment damage.

1 Introduction to Fiber Orientation of Paper and Paperboard

1.1 What is Fiber Orientation?

Paper and similar products are formed of networks of fibers which are intertwined in a thin sheet. An image of such a sheet is in Figure 1-1. The fibers are laid approximately flat in the sheet, since the sheet is thinner than the length of a typical fiber. The fibers also are aligned at many different directions, essentially randomly. Note, however, that although the alignment directions are random, more fibers are aligned in some directions than others.

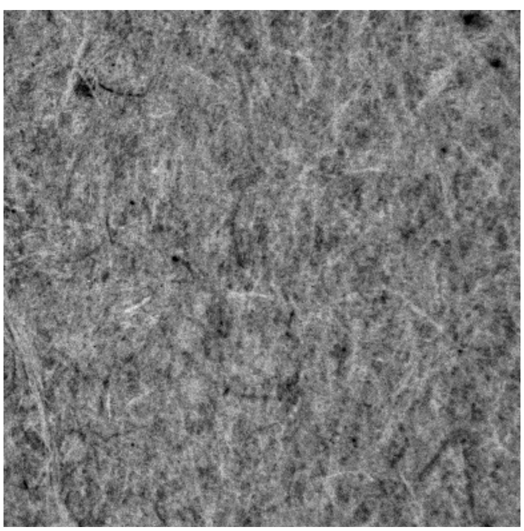


Figure 1-1. Image of paper surface epi-illuminated with annular light (image taken with FotoFiber sensor, contrast enhanced)

If each individual fiber in the image were isolated, and its angle measured, a histogram could be constructed for the number of fibers at each angle. This histogram describes the fiber orientation distribution. Fiber orientation distributions are usually characterized using two parameters:

- **average angle**: the average angle of fibers, which is also the angle of the major axis of the histogram
- **anisotropy**: the degree to which fibers tend to be aligned in the same direction.

Normally, the zero angle is chosen to be the machine direction. Usually, positive angles are clockwise from the machine direction, when the paper is viewed from above. However, in some mills, the positive direction for angles may be counterclockwise.

If the fibers are uniformly distributed in all directions, then the anisotropy is zero. If all of the fibers were aligned in exactly the same direction, then the anisotropy would be unity (this is not physically achievable for paper). Normally, the anisotropy of paper is fairly low, but nonzero.

The fibers used to make paper are predominantly obtained from softwood trees such as pine and hemlock, or from hardwood trees such as aspen and eucalyptus, or from plants such as cotton. The typical width of individual fibers ranges from 15µm to about 50µm, and lengths vary from about 2mm to 5mm. Fines may, of course, be much shorter.

In addition to the fibers, there can be fillers such as starch or clay or chalk. These can affect the strength of bonding between fibers, and also affect the transmission or reflection of light from the sheet. Some, such as clay, also affect the printing properties of the paper.

Filler materials vary widely in composition, with particle sizes generally much smaller than the scales of fibers. Chalk is commonly employed, and may be used either as precpitated calcium carbonate (PCC), with a particle size well below 1µm, or as ground calcium carbonate (GCC), with a particle size of about 1-3µm. Titanium dioxide (TiO_2) is used in lesser quantities with micron-scale particles. Various types of clay are also employed in some grades, with plates less than 1µm thick and a few microns in diameter.

In this user's manual the term **fiber orientation is defined as the distribution of alignment directions** discernible at the paper surface. The term **fiber orientation angle** refers to the average angle of the distribution, as described above, and the term **fiber orientation anisotropy** refers to the anisotropy of the distribution.

Note that the two surfaces of a sheet may have different fiber orientation distributions, even if the sheet is formed in a single layer. If the sheet is formed in a single layer, as is typical of most paper grades, the fiber orientation on both surfaces will usually be similar, although not identical. A sheet consisting of several layers which are formed separately, as is typical for many paperboard grades, can have greatly different fiber orientation on its surfaces.

1.2 Why Is Fiber Orientation Important?

There are two properties of cellulose fibers which determine most of the consequences of fiber orientation distributions in paper:

- When dry fibers are wetted, they expand much more in thickness than in length. When moist fibers are dried, they shrink much more in thickness than in length.
- The tensile strength of a fiber (along its length) is much greater than the strength of bonds holding it to other fibers.

From the first property, we can see that fiber orientation is going to affect the dimensional stability of paper as it is dried in the paper machine, and when it is wetted (e.g. by inking) or dried (e.g. heating) in processing, or when the humidity changes in the environment (e.g. a box in storage).

From the second property, we can see that many strength properties of paper and paperboard will be affected by fiber orientation distributions. If the fibers are not aligned in the expected way, the strength of paper or paperboard may be less than expected. Alternatively, the direction of greatest strength may not match the required direction (e.g. for stacking boxes).

1.2.1 Shrinkage effects, single layer

The effect of shrinkage on a disk of paper illustrates the two principal characteristics of the fiber orientation distribution. When a slightly moist circular disk of paper is dried (for instance from more than 10% moisture to about 2% moisture), it will deform into an approximately elliptical shape. Some possible outcomes are shown in Figure 1-2, with shrinkage greatly exaggerated for clarity.

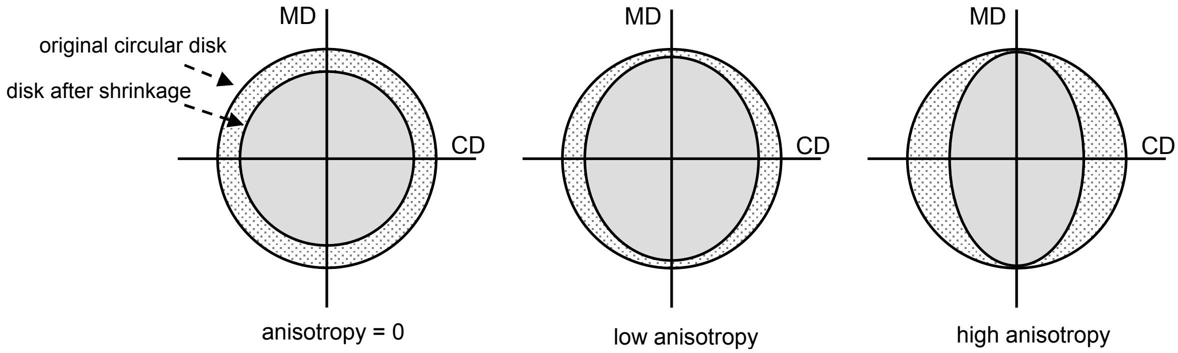


Figure 1-2. Effect of fiber orientation anisotropy on shrinkage of an originally circular disk of paper.

As the anisotropy increases, the fibers are more aligned in the machine direction, and the shrinkage in the cross-machine direction increases. The case shown with zero anisotropy is not actually achievable with machine-made paper, for reasons to be explained below. It can be closely approximated with hand-made paper, however.

In the previous figure, the average orientation angle was in the machine direction (the machine direction is normally chosen as the zero angle). However, the local orientation angle, which is the average angle over some small region of paper, often deviates from the machine direction. This is depicted for shrinkage of circular disks in Figure 1-3, with shrinkage greatly exaggerated for clarity.

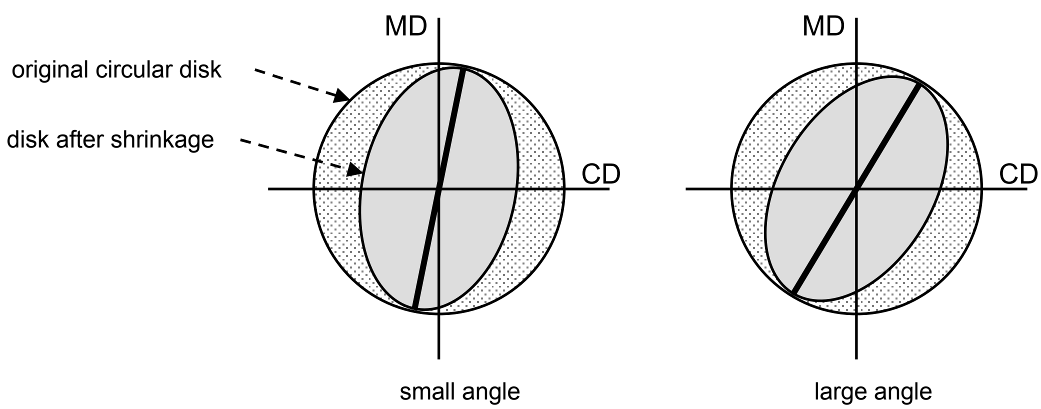


Figure 1-3. Effect of fiber orientation angle on shrinkage of an originally circular disk of paper.

For a given anisotropy, the axis of the shrunk ellipse deviates from the machine direction in accordance with its average fiber orientation angle.

1.2.2 Shrinkage effects, multi-layer

If a sheet is made by splicing together two or more layers which are formed separately, then the layers may not have exactly the same fiber orientation distributions. In particular, the two surface layers may differ in their anisotropies or in their fiber orientation angles, or both.

1.2.2.1 Anisotropy difference – curl

If the surface layers differ in their anisotropies, then the disk will usually curl on shrinking. This is caused by the shrinkage being greater in one surface layer than in the other. If their fiber orientation angles are similar, then the shrinkage will occur in the same direction on both surfaces. If the surfaces were unconstrained, they would shrink to different sizes. Because the shrinkage in each layer is constrained by the other layer, the aggregate shrinkage is an intermediate level, and the sheet tends to curl towards the side with the greater shrinkage/anisotropy, as depicted in Figure 1-4. The axis of curl depends on the average fiber orientation angle.

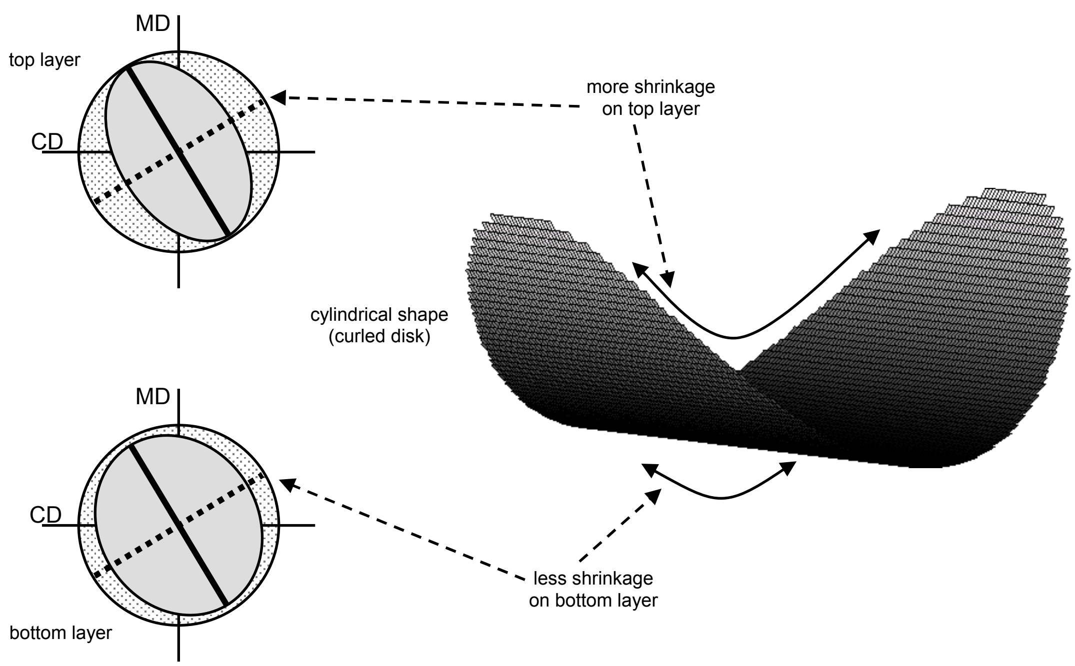


Figure 1-4. Effect of difference in surface fiber orientation anisotropy on shrinkage of an originally circular disk of paperboard.

Curl can occur for other reasons, related to the construction and operation of the dryers. If the sheet is dried more through one surface than the other, then it will tend to curl towards that surface. This curl is also caused by the shrinkage of fibers on drying, and tends to occur if a high rate of drying is used in the later stages of uni-run type drying sections.

1.2.2.2 Angle difference – twist

If the surface layers differ in their average fiber orientation angles, then the disk will usually twist into a saddle shape on shrinking. This is because the axes of shrinkage are different in the two surface layers. Figure 1-5 depicts how this occurs, where the two layers have similar anisotropy and thus shrink about the same amount. If a disk from a surface layer were allowed to shrink freely, it would deform into an ellipse. Because the surface layers have different average fiber orientation angles, they would shrink along different axes, if they were free to do so. However, the two layers are bound together, so the shrinkage of each layer is constrained by the other. The result is a deformation of the combined disk into a saddle shape, where the twist or skewness of the saddle is determined by the difference between the average fiber orientations of the surface layers. The extent of twist depends also on the amount of anisotropy in the layers.

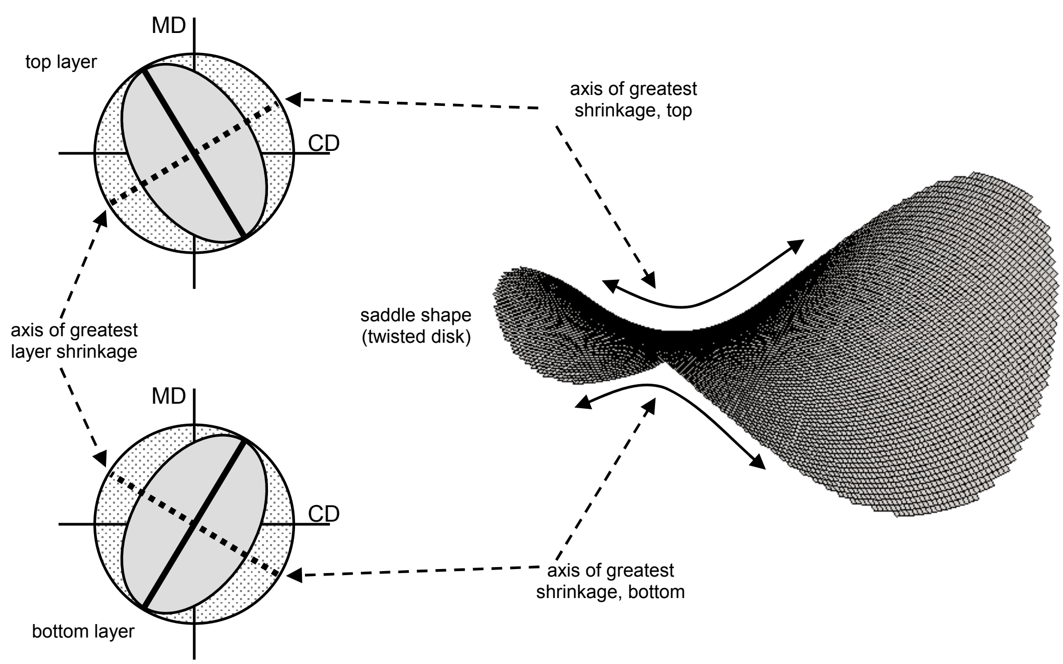


Figure 1-5. Effect of difference in surface fiber orientation angle on shrinkage of an originally circular disk of paperboard.

1.2.2.3 Composition and layering

In addition to the fiber orientation distribution, different layers may also differ in composition. The fiber types and filler types or quantities need not be the same in all layers, and this will have an effect on the degree of shrinkage or twist or curl which occurs in particular situations. Also each layer may have a different mass or thickness. If layers have different fiber orientation distributions and also differ in their basis weights, then the layer with the greater basis weight will have a greater effect on the net deformation of the sheet.

For sheets made of three or more layers, usually the surface layers predominate in determining the deformation of the sheet. This is partly because, being further from the central plane of the sheet, they can exert a greater bending moment around the central plane. It is also partly because the surface layers tend to have better quality fibers with fewer fines, so that shrinkage effects are more evident.

If all layers have similar fiber orientation angles and anisotropies, then a disk will shrink as if it were made of a single layer. Twist and curl will generally not occur (there can be secondary effects from differences in material composition). However, there may still be problems caused by incorrect anisotropy, or by deviation of the fiber orientation angle from the machine direction.

1.2.3 Strength effects

As mentioned above, fibers have high tensile strength along their length, but the bonds attaching them to other fibers are less strong. The strength of bonds between fibers is affected by many parameters, including the types of fillers and special additives in the stock from which the sheet is formed, and the thermal and mechanical processing of the sheet after the forming section. However, the strength of fiber-to-fiber connections is never as strong as the intrinsic internal strength of fibers.

There are many different mechanical properties which can be called the “strength” of paper or paperboard, and their relative importance varies among different grades. Tensile strength is important especially for roll-fed printing grades, burst strength for sack grades, and bending stiffness for some packaging grades, for instance.

1.2.3.1 Tensile stiffness

If the fibers are distributed uniformly in all directions, the tensile stiffness will also be equal in all directions in the plane of the sheet. This is achievable only with hand-made sheets of paper which can have anisotropy close to zero.

If the fibers are distributed nonuniformly, then the tensile stiffness will be greatest in the direction of the average fiber orientation angle, and weakest at right angles to that direction. The difference in strength in these two directions will increase as the anisotropy increases.

1.2.3.2 Bending stiffness

Bending stiffness of a three-layer paperboard is determined (approximately) by the tensile stiffnesses of the two surface layers, and the thickness of the filler layer between. In general, the filler layer has lower strength characteristics than the surface layers, and contributes much less to bending stiffness, even if it contributes most of the mass of the sheet.

If the fibers are distributed uniformly in all directions in both surface layers, the bending stiffness will also be equal in all directions in the plane of the sheet. This scenario is not achievable.

If the fibers are distributed nonuniformly, but distributed similarly in both surface layers, then the bending stiffness will be greatest in the direction of their average fiber orientation angles, and weakest at right angles to that direction. The difference in bending stiffness in these two directions will increase as the anisotropy increases. If the fibers are distributed differently in the two surface layers, then issues of twist and curl can arise, as discussed in §1.2.2, above

Printing papers have a bending stiffness index (per kilogram) comparable to that of aluminum. Folding boxboard has a bending stiffness index about four times greater than aluminum. Corrugated containerboards typically have bending stiffness indices several hundred times higher than aluminum.

1.3 Fiber Orientation in Paper and Paperboard Grades

Paper is typically a single-layer product, with numerous grades commonly used for particular printing purposes. Paperboard is typically a multi-layer product, commonly used in packaging, which may or may not need to be printable. Some other grades may be made as single or multiple layers.

Fiber orientation and related properties such as twist and curl are important for many grades of paper and paperboard.

Tissue and specialty grades of paper are not discussed in this document.

1.3.1 Fiber orientation in printing papers

Printing paper grades may be broadly divided into two categories: (i) those to be used in sheet-fed devices, such as inkjet or laser printers, photocopiers, and the like, and (ii) those to be used in roll-fed devices, such as commercial printing presses for newspapers or magazines.

1.3.1.1 Sheet-fed printing grades

Sheet-fed grades include the usual office grades used in laser printers, inkjet printers, and related devices such as photocopiers. The common requirement is for accurate and consistent handling of single sheets with free edges through a process with high positional reproducibility.

In toner-based devices (laser printers and copiers) and in wax-transfer devices (some color printers), the sheet is typically exposed to high temperatures during printing. This causes deformation through incremental drying. In color devices, there are typically three or four sequential applications of toner or wax, each accompanied by heating. If the deformation is nonuniform, or if the shrinkage has a significant machine direction component (i.e. large fiber orientation angle), then the dots applied in the second and subsequent print passes may be shifted relative to the dots of the first print pass. This is referred-to as misregister of printed images.

In liquid-ink devices (inkjet printers and copiers), the sheet is wetted by an aqueous ink and given a small time to dry. During the wetting and subsequent drying, there is initially an expansion of the fibers, followed by shrinkage which may differ from the expansion. Generally, multiple inks can be applied in a single pass, but the quantity of ink used may vary greatly from sheet to sheet (sparse text vs. photographic printing, for instance). Because multiple inks are applied simultaneously, misregister generally does not occur (or is not caused by the paper). However, there may be other distortions if a large amount of ink is applied to a region with a large fiber orientation angle. The local expansion will have a significant component in the machine direction, and the next pass of the print head may overlap the expanded previous pass, leading to a band-type defect in the printed image.

A common issue in sheet fed devices is jamming of the sheets as they are transported between processes in the device. This can occur if there is any tendency to twist or curl, since one edge or corner of the sheet may deviate out of the intended path, and the sheet becomes stuck or torn in passing between mechanisms in the device.

Another common problem caused by poor fiber orientation is stack leaning in the output tray. If the sheets deform out of square, or if they deform such that there is curl or twist, then the output stack will not remain straight as more sheets are dropped onto it. This causes problems especially in automated systems for handling printer output, such as automated collating and binding devices.

1.3.1.2 Roll-fed printing grades

Roll-fed grades include newsprint, SC, and gravure papers. Their common requirement is to be handled at relatively high speed without paper breaks. For this, they require good tensile strength, and are typically made with medium to high rush or drag. This orients fibers in the machine direction, giving a high anisotropy and high strength in the machine direction. As a result, fiber orientation angles are usually low.

Although dimensional issues are not very severe with low orientation angles, these grades may need to pass through multiple printing stages with repeated prewetting, inking, and drying steps. The prewetting is usually uniform across the sheet, and may occur before each inking step, or just once before the first inking step. Each inking step applies a different color ink (typically: cyan, magenta, yellow, black) in an image pattern. The quantities applied may vary between inks and the quantity of each ink may also vary across the sheet. If the images of sequentially applied inks are not precisely aligned, the appearance of the printed result may be unacceptable. This misalignment is called misregister, and it is the principal quality issue for fiber orientation in roll-fed printing grades. It applies only to grades to be used in color or other multi-inking processes, however.

Poor orientation may also contribute to tension problems (especially on edge rolls), leading to increased incidence of sheet breaks. A newsprint machine may handle several dozen webs simultaneously, joining the printed outputs synchronously to build a multi-page publication. Obviously, a sheet break in just one web can cause a significant interruption to printing production. This affects monochrome printing as well as color printing processes.

1.3.2 Fiber Orientation in Paperboard Grades

Paperboard grades are predominantly used in packaging materials.

1.3.2.1 Folding boxboard

Folding boxboard is made in two or more layers. Typically, at least one surface must be printable and is coated.

Both fiber orientation angle and anisotropy must be within limits in the surface layers. Twist must be avoided, to prevent problems in folding into dimensionally correct boxes. If twist is excessive, the boxes will be skewed during folding, leading to unacceptable box shapes. Alternatively, twist can cause inadequate glue adhesion leading to failure during packing or transport of the boxes.

Some degree of curl is usually desirable in folding boxboard. However, the curl must be on the intended axis and must be outward relative to the final box. This facilitates insertion of items into the box (pencils, etc) and withdrawal of items from the box by consumers, without requiring an oversized box.

1.3.2.2 Liquid packaging

Liquid packaging is a specialized form of folding boxboard, used to contain milk, fruit juices, and so forth for transport and storage. The box is glued to be watertight, and those for long term use generally have linings of metal and/or plastic. There is often a requirement to withstand refrigerated transport and storage. The materials must all be food-safe if the contents are intended for human consumption.

The fiber orientation requirements of liquid packaging are similar to those for folding boxboard, except that curl is not as beneficial. Twist must be avoided, so that the shape and volume of the carton are correct.

1.3.2.3 Corrugating medium & linerboard

Corrugating medium and linerboard are used to make containerboard, in which two or more sheets of linerboard are separated by sheets of corrugated medium. The layers are glued together. Boxes made from containerboard must be safe to handle and stackable to a given height while each carries a given payload (i.e. bottom box does not get crushed, stack does not lean or twist, etc.).

Corrugating medium, such as fluting, is often made in a single layer. Its fundamental requirement is that it should be easily corrugated and have adequate glue adhesion. It must be easily joined by gluing to liner layers, and is required to carry tensile loads between the liner layers. The glue used in making containerboard is usually an aqueous starch-based material, which wets the adhesion point, and dries on setting.

Corrugating medium requires low fiber orientation angles, since its axis of maximum strength should be along the direction joining the two liners. If angles are large, then there can be a torsional effect between the liners when the faces of the corrugated box are subjected to a load. This will cause deformation of the box, and reduced load-bearing and stacking performance.

Corrugating medium also requires uniformity in anisotropy and bending stiffness. This ensures reliable corrugation, since the corrugation axis is normally perpendicular to the machine direction, and variation in bending stiffness would give rise to variation in the geometry of the resulting fluting. Irregular fluting shape may cause regions where the corrugating is not glued adequately to the liner, leading to greatly reduced strength and dimensional integrity of boxes made with containerboard.

Linerboard may be made as a single layer or as multiple layers. It must retain its planar shape during conversion to containerboard, and must provide the necessary strength and dimensional stability thereafter.

Linerboard requires low fiber orientation angles. Otherwise, the axis of maximum strength will not correspond to the manufacture axis of a box, leading to twist or lean of boxes when stacked. It also requires low twist and curl, so that it does not deform out of plane during the joining to corrugating medium, leading to greatly reduced strength of the containerboard box. Twist and curl must also be avoided to reduce the risk of glue detachment later during use of the box, as the environmental humidity changes.

1.3.2.4 Sack

Sack requires nondirectionality in its strength properties. Hence, it is usually made with fairly low anisotropy. The fiber orientation angle is relatively unimportant, provided the anisotropy is low. Sack is usually made as a single-ply sheet, so twist and curl are relatively uncommon or not problematic.

An expansion press is often installed in the drying section of sack machines. This device compresses and expands the sheet in the machine direction as it passes between a compressible roll and a hard roll. The operation breaks fiber-fiber bonds which have been strained by shrinkage and stretching during early drying stages. It thus allows unstrained bonds to reform in subsequent drying. As a result, the tensile energy absorption (burst strength) of the sheet is increased. However, the relationship between fiber orientation structure and strength is changed significantly.

1.4 Tensile Stiffness Orientation

Measurement of fiber orientation is uncommon in paper mills. Traditionally, there has been no reliable measurement for this property, despite its importance in many grades. However, most mill laboratories have an instrument for measuring tensile stiffness orientation (TSO), which is related to fiber orientation.

1.4.1 Measurement of TSO

The principle for measuring TSO relies on the paper acting as an elastic membrane, in which the tensile stiffness determines the speed of propagation of mechanical waves. A circular disk of paper is clamped around its edges, and an ultrasound pulse is generated at its center.

Detectors around the edge of the disk record the time taken for the pulse to reach the edge in different directions. An alternative construction sends pulses across the whole width of the disk, with pulses sequentially generated at multiple points around the edge of the disk.

Paper mill laboratories typically have an automated system which analyzes a strip of paper for several properties, often including TSO. The device steps the paper strip through each measurement instrument in sequence, and produces a report with profiles of each measured property.

The TSO is usually described using an average angle, at which the stiffness is greatest, and a parameter for the anisotropy. Typically, the ratio of maximum to minimum stiffness is used, or the ratio of stiffness in the MD to stiffness in CD. For measurements at a single location, some TSO instruments will also display a polar histogram of the tensile strength in different directions.

1.4.2 TSO and fiber orientation

The TSO angle is strongly related to the fiber orientation angle. This is because the tensile strength along a fiber is greater than the bonding strength across fibers. For single layers of uncoated paper which have low or moderate amounts of filler, the TSO angle and fiber orientation angle are normally in good agreement (profile amplitudes may differ between TSO angle and fiber orientation angle, but the profile shapes will be quite similar). For single layers with higher filler amounts, the agreement is slightly less good.

Nevertheless, for most printing grades, a surface fiber orientation angle measurement made with a FotoFiber before coating will usually be in good agreement with a TSO angle measurement made in the laboratory.

For paperboard sheets consisting of several layers, the situation is more complicated. If the layers can be reliably separated, then analyzing each layer separately will usually indicate good agreement between the TSO angle and the fiber orientation angle. However, production of multi-layer sheets usually employs binding agents such as starch to prevent delamination of the sheet. These additives are included in the furnish to one or more layers, so that the layers bind together strongly in the presses and early drying sections. It can thus be rather difficult to cleanly separate the layers – each will tend to have holes or sections with only partial mass, and to have clumps of an adjacent layer attached. TSO measurements of one or more layers will consequently be unreliable or impossible to make.

The TSO of a multi-layer sheet is generally uninformative for the critical properties of twist and curl. These require measurement of the surface layers, rather than of the whole sheet. Consequently, laboratories must attempt the time-consuming manual separation of layers before making a TSO measurement on each single layer. Success in separating layers is far from certain, and nearly impossible for grades such as liquid packaging. It may be necessary to withdraw the layer binding agents from the stock near the end of a reel, if a laboratory measurement is planned, in order to facilitate better separation of layers in the laboratory. Obviously, such a change to the furnish will also have consequences for product quality.

Direct measurement of the surface fiber orientation gives a reliable estimate of the properties of the surface layer (or of both surface layers if a two-sided FotoFiber is used). This has been found to correlate quite well with TSO angle measurements of single-layer sheets, and with measurements of TSO angle of surface layers of multi-layer sheets, at least in those cases where the surface layers could be separated from the sheet.

1.5 Fiber Orientation in the Papermaking Process

The fiber orientation of paper is predominantly established in the forming section, where the jet from the headbox impinges on the wire.

1.5.1 Headbox jet and forming section

The paper machine headbox produces a thin, smooth jet of a dilute fiber suspension. This jet must have the correct speed and land on the moving wire at the correct angle.

The jet speed is often characterized and controlled either as jet-to-wire ratio (i.e. as a ratio to the wire speed) or as rush-drag (i.e. as an offset to the wire speed). If the jet speed exceeds the wire speed, its offset is positive and it is said to be in rush or rushing. In this case, the jet-to-wire ratio is greater than unity. If the jet speed is less than the wire speed, its offset is negative and it is said to be in drag or dragging. In this case, the jet-to-wire ratio is less than unity.

1.5.1.1 Jet speed accuracy

The nominal jet speed value must be treated with caution, and even some suspicion. Often, a simplified calculation is performed based on the pressure difference between the headbox nozzle pressure P_{nozzle} and the machine hall pressure P_{hall}. The simplest calculation of jet speed J is:

$$J = C_{jet}\sqrt{P_{nozzle} - P_{hall} + C_{nozzle}}\ , \tag{1.1}$$

where C_{jet} is a composite discharge coefficient for the headbox and is a compensation factor for the position of the pressure gauge in the nozzle. In practice, headbox vendors supply modified versions of this relation, in which C_{jet} and/or C_{nozzle} may be changed based on the slice opening and temperature.

A similar relation can be used, employing the pressure drop across the turbulence generator to compute the headbox flow, and dividing by the slice opening S to obtain the average jet speed.

$$J = \frac{C_{turbo}\sqrt{P_{turbo} - P_{nozzle}}}{S}, \tag{1.2}$$

where C_{turbo} is a composite discharge coefficient for the turbulence generator and P_{turbo} is the pressure at the inlet of the turbulence generator tube bank. The factor C_{turbo} is less variable than C_{jet}, so the total headbox flow can be reliably estimated with such a relation, but the calculation of jet speed becomes reliant on accurate knowledge of the average slice opening S, which usually is affected by thermal and other disturbances.

In reality, the jet consists of a suspension of fibers and fines whose consistency and composition can change, and its temperature typically exceeds 40°C. The apparent viscosity of the jet thus varies somewhat due to consistency, composition (fiber and filler types), and temperature. The jet is also affected by the projection of the slice apron as well as by the total slice opening, and these can change the landing position and slope of the jet impinging on the wire.

Some headbox vendors supply sophisticated relations for estimating jet speed, often specific to particular headbox designs. Such relations may require numerous measurements and have many terms and calibration constants for compensating effects of temperature and variations in operating conditions. Within their calibration limits, these relations are better than the simple calculations shown above but will still exhibit varying errors depending on operating conditions and accuracy of inputs. Outside those calibration limits, they are less reliable, and may even perform worse than the simple relations in some circumstances.

Computed jet speeds are usually not consistently accurate or consistently erroneous. At some machine operating points, the computed speed may be quite accurate, and at others it may be in error by several meters per minute. Consequently, the displayed values for rush-drag or jet-to-wire ratio should not be unconditionally accepted as true.

For reasons to be discussed below, jet speed changes of as little as 1 meter per minute (0.0167 m/s) can have significant effects on fiber orientation. The jet speed displayed in the control system, even if computed with some sophistication, may not have such great accuracy. Computed jet speeds should be taken as rough approximations only, in any attempt to understand or manipulate the fiber orientation of paper.

1.5.1.2 Jet angle and fiber orientation angle

The slice nozzle surfaces are finely machined, but always have some deviations from perfect flatness. Similarly, the turbulence generator has small imperfections. Together, this means that even with a perfectly uniform slice, there will be a nonuniform flow through the nozzle, and while the flow is predominantly along the nozzle, there will be various quite small flow components across the nozzle.

The slice, of course, is not perfectly uniform across the machine. In addition to small geometric imperfections in the slice lip and slice apron, the slice lip is usually deformable, and is equipped with screws for adjusting its shape across the machine.

One consequence of changing the slice lip shape is that the jet becomes thicker where the slice opening is widened, and thinner where it is narrowed, making the flow from the slice significantly nonuniform. However, because the flow through the turbulence generator is very nearly uniform across the headbox, this causes cross-flows to be established in the headbox nozzle, which redistribute the flow to the nonuniform slice opening. The cross-flows persist in the jet and their effect on fiber orientation is depicted in Figure 1-6.

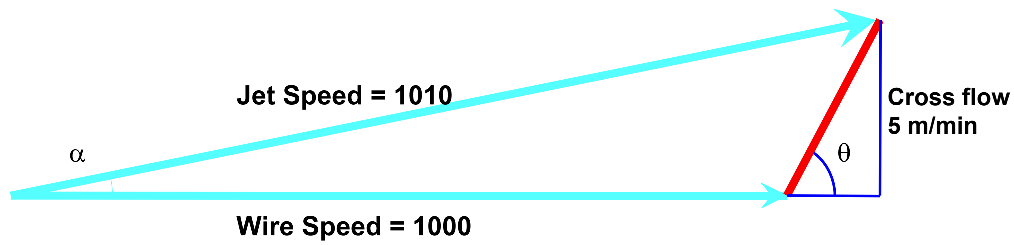


Figure 1-6. Effect of small cross flow in jet on fiber orientation angle.

Cross flows in the jet which are quite small in comparison to the total jet speed can have a large effect on the fiber orientation. This is because the jet speed and wire speed are not greatly different, and a cross flow may be comparable to the difference between jet speed and wire speed. The general relation between cross flows in the jet and the fiber orientation angle θ is:

$$\theta = \tan^{-1}\left(\frac{J_{CD}}{J_{MD} - W}\right), \tag{1.3}$$

where J_{CD} and J_{MD} are respectively the cross-machine direction and machine direction components of the jet velocity, and W is the wire speed.

In the example depicted, there is rush of about 10 meters per minute, and a cross flow of 5 meters per minute gives rise to a fiber angle of 26.6°. In fact, a cross flow of just 1 meter per minute in the jet would result in a jet angle of only 0.06°, but a fiber angle of about 5.7°, which is greater than the allowed quality limit in most paper or paperboard grades. Note that if there were drag instead of rush, the angles would be reversed (-26.2° for 5 meters per minute cross flow, and -5.7° for 1 meter per minute).

Figure 1-6 and equation 1.3 describe the situation for a single element of the jet with uniform jet velocity, or for an average over some region in time. In practice, there are fluctuations in the jet velocity over small scales in position and time. The turbulent fluctuations can be visualized as a distribution of velocity vectors added to the average jet velocity, resulting in a distribution of fiber angles around the average.

1.5.1.3 Slice lip and fiber orientation angle

Ideally, the jet is straight across the whole width of the headbox. In practice, this cannot be achieved. Even with a perfectly straight slice lip, there are local variations in the jet speed and angle due to (i) intrinsic nonuniformity in flow through the turbulence generator, (ii) imperfections in construction of the slice channel, (iii) thermal deformation of the slice channel and slice support beam, (iv) deformation of slice channel due to pressurization of an insufficiently rigid headbox. There are also local variations in retention across the wire for many reasons, so that even if the jet were uniform, there would be a non-flat weight profile.

In practice, the slice lip shape must be manipulated to counteract the nonuniformities in flow and possibly to compensate for the nonuniformity in retention. In a dilution headbox, the dilution system can be used to regulate the basis weight. However, it is the slice lip which can affect the flow field in the jet, and hence the fiber orientation profile.

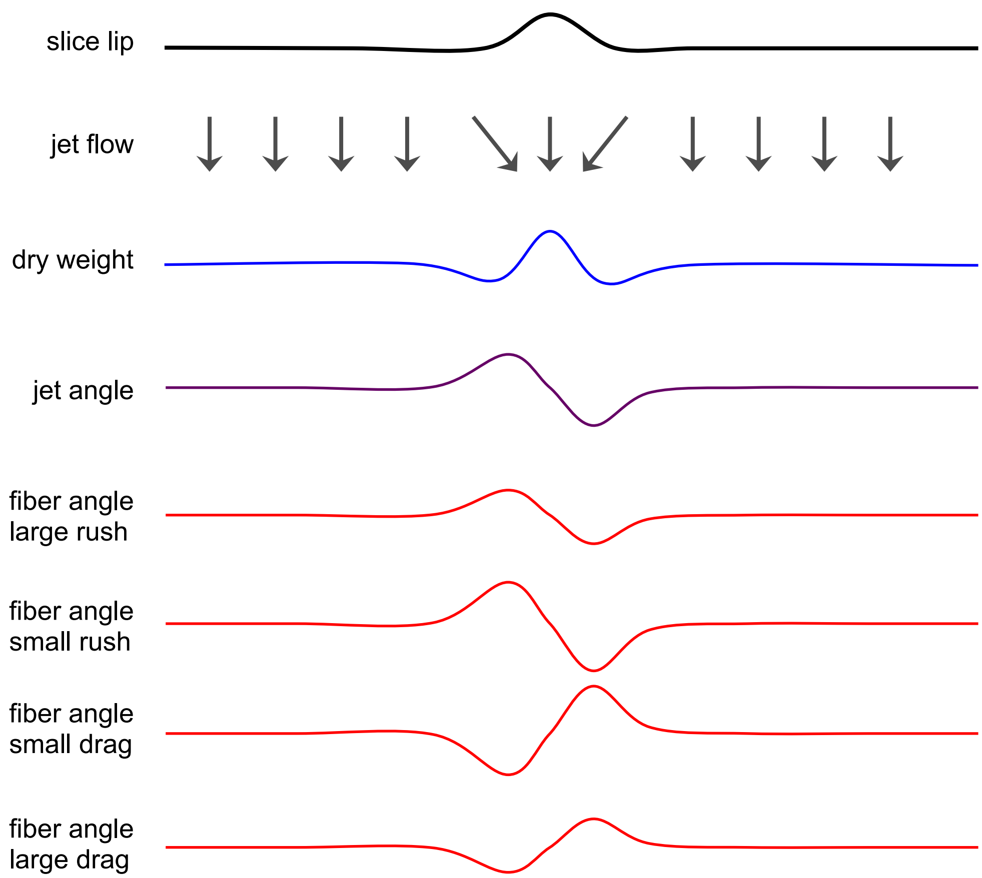


Figure 1-7. Effect of slice lip on dry weight and jet angle.

If one slice screw is moved, it causes a smooth change to the slice lip shape, and corresponding changes in the jet thickness and dry weight profiles. It also induces local cross flows to start in the headbox nozzle, and these persist into the jet. The responses in dry weight and jet angle to a change in one slice lip screw are depicted in Figure 1-7.

The change in jet angle will cause a change in fiber orientation angle. This will be a multiple of the jet angle change, where the magnitude and sign of the multiplier depends on the rush-drag in the forming section. The multiplier will also depend on the turbulence in the jet (e.g. from vanes in the slice nozzle) and in the forming zone (e.g. from impingement angle). In general, however, it behaves approximately as depicted in Figure 1-8. Note that the figure depicts a *normalized* ratio, as a fraction of the maximum ratio. In practice ratios from jet angle to fiber orientation angle are quite large, with maximum values exceeding 100. If the jet turbulence is low, the curve will have much sharper peaks, located closer to the zero point. If the jet turbulence is high, the curve will be smoother, with extrema further from the zero point. The maximum ratio will be large when turbulence is low, and small when turbulence is high.

Since the jet angle is generally not known, it is more useful to calibrate the process either (i) as a simple gain for the fiber orientation from the slice lip, or (ii) as a ratio of the fiber orientation gain to the dry weight gain for slice movements. In either case, the variation of gain with rush-drag will follow the same normalized curve such as is shown in Figure 1-8.

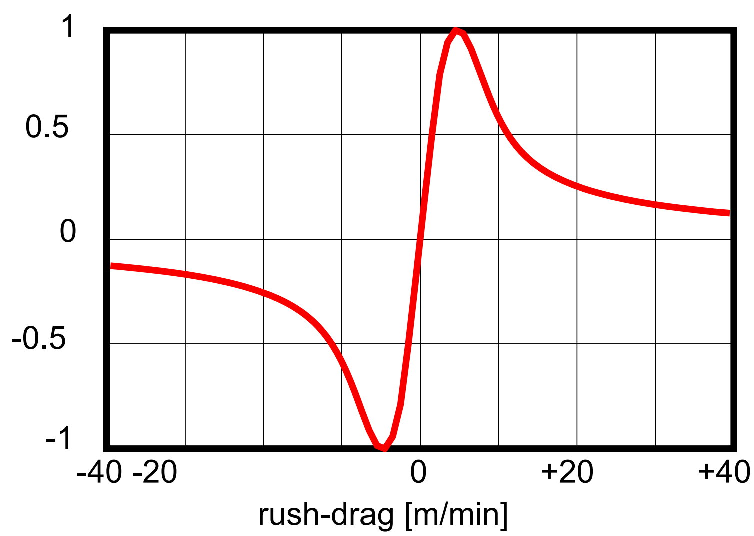


Figure 1-8. Normalized ratio of fiber orientation angle response to jet angle response

If the entire slice is moved in broad patterns, the response is also broad. This is due to the nonlinear aspect of the hydrodynamics in the headbox slice channel and jet. In particular, if the slice is slightly tilted, so that it is more open on one side than the other, then the entire jet will have a lateral velocity component towards the more open side. This can cause the average fiber orientation to deviate from zero across the whole sheet.

1.5.1.4 Edge flows and fiber orientation angle

Some headboxes are equipped with controllable edge flows. These provide the flow into the headbox nozzle at the edge regions of the headbox, so that the flow into the nozzle at the edges is controllable independently of the flow into the main part of the nozzle. Since the flow through the slice is essentially the same across the whole machine (because of equal pressure across the nozzle), and excess or deficit in flow supplied to the edge regions will result in a compensating cross flow, which will persist into the jet.

When a change is made to the edge flows, the response will be approximately as in Figure 1-9. Note that the response amplitude will depend strongly on the rush-drag state of the forming section, just as for slice lip changes in Figure 1-8. However, the shape and extent of the response at a particular jet speed are influenced by the slice opening, which determines the acceleration of the headbox flow in the nozzle. In general, at small slice openings, the response extends further into the sheet than at large slice openings.

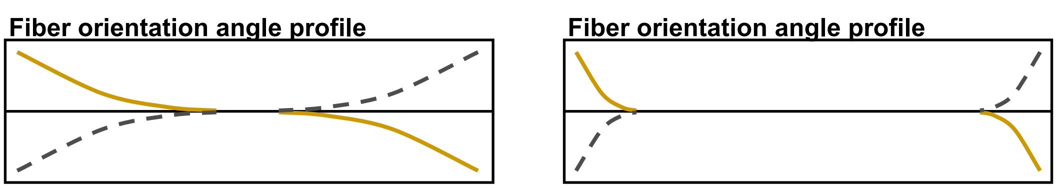


Figure 1-9. Fiber orientation angle responses to increase in edge flows. Left: small slice opening. Right: large slice opening. Solid lines and dashed lines are for rush and drag, respectively.

1.5.1.5 Rush-drag and fiber orientation anisotropy

When the jet speed exceeds the wire speed, it is said to be rushing the wire (or in rush), and has a jet-to-wire ratio greater than unity. When the jet speed is less than the wire speed, it is said to be dragging the wire (or in drag), and has a jet-to-wire ratio less than unity.

When the jet speed and wire speed are approximately the same, the anisotropy of the sheet will be low. Any cross-flows in the jet will cause relatively large orientation angles. When the jet speed differs from the wire speed by a large amount, the anisotropy will be high, whether the jet is in rush or in drag. Cross flows in the jet will cause relatively small orientation angles. An example of the relation between rush or drag and anisotropy is depicted schematically in Figure 1-10. Note that this relation depends strongly on the machine and can be quite different .

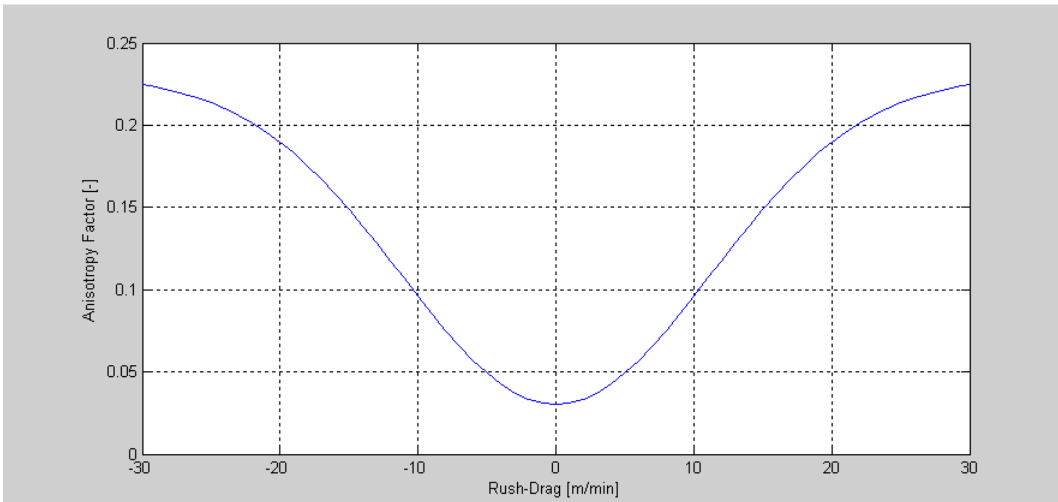


Figure 1-10. Example of variation of anisotropy with rush or drag.

There are many other influences on the anisotropy in addition to rush or drag. For example, if the turbulence in the jet is high, the anisotropy will be lowered. Jet turbulence is determined in part by the design of the tips of the vanes in the headbox nozzle, and to a lesser extent from the turbulence generator, the degree of acceleration in the nozzle (affected by total slice opening) and aerodynamic damping of the jet. The anisotropy of the sheet formed on the wire is further influenced by the impingement angle of the jet, leading to turbulence in the forming region. The jet impingement angle can be manipulated by changing the projection of the slice apron beyond the slice lip, and (especially if the slice lip is inclined) by the total slice opening.

Note that in machine-made paper, the anisotropy will not reach zero, even if the jet speed is the same as the wire speed. This is because the jet always has some variation in its local speed at different levels through its thickness. The core of the jet has a higher speed than its surfaces, partly because of shear forces as the jet detaches from the slice apron and the slice lip. The surfaces are also subject to aerodynamic drag which reduces the acceleration they experience by shear forces from the core of the jet. This is depicted in simplified form in Figure 1-11, which omits the effect of vanes in the headbox nozzle.

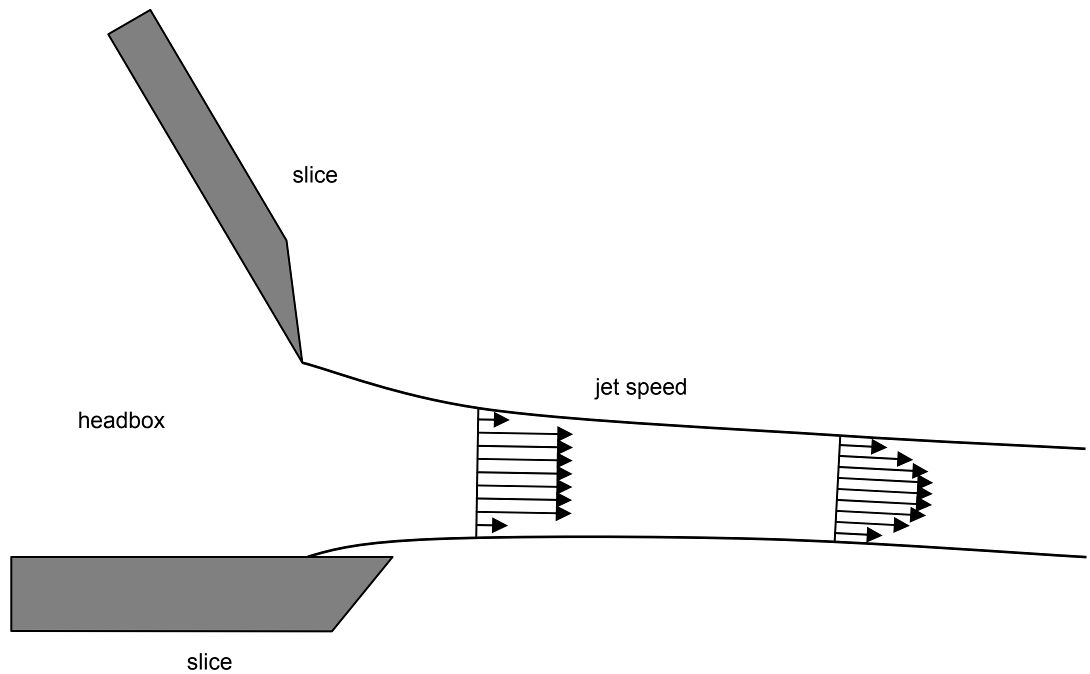


Figure 1-11. Evolution of jet speed distribution through jet thickness.

Even with an average local jet speed quite close to the wire speed, there will be some elements of the jet in rush, while others are in drag. Typically, when the jet-to-wire ratio is very close to unity, the core of the jet is in rush while the surfaces are in drag. This distribution of speeds will depend on the turbulence in the jet (due in part to vane tips in the headbox nozzle). When the local jet speed differs more from the wire speed, it will be almost all in rush or almost all in drag, but to varying extents.

1.5.2 Pressing, drying, and finishing

The fiber mat laid down during forming is not greatly altered in the dry end. However, there are some deformations due to the drawing and nonuniform shrinking of the viscoeleastic sheet.

1.5.2.1 Pressing and drying

The sheet is drawn (stretched) to maintain tension for conveying it from cylinder to cylinder across open gaps. When the moisture content is high, the sheet deforms viscously under tension, and it is stretched permanently by each draw, especially in the large draw from the wet press to the drying section.

As the moisture content is reduced in drying, the elastic strength of the sheet increases, and tension can be maintained without further plastic deformation. The sheet's mechanical behavior changes from being predominantly viscous leaving the presses to being predominantly elastic at the reeler.

As the sheet is dried below about 40% moisture content, it begins to shrink due to the hygroexpansivity of cellulose fibers. Since it is being drawn in the machine direction, shrinkage effects are observed in the cross-machine direction. Most of the shrinkage occurs in open gaps where the sheet is not constrained by contact with drying fabrics. The shrinkage is always greater near the edges of the sheet than near the center, since the sheet is less constrained positionally near the edges in open gaps.

The net effect of the shrinkage and drawing on sheet structure is depicted in Figure 1-12. The fiber mat deforms such that a square (or circular) region in the sheet at the wet end becomes slightly narrower and elongated at the dry end, becoming a rectangle (or ellipse). The effect is to slightly increase the orientation anisotropy and to slightly reduce the orientation angles. This effect is always greater near the edges of the sheet than near the center.

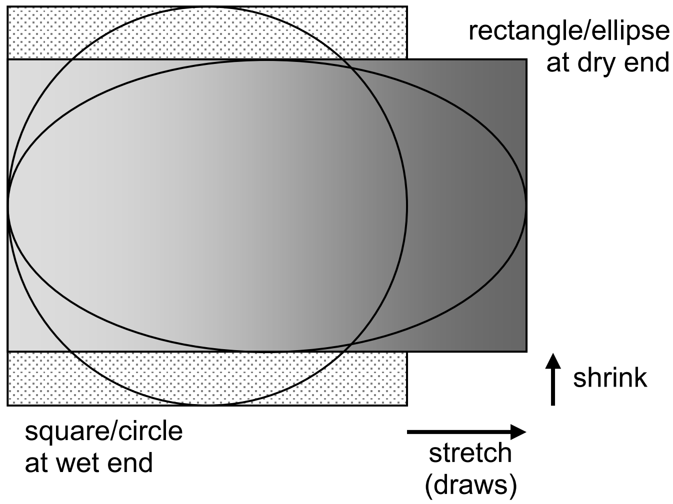


Figure 1-12. Deformation by drawing and shrinkage.

The plastic deformation, especially the large draw occurring between the presses and the dryers, has an effect on the strength properties of the paper. By deforming the sheet so that fibers move relative to one another, many inter-fiber bonds are broken. New bonds are formed during the drying process, but the strength axes can differ slightly from the orientation axes because of this deformation.

1.5.2.2 Coating

Coating does not affect the orientation of fibers within the sheet. However, it can have a great effect on the visibility of fibers at the surface of the sheet. It also adds material which can contribute to the strength of the sheet, but usually changing strength equally in all directions.

Film coating applies a light aqueous suspension of starch and other chemicals to the surface of the sheet. Typically, it does not completely obscure the surface of the base sheet, but it tends to fill many of the pits or gaps between surface fibers.

Because the surface fibers are partly obscured by film coating, it is recommended that surface fiber orientation be measured before the size press for best measurement accuracy. However, it is possible to obtain satisfactory FotoFiber measurements after the size press, provided the amount of sizing applied to the paper is not excessively large.

Blade coating adds a very smooth layer of minerals and/or polymers on the paper. Often, the coating mix includes clay and latex. In addition to filling pits and gaps in the surface, it tends to completely cover all of the surface with a significant thickness of coating, so that the base sheet surface is completely hidden.

Because the surface is usually completely obscured by blade coating, it is necessary to measure the surface fiber orientation before any blade coating operations.

1.5.2.3 Calendaring

Calendaring does not affect the orientation of fibers within the sheet. However, it can have a great effect on the visibility of fibers at the surface of the sheet. It also modifies the strength distribution of the sheet.

Soft calendaring compresses paper significantly. It also tends to flatten the surface features of the sheet, and introduce small scale glossiness. The effects are similar but less pronounced with precalendars which are often employed before a film coater.

Because soft calendaring reduces visibility of fibers at the surface, it is strongly recommended that surface fiber orientation be measured before soft calendaring. However, it is possible to obtain satisfactory FotoFiber measurements after a mild precalendaring operation.

In addition to greatly compressing the sheet, supercalendaring or gloss calendaring significantly changes the sheet surface, employing high temperatures and pressures, often accompanied by remoisturizing at the surface beforehand. The effect is to flatten and chemically alter the surface fibers and other surface material. If the sheet has been blade-coated before calendaring, then the fibers are already invisible. On lightly film-coated or uncoated sheets (such as SC paper), the visibility of surface fibers is greatly reduced, and glossiness of the surface further impedes measurement.

Because the surface is altered and visibility of fibers is greatly diminished, it is necessary to measure surface fiber orientation before any gloss calendaring or supercalendaring operations.

1.6 Solving Fiber Orientation Problems

The FotoFiber measurements, together with a basic understanding of the processes affecting fiber orientation and the quality requirements of the grade being produced can be used to help a mill solve problems related to fiber orientation. A full treatment of this topic is beyond the scope of the present manual, but some useful approaches to process optimization are outlined here. It is important to remember that changes to the fiber orientation angle profile will also affect the basis weight and caliper profiles, so the mill's objective must always be to achieve an acceptable balance between paper properties.

1.6.1 Offset in FO angle

In some cases, the FO angle profile average can deviate from zero. A small deviation is generally not a problem, but if the profile average is a few degrees from zero, it can have a considerable impact on quality. This may occur in combination with other shapes in the fiber orientation profile, which can be tackled separately.

The fundamental reason for a nonzero average angle is that the jet has a lateral velocity component across the whole sheet. There are several potential process causes for this situation. Other local variations in jet angle may also occur and lead to a non-flat FO angle profile, but the profile average is linked to the average jet angle across the machine.

1.6.1.1 Header balance

On older headboxes, an unbalanced main header can lead to nonuniform flow through the turbulence generator. This then results in a cross-flow in the slice nozzle across the whole headbox. The result is that the average FO angle may deviate from the machine direction by a few degrees.

Balancing the main header will solve this problem (if it is actually caused by an unbalanced header). Usually, there is a manual valve for controlling the recirculation from the main header. If a change in the setting of this valve causes a change in the average of the FO angle profile, then it can be used to control the average FO angle. Note that the nominal balance point (usually judged visually from movement of stock in a sight tube) may not correspond to a zero average fiber orientation, and the setting for zero FO angle may depend on the operating point.

This is not an issue on modern headboxes, which have higher pressure drops across the turbulence generator, or which have large MD flow accellerations in the slice nozzle. In this case, manipulating the header recirculation valve has little or no effect on the average FO angle.

1.6.1.2 Edge flows

On narrow machines, up to about 4 meters in width, the responses to the edge flows may meet or overlap in the center of the sheet. In this case, it is possible to control the average FO angle using the difference between edge flows.

The effect on the jet angle profile of movements to individual edge flows for a narrow machine is shown in Figure 1-13, left. The resulting effect in FO angle will depend on whether the machine is operating in rush or in drag. Provided the edge reponses overlap to some extent, the entire jet can have its angle changed by moving the edge flows in combination, as in Figure 1-13, right.

The average jet angle can be moved by changing the difference between the edge flows, such as by moving them by opposite amounts. The jet can be shifted towards the front of the machine by reducing the front edge flow and increasing the back edge flow. It can be shifted towards the back of the machine by increasing the front edge flow and reducing the back edge flow.

Alternatively, the entire jet angle profile can be tilted by increasing both edge flows, which will increase the angle at the back and reduce the angle at the front. Similarly, reducing both edge flows will decrease the angle at the back and increase the angle at the front.

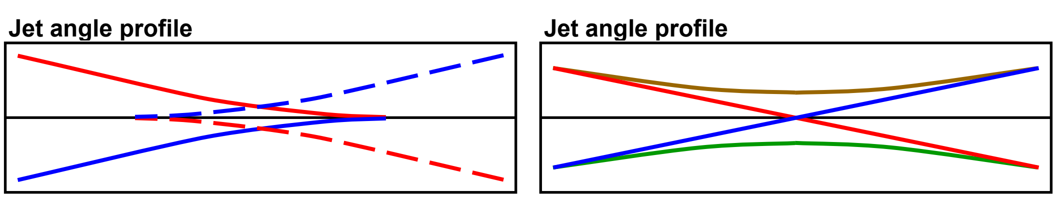


Figure 1-13. Edge flow effect on jet angle, narrow machine. Left: individual responses, red=increase, blue=decrease, solid=back edge flow, dashed=front edge flow. Right: combined responses, brown=front decrease, back increase, green=front increase, back decrease, red=both increase, blue=both decrease.

On wider machines, edge flows affect only the edge regions of the sheet. Edge bleed valves, found on some older headboxes, are not effective across the whole sheet, even on quite narrow machines.

1.6.1.3 Slice lip

Local changes to the slice lip, as shown in Figure 1-7, affect the fiber orientation locally, but have no effect on the average fiber orientation. This is true for any change which does not affect the average slope of the slice across the machine.

If the slice is given a slight tilt across the machine, however, the jet angle will be shifted across the entire machine, causing a change in the average fiber orientation angle. This is illustrated in Figure 1-14. Tilting the slice causes the jet to have a lateral velocity component towards the side on which the slice is more open. This will either increase or decrease the FO angle, depending on whether the jet is in rush or in drag, and the gain from jet angle to FO angle will vary with rush-drag in the same way as for other changes to the slice lip (see Figure 1-8).

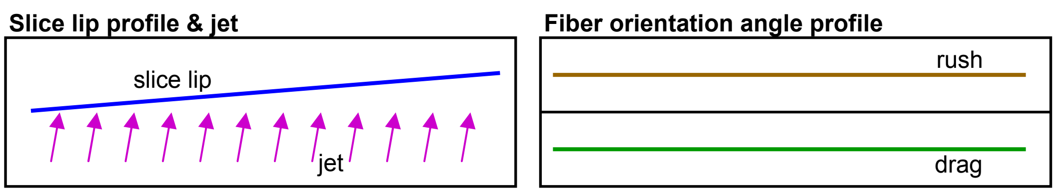


Figure 1-14. Effect of tilting the slice. Left: on jet angle. Right: on fiber orientation angle profile.

Note that even if the slice positional measurements indicate that the slice lip is flat, it may have a slight slope for other reasons. Typically, there is a beam on which the slice lip actuators are mounted, and this beam can be moved at the edges, either manually or through automation. Also, the slice opening depends not just on the upper lip, but also on the lower lip, or slice apron. The slice apron is nominally flat, and can be shifted in the machine direction, but not vertically. An unexpected tilt in slice opening across the machine may be caused by

- asymmetric thermal deformation of the slice support beam
- asymmetric thermal deformation of the headbox apron
- mechanical issue such as stiction or backlash with a support beam positioner

- miscalibration of position measurement for a support beam positioner

If stiction or backlash is present, one end of the entire slice may occasionally move by a significant amount, even though it may nominally have moved only a negligible amount. Thermal deformations can lead to significantly different slice opening when starting up after a machine shutdown.

1.6.2 S-profile in FO angle

This occurs commonly, both in single-ply and on the surfaces of multi-layer sheets. It happens most often with conventional headboxes, but can occur also with dilution headboxes.

