fNIR Imager & COBI Studio Manual

Cognitive Optical Brain Imaging Studio

fNIR Devices LLC.

Disclaimer

Neither fNIR Devices LLC. nor any of its worldwide subsidiaries shall be liable in any manner in respect to bodily injury and/or property damage arising from this product or the use thereof if the unit is not operated and maintained in strict compliance with instructions and safety precautions contained herein, in all supplements hereto and according to all terms of warranty and sale relevant to this product.

Caution

This device is limited by United States law for investigational and research purposes only.

Notice to Users: Accident Reporting

The FDA Medical Device Reporting Regulation, 21 CFR 803 and the CE Council Directive 93/42/EEC concerning Medical Devices require that

“the manufacturer of medical devices submit a report to the FDA or local competent authorities whenever he becomes aware of information that reasonably suggests that one of his installed devices:

• May have caused or contributed to a death or serious injury, or

• Has malfunctioned and, if the malfunction recurs, is likely to cause or contribute to a death or serious injury.”

In order for fNIR Devices LLC. to comply with these requirements, all users of this equipment, operators and service technicians, are required to provide the Quality Assurance Manager at fNIR Devices with the following information regarding all reportable events as soon as possible:

1. Identification of the model and serial number.

2. Description of the event. Include whether any serious injury or death has occurred.

Identification of the person who is submitting the information including phone number and fax number if available.

Table of Contents

1. What is in the Box?

Congratulations, you have just received the fNIR Imager, a non-invasive oxygenation and blood volume trend imager. The fNIR Imager is designed to allow you to track relative oxygen consumption as well as changes in blood volume. This manual will enable you to become familiar with the fNIR Imager operation, the technology of the unit, and the software (COBI Studio), which you will use to collect data from the device.

Based on the product type you purchased, your shipment should include one of the following hardware configurations.

fNIR Model 1100 (included in fNIR Systems 100, 200, 300 and 400)

- fNIR control box unit
- AC power supply unit (attached power cable)
- Adult Sensor Pad (attached cable that will be connected to fNIR control box)
- Electric cable between the fNIR control box and the AC power supply unit
- USB cable between the fNIR control box main unit and a personal computer
- DVD with software setup files (COBI Studio and USB drivers)

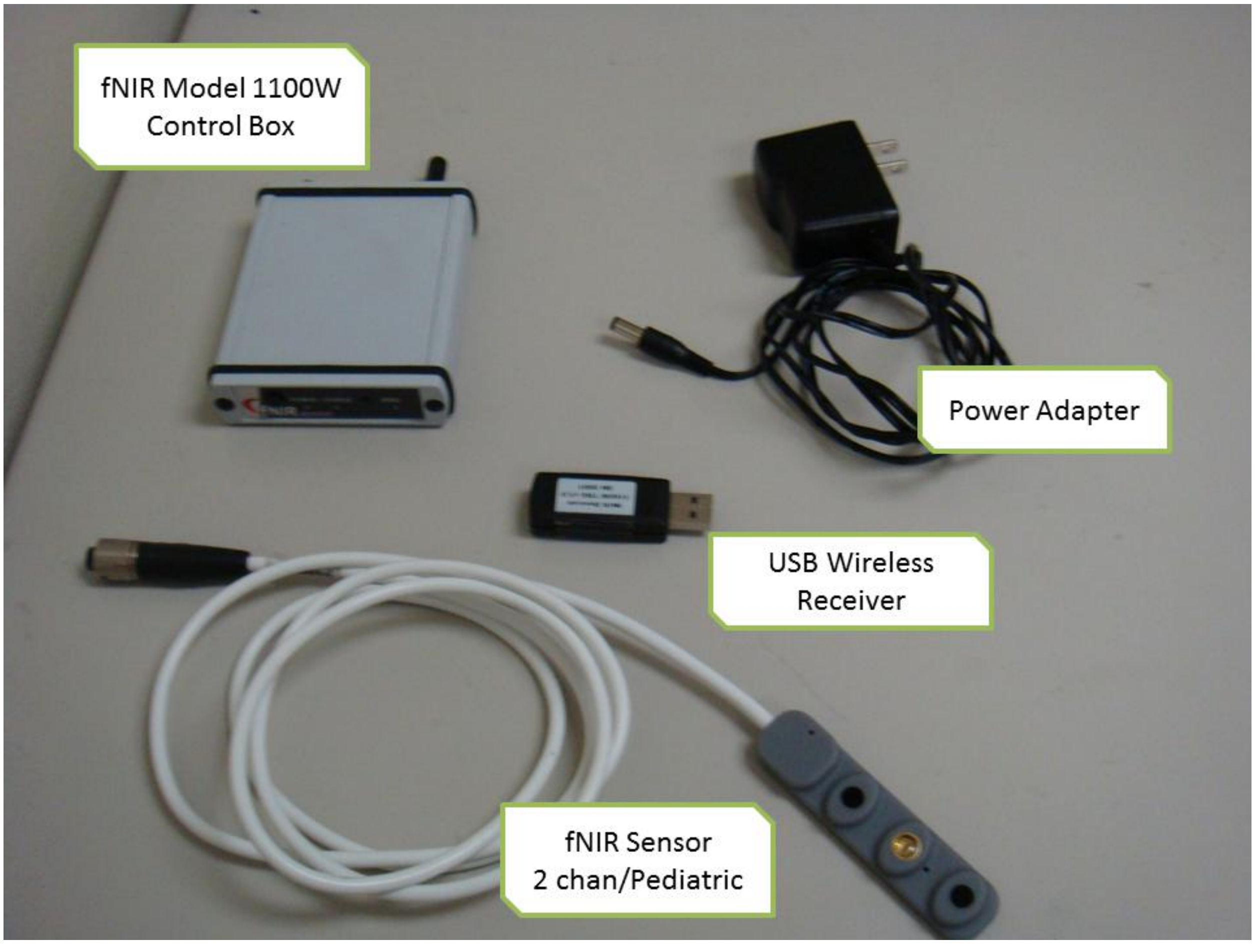
fNIR Model 1100W

- fNIR wireless control box unit
- AC power supply unit (attached power cable)
- Pediatric Sensor Pad (attached cable that will be connected to fNIR control box)
- Wireless receiver adaptor (USB based TRX dongle).
- DVD with software setup files (COBI Studio and wireless receiver drivers)

To operate the fNIR System you will need a personal computer (Desktop or Laptop) with USB (version 2 or higher) port. For more details on computer requirements please see the following section.

fNIR Systems 200, 300 and 400 ship with a dedicated data acquisition computer that is pre-configured and optimized for use with fNIR Imager.

Packaging contents for the fNIR Model 1100



Packaging contents for the fNIR Model 1100W (wireless unit)

Side by side size comparison of fNIR Model 1100 and 1100W

2. Background Information

2.1. Basic Theory of fNIR Imaging

All biological tissue is, to differing extents, permeable to electromagnetic (EM) radiation of different frequencies and intensities. This can also be considered as permeability of biological tissue to photons of different energy levels. This principle constitutes the basis of all imaging techniques that rely on transmission/scattering characteristics electromagnetic radiation, such as x-ray, Computed Axial Tomography (CAT), and photons for Near Infrared imaging. From the principles of spectroscopy, it is also known that different molecules absorb different wavelengths of EM radiation (which is synonymously referred to as light at smaller wavelengths) to different degrees, and likewise scatter that radiation to different degrees. In functional Near Infrared (fNIR) imaging, the molecule of concern is the hemoglobin molecule, which is the oxygen carrier for red blood cells. Since oxygenated hemoglobin, also referred to as oxy-hemoglobin or HbO_2, absorbs light at a slightly different portion of the NIR spectrum than the deoxygenated hemoglobin molecules (usually referred to only as hemoglobin or Hb), it is possible to detect the relative concentrations of the two molecules using optical spectroscopic methods.

Photons emanating from any light source follow a characteristic path through the target tissue back to a detector that lies on the same approximate plane as the source (see Figure 1 below). While the light is severely attenuated due to the scattering and absorption processes, it is nonetheless encoded with the spectroscopic signatures of the molecules encountered en route to the detector. By carefully choosing the wavelengths that are produced by the source, it is possible to detect the relative concentrations of Hb and HbO_2 in the target tissue. By comparing these levels to those obtained when the tissue is in its “baseline” state, and using some basic knowledge about “interesting” conditions for the tissue, it is possible to draw conclusions from systematic changes observed in these levels.

As a more concrete example, one may consider fNIR imaging of breast tissue. Here, the baseline condition of the breast tissue corresponds to its normal, healthy state. The interesting condition is the cancerous tissue. Since it is known that such tissue grows uncontrollably, the tissue must metabolize more than the baseline tissue. Therefore, to scan for tumors, one looks for concentrated areas of unusually high respiration levels.

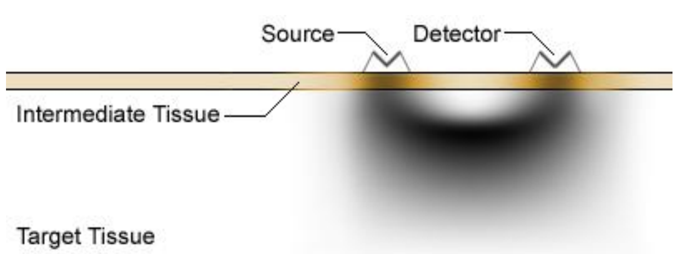


Figure 1. Simulated photon diffusion path through target tissue from source to detector. This simulation shows the photon path density, not the overall transmission level.

2.2. The Mathematical Basis of fNIR Imaging

At the heart of the calculations used with fNIR imaging is the Beer–Lambert Law, which defines a linear relationship between absorption of EM radiation and the concentration of the target absorptive material in a given medium. The full law includes factors accounting for the absorption coefficient (wavelength dependent) and path length. Though originally defined for transmittance, it can be shown to be effective for diffusion/scattering as well. The measurements are initially taken in terms of received photon concentration, which can loosely be termed the “received power.” For biological fNIR imaging use, baseline data is first gathered. This reading is considered the “transmitter power.” Given these values, we can write the law as:

$$Absorbance = -\log\left(\frac{received\ power}{transmitted\ power}\right)$$

Since the law itself is linear, the total absorbance of any species is the sum of the absorbances of that species for each wavelength. Using these properties of the law, it is possible to take the received photon densities to calculate the Hb and HbO_2 levels in the target medium in relation to the levels at baseline. This is a point that bears reiterating. The levels of Hb and HbO_2 measured are relative to the baseline only. It is not possible to arrive at absolute values of concentration using fNIR imaging on living samples. Once the Hb and HbO2 levels are computed, they are used to calculate the levels of oxygenation (in μM), and values that may be approximately treated as percent changes in blood volume. The formulae are as follows:

$$Hb = c_{empirical}\frac{od_{850}\cdot\varepsilon_{HbO_2,730} - od_{730}\cdot\varepsilon_{HbO_2,850}}{\varepsilon_{HbO_2,730}\cdot\varepsilon_{Hb,850} - \varepsilon_{HbO_2,850}\cdot\varepsilon_{Hb,730}}$$

$$HbO_2 = c_{empirical}\frac{od_{730}\cdot\varepsilon_{Hb,850} - od_{850}\cdot\varepsilon_{Hb,730}}{\varepsilon_{HbO_2,730}\cdot\varepsilon_{Hb,850} - \varepsilon_{HbO_2,850}\cdot\varepsilon_{Hb,730}}$$

$$blood\ volume = HbO_2 + Hb$$
$$oxygenation = HbO_2 - Hb$$
$$od:\ Optical\ density,\ obtained\ from\ Beer\text{-}Lambert\ law$$
$$\varepsilon:\ Extinction\ coefficient\ for\ given\ wavelength\ and\ molecule$$
$$c_{empirical}:\ Empirical\ adjustment\ value\ for\ the\ machine$$

3. Introduction

Cognitive Optical Brain Imaging (COBI) Studio is a hardware integrated software platform that enables users to acquire process and visualize fNIR signals. Figure 2, below depicts the components of the current fNIR Model 1100 system. And, Figure 3, depicts the system components of fNIR Model 1100W.