The fundamental reason is that the slice is in a “frown” shape, which causes inward flows in the jet near the edges. This situation arises because there is greater shrinkage near the edges of the sheet than near the center, so to get a flat basis weight profile at the reel, it is necessary to have the jet form a lighter sheet near the edges (i.e. before the shrinkage occurs). See Figure 1-15. The amplitude of the slice shape will depend mostly on the difference in shrinkage between the edges of the sheet and the center of the sheet.

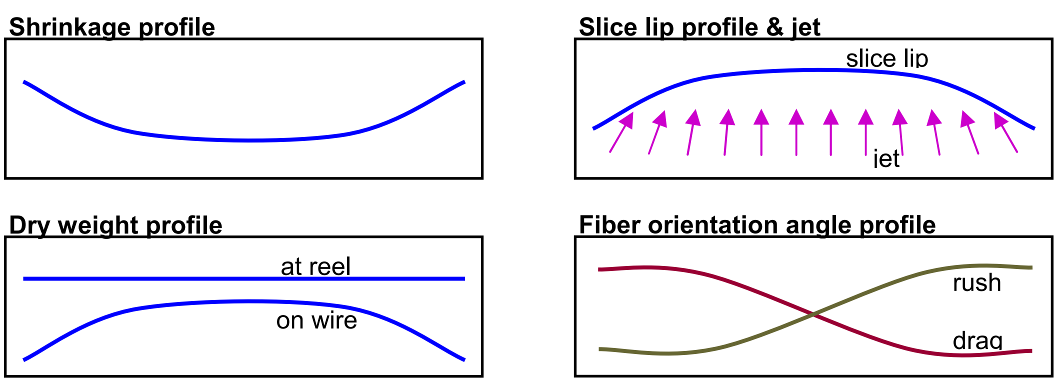


Figure 1-15. Interaction of profiles of shrinkage, dry weight, slice lip, and fiber orientation angle.

If the headbox is equipped with a dilution system, the dry weight and caliper profiles can be kept flat, even with a wide range of slice opening profiles. In this case, it should be possible to keep the slice straight, but due to deformation of the slice nozzle under hydraulic pressure, an apparently flat slice may effectively be in a “frown” shape anyway.

Moreover, thermal and other deformations to the slice apron and/or to the slice support bar can induce a variety of local imperfections in the jet velocity field.

1.6.2.1 Adjust edge flows

If the headbox is equipped with controllable edge flows, then they can be used to modify the jet angle near the edges of the sheet. Whether the edge flows should be increased or decreased will depend on the rush-drag state of the forming section, and the fiber orientation angle to be corrected. It is best to convert the fiber orientation angle correction (plus/minus) into a jet direction correction (inward/outward) at each edge.

- Reducing an edge flow will reduce the inward component of jet velocity.
- Increasing an edge flow will increase the inward component of jet velocity.

Take a conservative approach to the amplitude of edge flow correction. Several small corrective steps are safer than attempting a single large step. As noted above, the response to edge flows can vary in extent depending on the total slice opening. It may affect a very small region near the edge, or it may extend almost two meters into the sheet (see Figure 1-9). Recall also, that the gain for responses to edge flow changes depends strongly on the rush-drag value, just as for slice responses (see Figure 1-8). Thus, a modest error in the estimated jet speed may lead to a large underestimate or overestimate in the response amplitude.

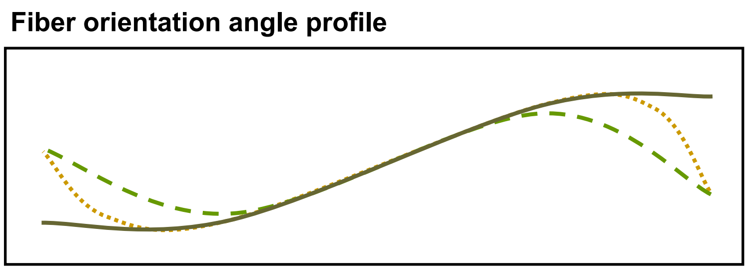


Figure 1-16. Correction of fiber orientation angle using edge flows. Dotted: large slice opening. Dashed: small slice opening.

1.6.2.2 Adjust slice shape

If the slice shape is adjusted on a conventional headbox making a single-ply grade, there will be an effect on the dry weight and caliper profiles as well as the fiber orientation angle profile. With a dilution headbox, this can be corrected independently using the dilution system, provided it has sufficient capacity. With a conventional headbox, the effect on dry weight and caliper (and potentially on runnability) must be taken into account.

On multi-layer machines, it is not possible to separate the dry weight profile into contributions from each headbox. Thus, a correction to a surface layer slice lip will have an effect on the weight of that layer. The total weight profile may be correctible using the dilution system on a filler layer, but properties related to the surface layer weight may be influenced. For example, the brightness profile of a white-top linerboard will be affected by changes to the slice lip of the top headbox.

Approach changing the slice lip shape as a search for a compromise between fiber orientation angle profile and other profiles, such as dry weight, caliper, or brightness. In general, a smooth change to dry weight is much more acceptable than a rough or sharp change of similar amplitude. However, the mill’s criteria for acceptable deviations from flatness in dry weight or brightness must be taken into account before attempting any slice lip changes. Greater deviations in dry weight can be tolerated in sheet-fed printing grades than in roll-fed printing grades, for example, and boxboard to be printed/converted from sheets or narrow rolls can tolerate greater deviations than linerboard to be converted in wide rolls.

By making a smooth change to the slice, especially near the sheet edges, the typical “frown” shape can be reduced or removed. The situation in Figure 1-15 can be improved to that shown in Figure 1-17.

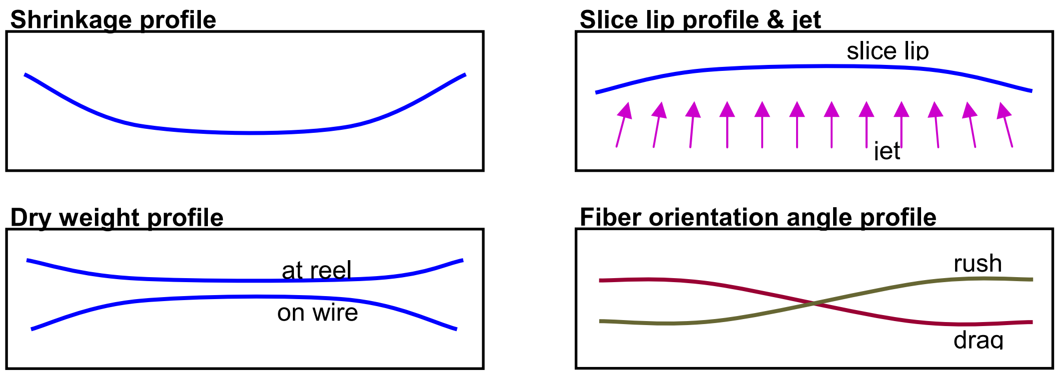


Figure 1-17. Effect of partially flattening the slice lip on fiber orientation angle and dry weight profiles.

If a headbox is equipped with controllable edge flows, it is recommended that the edge flows be used first to bring the fiber orientation angles at the edges to near zero. This reduces the amplitude of slice lip movement needed near the edge, and consequently reduces the disturbance to other profiles. At the same time, it can give a better fiber orientation angle profile than slice lip movement alone (see Figure 1-18). This recommendation is for both conventional headboxes and dilution headboxes.

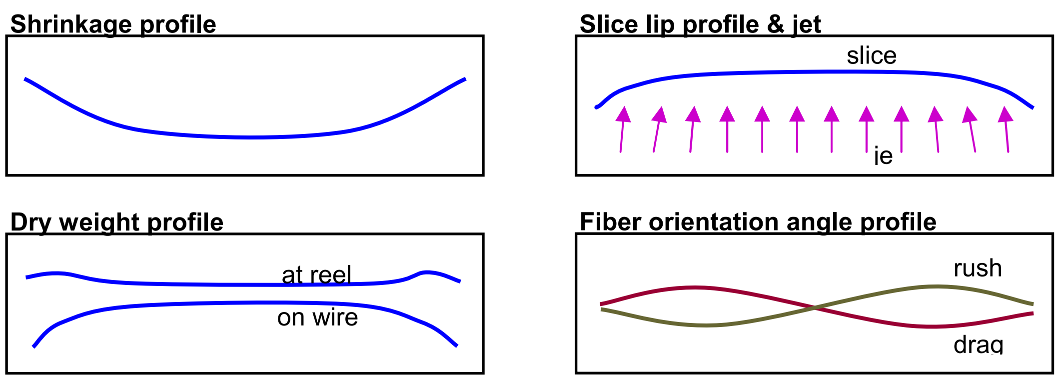


Figure 1-18. Effect of slice lip with edge flows already adjusted.

1.6.3 Twist problem in multi-layer paperboard

There is a significant correlation between twist and differences in surface layer fiber orientation, as explained in §1.2.2.2 and illustrated in Figure 1-5.

If the mill is experiencing a quality problem with twist in the paperboard, then there is almost certainly a difference between the fiber orientation angles on the two surface layers. There may additionally be a difference in their anisotropies. Note that while the fiber orientation angle profiles should ideally be flat on both surfaces, it is a **difference** in local fiber orientation angle which is associated with twist.

The strategy for eliminating twist is always to reduce the fiber orientation angle difference wherever there is a twist problem. If the fiber orientation profile is significantly better on one surface than on the other, try to improve the worse surface first. This has the advantage that it is necessary to work with only one headbox slice. It may also have secondary benefits on machine operation. Normally, the fiber orientation profiles are comparable in amplitude on both surfaces, and it is preferable to make approximately **equal and opposite changes on both headboxes**.

Always check the rush-drag to determine the direction of movement needed in the jet to correct the fiber orientation angle difference.

1.6.3.1 Broad twist issue

A broad twist issue is one in which the twist is in the same direction over a significant part of the sheet, and exceeds quality acceptance limits in much of that area. If the twist exceeds quality limits over a broad area, but with direction of twist changing every few actuator zones, then it should be treated as several narrow twist issues which happen to be adjacent.

If a broad twist issue occurs over essentially the whole sheet, or over one half of the sheet, then the techniques in §1.6.2.2 may be employed to reduce fiber orientation angle differences.

If a broad twist issue extends over several slice actuator zones in width, but only over a portion of the sheet, then a different approach is needed. Reducing the fiber orientation angle requires changing the lateral movement of the jet, which involves putting a slope in the corresponding region of the slice lip. The slice actuators outside that region must also be moved, but in a shape which tapers gradually back to zero. The slope on the slice outside the region to modify should be significantly less than the slope inside that region. The result is illustrated in Figure 1-19.

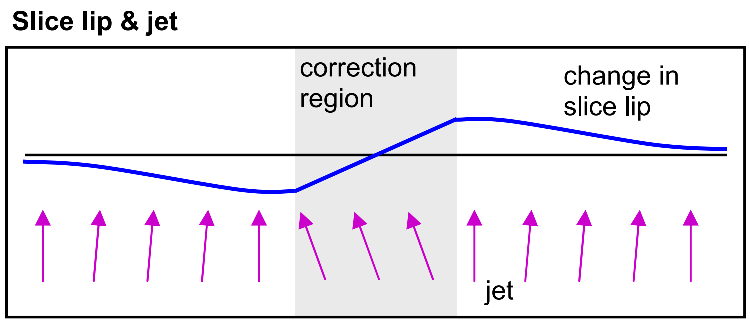


Figure 1-19. Using slice to adjust jet over a region for twist correction.

The following technique can be used:

- At the center of the region to modify, leave the slice actuator in its current position (i.e. no movement).
- Move actuators progressively greater amounts upwards from the center to one edge of the region to modify.
- Move actuators progressively greater amounts downwards from the center to the other edge of the region to modify.
- Beyond the edges of the region to modify, move actuators progressively smaller amounts, until reaching a point where the movement amount would be negligible.

Quite often, a positive twist issue in one region of the sheet will occur with a negative twist issue elsewhere in the sheet. In this case, all actuators between the two regions can move by a similar amount, Figure 1-20.

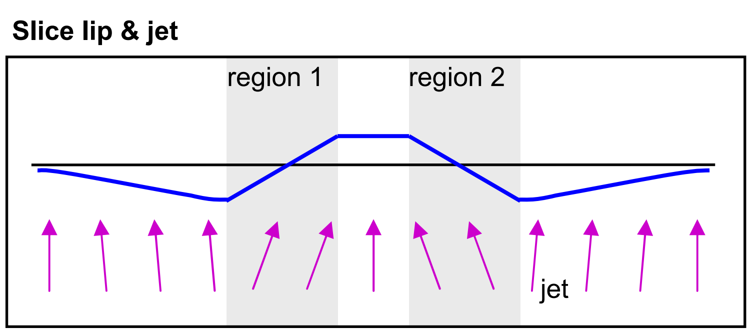


Figure 1-20. Opposite adjustments in multiple regions.

1.6.3.2 Local twist issue

Since the twist problem can be local, affecting just a narrow region of the sheet, the approach of making smooth changes to the slice lip may not always be appropriate. If the twist issue is at an edge of the sheet, then headbox edge flows may be useful in reducing fiber orientation angle differences (see §1.6.2.1).

If a narrow local change is to be made to a jet using the slice lip, then the following technique should be employed:

- To locally direct the jet more towards the front of the machine, increase the slice opening at the nearest actuator nearer the front, and reduce the slice opening at the nearest actuator nearer the back.
- To locally direct the jet more towards the back of the machine, reduce the slice opening at the nearest actuator nearer the front, and increase the slice opening at the nearest actuator nearer the back.
- If the actuator movements needed were large, or would lead to large local bending inthe slice lip, then the neighbouring actuators can be moved by a smaller amount to avoid reaching the slice bending limit. This can also avoid introducing a twist issue adjoining the corrected area.

The standard narrow correction pattern is shown in Figure 1-21, left. Variations to reduce the bending effect or mitigate effects on neighbouring areas are also shown in Figure 1-21, center and right.

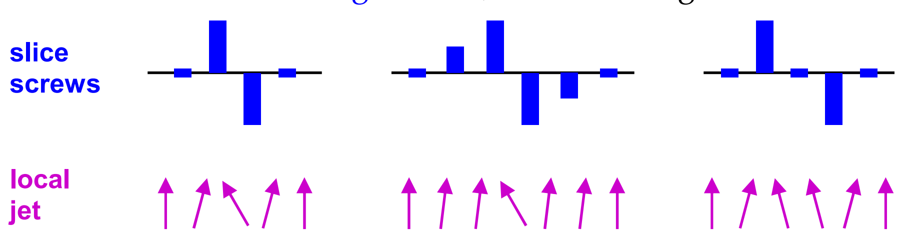


Figure 1-21. Slice movement patterns for correcting local twist issues.

1.6.4 Unexpected response amplitude

In making a change to the slice lip to improve the fiber orientation angle, the response which is seen may differ from the expected response. The difference can be quite large – in direction as well as in magnitude. If the direction appears to be opposite of the expected direction, first check definitions of positive and negative angles, etc., to make certain that the process and measurement directions are fully understood and properly applied.

The primary cause for unexpected response amplitudes is that the forming section is at a different rush-drag state than its "official" value. The calculated jet speed (and consequent estimate of rush or drag) must be treated as an approximation, and can easily be in error by a few meters per minute. As seen from Figure 1-8, a small change in the rush or drag can cause the fiber orientation response amplitude to change by a large amount. The sensitivity ro rush or drag errors is greatest in machines with low turbulence in the forming region, as occurs when there are no vanes in the slice nozzle, or the jet impingement angle on the wire is small.

The solution is to persuade the mill to calibrate their true jet speed. It is not practical to attempt control of fiber orientation angles without knowledge of the true rush or drag value.

1.6.5 Calibration of true jet speed

There are at least four ways to do this, with differing costs and convenience:

1. In some cases, the headbox manufacturer can supply a customized calculation for the jet speed, which is often accurate enough within a specific range of operating states. Outside its range of validity, however, it can produce significantly erroneous estimates. Note that due to process optimizations, headboxes are usually operated at or beyond their initial specifications within a few years.

2. A direct measurement of the jet (laser-doppler, laser cross-correlation, etc.) can be installed on open Fourdrinier formers, but not on gap-formers. This is typically very expensive, and its accuracy depends on further calibration by its supplier.

3. At each major operating point for the machine (wire speed, slice opening), the mill can construct a calibration as follows:

    - Step the headbox pressure in increments over a range which is expected to extend from drag to rush and includes the nominal operating pressure.

- At each headbox pressure, measure the exact sheet width at a convenient location after the drying section, but before the coaters or calendars. This measurement must be fairly meticulous.

- Plot the sheet width vs headbox pressure or nominal jet speed. The actual zero point (jet speed equals wire speed) occurs when the sheet width is maximum, and the calculated jet speed should be corrected by an offset to match this.

4. At each major operating point for the machine (wire speed, slice opening), the mill can construct a calibration as follows:

   - Put the scanner with FotoFiber sensors into fixed position near the middle of the sheet.

   - Step the headbox pressure in increments over a range which is expected to extend from drag to rush and includes the nominal operating pressure. Record the surface anisotropy at each setting once steady-state is reached.

   - Plot the surface anisotropy vs headbox pressure or nominal jet speed. The actual zero point (jet speed equals wire speed) occurs when the surface anisotropy is minimum, and the calculated jet speed should be corrected by an offset to match this.

Method 4, employing the online FotoFiber measurements, is faster and less labor-intensive than method 3, since it does not require manual measurement of sheet width. In fact, it takes only a few minutes to perform, and could be recommended to a mill as a standard procedure after a grade change. The two methods are usually in close agreement.

Moreover, on a multi-layer machine, method 3 must deal with each headbox sequentially, and becomes quite time-consuming. Method 4, on the other hand, can calibrate both surface headboxes simultaneously using the FotoFiber sensors. It is quite common for supposedly identical headboxes to require different offsets in jet speed.

Interestingly, mills with the laser-based measurements of jet speed (i.e. method 2), often do not rely on them for accurate rush-drag assessments. The experimental approaches (methods 3 and 4) are considered more reliable.

1.7 Further Reading

The following non-Honeywell documents may also be of interest:

K. Niskanen (ed.), *Paper Physics*, 2nd ed., volume 16 of *Papermaking Science and Technology*, Paperi ja Puu Oy, Helsinki Finland, 2008. [Chapters 1, 5, 6, 9]

H. Paulapuro (ed.), *Paper and Board Grades*, volume 18 of *Papermaking Science and Technology*, Paperi ja Puu Oy, Helsinki Finland, 2000. [Chapters 1, 2]

W. Scott and J. Abbott, *Properties of Paper: An Introduction*, 2nd ed., TAPPI Press, Atlanta Ga. 1995. [Chapters 3, 4, 8]

J. Shakespeare, "Tutorial: fibre orientation angle profiles – process principles and cross-machine control" *Proceedings TAPPI 1998 Process Control Electrical & Instrumentation (16-19 March, Vancouver BC)*, p.593-636.

2 FotoFiber Structure and Operating Principle

2.1 Introduction

This chapter gives an overview of the FotoFiber sensor structure and operating principle. The key features of the FotoFiber sensor are:

- Based on high-speed digital imaging and real-time analysis.
- Passively-contacting measurement.
- Consists of illumination and detector units mounted in the same sensor head.
- The sensor can be installed on top or bottom side of the sheet for measurement of the selected sheet surface.
- Two sensors can be installed opposite one another for two-sided measurements.
- Can be installed inboard or outboard (if outboard the Color sensor duopack must be used.)
- Can be used by Da Vinci systems with RAE 5 or newer (with latest updates).

FotoFiber sensor can be installed either inboard in 4-pack or 6-pack or alternatively outboard in a Color sensor duopack. The approved locations for a 6-pack are shown in Figure 2-1.

It is strongly recommended that FotoFiber be located downstream of any sensor which is sensitive to dust, since it contacts the sheet and may cause dust issues, especially in sheets with high filler content. For this reason, it is not recommended to install FotoFiber into the first (upstream) measurement location in a 4-pack or 6-pack. It is preferably installed into the last (downstream side) measurement location, so that dust issues do not arise in other sensors.

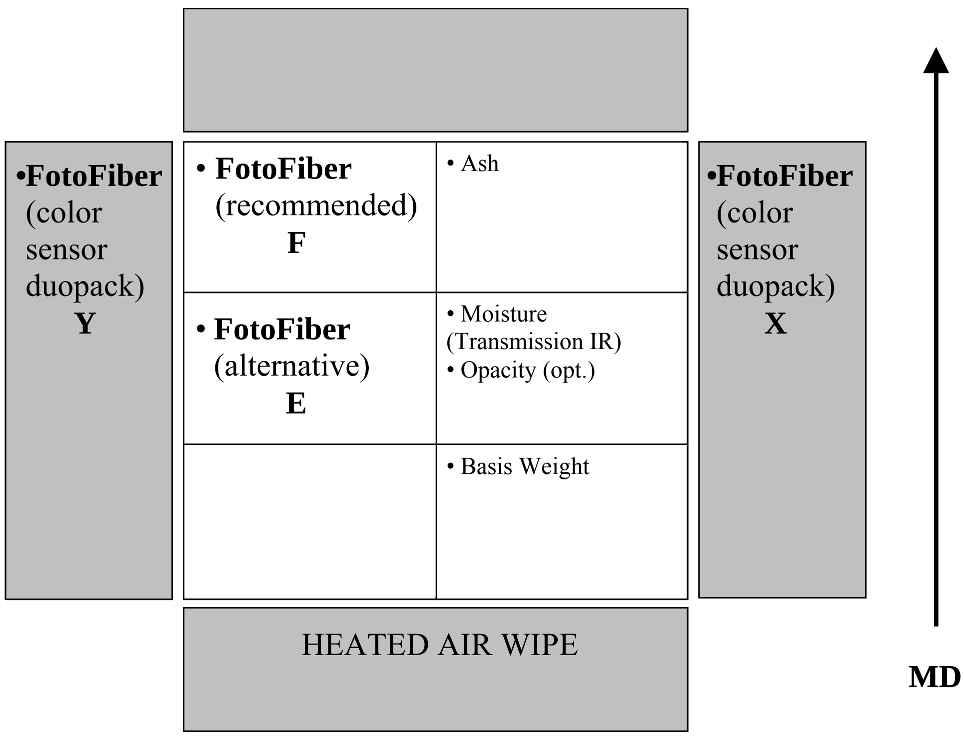


Figure 2-1. Approved locations for installing FotoFiber sensor. Recommended: F. Alternative: E, X, Y.

CD offsets with respect to the basis weight sensor are shown in Table 2-1 for these sensor positions.

Table 2-1. Offsets for FotoFiber positions.

E,	F	X	Y
PrecisionPak-4	-219.1mm -8.63″	403.1mm 15.87″	-720.6mm -28.37″
PrecisionPak-6	-174.65mm -6.876″	403.1mm 15.87″	-720.6mm -28.37″

2.2 FotoFiber Sensor Main Modules

The FotoFiber sensor consists of either one or two measurement units. If there is only one measurement unit, then a backing unit is located opposite it in the other head of the scanner. The units are designated **FOMM** = FotoFiber Measurement Module and **FOBM** = FotoFiber Backing Module. In a two-sided sensor, the FOMM units on each side of the sheet differ slightly. One FOMM is shown in Figure 2-2. In a single-sided sensor, the structure of the FOMM and FOBM units depend on which is to be installed above the sheet. The differences pertain only to the window and sheet-bearing rings.

FOMM

- Outputs short, directionally unbiased, annular flashes of white light
- Captures images of surface of paper/board web
- Computes surface fiber orientation distribution and parameters
- Communication to Da Vinci via MSS

FOBM

- Passive unit
- Assists in stabilizing web

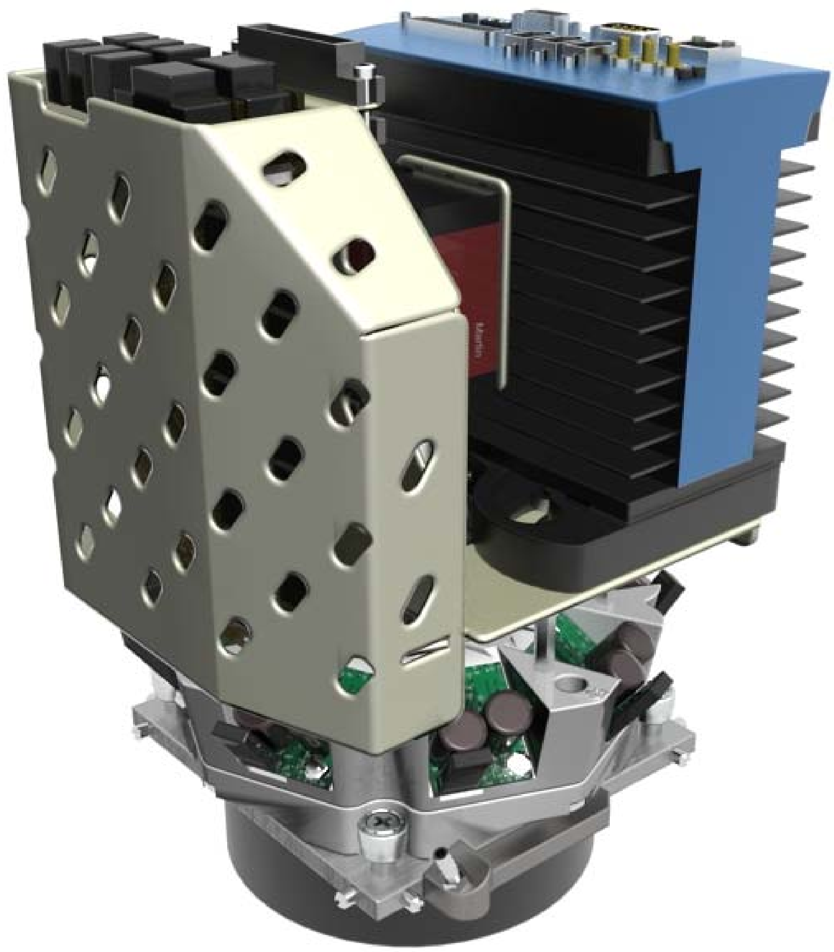


Figure 2-2. FotoFiber sensor main module

2.2.1 FotoFiber measurement module (FOMM)

The external electrical connections, switches and LEDs of FotoFiber Measurement Module (FOMM) are shown in Figure 2-3. This module performs all measurement functions of the FotoFiber measurement. It communicates with the Measurement Sub System (MSS). FOMM connector is connected to the sensor head by using the cable p/n 08723900. FOMM is powered through the DC 24V connector which is connected to the Lamp Power socket or AUX Power socket in the sensor head with the cable p/n 08724200 or p/n 08766300, respectively. There is a switch to power ON/OFF the FOMM. Moreover, the FOMM is protected by a fast-acting fuse rated at 5 amps. The normal current draw of the FOMM is between 1.0A and 1.1A at 24VDC.

Pushing the Reset button for a couple of seconds performs a soft reboot of FOMM. This button may be needed in firmware updates, for example. Dip-switches determine the operating mode of the FotoFiber sensor. The default operation (Da Vinci measurement mode) is achieved by setting all the switches in OFF position.

The VGA port provides diagnostic information during Da Vinci measurement (e.g. timestamp, last mode request / status, internal parameters). This feature can be utilized in troubleshooting, but is not suitable for use in scanning operation.

The ethernet port is used to install firmware updates to FotoFiber. Moreover, it is used in PC control mode, where various functions of the sensor can be tested, and the sensor can be operated outside the scanner using a PC. For example, the quality control test performed by the factory and some other special service procedures use this port. The status LEDs report various states of the FOMM. They can be very helpful in troubleshooting.

The illumination and imaging systems in FotoFiber have been designed to minimize internal reflections and entry of extraneous light to maximize contrast in the images.

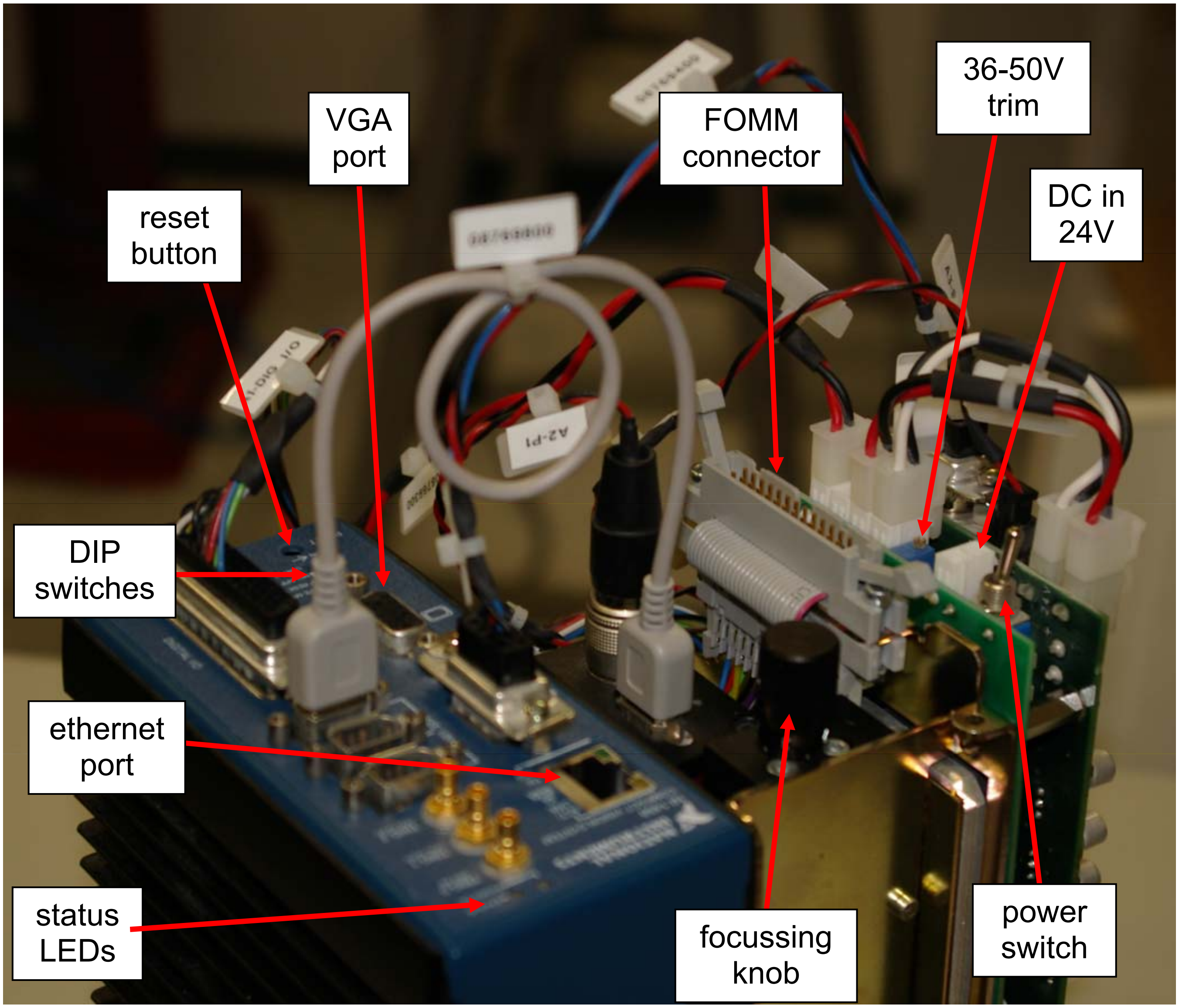


Figure 2-3. FotoFiber Measurement Module (FOMM). External connectors and adjustments.

The sensor gap side of FOMM is shown in Figure 2-4 and Figure 2-5.

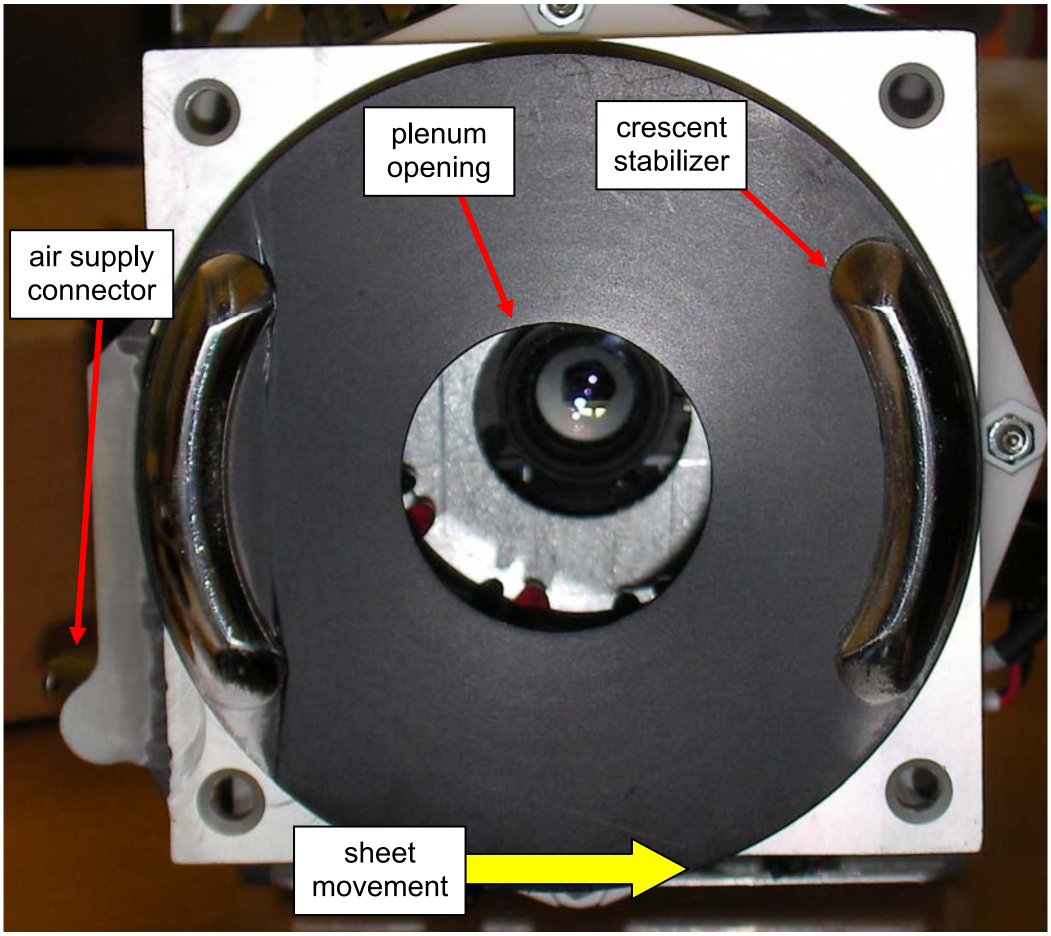


Figure 2-4. Gap side of FOMM in upper head (for two-sided sensor in a machine making low-filler grades).

When a two-sided FOMM is installed in the upper head, its sheet stabilizer is a pair of crescents, as shown in Figure 2-4. A 6mm thick borosilicate glass window is located inside the plenum, and is kept clean by a transverse air flow across the window surface inside the plenum. Note the direction of sheet movement, and the position of the air supply connector.

When a single-sided FOMM is installed in the upper sensor head, the sheet stabilizer is a complete ring located close to and concentric with the plenum opening. It is similar in size to the horseshoe shape in Figure 2-5, except it is a full circle.

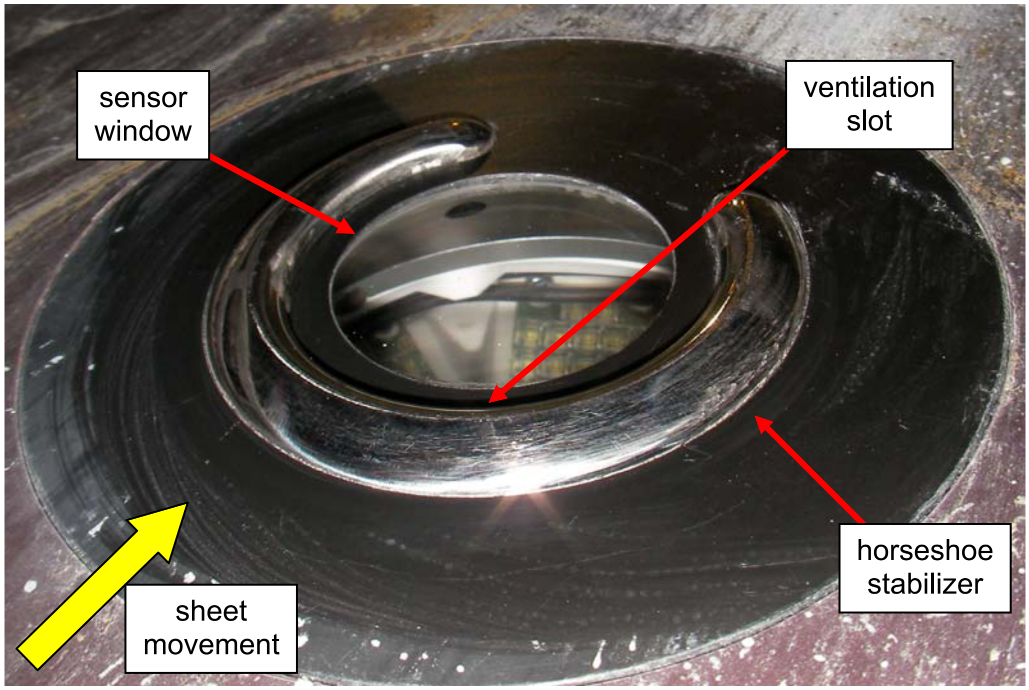


Figure 2-5. Gap side of FOMM in lower head (one-sided or two-sided).

When a single-sided or two-sided FOMM is installed in the lower head, the protective glass window is flush to the sensor head face plate and the sheet stabilizing ring is replaced by a ventilated horseshoe shape. Note the direction of movement of the sheet relative to the horseshoe.

In the single-sided measurement, the FOBM has a crescent-shaped stabilizer similar to that shown for the FOMM in Figure 2-4. This allows the heads to be separated without overlap of the stabilizing elements on the two heads.

2.2.2 FotoFiber backing module (FOBM)

This module is required only for single-sided measurements with a single FOMM. For dual-sided measurements, two FOMM modules are used instead.

There are no electronic or active mechanical components in the FOBM. It comprises simply a blank with one or two sheet stabilizing crescents. One crescent is used in high-dust mills, in which case the FOBM should always be installed so that the crescent is positioned on the downstream side.

2.2.3 Matching FOMM and FOBM

The FOMM for an upper head has an open plenum rather than a window near the sheet. If it is part of a one-sided sensor, then it has a circular ring around the opening. If it is part of a two-sided sensor, then it has arcs spaced upstream and downstream of the plenum opening. In high-dust environments, the upstream arc can be removed and replaced by a flat insert, flush with the blank surface (this reduces dust generation).

The FOMM for a lower head always has a horseshoe-shaped ring around a window. This is the case, whether it is part of a one-sided or two-sided sensor.

The FOBM is always a blank, with arcs spaced near its upstream and downstream edges. This is the case whether it is in the upper or lower head. In high-dust environments, the upstream arc can be removed and replaced by a flat insert, flush with the blank surface (this reduces dust generation).

These configurations are depicted in Figure 2-6.

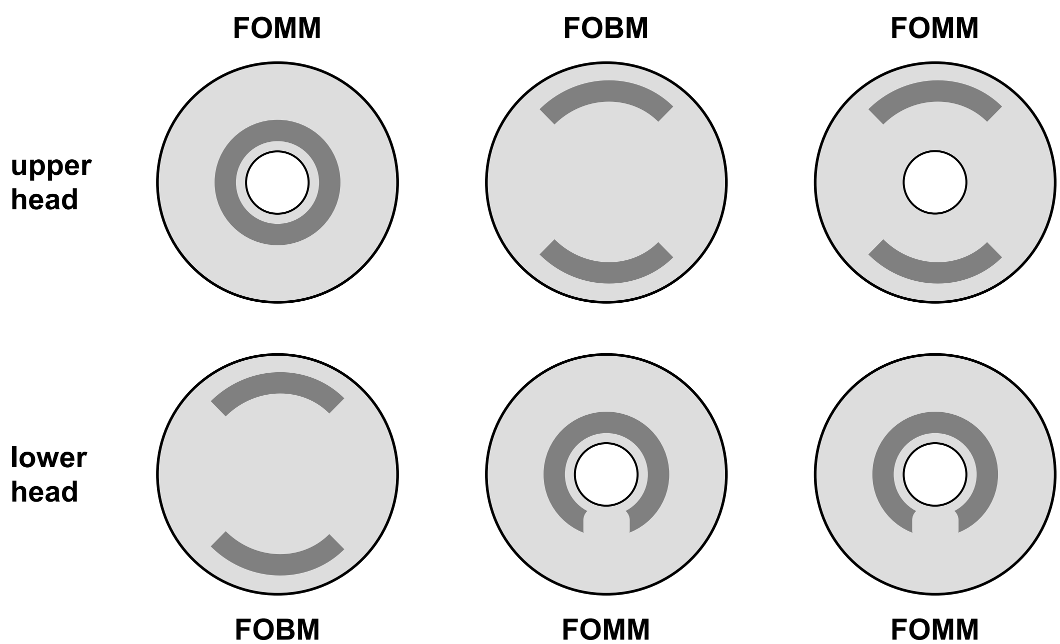


Figure 2-6. FOMM and FOBM combinations.

2.3 Operation Principle and Specifications

2.3.1 Operation principle

FotoFiber measurement of surface fiber orientation is based on digital imaging and image analysis performed in the sensor. The FotoFiber sensor traverses over the running paper web inside the scanner head. The sensor is mounted on one side of the sheet flush to the scanning head front plate. There is a 10 mm open gap between FOMM and the opposing FOBM or second FOMM, in which the web moves. FOMM takes digital images of the web. The web is epi-illuminated with short light pulses emitted by a ring light in FOMM . The pulses are timed to occur during the camera exposure. Images of the web are analyzed by mathematical algorithms in FOMM. The results (the fiber orientation distribution, and a parametric representation of the distribution) are sent to Da Vinci for building trends and profiles. In addition, images of the sheet are periodically sent, accompanied by their histograms and fiber orientation parameters.

The operation principle of the FotoFiber sensor in Da Vinci system is shown in Figure 2-7. The sensor needs 24 VDC power and pressurized air, but does not require water. Internal operation of the sensor is controlled by the Processor Module of FOMM. It receives mode commands from the Measurement Sub System (MSS) through a serial link, which employs CSLP (Camera Sensor Link Protocol) for communication. The Processor Module executes commands and reports slice data, standardization data, alarms, etc. back to the MSS. The serial link is connected to the standard serial port of PCDAQ/PCI card (p/n 05438200) in the MSS. Note that the SDAQ port cannot be used. The MSS is connected to a Da Vinci server through an Ethernet connection. The Da Vinci server gathers FotoFiber data and provides standard tools for displaying the data as profiles, trends, colormaps, and so forth. Moreover, FotoFiber software in the DaVinci includes special tools for displaying on-line polar histograms and surface images. Also there is a sample measurement mode which can be used when the sensor is offsheet.

The Processor Module operates a monochrome industrial camera with two connections: IEEE 1394b-a cable (p/n 60000940) for power, image transfer and configuration and a trigger cable. The camera is configured automatically for different grades and operation modes by the Processor

Module. Imaging by the camera and illumination by FOMM is timed by the triggering from the Processor Module. A special high-resolution low-distortion macro lens projects a sharp image of the web on the CCD chip of the camera. Images are transferred to the Processor Module, which calculates the fiber orientation distribution and its parametric description from them.

FOMM includes eight pulsed white light LED panels, each with 24 LEDs which have individual lenses to maximize illumination intensity. The LED panels are each driven by a dedicated PCB which controls the pulse length and strength. The individual strengths are modulated using calibration curves so that the illumination is directionally uniform (i.e. no directional bias). The LEDs are synchronized to produce pulses with very precise agreement in timing, differing by no more than a few nanoseconds. Intensity and duration of light pulses are configured by the Processor Module of FOMM through a serial link to the strobe controller, which governs the LED driver boards. The strobe controller generates a light pulse with the configured characteristics every time it receives a trigger pulse from the Processor Module.

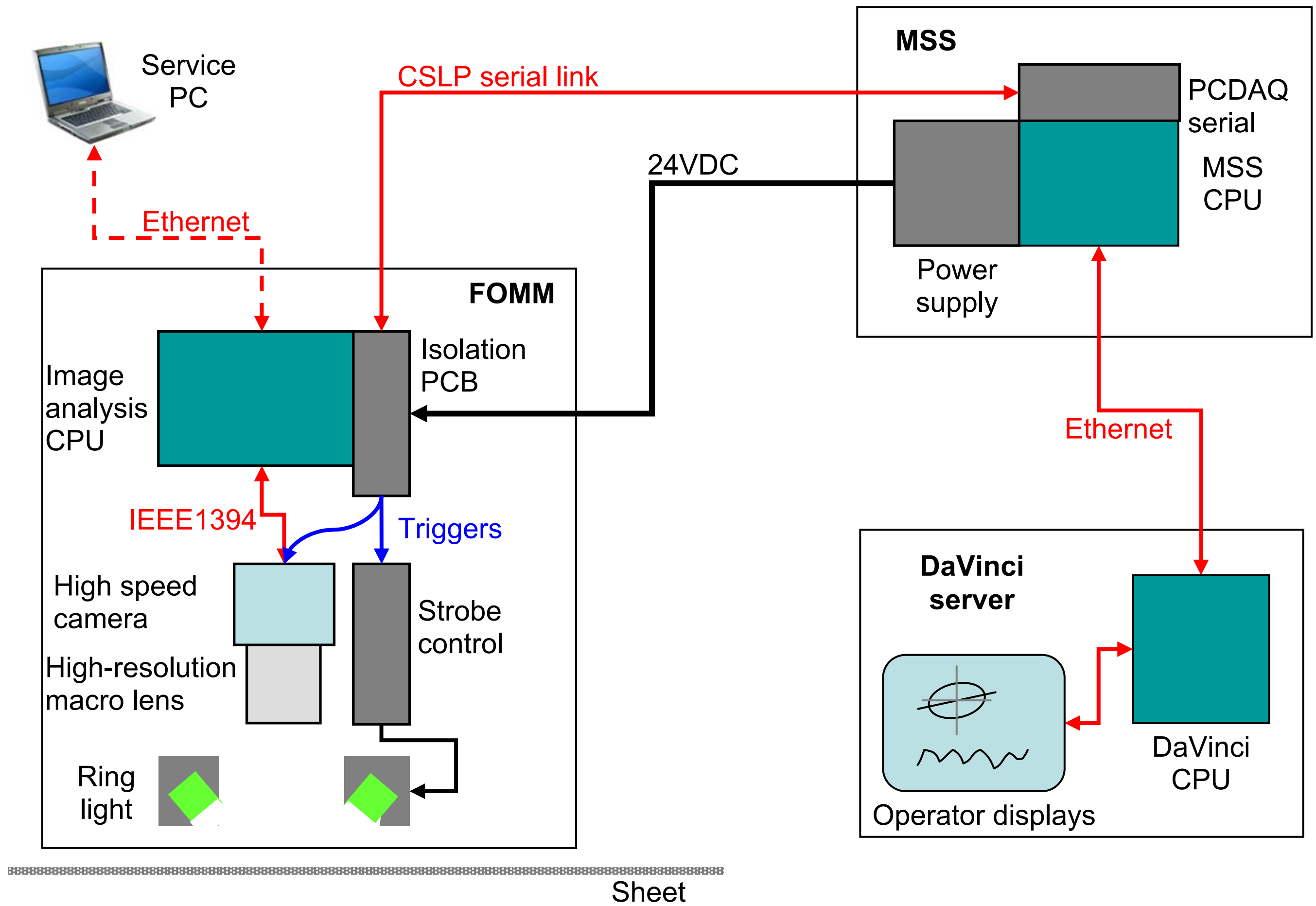


Figure 2-7. Operation principle of FotoFiber

In addition to normal Da Vinci operation mode, FotoFiber includes a PC controlled mode.

The PC controlled mode is used in the factory testing procedure, but it may also be used by Honeywell technicians on the field for troubleshooting purposes. In this mode, the Processor Module and a PC are connected together with a cross-wired ethernet cable (FOMM ethernet port is shown in Figure 2-3). Special software on PC can be used to control the functions of FotoFiber in this mode.

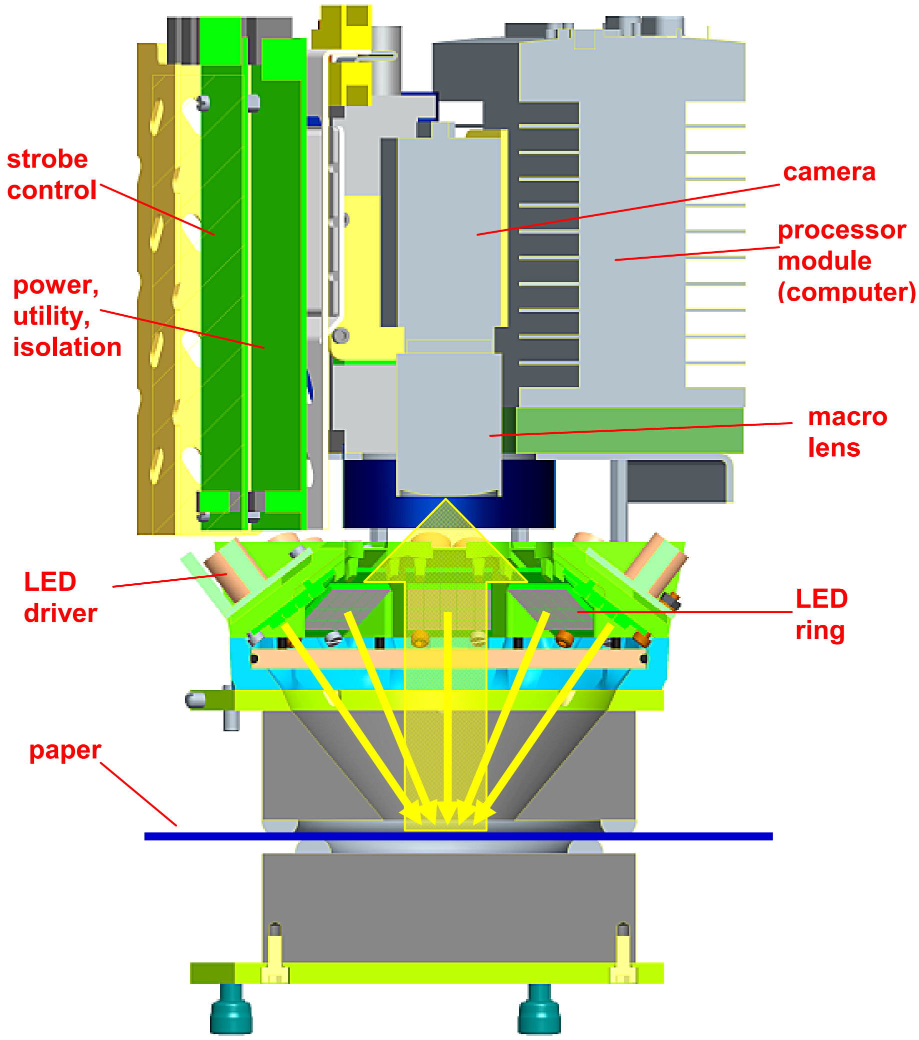


Figure 2-8. Schematic layout of FotoFiber (single-sided measurement).

2.3.2 On-sheet scanning operation

Scan procedure consists of the following steps:

1. Prepare scan.
2. Do slice measurements at 10hz frequency (cf. steps below) and gather scan average of image intensity.
3. Pass data to End of Scan operations.

Slice measurement (performed at 10Hz) consists of the following steps:

4. Take an epi-illuminated image of the web.

5. Apply mathematical algorithms to the corrected image to calculate the fiber orientation histogram and its parametric representation (see §2.4).

6. Communicate the measured fiber orientation parameters to the Da Vinci host.

Detailed measurement (performed at 0.5Hz) consists of the following additional step:

7. Send computed measured histogram, its fitted histogram and fiber orientation parameters to Da Vinci system for operator display.

Image communication (performed at 1 or more specified locations in the scan) consists of the following additional step:

8. Send measured image, computed measured histogram, its fitted histogram and fiber orientation parameters to Da Vinci system for operator display.

2.3.3 End of scan operation

All parameters of imaging (including camera and light pulse parameters) are adjusted at the end of scan. These tasks include:

1. Auto-adjust light pulse length based on machine speed, to keep the amount of motion blur within acceptable limits.

2. Auto-adjust light source total intensity and the camera gain based on scan average in order to have a constant signal level (mean graylevel) from the camera.

3. Balance the levels used in each illuminator channel to keep directional uniformity of illumination, using channel efficiency factors from standardization

This allows significant grade changes without any preparation; the sensor adjusts itself automatically to changes in light absorption and reflection of the web.

2.3.4 Standardization

The purpose of standardization is to compensate the illumination channels for differences in intensity (as seen by the camera) due to mild dirt build-up, aging of components, and changes in the color of the paper. It will also indicate malfunctioning or aberrant performance of an illuminator channel.

ATTENTION The FotoFiber sensor must perform standardization on-sheet. It must use the current production paper as its standardization reference. Internal references are neither supplied nor needed.

When a manual or scheduled standardization is initiated for the other sensors, the FotoFiber sets an internal flag that its next scan will be for standardization. The flag is set to the same value as the scanning standardization enabled parameter flag. It waits about one second, then sends a standardization finished message to the MSS. This message contains a flag for the DaVinci to ignore the data.

If the standardization flag is set, then when the next scan starts the FotoFiber performs the following standardization sequence:

1. Set camera to standardization mode (store current gain, and set gain to maximum).

2. Switch off all strobe channels.

3. Wait until on-sheet.

4. For each strobe channel, in a predetermined sequence:
    1. enable the channel and set the channel strength to the average channel level used in the last scan
    2. capture and discard a number of images
    3. capture a number of images, and compute the average of their mean gray levels
    4. compute the raw ratio of the average gray level to the calibration gray level for the same pulse length and strength
    5. disable the channel

5. Compute channel efficiency factors by dividing raw ratios by average of all raw ratios.

6. Set error or warning flags if necessary:

    1. if any channel gray level is out of range, set an error flag
    2. if any channel factor is out of range, set a warning flag

7. Set camera to scan mode (restore gain)

8. Enable all strobe channels

9. For the rest of the scan:
    1. capture and discard a number of images
    2. capture and count the remaining images as combined images
    3. compute the average of their mean gray levels

10. Set error or warning flags if necessary:
    1. if the combined gray level is out of range, set an error flag
    2. if the number of combined images is low, set a warning flag

11. Report the following data to the MSS
    1. warning and error flags
    2. number of gray scan images
    3. channel gray levels
    4. channel factors

12. If there were no error flags, set next scan to be a measurement scan. Otherwise, set next scan to be a standardization scan.

Standardization must complete in a single traverse; it cannot be split over multiple traverses. The time required on-sheet in a single traverse for standardization depends on several of the configuration parameters and preferably exceeds 12 seconds (see §5.4.2.2).

The channel factors, channel gray levels, number of combined images and combined image mean gray level for the most recent standardization are shown on the standardization display. The display also has trends of these values and of the error and warning flags.

2.3.5 On-sheet single-point operation

FotoFiber also has a single-point measurement mode. However, the procedure involves an on-sheet adjustment of illumination followed by an on-sheet standardization, before measurement commences.

Single-point procedure consists of the following steps, after the sensor has reached the designated single-point position on-sheet:

1. Adjust the illumination intensity to achieve the target gray level.
2. Balance the illumination using existing channel factors.
3. Perform a standardization using the illumination conditions established in previous steps. This consists of steps 4-8 in the scanning standardization (see §2.3.4) giving new channel factors.
4. Rebalance illumination using the new channel factors.
5. Do slice measurements at 10hz frequency (cf. steps below).

Slice measurement (performed at 10Hz) consists of the following steps:

6. Take an epi-illuminated image of the web.
7. Apply mathematical algorithms to the corrected image to calculate the fiber orientation histogram and its parametric representation (see §2.4).
8. Communicate the measured fiber orientation parameters to the Da Vinci host.

Detailed measurement (performed at 0.5Hz) consists of the following additional step:

9. Send computed measured histogram, its fitted histogram and fiber orientation parameters to Da Vinci system for operator display.

Image communication (performed every 20 seconds during single-point measurement) consists of the following additional step:

10. Send measured image, computed measured histogram, its fitted histogram and fiber orientation parameters to Da Vinci system for operator display.

2.3.6 Reference mode

The FotoFiber sensor has a sample measurement feature available as an off-sheet function in the Da Vinci Maintenance mode.

A reference measurement should always be performed before making sample measurements, preferably using one of the samples to be measured, or a similar sample. A reference measurement can also be used for standardization of the sensor if scanning standardization is disabled.

Reference measurement procedure consists of the following steps:

1. Configure Da Vinci system to Maintenance mode.
2. Set Reference Integration Time to at least 40 seconds.
3. Enter sample to the sensor gap in the same orientation as the paper web (MD and CD directions as in the paper web).
4. Push Sample button.
5. Look at the results gathered on the maintenance display (see Figure 5-31).

When the reference button is pressed, the FotoFiber performs the following sequence, which is similar to the scanning standardization sequence:

1. Set camera to scan mode
2. Find a suitable illumination level:
    1. set pulse length according to nominal machine speed for sample mode
    2. set all channels to initial level
    3. capture a number of images, and compute the average of their mean gray levels
    4. adjust channel levels to bring gray level to target
    5. repeat steps 3 and 4 (maximum 3 iterations needed)
3. Set error flag if the gray level is out of range
4. Set camera to standardization mode (store current gain, and set gain to maximum).
5. Switch off all strobe channels.
6. For each strobe channel, in a predetermined sequence:
    1. enable the channel and set the channel strength to the average channel level used in the last scan
    2. capture and discard a number of images

    3. capture a number of images, and compute the average of their mean gray levels
    4. compute the raw ratio of the average gray level to the calibration gray level for the same pulse length and strength
    5. disable the channel

7. Compute channel efficiency factors by dividing raw ratios by average of all raw ratios.

8. Set error or warning flags if necessary:
    1. if any channel gray level is out of range, set an error flag
    2. if any channel factor is out of range, set a warning flag

9. Set camera to scan mode (restore gain)

10. Enable all strobe channels

11. Report the following data to the MSS
    1. warning and error flags
    2. number of gray scan images
    3. channel gray levels
    4. channel factors

12. Set mode to idle.

Note that up to six iterations can be used for the strobe controller to bring the gray level to the target. In most cases, three iterations will give a very close match. However, the reference integration time is long enough to allow six iterations, being longer than the on-sheet standardization time.

2.3.7 Background

The FotoFiber sensor does not have a background function.

2.3.8 Sample measurement

FotoFiber sensor has sample measurement available as an off-sheet function in the Da Vinci Maintenance mode. Note that the orientation angle measured in sample mode will depend on the alignment of the sample in the measurement gap.

A reference measurement should be made on the first sample to allow the sensor to adjust the illumination parameters correctly. Otherwise, the image could be severely overexposed or underexposed, leading to an unreliable measurement. When making a series of sample measurements on samples of similar color and lightness, there is no need to make another reference measurements. However, if sample measurements are to be made on samples with greatly differing color or lightness, then a separate reference step should be performed before each series of samples of similar color and lightness, and using a sample characteristic of that series.

The sample measurement procedure consists of the following steps:

1. Configure Da Vinci system to Maintenance mode.
2. Set Sample Integration Time to at least 5 seconds (the default is 40 seconds, which averages more raw readings).
3. Enter sample to the sensor gap in the same orientation as the paper web (MD and CD directions as in the paper web).
4. Push Sample button.
5. Repeat Steps 4 and 5 until all samples have been measured.
6. Look at the results gathered on the maintenance display (see Figure 5-33).

2.4 Image Analysis

The image acquired by the FotoFiber during its measurement modes is analyzed using proprietary (patented) methods, outlined below. The analysis result is the polar histogram of the surface fiber angle distribution, and the parameters fitted to the distribution. Two of the fitted parameters are the main measurement results: the average fiber orientation angle and the fiber orientation anisotropy.

2.4.1 Image preprocessing

The illumination compensation at each end of scan ensures that the overall gray level of images is essentially constant, and that the illumination is equal from all directions. There is thus no need to adjust the image before analysis. The image is 16 bit grayscale to ensure sufficient precision.

2.4.2 Pixel angles and amplitudes

A fractional order gradient operator is applied to the image along each axis, producing an x-enhanced image and a y-enhanced image. The gradient operator is ½ order by default (i.e. it is a semiderivative operator). The x-gradient operator includes smoothing in the y-direction, and the y-gradient operator includes smoothing in the x-direction. These operations are applied to a circular region of the image J, producing directionally enhanced images H_x and H_y:

$$H_x = D_x^{1/2} J \qquad H_y = D_y^{1/2} J$$

For a random sample of the pixels in a circular disk (typically between one quarter and one half of the pixels), centered in the image, an angle θ and squared amplitude p^2 are computed:

$$\theta = \tan^{-1}\left(\frac{H_y}{H_x}\right),$$

$$p^2 = \left(H_x\right)^2 + \left(H_y\right)^2$$

The gradient operator is renewed at the start of each scan, and changes to the order are not effective until the next scan. The random mask is typically renewed at each standardization.

2.4.3 Polar histogram and parameters

A polar histogram $r(\varphi)$ is constructed using 1° wide data boxes. For every analyzed pixel, the squared amplitude p^2 is accumulated into the bin indicated by its angle θ. The square root is taken of the final accumulated value in each bin:

$$r\left(\varphi\right) = \sqrt{\sum \left\{ p^2 \,\middle|\, \varphi_{k-1/2} \le \theta < \varphi_{k+1/2} \right\}}$$

This yields the measured polar histogram. A smooth curve approximation is also fitted to the measured histogram, using least-squares:

$$\hat{r}\left(\varphi\right) = 1 + e\cos\left(2\varphi - 2\alpha\right)$$

This curve form is a good fit to typical orientation distributions encountered in paper. The fitted parameters are:

α the average fiber orientation angle in the image

e the anisotropy of the orientation distribution.

A fitting residual and some other diagnostics are also computed. The MD/CD ratio and Max/Min ratio of the fitted distribution are computed from the average angle and anisotropy:

$$\frac{Max}{Min} = \frac{1+e}{1-e} \qquad \frac{MD}{CD} = \frac{1+e\cos\alpha}{1-e\cos\alpha}$$

The image processing is illustrated in Figure 2-9 for a typical surface image of uncoated paperboard. In the polar histogram plot, the green trace indicates the measured distribution of orientation angles, while the yellow trace indicates the fitted curve and the main axis of the fitted curve (i.e. the direction of the average fiber orientation angle α). Note that the intermediate images are not accessible in the sensor.

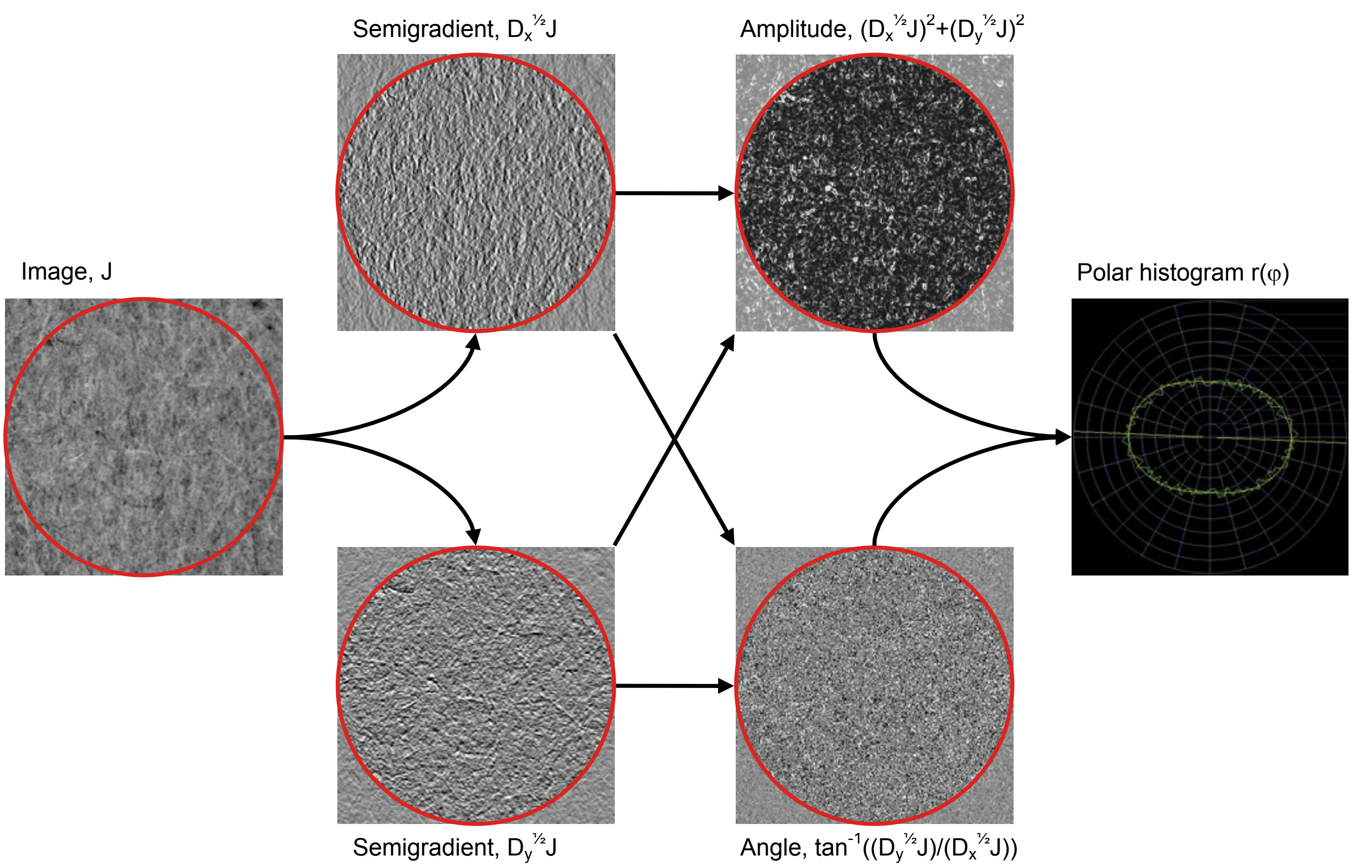


Figure 2-9. Processing for measured image.

3 Da Vinci FotoFiber Software

3.1 Functional Overview

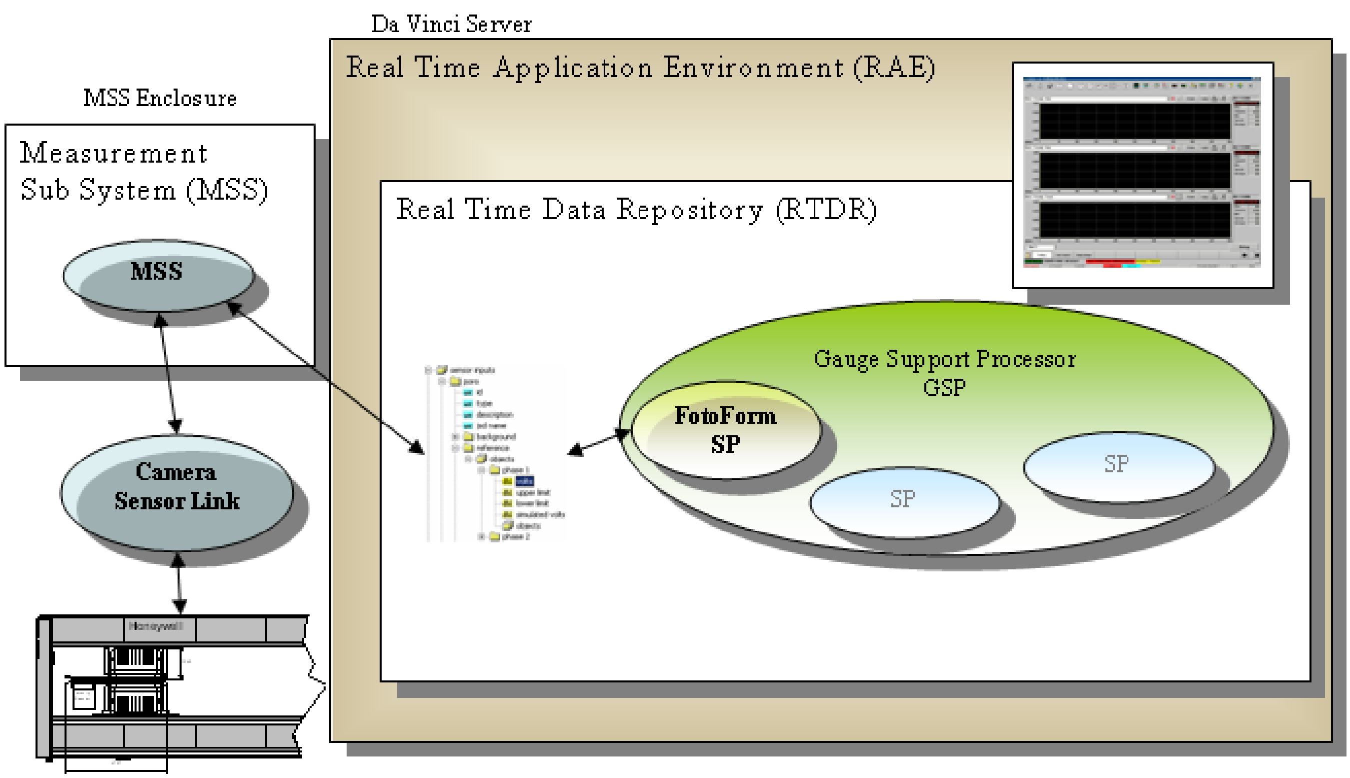


Figure 3-1. Da Vinci FotoFiber Software overview

3.1.1 Data flow

Precision FotoFiber sensor is connected to Da Vinci via a fast serial link between the Da Vinci PCDAQ card and the Processor Module of FRMM. All communication to and from the sensor is done via this link, which employs Camera Sensor Link Protocol (CSLP). Communication mode of the link is full duplex 4-wire RS 485, Baud rate: 76800, Data bits: 8, Stop bits: 1, Parity: No parity.

3.1.1.1 Camera sensor link messages

Camera Sensor Link data is located in **scannerX/mss/ssX FotoFiber/setup** RTDR record, where X = sensor set number.

Table 3-1. FotoFiber sensor → MSS

Message Ty	pe	Bytes	→ RTDR
Configuration Data Request	10_H/16	1	---
Alive and Well	30_H/48	4	---
Mode Status	11_H/17	1	---
Stdz Data	12_H/18	80	Standardize Data Buffer
Slice Data	13_H/19	44	OFSxAIA… OFSxAIJ *1
End of Scan Data	14_H/20	40	End Of Scan Data Buffer
Image Data	15_H/21	20001	Image Data Buffer 1..5
Diagnostic Data	16_H/22	40	Diagnostic Data Buffer
Alarm Message	17_H/23	40	Alarm Message Buffer
Versatile Data	32_H/50	Max 2Mb	Versatile Data Buffer

*1 ScannerX/mss/ssX fotofiber/sensor inputs/

Table 3-2. MSS → FotoFiber sensor

Message Ty	pe	Bytes	RTDR →
Configuration Data	20_H/32	200	Configuration Data Buffer
Alive and Well	30_H/48	4	Process Data *2
Mode Change Request	21_H/33	1	---
Diagnostic Request	22_H/34	2	---
Initial TIC Count	23_H/35	1	---
Trigger Image	24_H/36	5	---
Recipe Parameters	31_H/49	80	Recipe Data Buffer
Versatile Data	32_H/50	Max 2Mb	Versatile Data Download

*2 First item is Line speed in meters per second. This is sent to the sensor in the alive and well message.

3.1.2 Sensor processor

The Sensor Processor of the Precision FotoFiber sensor is located under Hmx\Gauging\Labview Vis\Processors\Precision FotoFiber\ folder and it handles all data send from the sensor.

The correspondence between the Sensor Processor activity, the Sensor Inputs child record and the VI that handles data is shown in the following table.

Table 3-3. Correspondence Sensor Processor / Sensor Inputs Child Record

Sensor Processor activity	Sensor Inputs child record	Handled by VI
Maintenance Background	Background	Not in use
Maintenance Reference	Reference	SP PFOx Reference.vi
Maintenance Sample	Sample	SP PFOx Single Point.vi SP PFOx Sample Image Data.vi
Production Background	Background	Not in use
Production Standardize	Reference	SP PFOx Reference.vi
Production Single Point	Single Point	SP PFOx Single Point.vi
Production Periodic Measurement	Periodic	SP PFOx Single Point.vi
Production EOS Forward and Production EOS Reverse	Scan	SP PFOx End of Scan.vi SP PFOx Image Data.vi
Production Buffered Single Point	Buffered Single Point	SP PFOx Buffered Single Point.vi
Scan Forward	Scan	SP PFOx End of Scan.vi
Scan Reverse	Scan	SP PFOx End of Scan.vi

3.2 RAE Configuration

Precision FotoFiber sensor software is a standard feature of the following RAE versions and later.

- RAE 4.00.11
- RAE 5.00.05

Precision FotoFiber sensor software can be added to the following RAE versions by installing the FotoFiber Add-on package:

- RAE 4.00.08
  RAE 4.00.09
  RAE 4.00.10
- RAE 5.00.01
  RAE 5.00.02
  RAE 5.00.03
  RAE 5.00.04

If your system is among the Add-on compatible versions, contact Honeywell QCS TAC for assistance to get the FotoFiber Add-on package.

If your system is an earlier version than those listed above, it will need to be upgraded to a suitable version before FotoFiber can be installed. It is recommended that any upgrade be to the newest version of RAE.

3.2.1 Add FotoFiber sensor to the system

One or more FotoFiber sensors must be added to the system definition, and the system database must then be recrunched.

1. Open Configuration Data Repository Browser.
2. Go to the /Systems/SysXxxx/framepackages/Same or Similar Spot/frames/scannerX/sensorsets/
3. Right-click on the **sensorsets** and select **Add Object**… (Figure 3-2)

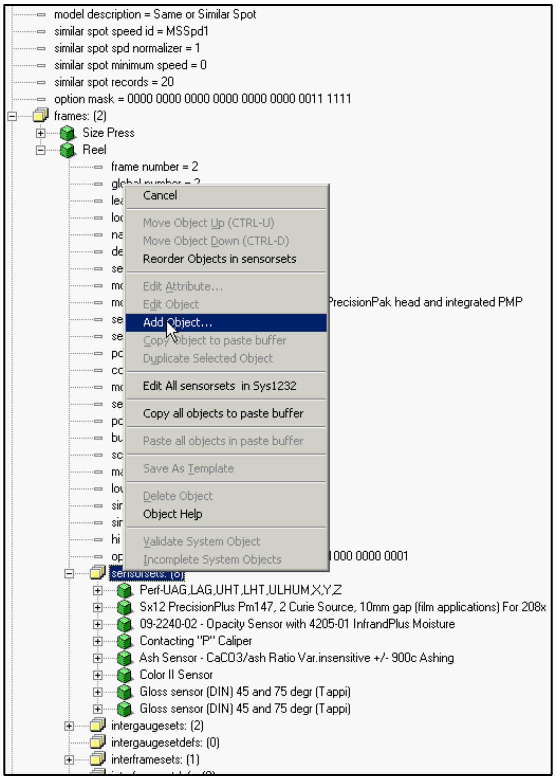


Figure 3-2. Adding a sensor object to the system.

4. Select **Fiber orientation** from the sensor list and click **Save** (Figure 3-3).

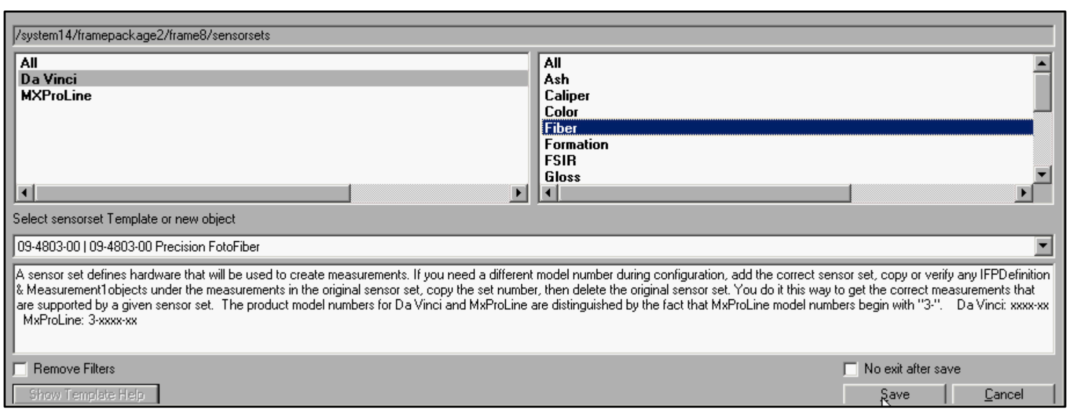


Figure 3-3. Adding a FotoFiber object.

A FotoFiber sensor is added to the sensor set of the selected system.

5. Check the **set #** for the added sensor (Figure 3-4). The software build should give the correct value by default. However, if there

are two FotoFiber sensors in the same scanner, they must have different **set #** values, typically 1 and 2.

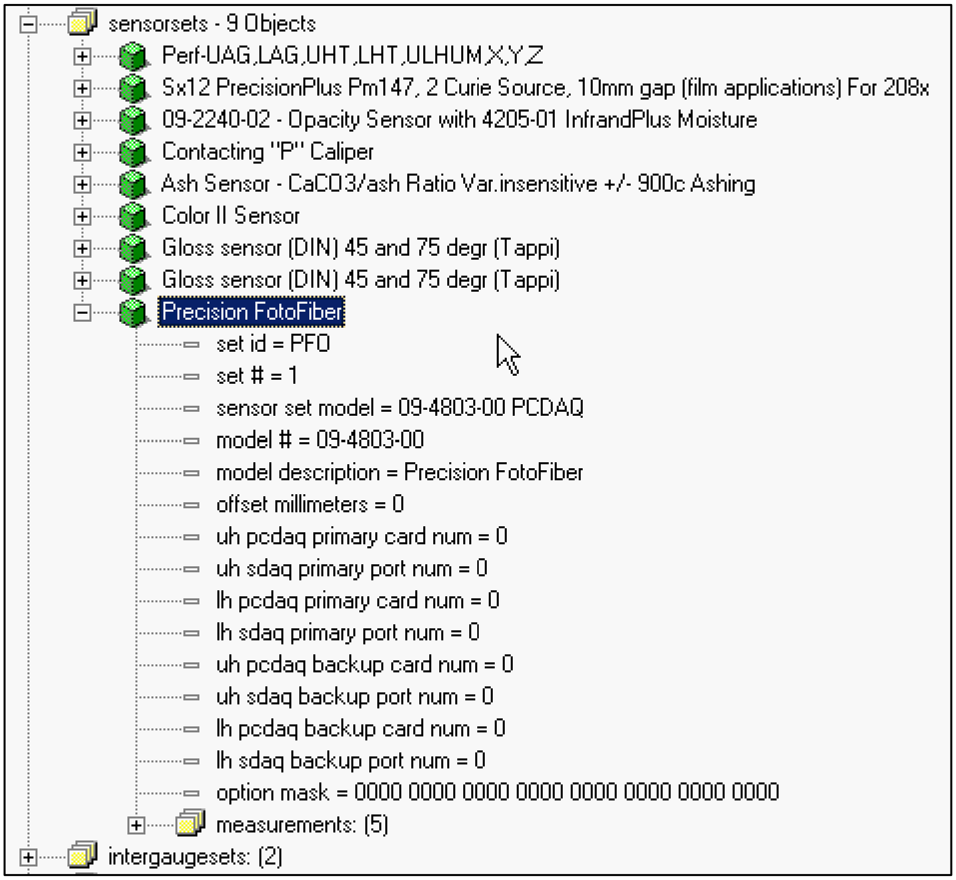


Figure 3-4. FotoFiber parameters in config browser.

6. Select **Cruncher / Export System Setup File**.
   Click **Yes** and click **OK** in the *Configuration Browser* windows (Figure 3-5).

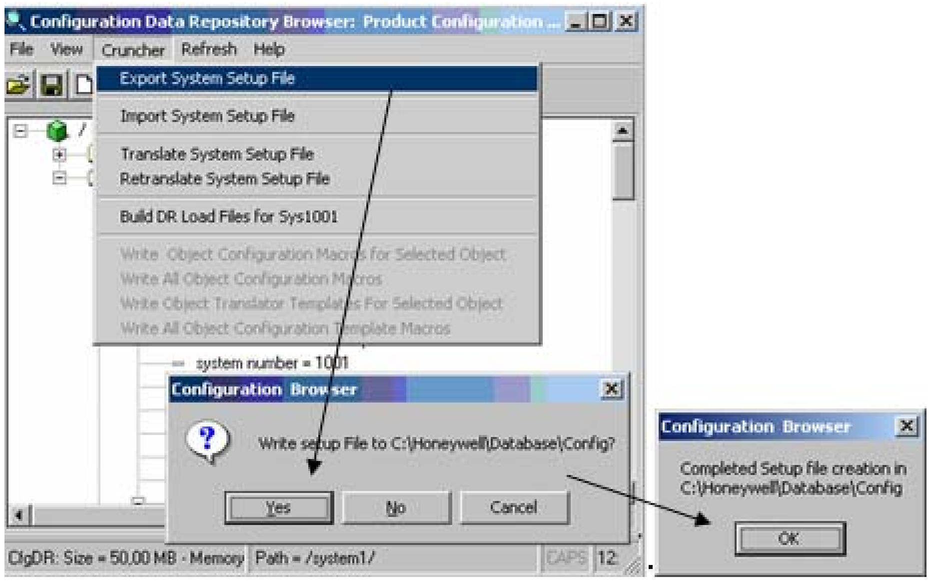


Figure 3-5. Exporting the system setup file.

7. Select **Cruncher / Build DR Load Files for SysXxxx**
   Click **OK** in the *Configuration Browser* window (Figure 3-6).

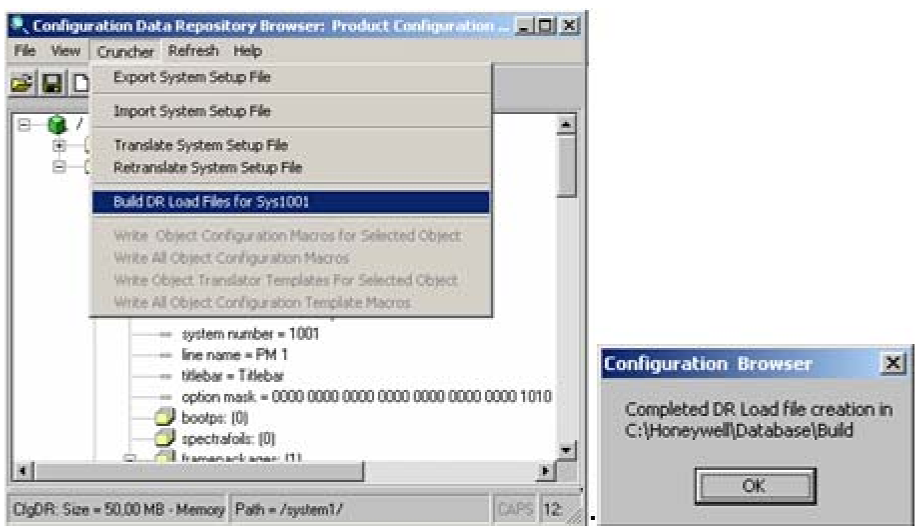


Figure 3-6. Building the DR file.

3.2.2 Set configuration parameters

Some basic parameters must be checked using the RTDR browser, and any changes must be saved to permanents database using the **Set perm** button.

3.2.2.1 Light controller type

Light controller type is defined by the **scannerX/mss/ssX FotoFiber /FotoFiber X processor/configuration parameters/cnfg parameters** RTDR parameter with index zero (0), where X = sensor set number.

There are two choices; 1=PP810 and 2=PP880 (default=2). This must not be changed from the factory setting. FotoFiber always uses the PP880, and this parameter must always be set to 2. See Figure 3-7.

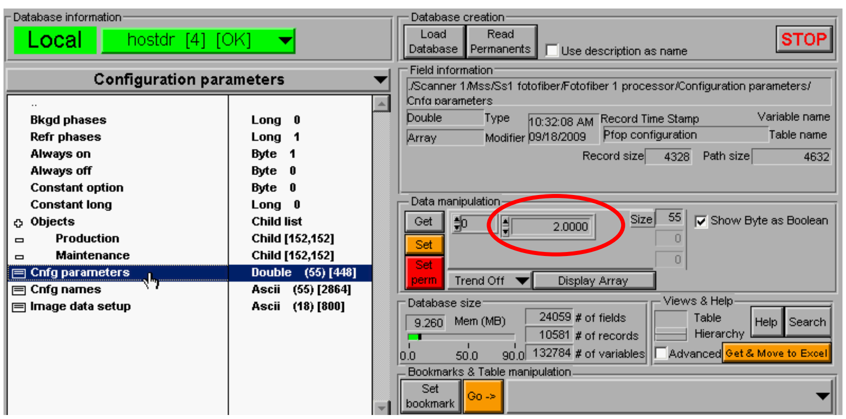


Figure 3-7. Light controller type must be 2.

3.2.2.2 Sample and Reference integration times

The default integration times for sample mode and reference mode should be checked, and changed if necessary. The RTDR parameters should be:

/scanner X/mss/ssx fotofiber/setup/Reference time ms 40

/scanner X/mss/ssx fotofiber/setup/Sample time ms 40

3.2.2.3 Image data definitions

The image data folder and file names are defined with the **image data setup** configuration parameter. Default values are set by the build file

(BuildOFSP.mac) and they don't need to be changed. In RTDR, the data is stored in an ascii array, Figure 3-8.

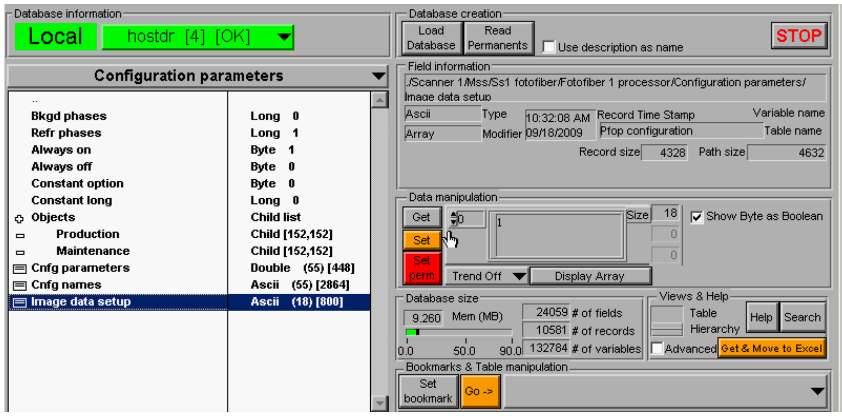


Figure 3-8. Image data setup.

The actual directory names and file names start at offset 1 in the image data setup array. The standard values are shown in Figure 3-9.

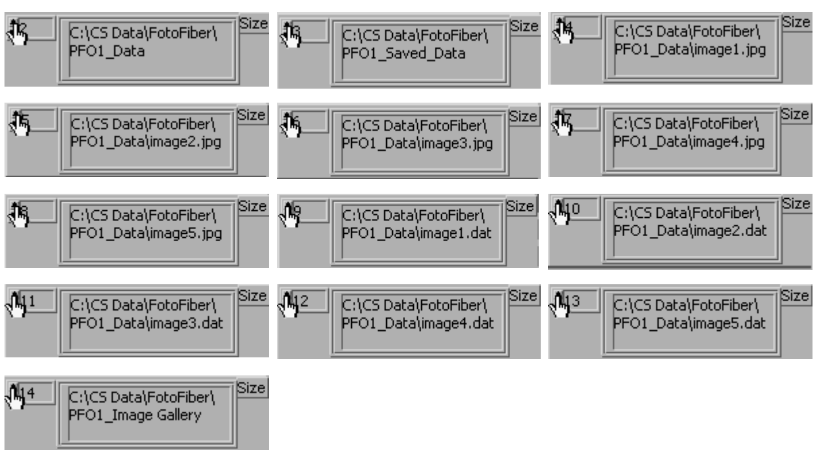


Figure 3-9. Default values for image data strings.

3.2.3 Set line speed scaling

FotoFiber needs to receive current line speed in units m/s from Da Vinci for proper exposure adjustment As the line speed available in RTDR parameter ./scannerX/status/scan data/**speed** may not always be in these units, a scaling is needed:

Line Speed [m/s] = speed * speed slope + speed intercept

RTDR parameters ./calibration parameters/**speed slope** and ./calibration parameters/**speed intercept** need to be configured in order to get correct scaling. See Figure 3-10.

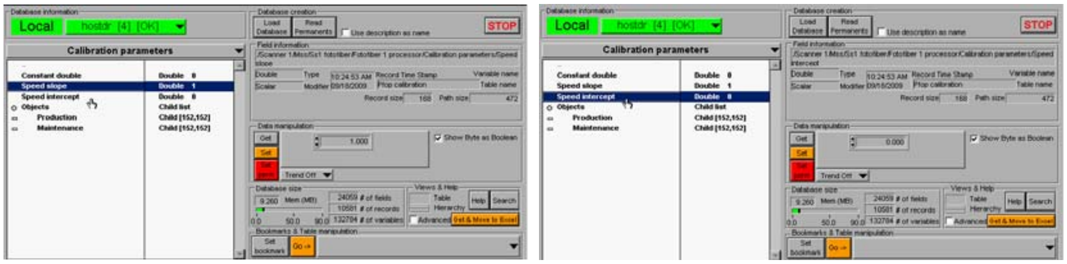


Figure 3-10. Slope and intercept for speed calibration.

Reading, scaling and writing the scaled line speed to ./scannerX/mss/setup/**process data buffer** RTDR parameter is performed by **SP PFOx Read Line Speed.vi.**

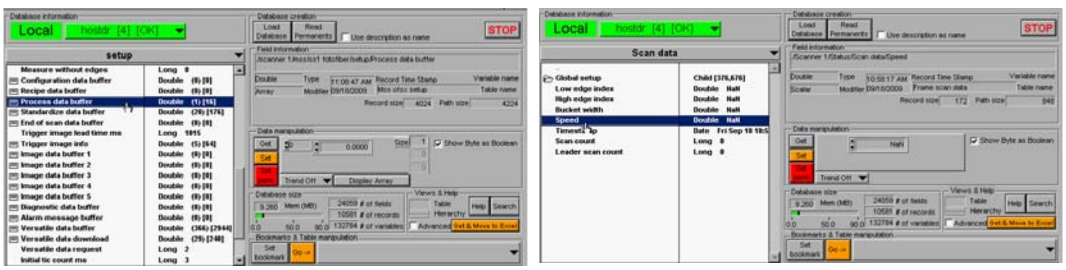


Figure 3-11. Process data and line speed in RTDR.

3.2.4 MSS/PMP Configuration

The sensor location in the head must be defined for the PMP, so that measurements from FotoFiber can be properly aligned in profiles with measurements from other sensors.

The communication parameters between the MSS and the FotoFiber must also be configured. These include the communication port number and expected communication delay time.

Configuration of the MSS/PMP is treated in §5.4.3, with other post-installation setup.

3.3 User Interface

4803 Precision FotoFiber displays are located under the FotoFiber display category. There are three displays: FotoFiber Display, FotoFiber Image Gallery and FotoFiber Engineering. Images and descriptions of these displays are presented below. The related VIs are listed in Table 3-4.
The FotoFiber displays are located at:
Hmx\Gauging\Labview Vis\Displays\Precision FotoFiber\
The pop-ups are located at:
Hmx\Gauging\Labview Vis\Displays\Precision FotoFiber\Sub Level.

Table 3-4 VIs of FotoFiber displays

Display File	Name	Type
FotoFiber Display	**Precision FotoFiber Display.vi**	Display
FotoFiber Standardization	**Precision FotoFiber Standardization.vi**	Display
FotoFiber Edge	**Precision FotoFiber Edge.vi**	Display
FotoFiber Engineering	**Precision FotoFiber Engineering.vi**	Display
Image Positions	PFO Image Positions.vi	Pop-up

3.3.1 FotoFiber display

The FotoFiber Display (Figure 3-12) is designed to provide thorough, real-time status of the surface fiber orientation. The fiber orientation measurement is displayed as a polar histogram plot, with parametric description of the polar histogram displayed in numeric form and as a profile. In addition, on-line surface images are shown from up to four CD positions of the web. The FotoFiber Display is the most important display for analyzing the current state of fiber orientation. The display items are presented in detail in the following sections.

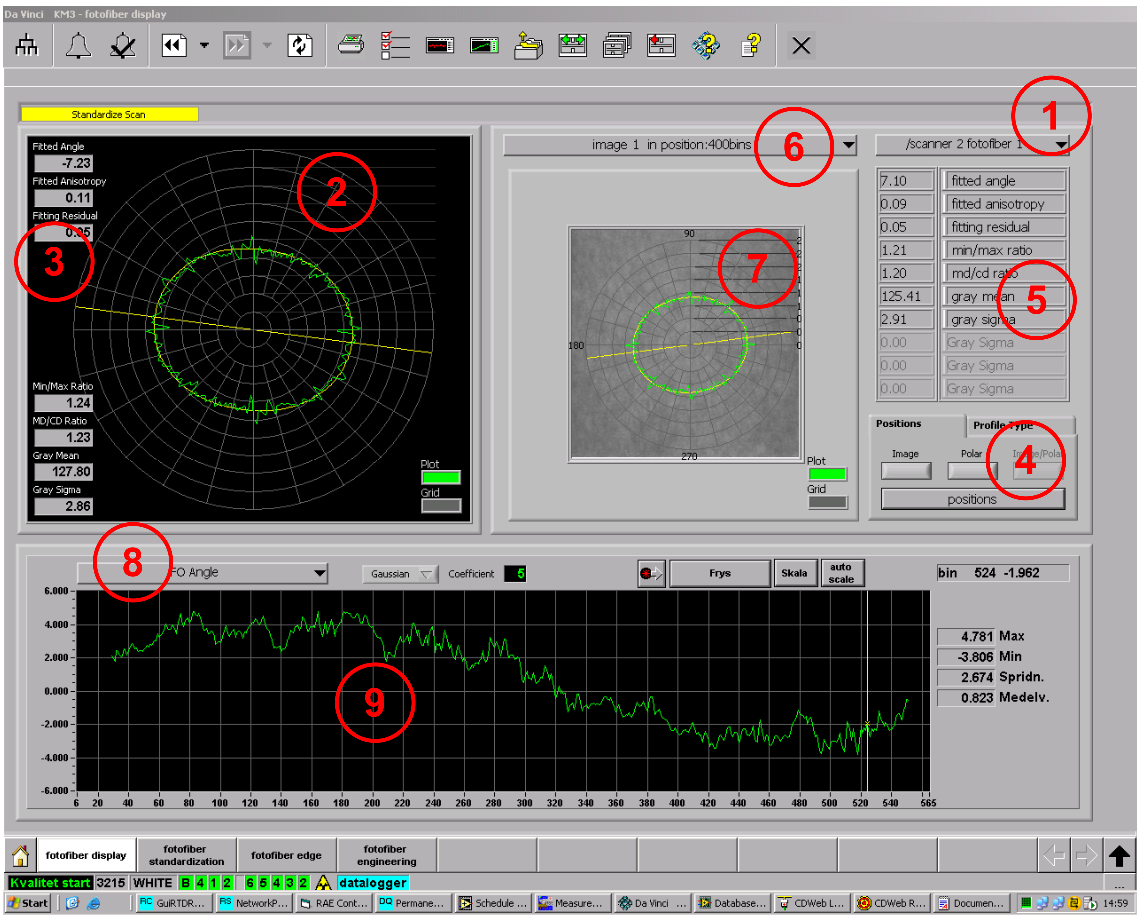


Figure 3-12. FotoFiber Display

Table 3-5 Items of the FotoFiber Display

1.	Selection of FotoFiber sensor
2.	Current polar histogram of fiber angle distribution

3.	Measurement summary for current polar histogram
4.	Image display properties and CD positions
5.	Measurement Summary for Selected Image
6.	Selection among defined image positions for display
7.	Selected image and/or its polar histogram
8.	Selection of fiber orientation property to plot
9.	Profile of selected fiber orientation property

3.3.1.1 Selection of FotoFiber sensor

All FotoFiber sensors installed to the system are listed in the FotoFiber selection menu. Your system can have one FotoFiber or multiple FotoFibers on one or more scanners (maximum two per scanner). Select the one you want to monitor. You can change your selection at any time. Only one FotoFiber sensor can be monitored at a time.

Figure 3-13. Selection of FotoFiber sensor

3.3.1.2 Current polar histogram of fiber angle distribution

The Polar Plot shows graphically the distribution of fiber angles in a single measurement. It is typically updated every two seconds and shows the result of the most recent measurement at that time.

Each direction in the plot corresponds to the same direction in the sheet. The machine direction is horizontal, with direction of movement to the right, and the clockwise direction usually corresponds to the clockwise direction in the sheet viewed from above. Larger distances from the center for a particular angle indicate a higher frequency of occurrence of that angle.

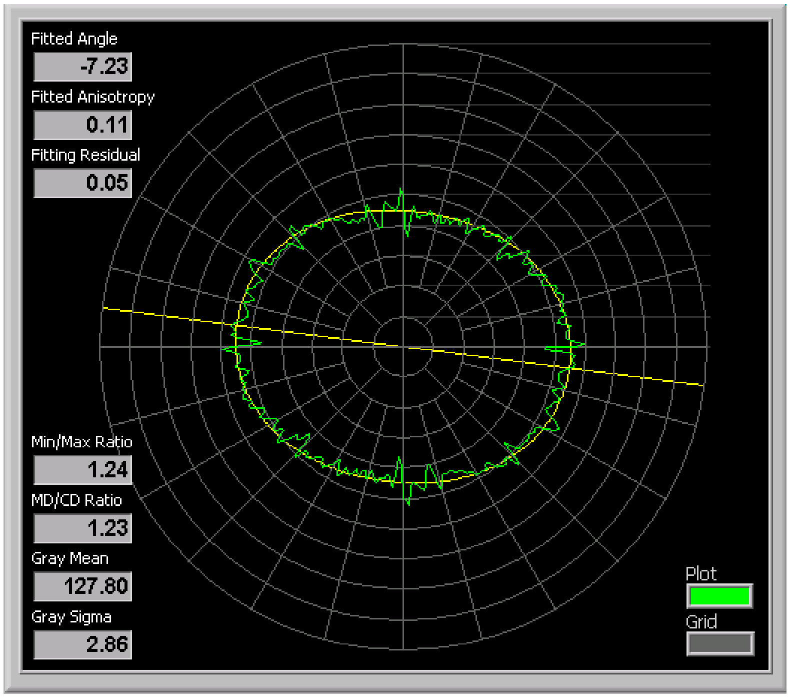


Figure 3-14. FotoFiber Polar Histogram

The green curve indicates the occurrence of each angle in the measurement, while the yellow curve shows the fitted approximation to the measurement. The yellow straight line indicates the major axis of the fitted curve, and hence the average orientation of the fibers. A curve which is nearly circular indicates a low anisotropy, while an elongated curve indicates a higher anisotropy.

3.3.1.3 Measurement summary for current polar histogram

Several numeric properties are shown on the polar histogram. These indicate values of parameters computed from the histogram, including the principal fiber orientation parameters.

Table 3-6 Numerical Values for the Polar Histogram

Fitted Angle	The average orientation angle of the measured distribution
Fitted Anisotropy	The degree of anisotropy of the measured distribution
Fitting Residual	Indicates how closely the curve fits the measurement
Max/Min Ratio	Ratio of greatest and smallest widths of the curve
MD/CD Ratio	Ratio of curve width at 0° to curve width at 90°
Gray Mean	Average gray level of the image
Gray Sigma	Contrast level of the image

If logged in as operator, then the Fitting Residual, Gray Mean, and Gray Sigma are not displayed on the polar histogram.

3.3.1.4 Image display properties and CD positions

FotoFiber sensor can deliver up to four images per scan from different CD positions for visual assessment on the FotoFiber Display.

ATTENTION It is recommended that in most cases only one image be delivered per scan, due to the high load on communication.

These positions are configured in the Image Positions pop-up (Figure 3-15) that can be launched by clicking on the Positions button on the FotoFiber Display (Item 3, Figure 3-12 and Table 3-5). The positions are given as distances, in millimeters, from the low end offset, from the smallest value to the highest. The positions are fixed relative to the scanning frame, but not to the web if the web width or position change. If the user does not want images from all four positions, zero must be entered as the distance for the image to be omitted. Values of CD positions are limited between the current web edges. The edges of the web are read from RTDR parameters:

- The lower limit: ./scannerX/mss/unit info/low end offset mm
- The upper limit: ./scannerX/mss/hi other end/scan position

If any of the values is outside the limits an error message is shown (Figure 3-15, right). In that case enter valid values to the invalid fields and click the ENTER button in the pop-up.

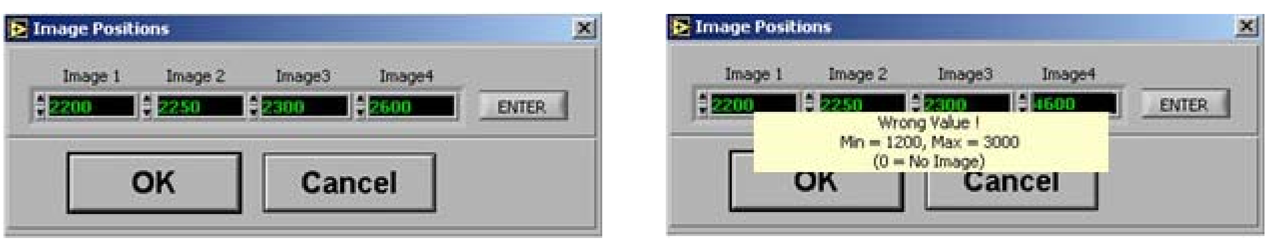


Figure 3-15. Image Positions pop-up: Valid positions (left), error message after entering an invalid position (right)

3.3.1.5 Selection of CD position for the on-line image

One preconfigured image position (Figure 3-15) can be monitored at a time on the FotoFiber Display as the On-line image. The pull-down menu (item 4, Figure 3-12 and Table 3-5) is used to select the image position, as shown in Figure 3-16.

If a position is not defined (zero is entered as the position, cf. §3.3.1.3), the text "IMAGE *x* In Position: *No Image!*" is shown in that row.

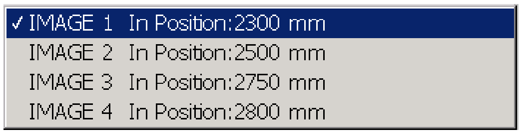


Figure 3-16. CD position selection for the On-line image

ATTENTION It is recommended that in most cases only one image be delivered per scan, due to the high load on communication.

If the scanner is in single point measurement, then only image 5 is displayed. The position of image 5 is the single point position, and this image is updated every 20 seconds.

3.3.1.6 Profile

FotoFiber Display's profile is customized to show a CD-smoothed trend profile of any of the FotoFiber measured variables. Most typically the user may want to see either the fiber orientation angle or the fiber orientation anisotropy as a profile.

Figure 3-17. CD profile (selected property is FO angle).

3.3.2 FotoFiber standardization display

The task of standardization is to determine the relative efficiencies of the eight illumination channels under current operating conditions. The current operating conditions include the strobe pulse length, average strobe channel level, and the current paper being measured. As mentioned in §2.3.4, FotoFiber standardization occurs on-sheet, in the first traverse after other sensors have standardized offsheet. The FotoFiber Standardization display is shown in Figure 3-18.

If FotoFiber standardization fails (as can happen after a machine startup, or if a major grade change occurs while the sensor is offsheet), it repeats the standardization. Because FotoFiber standardization does not obstruct scanning operation of any other sensor, there is no penalty in performing repeated standardizations.

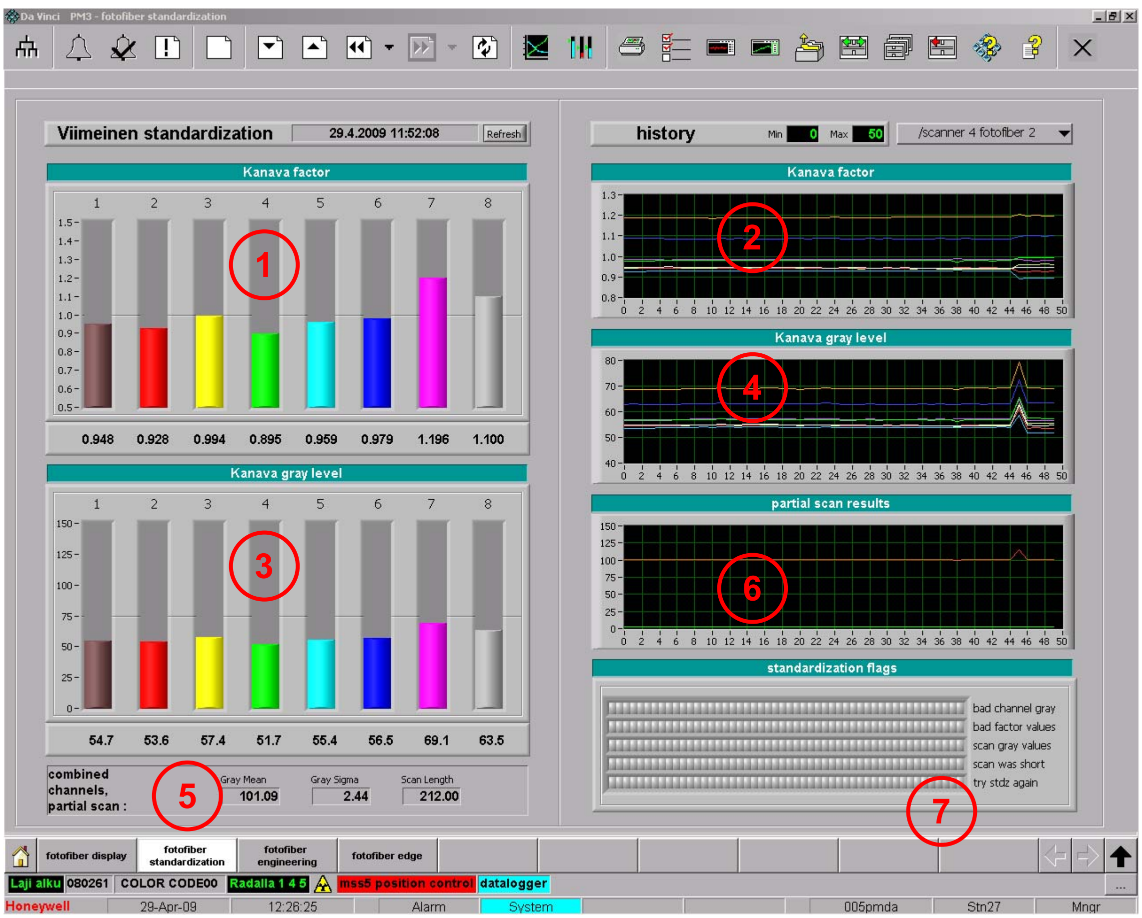


Figure 3-18. FotoFiber Standardization Display.

The main items in the FotoFiber Standardization display are:

1. Channel Factors at the last successful standardization, shown as bar graphs with numerical values beneath. These indicate the relative efficiency of each channel compared to its calibration data. They are used to compensate for variations in sheet color as well as dust on the illumination window and aging of components. The channel factors should remain between 0.6 and 1.6 for proper operation of the sensor.

2. A trend of channel factor values in the last 50 successful standardizations. Colors of traces match those of the bars in #1.

3. Channel gray levels at the last successful standardization, shown as bar graphs with numerical values beneath. These indicate the absolute illumination level achieved by each channel with identical parameters. The absolute levels achieved should be in the acceptable range for proper operation of the sensor (typically between 25 and 225, adjustable using parameters #27 and #28 in the engineering display §3.3.4).

4. A trend of channel gray levels in the last 50 successful standardizations. Colors of traces match those of the bars in #3.

5. Statistics for the partial scan operating all channels together at the nominal settings in the last successful standardization scan: mean gray level, mean gray sigma (image contrast), and length of partial scan. The mean gray level should be close to the target (typically 100, but set using parameter #26 in the engineering display §3.3.4), and the scan length should be at least 5 and preferably more than 20. The mean gray sigma is typically small (1% to 5% of the mean gray level), and will vary depending on the grade of paper being measured.

6. A trend of the mean gray level, mean gray sigma (image contrast), and length of partial scan for the last 50 successful standardizations. Note that the plot scale must be set differently to optimize presentation of each parameter, since their values are greatly different (typically differing by two orders of magnitude).

7. A trend of warning and error flags for the last 50 standardization attempts, whether successful or not. Note that since flags are shown from unsuccessful standardizations as well as successful standardizations, this trend does not necessarily have a one-to-one

correspondence with the other trends, which contain only results from successful standardizations. The flags are:

- **bad channel gray**. An error causing standardization to fail. If this occurs in normal operation then sensor maintenance is needed.
  Colored red if the flag is set.

- **bad factor values**. A warning indicating that one or more channel factors were out of range. If this warning persists, sensor maintenance may be needed.
  Colored yellow if the flag is set.

- **scan gray values**. An error causing standardization to fail. If this occurs in normal operation then sensor maintenance is needed.
  Colored red if the flag is set.

- **scan was short**. A warning indicating that there were not enough measurements during the standardization. If this warning persists, then sensor or scanner parameters may need to be adjusted.
  Colored yellow if the flag is set.

- **try stdz again**. A notification that the sensor will attempt to standardize again after a failed standardization. This often occurs on the first standardization after a machine startup or occasionally after a grade change in which the sensor was offsheet (causing the illumination parameters to be inappropriate). If the initial sensor state is far from the state appropriate to current operating conditions, it may take a few attempts to reach a successful standardization. This flag is set only if one of the error flags is set.
  Colored blue if the flag is set.

If any standardization error or warning flags occur repeatedly, then troubleshooting is needed to determine and rectify the cause, see §7.1.1.

3.3.3 FotoFiber edge display

While at the sheet edge at each end of scan, the Processor Module of the FotoFiber sensor recomputes its illumination parameters, and communicates the updated parameters to the sensor's strobe controller. The computation is based on the scan average of the graylevel of the just-completed scan, the calibration curves for each illumination channel, and the channel factors from the last successful standardization. The results of the edge calculations are sent to the DaVinci, and are shown in the FotoFiber Edge display, as in Figure 3-19.

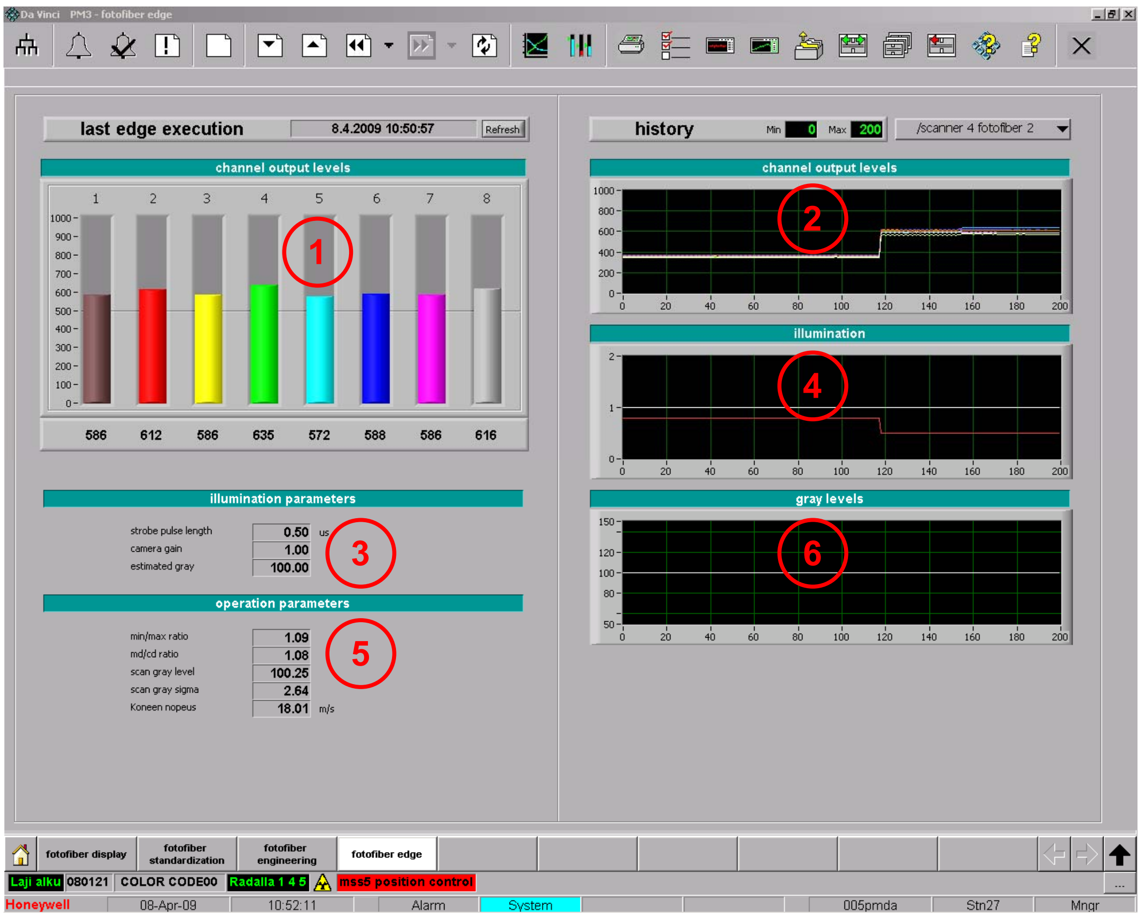


Figure 3-19. FotoFiber Edge Display.

The main items in the FotoFiber Edge display are:

1. Current illumination channel output levels (integer 0-999), shown as bar graphs with numerical values beneath. These indicate the relative electrical discharge through the different LED panels.

2. A trend of the channel output levels for the last 50 end-of-scan computations. Colors of traces match those of the bars in #1.

3. Common parameters: (i) strobe pulse length, which is the same for all channels, in the range 0.2µs to 1.5µs, (ii) camera gain, or sensitivity boost factor, in the range 1.0 to 2.0, and (iii) the estimated gray level for the next scan.

4. A trend of the strobe pulse length (red) and the camera gain (gray) for the last 50 end-of-scan computations. They are plotted on a common scale for convenience.

5. Scan average of selected parameters. The gray level and machine speed values may be useful in troubleshooting.

6. A trend of the estimated gray level (red) and the actual gray level (gray) for the last 50 end-of-scan computations. Normally the two traces are very closely coincident, and can only be separated if the scale is narrowed to a very small range.

3.3.4 FotoFiber engineering display

The FotoFiber Engineering display (shown in Figure 3-20) is a tool for configuring and diagnosing the FotoFiber sensor. The items of the FotoFiber Engineering display are listed in Table 3-7, and selected items are explained below.

The FotoFiber sensor to be configured or diagnosed is selected for this display from the pull-down menu (item 1) just like on the FotoFiber Display (cf. section 3.3.1.1). Items 2 and 3 handle FotoFiber configuration through customizing and uploading Configuration Parameters. States of FotoFiber can be traced using items 4 to 6. Camera Sensor Link data is summarized in item 7. These items are discussed more thoroughly in the following sections.

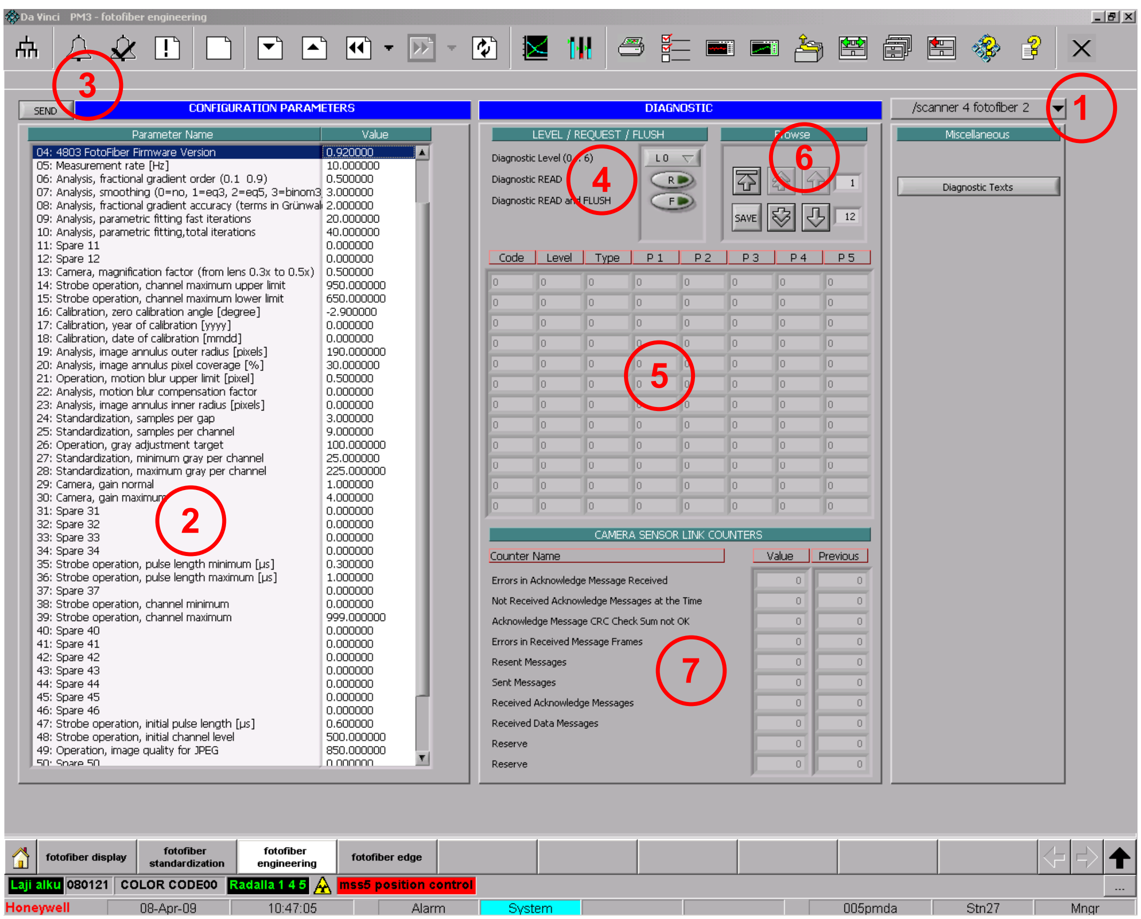


Figure 3-20. FotoFiber Engineering display

Table 3-7 Items of FotoFiber Engineering display

1.	FotoFiber sensor selection
2. Configuration	Parameters
3.	Send Configuration Parameters button
4.	Diagnostic level and request controls
5. Diagnostic	data
6.	Diagnostic data browse / save buttons
7.	Camera Sensor Link counters

3.3.4.1 Configuration parameters

FotoFiber functionality can be adapted and customized through the Configuration Parameters on the FotoFiber Engineering display (item 2, Figure 3-20). Configuration Parameters are sent to the sensor automatically in FotoFiber sensor startup. When FotoFiber is already running, Configuration Parameters can be sent to the sensor by clicking SEND button. This is necessary after making changes to the parameters.

Many of the parameters are not to be changed without consulting the sensor development team, as they may have complicated consequences.

FotoFiber has 54 configuration parameters, presented in detail in Table 3-8. Note that the Engineering Display must be scrolled to see all of the parameters. The parameter indices are color-coded in Table 3-8, according to the freedom to change the parameter.

Red – parameter cannot be changed.
Yellow – parameter should not be changed, except under explicit direction of TAC personnel or the sensor developers.
Gray – parameter is not used, and changes will have no effect on sensor operation.
White – parameter can be changed during normal commissioning, troubleshooting, or maintenance of the sensor.

Table 3-8. FotoFiber Configuration Parameters

Index	CNFG Parameters	CNFG Names
0	2	LED controller type (1=PP810,2=PP880)
1	90.0	Polar Rotation [dec]
2	0.0	Reserved 2

3	0.0	Diagnostic OFF/ON (0=Off, 1..3=On)
4	0.0	4803 FotoFiber Firmware Version
5	10	Measurement rate [Hz]
6	0.5	Analysis, fractional gradient order (0.1 – 0.9)
7	3	Analysis, smoothing (0=no, 1=eq3, 2=eq5, 3=binom3, 4=binom5)
8	2	Analysis, fractional gradient accuracy (terms in Grünwald series)
9	20	Analysis, parametric fitting, fast iterations
10	40	Analysis, parametric fitting, total iterations
11	0	Spare parameter 11
12	0	Spare parameter 12
13	0.5	Camera, magnification factor (from lens 0.3x to 0.5x)
14	950	Strobe operation, channel maximum upper limit
15	600	Strobe operation, channel maximum lower limit
16	0.0	Calibration, zero calibration angle [degree]
17	0000	Calibration, year of calibration [yyyy]
18	0000	Calibration, date of calibration [mmdd]
19	190	Analysis, image annulus outer radius [pixels]
20	30.0	Analysis, image annulus pixel coverage [%]
21	0.3	Operation, motion blur upper limit [pixel]
22	0.0	Analysis, motion blur compensation factor
23	0	Analysis, image annulus inner radius [pixels]
24	3	Standardization, samples per gap
25	5	Standardization, samples per channel
26	100.0	Operation, gray adjustment target
27	25.0	Standardization, minimum gray per channel
28	225.0	Standardization, maximum gray per channel
29	1.0	Camera, gain normal
30	2.0	Camera, gain maximum
31	0	Spare parameter 31
32	0	Spare parameter 32
33	0	Spare parameter 33
34	0	Spare parameter 34
35	0.3	Strobe operation, pulse length minimum [µs]
36	1.0	Strobe operation, pulse length maximum [µs]
37	0	Spare parameter 37
38	0	Strobe operation, channel minimum
39	999	Strobe operation, channel maximum
40	0	Spare parameter 40
41	0	Spare parameter 41
42	0	Spare parameter 42
43	0	Spare parameter 43

44	0	Spare parameter 44
45	0	Spare parameter 45
46	0	Spare parameter 46
47	0.5	Strobe operation, initial pulse length [µs]
48	400	Strobe operation, initial channel level
49	850	Operation, image quality for JPEG
50	0	Spare parameter 50
51	0	Strobe delay from initial tic [µs]
52	10.0	Sample, pseudo machine speed [m/s]
53	83	Sensor options bitfield (0-65535): bit 0: 1 Enable standardization during scan bit 1: 2 Renew pixel mask after standardization bit 2: 4 Apply pixel blacklist mask bit 3: 8 Enable flatfield compensation bit 4: 16 MD axis in image (0=X, 1=Y) bit 5: 32 Fitting curve form (0=bilobe, 1=ellipse) bit 6: 64 Enable change of measurement rate bit 7: 128 Disable image analysis bit 8: 256 Angles are clockwise (0=anticlockwise, 1=clockwise) bit 9: 512 spare bit 9 bit 10:1024 spare bit 10 bit 11:2048 spare bit 11 bit 12:4096 spare bit 12 bit 13:8192 spare bit 13 bit 14:16384 spare bit 14 bit 15:32768 spare bit 15
54	1500	Operation, minimum EOS delay [ms]

Parameter changes do not take effect until the sensor is idle or at the end of a scan. Parameter changes made during a scan (whether measurement scan or standardization scan) or during single point or reference or sample modes are deferred until the sensor is idle or at the end of a scan.