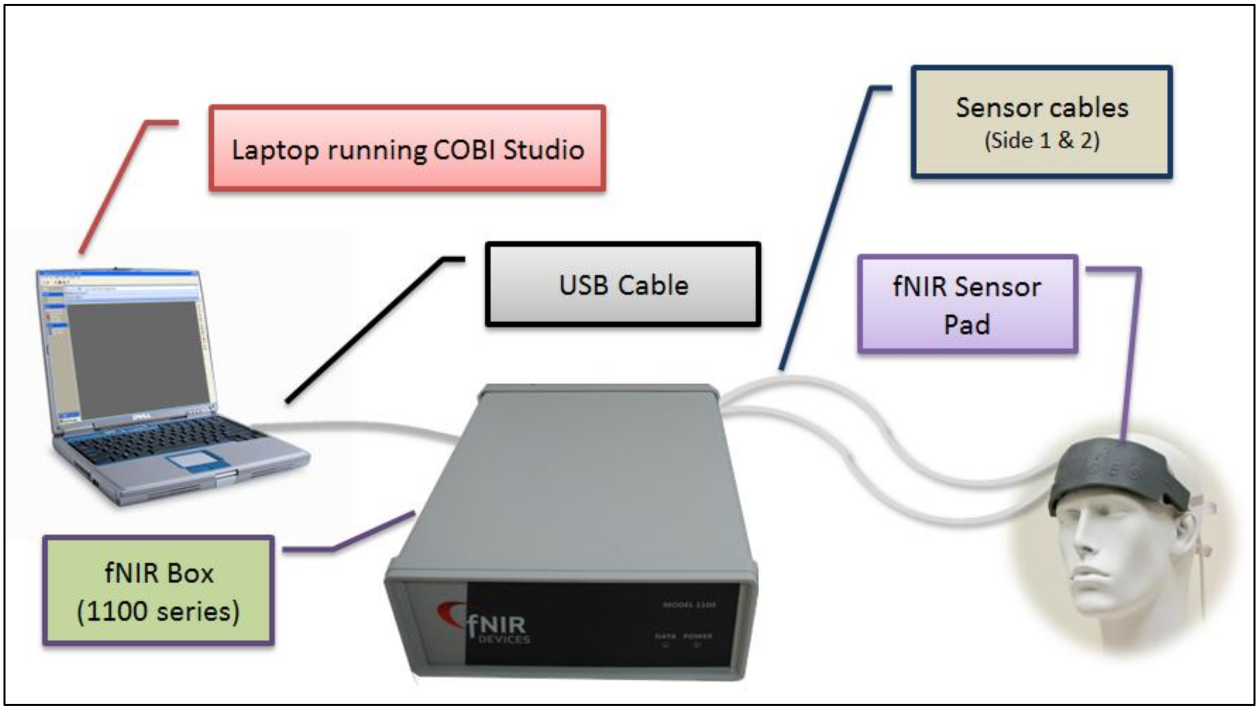


Figure 2 Components of fNIR Model 1100 System

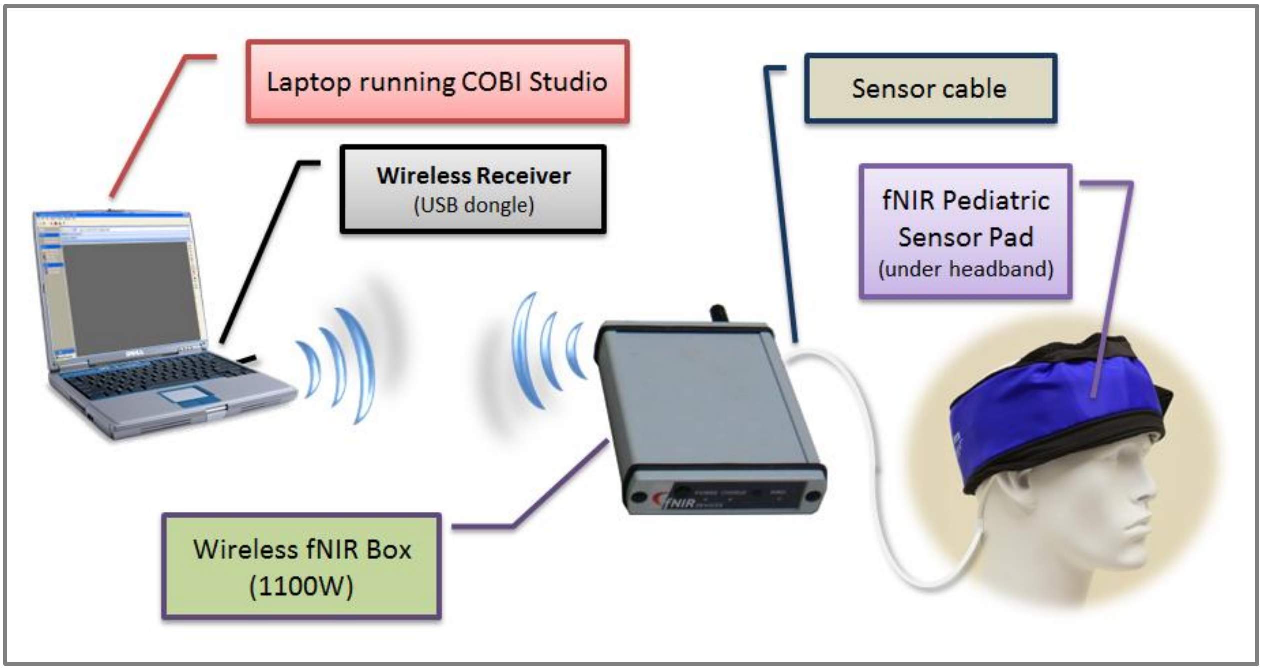


Figure 3 Components of fNIR Model 1100W System

COBI Studio is an extendable software environment that uses dynamic link libraries to facilitate selected key features at run time. A dynamic link library that interacts with the sensory hardware or any other source of data is defined as the **COBI device** or device; which are basically data adapters. By selecting different devices at run time, a user can change the data source. Devices that are currently available are those that collect data from fNIR Imager hardware, from a TCP/IP port – wireless network, a file in computer HDD– network share or a simulator (creates artificial data for simulation). Adding different COBI devices will enable COBI to interact and collect data from new kinds of physical devices.

COBI Studio has a configurable user interface. Users can adjust the view and change visualization options to accommodate their needs. COBI Studio provides several customizable tools; including 2D graphs and topographic views in order to visualize data. A user can select and place these tools into the current view. The placement of these tools, the data integration structure and the view of the COBI program is defined as the **COBI layout** or layout. A user can create new layouts, save the current layout, or load and edit layouts from files. The layout provides a customizable way for users to interact with data.

The main screen, as shown in Figure 4, highlights the various options available for the user including a main menu, toolbars and side pane for general commands and settings, and a layout area for visualization of raw or oxygenation data by graphs.

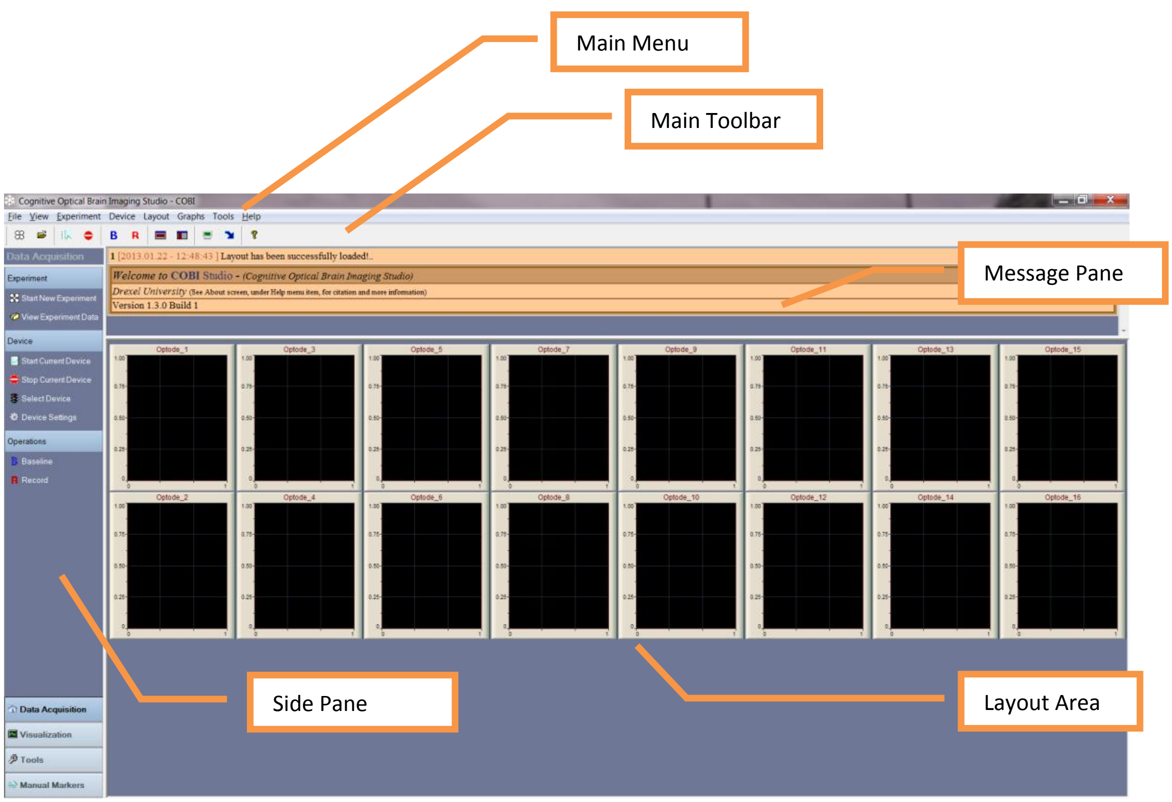


Figure 4. COBI main window and components

3.1. Requirements

System Requirements are as follows:

1. CPU: 2GHz or better processor, recommended quad-core.
2. Memory: Minimum system RAM of 1GB, recommended 2GB or more.
3. Operating Systems: Windows XP, Windows Vista, Windows 7 and Windows 8

For fNIR hardware interface:

4. USB 2.0 ports
5. National Instrument NIDAQmx driver

For Network interface:

6. Wireless or LAN Network adapter

4. Setup

The setup process includes installation of National Instrument USB Driver and installation of COBI Studio to the computer that is going to be used with fNIR Imager. COBI Web Update utility can be used to check and download updates for all COBI Studio modules. After installation, one time settings are required for COBI Studio to operate the fNIR Imager.

4.1. USB Driver Installation (Model 1100)

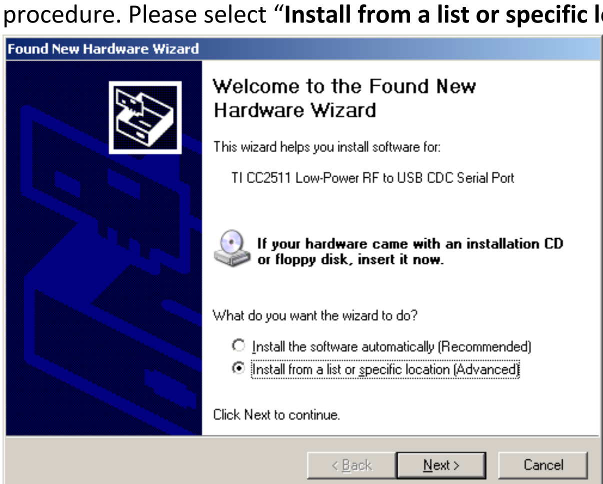
WARNING: Do not connect the device (USB cable) to the computer before installing the National Instrument USB driver (NIDAQmx).

1. Run 'Setup.exe' in the following folder of the disc: \Driver\USB
2. Follow onscreen directions. (click next)
3. Once the installation ends, restart the computer.
4. Connect USB cable from fNIR Imager to the computer (while fNIR Imager is powered). The computer should identify and finalize driver installation

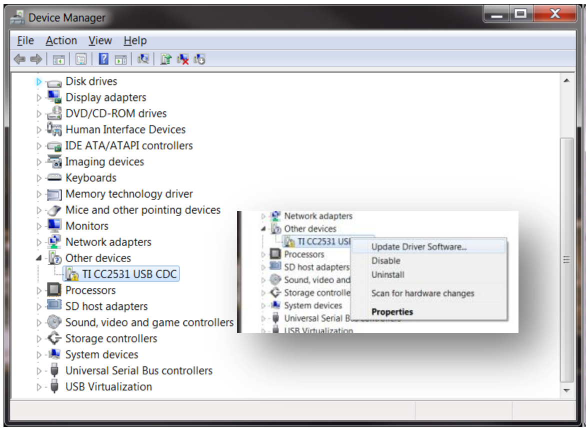
4.2. Wireless Receiver Driver Installation (Model 1100W)

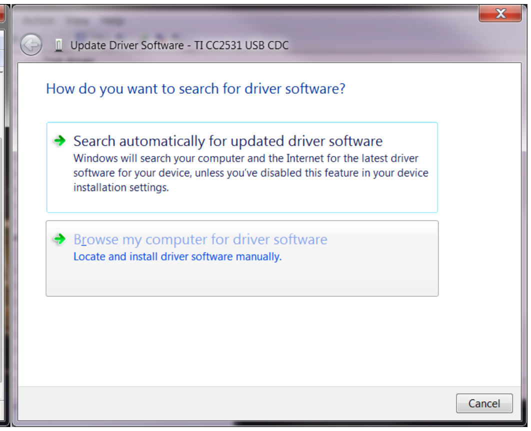
1. Driver files are located at the following folder of the disc: \Driver\Wireless
2. Plug the USB-dongle (receiver) into the computer. When plugged first time, the following notice will appear

3. The Windows installation Wizard will start and guide the user through the driver installation procedure. Please select “**Install from a list or specific location**” as shown below.

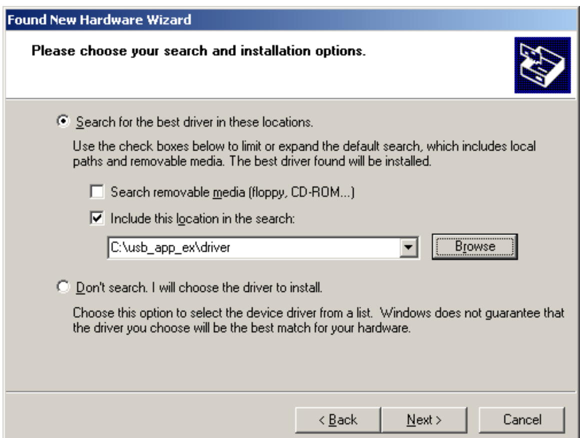


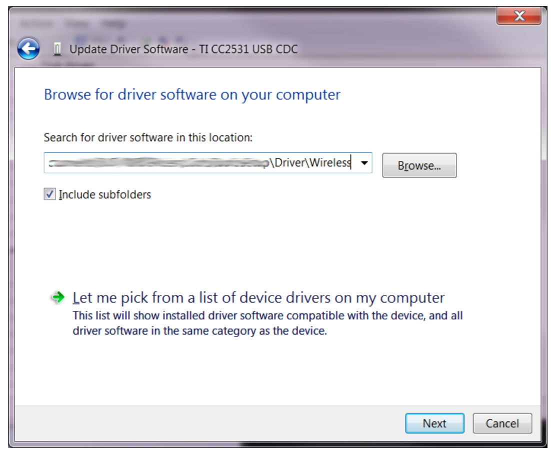
Note: Driver update can also be initiated from Device manager.



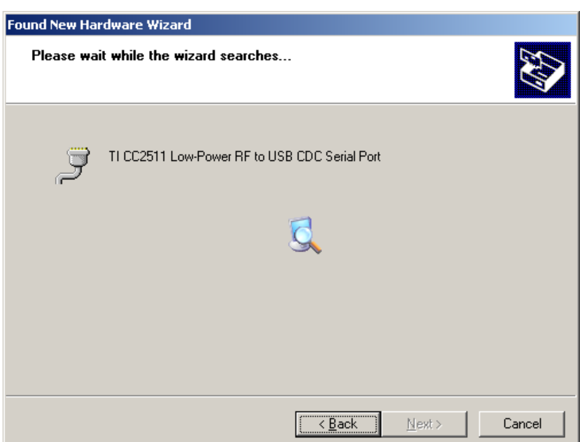


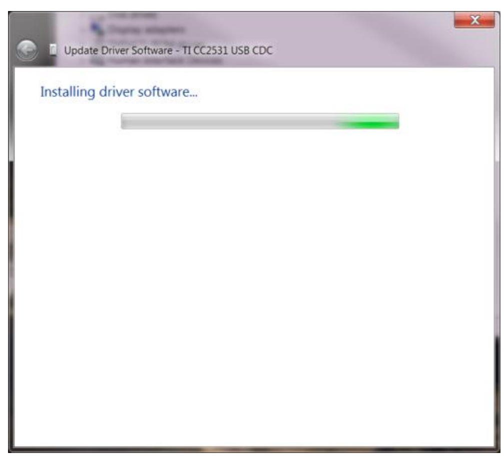
4. Click ‘Next’ to advance to the next step. Select “Search for the best driver in these locations” as shown in Figure 3. Make sure that the wizard searches the driver directory on the disc containing the driver file: usb_cdc_driver_cc2531.inf.



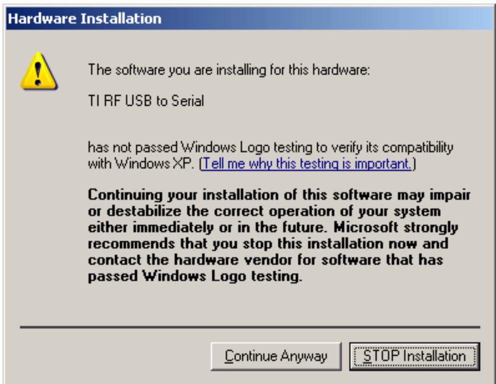


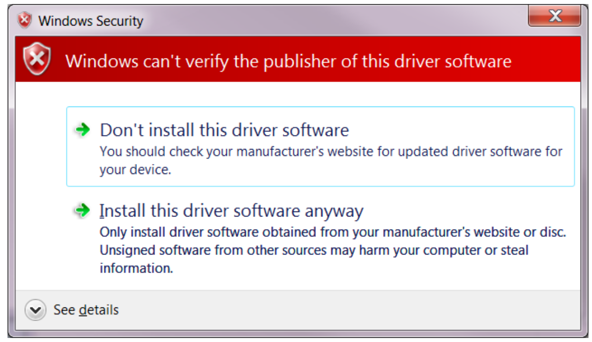
5. Click Next to advance to the next step. Windows will now search for the driver which may take some time.



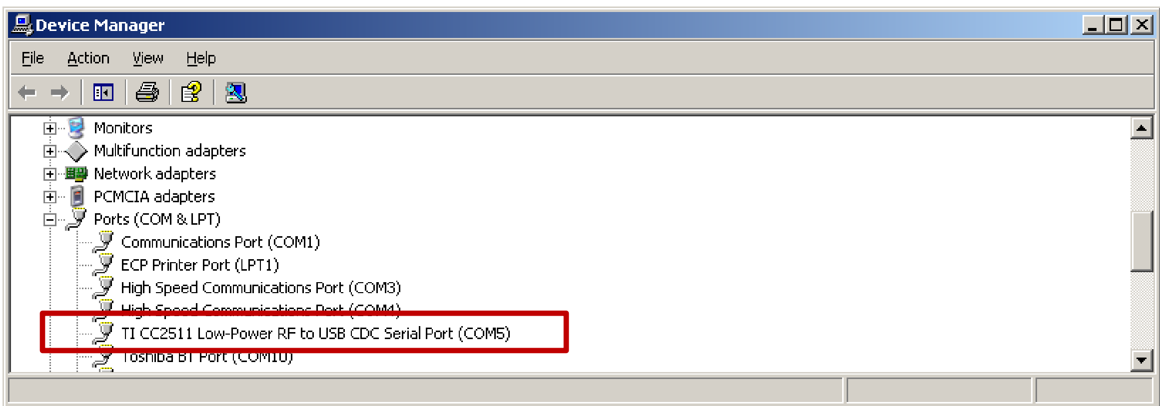


6. You are now likely to encounter one of the warning dialogs shown below. If that’s the case you can safely click ‘Continue anyway’ or ‘Install this driver’ and the installation will be complete.

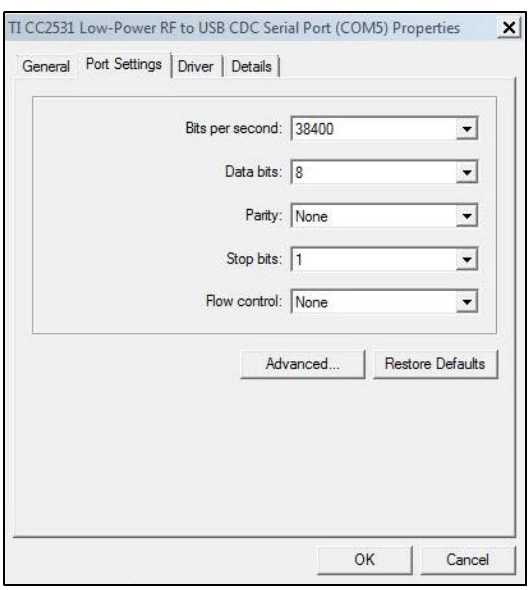




7. When Windows has finished installing the device, a new serial port will show in the device manager in Windows. See below.

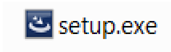


8. The Virtual COM-port is now ready and can be used as any standard serial port. Right-click on the installed CDC Serial Port, select "Properties" and then the "Port Settings" tab. Configure as shown below. Configure COBI to use the same COM port and settings.

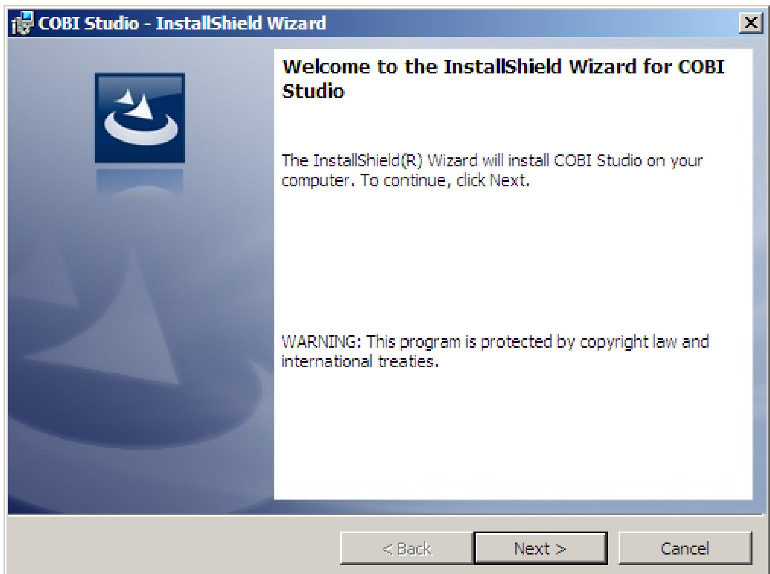


4.3. COBI Studio Installation

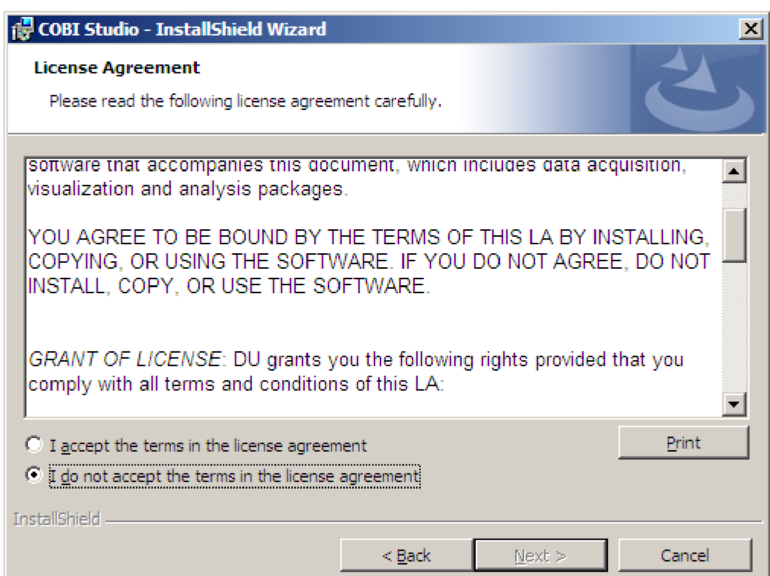
1. Run setup.exe file by double clicking on it.