3.3.4.2 Parameters adjustable normally

Some of the parameters in Table 3-8 are described here in more detail. The focus is on those which are potentially in need of adjustment in the field. The initial setting of several of these parameters is described in §5.4.2, performed after installation.

13 – Camera, magnification factor. This informs the sensor of the optical magnification of the attached macro lens. It is needed for correct computation of pulse lengths (which depend on image scale as well as machine speed). The standard lens is adjustable from 0.3× to 0.5× magnification, and is usually set to about 0.45×, as being suitable for sheets of hardwood fibers and sheets with a mix of hardwood fibers and softwood fibers. If the installation is measuring sheets which only have softwood fibers, it may be possible to adjust the magnification, in which case this parameter should be changed to match the set optical magnification.

16 – Calibration, zero calibration angle. This parameter defines the zero angle for the camera. The camera mounting brackets result in a small amount of rotational uncertainty in the camera alignment. This is fixed whenever the camera is installed, and this parameter must be identified whenever the FotoFiber camera is changed.

17 – Calibration, year of calibration [yyyy].
18 – Calibration, date of calibration [mmdd]. These two parameters indicate which set of illuminator calibration data should be used. The two integers define the name of the directory holding the calibration files in the FotoFiber. The factory calibration directory is year=0000 and date=0000, and should remain valid for several years if no illuminator components are changed. If a recalibration is performed in the field, the calibration data will be in a different directory, named according to the date of calibration, such as 20090819 for a calibration performed on 19 August 2009. See §6.2.3 for the illuminator calibration procedure.

21 – Motion blur upper limit [pixel]. This is used, together with the machine speed and the pixel scale, to calculate a suitable strobe pulse length. The default value is 0.3 and rarely needs to be changed.

24 – Standardization, samples per gap.
25 – Standardization, samples per channel. These two parameters how many images should be discarded (samples per gap) when changing illumination channels during a standardization scan, and how many images should be averaged (samples per channel) when testing each illumination channel. There is usually no need to change them. However, if the scan time is less than about 15 seconds onsheet, then they should both be reduced; otherwise standardization may never complete successfully. They should be reduced if the standardization scan was short warning is received during standardization (item #7 on FotoFiber Standardization display Figure 3-18). On the other hand, if the

standardization succeeds and the standardization scan length (item #5 on FotoFiber Standardization display Figure 3-18) exceeds the number of samples per channel by more than 100, then one or both parameters can be increased. It is preferable to increase the samples per channel parameter, and there is never any need to make samples per gap larger than 3. See also §5.4.2.2 and §7.1.1.1 for estimating suitable values for these parameters.

26 – Operation, gray adjustment target. This is the target for the gray level of images as measured by the camera. It is used in the edge calculations in determining the strobe channel levels to use. The estimated gray level appearing in item #3 of the FotoFiber Edge Display in Figure 3-19. will equal this quantity, unless the strobe reaches an operating limit. The default value of 100 is acceptable in nearly every case.

51 – Strobe delay from initial tic. This is meaningful only for two-sided measurements. For a single-sided measurement, it should be set to zero. For two sided measurements, one of the sensors should have a zero for this parameter, and the other should have a value of 32000. The result is that one of the sensors delays by 32ms in its strobing from the initial message sent by the MSS at start of a measurement mode. There is jitter of about 15ms in message timing from the MSS, so this delay in one sensor prevents simultaneous flashing by the two sensors.

52 – Sample, pseudo machine speed. This is the value used as a machine speed in computing the strobe length for sample mode and reference mode operation offsheet. It has a default of 10 meters/second, and can be left at that value or changed to a value in the production speed range of the mill.

53 – Sensor options bitfield. This is a bitfield which can control certain diagnostic or debugging features of the FotoFiber. Most of these are reserved for development use. However, some of the bits it also contains three bits of interest during normal setup. The standard values for the bitfield are 67 (clockwise angles positive) and 323 (anticlockwise angles positive).

> **bit 0**: Enable standardization during scan. If this bit is ON (i.e. the bitfield value is an uneven number), then the sensor will attempt to standardize in the first scan after other sensors have standardized offsheet. To prevent this behavior, make the bitfield value an even integer instead (e.g. if the bitfield value is 67 change it to 66). With

scanning standardization disabled, the sensor can be standardized only in reference mode offsheet.

bit 4: MD axis in image. If a FotoFiber sensor must be installed into a sensor head in which space is constrained (by presence of nonstandard equipment, for instance), it may be necessary to rotate the upper assembly of the sensor in order to fit it in. In this case, the normal MD and CD axes will be switched in the camera, and this bit should be set to 1. The value to add or subtract is 16 for bit 4. When the sensor is rotated 90° during installation, if the bitfield is 67, change it to 83, or if the bitfield is 323, change it to 339.

bit 8: Angles are clockwise. The positive direction for orientation angles may already be established at the mill. This bit can be set to make the FotoFiber agree with mill convention. In a two-sided measurement, one of the sensors must be use clockwise angles as positive, the other must use anticlockwise. This is because one is “upside-down” relative to the other.

3.3.4.3 Parameters adjustable via QCS-TAC or developers

For adjustment of all other defined parameters (including bits other than bit 0, bit 4, and bit 8 in the sensor options bitfield), it is necessary to contact QCS-TAC or the sensor developers.

3.3.4.4 Sensor diagnostic

FotoFiber sensor saves diagnostic information of the sensor functioning. Information consists mainly of mode changes and mode statuses. Diagnostic information is divided to seven (7) diagnostic levels (0...6) listed in Table 3-9.

Diagnostic items on the FotoFiber Engineering display are shown in detail in Figure 3-21. The diagnostic level is selected by item 1 (pull-down menu). As the level is selected or whenever Diagnostic Read or Diagnostic Read and FLUSH button (item 2) is clicked, the Diagnostic Data table (item 3) is updated. The Diagnostic Read button only reads the data while the Diagnostic Read and FLUSH button also clears the data buffer. Diagnostic Data table can be browsed with Home, Page Up, Page Down, Previous Line and Next Line buttons (item 4). If the user wants to save diagnostic data for later analysis or troubleshooting, clicking the Save button opens up a file save dialog (Figure 3-22) from which an ASCII file can be generated. The arrangement of the file is identical to the Diagnostic Data table. The contents of the Diagnostic Data is explained in Table 3-10.

As shown in Table 3-9, only diagnostic levels 1, 2 and 6 are currently in use. Selecting any of the unused levels (3, 4 or 5) or level 6 leaves the Diagnostic Data table grayed and filled with zeros. However, selecting Level 6 updates the Camera Sensor Link counters (item 7, Figure 3-20 and Figure 3-23) just below the Diagnostic Data table. These counters report the status of Camera Sensor Link (between FotoFiber and MSS). If any of the error counts starts to accumulate, there is some problem with the link. In normal conditions the counters should remain zero.

Table 3-9. Diagnostic Levels of FotoFiber

Level	Description
0	Unused
1	Post Master
2	State Machine
3	Unused
4	Unused
5	Unused
6	Camera Sensor Link Counters

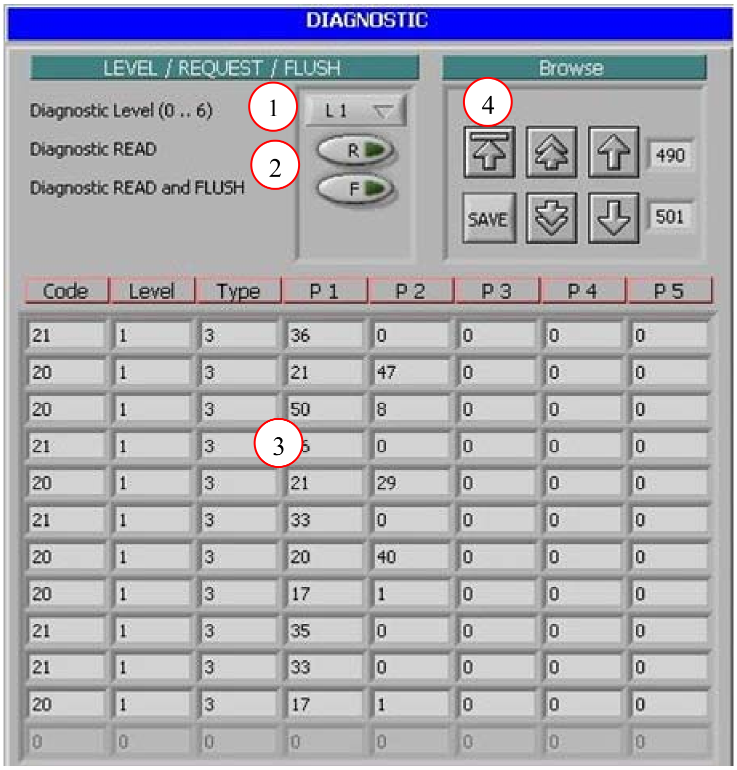


Figure 3-21. Diagnostic items on FotoFiber Engineering display:
1) Diagnostic Level (0..6) selection,
2) Diagnostic READ and Diagnostic READ and FLUSH buttons,
3) Diagnostic Data table and
4) Diagnostic Data Browsing buttons (Home, Save, Page Up, Page Down, Previous Line and Next Line)

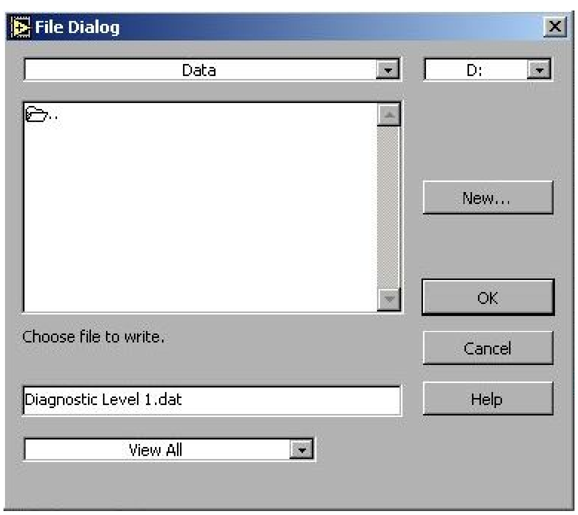


Figure 3-22. Diagnostic Data save dialog

Table 3-10. Contents of Diagnostic Data

<table>
<tr><th>Diagnostic Data</th><th>Description</th></tr>
<tr><td>Code</td><td>Identify function of sensor whose diagnostic is shown. There are ten (10) codes for all sensor functions.
<table>
<tr><td>10…19</td><td>Camera Sensor Link Diagnostic</td></tr>
<tr><td>20…29</td><td>Post Master Diagnostic</td></tr>
<tr><td>30…39</td><td>State Machine Diagnostic</td></tr>
<tr><td>40…49 Ini</td><td>t Diagnostic</td></tr>
<tr><td>50…59 Scan</td><td>Diagnostic</td></tr>
<tr><td>60…69 St</td><td>andardize Diagnostic</td></tr>
<tr><td>70…79 Edge</td><td>Diagnostic</td></tr>
<tr><td>80…89 Sam</td><td>ple Diagnostic</td></tr>
<tr><td>90…99 Si</td><td>ngle Diagnostic</td></tr>
<tr><td>100…109 Li</td><td>ght Diagnostic</td></tr>
<tr><td>110…119 L</td><td>auncher Diagnostic</td></tr>
<tr><td>120…129 P</td><td>aram eter Diagnostic</td></tr>
<tr><td>130…139 Di</td><td>ag Diagnostic</td></tr>
</table></td></tr>
<tr><td>Level Di</td><td>agnostic level</td></tr>
<tr><td>Type Data</td><td>type</td></tr>
<tr><td>P1...P5</td><td>Diagnostic parameters to where diagnostic data is saved.</td></tr>
</table>

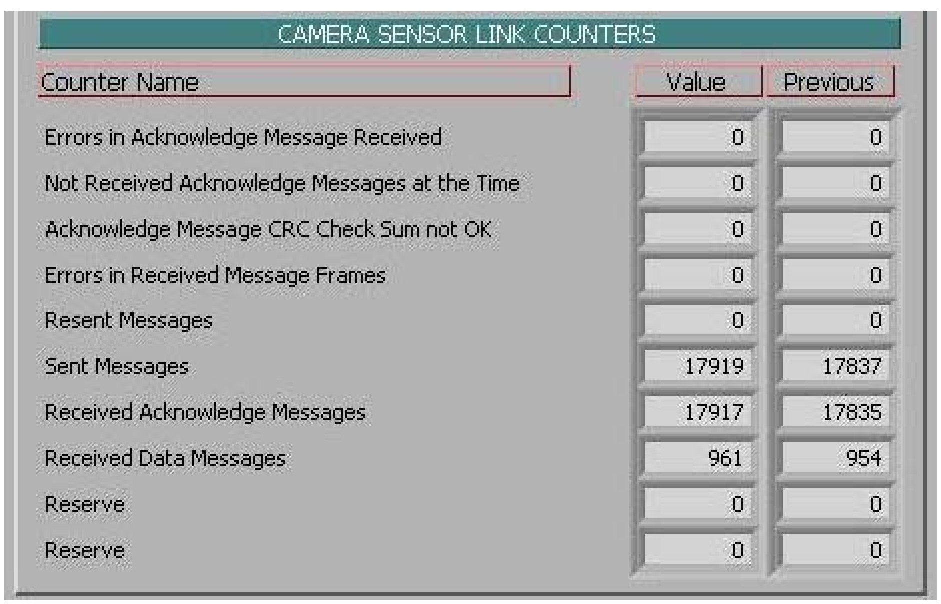


Figure 3-23. Camera Sensor Link counters

4 Detailed FotoFiber Structure

This section describes selected details of the FotoFiber sensor's structure.

4.1 Power Connections

The power connections are shown in Figure 4-1., where the switch is in the OFF position.

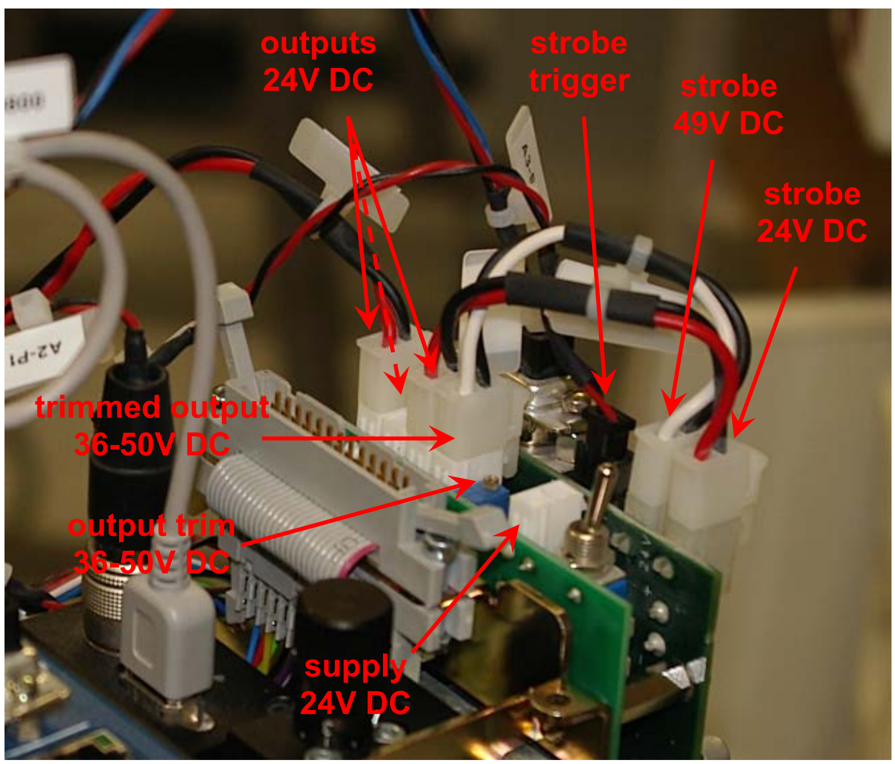


Figure 4-1. FOMM DC internal connections from power and isolation PCB (p/n 20100078) to strobe control PCB (p/n 20100079)

There is a single 24V DC power input to the FotoFiber power and isolation PCB (p/n 20100078). It supplies power for all sensor functions. This PCB has a DC/DC converter which supplies clean 24V DC power to three outputs. Two of these outputs are used; the third is spare (indicated by dashed line arrow in Figure 4-1). It also has an adjustable output from 36-50V DC with a trim to adjust it. This output is used by the strobe control PCB (p/n 20100079), and is normally set to 49V. Normally, the 49V connection uses black and white conductors, while the 24V connections use black and red conductors. However, note carefully the relative positions of the 49V and 24V sockets on both PCBs in Figure 4-1, and always ensure that they are properly connected before powering up the sensor.

The FOMM module can use either the 4215 Color sensor lamp power supply or the AUX power supply within the head. The connection type at the FotoFiber is the same, but the cables differ in their config board connectors. The AUX power cable is p/n 08766300, while the 4215 color sensor lamp power cable is p/n 08724200.

CAUTION Note that all of the sockets are of the same type, so some care is necessary in choosing which connector to use. Connecting a 24V device to the 36-50VDC socket could permanently damage the device.

Power supply requirements:

- 24V DC +-10 %
- Current max. 1.5A (typically 1.0A to 1.1A in operation)
- It is recommended that the FotoFiber should not share a power supply with other devices.

Connector type: Molex Mini-Fit Jr Crimp Power Connector, 5559 Panel Mount Plug. Manufacturer part no: 39-01-2021

Pin	FOMM power supply
1	+24 VDC
2	24 VDC GND

Note that Pin 1 on the sockets is the pin closer to the PCB. The polarity of the plug must match that of the socket.

OUTPUTS 24V DC

These are three identical Molex sockets. Two are used and the third is reserved, but all three are equivalent in function. One is used to supply power to the PM, another supplies 24VDC to the strobe controller (shown in picture).

OUTPUT 36-50V DC

This supplies the power to drive the LED panels for illuminating the sheet. The rms current is only a few milliamps. It should be set within the range 49-49.5V DC at the factory, but can be adjusted using the trim.

CAUTION This 36-50V DC connector is identical in appearance to the 24V DC connectors, but is the one adjacent to the output trim. The 24V and 48V sockets should be clearly marked on both PCBs.

The conductors on the cable for this 36-50V DC connector are black (-) and white (+), instead of the black and red used in the 24V DC cables.

OUTPUT TRIM FOR 36-50V DC

This trim is used to adjust the maximum voltage used to drive the LEDs. It can be adjusted using a small screwdriver.

4.2 Communication Connections

4.2.1 Camera sensor link (CSL)

The communication between FotoFiber sensor and MSS is handled by the Camera Sensor Link (CSL), which is fast serial link using Camera Sensor Link Protocol (CSLP). The link is full duplex and communication speed is 76800 bits/s. The Processor Module output signal is at TTL-level (0-5V) which is converted in the power and isolation PCB to RS422. RS422 is a four wire connection which allocates two wires for transmitted data and two wires for received data. Output signals are isolated from the sensor power supply.

FOMM connector is similar to 4215 Color sensor signal connector. The CSLP link is used for communication between the FOMM and the MSS.

Provision has been made also for communication with a companion device, and for sending a fast analog trigger for synchronization with the companion device. These are not in use.

Connector type: 3M Cable Plug 26-pole
Manufacturer part no: 4626-6000

Pin	Signal	Description
1-14		Not in use
15	FOMM TX+	CSLP link between sensor and MSS. RS422.
16	FOMM TX-	CSLP link between sensor and MSS. RS422.
17	FOMM RX+	CSLP link between sensor and MSS. RS422.
18	FOMM RX-	CSLP link between sensor and MSS. RS422.
19		Not in use
20		Not in use
21	Comp A	Communication link to companion device. RS 485.
22	Comp B	Communication link to companion device. RS 485.
23	Sync Trig+	Trigger to companion device. 24V fast binary signal.
24	Sync Trig-	Trigger to companion device. 24V fast binary signal.
25		Not in use
26		Not in use

4.2.2 Light control link

The Processor Module can control FOMM light parameters via the Light Control Link. The strobe controller can report its operating parameters to the PM, and the PM can send new parameters. Some parameters are relevant only during standardization scans or during maintenance operations. Others are relevant whenever the strobe is operating.

The link is half duplex RS232 and communication speed is 9600 bits/s. Standard 9-pin D-sub miniature connectors are used at both ends of the link, but only 3 of the pins are in use (pins 2, 3, and 5).

4.2.3 Light trigger

The Processor Module triggers light ON via triggering line. The trigger signal is a very short pulse, with typical length 20μs. The light pulse length is controlled by strobe parameters, and is typically less than 1.0μs, and this precisely timed pulse is sent to all the LED driver PCBs simultaneously, limiting jitter in flash timing to about 10ns. The trigger signal is TTL-level (0-5V) which is converted to a 24 V isolated signal in the power & isolation PCB. This isolated signal is then delivered to the strobe control PCB. Only two wires are needed for the Light trigger signal.

4.2.4 Camera trigger

The camera exposure is triggered by the Processor Module. The signal is TTL level (0-5V) and pulse duration is very short, typically 20μs. The camera trigger occurs about 10μs before the Light trigger. This ensures the camera exposure is active when the strobe is discharged.

4.3 LED Indicators

4.3.1 Strobe control LED indicators

There are several LED indicators on the FOMM.

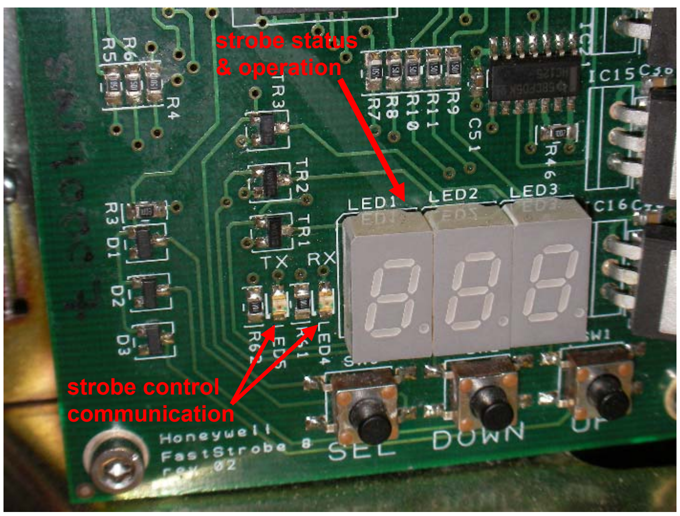


Figure 4-2. LEDs of Strobe Controller PCB

STROBE CONTROL COMMUNICATION INDICATORS

These are two small LEDs on the strobe controller PCB (p/n 20100079). They flash whenever data is transferred between the strobe controller and the processor module. Typically, this happens when the strobe is initialized after sensor power-on, during end of scan adjustments to strobe levels, during a standardization scan, during offsheet sample and reference measurements, and during specific maintenance operations, such as strobe recalibration.

STROBE STATUS & OPERATION DISPLAY

This is a three-digit digital display. When the sensor is powered on, the strobe controller executes a self-test. It first displays its firmware revision number on the display (“003” for instance). It then performs some diagnostics on its own operation.

If an error condition is found, it displays the error number preceded by the letter E (“E04” for instance). Spurious errors are occasionally generated if the power is rapidly cycled off and on. If an error occurs, the sensor should be powered down for about a minute, then powered up again.

During normal operation, alternating horizontal line triplets will be displayed (“‾‾‾” and “_ _ _”), but when a strobe trigger is received, the text “PUL” will be displayed briefly.

PUSHBUTTONS BELOW OPERATION DISPLAY

There are three pushbuttons located below the operation display LEDs. These are used only in bench testing of the strobe controller, or in testing the strobe function using an external trigger instead of the trigger from the Processor Module. They may be used in advanced sensor diagnosis under guidance from QCS-TAC or a sensor developer, but are not needed in any normal sensor maintenance or troubleshooting.

The SEL pushbutton, if held for a few seconds, will activate the pushbutton functions.

First, a channel number will be shown on the display, starting with channel 1, and after a brief delat the output level for the channel will be displayed. The output level can be adjusted in the range 0-999 with the UP and DOWN buttons. Pushing SEL again will set the level, and change the display to the next channel number.

After the eight channels have been processed, pushing the SEL button sequentially will show in turn the pulse length, pulse delay, channel mask, and debounce. Each of these can be adjusted with the UP and DOWN pushbuttons, before using the SEL pushbutton to proceed to the next item.

4.3.2 Processor module LED indicators

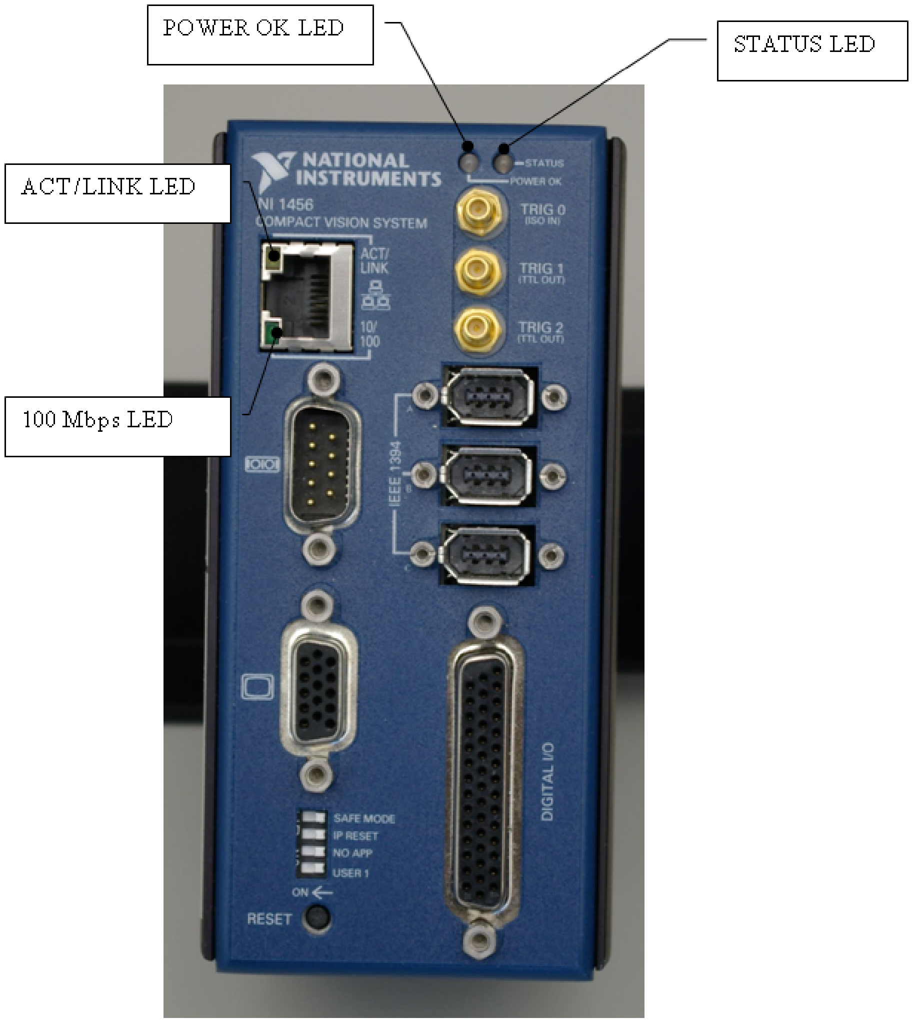


Figure 4-3 FOMM; LEDs of Processor Module (p/n 08769000)

POWER OK LED

Under normal operating conditions, the **POWER OK** LED remains green while the PM is powered on. The green **POWER OK** LED indicates that PM main power receiving power and that the PM is not in a fault state. The red **POWER OK** LED indicates that the PM has shut down because of a fault state. A fault state occurs when the user shutdown input is set, the processor overheats, or the watchdog timer expires.

STATUS LED

The orange **STATUS** LED remains OFF under normal operating conditions and flashes a specific number of times to indicate error conditions or certain DIP switch settings. The **STATUS** LED remains ON if the PM detects an internal error.

ACT/LINK LED

The orange **ACT/LINK** LED blinks when the PM receives data from or transmits data to the network through the Ethernet connection. Unrelated network activity causes this LED to blink occasionally even the PM is inactive.

100 Mbps LED

The green **100 Mbps** LED is ON when the network provides 100 Mbps support and the CVS-1456 device is communicating at 100 Mbps. If the **100 Mbps** LED is OFF, the PM is not operating at 100 Mbps.

4.4 Fuse, Switches, Jumpers

4.4.1 Fuse

FotoFiber has one fuse (p/n 51600543), located near the power switch on the power and isolation PCB (see Figure 4-4). In the event of a serious hardware misconfiguration, such as reversed polarity or overvoltage, this fuse will protect the rest of the FotoFiber circuitry.

Fuse Dev	ice	Description
F1	FOMM	FUSE,VERY FAST,SURFACE MOUNT,5A,6.10 x 2.69mm

4.4.2 Power switch

The FotoFiber has a power switch on the power and isolation PCB, located beside the 24V DC input power socket.

This power switch should be used to power off the sensor before disconnecting the external communication and power cables. The switch is shown in the **OFF** position in the picture. The FotoFiber sensor must be powered down with the external power cable disconnected before attempting to disconnect any of its internal cables.

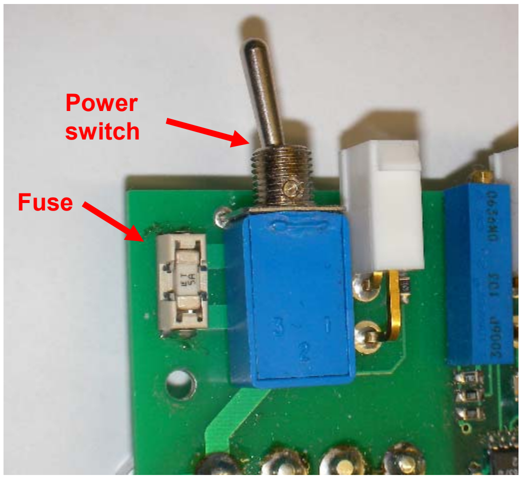


Figure 4-4 FOMM; Fuse and power switch on the power and isolation PCB (p/n 20100078). The switch is in its OFF position.

4.4.3 DIP switches

The FotoFiber sensor has four DIP switches on the Processor Module in FOMM (Figure 4-5). To enable a DIP switch, move it to the **ON** (left) position and then reset the Processor Module by pressing the **RESET** button for at least two seconds.

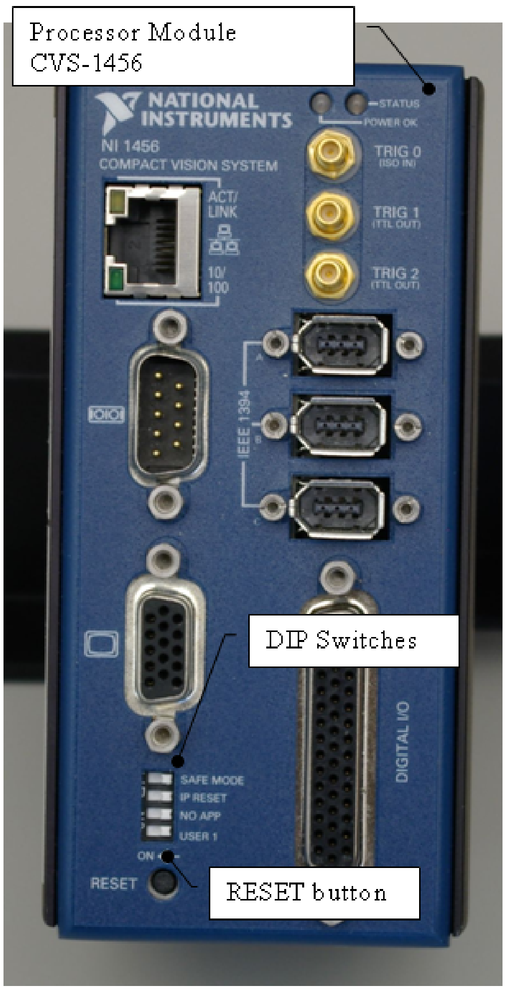


Figure 4-5 FOMM; DIP Switches of Processor Module (p/n 08769000)

Table 4-1 Default settings for Processor Module's DIP switches

DIP switch	Setting
SAFE MODE	OFF
IP RESET	OFF
NO APP	OFF
USER1 OFF	

SAFE MODE switch is used to reconfigure TCP/IP settings and to download or update software from the development computer. Downloading incorrect software to the Processor Module device may cause it to hang during restart or become inaccessible over the network. Powering on or resetting the PM in Safe mode starts the CVS-1456 device but does not start the embedded LabVIEW RT engine. To resume normal operations, restart the PM with the SAFE MODE switch in the OFF position.

IP RESET switch is used to clear the PM IP settings. Move the IP RESET switch to the ON position and reset the PM. Use IP RESET to reset the TCP/IP settings when moving the system from one subnet to another or when the current TCP/IP setting is invalid.
Resetting the PM with the IP RESET switch in the ON position resets the IP address to 0.0.0.0. You can then set up a new network configuration for the PM from a development machine on the same subnet, or you can use an Ethernet crossover cable to connect the PM directly to the development computer. Resetting the IP address is generally not necessary in the field.

NO APP switch is used to prevent the PM from automatically running programs at startup, move the NO APP switch to the ON position and reset the PM. If the PM becomes inaccessible because of the startup program, enable the NO APP switch and reset the PM.
Enable this switch to prevent the PM default startup program or vision Builder AI from running at startup.

USER1 switch is user-configurable and has no default functionality. In the FotoFiber sensor, the USER1 switch is used at boot time to select between normal operation and maintenance operation of the sensor. If the USER1 switch is OFF, then the sensor will boot normally. If the USER1 switch is ON, then the sensor boots with a different firmware, which supports a number of special maintenance and diagnostic procedures, as well as calibration and test measurement (see §6.2 and §7.3).

4.4.4 Jumpers

There are several jumper sites on the power & isolation circuit board, but only one is significant to FotoFiber operation. The jumper is not accessible unless the sensor is dismantled to replace the strobe control PCB or the power & isolation PCB (p/n 20100078). There should be no need to change the jumper setting, unless the jumper became dislodged during transport of a replacement power & isolation PCB.

Jumper J1 selects between TTL and 24V isolated output levels for the trigger signal sent to the camera, and is the 3-pole jumper located closest to the camera trigger output connector. The jumper should be on the two poles closest to the camera trigger output connector to select the 24V isolated level (see Figure 4-6).

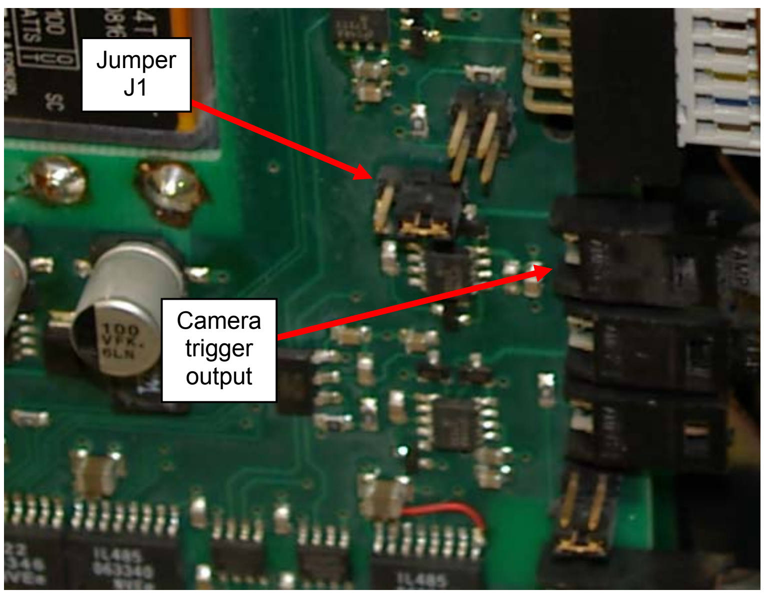


Figure 4-6. Location of jumper J1 for camera trigger signal level. Jumper is shown in default (correct) position.

4.5 Special PCBs

The FotoFiber contains 4 purpose-built PCBs. With some kinds of sensor problem, diagnosis may include examining these boards. The artwork for the boards is shown here, to help clarify communication when diagnosis is assisted by QCS-TAC.

4.5.1 LED panel PCB

There are 8 LED panel PCBs (p/n 20100081), each powered by a LED driver PCB.

Conductors leading from the LED driver PCB are soldered to pads at V+ (red #16 gauge conductor) and V- (black #16 gauge conductor). These solder connections are vulnerable if the sensor is subjected to mechanical shock or severe vibration.

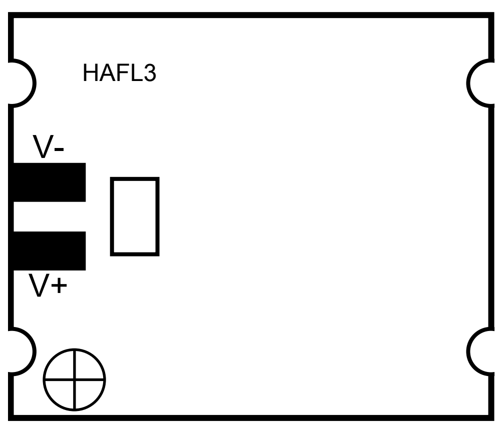


Figure 4-7. LED panel PCB

There are 24 LEDs on the other side of this PCB, each with a lens. The lenses can become detached if the sensor is subjected to mechanical shock or severe vibration. They can be re-attached using superglue.

The LED panel PCBs are 32mm long and 17mm wide, approximately.

4.5.2 LED driver PCB

There are 8 LED driver PCBs (p/n 20100080), one for each LED panel, with artwork as in Figure 4-8.

Each LED driver PCB has a cable to the Strobe Control PCB connected in the socket at PL1. There are two lengths of cable, ordered as a set (p/n 08770600). The cables can be dislodged from or loosened in the socket if the sensor is subjected to mechanical shock or severe vibration

Conductors leading to the LED panel PCB are soldered to pads at L+ (red conductor) and L- (black conductor). These solder connections are vulnerable if the sensor is subjected to mechanical shock or severe vibration

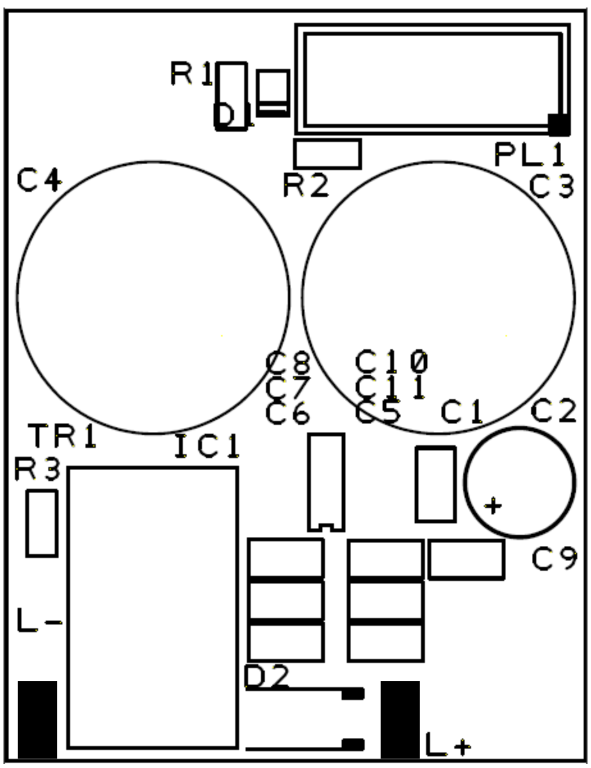


Figure 4-8. LED driver PCB

Mis-handling of the sensor which results in lateral forces on the capacitors C3 and C4 or on the socket PL1 may cause them to be electrically separated from the PCB.

The LED driver PCBs are 34mm long and 22mm wide, approximately.

4.5.3 Strobe control PCB

The strobe control PCB (p/n 2010079) has a TTL trigger input at socket PL11 (Trig), a 24V DC supply at CONN1 (24V), and a trimmed 49V DC supply at CONN2. Artwork for the PCB is shown in Figure 4-9.

Sockets PL1 to PL8 have cables leading to the LED driver PCBs, while SKT2 has a RS242 serial link to the processor module.

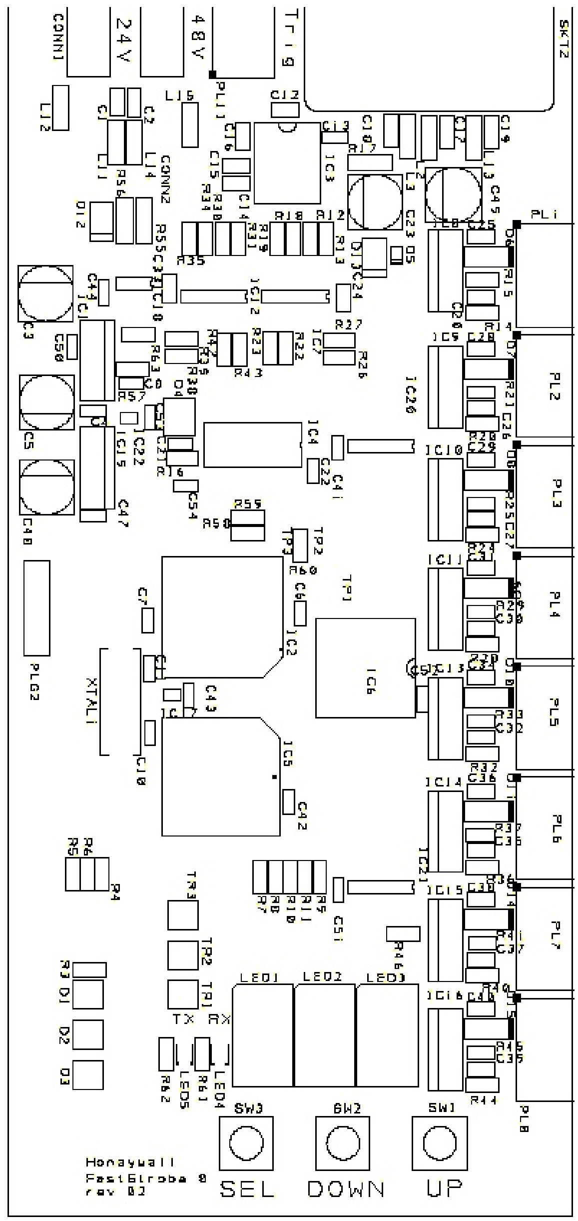


Figure 4-9. Strobe control PCB.

4.5.4 Power and isolation PCB

The Power and isolation PCB (p/n 20100078) is located behind the strobe control PCB. Only its connectors are accessible in normal maintenance. Its art work is shown in Figure 4-10.

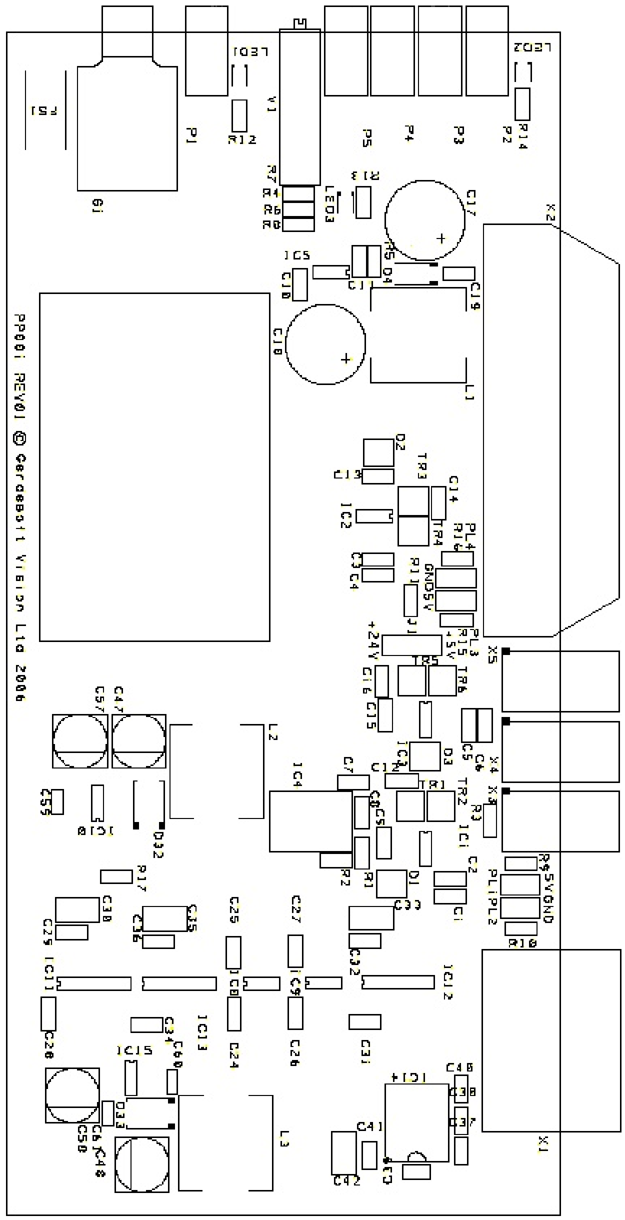


Figure 4-10. Power and isolation PCB.

The power and isolation PCB is 150mm long and 70mm wide, but its connectors protrude about 8mm on the long side and about 4mm on the short side. The switch protrudes about 16mm.

4.6 Pneumatics

An air hose is required to provide cleaning air flow to the sensor. In the upper sensor construction, this is used to clean the window inside the plenum, and to purge the plenum of any dust. In the lower sensor construction, this is used to clean the window near the sheet, and to blow dust out of the horseshoe ring.

There is a short hose with a receptacle for the air-hose connector, attached to the flange plate of the sensor (see Figure 4-11). The receptacle at the end of the hose is of 1/8 inch screw-on type (p/n 61000092).

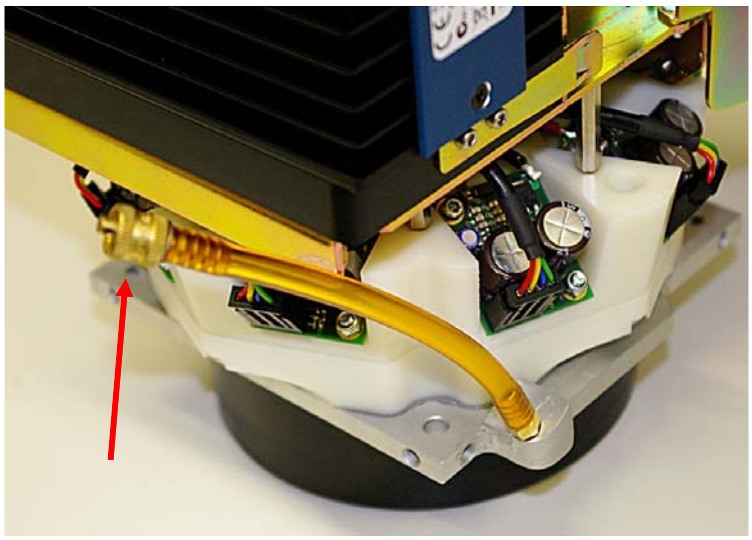


Figure 4-11. Air connector for FotoFiber.

5 Installation

FotoFiber sensors may be delivered with a new scanner, or added to a suitable existing scanner. Both single-sided and two-sided installations are possible. It may also be necessary to remove a sensor for certain maintenance operations from time to time.

5.1 Installation Requirements

Before installing the FotoFiber sensor, make sure the Da Vinci system meets the following requirements:

- The MSS has a PCI slot, and a PCDAQ/PCI card (p/n 05438200) has been installed. See Appendix.
- PCDAQ ports are available on the PCDAQ card. Two ports are needed for a two-sided installation, one port for a one-sided installation.
- Compressed air is available in the head manifold, with a spare capacity of 30L/min. For a two-sided installation, this air supply must be available in both heads. For a one-sided installation, it must be available in the head in which the FotoFiber is to be installed.
- 24V, 10A Auxiliary Power Supply (p/n 09857800) is installed
- Scanner version is 4000
- Cabling for the Color sensor (p/n 09421510) exists and is available. For a two-sided installation, this cabling must be available in both

heads. For a one-sided installation, it must be available in the head in which the FotoFiber is to be installed.

- Suitable version of Da Vinci RAE 4 or RAE 5 (see §3.2).

Consult Honeywell QCS TAC if these requirements are not met.

5.1.1 Materials needed

The materials needed are not the same for single-sided (4803-1) and two-sided (4803-2) FotoFiber installation, but there are also common items.

Single-sided sensor

- 1 FotoFiber sensor upper measurement head (p/n 08765800)
- 3 Socket-head 10-32×0.5″ machine screws (p/n 28110006)
- 1 FotoFiber backing module (p/n 08766200)
- 1 CSLP communication cable (p/n 08770900)
- 1 AUX power cable (p/n 08766300) **OR**
  1 Color sensor lamp power cable (p/n 08724200)

If there is no free air hose in the scanner head, then it is necessary to add one, and the following additional items are needed:

- 1 air hose screw connector (p/n 61000209)
- 1 hose clamp (p/n 28000154)
- 1 air hose nipple with screw thread (p/n 61000700)
- 1 air hose, about 2m long (p/n 41000029)
- 1 air hose quick-connector (p/n 61000119)
- 1 air manifold quick-connector (p/n 61000513)

Two-sided sensor

- 1 FotoFiber sensor upper measurement head
- 1 FotoFiber sensor lower measurement head
- 6 Socket-head 10-32×0.5″ machine screws (p/n 28110006)
- 2 CSLP communication cables (p/n 08770900)

- 2 AUX power cable (p/n 08766300) **OR**
  2 Color sensor lamp power cable (p/n 08724200) **OR**
  1 of each of these cables.

If there are no free air hoses in the scanner head (one is needed in upper head, another in lower head), then it is necessary to add hoses into the upper and/or lower heads, and the following additional items are needed:

- 1 or 2 air hose screw connector (p/n 61000209)
- 1 or 2 hose clamp (p/n 28000154)
- 1 or 2 air hose nipple with screw thread (p/n 61000700)
- 1 or 2 air hose, about 2m long (p/n 41000029)
- 1 or 2 air hose quick-connector (p/n 61000119)
- 1 or 2 air manifold quick-connector (p/n 61000513)

Common, for single-sided or two-sided sensor

- 1 Y-cable (p/n 6580801031)
- 1 Calibration and focus chart (p/n 08773300)
- 1 Lens Pen (p/n 54000353)
- Small amount of thread locking compound (p/n 16000235)

5.1.2 Preparation and tools

Installing a single-sided FotoFiber sensor requires about 30 minutes. About 5 minutes will also be needed for installing the blank opposite it in the other head. Installing a two-sided FotoFiber takes about 30 minutes for each side. These should be considered absolute minimum times, and it is advisable to reserve a longer time.

Preferably, installation of sensors takes place during a whole-day shutdown, but it is also possible to install in a running machine, provided the scanner can be offline for a long enough time. A two-sided FotoFiber may be installed into a running system in two separate operations, provided that when the scanner is to be operated with only one FotoFiber, either that FotoFiber is powered down or there is a suitable backing unit opposite it in the other head. This allows the interruption to scanning to be divided into two periods, which may be more suitable for the mill.

The scanner head must be safely offsheet for the time needed, and the environment should not be subject to droplets or dust. It is recommended that installation of a FotoFiber be performed during a machine shutdown.

ATTENTION It is essential that a working air supply be connected to FotoFiber immediately on installation, before any attempt to scan the sheet (whether FotoFiber is powered on or not). Traversing the sheet without a cleaning air flow to the sensor may result in severe dirt build-up, necessitating removal of the sensor for major cleaning.

The following tools may be required, and should be at hand:

- Needle-nose pliers
- Long handle roundhead hexagonal keys (metric and imperial)
- Wrench set (metric and imperial)
- Screwdrivers (small flathead and long Phillips #1)
- Voltmeter with thin probes
- Xacto-type sharp knife (or wire-cutting pliers)

Since handling the sensor is likely to leave fingerprints and other marks on the sensor window, it is recommended that the sensor windows be cleaned immediately after installation. The Lens Pen (p/n 54000353) and clean compressed air (mill air or canned optical-quality air) should be available.

5.1.3 On-site spare parts

A small number of spare parts are generally supplied with the FotoFiber. These should be stored in a suitable place on-site, in a container clearly marked as “FotoFiber Spares” or similar:

- 1 LED driver PCB (p/n 20100080)
- 1 LED panel PCB (p/n 20100081)
- 1 spare strobe control cable (from cable set p/n 08770600)

The Lens Pen and the Calibration and focus chart may be stored in the same place as these spare parts.

5.2 Installing the Sensor

5.2.1 Check alignment and fit

Since the internal space is not the same in all types of head, it is necessary to check first that the FotoFiber can fit as delivered from manufacturing. The recommended installation location is "F" as shown in Figure 2-1. In particular, the size and positioning of the environmental unit can constrain the positioning of the FotoFiber.

ATTENTION The air supply to the FotoFiber must be introduced on the upstream side of the sensor. In other words, the air must move into the sensor in the same direction as the movement of the sheet through the sensor gap. The air must not be introduced from the downstream side, or in either cross-machine direction. This requirement holds for sensors in the upper head and in the lower head. The approved alignment relative to the paper movement is shown in Figure 5-1 (see also Figure 2-6).

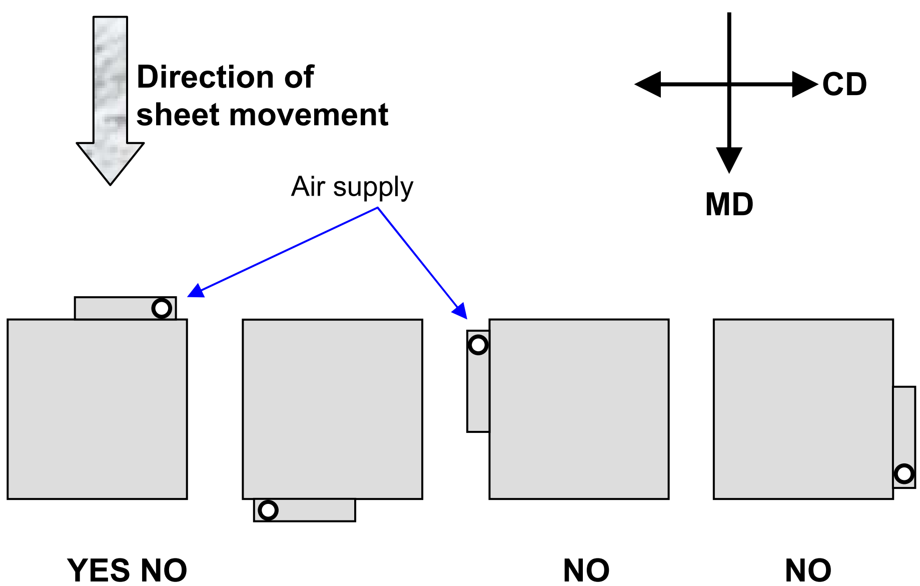


Figure 5-1. Approved alignment of FotoFiber in head.

The upper structure of the FotoFiber overhangs more on the side with the processor module than on other sides, and this may impede installation in the approved alignment. However, it is possible to detach the upper section of the FotoFiber from the lower section, and to reattach it with a rotation of ±90° or 180°. This will move the overhang of the processor module to a different side.

If rotation is needed, it is preferable to use a rotation of 180°, since this will not entail any changes to configuration parameters. If a rotation of +90° or -90° is needed, then bit 4 of the Sensor options bitfield (parameter #53, see §3.3.4.2) must be set to 1.

5.2.1.1 Rotating upper section

Rotating the upper section relative to the lower section should only be attempted with the sensor removed from the head, on a stable surface in a clean environment.

The upper section and lower section can be separated by removing four bolts holding the light source assembly (upper polymer octagon) to the window holder (lower polymer octagon). To access one of the bolts, it is necessary to swing the processor module out on its hinged base, as in Figure 5-2, left.

The bolts are at the protruding corners of the octagons, and can be found easily by locating the four nuts in small recesses in the lower surface of the lower polymer octagon. Each nut must be held with a small pliers or other tool while the bolt is loosened with a long hex key.

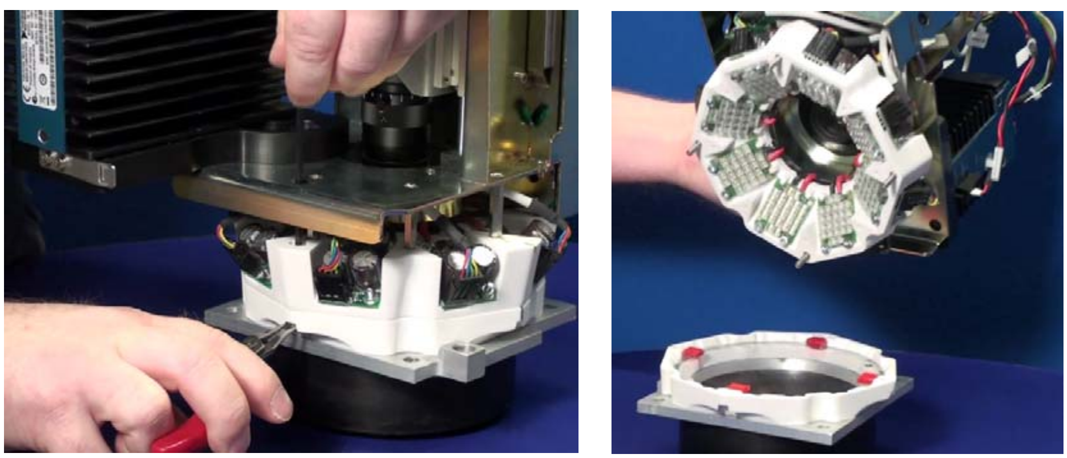


Figure 5-2. Separating upper and lower sections of FotoFiber (prototype is shown, final construction is trivially different).

When all four bolts are fully loosened and the nuts removed, the upper section can be lifted off the lower section (Figure 5-2, right). It is not necessary to remove the bolts, and leaving them in place can assist in repositioning the upper section on the lower section. A rotation should be chosen which will allow the FotoFiber to fit in the head (preferably 180°, but ±90° is also allowed).

When the upper part is replaced on the lower part with the desired rotation, the nuts can be replaced on the bolts. A thread locking compound (p/n 16000235) should be applied when fastening the nuts onto the bolts.

5.2.2 Mechanical installation

Installation involves removing the existing blank, then installing and fastening the FotoFiber. If it is a single-sided FotoFiber, then a suitable FOBM with sheet bearing rings must be mounted opposite it.

5.2.2.1 FOMM

The FotoFiber must be positioned in the correct alignment (see Figure 5-1), and fastened to the sheet guide plate using three socket-head 10-32×0.5” machine screws (p/n 28110006) and split-ring washers (p/n 28310007), as in Figure 5-3. In general, it is not possible to attach a screw through the fourth mounting hole, due to geometric constraints inside the head. A long-handled round-head hex key will be needed to tighten the screws.

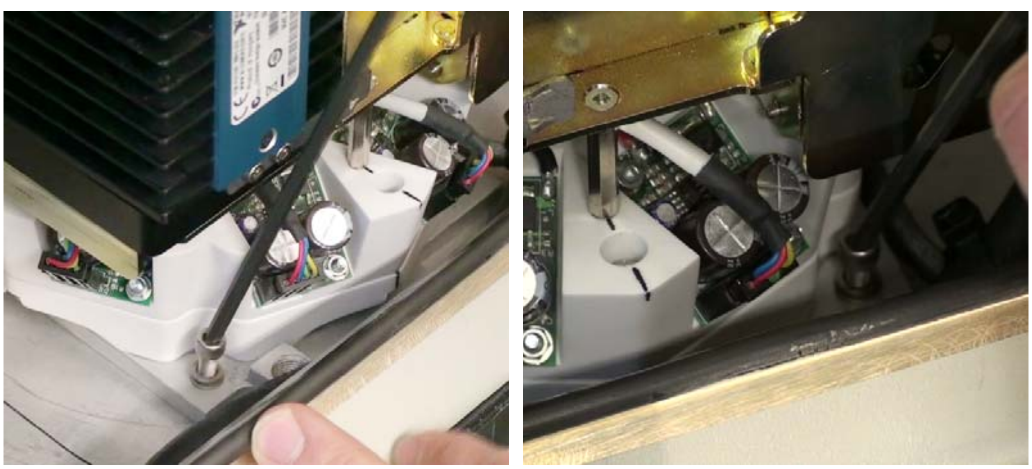


Figure 5-3. Fastening FotoFiber to sheet guide.

5.2.2.2 FOBM

The FOBM is only to be installed opposite a single-sided FOMM. Different FOBM modules are designated for upper and lower heads. The FOBM is installed using a Philips #1 screwdriver.

5.2.3 Connections inside head

There are three connections to be made between the sensor and the head: power, communication, and air.

CAUTION The power switch for the FotoFiber sensor should remain in the OFF position until the entire installation is complete. Preferably, the external power cable is the last connection to be made.

5.2.3.1 CSLP communication

The communication cable (p/n 08770900) is plugged into the 26-pin socket on the top of the FotoFiber sensor. The other end should be plugged into a suitable CSLP socket in the head. With a config-F board, this is a color sensor socket (shown in Figure 5-4). With a config-G board, there is a dedicated FotoFiber socket.