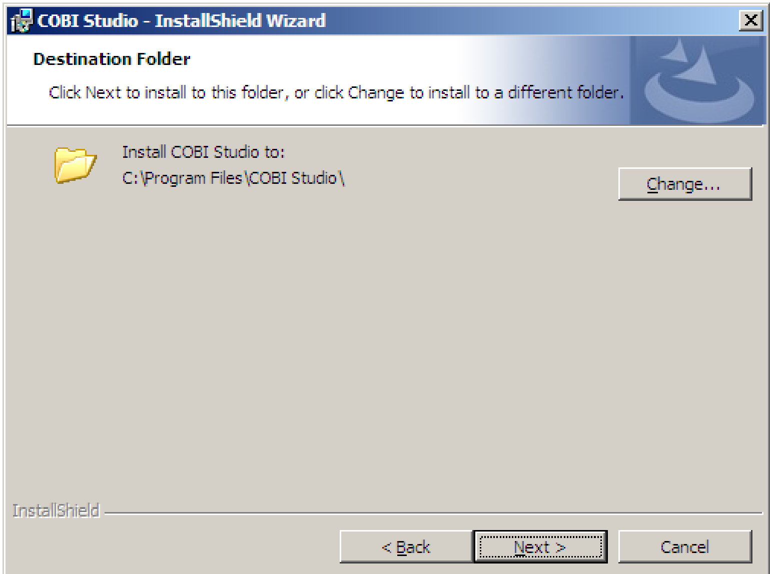
2. Press *next* to start installation procedure.



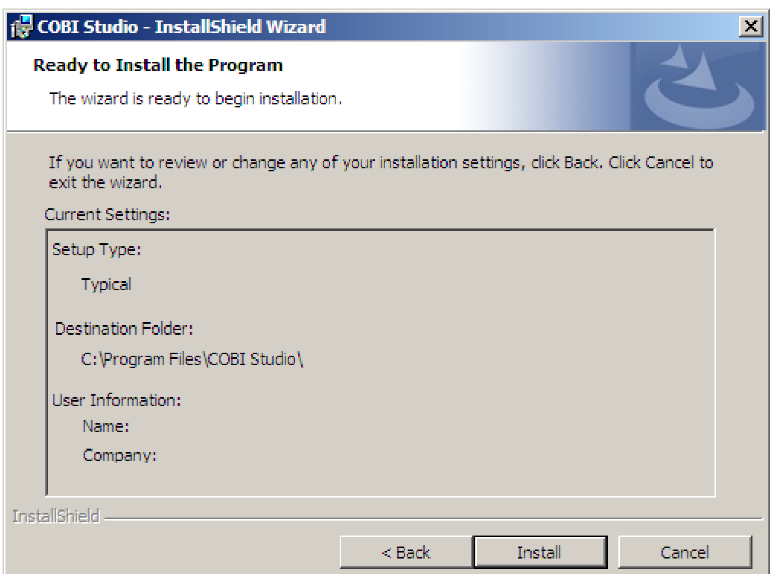
3. Please read the license agreement and accept the conditions of the agreement to continue with the installation.



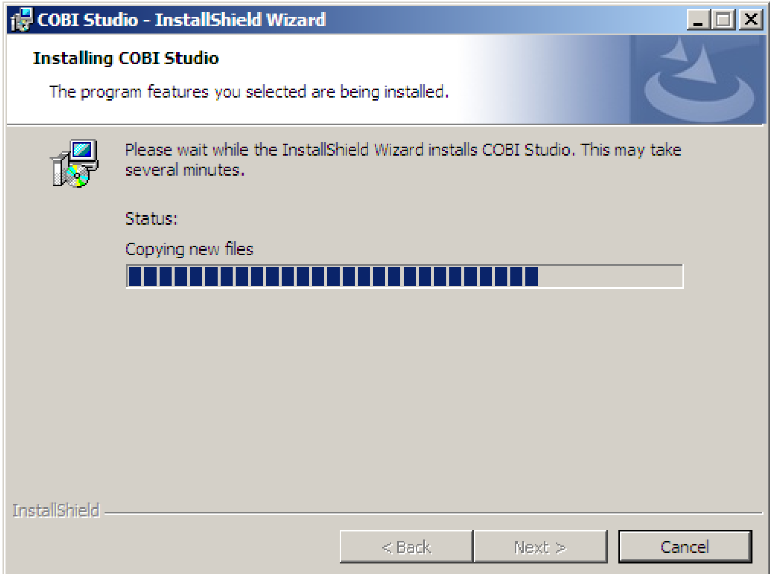
4. Press *next* to accept installation folder.



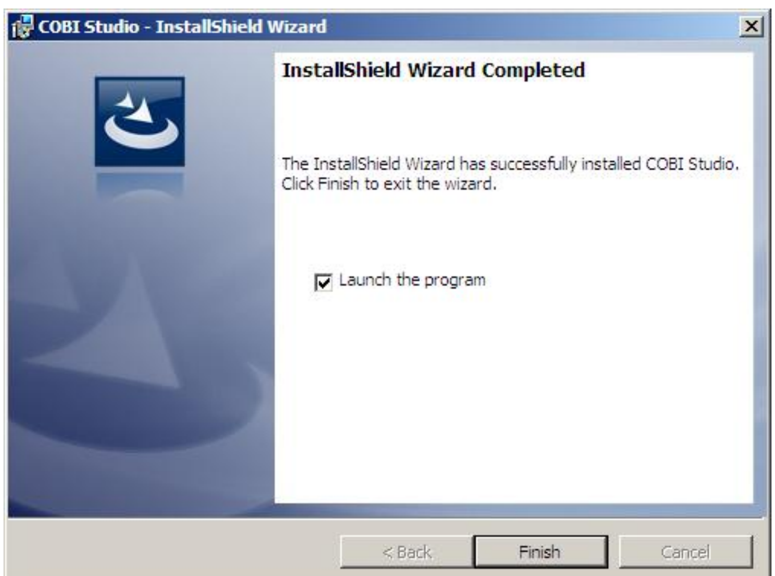
5. When you are ready, press *next* to confirm the settings and copy the files.



6. Progress will be shown as follows during the installation.

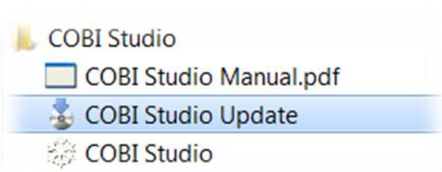


7. Finally, you should receive the following end message. If the "launch the program" is checked, COBI Studio Update tool will be executed to check for any updates (See next section).



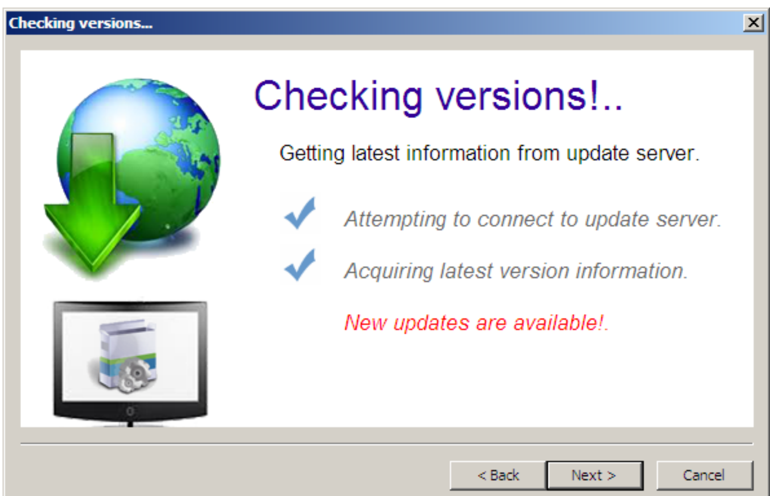
4.4. Web Update

1. Press *close* to finalize setup. Next, please run '*Start>COBI>Update from Web*' to get the latest versions

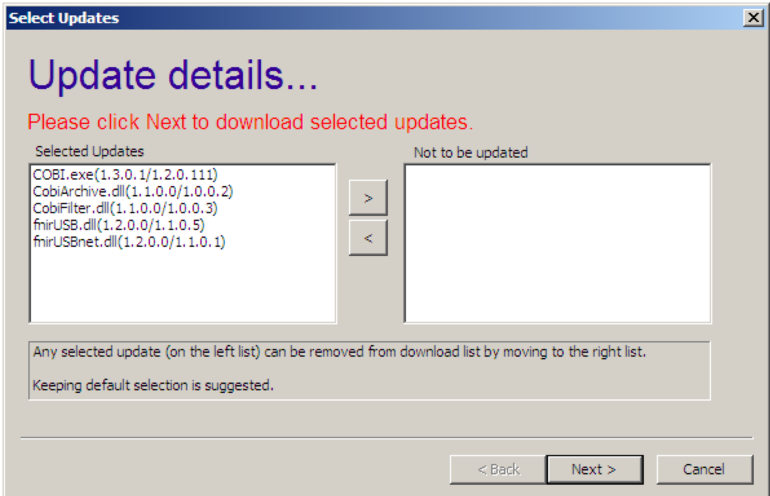


2. Web Update tool will appear as follows. Make sure you are connected to internet and close COBI Studio.

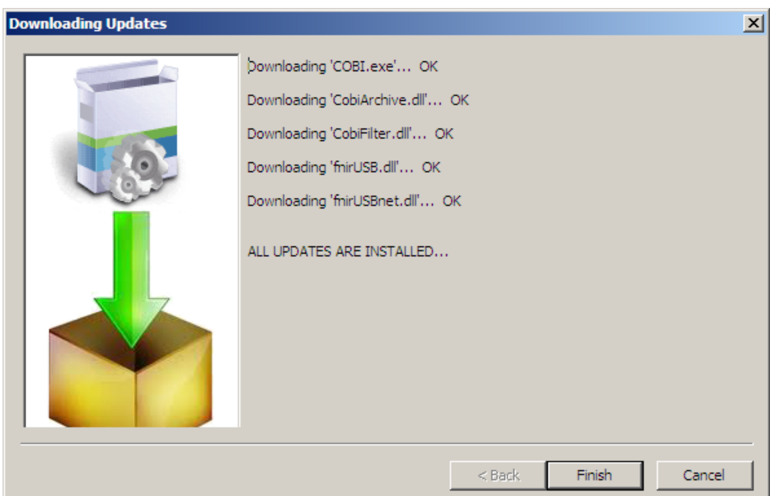
3. If you have updates available, the following screen will appear. Otherwise, Update tool will tell you that all files are up-to-date.



4. Available updates and the version numbers are listed. You can edit the list and select only the updates you want.



5. Finally, when the updates are downloaded, the following message as shown in the figure below is displayed. Some updates may require update application to restart.

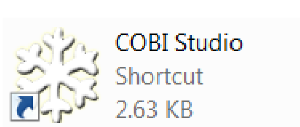


4.5. Initial Settings for COBI Studio

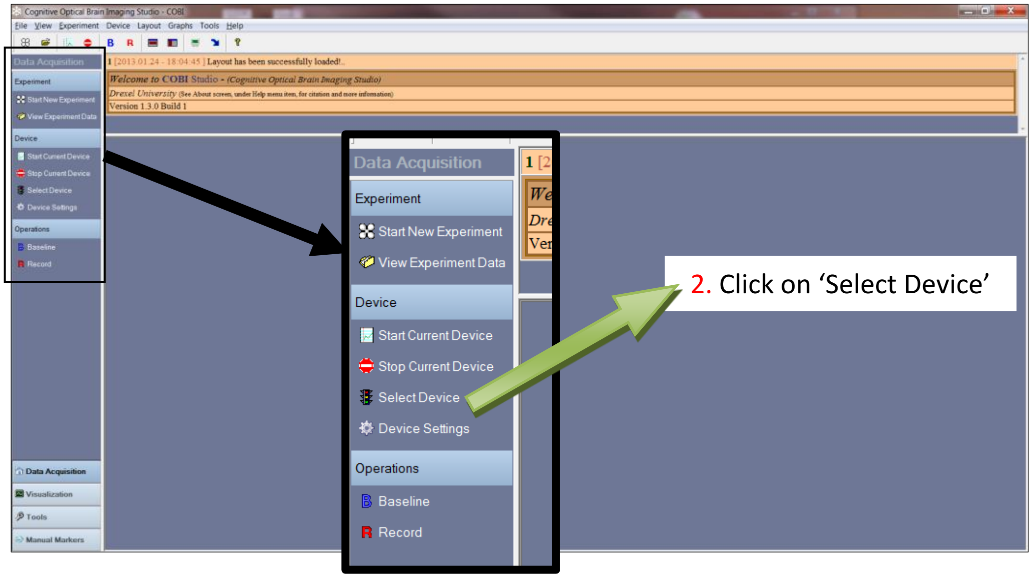
After a new installation, the following settings are required for COBI Studio to operate the fNIR Imager. These are one-time settings, and will be kept until the user changes them.

After the installation:

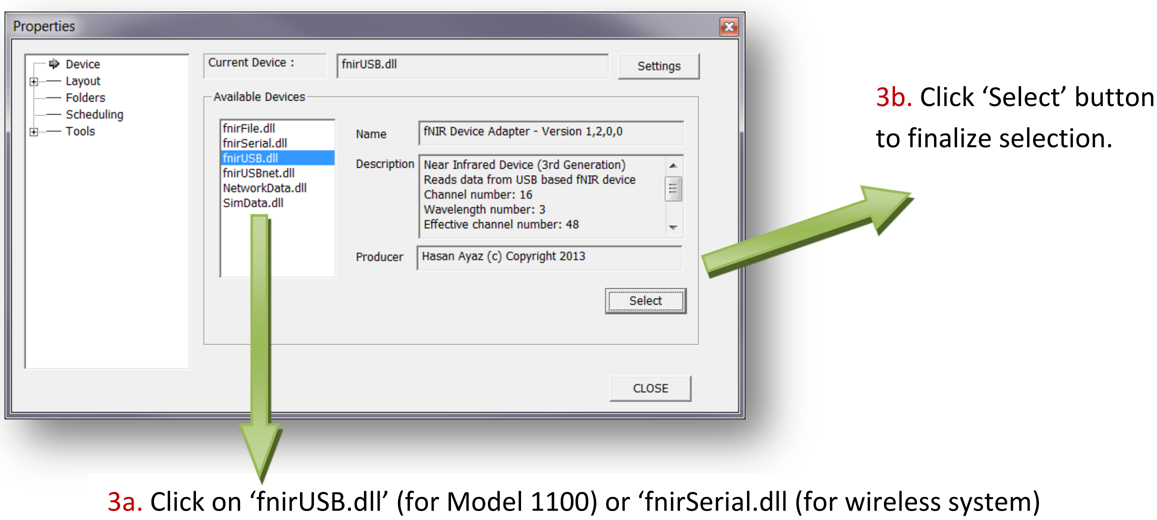
1. Launch the COBI Studio either by double clicking the shortcut on the desktop or selecting '*Start>COBI>COBI Studio*' from Windows Start Menu.



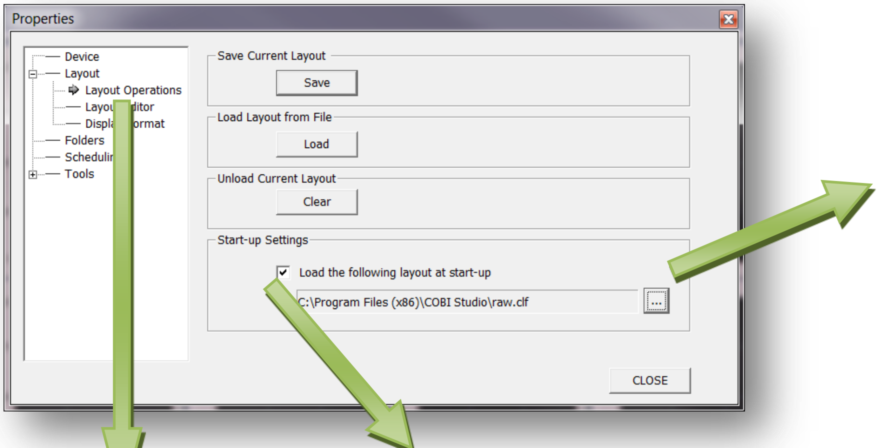
2. On the main window, Click on 'Select Device' from side menu (on the left hand side)



3. Select 'fnirUSB.dll' from the list and click 'Select' button (If fnirUSB.dll is not in the list, the driver installation was not completed.) For wireless system, select fnirSerial.dll (and make sure the same com port as driver is selected).



4. On the same window, on the left, go to *Layout>Layout Operations*
5. Check 'Load the following layout at start-up'



6. Click '…' button and select on the open file dialog, select 'raw.clf' that is in the COBI installation folder.

5. Check 'Load the following layout at start-up'

4. Select Layout>Layout Operations

6. Click on '...' button and select 'raw.clf' under the COBI Studio Installation Folder. (This folder is usually c:\Program Files\COBI Studio)

7. Click 'Close' button and restart COBI Studio

5. Operating Procedure

This section summarizes the main steps for operating fNIR Imager collecting data with COBI Studio.

5.1. Applying the Adult Sensor

Applying the sensor pad correctly is the most important step in getting good data.

Depending on the subject's hair length, a hair band can be used to hold the subject's hair. Then, pull the subject's hair back with one hand and gently hold the sensor pad with the palm of your other hand to place onto the subject's forehead. DO NOT STRAIN THE WIRES ON THE SIDES OF THE SENSOR PAD; INSTEAD USE STRAPS (two on both sides and cord locks) TO POSITION THE SENSOR; MAKE SURE THAT THE CONNECTOR EDGE "1" IS ON THE LEFT SIDE OF THE SUBJECT'S FOREHEAD.

Keep the sensor pad on the forehead and maneuver the two cables to the back of the subject's head. Stay in this position while you fasten the two cables (from two connectors of sensor pad) all the way around the subject's head, and then use a clip to keep them in place. Use the cord locks with the cloth straps and adjust the tightness to make tight fit while comfortable for subject. Make sure that the headband is tight and the sensor makes good contact with the forehead, but it must not be too tight or it will constrict blood circulation. Finally, place an opaque cover (e.g. headband, cap or tape) over the subject's head, to keep out the extraneous light (i.e. sunlight). If possible, dim the lights or cover windows in the examination room during the test.

5.2. Applying the Pediatric Sensor

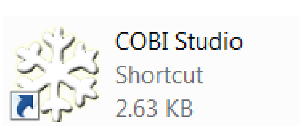
Applying the pediatric sensor similar to the adult sensor, except, it is smaller and localized. Use a flat strap to tie around the head for positioning the sensor. Placing an opaque elastic headband or cap over the sensor could help preventing ambient light reaching the sensor and also help fixating its position. Make sure that the headband is tight and the sensor makes good contact with the forehead, but it must not be too tight or it will constrict blood circulation.

5.3. Binding Procedure (wireless system)

1. Insert wireless receiver dongle (TRX wireless USB adaptor) into a PC USB port. Verify the COM port assignments in COBI Studio and the Windows Device Manager match.
2. Power on the 1100W unit transmitter.
3. Press the "BIND" button on the wireless adaptor ONCE.
4. Press the "BIND" button on the 1100W transmitter ONCE.
5. Verify the red "BIND" indicators on both the 1100W transmitter and the USB wireless adaptor.
6. System is ready to operate.

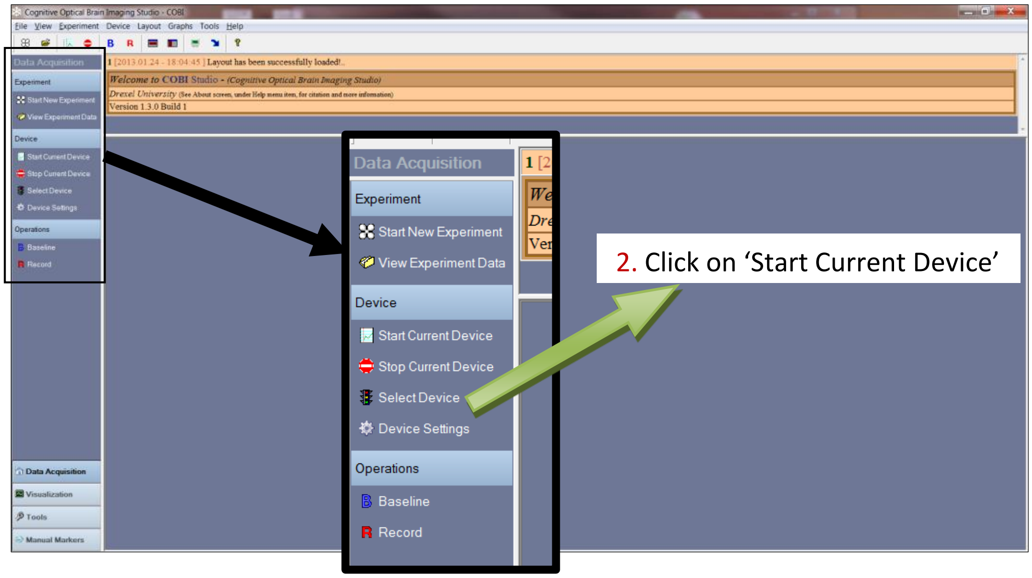
5.4. Starting COBI Studio

1. Launch the COBI Studio either by double clicking the shortcut on the desktop or selecting *'Start>COBI>COBI Studio'* from Windows Start Menu.



2. On the main window, click on 'Start Current Device' from side menu (on the left hand side)

   NOTE: Make sure, fNIR Imager is powered on and is connected to the computer and the sensor pad.



Once the current COBI device (fnirUSB.dll) is successfully started to operate the fNIR Imager, the following messages appear at the message pane of the main window:

- [fnirUSB.dll] Dev1: NI USB 6221 will be used for data acquisition
- Started device *fnirUSB.dll* ....

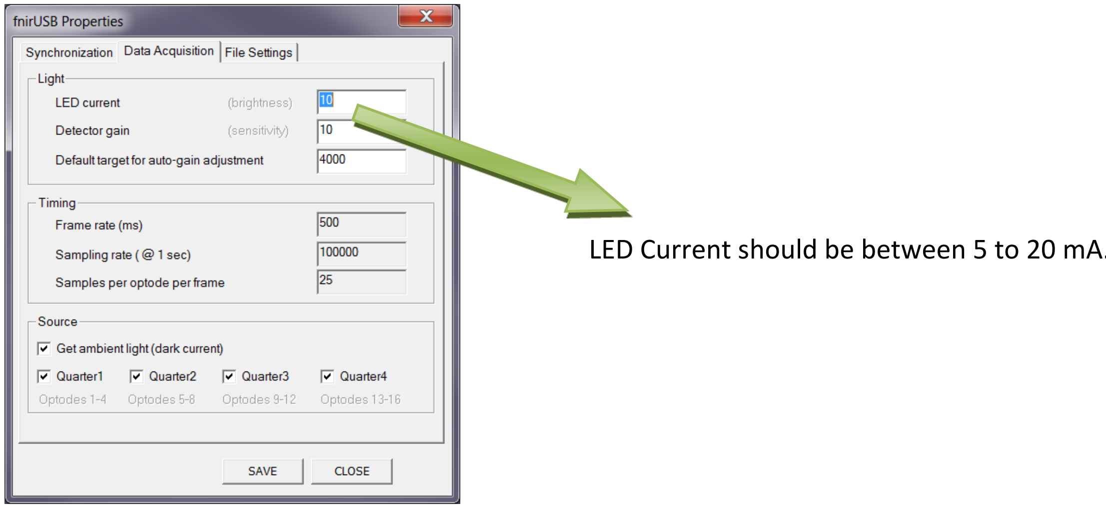
And, graphs start being updated to show new data.

3. Wait for signal traces to stabilize. If any of the values in the box on the top left are high (> 4000mV), the sensor pad is not in contact to the subject. The sensor pad needs to be tightened slightly. If the values are low (< 400mV), check for hair under the sensor.