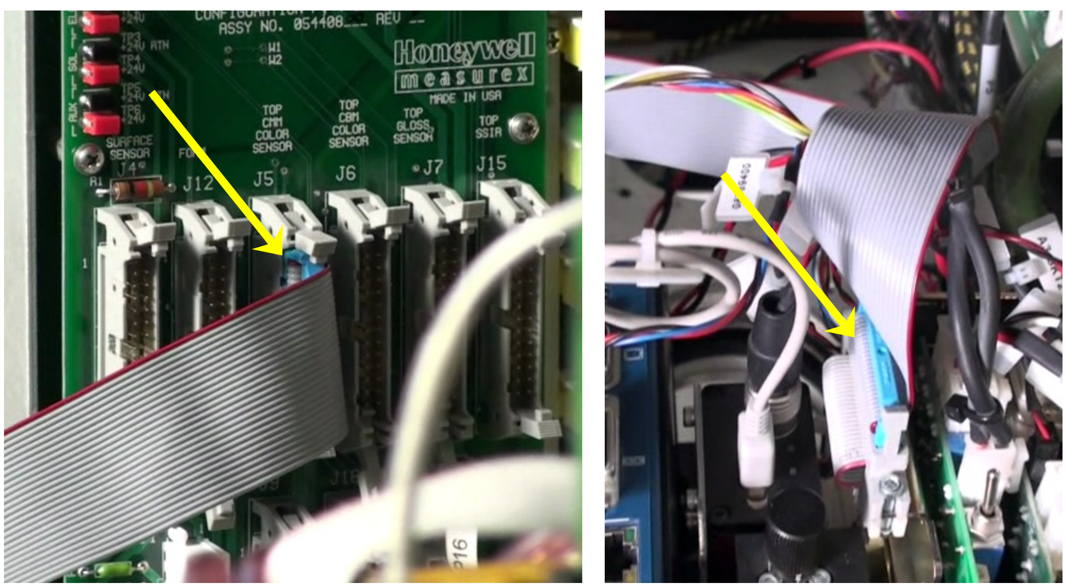


Figure 5-4. Connection of CSLP ribbon cable inside head. Left: at config board. Right: at FotoFiber sensor.

5.2.3.2 24V DC power

The 24V DC supply should be plugged into the FotoFiber using *either* an AUX 24V cable (p/n 08766300, used in Figure 5-5) *or* a Color sensor lamp power cable (p/n 08724200, used in Figure 5-6).

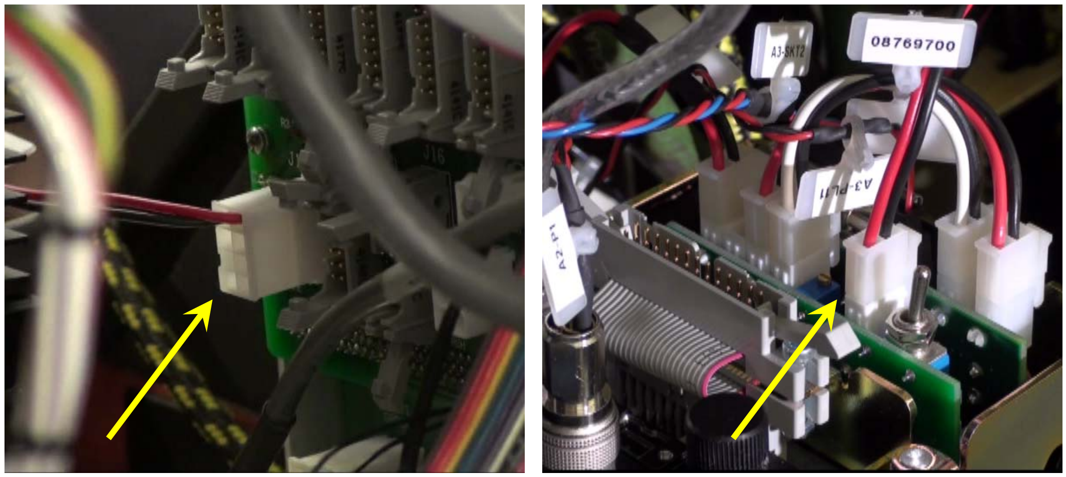


Figure 5-5. Connecting to 24V DC power using the head AUX power supply and cable (p/n 08766300).

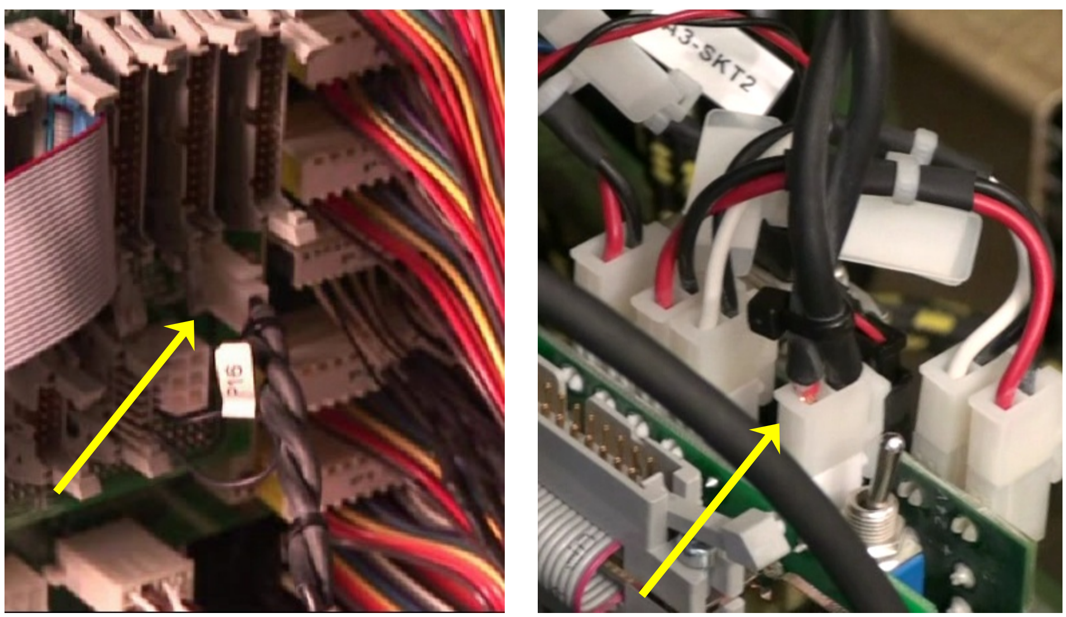


Figure 5-6. Connecting to 24V DC power using the color lamp power supply and cable (p/n 08724200).

5.2.3.3 Air supply

The FotoFiber Sensor head requires compressed air to operate. Ensure that the air supply at the entrance to the sensor head is 275 kPa. Regulate if necessary. The default installation choice for scanner 4000-10/00 is to use the head's standard air manifolds and add a hose for the FotoFiber sensor, if necessary (Figure 5-7) and connect it to FotoFiber (Figure 5-8).

It is recommended that a quick connector (p/n 61000513) be installed in the air manifold of the scanner head. The corresponding connector (p/n 61000119) should be fitted to one end of the air hose (p/n 41000029). The air hose should be left significantly over-length, with the surplus coiled and tied neatly inside the head. The extra length is needed because it is often necessary to shorten the hose by 1-2cm each time the sensor is removed for maintenance. The hose end inside the head is attached to the nipple on the FotoFiber.

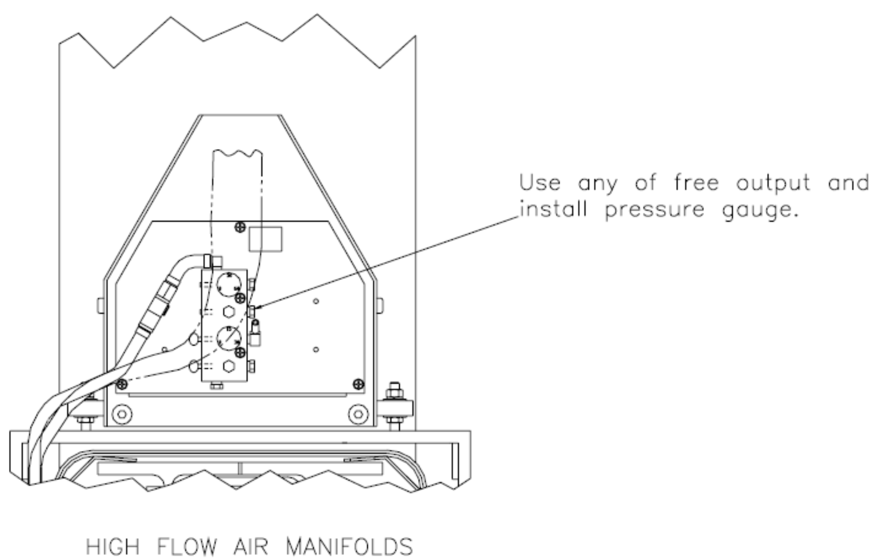


Figure 5-7. Air supply outside scanning head.

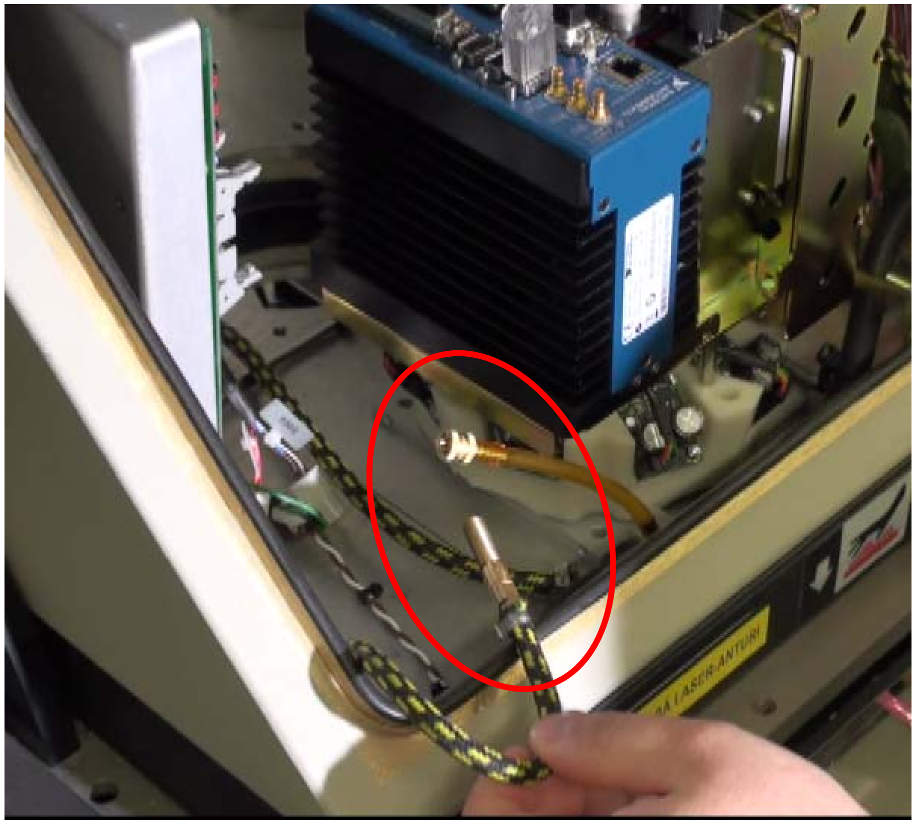


Figure 5-8. Connect air hose to FotoFiber receptacle.

5.3 End-bell and MSS Connections

The FotoFiber Sensor communicates with the DaVinci system via a PCI-PCDAQ board in the MSS. Perform the following steps to confirm the cabling and endbell installation:

1. Power off the scanner before proceeding
2. Check that a PCI-PCDAQ card (p/n 05438200) is installed in the scanner MSS (Figure 5-9 left).
3. Check from PCI-PCDAQ that all jumpers are OUT (=OFF). You may need to remove the board from MSS to see this.
4. Install PCI-PCDAQ to the MSS.

5. Check or install the Y cable (p/n 6580801031, Figure 5-9 right) from PCI-PCDAQ connector J1 to J1 and J2 in Endbell Config board (Figure 5-10 left & right, and Figure 5-11).

6. Make sure by measuring and comparing your notes to system drawings that communication lines (TX+, TX-, RX+, RX-) marking match each other. Default port for single upper head FotoFiber Sensor in PCI-PCDAQ is Port number 1. (Port #2 is used for lower head or dual sensor).

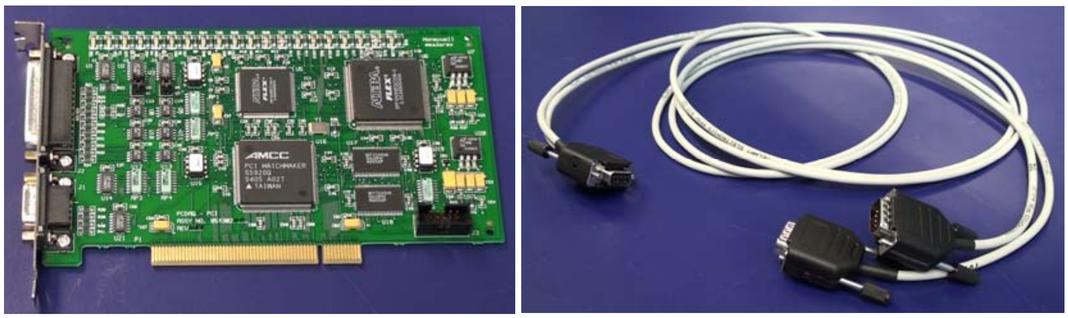


Figure 5-9. Left: PCI-PCDAQ board. Right: Y-cable for end-bell.

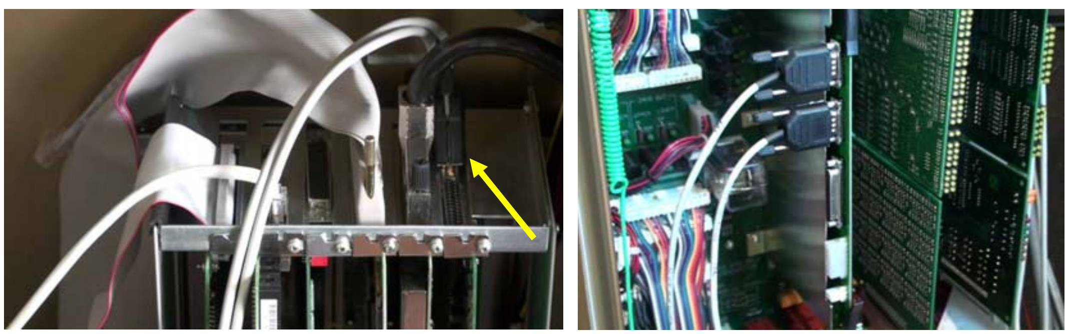


Figure 5-10. Y-cable installed to PCDAQ (left) and config board (right).

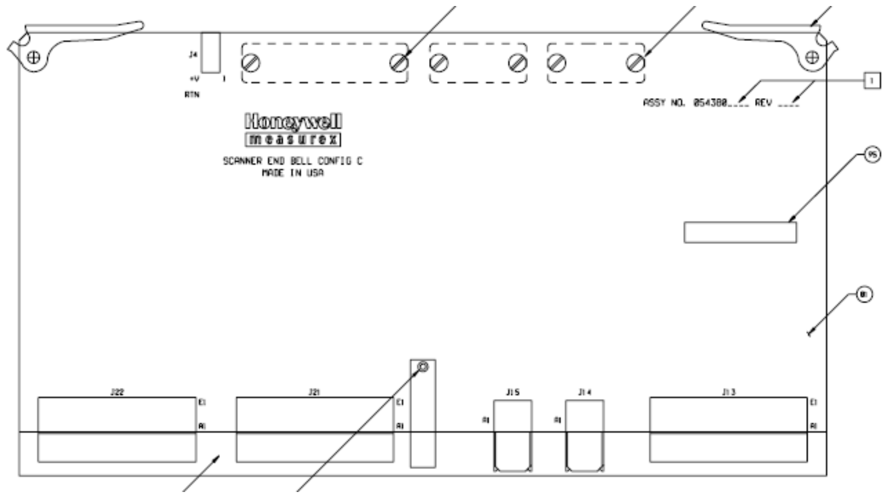


Figure 5-11. End bell config board.

5.4 Hardware Configuration

5.4.1 Hardware checks

The sensor hardware should have been correctly configured during post-manufacture testing at the factory. However, the following items should be checked after the installation is complete:

- The air-flow to the sensor should be palpable at the outlet from the sensor. This can be checked by holding one's hand (i) across the plenum opening of an upper head sensor, or (ii) in front of the air slot in the horseshoe of a lower head sensor.
- The trimmed DC output from the power and isolation PCB should be between 49V and 49.5V DC. This should be checked and adjusted if necessary, following the procedure in §6.3.1.2.
- The camera focus should be checked during operation, after the sensor has reached a normal working temperature. If necessary, focus can be adjusted using the procedure in §6.2.2.
- The window should be clean and free from dirt or smears from handling during installation. This is especially needed for the window of a lower head sensor. Inspect and clean if necessary, using the procedures in §6.1.

5.4.2 Sensor parameters

Sensor software parameters are configured using the FotoFiber engineering display, as explained in §3.3.4. For most parameters, the default values will be acceptable, but some are site-dependent. The following parameters must always be checked.

5.4.2.1 Magnification parameter

The magnification of the camera lens is parameter #13 in §3.3.4.2, with 0.45 as default value.

Typically, the lens magnification is set to 0.45× which is suitable for grades containing hardwood fibers or a mixture of hardwood and softwood fibers. If the machine will produce grades which contain *only* softwood fibers, then the lens magnification may be set to 0.40× (this may require removing the camera from the sensor for adjustment of the lens), and the parameter can be updated. If the lens magnification is changed, the sensor *must* be refocused, as in §6.2.2.

5.4.2.2 Standardization samples

The number of flashes measured per channel is parameter #25 in §3.3.4.2, with 5 as default value. The number of flashes skipped while changing active channels is parameter #24, with 3 as default value.

The minimum scan time, T_{min} (minimum number of seconds measuring on-sheet) expected on-site must be known. This minimum should take the possibility of scanning between fixed limits into account, as well as edge-to-edge scanning.

ATTENTION If the minimum scan time T_{min} is expected to be less than 12 seconds, then it will be necessary to either (i) reduce the scan speed to achieve a longer T_{min}, or (ii) reduce the values for #24 and/or #25. In this case, refer to §7.1.1.1 for the calculation of suitable values for parameters #24 and #25.

If the minimum scan time T_{min} is expected to exceed 12 seconds, then it may be possible to increase #25, thus giving more reliable channel efficiency factor measurements. However, the number of flashes remaining for all channels to be used together, F_{rem}, must be adequate.

$$F_{rem} = \left(T_{min} - 1.8\right)\#5 - 8(\#24 + \#25)$$

The 1.8 second offset represents time taken for 9 strobe state transitions (switching channels on or off). F_{rem} should be at least as large as #25, but if it exceeds #25 by more than 30, then #25 can be increased. If #25 is 10 or more, then there is no further need to increase it, even if F_{rem} is quite large. The calculation can be understood by referring to the standardization procedure in §2.3.4. The default value of 3 for #24 is adequate.

5.4.2.3 Sensor rotation

If it was necessary to rotate the upper section of a sensor by ±90° relative to the lower section, then bit 4 of the sensor options bitfield (parameter #53 in §3.3.4.2) must be changed.

The nominal MD axis for the image is the long axis of the camera. This is the same as the long axis of the processor module, which is more easily observed. If the long axis of the processor module is aligned in the machine direction, then bit 4 should be 0. If the long axis of the processor module is aligned in the cross-machine direction, then bit 4 should be 1.

5.4.2.4 Strobe delay

In a two-sided sensor installation, both sensors receive the same initial tic message, which can have jitter of ±5ms, ±10ms, or ±15ms. It is necessary to delay the strobing of one sensor by a sufficient amount to prevent flash-through disturbances on occasional scans.

For **one sensor only** in a two-sided sensor, the strobe delay from initial tic (parameter #51 in §3.3.4.2) should be set to 32000µs. The other sensor should have zero for its parameter #51 value.

For a single-sided sensor, parameter #51 should always be zero.

5.4.2.5 Clockwise/anticlockwise as positive

Each mill has a convention for the positive direction for angles. The zero direction is always the machine axis. A positive angle may be defined as being in the anticlockwise direction from the machine axis, viewed from above the wire.

The mill convention must be obtained by consulting the mill laboratory personnel. It may also require observing how a CD strip is taken from the reel and how it is handled as it is brought to laboratory and analyzed in the laboratory. Keep track of top/bottom surfaces, drive/tending edges, and headbox to reel direction on the sample.

The angle convention for FotoFiber is set using bit 8 of the sensor options bitfield (parameter #53 in §3.3.4.2). In a two-sided sensor installation, one sensor will have clockwise as positive, while the other will have anticlockwise as positive. The default (bit 8 is zero) is for anticlockwise angles to be positive, as viewed by the sensor camera.

5.4.2.6 Zero angle

This is parameter #16 in §3.3.4.2. It is used to compensate for combined deviations in the alignment of the MD direction in the image compared to the true MD axis.

The variation in alignment of the image detector inside the camera is typically up to ±1° for most camera models. The alignment of the camera inside the FotoFiber can vary by up to ±0.5°, due to tolerances in mechanical fixtures. The alignment of the FotoFiber inside the head can vary by up to ±0.5°, due to tolerances in mechanical fixtures. The combined alignment deviation may change slightly each time the sensor is removed from and remounted in the head. The change may be greater if the camera is also removed and remounted in the sensor.

The zero angle is expressed in degrees, in the mill's coordinate system. This parameter can be assessed only after the clockwise/anticlockwise bit is set. It should be set to zero initially, and can later be estimated to bring the FotoFiber's average angle into agreement with the mill's average TSO angle. It may need to be updated each time the FotoFiber is removed from and remounted in the head.

5.4.3 MSS and Da Vinci parameters

5.4.3.1 Machine speed

Ensure that the machine speed has been properly set up as in §3.2.3.

5.4.3.2 Sensor job set for MSS

To set up the MSS Job Set IO for FotoFiber:

1. Open the MSS Job Set IO Setup popup on the MSS Setup and Diagnostics display (Figure 5-12).

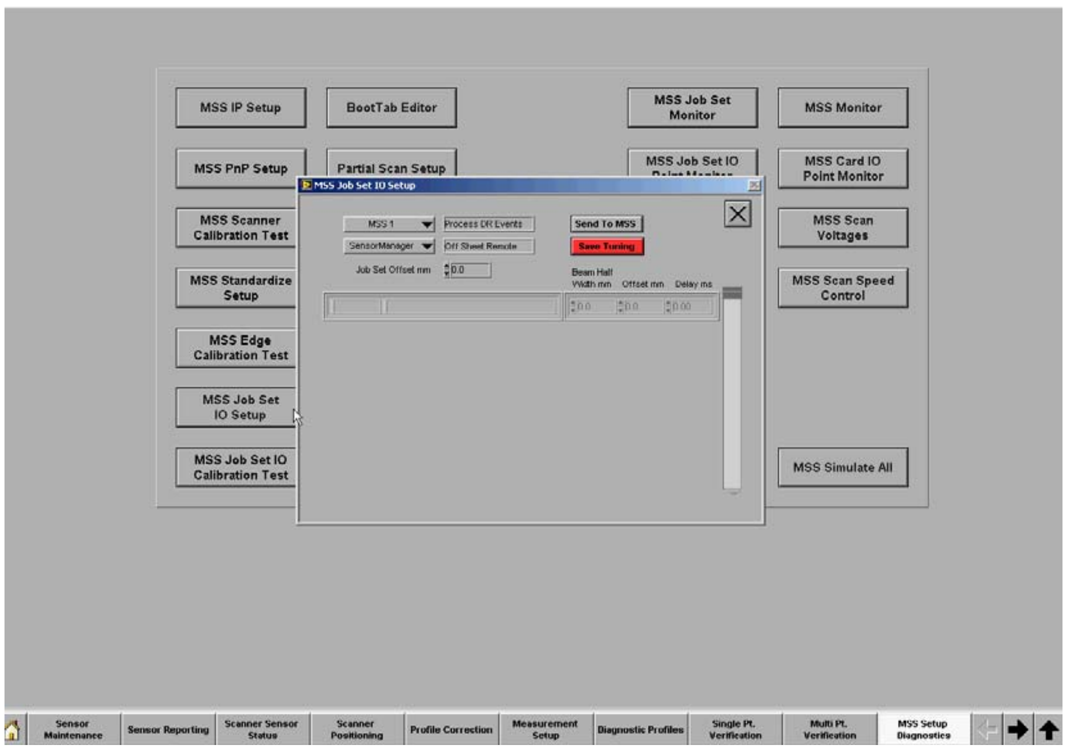


Figure 5-12. MSS Job Set IO setup.

2. Use the drop-down list to select the appropriate MSS and FotoFiber sensor (Figure 5-13).
   ATTENTION The FotoFiber may be listed as “OptForm” in some versions of RAE.

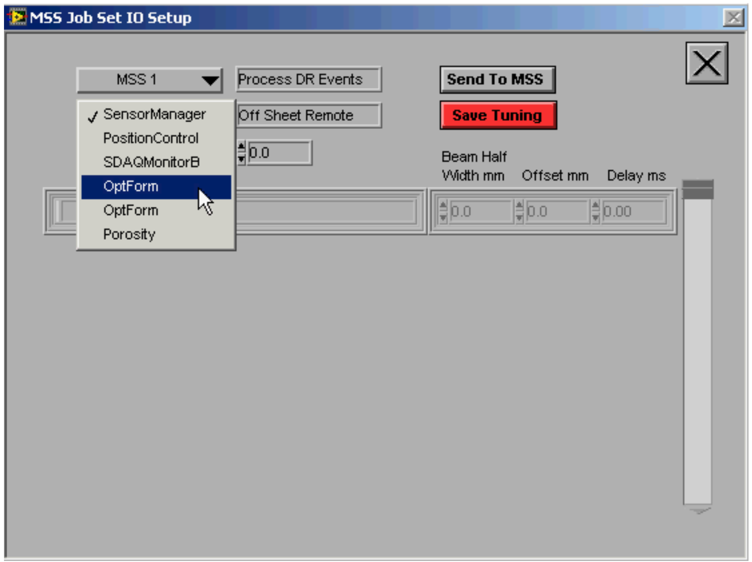


Figure 5-13. Select MSS and FotoFiber (here listed as OptForm) sensor.

3. Set correct beam half-width, Delay, and Job Set offset (Figure 5-14). These values are identical for all of the FotoFiber measurements. Default values for beam half-width and delay are shown in Figure 5-14. The sensor offset value can be obtained from Table 2-1 based on the installation location in the head.

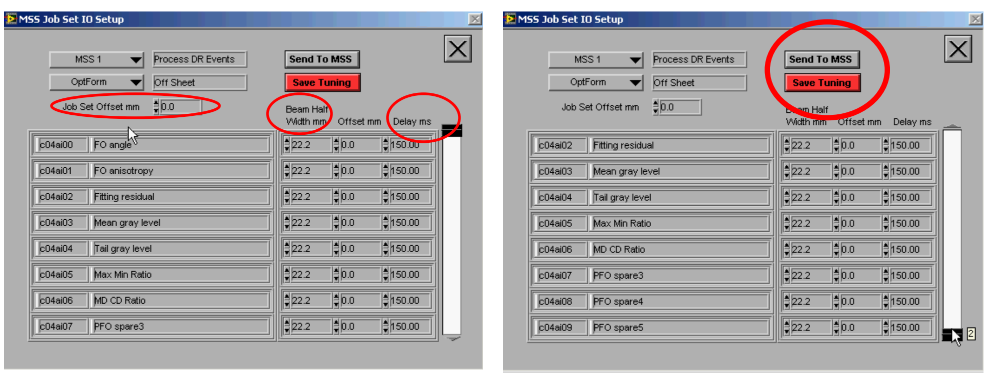


Figure 5-14. Specifying Job Set parameters.

4. After entering the correct values, click both the **Send to MSS** and **Save Tuning** buttons in the Job Set IO Setup popup (Figure 5-14).

5.4.3.3 MSS PCDAQ setup

The PCI PCDAQ card parameters must be set up for the MSS to use.

1. Open database browser, navigate to the correct MSS, and then to "Daq XX formation" card setting, where XX is the PCDAQ card number (Figure 5-15).

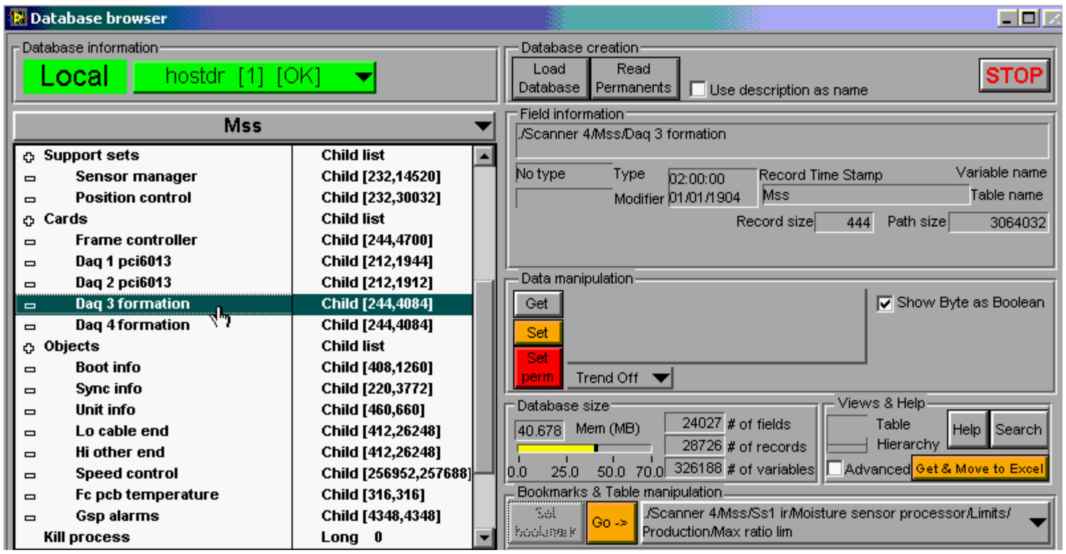


Figure 5-15. RTDR browser, select DAQ interface.

2. Check and set the required values. Follow the scanner and MSS manuals for details. In this example (see Figure 5-16), we use the values:

Card type	= 13
Pio card address	= (automatic)
Base address	= 0
Pnp serial number	= 15 (card position dependent)
Pnp product vendor	= 436211884 (card dependent)
Interrupt	= 0
Card option	= 10
Display jobset id	=0

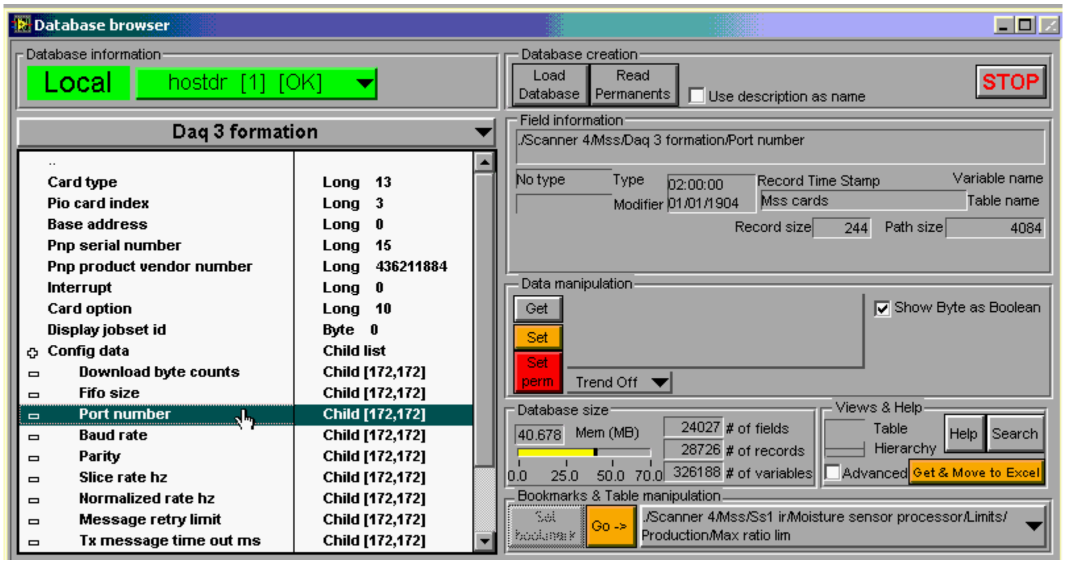


Figure 5-16. RTDR browser, PCDAQ interface parameters.

3. Next, select Port number for the card (see Figure 5-16).

4. For one Foto sensor, set the port number equal to 1 (see). This is the RS port number on the PCDAQ card. The PCDAQ card has two RS ports, numbered 1 and 2.

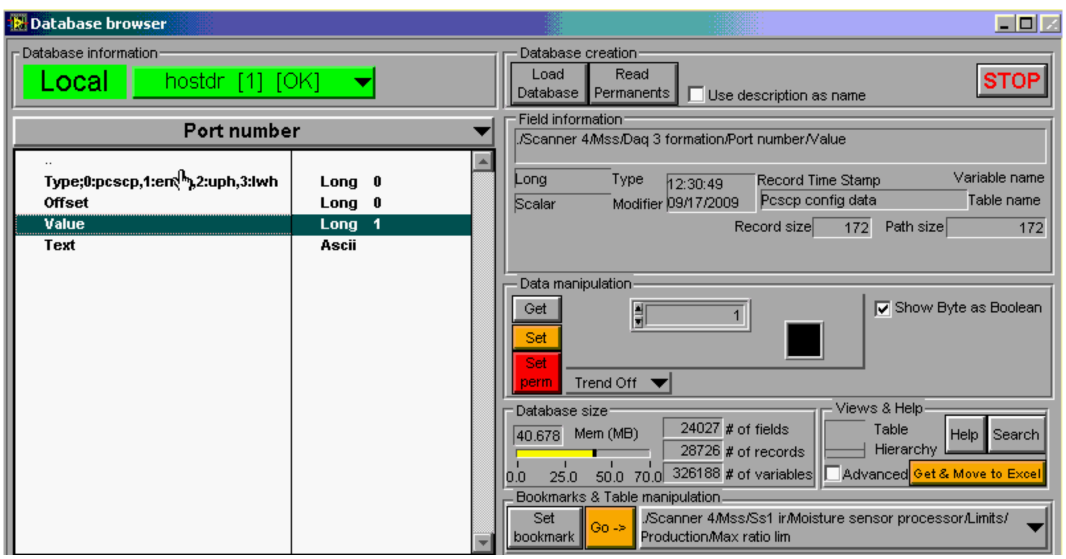


Figure 5-17. RTDR browser, PCDAQ interface RS port number.

5. If the scanner has two FotoFiber sensors, then there will be a "Daq YY formation" card in the card list, where YY≠XX. Usually, the

physical PCDAQ card is the same, and this is just the interface to the second sensor.

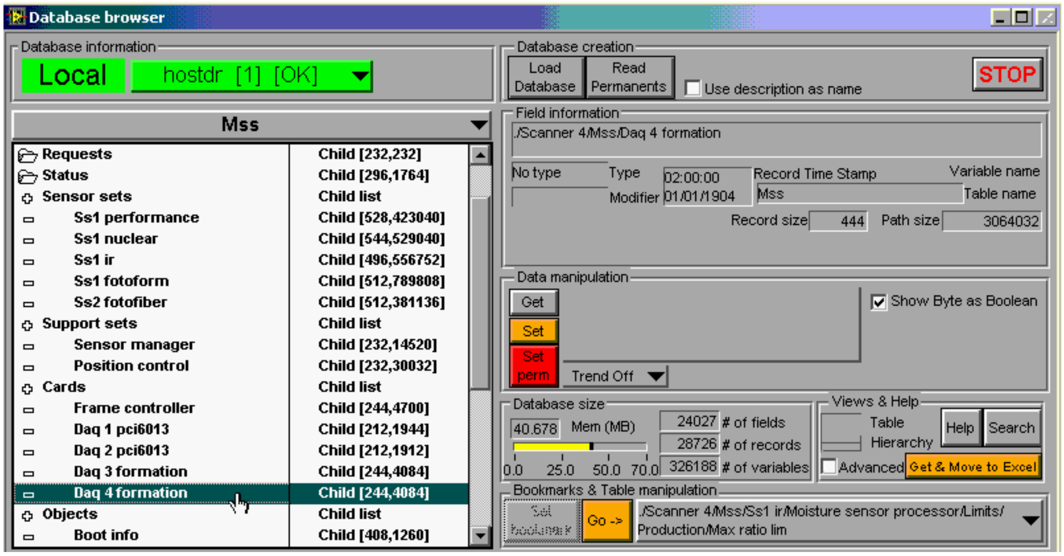


Figure 5-18. RTDR browser, select DAQ interface for second sensor.

6. Select this second interface and check or enter the card parameters as for the first interface. If this is physically the same card, than all parameters except "Pio card index" will be the same (Figure 5-19). If it is a different physical card, then all parameters must be determined using procedures in the scanner and MSS manuals.

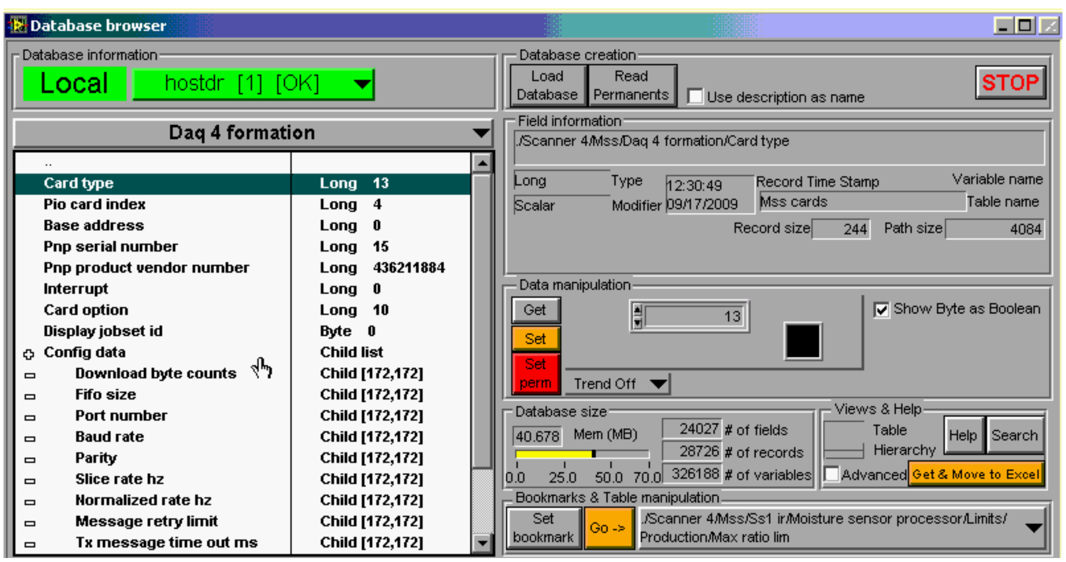


Figure 5-19. RTDR browser, second PCDAQ interface parameters.

7. Select the Port number for this interface. If it is the second port on the same card, then set the port number to be 2 (Figure 5-20).

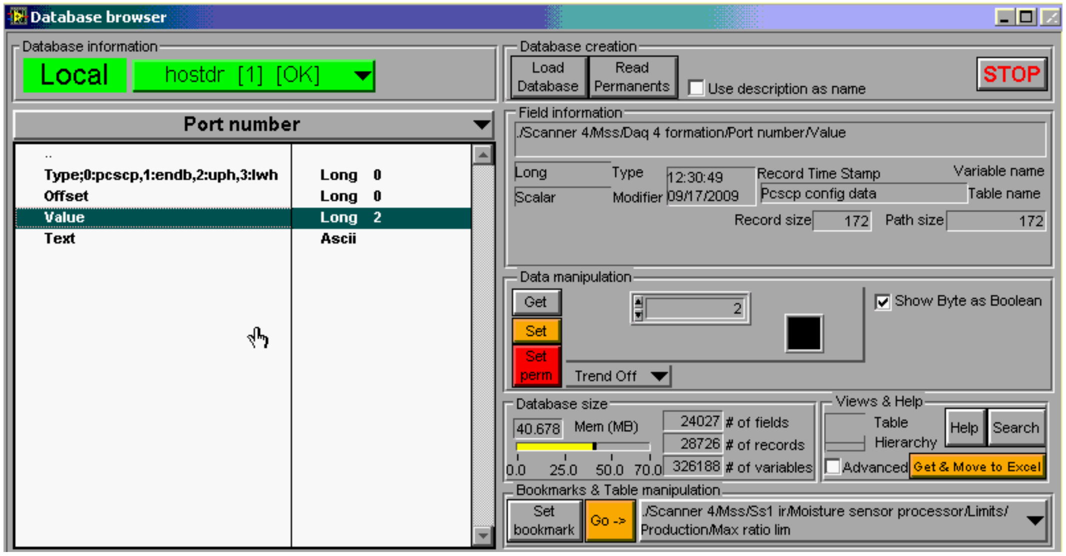


Figure 5-20. RTDR browser, second PCDAQ interface RS port number.

5.4.3.4 Communication parameters

Set the correct port number and card using the MSS Remote.

1. Open MSS Monitor popup from the MSS Setup and Diagnostics display, and click the "MSS Remote" button (Figure 5-21).

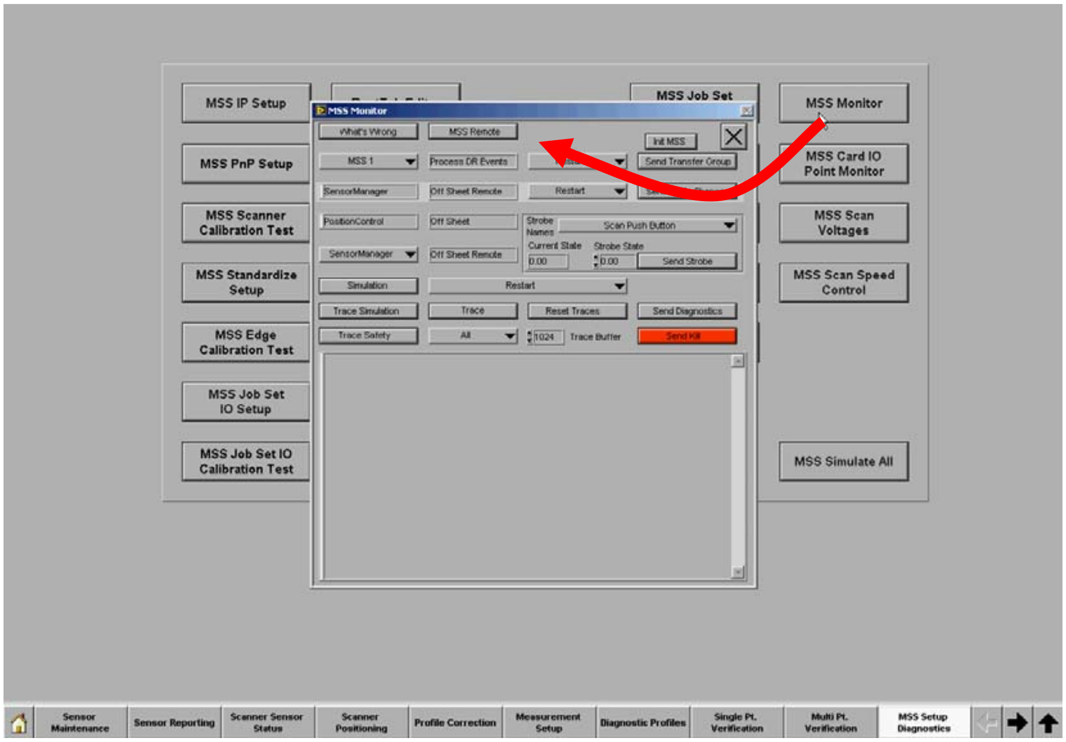


Figure 5-21. Start MSS Remote.

2. The MSS Remote display will open. Check that there are no MSS errors (Figure 5-22).

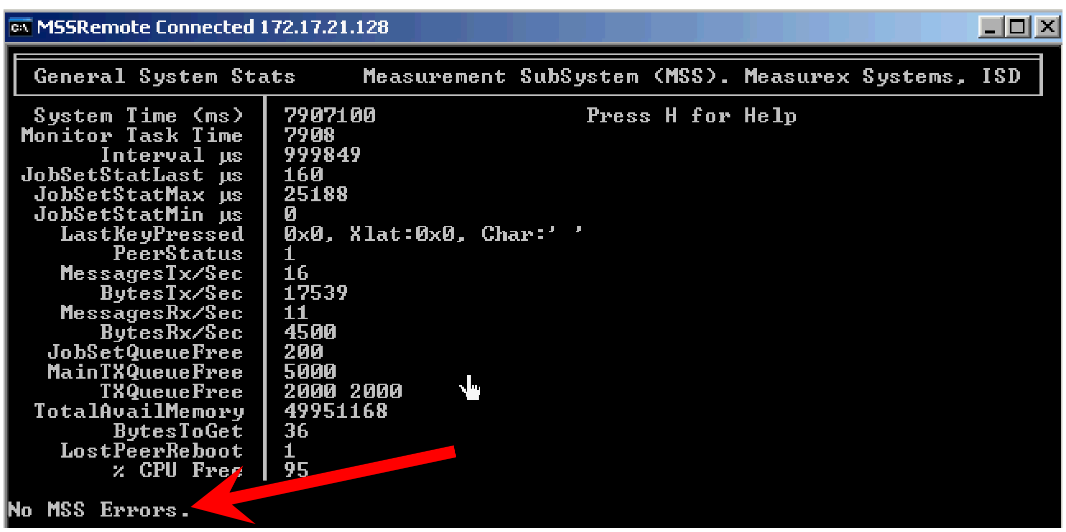


Figure 5-22. MSS Remote display. No MSS errors indicated.

3. Navigate to CARD MONITOR using the "C" key on the keyboard. Help is available by pressing the "H" key.

4. Navigate to the correct sensor (CARD TYPE = Foto Sensor ...) using the UP arrow key.

5. Check that the communication is set for Port #1 (or Port #2 if appropriate).

6. Check that the BoardFound status is YES. See Figure 5-23. There are several other pages of diagnostic information, which can be viewed by using the LEFT/RIGHT arrow keys.

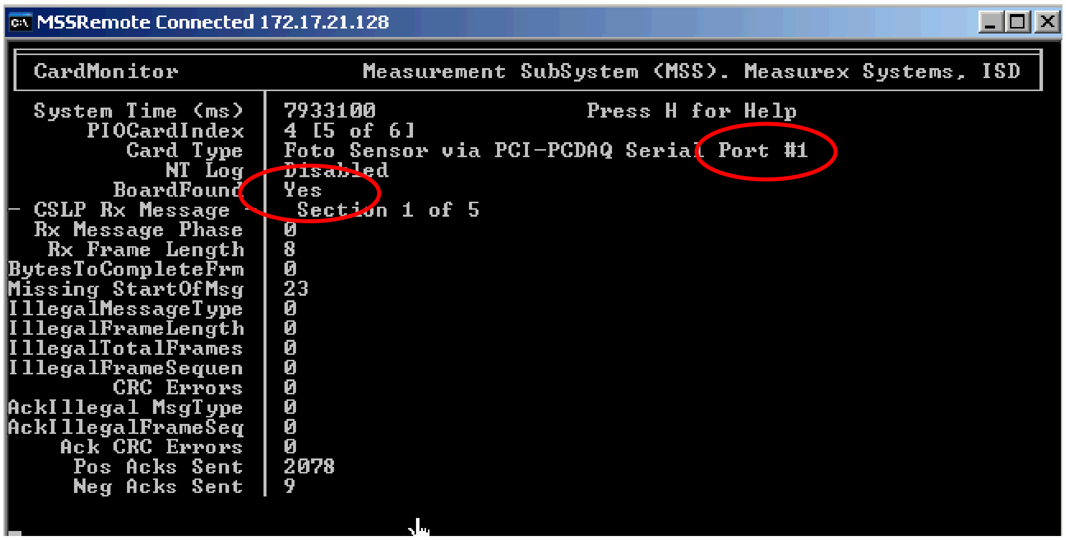


Figure 5-23. MSS Remote, CardMonitor.

7. Navigate to PCI Devices using the "A" key, and locate the communication board for FotoFiber. The list will initially be shown with board #1 at the top. Use the UP/DOWN arrow keys to move this entry to the top of the list, as in Figure 5-24.

8. Record the VendorID and DeviceID values. In Figure 5-24, the VendorID = 10AC, and the DeviceID = 1A00.

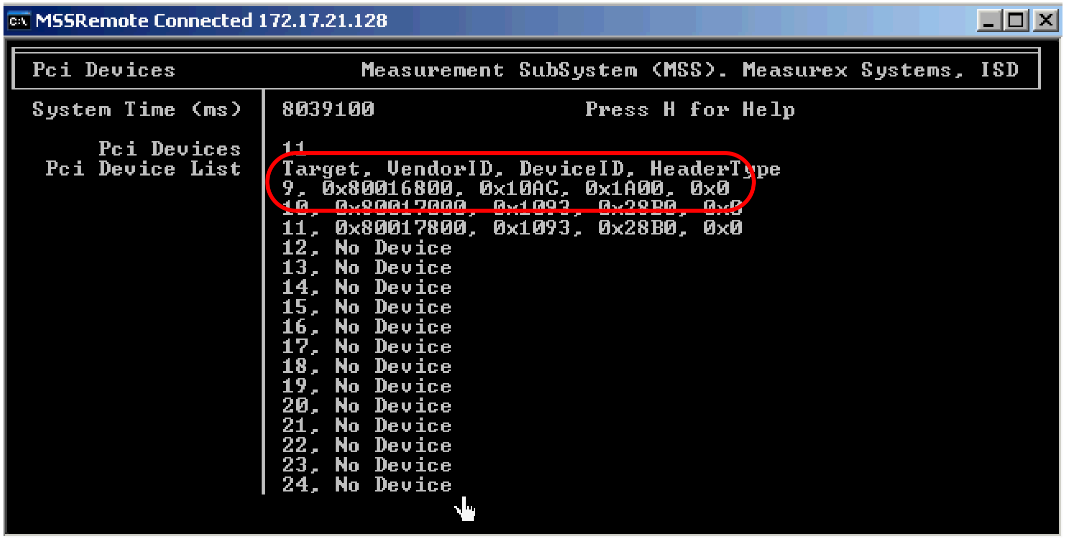


Figure 5-24. MSS Remote, PCI PCDAQ board data.

9. With this card still at the top of the list, use the LEFT/RIGHT arrow keys to change to the screen showing the Device Number (DevNum) for the board, as in Figure 5-25. Make a note of the DevNum value. In Figure 5-25, DevNum = D.

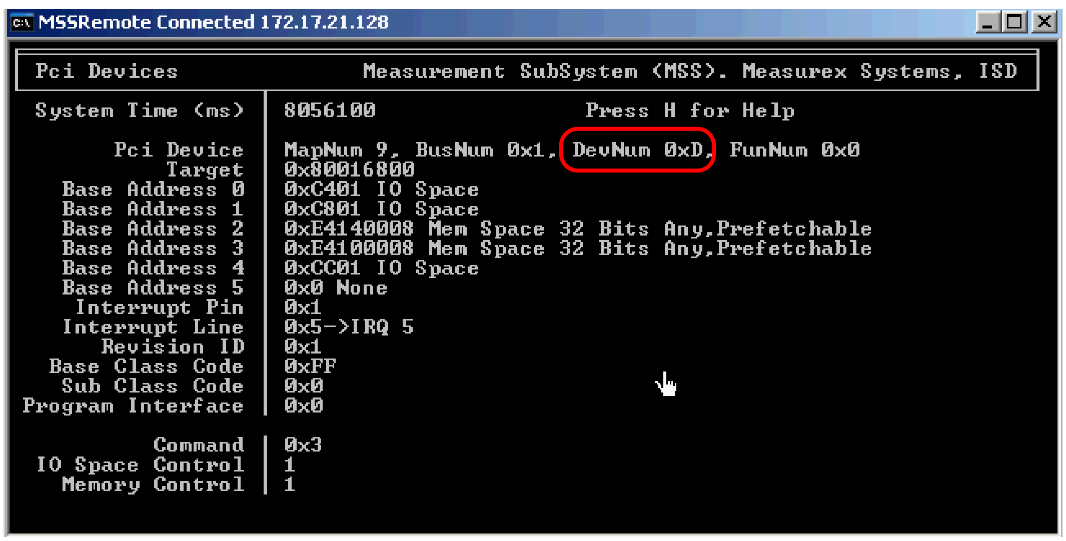


Figure 5-25. MSS Remote, Locating DevNum.

10. Open the MSS PnP Setup popup from the MSS Setup and Diagnostics display.
    Consult the site-specific manuals for the scanner and MSS to help check values for the FotoFiber communication card. Since there are

numerous combinations of hardware and software, it is not possible to cover all possibilities here.

a. Note that the text "formation" may appear for the FotoFiber sensor. If there are several sensors in the same scanner, the order of listing will indicate which communication card name to check.

b. The PCI Slot ID should be the DevNum recorded earlier. In this example, it is D, based on Figure 5-25.

c. The PCI Vendor # should be formed as a catenation of the DeviceID and VendorID. In this example, the catenated value is 1A0010AC, based on Figure 5-24, and there are two FotoFibers connected to the same PCDAQ.

d. Save the setup by clicking the "Save Setup" button.

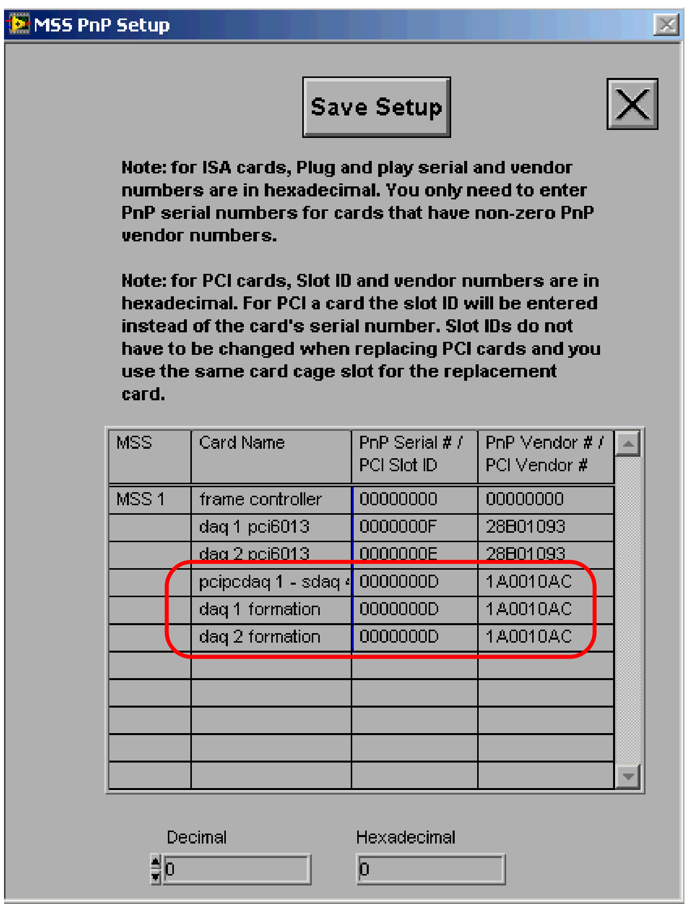


Figure 5-26. MSS PnP Setup.

11. Reboot the MSS.

12. Open the MSS Job Set IO Point Monitor popup from the MSS Setup and Diagnostics display. Select the appropriate MSS and sensor (which may be listed as OptForm), and check that signal values and DIO states look correct, Figure 5-27.

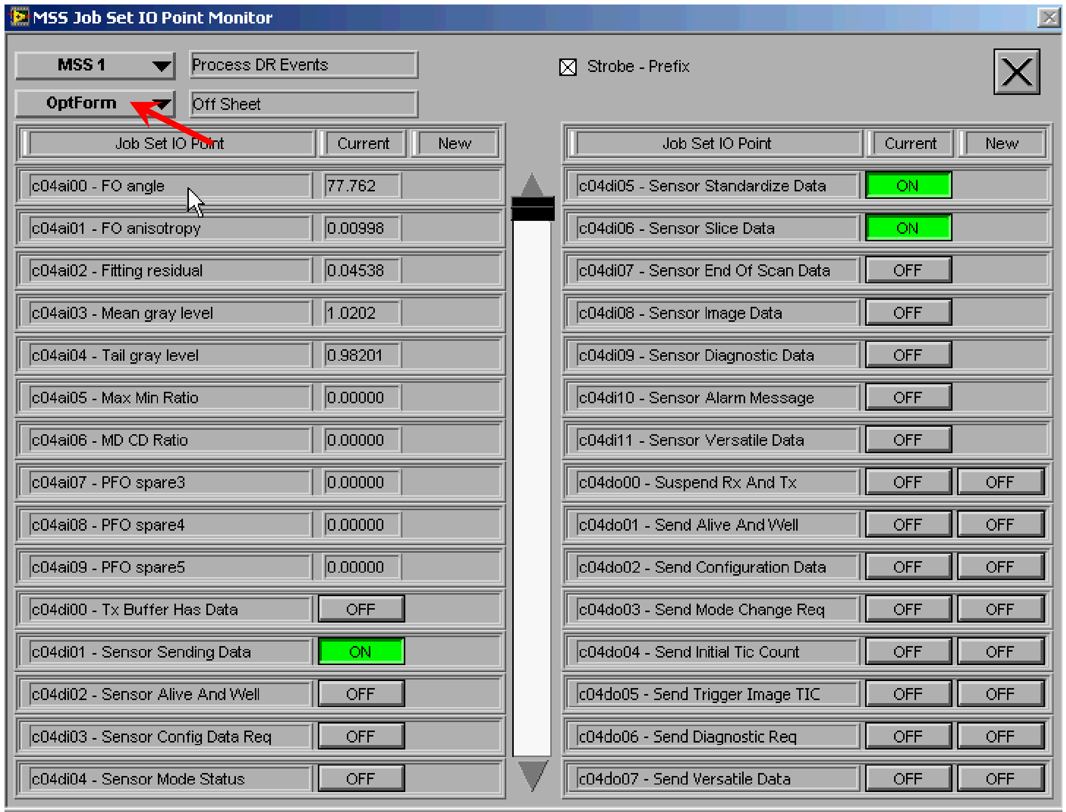


Figure 5-27. Job Set IO Point Monitor.

5.5 Sensor Startup

5.5.1 Sensor communication to Da Vinci

After the FotoFiber is installed and communication has been configured for the MSS, it is necessary to check that the communication is working correctly, and to enable communication if required.

1. Navigate to the Scanner Sensor Status display, and select the correct MSS and FotoFiber sensor (Figure 5-28).

2. The communication software should auto-enable, but if it is not enabled, then manually enabling the sensor should work.

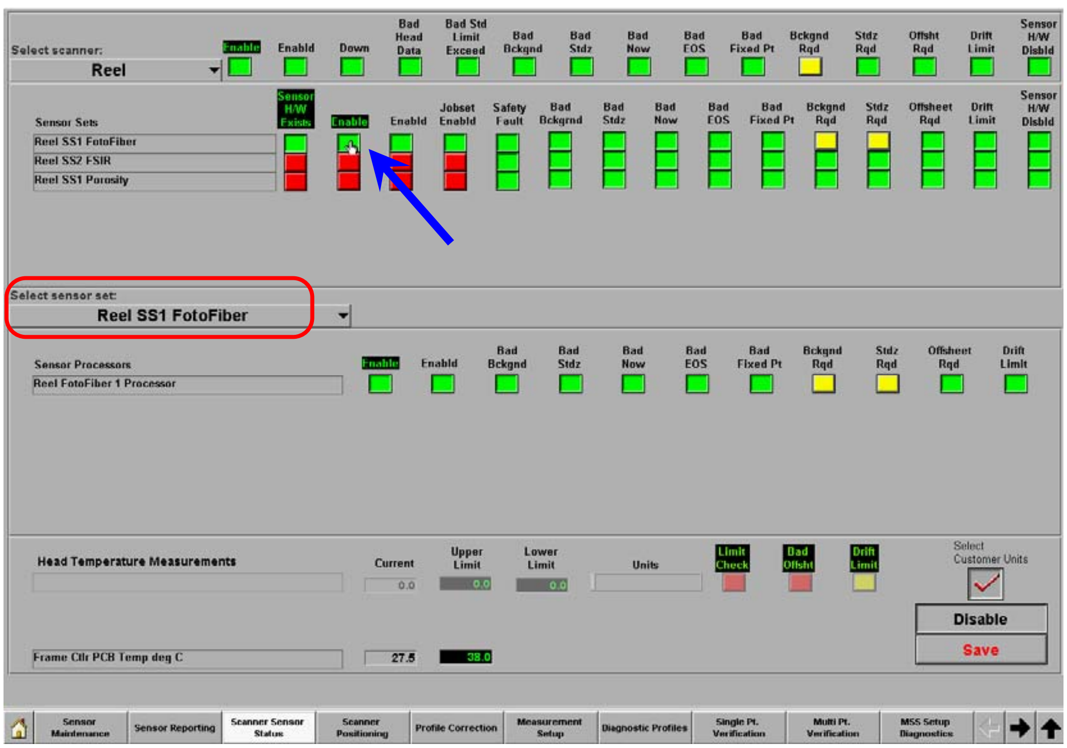


Figure 5-28. Scanner Sensor Status display.

With communication working to the Da Vinci, proceed to post-startup tests.

If communication cannot be enabled (i.e. its status reverts to disabled a few seconds after being enabled), then it is necessary to do some troubleshooting (see §7.4.1.6).

5.5.2 Post-startup checks

The Reference and Sample functions can be used to verify that basic sensor functions are working while the paper machine is shut down. If there are two FotoFibers, the same steps can be repeated for each.