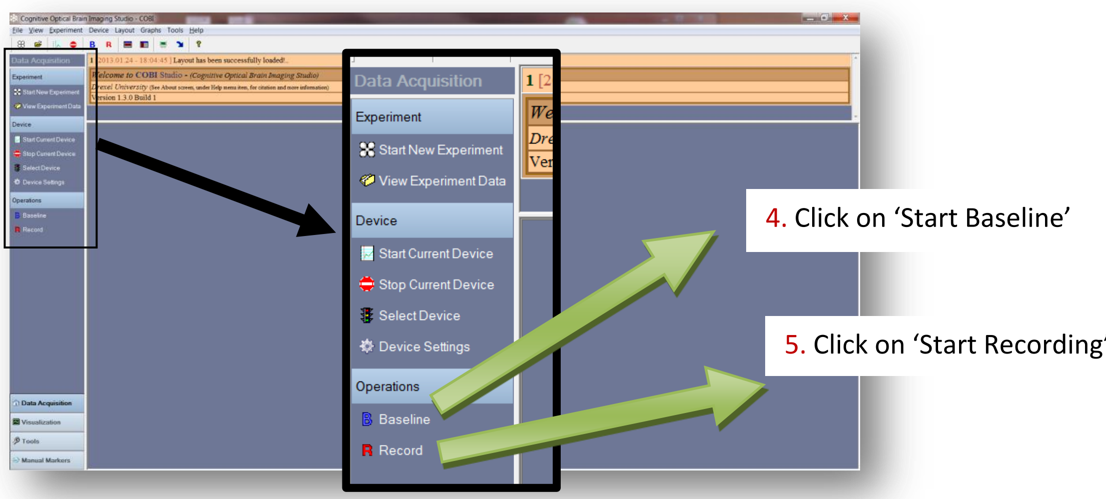
NOTE: Depending on different contours, positions, and skin color of the subject several device parameters may need to be changed. To do that, first "Stop Current Device", and then click "Device Settings" at the side pane.

The following window will appear. In the 'Data Acquisition Settings' tab, you can view and change a couple of parameters. 'LED Drive Current' should have a value in between 5mA to 20mA. Larger values will result in brighter light and will increase the signal levels.

For more information about fnirUSB.dll properties, see page 42. After you type in a value, click on the 'Save' button and go to step 2 (to re-start data acquisition).



4. As verified in step 3, if signal levels are acceptable, click on ‘Start Baseline’ on side pane. After 10 seconds, baseline will automatically end. Baseline signal levels will be used to calculate oxygenation via Modified Beer Lambert Law. Baseline start and end messages will appear on the message pane.



5. After baseline is ended automatically (can be seen at the message pane), click on ‘Start Recording’ on side pane. Message pane should display ‘Recording…”. After this point, all data will be saved to the specified data file. For more information about data file structure, please see page 43.

WARNING: No data is saved to file unless ‘Recording’ is started. Recording event can be scheduled to start right after baseline completion. See View>Scheduling menu item options.

NOTE: Data file to be used (file name, etc.) can be specified at the 'File Settings' tab of 'Device Settings' window before data acquisition is started. 'Device Settings' window can be accessed by clicking on 'Device Settings' on the side pane. **WARNING:** The same filename will be used Use 'experiment mode' to automatically name and organize data files. See page 30 for more information about 'experiment mode'.

6. After recording is started, subject can perform the experiment protocol.
7. After the experiment protocol is finished, click 'Stop Current Device' to stop data acquisition. The following message should be displayed at the message pane:

 - Stopped device *fnirUSB.dll* **!**

WARNING: If you are not using the 'Experiment Mode', it is recommended to copy the data file to a new folder, since if you re-start data acquisition (using the same file settings), the previous data file will be overwritten. For information about the 'Experiment mode', see page 30.

6. Basic Configurations & Settings

Basic configurations include configuring the data adapter, layout, device settings and finally beginning the data acquisition. Please note the various settings dialogs referred below can also be accessed via the top menu or the toolbar, but the easiest access is through the side pane. In addition, any error messages, guiding information and reports are displayed in the message pane.

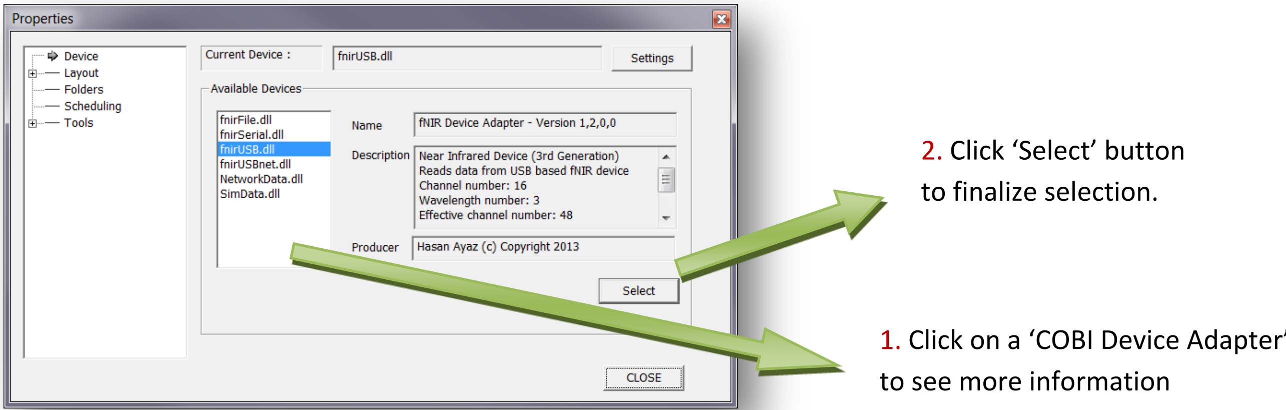
6.1. Configuring Data Source

COBI can be configured to acquire data from different sources. A dynamic link library that interacts with the sensory hardware or any other source of data is defined as **COBI device** or device. In Table 1 below, a description of each available device is provided.

Table 1. Summary of the COBI Devices that comes with the installation

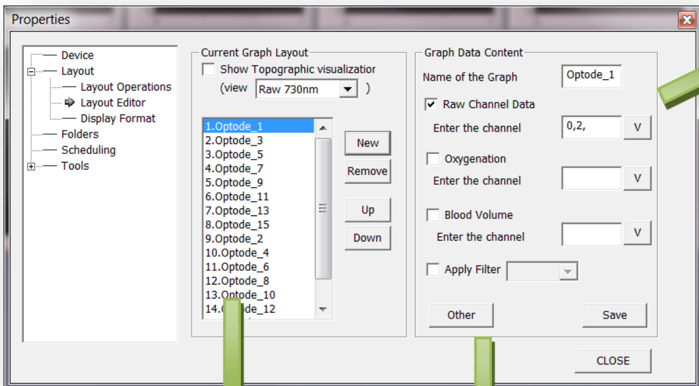
COBI Device	Description
fnirUSB.dll	For data acquisition from fNIR Imager hardware through USB port
fnirUSBnet.dll	For data acquisition from fNIR Imager and broadcasting over network
fnirSerial.dll	For data acquisition from wireless fNIR device through wireless dongle
fnirFile.dll	For loading/replaying existing fNIR data file from hard-disk
SimData.dll	For viewing simulated/artificial data to test
NetworkData.dll	For data acquisition through local/internet network from fnirUSBnet.dll

To see or change the current COBI device, click on "select device" on the side pane. The following window will appear that displays the available devices list.

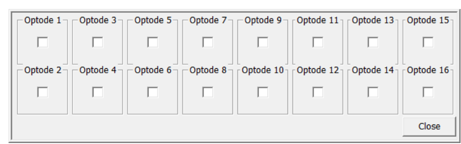

Properties
Device
Layout
Folders
Scheduling
Tools
Current Device :
fnirUSB.dll
Settings
Available Devices
fnirFile.dll
fnirSerial.dll
fnirUSB.dll
fnirUSBnet.dll
NetworkData.dll
SimData.dll
Name
fNIR Device Adapter - Version 1,2,0,0
Description
Near Infrared Device (3rd Generation)
Reads data from USB based fNIR device
Channel number: 16
Wavelength number: 3
Effective channel number: 48
Producer
Hasan Ayaz (c) Copyright 2013
Select
CLOSE
2. Click 'Select' button
to finalize selection.
1. Click on a 'COBI Device Adapter'
to see more information

6.2. Configuring Layout

COBI Studio allows users to setup customized layouts that include temporal and spatial graphs, their numbers, locations, data binding settings and visual settings. Once a custom layout is configured, it can be saved as an individual layout file and can be loaded later. Layout Manager is the tool to edit/load/save layouts. Layout Manager can be accessed from the LM toolbar button or from the side pane. Notice the list on the left-hand side that allows browsing to other settings.

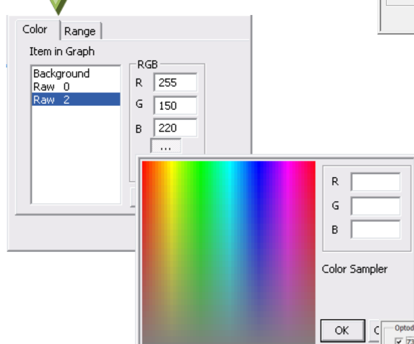


Data-binding can be set manually by typing the channels separated by a comma, or automatically using the dialogs below (by clicking the V buttons).

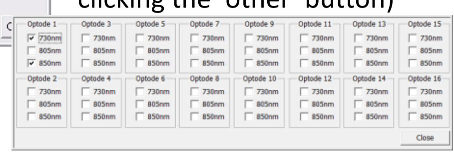


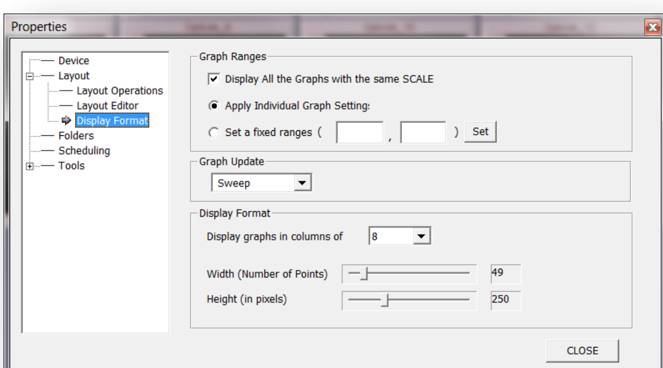
Click on an item (graph) to see its settings on the right-hand side. You can add new graphs or remove existing ones. The order can also be changed using 'up' and 'down' buttons.

Topograph can be added or removed and its contents (raw channels, oxy or BV can be selected at the top of the dialog.



Colors of individual channel lines, background and ranges can be set for each graph by using the dialog on the left (by clicking the 'other' button)





To view this dialog click on the '**Display Format**' item either on the left-most menu or at the side pane.

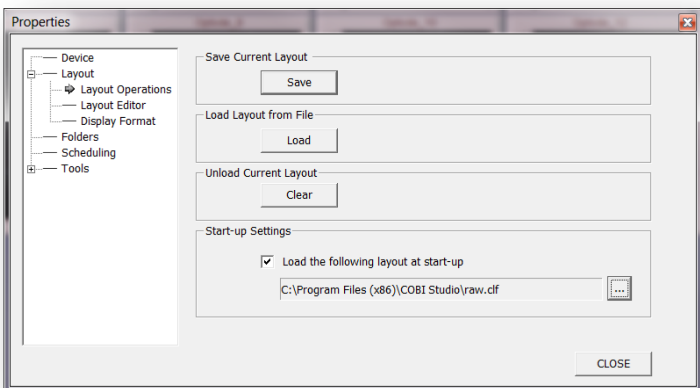
Global ranges (fixed or automatic) can be set here. Graphs can be updated by sweep or trace methods. Sweep is recommended for layouts with multiple graphs.

Moreover, in the display format dialog, graph height can be set as well. This will be shared by all graphs. An individual graph that covers the entire screen can be made as well as multiple graphs that fit in one screen. The width of the graphs is calculated automatically from the screen width by using the 'display graphs in column of' parameter. This specifies how many graphs will be placed next to each other in a single row. The Width parameter specifies how many data points each graph will draw at once.

6.2.1. Save/Load Layout

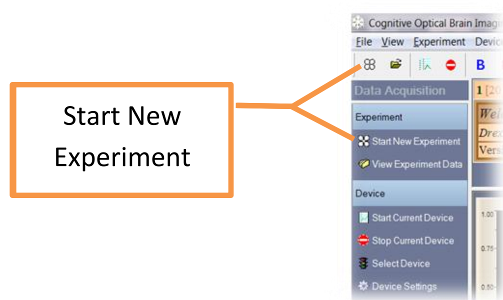
All layout settings can be saved into a file at the 'layout operations' dialog. This can be either reached from the side pane, or by opening the properties dialog first and selecting 'layout operations' from the list on the left.

Layout operations dialog allows users to save the current layout to a file, load an existing layout file or just clear the layout from all graphs and topographs. Also, a certain layout file can be set to load automatically when COBI Studio is launched. Two layout files (raw.clf and oxy.clf) come with the installation.



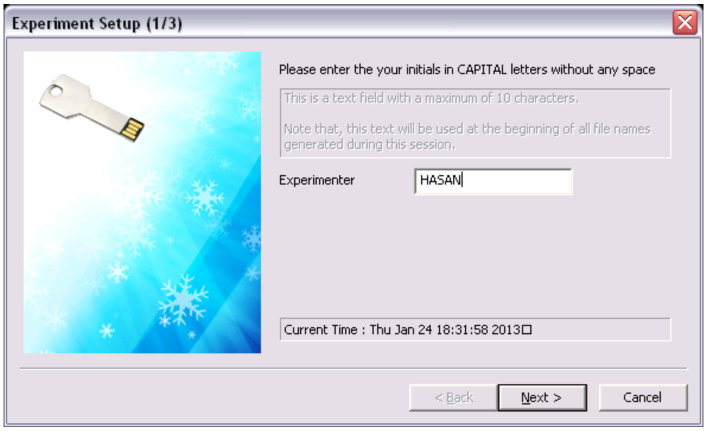
6.3. Configuring Experiments

COBI Studio is designed for performing serial experiments. To save all experimental data (fNIR, synchronization markers from external presentation stimuli, etc.) in a standardized way, COBI provides the experiment tool. A new experiment can be initiated by clicking the toolbar button or the side pane link as shown in the figure to the right.

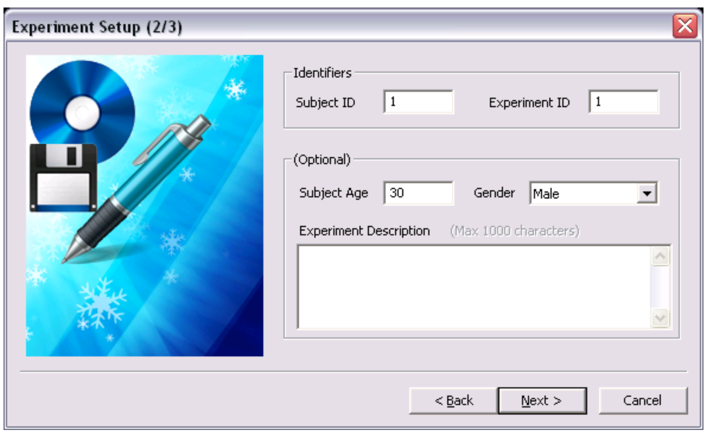


When 'start new experiment' is clicked, a wizard with the following screens appear. These screens collect information related to the experiment and save it along with all other experimental data. This helps with tracking information.

1. The first screen requires the user to enter his/her initials. Also, the experiment date that will be saved is shown for confirmation. If the date is wrong, check the system date of the windows operating system. Click Next to continue.

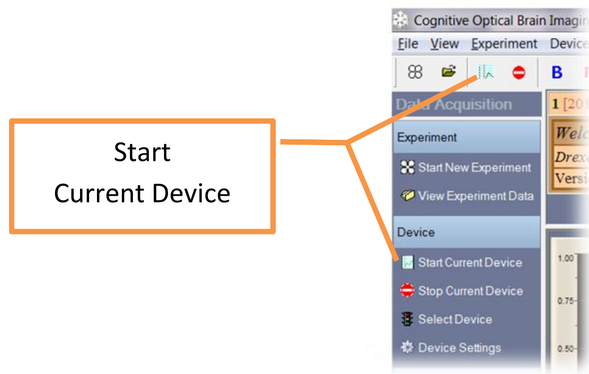


2. The second screen allows the user to enter subject ID, experiment ID and optional subject information and description text about the experiment where a user can give specific information.



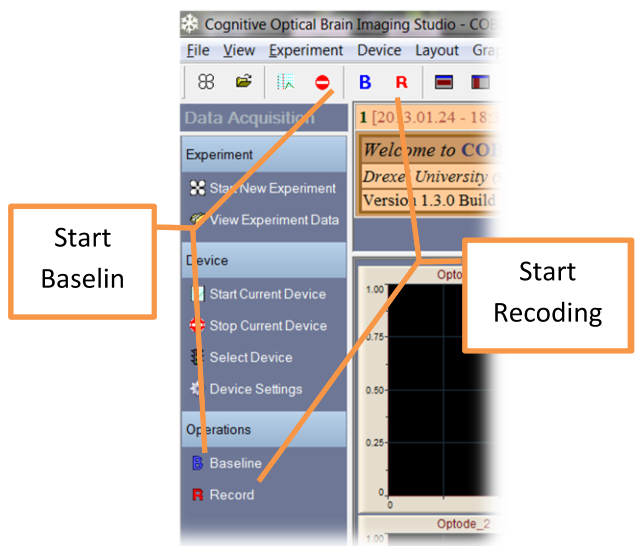
3. Finally, the user is presented with a summary of the information entered and asked to confirm and click finish. Once finish is clicked, the following message appears at the message pane (of the main window).

7. Start Acquisition & Recording



Data acquisition can be started by clicking on the 'start current device' in the toolbar or in the side pane. Current device can be set to different options. To get data from the fNIR Imager hardware, current device should be fnirUSB.dll or its variants (fnirUSB*.dll). For more information about setting a device, please see hardware configuration on page 27.

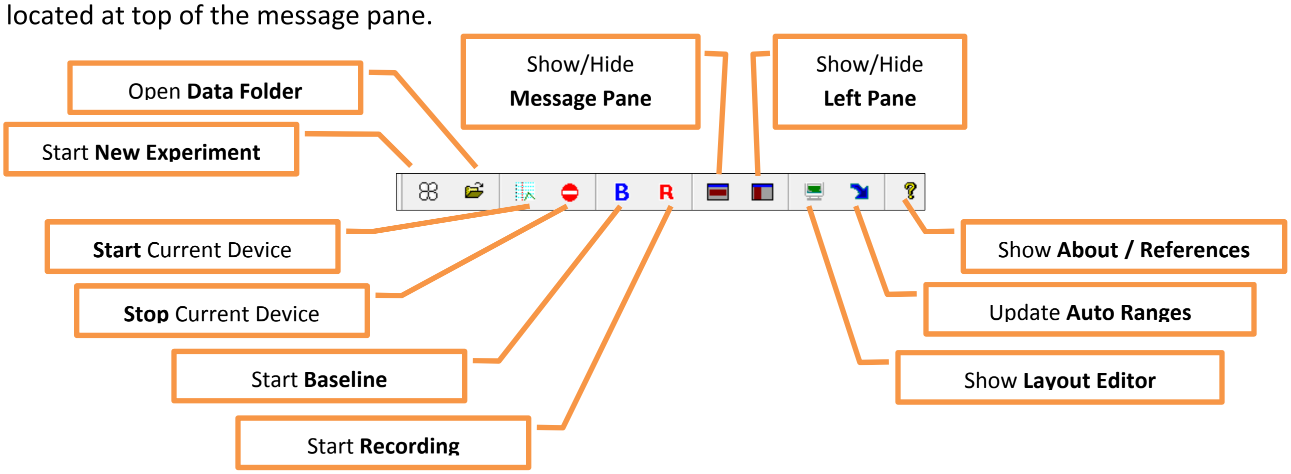
When 'start current device' is clicked, the message pane shows the information streaming from the device: whether it has started successfully or information about the settings. If there are graphs in the layout, data will start appearing in them. Each graph will display "Not recording" with red background until recording starts. To save data, first a baseline should be started and then 'start recording' should be clicked as shown on the figure. When recording starts, "Rec." text is displayed at bottom of the graphs.



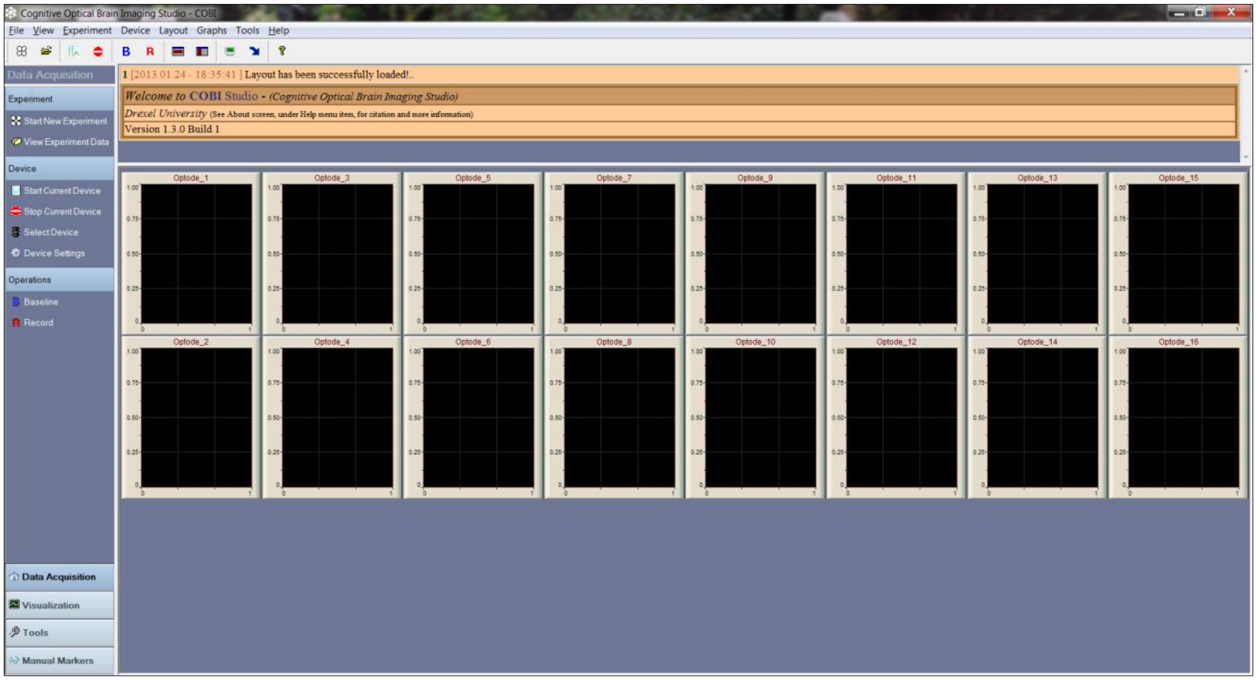
CAUTION! Data is not saved unless, first "**start baseline**" and then "**start recording**" are clicked.