1. Navigate to the Sensor Maintenance display and select the appropriate FotoFiber sensor (see Figure 5-29).

2. Put the scanner in Maintenance Mode (see Figure 5-29). Retrieve a production recipe if necessary.

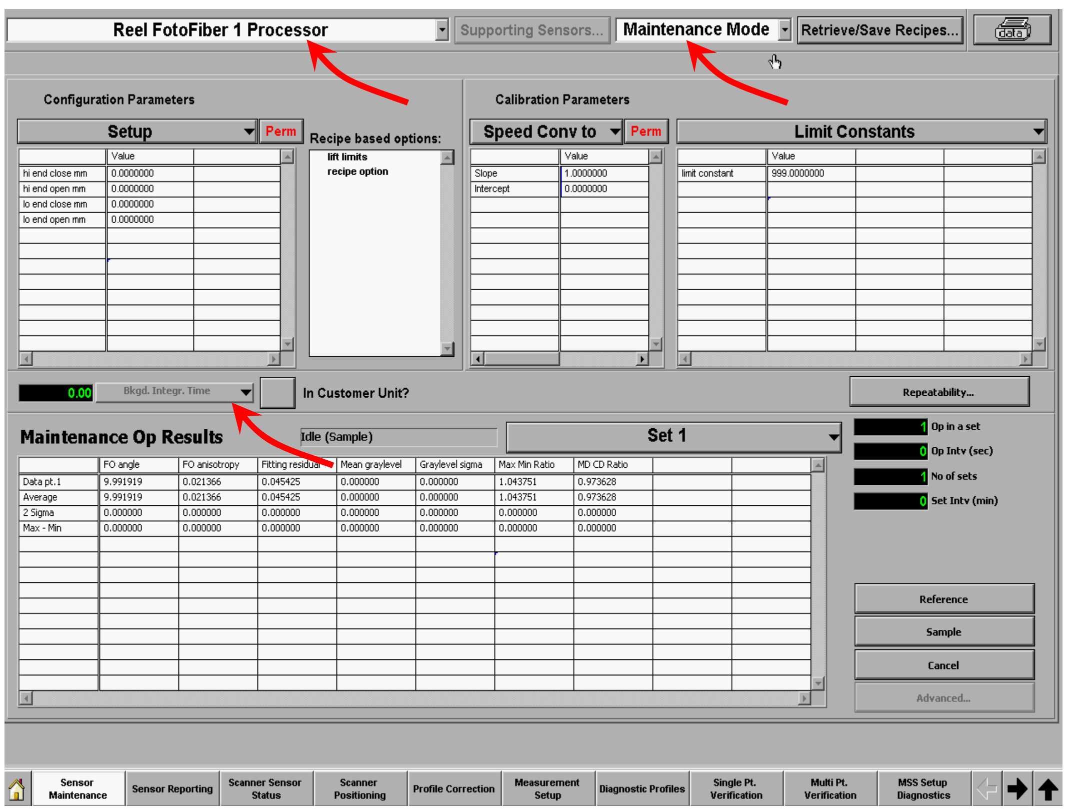


Figure 5-29. FotoFiber in maintenance mode.

3. Using the pull-down list (showing greyed-out Bkgnd. Integr. Time in Figure 5-29), check the Reference integration time and Sample

integration time and update the parameters if needed (see Figure 5-30). These are the same parameters as were set up in §3.2.2.2.

a. Refr. Integr. Time = 40 seconds

b. Sampl. Integr. Time = 40 seconds

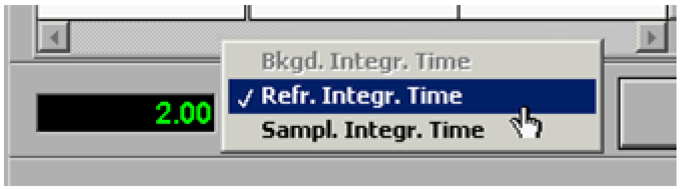


Figure 5-30. Setting integration times for Reference and Sample.

4. Next, insert any plain piece of paper or paperboard into the sensor gap, preferably near white in shade, and without any markings. Then shoot a reference using this material (Figure 5-31).

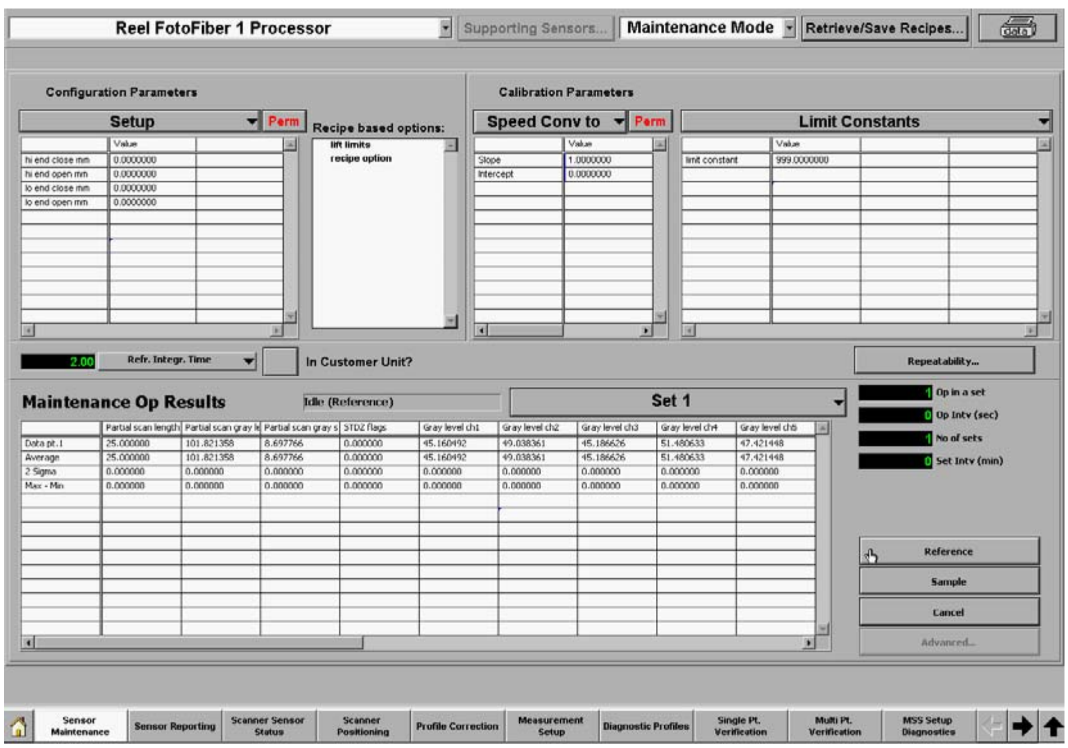


Figure 5-31. Shooting a reference.

5. Inspect the resulting data, some of which is visible in the lower part of Figure 5-31. It may be necessary to scroll the slider sideways to see all of the channel data, as in Figure 5-32. The gray levels should not be markedly different for each channel, and all of the gray

factors should be fairly close to unity. If any channel factor is at or near a limit (range 0.6 to 1.6), or if any channel gray level is less than 15, then the reference should be repeated. If the problem recurs, then maintenance may be needed for the sensor.

	Gray level ch5	Gray level ch6	Gray level ch7	Gray level ch8	Gray factor ch1	Gray factor ch2	Gray factor ch3	Gray factor ch4	Gray factor ch5
Data pt.1	47.421448	46.691605	45.703934	44.205414	0.963710	1.046463	0.964268	1.098580	1.011958
Average	47.421448	46.691605	45.703934	44.205414	0.963710	1.046463	0.964268	1.098580	1.011958
2 Sigma	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Max - Min	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

	Gray factor ch1	Gray factor ch2	Gray factor ch3	Gray factor ch4	Gray factor ch5	Gray factor ch6	Gray factor ch7	Gray factor ch8
Data pt.1	0.963710	1.046463	0.964268	1.098580	1.011958	0.996384	0.975307	0.943329
Average	0.963710	1.046463	0.964268	1.098580	1.011958	0.996384	0.975307	0.943329
2 Sigma	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000
Max - Min	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000	0.000000

Figure 5-32. Typical reference data.

6. Next, insert another piece of paper or paperboard into the measurement gap. It is preferable if a sample with clear directional markings is used for this test. One possibility is to use the area of the Calibration and Focus target which has straight lines (Figure 8-1). Position the area with markings in the sensor gap, and shoot a sample (Figure 5-33). Note the measurement for FO angle.

7. Rotate the patterned sample and shoot it again, keeping the patterned area in the measurement gap. Note the change in the measured FO angle, which should be similar to the angle the sample was rotated by.

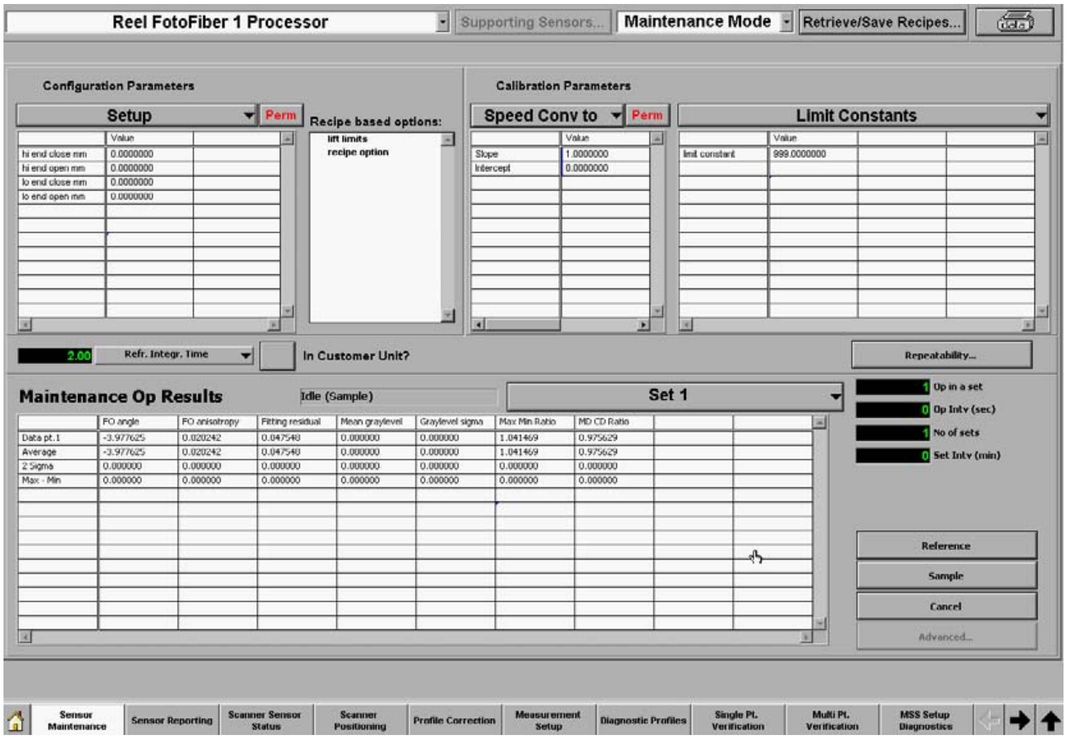


Figure 5-33. Shooting a sample.

Note that the sample integration time can be set to shorter values than the default 40 seconds. However, it should not be set shorter than 5 seconds.

5.6 Removing the Sensor

Removing the sensor from the head is the opposite to installing it. Removal of the sensor is needed for some kinds of service operations, as well as for repair.

First, switch the power off to the sensor, using the switch on the Power and isolation PCB. Immediately afterwards, disconnect the 24V DC power cable from the socket beside the power switch. The CSLP communication cable can then be disconnected from the sensor. Leave the cables inside the head, still connected to the config board, but tie them neatly out of the way.

The hex cap machine screws holding the FotoFiber to the head can then be removed, using a long round-end hex key. These screws should be preserved for later re-installation.

A suitable blank must be inserted into the head to fill the gap, if the scanner is to be operated without the FotoFiber. If the scanner is to be operated with only one sensor from a 2-sided FotoFiber, then the blank must have a support ring or arc which complements the remaining sensor.

6 Maintenance

6.1 Sensor Cleaning

6.1.1 External cleaning

A Lens Pen (p/n 54000353) is supplied with the FotoFiber sensor installation kit, and a replacement can be ordered as a spare part. Always remember to replace the cap on the Lens Pen after each use, and to then give the cap a half turn. Accumulated dust should be shaken off the brush after use, and the brush should then be retracted inside the Lens Pen.

Clean oil-free compressed air should also be available for cleaning the sensor window. If mill compressed air is not available, or is not of suitable quality, then canned air can be obtained from photographic equipment stores or optical suppliers. Optical tissues and lens cleaning fluid should be available in case of need.

Both upper and lower heads should be cleaned, whether the sensor is two-sided (two FOMM units) or single-sided (one FOMM and one FOBM).

6.1.1.1 Lower head sensor

Cleaning a lower head sensor externally involves the following steps:

1. Take the sensor head offsheet for maintenance (set safety interlocks to prevent scanning), and separate the heads.

2. Remove bulk loose material from the sensor and its surroundings using compressed air tangential to the surface.

3. Remove or loosen dust on the window and horseshoe ring using the brush end of the Lens Pen.

4. If there is material adhering strongly to the window or horseshoe (e.g. oil or starch or coating material), then it is necessary to remove it using optical cleaning fluid and tissues.

5. Remove any smears or fingerprints from the window using the pad end of the Lens Pen, which should be rubbed in small circles or a spiral pattern over the window.

6. Inspect the window for scratches; a window with clear scratches should be replaced at the next shutdown.

7. Visually inspect the lens and the inner surface of the window for dirt within the sensor; if necessary a cleaning of the internal surfaces should be performed at the next shutdown.

Cleaning the window of a lower head sensor using a Lens Pen is shown in Figure 6-1. Left: the brush end is swept across the window, horseshoe, and surroundings to remove loose dust. Right: the pad is rubbed across the window with circular or spiral movements, keeping the pad flush against the window. Remember to rotate the cap after putting it back on the Lens Pen.

Figure 6-1. Cleaning a lower head sensor window with a Lens Pen.

6.1.1.2 Upper head sensor

Upper head sensors are less prone to dust accumulation. Cleaning an upper head sensor externally involves the following steps:

1. Take the sensor head offsheet for maintenance (set safety interlocks to prevent scanning), and separate the heads.
2. Remove bulk loose material from the sensor and its surroundings using compressed air tangential to the surface.
3. Remove or loosen dust on the recessed window and the sheet ring or arcs using the brush end of the Lens Pen.
4. Visually inspect the recessed window for strongly adhering dirt; if necessary a cleaning of the recessed window should be performed at the next shutdown.
5. Visually inspect the lens for dirt within the sensor; if necessary a cleaning of the internal surfaces should be performed at the next shutdown.

Using canned air (optical quality, obtainable from photographic equipment shops and optical suppliers) to clean the window and plenum of an upper head sensor is shown in Figure 6-2. Note that an extension tube on the air-can nozzle allows the compressed air to be accurately directed at the surface of the window inside the plenum.

Figure 6-2. Cleaning an upper head window/plenum using canned air.

6.1.1.3 Backing module

Cleaning a backing module involves the following steps:

1. Take the sensor head offsheet for maintenance (set safety interlocks to prevent scanning), and separate the heads.

2. Remove bulk loose material from the backing module and its surroundings using compressed air tangential to the surface.

3. Remove or loosen dust on the FOBM surface and its sheet ring or arcs using the brush end of the Lens Pen.

6.1.2 Internal surfaces

The Lens Pen and clean compressed air can be used if it is necessary to clean internal optical surfaces of the FotoFiber. This is normally unnecessary, but may be needed if the interior of the head is exposed to dust. This could happen, for example, if the environment becomes dusty due to mill operational mishaps or other unexpected incidents while sensor maintenance is being performed.

Dust should be removed from general surfaces inside the head using a vacuum cleaner and/or by blowing with clean compressed air. To clean internal optical surfaces of the FotoFiber, it is necessary to remove the sensor from the head (see §5.5), and bring it to a clean dry environment. Depending on the severity of dirt build-up inside the sensor, it may be necessary to partly disassemble the unit to access optical surfaces.

6.1.2.1 Inner surface of lower head sensor window

The outer surface of the window of a lower sensor can be cleaned as described in §6.1.1.1. To access the inner surface of a lower sensor window for cleaning, follow this procedure, with the sensor in a clean dry environment:

1. Make an alignment mark on the octagonal polymer parts with a felt pen

2. Open the four bolts holding the upper and lower octagonal parts together with a hex key. A small needle-nose pliers may be needed to hold the nuts and prevent them from turning. The processor

module must be swung out on its hinged base to access one of the bolts.

3. Place the nuts and bolts into a container where they will not be affected by strong air flows

4. Gently separate the upper and lower parts of the sensor. Hold only the stronger parts of the sensor - do not apply any force to the connectors or components on the small circuit boards (LED driver PCBs p/n 20100080)

The inner surface of the window can be accessed via the plenum. When cleaning with compressed air and the brush end of the Lens Pen, be sure to remove any dust adhering to the ring clip above the window. Finally, use the pad end of the Lens Pen to remove any spears from the window.

Reassembly is the reverse of the disassembly procedure. Ensure that the marks made on the octagonal polymer parts are aligned.

After the sensor is replaced in the head, it is advisable to clean the outer surface of the sensor window, to remove smears or finger prints from handling.

6.1.2.2 Either surface of upper head sensor window

The window of an upper sensor is recessed above the open plenum. The outer surface of the window on an upper sensor may require cleaning from time to time. To remove the inner window from an upper sensor for cleaning, follow the following steps (refer also to Figure 5-2 in §5.2.1.1):

1. Make an alignment mark on both polymer octagons parts with a felt pen.

2. Open the four bolts holding the upper and lower octagonal parts together with a hex key. The bolts are in the protruding corners of the polymer octagons. A small needle-nose pliers may be needed to hold the nuts and prevent them from turning.

3. Place the nuts and bolts into a container where they will not be affected by strong air flows.

4. Gently separate the upper and lower parts of the sensor. Hold only the stronger parts of the sensor - do not apply any force to the

connectors or components on the small circuit boards (LED driver PCBs p/n 20100080).

5. With the lower part of the sensor on a clean flat surface, pry the window free from the holder. A flat-head screwdriver may be used for this. See Figure 6-3.

Clean the window first with optical-quality compressed air directed across one surface, then the other surface. Next, use the brush end of the Lens Pen to remove any remaining particles from both surfaces of the window. Finally, use the pad end of the Lens Pen to remove smears from each surface, including any finger prints left from handling the window (hold the window only by its edges for this step.)

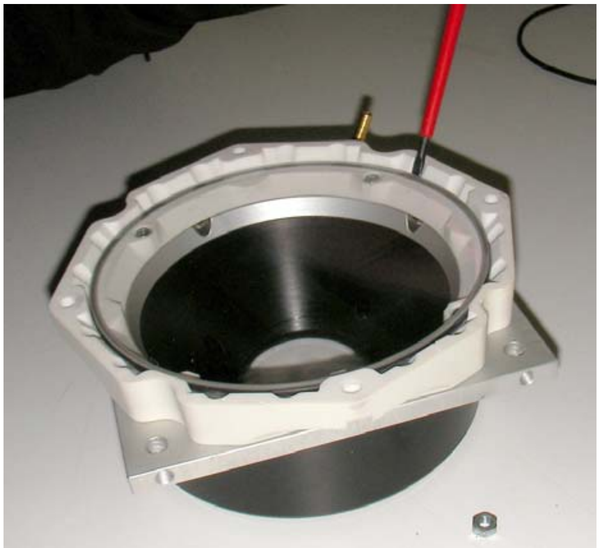


Figure 6-3. Removing upper sensor window for cleaning.

Reassembly is the reverse of the disassembly procedure. Ensure that the marks made on the octagonal polymer parts are aligned when the polymer octagons are joined.

When attaching the nuts onto the bolts to hold the upper and lower polymer octagons together, a thread locking compound should be applied (p/n 16000235).

6.1.2.3 Lens

If a significant amount of dust enters the scanner head, cleaning the lens may also be required. To access the lens for cleaning, it is necessary to remove the camera and lens from the sensor, following this procedure:

1. Record the rotational position of the camera positioning knob. Preserve the positioning knob in the recorded position throughout the entire operation (otherwise, refocusing of the sensor will be needed, as described in §6.2.2).

2. Release the clip and swing the Processor Module outwards on its hinged plate (see) to gain access to the camera stand.

3. Remove the trigger cable and the IEEE1394 communication cable from the camera, but leave them attached to the processor module.

4. Using a hex key, remove the screws holding the camera to its bracket, and place the camera and lens on a clean surface. Hold the camera carefully when removing the last screw, to prevent it falling.

5. Place the screws in a container where they will not be affected by strong air flows.

Note: it may be advantageous to have the sensor on its side on a suitable surface for step 4, since there is less risk of the camera, lens, or screws falling. However, care should be taken to prevent undue loads on connectors or circuit boards, so it is advisable to provide a soft surface, such as a clean folded towel or foam.

There is no need to separate the lens from the camera. Do not use compressed air on the surface of the lens. The camera lens should be cleaned with the brush end of the Lens Pen to remove dust, then with the pad end of the Lens Pen to remove smears.

Reassembly is the reverse of the disassembly procedure. Ensure that the marks made on the octagonal polymer parts are aligned.

6.2 Focusing and Calibration

Focusing and calibrating the sensor are Honeywell service operations. They should not be required in normal operation of the sensor.

These procedures require a PC or laptop with an Ethernet connector and FotoFiber diagnostic software (see Appendices), as well as the FotoFiber focus & calibration target (p/n 08773300), depicted in Figure 8-1 in the Appendix.

6.2.1 Setup for maintenance procedures

The focusing procedure can be performed with the sensor in the scanner head (provided there is either a FOBM or a second FOMM opposite it), or on a clean flat surface. However, it is strongly recommended that illuminator calibration be performed with the sensor outside the head, on a bench in a clean workspace.

6.2.1.1 Setup on bench

If performed on a bench, an external power supply must be available to provide at least 1.5A of clean 24V DC. This must have a suitable connector for connecting to the FotoFiber.

Connector type: Molex Mini-Fit Jr Crimp Power Connector, 5559 Panel Mount Plug. Manufacturer part no: 39-01-2021

Pin	**FOMM power supply**
1	+24 VDC
2	24 VDC GND

Note that Pin 1 on the socket is the pin closer to the PCB.

The external power polarity should be verified before proceeding. With the sensor power switch in the OFF position, the USER1 DIP switch should be set to ON. The other DIP switches should be OFF. The power connector should be plugged into the 24V input socket on the power and isolation PCB (socket closest to power switch, see Figure 4-1).

A PC or laptop with the Intelligent Sensors FotoFiber diagnostic software should be connected using a standard cat5 or cat6 ethernet cable to the

Ethernet port on the processor module. The PC should have IP address 169.254.100.100 for the wired ethernet port, and **all other network interfaces MUST be disabled**. The Intelligent Sensors software should be started, and then the FotoFiber should be powered ON.

The FotoFiber sensor will boot *twice* (this takes a minute or so), during which time the Intelligent Sensors package will indicate "busy", as in Figure 6-4, upper. There may be a further delay of up to a minute for the PC and the FotoFiber to establish communication and set up shared data structures over the network. After communication is fully established, the status will change to "ready", as in Figure 6-4, lower.

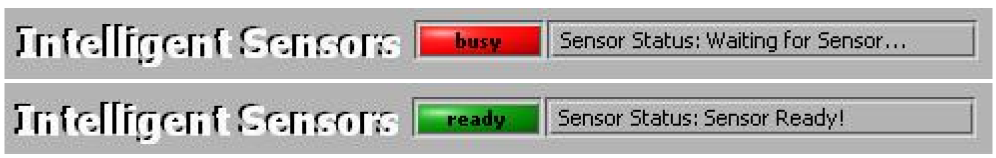


Figure 6-4. PC software waiting for communication (top), and after communication is established (bottom).

ATTENTION Do not start any procedures or click any menu items until the status is "ready". Starting any procedure before the status is "ready" will cause the PC and the FotoFiber to become uncoordinated.

6.2.1.2 Setup in head

If performed within the scanner head, the sensor should be powered OFF using its switch, and the USER1 DIP switch on the processor module should be set to ON. The other DIP switches should be OFF.

A PC or laptop with the Intelligent Sensors FotoFiber diagnostic software should be connected using a standard cat5 or cat6 ethernet cable to the Ethernet port on the processor module. The Intelligent Sensors software should be started, and then the FotoFiber should be powered ON.

The FotoFiber sensor will boot *twice* (this takes a minute or so), during which time the Intelligent Sensors package will indicate "busy" status. After communication is established, the status will change to "ready", as in Figure 6-4.

ATTENTION Do not start any procedures or click any menu items until the status is "ready". Starting any procedure before the status is "ready" will cause the PC and the FotoFiber to become uncoordinated.

6.2.2 Focusing procedure

Focusing is needed if the camera, lens, or their mounting unit is replaced. The procedure is:

- Set-up the sensor for focusing
- Start imaging and center the target
- Use the focusing wizard

6.2.2.1 Setup for focusing

Focusing can be performed with the sensor in the head, as in Figure 6-5 left, or on a bench, as in Figure 6-5 right. The corresponding setup procedure in §6.2.1 should be followed.

A focusing target rosette pattern should be approximately centered in the image, then the assisted focusing test can be used.

For focusing with the sensor outside the head, the FotoFiber focus & calibration target (p/n 08773300) should be placed on the bench with the printed side facing up, and the FotoFiber should be placed on top of it, above the group of rosette patterns. For focusing with the sensor in the head, the FotoFiber focus & calibration target (p/n 08773300) should be inserted into the sensor gap, with the printed side facing the sensor to be focused, and positioned so that the rosette patterns are approximately in the sensor's measurement area.

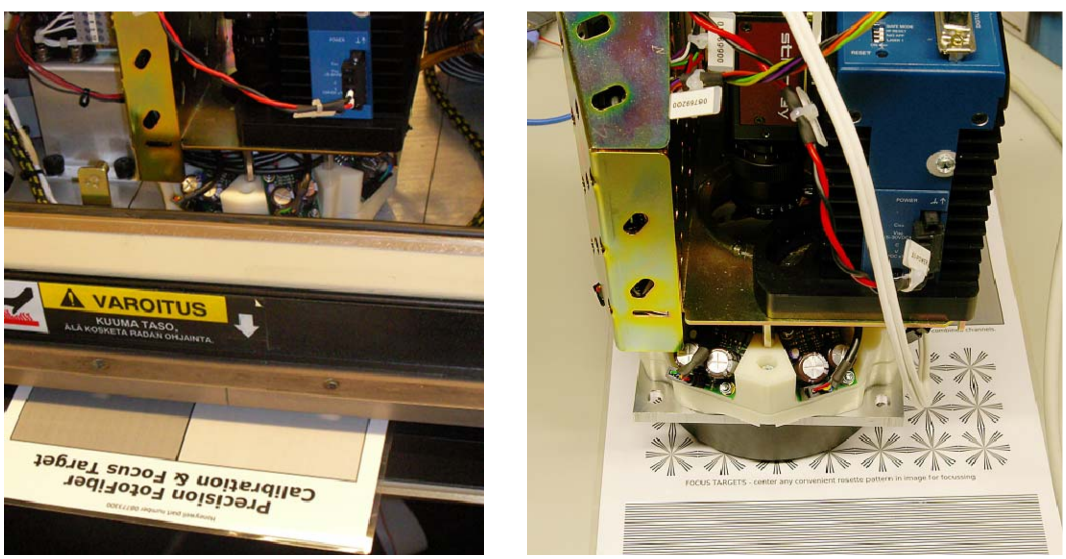


Figure 6-5. Positioning the focus target.

6.2.2.2 Start imaging and center the target

On the PC software, the "Operate PP880 and camera" item should be selected from the "Fiber Orientation" menu. To start the image acquisition, click the "Change Settings" button on the Camera tab.

Figure 6-6. Camera setup.

The imaging will initially have default strobe parameters, and the image is likely to be too dark to discern properly. On the Strobe tab of the display, verify that the Equalize Channels indicator is ON (yellow), and that the other eight indicators are also ON. If any is OFF (dark gray), switch it ON by clicking on its indicator. Verify also that the Pulse duration is about 0.5µs (the default value). See Figure 6-7.

Next set a value such as 300 or 400 in the Equalize Channels databox, and click the "Set Levels" button, and the "Set Mask" button. Commands are communicated slowly, so it may be necessary to wait a few seconds between these clicks, or to click the buttons again after a short wait.

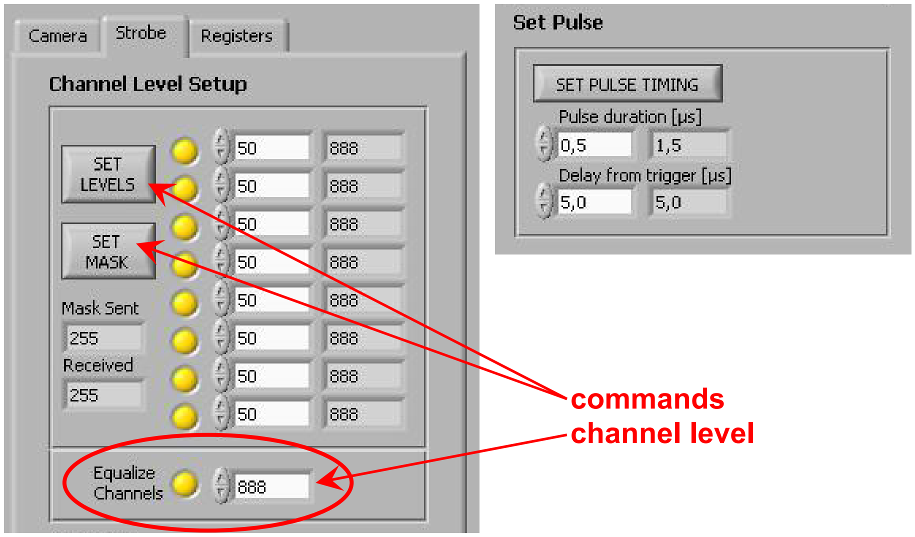


Figure 6-7. Strobe parameter adjustment.

The image should now be bright enough to see properly. If desired, the level can be adjusted again, but it is not necessary to optimize the image brightness. Move the focus & calibration target until a rosette is nearly centered in the image. Note that the direction of movement in the image may differ from the direction of movement of the target.

ATTENTION Click the "Close Test" menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

6.2.2.3 Focusing wizard

After closing the "Operate PP880 and Camera" procedure, select the "Focusing Wizard" procedure from the FiberOrientation menu.

The strobe pulse strength will be automatically adjusted, taking a few seconds. The image shown may vary from very bright to very dark during this step.

When the image is shown with a focus rating scale, it is ready for focus adjustments. First, click the "reset" button, then turn the focus knob until the image of the rosette is quite blurred (see Figure 6-8 and Figure 6-9 left).

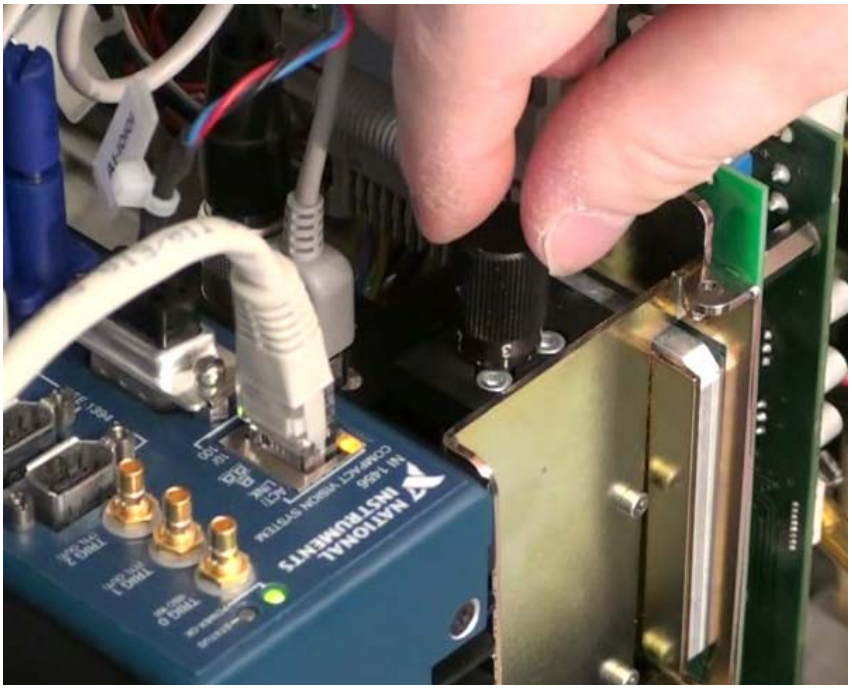


Figure 6-8. Using the focusing knob.

Turn the focus knob the other way, and watch both the indicator dial (when the image is in focus, the indicator value will be 100) and the center of the pattern in the image. When the image is well focused, the rectangular array of nine dots at the center of the rosette should be clearly discernible. See Figure 6-9, right.

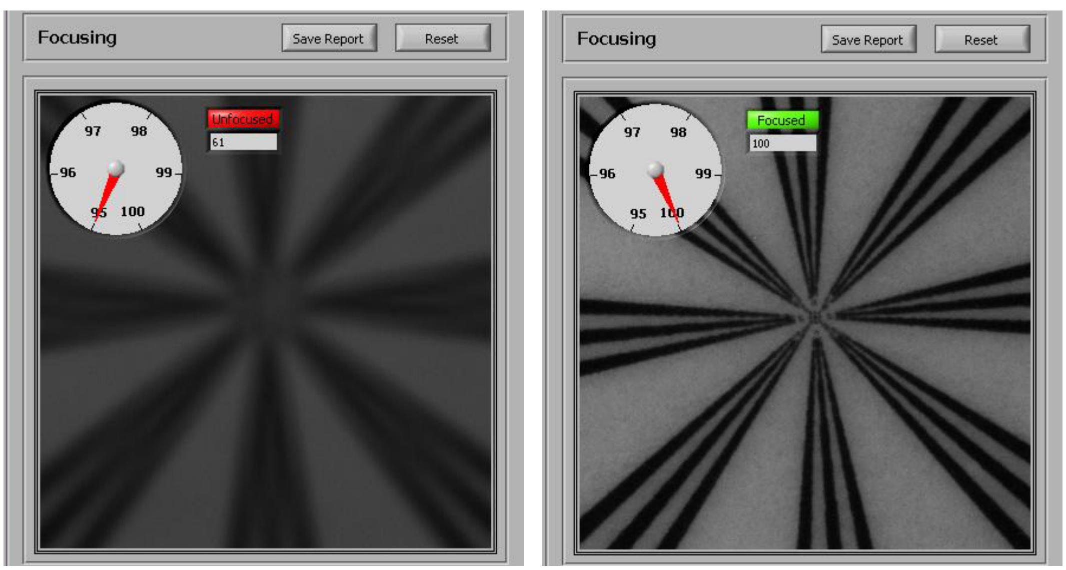


Figure 6-9. Focus wizard. Left: badly unfocused. Right: well focused.

When the focus is good enough, the "Save Report" button can be clicked to record the final image. This step is required if the focus procedure was performed in conjunction with the illuminator calibration procedures in §6.2.3. Note that clicking the "Save Report" will save the image exactly as it appears at that time.

ATTENTION Click the "Close Test" menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

6.2.3 Illuminator Calibration

Illuminator calibration is a Honeywell service operation. It is needed if any illuminator component is replaced (LED panel or LED driver PCB). It may also be performed occasionally to compensate for changes in component performance with age. Illuminator calibration involves testing of **all** illuminator channels, even if components were replaced in only one channel. The procedure is:

- Set-up the sensor for illuminator calibration
- Calibrate combined illuminators
- Calibrate individual illuminators
- Re-focus sensor, and update parameters in Da Vinci

Calibrating the illuminators requires a PC or laptop with an Ethernet connector and FotoFiber diagnostic software, as well as the FotoFiber focus & calibration target (p/n 08773300).

6.2.3.1 Setup for illuminator calibration

It is strongly recommended that illuminator calibration be performed with the sensor outside the head. It is ideally performed in a clean workspace which is not subject to large or sudden variations in lighting (i.e. no flashing light sources nearby).

The testing environment should be prepared as for focusing, including a suitable 24V DC power supply and power cable, and a suitable PC with Ethernet cable and Intelligent Sensors software as described in §6.2.1.1. The USER1 DIP switch should be set to ON in the FotoFiber.

Start the Intelligent Sensors software and power on the FotoFiber, then wait until communication has been established with the sensor (see Figure 6-4). Start imaging and center a focus target as in §6.2.2.2, then defocus the image by turning the focus knob several times. Ideally, the resulting image of the rosette pattern would be quite blurred, as in Figure 6-9, left.

ATTENTION Click the "Close Test" menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

6.2.3.2 Calibrate combined illuminators

In this procedure, the medium gray (30% gray) area of the Calibration and focus target should be positioned beneath the sensor, as shown in Figure 6-10. The target and sensor should not be moved while the test is in progress.

It is recommended also that the ambient lighting should not be changed significantly during the test, and that no other strobe or flashing lights be nearby. If this is not possible, the sensor should be shielded from flashing lights, such as by placing a curtain or other barrier between the FotoFiber and the flashing light.

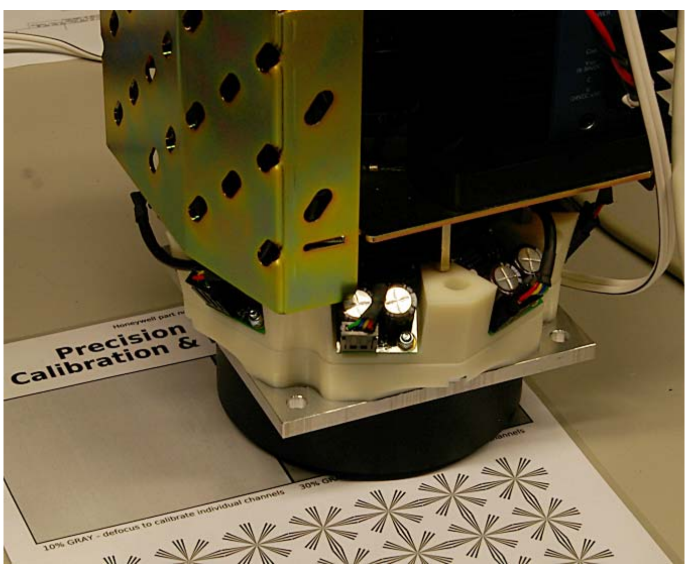


Figure 6-10. Sensor position for calibrating all combined illuminators.

all illuminator channels receive pulses of the same amplitude and duration, and the gray level is measured by the camera.

The "Calibrate all combined channels" procedure should be selected from the FiberOrientation menu. The default directory used for saving data is C:\Calibrate\00000000 which is reserved for factory use. This directory name must be changed before data resulting from the test is saved, and it is recommended that it be changed before starting the test.

Click the "Initialize" button. The graphs should all receive zero curves. Note that it is possible to view data from previously saved calibrations by entering the corresponding directory name and clicking the "Load Files" button. If previous calibration data is loaded, it is recommended that the "Initialize" button be clicked again before starting the test.

ATTENTION The date of calibration should be used as the subdirectory name instead of 00000000. **The date must be in the form yyyymmdd**, as shown in Figure 6-11 for a calibration performed on 28 August 2009. The same directory name must be used for both the Calibrate all individual channels procedure and the Calibrate all combined channels procedure. Deviation from these guidelines is likely to result in sensor malfunction.

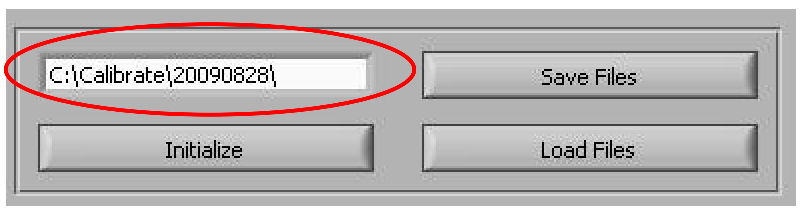


Figure 6-11. Use date of calibration as subdirectory name.

Next, click the "Start Test" button. The LEDs in the sensor should now start a sequence of flashes at varying durations and amplitudes. A green indicator will appear on the Start button, and the currently active pulse length will be shown beneath, as in Figure 6-12. A live image and histogram will also be periodically updated on the display (shown on right side of Figure 6-13).

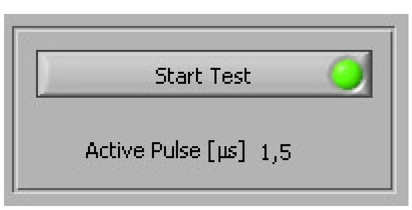


Figure 6-12. All combined channels: test active with pulse length progress information.

The test takes between 10 and 15 minutes to complete, depending on the sensor configuration. The green indicator will vanish from the Start button when the test is complete, and the measured curves will appear in the graphs, as in Figure 6-13.

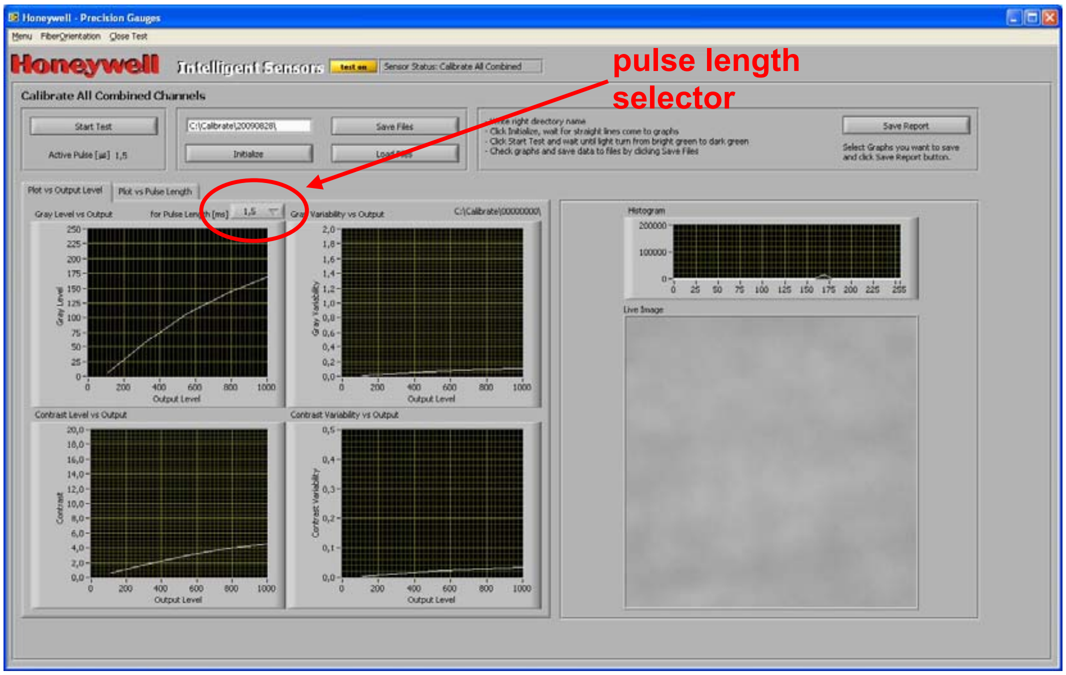


Figure 6-13. Calibrate all combined channels, test finished. Plots vs. output level.

The plots on the “Plot vs. Output Level” tab should be inspected, Figure 6-13. For each pulse length: the Gray Level (upper left) curve should be smoothly increasing with output level, and the Gray Variability (upper center) curve should not have any large spikes upward. For the maximum pulse length, the Gray Level maximum should be between 100 and 250.

The plots on the “Plot vs. Pulse Length” tab should also be inspected, Figure 6-14 (it’s the same data as in Figure 6-13, viewed on different axes). For each output level: the Gray Level (upper left) curve should be linearly increasing with pulse length for each output level, and the Gray Variability curve should not have any large upward spikes.

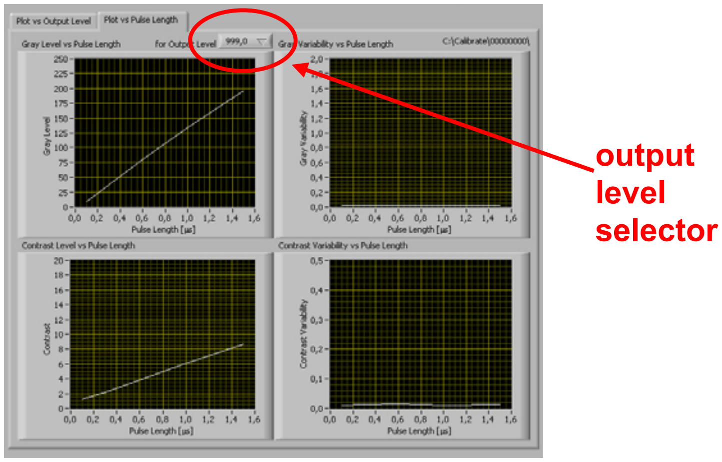


Figure 6-14. All combined channels. Plots vs. pulse length.

If these criteria are met, the data can be saved by clicking the “Save Files” button. Otherwise, the test should be repeated. The result graphs should also be saved by clicking the “Save Report” button in the upper right.

Note that clicking the “Save Report” will save the block of four plots exactly as they appear at that time. If the calibration was accepted, it is recommended to select a high output level and a long pulse length on the respective tabs, as these tend to be the most informative plots. If the calibration was not acceptable, then select the output level and pulse length which most clearly show the reason for not accepting the result. This may be useful if TAC support is needed.

ATTENTION Click the “Close Test” menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

6.2.3.3 Calibrate individual illuminators

In this procedure, the light gray (10% gray) area of the Calibration and focus target should be positioned beneath the sensor, as shown in Figure 6-15. The target and sensor should not be moved while the test is in progress. It is recommended also that the ambient lighting should not be changed significantly during the test, and that no other strobe or flashing lights be nearby.

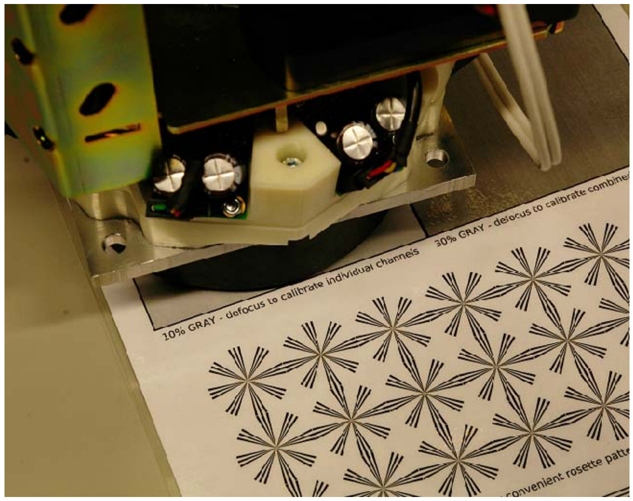


Figure 6-15. Sensor position for calibrating all individual illuminators.

The “Calibrate all individual channels” procedure should be selected from the FiberOrientation menu. The default directory used for saving data is C:\Calibrate\00000000 which is reserved for factory use. This directory name must be changed before data resulting from the test is saved, and it is recommended that it be changed before starting the test.

Click the “Initialize” button. The graphs should all receive zero curves. Note that it is possible to view data from previously saved calibrations by entering the corresponding directory name and clicking the “Load Files” button. If previous calibration data is loaded, it is recommended that the “Initialize” button be clicked again before starting the test.

ATTENTION The date of calibration should be used as the subdirectory name instead of 00000000. **The date must be in the form yyyymmdd**, as shown in Figure 6-11 for a calibration performed on 28 August 2009. The same directory name must be used for both the Calibrate all individual channels procedure and the Calibrate all combined channels procedure. Deviation from these guidelines is likely to result in sensor malfunction.

Click the “Initialize” button. The graphs should all receive zero curves. Next, click the “Start Test” button. The LEDs in the sensor should now start a sequence of flashes at varying durations and amplitudes. A green indicator will appear on the Start button, and the currently active channel number and pulse length will be shown beneath, as in Figure 6-16. A live image and histogram will also be periodically updated on the display (shown on right side of Figure 6-17).

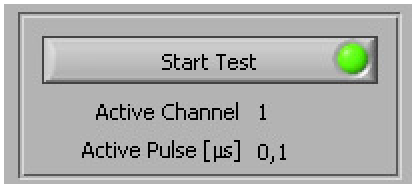


Figure 6-16. All individual channels: test active with channel and pulse length progress information.

The test takes between 35 and 50 minutes to complete, depending on the sensor configuration. The green indicator will vanish from the Start button when the test is complete, and the measured curves will appear in the graphs, as in Figure 6-17.

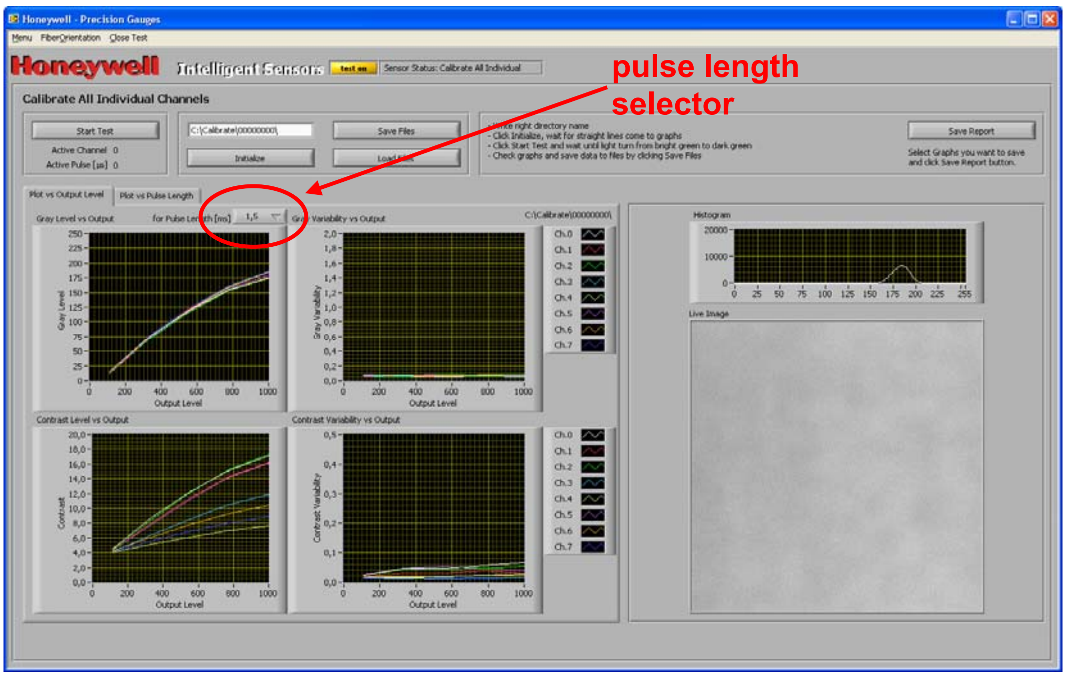


Figure 6-17. Calibrate all individual channels, test finished. Plots vs. output level.

The plots on the “Plot vs. Output Level” tab should be inspected, Figure 6-17. For each pulse length, the Gray Level curve (upper left plot) for each channel should be smoothly increasing with output level, and all eight curves should be fairly close together. For the maximum pulse length, the Gray Level maxima should all be between 100 and 250. For each pulse length, the Gray Variability curve (upper center plot) for each channel should not have any large spikes upward.

The plots on the “Plot vs. Pulse Length” tab should also be inspected, Figure 6-18 (this is the same data as in Figure 6-17, viewed on different axes). For each output level, the Gray Level curve (upper left plot) for each channel should be linearly increasing with pulse length, and all eight curves should be fairly close together. For each output level, the Gray Variability curves should not have any large upward spikes.

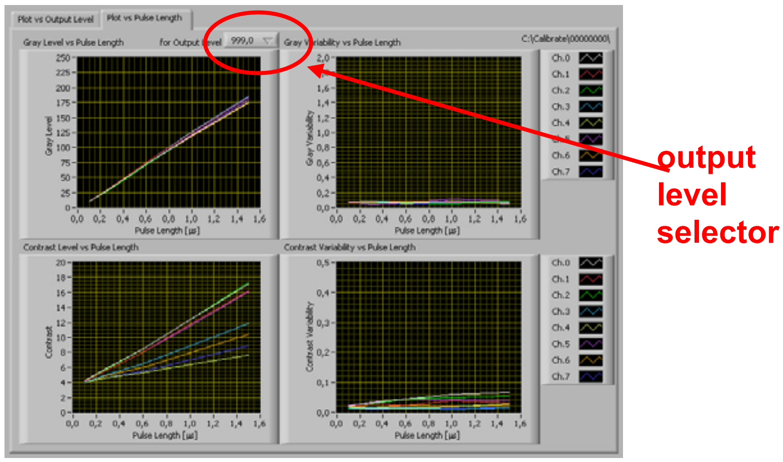


Figure 6-18. All individual channels. Plots vs. pulse length.

If these criteria are met, the data can be saved by clicking the “Save Files” button. Otherwise, the test should be repeated. The result graphs should also be saved for reporting by clicking the “Save Report” button in the upper right of the display in Figure 6-17.

Note that clicking the “Save Report” will save the block of four plots exactly as they were most recently viewed. If the calibration was accepted, it is recommended to select a high output level and a long pulse length on the respective tabs, as these tend to be the most informative plots.

If the calibration was not acceptable, even after repeated calibration attempts, then select the output level and pulse length which most clearly show the reason for not accepting the result before generating a report. It may be useful to send this report to QCS-TAC when requesting assistance.

ATTENTION Click the “Close Test” menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

6.2.3.4 Refocus the FotoFiber, enable the new calibration

When the calibration procedures are complete, the camera should be focused again, following the procedure in §6.2.2. Remember to save the focus report also. The USER1 DIP switch should then be switched OFF.

If the calibration data was acceptable in both tests (individual illuminators and combined illuminators) and was saved into the same directory, then it can be taken into use in FotoFiber operation. To do this, the year and date used to form the subdirectory name must be entered into parameters #17 and #18 respectively on the FotoFiber Engineering display (see §3.3.4), and sent to the sensor.

6.2.4 Report builder

The procedures for focusing (§6.2.2.3), and for calibration of illuminators (§6.2.3.2 and §6.2.3.3) have "Save Report" buttons, which should be clicked at the end of each of these procedures.

Starting the "Report Builder" procedure on the FiberOrientation menu gives a display with the fields shown in Figure 6-19. The sensor serial number or other sensor identifier (e.g. specify mill, scanner, upper/lower sensor) should be entered into the text box. The test results to include are specified with the radio buttons on the right. Note that only the calibration and focusing tests are supported for FotoFiber.

Clicking the "Build and Save Report" button puts the saved images from the selected procedures into a single html file. This can then be viewed in a browser. Preferably, whenever the calibration is changed or the sensor id refocused, the appropriate report should be generated. A printed copy of the report can be included with other sensor calibration reports on site.

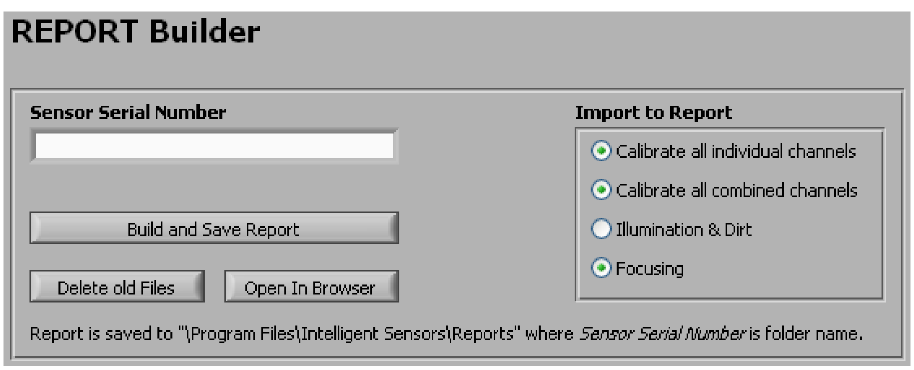


Figure 6-19. Calibration report builder setup.

A sample calibration report is shown in Figure 6-20. , containing a focus check image as well as acceptable illuminator calibration curves.

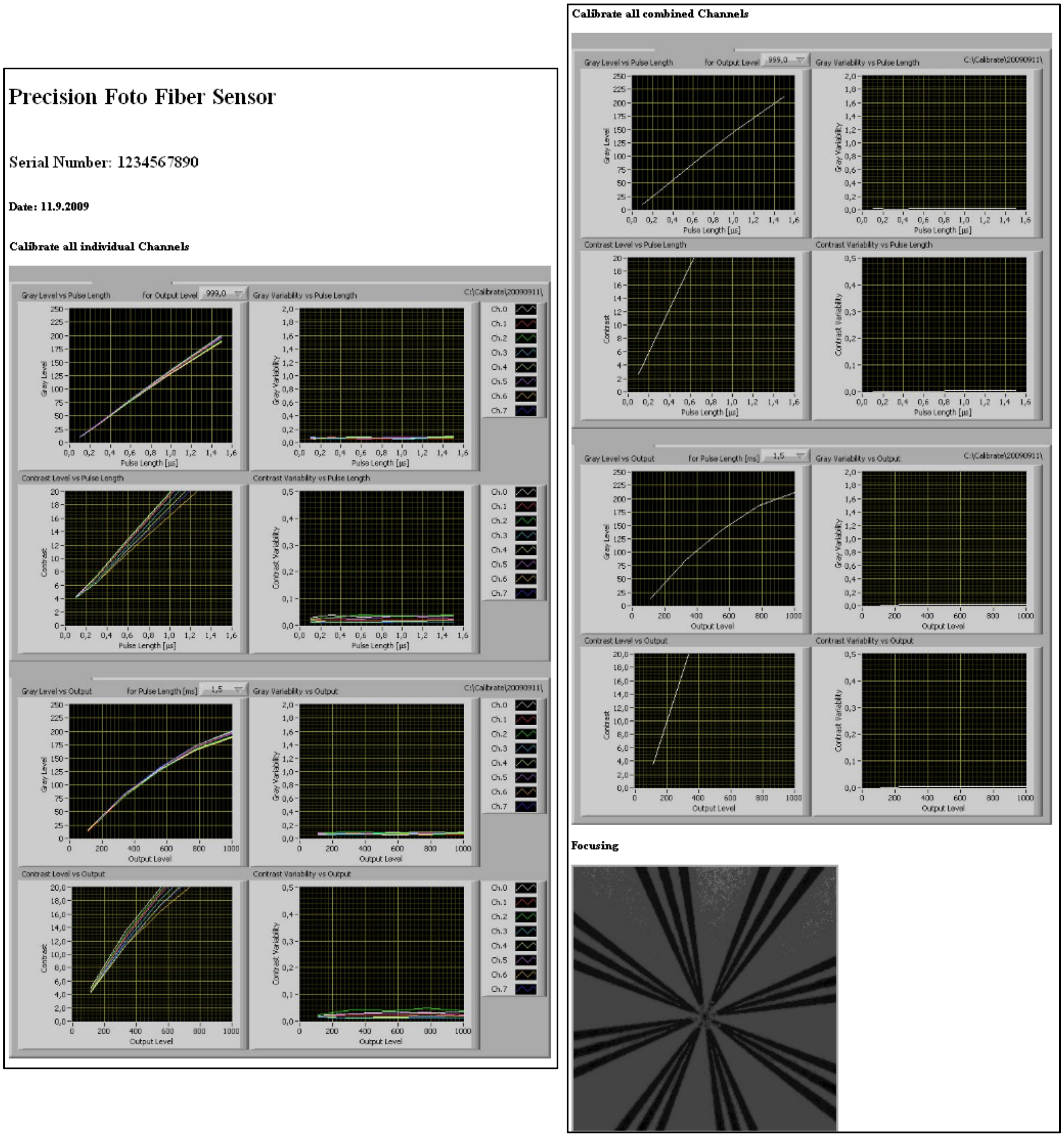


Figure 6-20. Sample calibration report, split into two pages.

The files saved by the test procedures are created in a temporary directory. After the report is built, these files can be deleted by clicking the “Delete old Files” button. Do not delete the files until *after* the report has been bult.

6.2.5 Offline copy of calibration

It is useful to preserve an offline copy of the calibration files after each calibration is performed. It is recommended that a copy of the FotoFiber's entire C:\Calibrate directory tree be kept in a suitable location in the Da Vinci server. These files may prove useful in (i) diagnosing unexpected measurement results, (ii) preserving calibration if the FotoFiber firmware needs to be updated or if the FotoFiber processor module needs to be replaced, and (iii) monitoring long-term changes in performance of FotoFiber's illumination channels.

The files can be copied via ftp, for instance using Windows Explorer to open the address ftp://169.254.100.102/CALIBRATE. Alternatively, the text-mode ftp program can be used in a command terminal, to connect to 169.254.100.102 (username: anonymous, no password needed).

The CALIBRATE directory always has a 00000000 subdirectory containing the original factory calibration files. There may be one or more other directories containing calibration data from specific dates, each named yyyymmdd where yyyy is the year, mm is the two digit month, and dd is the two digit day of the calibration. Typical contents of the CALIBRATE directory are shown in Figure 6-21, and the files in a particular calibration directory are shown in Figure 6-22. The selection of files will not change, unless calibration setup parameters are modified.

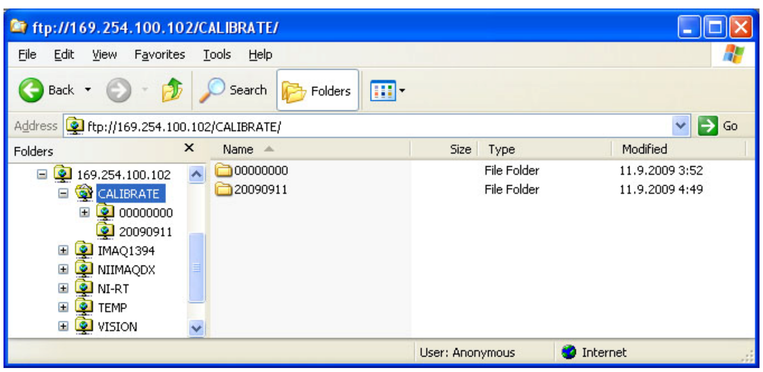


Figure 6-21. Calibration directories in FotoFiber processor module.

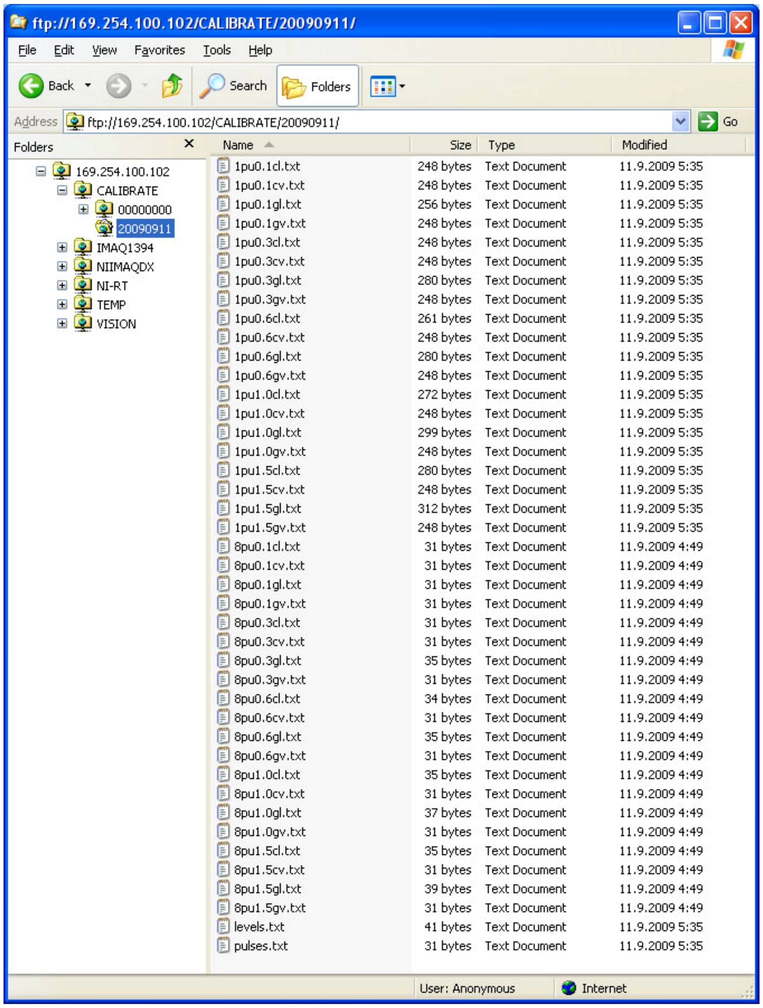


Figure 6-22. Calibration files for one calibration.

6.3 Field Repairs and Adjustments

6.3.1 Voltage to strobe controller

The strobe controller requires power inputs at two voltage levels, as described in §4.1. They must be within acceptable limits.

6.3.1.1 Check conditioned 24V DC

The 24V DC input is taken from the block of three conditioned 24V DC output sockets on the power and isolation PCB. These outputs have common wiring, so it is usually sufficient to check the voltage at the unused socket.

The voltage can be checked with the head offsheet, by carefully connecting voltmeter probes to the pins in the unused socket (shown by dashed line arrow in Figure 4-1). Any level between 18V and 30V is acceptable.

6.3.1.2 Check and adjust trimmed 49V DC

The trimmed output is located beside the trim adjustment screw. Normally, the cable for the trimmed output will have a white conductor for the +49V line, to distinguish it from the other power lines.

This voltage should be in the range 49.0V to 49.5V, and can be adjusted using the trim screw if necessary. Note that one full clockwise rotation of the trim screw increases the voltage by about 1½V. To check and adjust this voltage, follow the steps:

1. Switch off the sensor power, using the switch shown in Figure 4-1.
2. Disconnect the 49V power connector from the socket on the Strobe control PCB, leaving the other end of the cable connected to the trimmed output socket on the Power and utility PCB.
3. Position a voltmeter near the sensor, and ensure that its probes can easily reach the disconnected end of the 49V cable.

4. Power on the FotoFiber with its switch, and wait about 20 seconds for booting to complete

5. Measure the voltage at the disconnected end of the 49V cable (Figure 6-23).

6. If the voltage is in the range 49.0V to 49.5V, then no adjustment is needed. If it is outside this range, it needs to be adjusted. To adjust the voltage, use a small screwdriver to turn the screw on the voltage trim shown in Figure 4-1. One clockwise turn increases the voltage by about 1½V.

7. Switch off the sensor power, then reconnect the 49V cable to the Strobe control PCB.

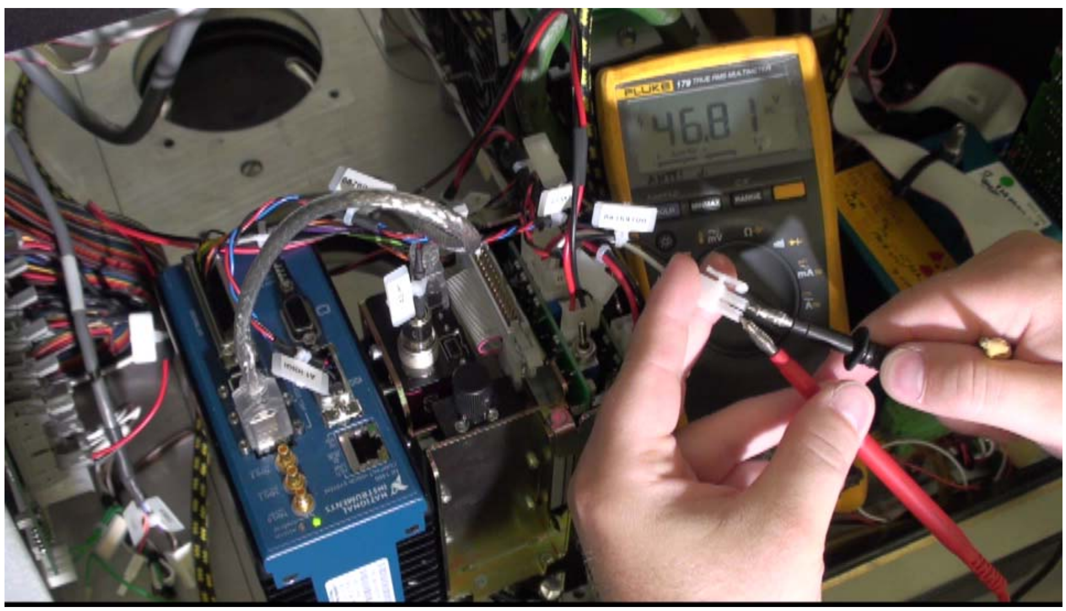


Figure 6-23. Measuring trimmed output voltage.

6.3.2 LED panel/LED driver

If the sensor is subjected to mechanical shock or severe vibration, it is possible that one or more of the solders on the LED panels or LED driver PCBs will be damaged. This will result in failure of one or more channels at standardization, typically both the channel factor flag and the channel gray flag will be ON for the affected channels.

It is also possible that a LED panel or LED driver will degrade with age, to the point where it must be replaced. The symptoms will be a progressive downward drift in the channel factor.

Repairing or replacing components in the light source assembly requires a whole day. Use static-proof bags and small containers to hold the circuit boards, cables, and screws which must be removed from the sensor. It is advisable to have a supply of labels at hand, and to clearly label all parts as they are removed. Use a camera to record the initial cable and circuit board configuration if possible.

First, the cables must be removed from their sockets in the strobe control PCB and LED driver PCBs. Similarly, the 24V, 48V, trigger, and light control link cables must be unplugged from the strobe control PCB. Then the strobe control PCB can be removed from the struts attaching it to the power and utility PCB.

Next, the metal floor and the upper parts of the sensor can be removed. There are six screws to remove, five connected to struts mounted on the light holder, and one into a threaded insert in the light holder.

Before removing the struts from the light holder, it is helpful to mark the threaded insert which received a screw (see Figure 6-24 left). The light holder can then be detached from the base of the sensor, by removing the bolts as in §5.2.1.1.

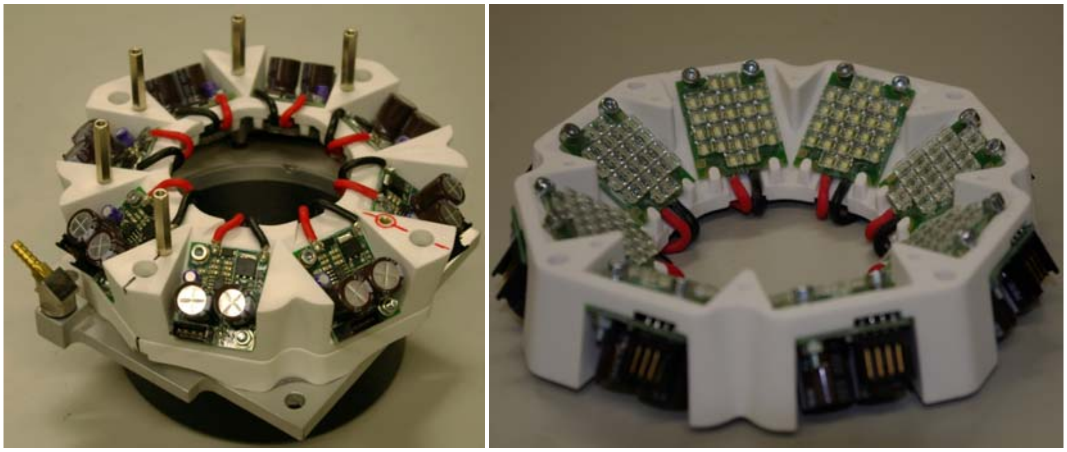


Figure 6-24. Light assembly removal from sensor.

In re-assembling the sensor, the steps are the reverse of those taken to disassemble it. However, pay careful attention to putting the eight cables from the strobe control PCB to the LED driver PCBs in exactly the same sockets they came from. The default assignment is shown in Figure 6-25. The indicated threaded hole is the one which is under the strobe control PCB, and does not receive a strut.

When attaching the nuts onto the bolts to hold the upper and lower polymer octagons together, a thread locking compound should be applied (p/n 16000235).

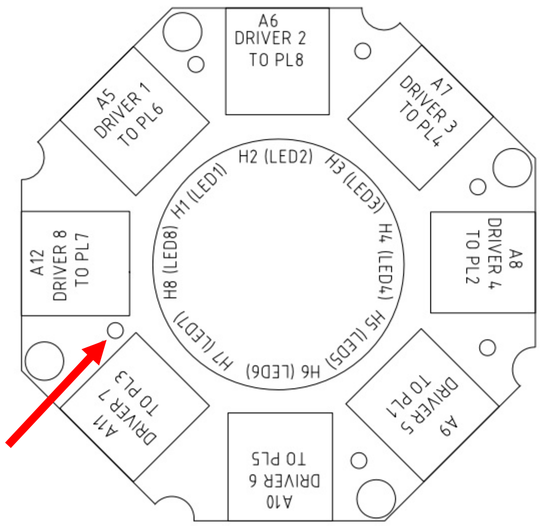


Figure 6-25. Assignment of strobe control cables to LED driver PCBs. Strobe control PCB is installed above indicated hole. PL1 to PL8 denote which strobe control PCB socket to use.

6.3.3 Re-glue lower sensor window

The lower sensor window may become dislodged during an unusually vigorous cleaning. In this case, it is necessary to remove the sensor and re-glue the window.

To access the lower sensor window, it is necessary to separate the upper and lower sections of the sensor, as in §5.2.1.1, giving access to the window from the inside. The window is held in place by a circular clip in an annular recess. This clip must be removed to remove the window, so that all old glue can be cleaned from the rim of the window and the aperture of the sensor.

6.4 Firmware Update

The FotoFiber firmware can be updated in the field, using the Intelligent Sensors package. A firmware update may be needed in conjunction with a future MSS upgrade or a Da Vinci upgrade, or may be needed to add new functionality or solve a site-specific problem.

The original firmware may need to be reloaded onto the FotoFiber if the Processor Module needs to be replaced (a new Processor Module ordered as a spare part will not be delivered containing FotoFiber firmware), or if it appears that an existing file has become corrupt.

6.4.1 Preparation for loading firmware

It is recommended that the FotoFiber be removed from the scanner head for firmware update. The firmware can be loaded onto an existing the Processor Module in the sensor. If a new Processor Module is to be installed in the sensor, the firmware can be loaded onto it before or after it is installed in the sensor. However, the Processor Module has an uncommon power connector, so it may be more convenient to install it in the sensor first.

6.4.1.1 Firmware version

Ensure that the correct firmware version is available. If necessary, contact QCS-TAC for guidance on firmware versions.

If the standard firmware is to be installed on a new Processor Module, a copy was supplied with the Intelligent Sensors software, and can be found in the directory “C:\Program Files\Intelligent Sensors\Fiber Image”.

If a new version of firmware is to be installed, you should have received a copy as part of a system upgrade, or in conjunction with support for a site-specific issue.

6.4.1.2 Hardware setup

With the FotoFiber power switch in the OFF position, the IP Reset DIP switch and the Safe Mode DIP switch on the processor module should both be set to ON. The other DIP switches should be OFF.

A 24V DC power supply and power cable as described in §6.2.1.1 are needed, and should be connected to the FotoFiber.

A PC or laptop with the Intelligent Sensors FotoFiber diagnostic software should be connected using a standard cat5 or cat6 ethernet cable to the Ethernet port on the processor module. The PC must have IP address 169.254.100.100 and its **other network interfaces must be disabled** (see also Appendix C.2).

The Intelligent Sensors software should be started, and then the FotoFiber should be powered ON. The FotoFiber will not load any application firmware when it is booted with the Safe Mode DIP switch ON.

6.4.2 Loading firmware

Start the firmware loader from the Menu of the Intelligent Sensors software, see Figure 6-26.

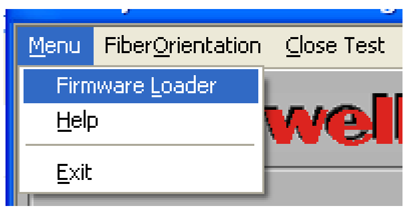


Figure 6-26. Firmware loading process.

The firmware loader window is shown in Figure 6-27, left. Note that its quick help box summarizes the steps needed to deploy the firmware. Click the folder button beside the path textbox, and navigate to the directory which contains the FotoFiber firmware, Figure 6-27, right. When the correct directory is displayed, click the “Current Folder” button.

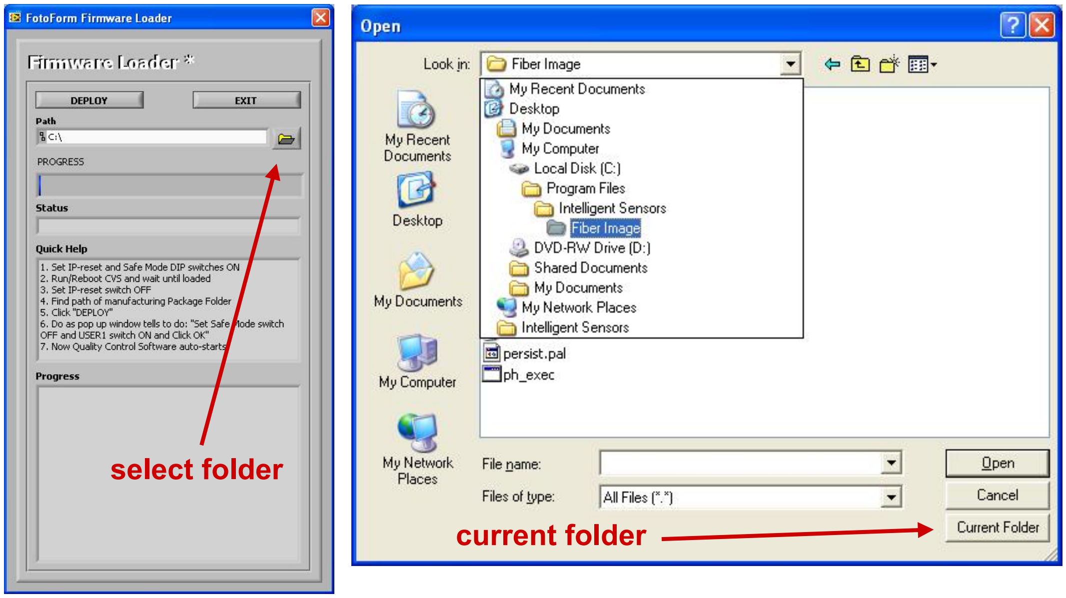


Figure 6-27. Left: firmware loader. Right: selecting the Fiber Image.

Check that the correct directory appears in the path textbox, then click the "Deploy" button to start deploying the firmware to the FotoFiber, Figure 6-28 left. Progress messages will be displayed in the lower text box. During the procedure, it will be necessary to change the DIP switch configuration, Figure 6-28 center. The program will prompt for the change at the appropriate time. Make the DIP switch changes before clicking the OK button, as the FotoFiber will be rebooted shortly after clicking OK.

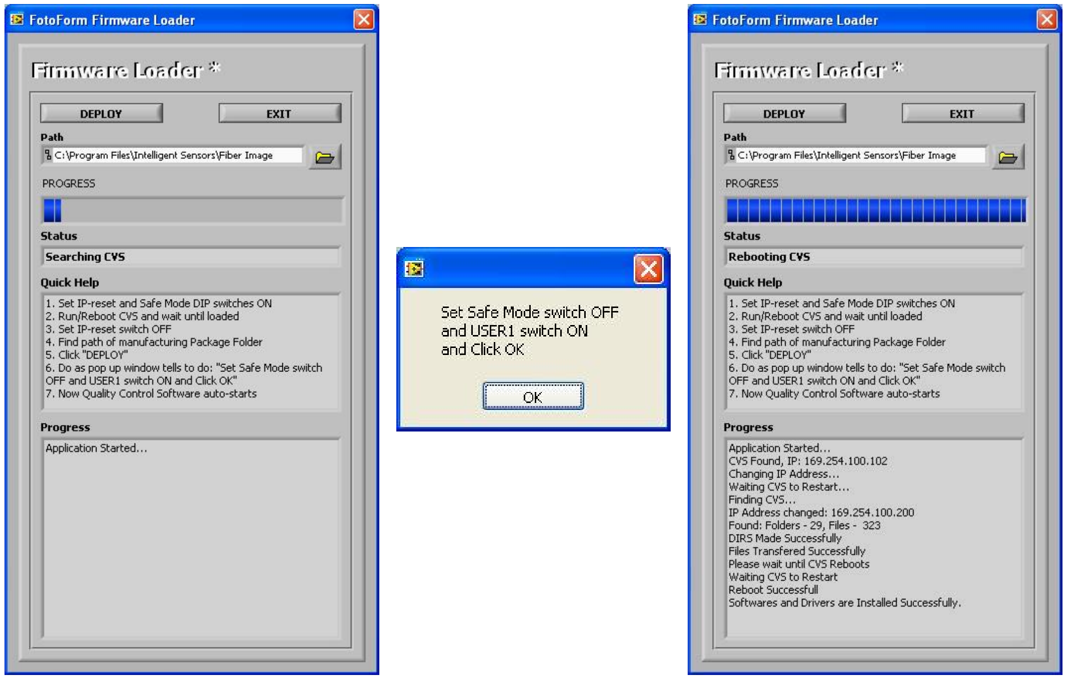


Figure 6-28. Firmware deployment steps.

When the firmware deployment is complete, the progress text will contain the message “Software and Drivers are Installed Successfully”, Figure 6-28 right. Note that a FotoFiber is temporarily given the IP address 169.254.100.200 during firmware update, but this is always automatically reverted to the default FotoFiber IP address 169.254.100.102 when the firmware update is complete.

It is recommended that calibration and focusing be done after the firmware has been updated. The sensor will contain only default calibration data, which is probably not optimal for any particular sensor. However, if the previous calibration data was saved (see §6.2.5), and is considered to be valid, then it can be transferred to the sensor using ftp. Recall that the year and date of calibration may need to be updated as parameters #17 and #18 respectively on the FotoFiber Engineering display (see §3.3.4), to match the directory containing the calibration data.

6.5 Preventive maintenance schedule

The recommended preventive maintenance schedule is shown in the following table

Table 6-1. Preventive maintenance schedule

Action Interv	al	Note
Monitor FotoFiber standardization factors and warning flags	1 / day	Anomalous channel factors may indicate a problem with illumination channel, or a severe local dirt problem.
Monitor FotoFiber Display for abnormal images and parameter values	1 / day	A look at the image can reveal any serious problem quickly
Clean sensor window	Depends on dust & dirt levels at scanner. For a lower head FotoFiber: - clean mill: 1-2 / week - dusty mill: 1-2 / day An upper head FotoFiber needs cleaning less often than a lower head FotoFiber in similar circumstances.	A cleaning kit is supplied with the sensor. Clean sensor windows whenever other sensors are being cleaned in the same scanner, or if the image has markings.
Record values of channel factors and channel gray levels or take a FotoFiber Standardization Display screenshot.	1 / month	Preferably done a short while after cleaning the sensor. Record differences between channels. Long term changes can be spotted by comparing screenshots.
Check voltage supplied to strobe controller	1 / year	The trimmed output from the power and isolation PCB should be in the range 49-49.5VDC. Honeywell service item, during annual machine maintenance shutdown.
Check or adjust camera focus	1 / year	Honeywell service item, during annual machine maintenance shutdown.
Recalibrate illuminator response curves	1 / year	Honeywell service item, during annual machine maintenance shutdown.

7 Troubleshooting

7.1 Standardization Issues

7.1.1 Persistent error/warning flags

Standardization error flags may occur in the first standardization after a machine startup or after a grade change in which the sensor was off-sheet. The sensor will repeat the standardization attempt until successful. If an error flag persists in several consecutive standardizations, then standardization is failing and it is essential to determine the cause and rectify the situation.

7.1.1.1 Short scan

This flag warns that the sensor may be vulnerable to a particular type of standardization failure. If the scan length at standardization (item #5 in the standardization display §3.3.2) is very short, then the standardization result may not be reliable. Although this is a warning flag, it can occur in combination with standardization failure due to the scan time being too short for standardization to complete. If the scan length becomes zero, then the last standardization step using all illuminator channels together cannot be completed, and standardization of one or more individual channels may also have been incomplete.

ATTENTION This warning may also occur if the initial values entered in §5.4.2.2 are no longer valid. This could occur, for example, if the scan speed has been increased, or if the scanner is set to scan a significantly narrower portion of the sheet than was expected when the initial values were computed. It may also happen if the job set for the FotoFiber has a significantly incorrect value for the sensor offset.

Referring to the standardization procedure in §2.3.4, it is clear that the standardization can be completed only if the scan time is long enough for each of the eight channels to be processed individually, and for *at least* 5 images to be taken with all eight channels used simultaneously. The time taken for each channel is determined by the measurement rate (parameter #5 in the engineering display, §3.3.4), together with the number of flashes to use per channel (parameters #24 and #25). There is also a delay of 200ms in the light control link each time the illuminator state is changed, causing a total of 1.8s delay. The minimum on-sheet time needed for standardization to complete is thus:

$$T_{min} = \frac{8(\#24 + \#25) + 5}{\#5} + 1.8\,,$$

With default values (measurement rate #5=10Hz, samples per gap #24=3, samples per channel #25=5), T_{min} is about 9 seconds. The recommended on-sheet measurement time should be at least two seconds longer than this.

If the machine is relatively narrow and the scan speed is relatively high, then it is possible that the scan time is less than 10 seconds. In this case, standardization may fail to complete. If the short scan flag is on, then less than 5 images were obtained with all channels flashing simultaneously. If the scan length is zero, then standardization failed.

Check that the measurement rate (parameter #5) is 10Hz. If it is less than 10Hz, then contact QCS-TAC for guidance. If the measurement rate is 10Hz, or it cannot be increased to 10Hz, then either:

- Reduce the scan speed so that the scan time is at least 12 seconds, even with the narrowest sheet. This is the preferred approach, but may not always be feasible.
- Reduce the samples per gap (parameter #24)
- Reduce the samples per channel (parameter #25)

Contact QCS-TAC for guidance if it is necessary to change parameter #24 to less than 2 or to change parameter #25 to less than 4 (their default values are 3 and 5 respectively). Provide QCS-TAC with a good estimate of the on-sheet measurement time.

7.1.1.2 Scan gray values

Check the mean gray level (item #5 in Figure 3-18).

If it is greater than 225, then

- The illumination subsystem is probably malfunctioning. Contact QCS-TAC for further support in diagnosing the problem.

If it is less than 25, then

- Check the machine speed being sent to the FotoFiber (item #5 in the Edge display, Figure 3-19). This should be in meters per second, and should not exceed 30. High machine speeds lead to short strobe pulse lengths. If the machine speed value appears to be incorrect, then the cause of the incorrect value should be traced and corrected (see §3.2.3). Abnormally large speed values may result from use of incorrect units such as feet per second or meters per minute.
- Inspect the sensor window. There may be a heavy dirt accumulation which needs to be cleaned.
- Check the lens aperture. In some cases this can be seen easily by looking through the sensor window towards the lens (as in Figure 2-4). In other cases it will require removing the camera and lens from the sensor (see §6.1.2.3). The lens aperture ring should be set and locked at f/4. If there is some "play" range in the f/4 setting, the ring should be locked at the more open end of the range, so that it appears approximately as in Figure 7-1.
- Check the shade being produced. If it is a very dark shade and the machine speed is high, then the sensor may be out of its operating range. This is not a problem with the sensor, and normal function will resume when the shade is less dark or the machine speed is reduced. If operation with dark shades at high machine speeds is absolutely essential, then the maximum camera gain can be adjusted (configuration parameter #30 in the Engineering display, Figure 3-20). However, this should be attempted only with QCS-TAC guidance and approval.
- If the shade is not particularly dark, the machine speed value is realistic, and the window is reasonably clean, then the illumination system is probably malfunctioning. Contact QCS-TAC for further support in diagnosing the problem.

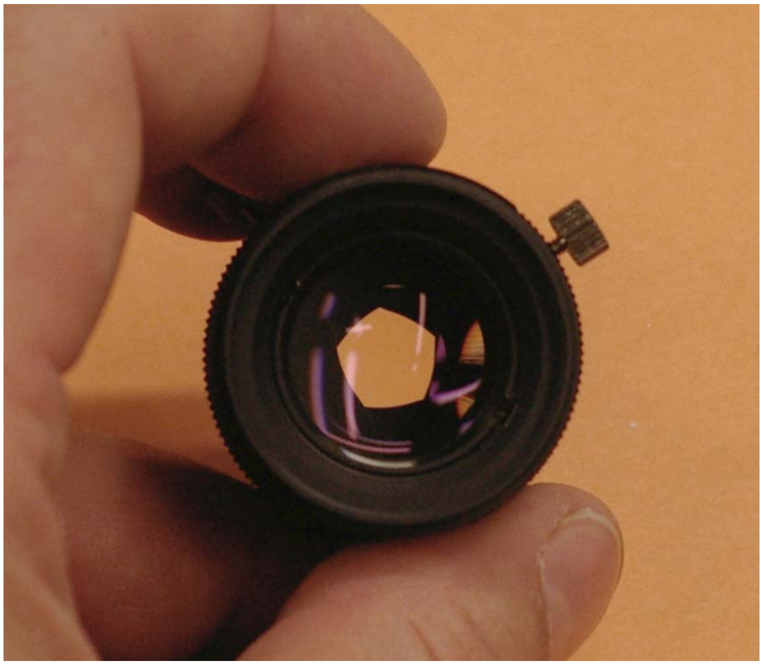


Figure 7-1. Lens aperture, set to f/4. Locking screw is visible at side.

7.1.1.3 Channel gray values

If the scan gray values error flag is set, then the channel gray values error flag is also likely to be set. If both flags are set, then follow the steps in §7.1.1.1 instead. The steps given here assume that the scan gray values error flag is not set.

Check the limits for the minimum and maximum gray per channel (configuration parameters #27 and #28 in the Engineering display, Figure 3-20).

- The minimum limit is normally 25, and the maximum limit is normally 225. If the actual limits are significantly different, then contact QCS-TAC for further support. The limits may have been inadvertently misconfigured in earlier maintenance, or may have been set to nonstandard values to overcome a site-specific issue.

If the minimum and maximum limits are normal, then check the individual channel gray levels (item #3 in Figure 3-18). If the channel gray values flag is set, then one of them will have a value greatly different from the others.

If one is greater than the maximum level and the others are not, then

- The illumination subsystem is malfunctioning (the strobe control PCB may need to be replaced). Contact QCS-TAC for further support in diagnosing the problem.

If one is less than the minimum level and the others are not, then

- The channel with the low gray level has failed. Remove the sensor from the head for further diagnosis. The failure mode is probably one of:

  a. Loose cable from strobe controller to LED driver PCB. Check that all cables from the strobe controller to the LED driver PCBs are properly seated in their sockets.

  b. Broken solder for one of the conductors joining LED panel PCB to LED driver PCB. Inspect all soldered connections on the light source assembly. Repair solders if necessary. See §6.3.2.

  c. Failed LED panel PCB. Typically, some of the emitters will work and some will not during test operation. A few may appear abnormally bright. Replace LED panel PCB if necessary. See §6.3.2.

  d. Failed LED driver PCB. If the MOSFET on the LED driver fails, then it produces DC current at 15mA instead of sub-μs pulses of 100A. In this case, some or all of the emitters on the connected LED panel will be on, but not very bright. Replace LED driver PCB if necessary. See §6.3.2.

7.1.2 Diverging channels

The eight illumination channel output levels are adjusted in operation to produce uniform illumination intensity. The levels are adjusted using their calibration curves and the channel factors from standardization. These values will normally differ between channels, but not by a great amount. The sensor can operate quite satisfactorily even with fairly large channel to channel differences in levels or factors.

However, large or steadily increasing differences between channels may indicate an approaching problem with the sensor, and should be investigated before sensor performance is affected.

7.1.2.1 Channel output levels

In general, the output levels will differ between channels, due to differences in components etc. However, the differences between individual channel levels should normally be only a fraction of their average level.

If the difference between the highest channel output level and the lowest channel output level (bar graphs item #1 in the edge display Figure 3-19) exceeds 50% of the average channel output level, then:

- For an upper sensor, check the recessed window for local dirt obscuring one or more LED panels. Clean if necessary. See §6.1.2.2.

- Visually inspect the LED panels (look through the sensor window) to see if the mini-lenses have been detached from any LED emitters. If some have fallen off, the mini-lenses should be recovered from inside the sensor and reattached to the emitters using superglue. See §6.3.2.

- Check the 49V trimmed output from the power and isolation PCB to the strobe control PCB, and adjust if necessary, following the steps in §6.3.1.2. If this voltage is less than 49V, then the strobe channels will become saturated at less than their maximum setting. If it is significantly less than 49V it may cause inadequate illumination whenever some of the channels are operating near their maximum (parameter #14 in Figure 3-18, default value 950).

7.1.2.2 Channel factors

In general, the channel factors will differ between channels, due to differences in spectrum and aging effects on components. However, all of the factors should be close to unity.

If any factor exceeds 1.6 or is less than 0.6 then the standardization must be considered unreliable. If the channel factors are diverging, it is better to intervene before they reach those levels.

If the largest factor exceeds 1.33 or the smallest is less than 0.75, then

- Is an unusual strongly-colored grade being produced? Due to spectral variation among LEDs, factors may diverge during production of some very strongly colored shades (those whose reflectance spectrum has large transitions over narrow spectral ranges). The factors will revert to normal ranges when the problem shade is not being produced. This is not a problem.
- If channel output levels are also diverging, perform the same checks as in §7.1.2.1.
- If the FotoFiber has been in service for more than a year since its last calibration, recommend to the mill that a channel recalibration be scheduled for an upcoming shutdown.

7.2 Unexpected Measurement Results

If the orientation angle or anisotropy values appear to be incorrect, or if their profiles have unusual shapes, then the problem may be due to diverging channels, as in §7.1.2. However, there may be other causes.

7.2.1 Abnormal anisotropy values

First, is the anisotropy value real? Always view the computed jet-to-wire ratios and rush-drag differences with some skepticism. Moreover, the surface anisotropy can be affected by the stock mix and the impingement angle as well as the rush-drag. Inquire from the operators if the slice opening or the slice apron position have been changed.

To verify that the anisotropy is responding to the process, ask the operators to briefly change the headbox pressure to see if the measured anisotropy changes.

To address problems with anisotropy measurement, check the image on the FotoFiber display. If there is dirt on the image it will affect the anisotropy. In general, streaky marks will cause elevated anisotropy values, while smears or smooth dirt build-up will cause lowered anisotropy values. Next, inspect the sensor window, and clean it if necessary. Dirt accumulation on the window is the primary cause of anisotropy errors; a uniform layer of dust on the window causes reduced anisotropy measurement values without affecting angle measurement. If this problem occurs regularly, then the airflow to the sensor should be checked, and the sensor cleaning schedule may need to be adjusted.

If the sensor window is clean, but the image is particularly blurred, then it is advisable to check the sensor focus at the next opportunity.

7.2.2 Offset in profile average angle

Note that the average angle in raw scans will usually differ between forward and backward traverses. This is because the sheet path through the sensor gap is not tangential to the sheet stabilizing rings, so it gets deflected slightly in passing through the FotoFiber measurement gap. This deflection depends on the speed and direction of scanner movement, as well as on the tension in the sheet.

ATTENTION Variability in the profile average should always be judged from the **trued scan** value, which is an average of forward and backward traverses.

If the offset is relatively small (1° or 2°) and does not change much, then it may be due to misalignment of the sensor. The alignment may change slightly each time the sensor is removed and reinstalled in the head, especially if the camera is replaced. See §5.4.2.6.

If the offset is large (5° or more) and changes only very slowly, then sensor alignment alone cannot explain it. In some cases, there may be a systematic error in the laboratory measurement procedure, such as the CD strip being taken at a slight angle to true CD, or being fed into the TSO analyzer at a slight angle (perhaps manifested as a shift to shift variation). In other cases, it may be caused in part by a misalignment of the whole jet (grade to grade variation). See §1.6.1 for discussion of possible process adjustments.

If the offset is variable in magnitude, and varies over short periods, then it may be due to inadequate tension in the sheet. If the sheet is not flat in the measurement gap, FotoFiber cannot measure the fiber orientation accurately. In this case, the FO angle profile will usually also exhibit a lot of short term variation in shape. Note that when tension problems occur, they are often accompanied by sheet breaks.

7.2.3 Jumps in whole profile

In a two-sided installation, if the coordination between the upper and lower sensors is incorrect, then the whole profile (fiber angle and/or anisotropy) from one or both sensors will intermittently be anomalous. When this happens, then roughly one scan in every 20 to 100 will seem to jump in amplitude and level across the whole sheet, but revert to normal in the next scan.

This type of anomaly occurs when both sensors flash during the camera exposure of one sensor, causing flash-through which biases the information content in the image and an elevated gray level. Since the gauges maintain very precise timing internally, if flash-through occurs for one measurement in a scan, it will occur through the whole scan.

Check the strobe delay from initial tic parameter (#51 in the engineering display §3.3.4) for each sensor. In one sensor, this parameter should be zero. In the other sensor, it should be about 32000µs. There is jitter of up to 15 ms in the messages from the MSS to the sensors (synchronization of messages to sensors typically ±0ms, ±5ms, ±10ms, or ±15ms), so there must be a large enough timing offset added in one sensor to prevent flash-through. If the parameter is already at 32000µs, then switch the delay between the sensors (i.e. change parameter #51 from 0 to 32000 for one sensor, and from 32000 to 0 for the other).

7.2.4 No image updates

If the image is not being updated on the FotoFiber display, then check the following:

Is the image position valid? If it is not within the measured part of the sheet, then no image will be sent by FotoFiber.

Are there too many defined image positions? Images are sent in small packets in the spare bandwidth on the CSLP link, after the slice data and NOW messages. If this is overloaded, then complete images may not be sent. It is recommended that only one image be sent per scan, unless the scan time is quite long (e.g. sending 2 images requires a scan time of at least 40 seconds). If the scan time is very short, less than 12 seconds, it is recommended that no images be sent.

7.3 Miscellaneous issues

7.3.1 Incorrect strobe pulse length

The strobe pulse duration is shown in item #3 of the Edge display in Figure 3-19. It is computed based on the machine speed, magnification, and the allowed degree of blurring (parameter #21 in §3.3.4.2).

If the pulse is too long, then the image will be blurred in the machine direction. The angles will be reduced in amplitude, and the anisotropy values will be increased. This will often be evident by inspecting the image. There are several possible causes for long pulses:

- Blur limit (parameter #21 in §3.3.4.2) set higher than 0.5; its default value of 0.3 is probably acceptable in all cases.
- Incorrect speed supplied, or speed supplied in incorrect units. The machine speed (shown in item #5 of the Edge display in Figure 3-19) should be in meters per second. An incorrect value can cause inappropriate pulse lengths. Check the conversion factors and data sources set up in §3.2.3.

7.3.2 FotoFiber ceases measuring at mode change

This can occur if the scanner is switched directly between two measurement modes (scanning to single-point or vice-versa), without the scanner going to the offsheet position between these measurement modes. Note that it is not sufficient merely to push the offsheet button and then push the new measurement mode button – it is necessary to wait for the scanner to reach the offsheet position before pushing the new measurement mode button.

This situation occurs because the MSS does not communicate skipped states to the FotoFiber, and only communicates that a measurement state has ended when the scanner goes offsheet. The FotoFiber and MSS can thus can be in inconsistent states, leading to communication failure.

To rectify this situation, first try sending the scanner offsheet for a few seconds, then back onsheet. Depending on the inconsistency, this may resolve the problem. Otherwise, the scanner should be taken off sheet, and the FotoFiber should be reset either by cycling its power switch or by pressing the soft-reset button. Allow enough time (typically 30 seconds) for the FotoFiber to reboot fully before starting a scan. If the reset is performed by cycling the power switch, ensure that the powered-off state lasts at least 10 seconds.

7.3.3 Scanner halts at end of scan

This may occur at the end of the first measurement scan after standardization, or at the end of the first traverse after resetting the FotoFiber.

7.3.3.1 Scanner halts after standardization

The FotoFiber must perform a number of calculations and make adjustments to its strobe control parameters at the end of every scan. A delay value is defined to allow these calculations and adjustments to be made (parameter #54 in in §3.3.4.2). If the delay is inadequate, the FotoFiber will not be ready for the next start of scan, and will not be able to perform the correct handshaking with the MSS at the end of that scan.

If this occurs, it is necessary to increase the EOS delay (default 1500ms). To restore movement to the scanner it is necessary to disable the FotoFiber in the Da Vinci. To restore function to the FotoFiber, the scanner should be taken off sheet, and the FotoFiber should be reset either by cycling its power switch or by pressing the soft-reset button. Allow enough time (typically 30 seconds) for the FotoFiber to reboot fully before starting a scan. If the reset is performed by cycling the power switch, ensure that the powered-off state lasts at least 10 seconds.

7.3.3.2 Scanner halts after FotoFiber reset

When the FotoFiber is reset, it requires almost 30 seconds to boot and initialize communications. If the USER1 DIP switch has changed position since the previous reset, the FotoFiber will reboot twice (with a change of active firmware), requiring about 60 seconds. If the scanner commences scanning or fixed-point measurement before the FotoFiber is fully ready, it will not be able to perform the correct handshaking with the MSS.

If this occurs, it is necessary to take the scanner offsheet, and the FotoFiber should be reset either by cycling its power switch or by pressing the soft-reset button. It is essential to allow sufficient time for the FotoFiber to complete its boot-up (30 or 60 seconds, depending on whether the USER1 DIP switch has changed position) before starting any measurement mode. If the reset is performed by cycling the power switch, ensure that the powered-off state lasts at least 10 seconds.

7.4 Function Testing

Function testing procedures can be used to test the illuminators and camera of the FotoFiber, and to test the measurement capability in maintenance mode. Function testing requires a PC or laptop with an Ethernet connector and FotoFiber diagnostic software (see Appendices). The procedures can be carried out with the sensor in the head or on a bench, and the setup for function testing is the same as for focusing, see §6.2.1.

7.4.1 VGA output

The FotoFiber VGA port of the processor module is used to display firmware-related messages on boot-up. In measurement mode (i.e. with USER1 switch OFF), the FotoFiber also produces a diagnostic narrative from active operations on the port. To assist in troubleshooting, QCS-TAC may request that the VGA output be monitored. With the sensors offsheet and the covers removed from the head, it is possible to connect a VGA monitor to the VGA port. The monitor must be externally powered.

CAUTION It is essential to prevent scanning while a VGA monitor is connected to the FotoFiber. Scanning while a VGA monitor is connected will lead to a sheet break, possibly accompanied by damage to the paper machine, scanner, sensor, or VGA monitor. Use hardware interlocks, and ensure that it is not possible for scanning to be remotely started.

The output to the VGA monitor will show boot-up messages which can be useful in assisted troubleshooting guided by QCS-TAC or the sensor developers. Issues which can be detected in this way include:

- Processor module failure
- Corrupt executable files or configuration files
- Communication failure with MSS
- Inconsistent configuration data sent by MSS

On every boot, the MAC address of the ethernet adapter is shown, together with its assigned IP address. In maintenance mode (USER1 DIP switch ON), there is no diagnostic narrative.

7.4.1.1 Boot after USER1 switch changed

On booting after the USER1 DIP switch has changed position, the FotoFiber must set different firmware to active, then boot again. The subsequent boot will use firmware corresponding to the new position of the USER1 DIP switch. In this case, the VGA output will appear similar to Figure 7-2.

Note that the "Cleared 1 lost cluster(s)" message is normal on booting the sensor after it has been powered down using the power switch.

Note also that there is a delay of several seconds between the "system will REBOOT AUTOMATICALLY" message and the actual reboot.

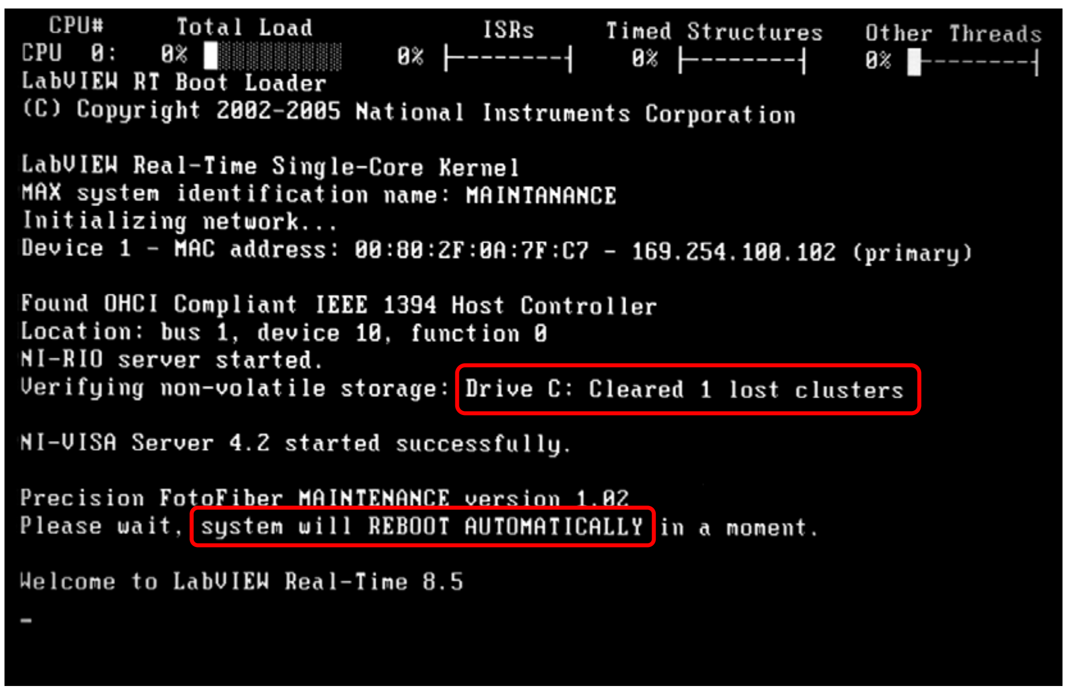


Figure 7-2. Diagnostic monitor – boot after USER1 DIP switch changed.

The example in Figure 7-2 is for the first boot when the sensor is switched to measurement mode (USER1 DIP switch OFF) after being in maintenance mode.

7.4.1.2 Maintenance mode, normal boot

The VGA output for a normal boot in maintenance mode is shown in Figure 7-3.

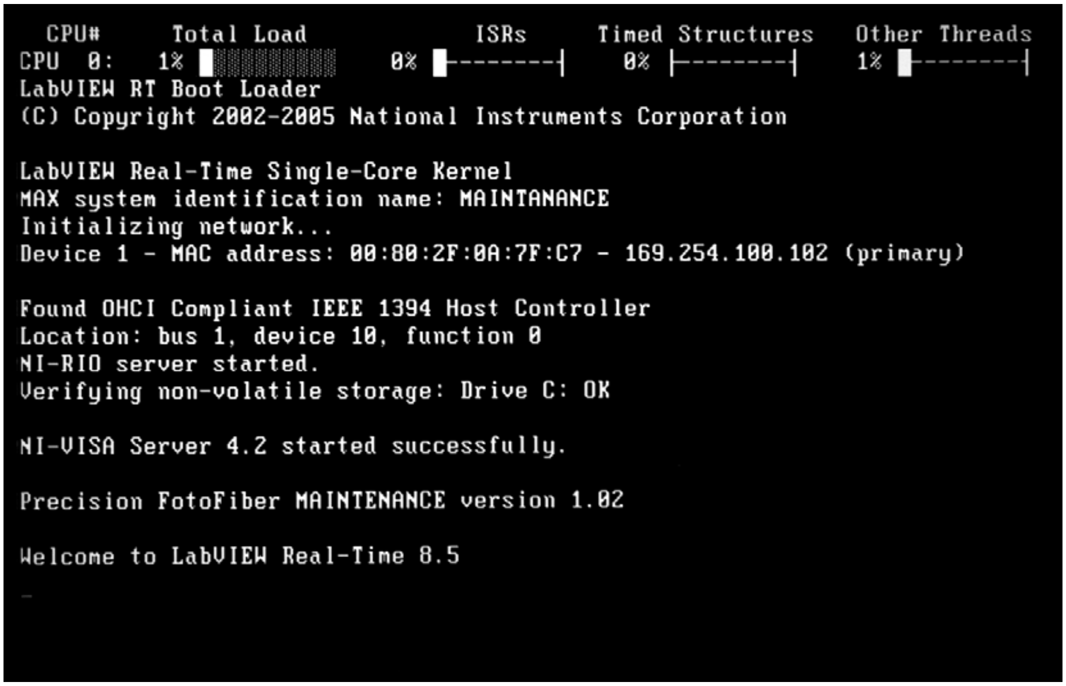


Figure 7-3. Diagnostic monitor – normal boot in maintenance mode.

Note that there is no further diagnostic narrative after booting in maintenance mode.

7.4.1.3 Measurement mode, normal boot

In measurement mode (USER1 DIP switch OFF), the VGA output at startup is typically as shown in . There is then a pause which may last a few seconds, as the sensor waits for configuration parameters to be sent by the MSS. When the parameters are received, the diagnostic narrative continues as in Figure 7-5.

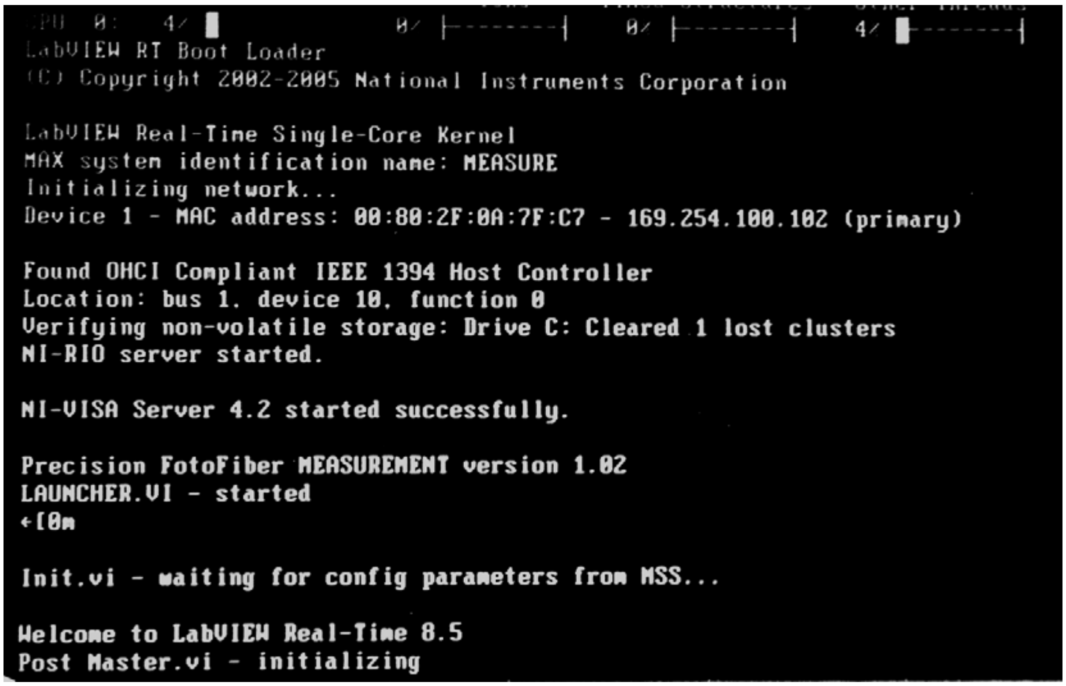


Figure 7-4. Diagnostic monitor – normal boot in measurement mode, waiting to receive configuration parameters from MSS.

When the parameters are received, the diagnostic narrative continues as in Figure 7-5. A number of significant configuration parameters are listed, and the camera model is identified (in this case, a Marlin F080B, but other models are also supported, such as the Stingray F080B). Some notable parameters shown are, with equivalents in Table 3-8:

- option mask ↔ parameter #53
- JPEG q ↔ parameter #49
- strobe Hz ↔ parameter #5
- EOS delay ↔ parameter #54
- gray target ↔ parameter #26
- zero angle ↔ parameter #16

Note especially the two graphical characters which alternate across the lower lines of the display, and inside the indicated oval in Figure 7-5. These are printed when the sensor sends its "Alive and well" message to the MSS, and when the sensor receives an "Alive and well" message from the MSS

- the "underlined ordinal" character: FotoFiber → MSS
- the "box corner" character: MSS → FotoFiber

The "Alive and Well" messages should occur roughly every 4 seconds, and will normally appear appended to the text messages.

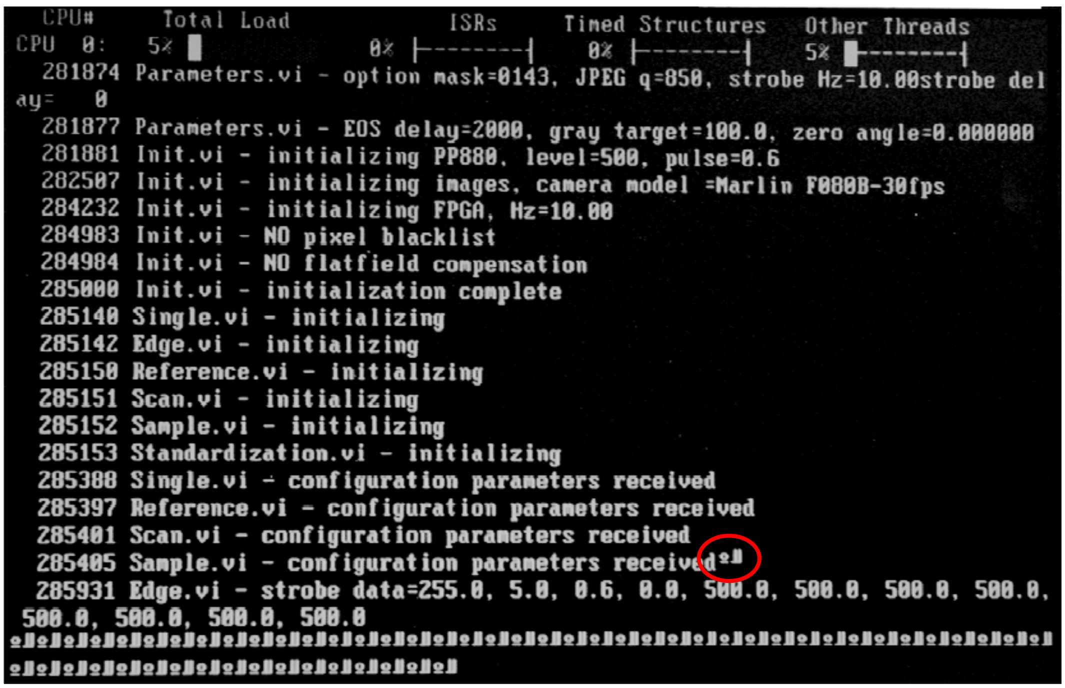
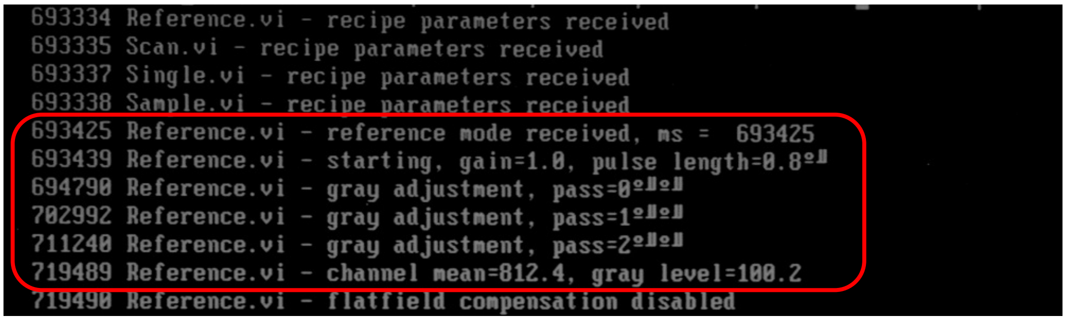


Figure 7-5. Diagnostic monitor – processing configuration parameters received from MSS.

7.4.1.4 Reference mode

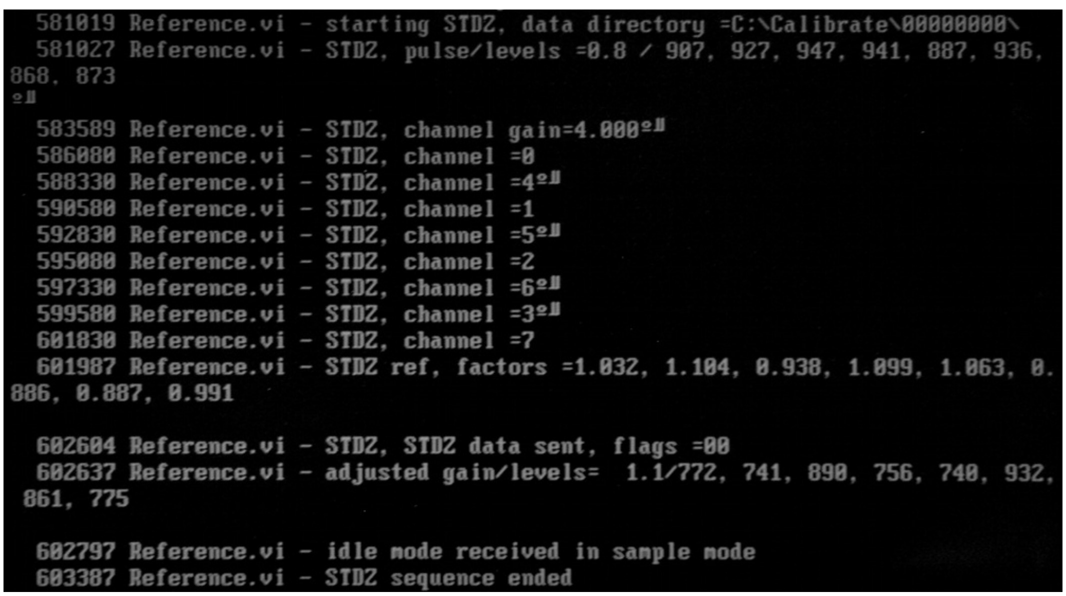
Reference mode performs first a graylevel adjustment, with diagnostic narrative such as that shown in Figure 7-6. Up to 6 passes may be used for gray level adjustment.



```
693334 Reference.vi - recipe parameters received
693335 Scan.vi - recipe parameters received
693337 Single.vi - recipe parameters received
693338 Sample.vi - recipe parameters received
693425 Reference.vi - reference mode received, ms =  693425
693439 Reference.vi - starting, gain=1.0, pulse length=0.8♀‼
694790 Reference.vi - gray adjustment, pass=0♀‼♀‼
702992 Reference.vi - gray adjustment, pass=1♀‼♀‼
711240 Reference.vi - gray adjustment, pass=2♀‼♀‼
719489 Reference.vi - channel mean=812.4, gray level=100.2
719490 Reference.vi - flatfield compensation disabled
```

Figure 7-6. Diagnostic monitor – reference mode gray adjustment.

This is followed by standardization, which sequentially checks each illumination channel, with diagnostic narrative such as in Figure 7-7. The resulting channel efficiency factors and the recommended camera gain and illumination channel levels for measurement are shown.



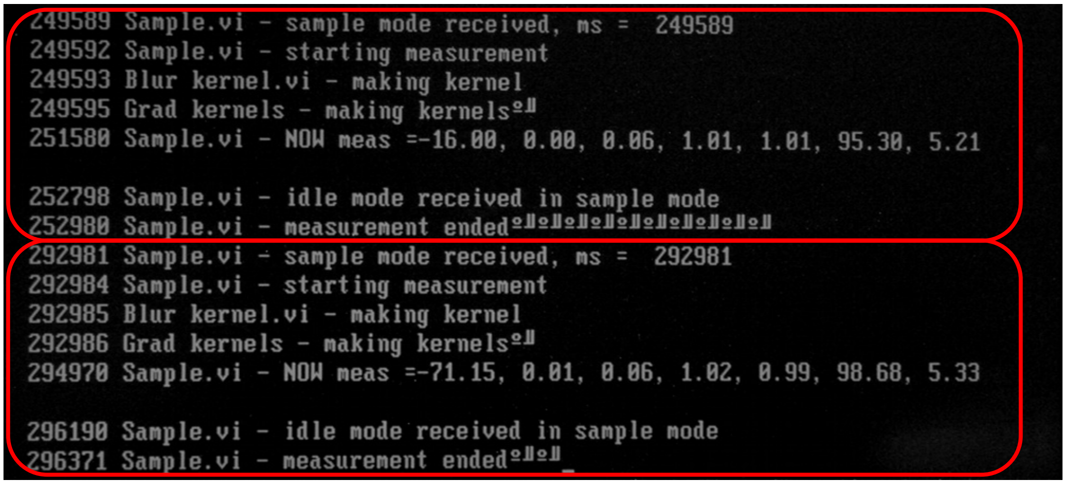
```
 581019 Reference.vi - starting STDZ, data directory =C:\Calibrate\00000000\
 581027 Reference.vi - STDZ, pulse/levels =0.8 / 907, 927, 947, 941, 887, 936,
868, 873
♀‼

 583589 Reference.vi - STDZ, channel gain=4.000♀‼
 586080 Reference.vi - STDZ, channel =0
 588330 Reference.vi - STDZ, channel =4♀‼
 590580 Reference.vi - STDZ, channel =1
 592830 Reference.vi - STDZ, channel =5♀‼
 595080 Reference.vi - STDZ, channel =2
 597330 Reference.vi - STDZ, channel =6♀‼
 599580 Reference.vi - STDZ, channel =3♀‼
 601830 Reference.vi - STDZ, channel =7
 601987 Reference.vi - STDZ ref, factors =1.032, 1.104, 0.938, 1.099, 1.063, 0.
886, 0.887, 0.991

 602604 Reference.vi - STDZ, STDZ data sent, flags =00
 602637 Reference.vi - adjusted gain/levels=  1.1/772, 741, 890, 756, 740, 932,
 861, 775

 602797 Reference.vi - idle mode received in sample mode
 603387 Reference.vi - STDZ sequence ended
```

Figure 7-7. Diagnostic monitor – reference mode channel standardization.

"Alive and Well" messages appear throughout the narrative.

7.4.1.5 Sample mode

Typical diagnostic narrative output is shown in Figure 7-8 for shooting a sample. Two successive sample measurements are shown.



```
249589 Sample.vi - sample mode received, ms =  249589
249592 Sample.vi - starting measurement
249593 Blur kernel.vi - making kernel
249595 Grad kernels - making kernels
251580 Sample.vi - NOW meas =-16.00, 0.00, 0.06, 1.01, 1.01, 95.30, 5.21

252798 Sample.vi - idle mode received in sample mode
252980 Sample.vi - measurement ended
292981 Sample.vi - sample mode received, ms =  292981
292984 Sample.vi - starting measurement
292985 Blur kernel.vi - making kernel
292986 Grad kernels - making kernels
294970 Sample.vi - NOW meas =-71.15, 0.01, 0.06, 1.02, 0.99, 98.68, 5.33

296190 Sample.vi - idle mode received in sample mode
296371 Sample.vi - measurement ended
```

Figure 7-8. Diagnostic monitor – sample mode measurements.

The values listed in the NOW measurement are:

- fitted FO angle, in degrees
- fitted FO anisotropy
- fitting residual
- max/min ratio
- MD/CD ratio
- mean gray level
- gray level sigma (contrast)

"Alive and Well" messages appear throughout the narrative.

7.4.1.6 No communication with MSS

If the FotoFiber does not appear to be communicating with the DaVinci, the diagnostic output can help isolate the problem.

The sequence of characters at the bottom of the screen indicates that the sensor is sending "Alive and Well" messages to the MSS. However, there are no characters indicating that it is receiving the corresponding "Alive and Well" messages from the MSS. Either the MSS is not operating, not configured properly, or there is a problem with the communication line.

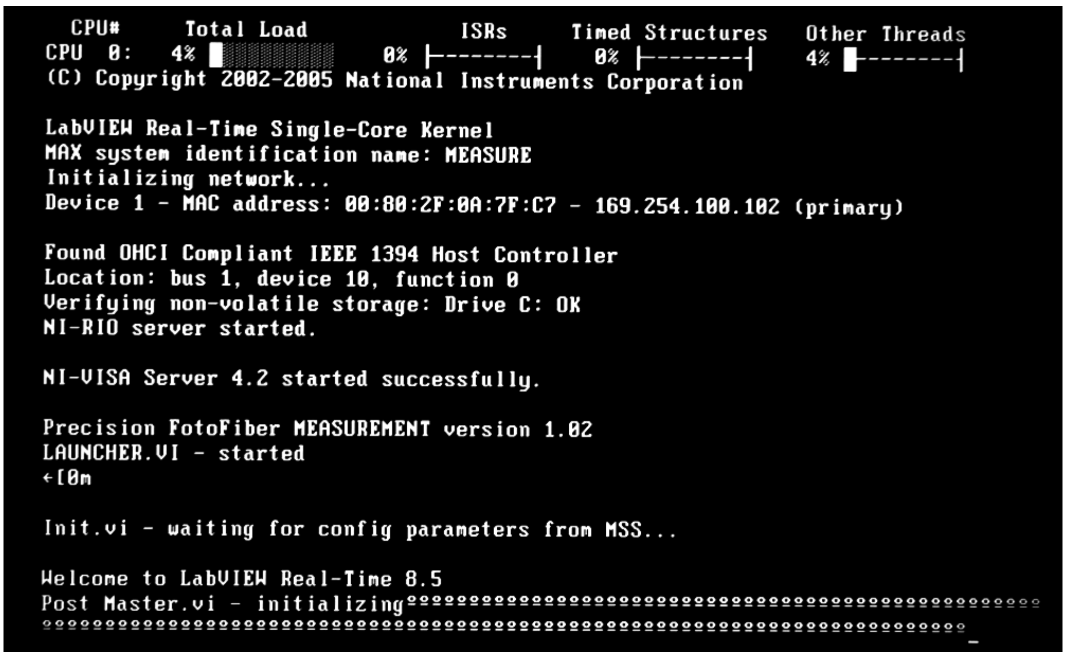


Figure 7-9. Diagnostic monitor – FotoFiber booted, but no communication with MSS.

If there are "Alive and Well" messages going in both directions, as as the bottom of Figure 7-5, then the communication link is working. In this case, if the sensor does not appear to communicate with the DaVinci, then the MSS probably expects a different sensor on the port, and may well have sent inappropriate configuration parameters to the FotoFiber. The assignment of communication ports in the MSS should be checked, and corrected if necessary.

7.4.2 Illuminators and camera

The procedure “Operate PP880 and Camera” can be used to test the camera and illuminators, and communication between the processor module and the strobe controller.

This procedure is separate to the focusing and calibration procedures described in §6.2.2 and §6.2.3. It can be used to test individual illumination channels, camera operation, and lens problems.

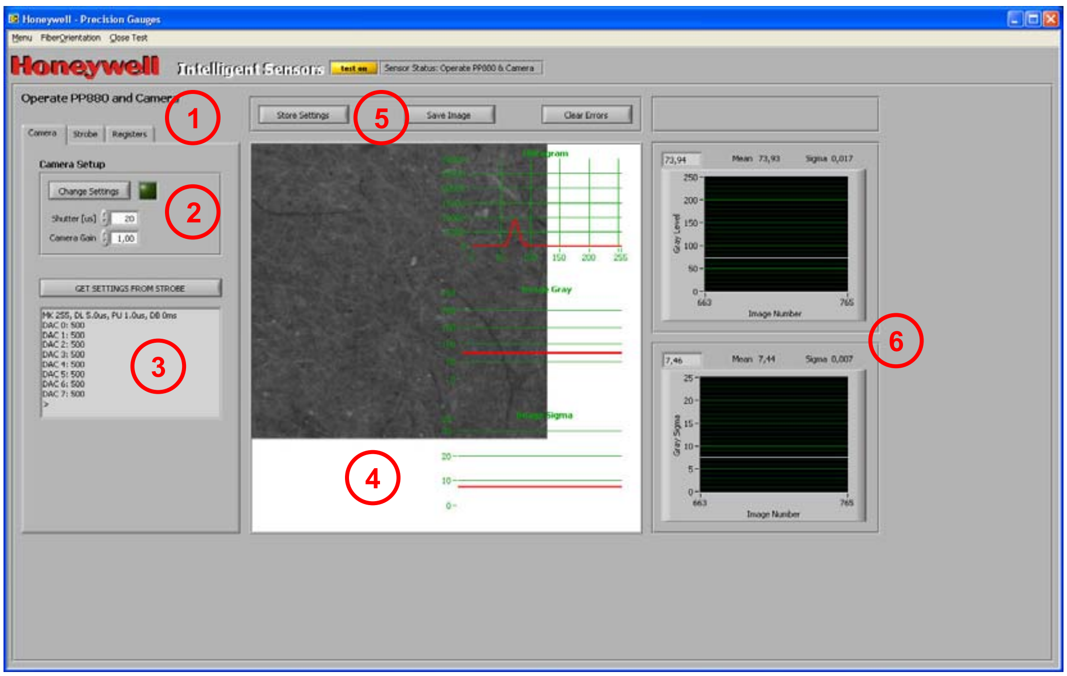


Figure 7-10. Operate PP880 and Camera, camera tab.

When the procedure is started, the camera may not have suitable parameters, and may not be acquiring images. On the “Camera” tab, shown in Figure 7-10, the shutter time (in integer microseconds) and the camera gain (1.00 to 4.00) may be entered. The default values of 20μs for shutter time and 1.0 for camera gain are suitable for all standard test purposes. If these values are changed, clicking the “Change Settings” button will apply the new settings. It will also restart image acquisition, whether the parameters are changed or not.

The current image and its statistics are also displayed, together with a trend of statistics from recent images.

Clicking the "Get settings from strobe" button on the camera tab will cause the processor module to request the strobe controller to report its current settings. The communication between these two modules is in ASCII text, and the message received from the strobe controller will be displayed in the box beneath the button. The message is composed of items separated by commas. Each item has a prefix and a value, as shown in Table 7-1.

Table 7-1. Strobe link message items.

Item	Typical value	Value range	Brief description
MK	255	0-255	Bitmask for active channels
DL	5.0us	0-10.0us	Delay from trigger edge to strobe
PU	0.5us	0-2.5us	Strobe pulse length
DB	0ms	always 0ms	Debounce (trigger repeat inhibit)
DAC 0:	500	0-999	Output level for channel 0
DAC 1:	500	0-999	Output level for channel 1
DAC 2:	500	0-999	Output level for channel 2
DAC 3:	500	0-999	Output level for channel 3
DAC 4:	500	0-999	Output level for channel 4
DAC 5:	500	0-999	Output level for channel 5
DAC 6:	500	0-999	Output level for channel 6
DAC 7:	500	0-999	Output level for channel 7

Note that the delay and pulse are in microseconds, with precision 0.1µs. The debounce function is not required and the debounce parameter should always be zero.

Note also that while illuminator channels are numbered from 1 to 8 in the Da Vinci Standardization display (§3.3.2) and Edge display (§3.3.3), they are numbered 0 to 7 in the strobe control interface. The active channel bitmask uses 2^N to enable channel N, with N from 0 to 7.

The strobe tab is shown in Figure 7-11. It allows the pulse duration (range 0.1 to 2.0µs) and the delay from trigger to pulse (range 0.1 to 20.0µs) to be entered into the databoxes with white backgrounds, and activated using the "Set Pulse Timing" button. When activated, the currently active values are reported back into the databoxes with gray blackgrounds.

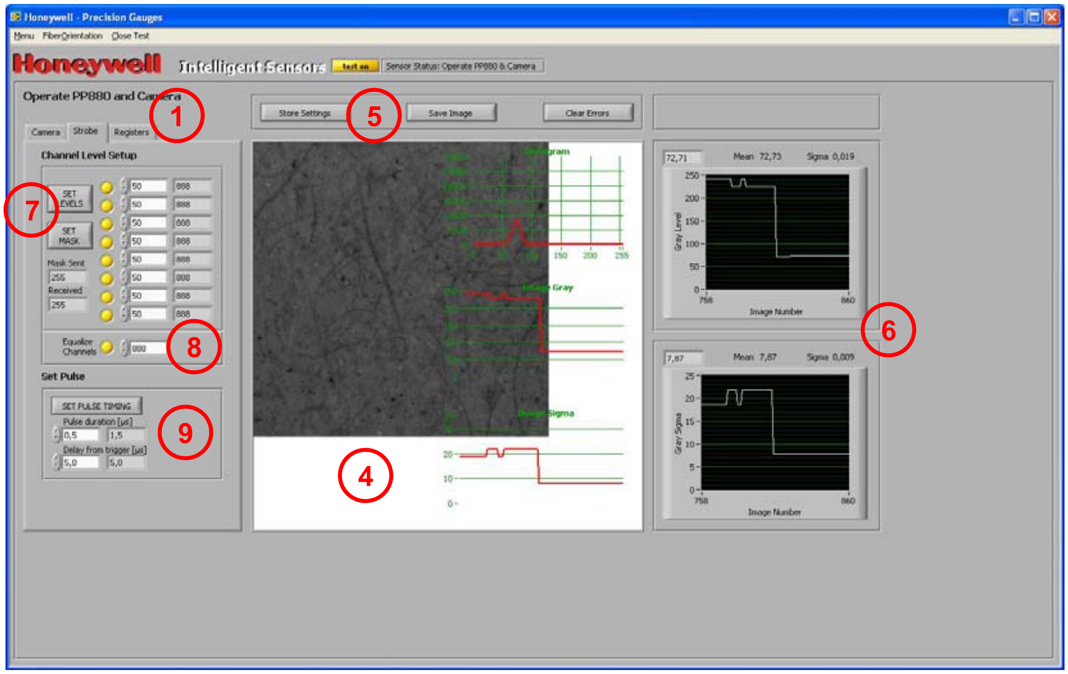


Figure 7-11. Operate PP880 and Camera, strobe tab.

A common value can be used for all illuminator channel levels, if the equalize channels indicator is set ON (yellow). If it is OFF (dark gray), the equalize value is ignored, and values must be set individually for each channel. The "Set Levels" button sends either the common value to all channels or sends their individually specified values, depending on the state of the equalize indicator. The currently active values are reported back for all channels and shown in the databoxes with the gray background.

Each channel has an indicator which is set to determine whether it is active or not (ON=yellow, OFF=dark gray). The "Set Mask" button sends a channel mask specifying the active channels to the strobe controller. Examples are in Figure 7-12.

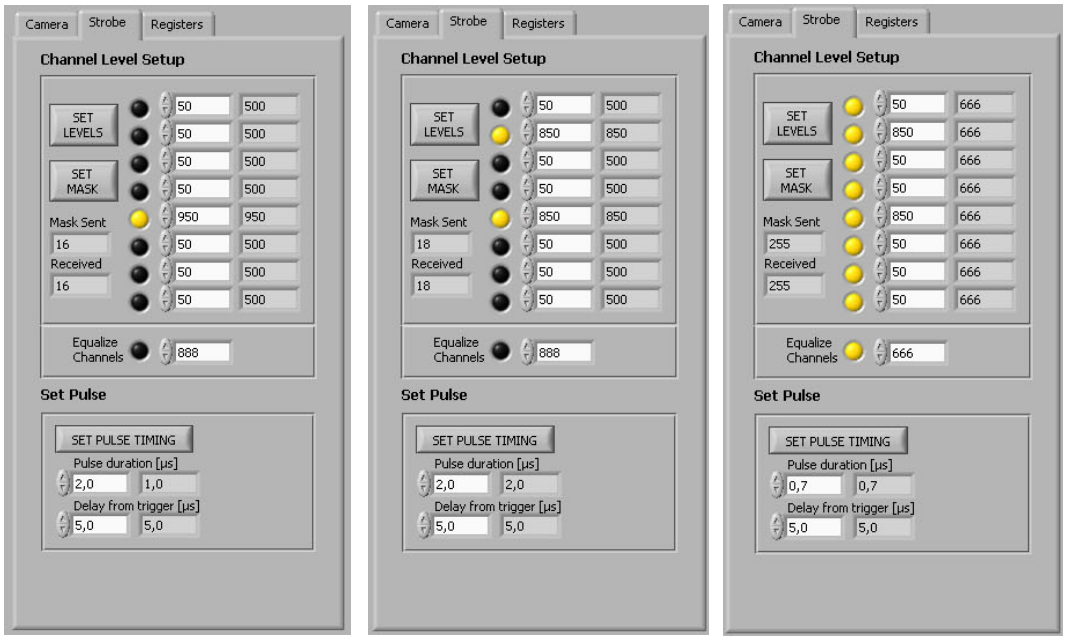


Figure 7-12. Control of individual channels using mask and levels. Left: channel 5 at 950. Center: channels 2 and 5 at 850. Right: all channels on and equalized at 666.

The Registers tab is used for inspecting or modifying camera registers, shown in Figure 7-13. It should be used only with guidance from QCS-TAC or the sensor developers.

The address of a register is entered in hexadecimal (IIDC 1.31 standard registers and vendor-specific registers for the camera). All register addresses and register contents are 32 bit. Clicking the Read Register button will display the register contents in hexadecimal in the field beside the button. To modify the register contents, a new hexadecimal value should be entered into the field beside the Write Register button, and the Write Register button should be clicked.

Figure 7-13. Camera registers tab.

A selection of IIDC register addresses and their standard contents is given in Table 7-2. All entries are in hexadecimal in the table.

Table 7-2. Selected IIDC registers and their contents.

Register address	Default contents	Brief description
F1000208 80000000		Timebase selector
F100020C 80000005		Extended shutter
F1000250 80000000		Shading correction
F1000300	80020000	Input trigger 1 pin control
F1000320	80020000	Output pin control
F1000340	80000000	Delayed integration enable
F1000400 80000000		Trigger delay

The items of the various display tabs are summarized in Table 7-3. Note that the items 4, 5, 6 on the right of the display are common to all tabs.

Table 7-3 Items of Operate PP880 and Camera procedure display.

1 Tab	selector
2.	Camera parameters and activation button
3.	Strobe parameter request and message buffer
4.	Live image area with statistics
5.	Buttons for saving image or settings
6.	Statistics trends for images
7.	Parameters for individual illuminator channels and activation buttons
8	Equalization of all channels
9	Strobe timing parameters and activation button
10	IIDC register inspection and manipulation

ATTENTION Click the "Close Test" menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

7.4.3 Measurement capability

The procedure "Fiber Orientation Measurement" on the FiberOrientation menu can be used to make measurements of fiber orientation in maintenance mode

Note: the "Fiber Orientation Single Point" procedure is similar, but is useful only if the sensor is deployed in a laboratory apparatus with a paper handling device. It is not useful for sensors intended to be mounted in a scanner head, whether they are in the head or on a bench for maintenance.

The fiber orientation measurement display is shown in Figure 7-14. It displays the polar histogram and fitted curve on the left, with the fitted fiber orientation parameters (orientation angle and anisotropy in upper left; MD/CD and max/min ratios in lower left). On the upper right is the live image being analyzed, with its gray level histogram in bottom center, and trends of gray level and contrast on the bottom right.

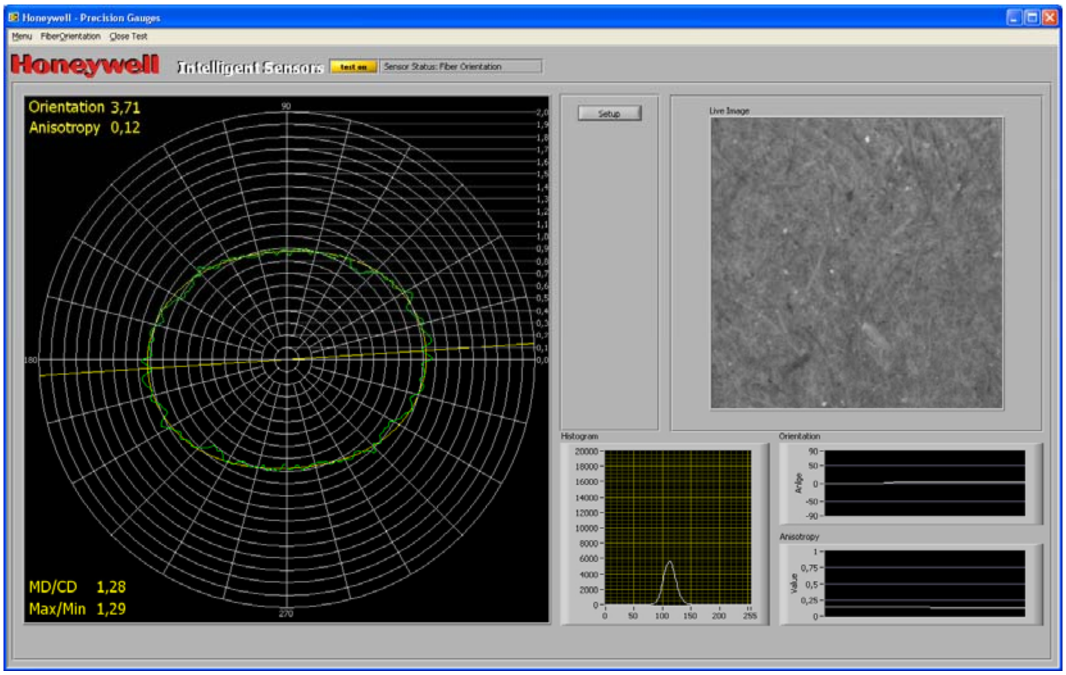


Figure 7-14. Fiber orientation measurement display.

Clicking the “Setup” button in the upper center displays the setup panel in the area beneath the button (see Figure 7-15).

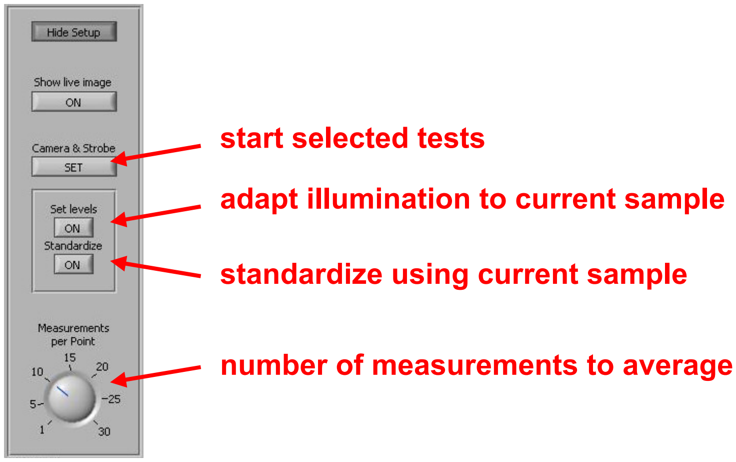


Figure 7-15. Setup panel for measurement display.

When a measurement session is started, it is advisable to go through the setup. First, click the Standardize button with a typical sample inserted. This will request the sensor to check the efficiencies of each channel for illuminator balancing.

If samples of rather different color or brightness are to be measured, it is recommended that the "Set levels" button be clicked after changing to a sample of different brightness or gray level. This will request the sensor to adapt the illuminator strengths to the current sample.

The selected tests (standardization and/or level adaptation) will be performed when the "Set" button is clicked. Normal measurement will resume afterwards, using the newly obtained settings.

The number of raw measurements to average in each displayed measurement result (histogram & parameters) can be controlled using the dial. The default is 10 measurements per average.

ATTENTION Click the "Close Test" menu item to continue. Starting another procedure without closing the active procedure will cause the PC and the FotoFiber to become uncoordinated.

8 Appendices

A FotoFiber Spare Parts (SP09480300)

The Lens Pen (p/n 54000353) used in cleaning the sensor window should be replaced annually. If it is used heavily, such as in a dusty mill, it may need to be replaced more often. Other spare parts are not required in normal use of the sensor.

38100009	CAMERA,IEEE 1394B,CCD,B/W,XGA
38002007	LENS, C-MOUNT
20100079	STROBE CONTROLLER
20100078	UTILITY BOARD
08770600	FOTOFIBER HARNESS ASSY, LED CABLE SET
08770100	FF LIGHT SOURCE ASSY
07848200	FF PLENUM WINDOW
25000774	FF PLENUM WINDOW O-RING
20100081	LED PANEL
20100080	LAMP DRIVER PCB
51600543	FUSE,VERY FAST,SURFACE MOUNT,5A,6.10 x 2.69mm
54000353	LENS PEN
25000770	COMPACT LINEAR UNIT,50MM STROKE
08769200	FOTOFIBER HARNESS ASSY, DIGITAL I/O CABLE
08769300	FOTOFIBER HARNESS ASSY, PROCESSOR MODULE POWER CABLE
08769400	FOTOFIBER HARNESS ASSY, SERIAL LINK CABLE
08769500	FOTOFIBER HARNESS ASSY, STROBE TRIGGER CABLE
08769600	FOTOFIBER HARNESS ASSY, 24V SUPPLY CABLE
08769700	FOTOFIBER HARNESS ASSY, 48V SUPPLY CABLE
08769800	FOTOFIBER HARNESS ASSY, CAMERA FIREWIRE
08769900	FOTOFIBER HARNESS ASSY, CAMERA TRIGGER CABLE
08770000	FOTOFIBER HARNESS ASSY, LINK TO MSS
08770500	FOTOFIBER HARNESS ASSY, SIGNAL GENDER CHANGER
08773300	FOTOFIBER CALIBRATION AND FOCUS TARGET

B Calibration and focus target

The calibration and focus target (p/n 08773300) has three areas used in maintenance procedures, indicated in Figure 8-1.

- Medium gray rectangle (30% gray), to be used for calibrating the illuminators when all are used in combination.
- Light gray rectangle (10% gray), to be used for calibrating individual illumination channels.
- Rosette pattern area, to be used in focusing the optics.

The target should be kept flat; it should never be folded or rolled up. It should be kept in a clean place with the Lens Pen and on-site spare parts, preferably in a clean envelope.

Note that the focus target requires high resolution printing to be useful. The reduced size version in Figure 8-1 would not be adequate for testing focus of the sensor optics.

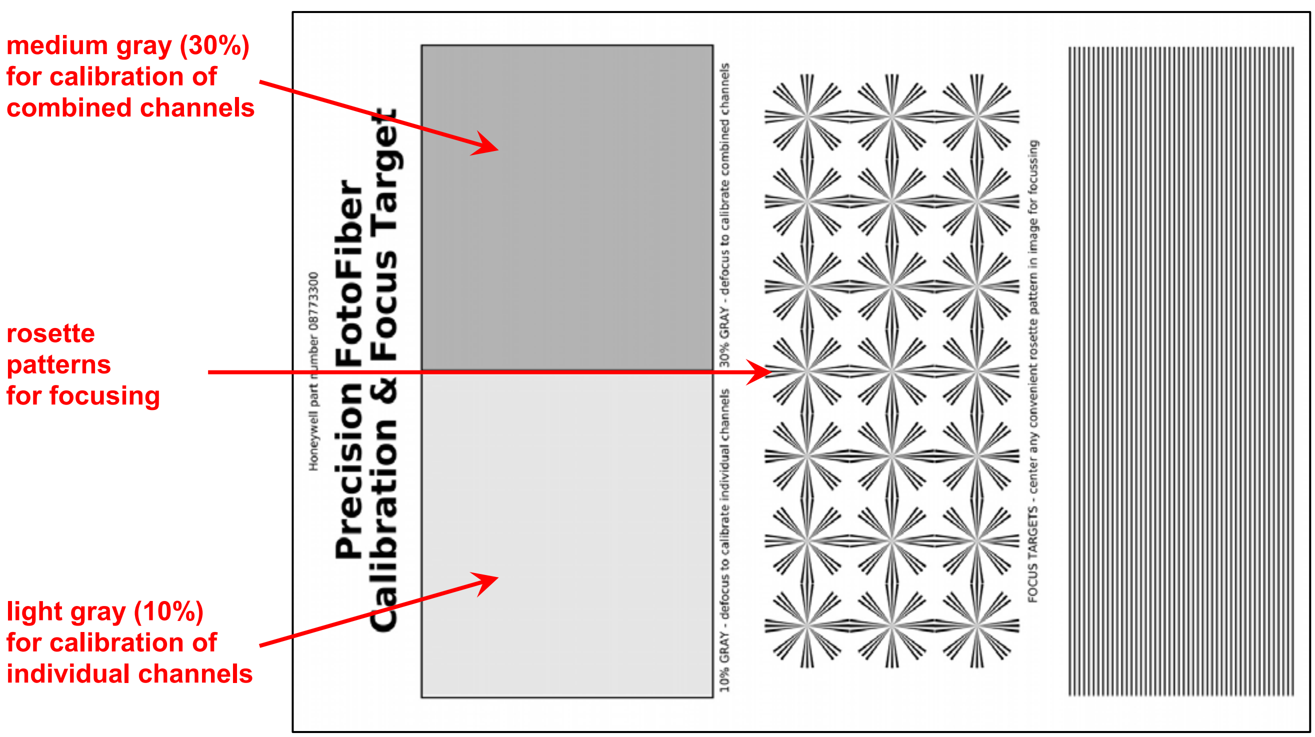


Figure 8-1. Layout of calibration and focus target.

C Installation and Use of PC Software

Several of the maintenance and troubleshooting procedures require a PC with the Honeywell Intelligent Sensors software package. This software is provided to attendees of the FotoFiber sensor training course, which includes instruction on use of the software. The items needed for installing the software are:

- PC or laptop. Recommended minimum configuration is a Pentium class processor with 1GB RAM, SVGA display, RJ45 wired ethernet port (at least 10 Mbit/s), and at least 200MB free disk space.
- Microsoft Windows (version XP or newer, with service packs), already installed on PC or laptop.
- Media containing the Intelligent Sensors installation package. Note that if the installation package is copied to the hard disk, it requires an additional 200MB of disk space.

C.1 Installation of Intelligent Sensors software

To install the software on a suitable PC, follow the steps below:

1. With a file browser such as Windows Explorer, navigate to the installation package folder, and run the setup.exe file (the exe file extension may be hidden in Windows Explorer). See Figure 8-2.
2. The installer will start, and after it has initialized, it will propose directories for installation. Accept the defaults, and click “Next”. See Figure 8-3, left.
3. A license agreement from National Instruments will be displayed. Accept the agreement and click “Next”. See Figure 8-3, right.
4. The operations to be performed will be summarized (there may be multiple operations), as in Figure 8-4, left. Click “Next” to install.
5. A progress indicator is shown as files are installed on the PC.
6. When the installation is complete, a notification will be shown, as in Figure 8-4, right. Click “Finish” to exit the installer. It may be necessary to reboot the PC before using the Intelligent Sensors package.

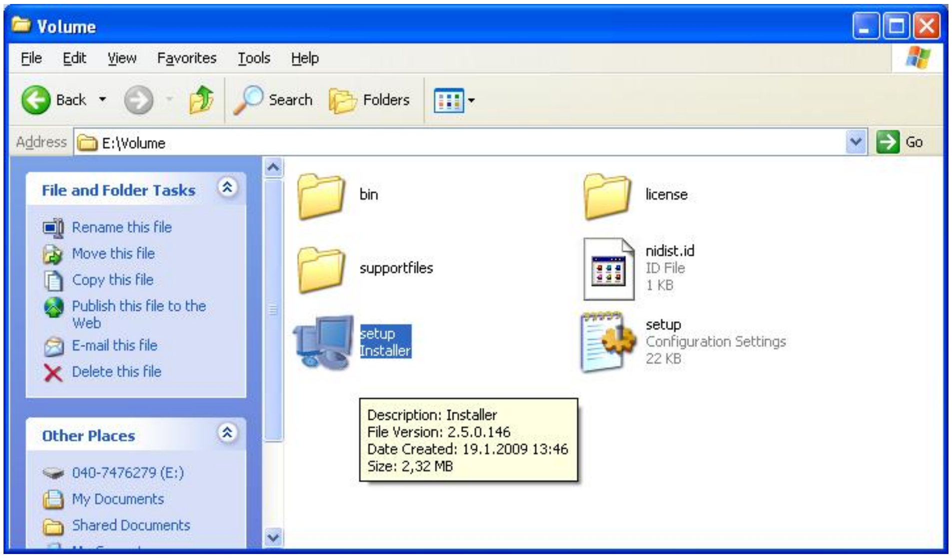


Figure 8-2. Installation package folder.

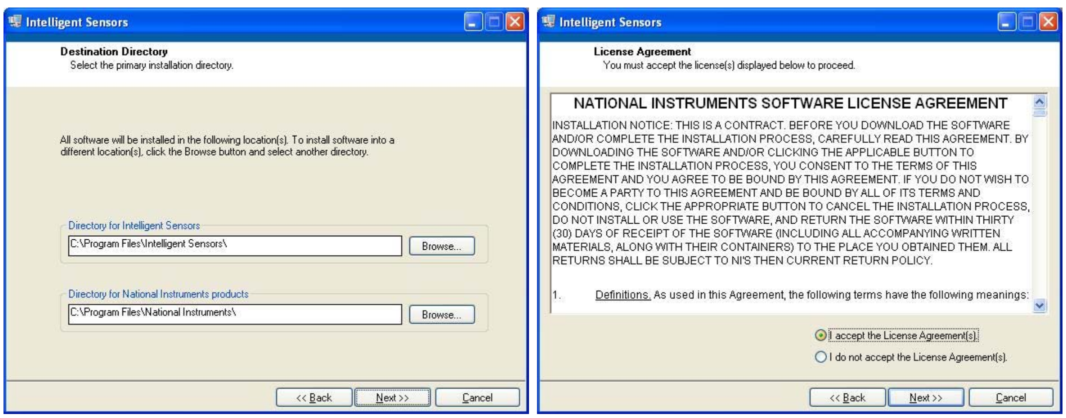


Figure 8-3. Left: program installation directories. Right: National Instruments license agreement.

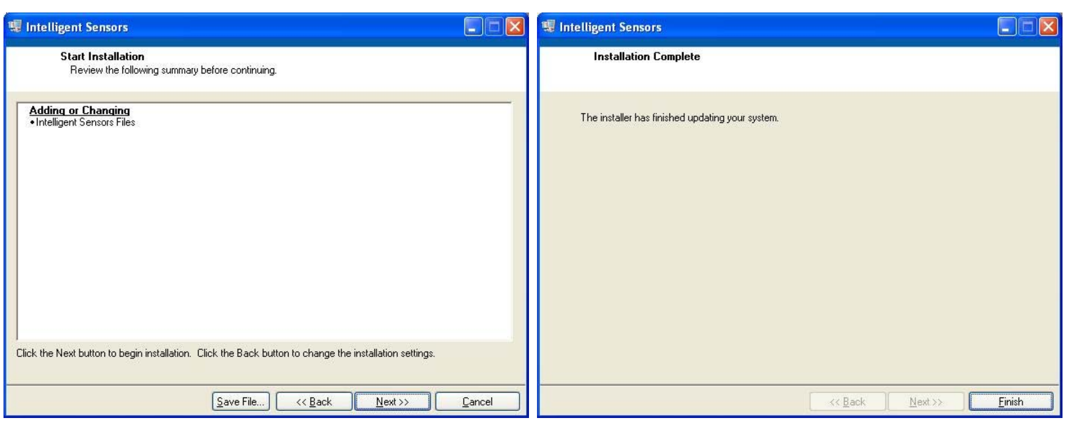


Figure 8-4. Left: installation summary. Right: installation complete.

C.2 Using Intelligent Sensors software

C.2.1 Preparation

A Cat5 or Cat 6 ethernet cable (UTP or STP) is needed for connecting the PC to the FotoFiber.

Before using the Intelligent Sensors package, the following preparations should be made on the PC (Settings, Network Connections):

- Disable all network interfaces except **one** wired ethernet adaptor. Ensure that WLAN adapters are disabled, any 3G dial-up interfaces are disconnected, and that networking is disabled for IEE1394 (FireWire) interfaces, if any. An example is shown in Figure 8-5.
- For the remaining Local Area Connection, open the properties dialog, and scroll down to select the Internet Protocol (IP) item. See Figure 8-6, left.
- Click the “Properties” button for the LAN interface, and set the IP parameters as shown in Figure 8-6, right. The IP address must be 169.254.100.100, and netmask must be 255.255.0.0 (Windows will set this netmask automatically).

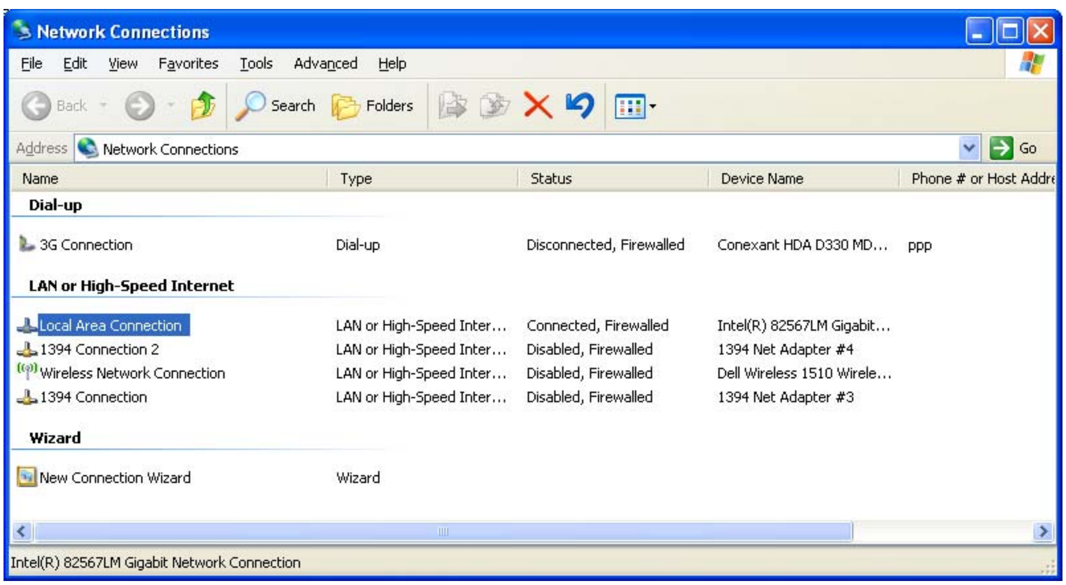


Figure 8-5. Wired LAN interface enabled, all others disabled.

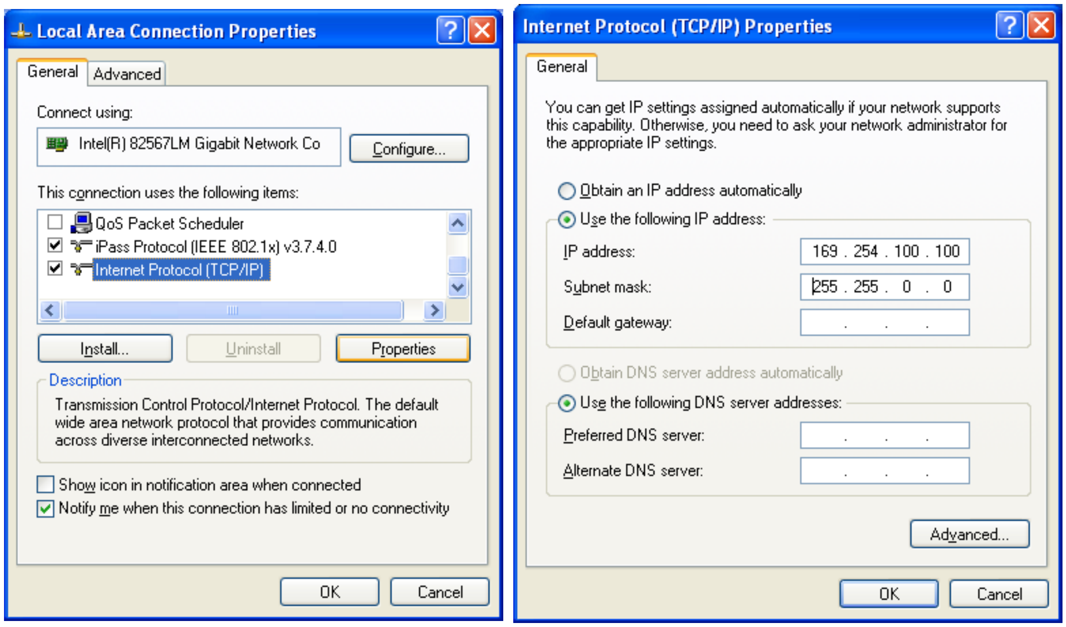


Figure 8-6. Set IP parameters for wired LAN.

C.2.2 Starting the program

The “Programs” sub-menu of the Windows “Start” menu will have an entry for the Intelligent Sensors package. Start this program, and wait a few seconds for it to initialize.

Figure 8-7. Starting the Intelligent Sensors program.

The status string near the top center of the display window should contain the message “Sensor Status: Waiting for Sensor…” as in Figure 8-8, top. If there is no text after the “Sensor Status:” (see Figure 8-8, bottom), then the network is probably misconfigured. Check that the IP address has been set correctly, and that all other network interfaces are disabled.

Figure 8-8. Program status. Top: normal startup. Bottom: network misconfigured or multiple network interfaces enabled.

C.2.3 Establishing link to FotoFiber

With the FotoFiber power switch in the OFF position, the USER1 DIP switch on the Processor Module should be set to ON. The other DIP switches should be OFF (if needed for a maintenance procedure, the program will indicate any other DIP switch changes).

A PC or laptop with the Intelligent Sensors FotoFiber diagnostic software should be connected using a standard cat5 or cat6 ethernet cable to the Ethernet port on the processor module. The Intelligent Sensors software should be started, and then the FotoFiber should be powered ON.

If the USER1 DIP switch was changed, the FotoFiber sensor will boot *twice* (the active firmware is selected based on the USER1 switch). If it was not changed, the FotoFiber will boot only once. During the booting time, the Intelligent Sensors package will indicate "busy", as in Figure 8-9, upper. There may be a further delay of up to a minute for the PC and the FotoFiber to establish communication and set up shared data structures over the network. After communication is fully established, the status will change to "ready", as in Figure 8-9, lower.

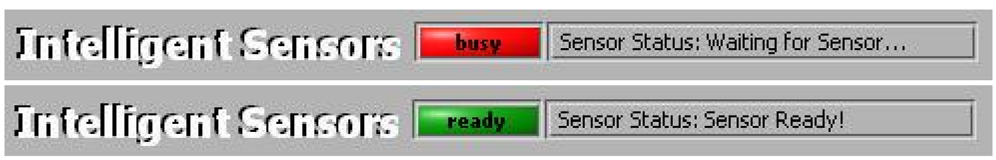


Figure 8-9. PC software waiting for communication (top), and after communication is established (bottom).

ATTENTION Do not start any procedures or click any menu items until the status is "Sensor Ready!". Starting any procedure before the sensor and PC have properly established communication will cause the PC and the FotoFiber to become uncoordinated.

C.3 Software parameter setup

There are several parameters used to define the camera and strobe states to use in calibration, focusing, and function testing. These can be inspected and modified using the Setup procedure in the FiberOrientation menu, shown in Figure 8-10. The default values are acceptable for all of these parameters.

If the FotoFiber is to be used as a bench measurement device outside the scanner, then the direction of positive angle may need to be changed using the Clockwise button (ON=clockwise angles positive, OFF=anticlockwise angles positive). The zero angle may also need to be adjusted. Note that operation as a bench measurement device is not a supported product function, so it is rarely necessary to change these parameters.

CAUTION Do not change any other parameters, except as instructed by QCS-TAC or the sensor developers. Inconsistent camera setup or improper settings for registers may disable the sensor.

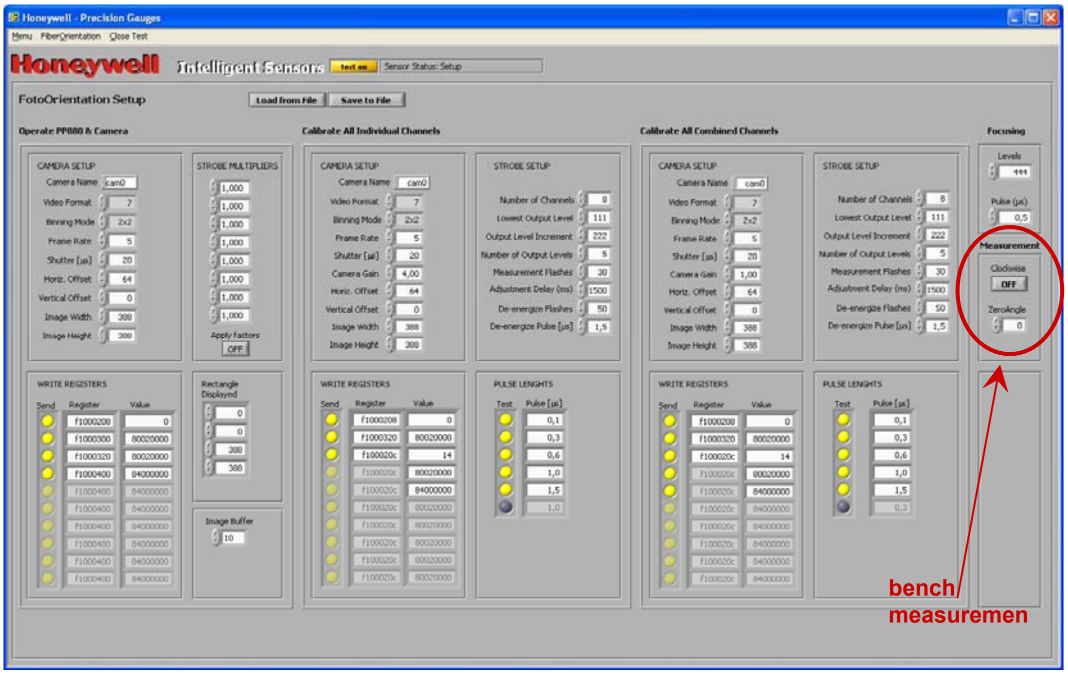


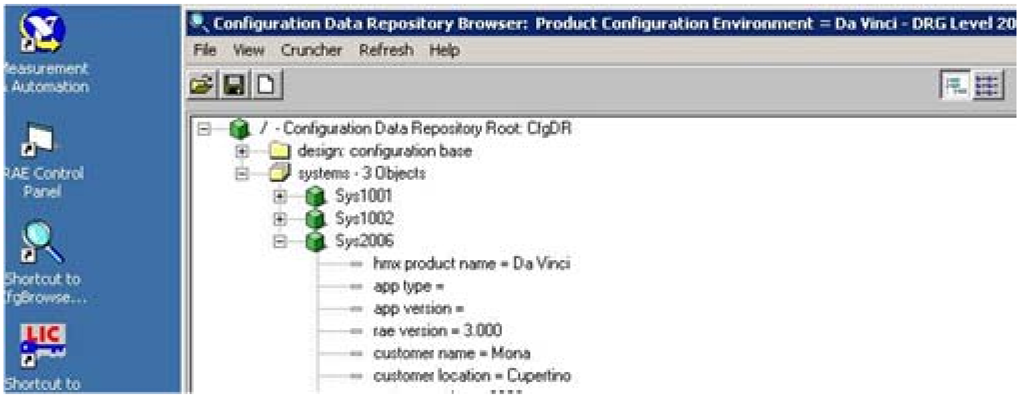
Figure 8-10. Setup parameters for calibration and testing.

D PCDAQ/PCI Configuration

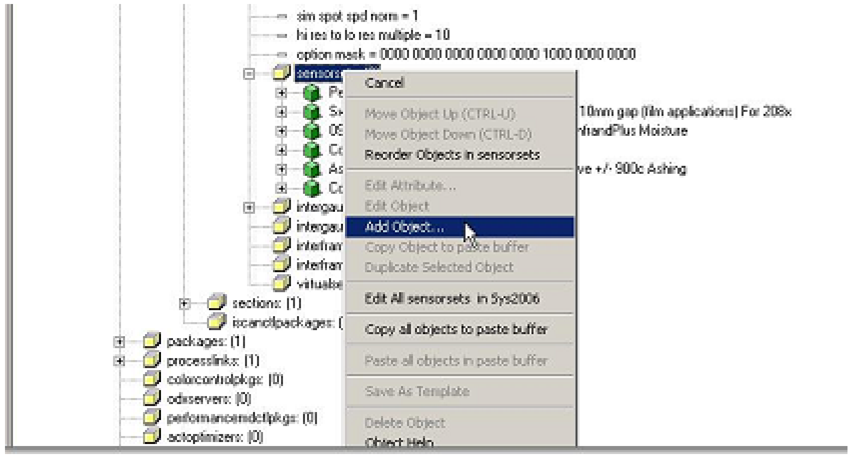
These instructions for PCDAQ/PCI configuration have been done for Porosity sensor. Follow the instructions just replacing Porosity by FotoFiber wherever needed.

1. Shutdown RAE

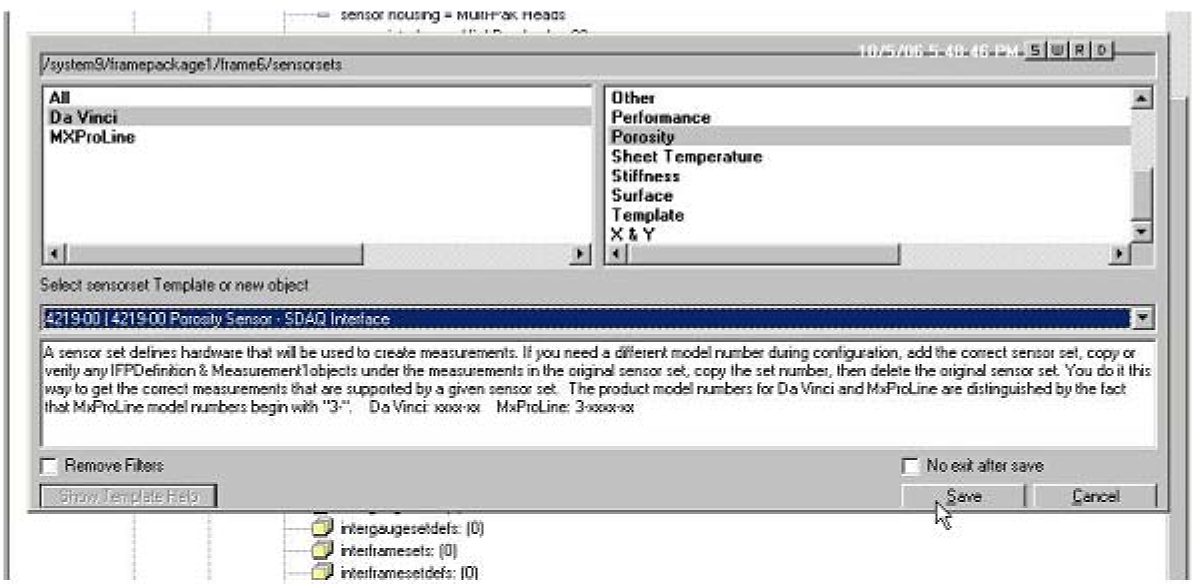
2. Open Config Browser



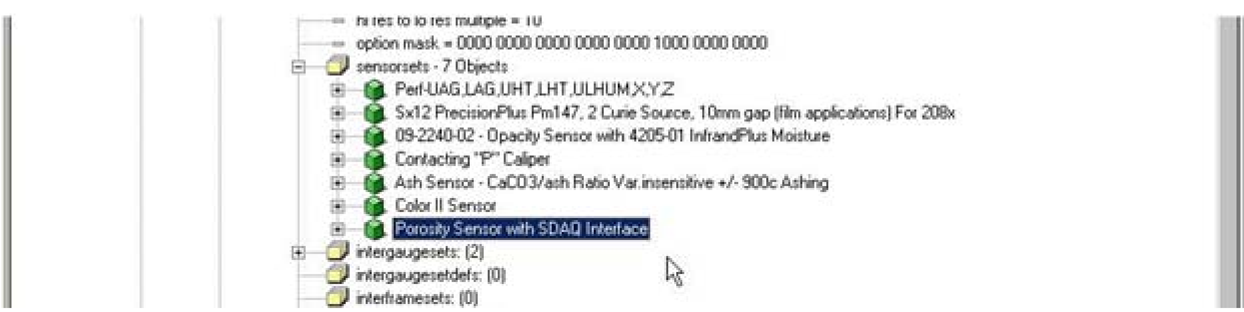
3. Right-click the sensorsets and select Add Object



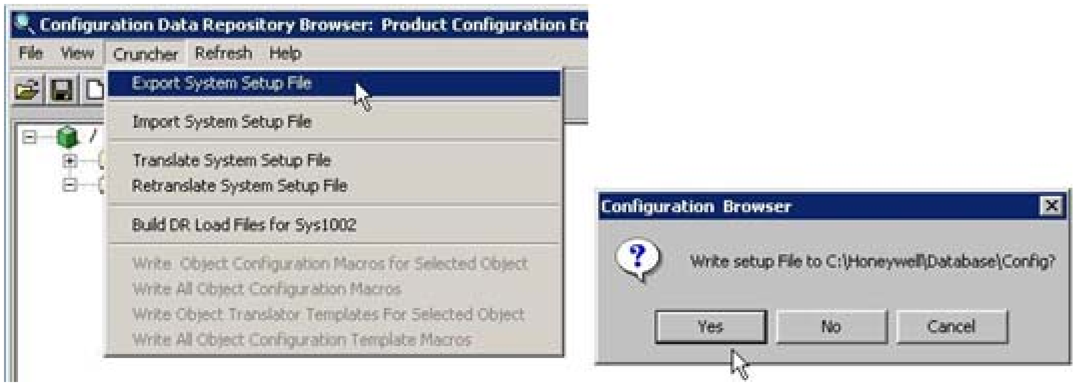
4. Select correct sensor (FotoFiber) and click Save.



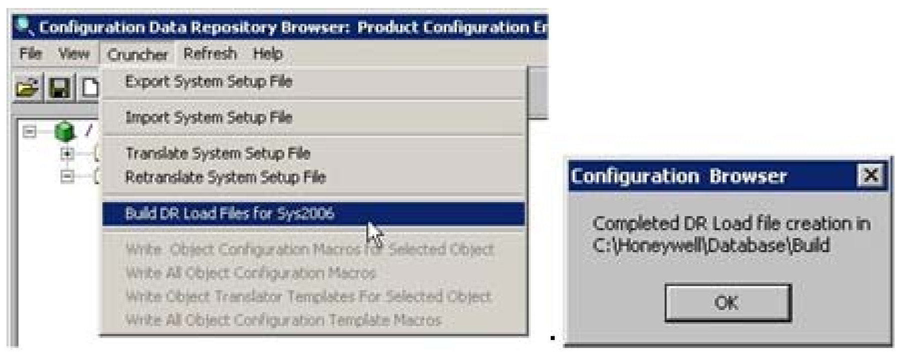
5. The new sensor should now appear on the list



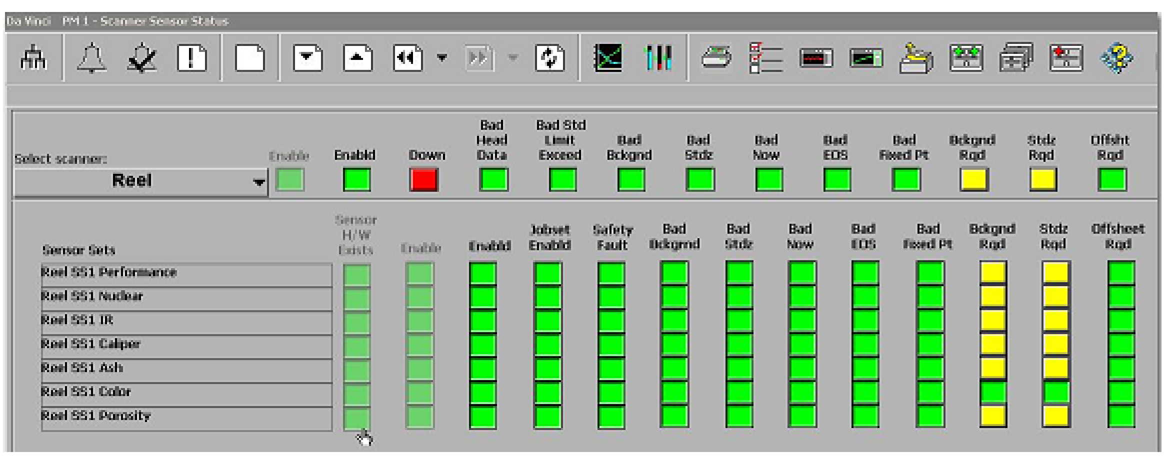
6. Activate your system and select Cruncher / Export System Setup File. Select Yes from the dialog if everything goes OK.



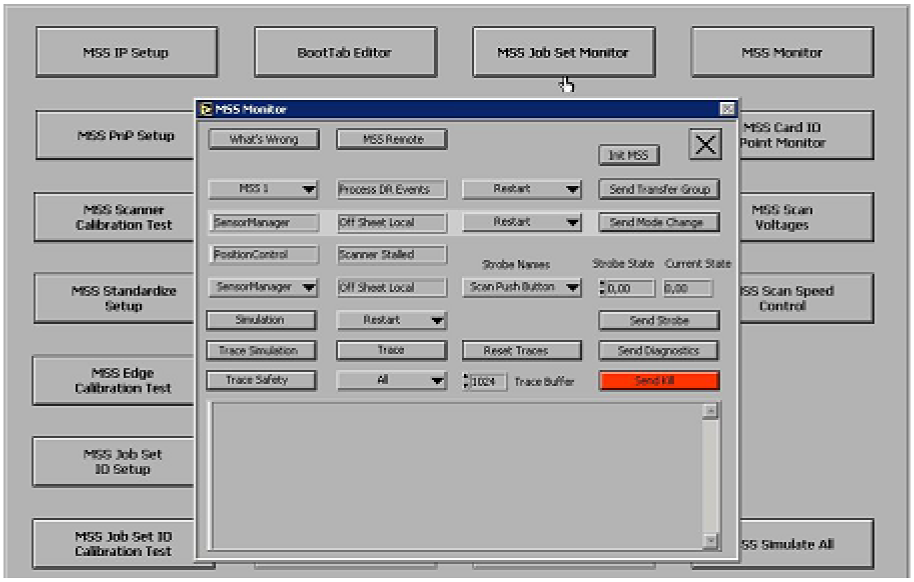
7. Select Cruncher / Build DR Load Files for SysXXXX and click OK.



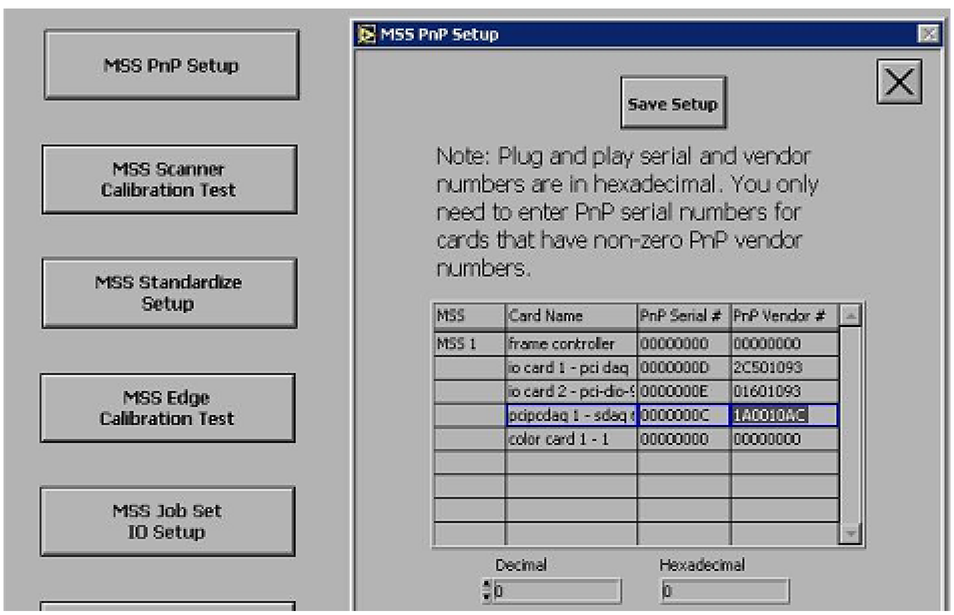
8. Launch RAE and enable new sensor



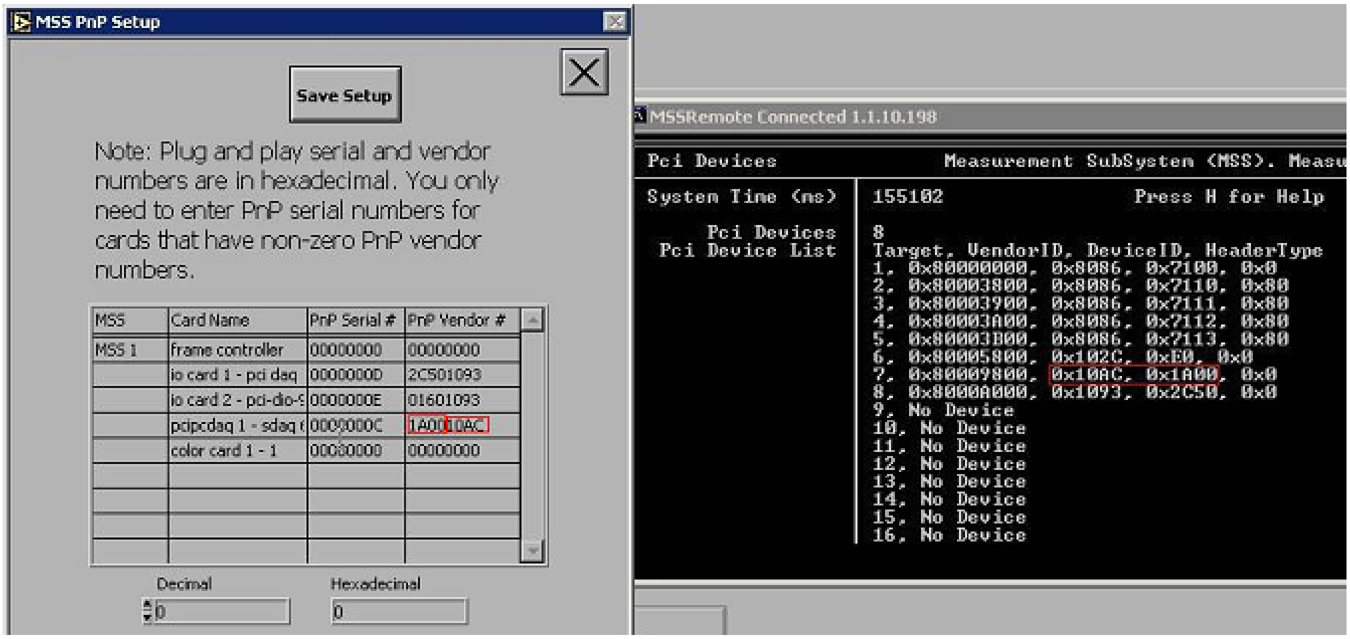
9. Check MSS condition (= process dr events..)



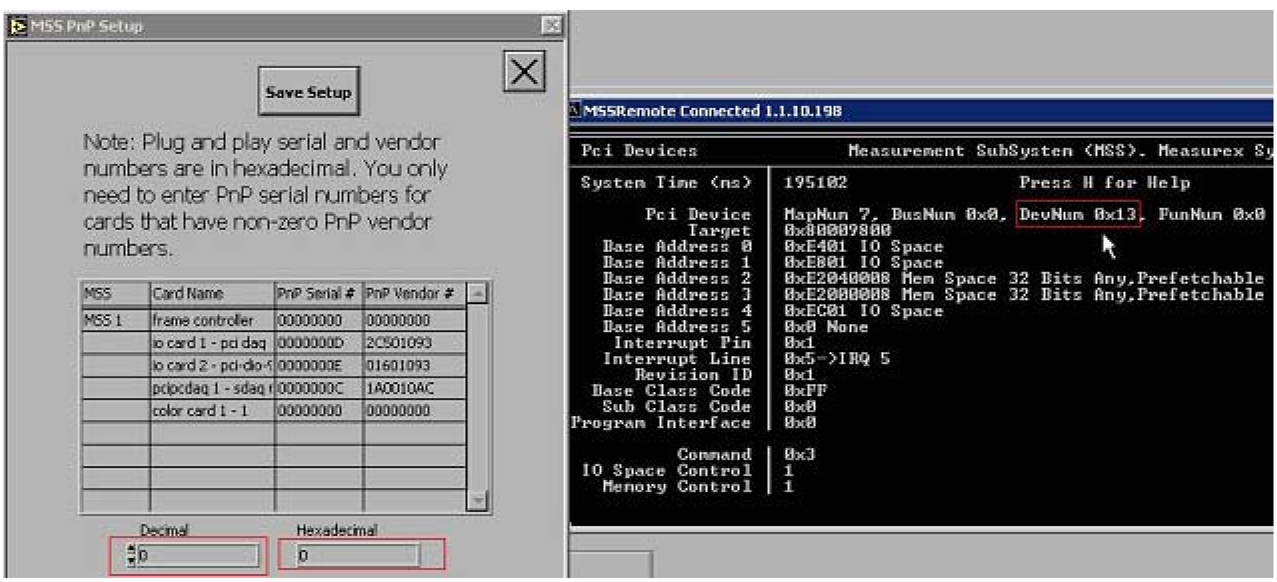
10. Check PnP Serial and PnP Vendor numbers and set them up.



11. Build PnP Vendor number by concatenating VendorID and DeviceID.



12. Build PnP Serial number by converting DevNum xxxx to hexadecimal number.



13. Check that you have signals going OK (here zeros). If OK, PCDAQ/PCI configuration is complete!