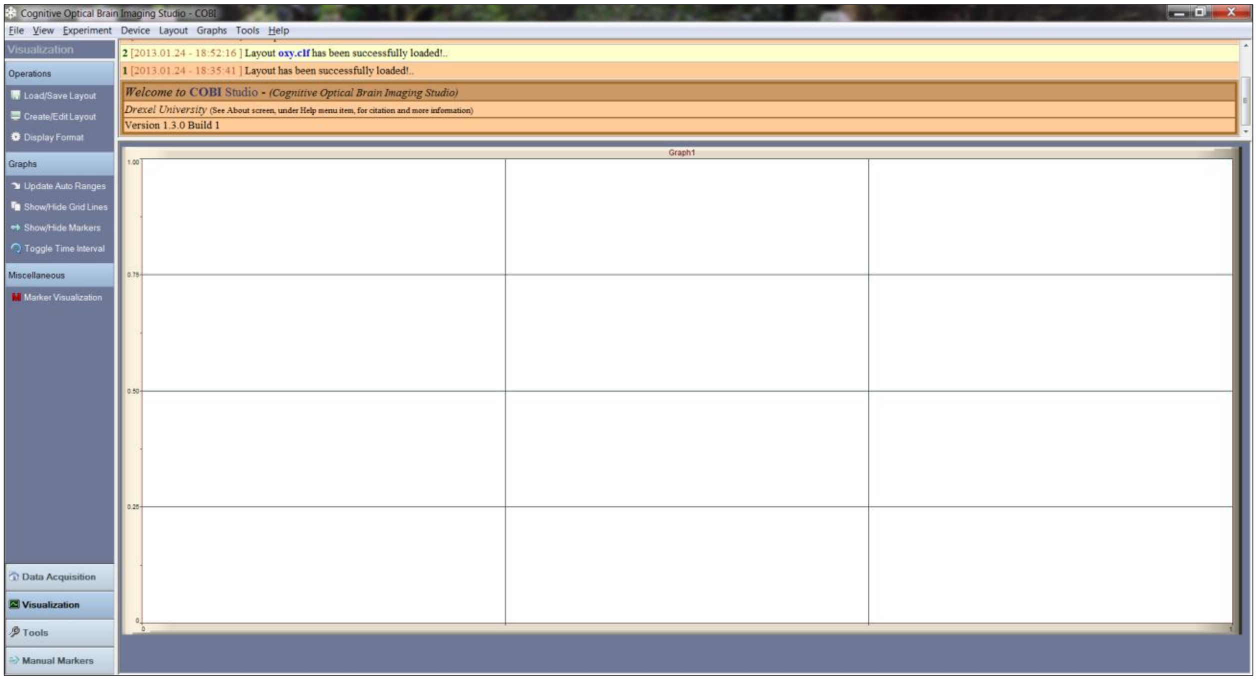
8. User Interface & Functions

The figure below depicts the buttons and the respective functions of the main toolbar (horizontal) that is located at top of the message pane.



Below are screenshots of some of the main windows of COBI with various layout configurations. The first one is the default main-window with side pane, message pane, layout area with main (horizontal) and run-time (vertical) toolbars. In the second window, the message pane and the side pane are closed, and topographic visualization is enabled. The third one is a single graph that covers the whole layout area.





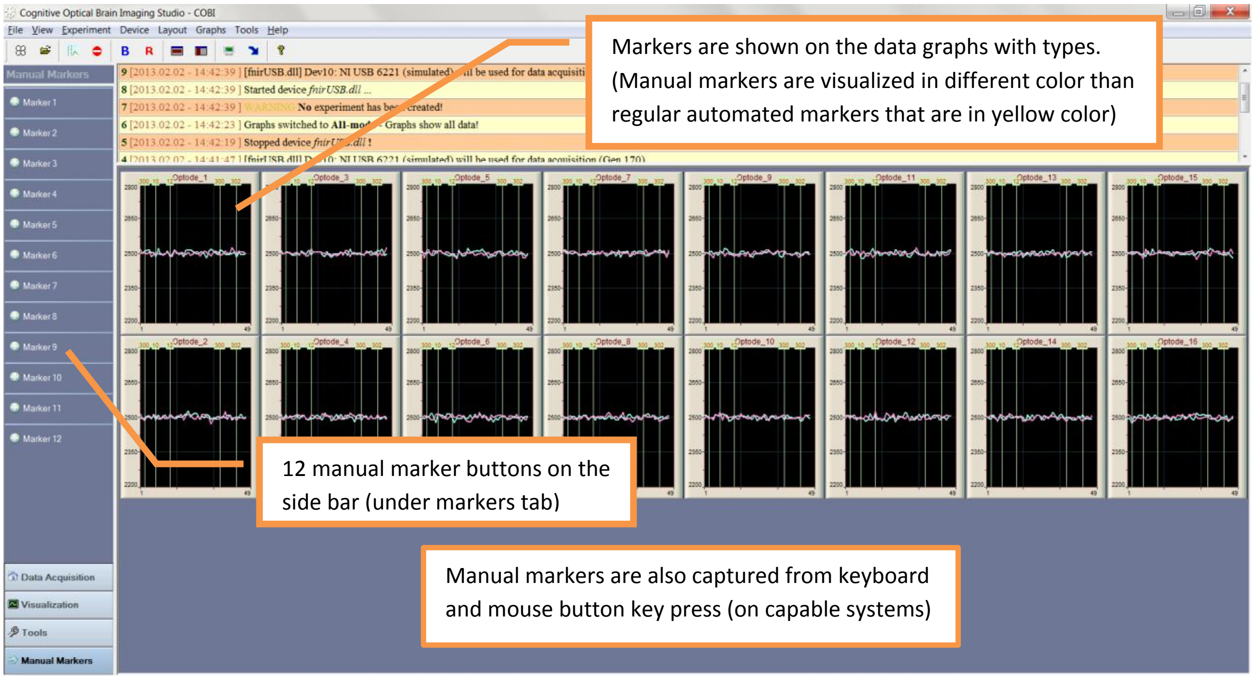
9. Advanced Settings & Features

This section includes several settings that require some basic understanding of COBI and are not essential for the basic operation of data acquisition.

9.1. Manual Markers

Markers, in general, are recorded timestamps for events during a data acquisition session to synchronize acquired data. There are two types of markers: **auto-markers** (or just markers) and **manual markers**. Auto-markers are automatically generated by an external system (remote computer such as presentation computer) and input to the COBI Studio through serial or parallel port. (See page 39). On the other hand, **manual markers** are generated manually by clicking a button within COBI Studio. Manual markers can be useful in a variety of settings, and help data analysis by indicating exact times of certain actions. Manual markers in COBI are numbered from 1 to 12 (in side pane on main window and also through keyboard F1 through F12 keys) and 300 to 302 for (mouse button keys, left, middle and right); hence each can be used to identify unique events.

Pressing the manual marker buttons (either at the left pane of main window or through keyboard/mouse buttons on capable systems) as shown below will save the exact time and the manual marker type (1-12 or 300-302) to the **manual marker file** and also a message is shown in the message pane. Manual markers are saved in a file other than auto-markers files. The default name is 'manualmarker.mrk'; however, if experiment wizard is used, manual marker file name for that session is set according to entered information as with other data files.

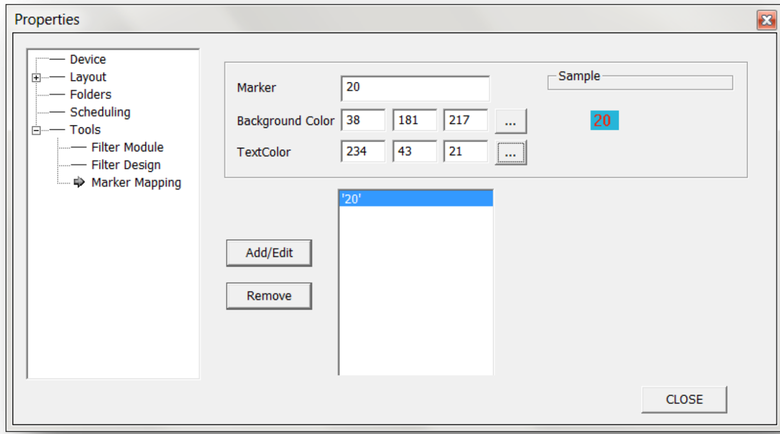


The manual marker file is in tab-separated text file format and each marker is recorded on a single line. The first column is the current time information relative to second start code in the raw fNIR file header and the second column is the type of manual marker (1-12 and 300-302). The third and fourth columns include high frequency counter timer data and the last column includes a human-readable date and time format. To find the time from the start of experiment, the second start code in the fNIR data file (see page 45) has to be divided by 1000 and subtracted from the first column of the manual marker file.

9.2. Marker Mapping

Marker Mapping is tool for customizing visualization of automated markers. It can be accessed from the side pane on the main window or from the list of the properties dialog box located on the left hand side. See the graph below for the marker mapping screen.

By default, automated markers are yellow vertical lines with titles in red. See Figure 5 (on page 40) for a sample graph with several markers. The Marker Mapping tool allows a user to assign different text and background colors to a marker. When a marker with the specified title arrives, the system draws the marker according to its customized settings. The marker list can contain any number of items and these can be removed by using the button on the left. The settings are saved to the COBI configuration file and can be automatically retained.



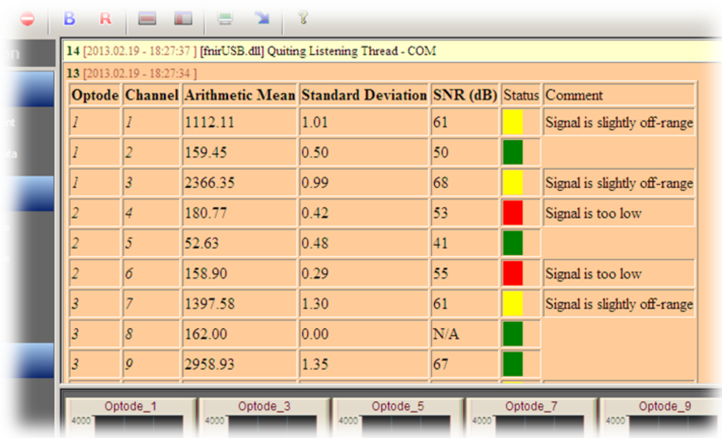
9.3. Self-Check

WARNING: This feature requires a solid phantom (i.e., a material that mimics optical properties of brain tissue).

Self-Check can be accessed from side pane on the main window or from the top menu: Analyze>Do Self-Check. When enabled, this feature will test signal levels at each channel and generate a report. To perform a self-check, do the following steps:

1) Place the sensor pad on a phantom with uniform optical properties
2) Wrap the sensor pad and phantom with a black cloth to prevent ambient light leakage
3) Connect the sensor pad to fNIR Imager Hardware and to the computer
4) In COBI, select fnirUSB.dll as the current device.
5) In COBI, click Self-Check to enable it.
6) In COBI, start current device

In the message pane, COBI will indicate that the self-check process has started. The device will be automatically stopped once enough data is collected or you can stop the device if you think enough data is collected. Then, the mean and standard deviation of each channel is calculated along with the signal level. The final report is presented in the message pane and given a color code (green=ok, yellow=some warnings, red=caution). The report and all messages on the message pane can be saved to a file for further reference from the top menu "File>Save Pane Messages". Below is a sample part from a report.



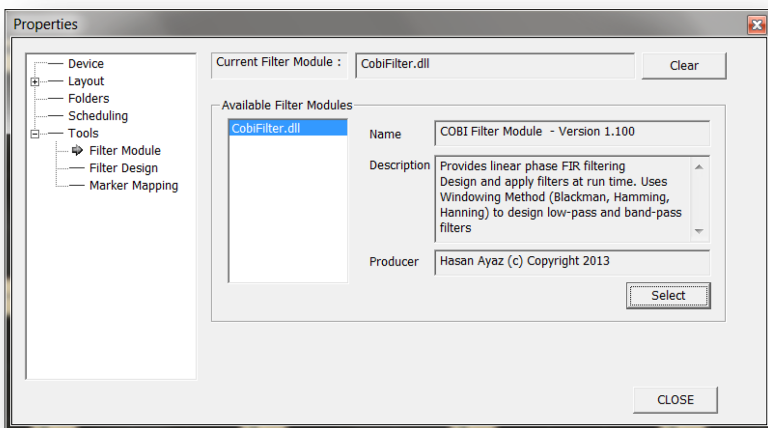
14 [2013.02.19 - 18:27:37] [fnirUSB.dll] Quiting Listening Thread - COM
13 [2013.02.19 - 18:27:34]

Optode	Channel	Arithmetic Mean	Standard Deviation	SNR (dB)	Status	Comment
1	1	1112.11	1.01	61		Signal is slightly off-range
1	2	159.45	0.50	50		
1	3	2366.35	0.99	68		Signal is slightly off-range
2	4	180.77	0.42	53		Signal is too low
2	5	52.63	0.48	41		
2	6	158.90	0.29	55		Signal is too low
3	7	1397.58	1.30	61		Signal is slightly off-range
3	8	162.00	0.00	N/A		
3	9	2958.93	1.35	67		

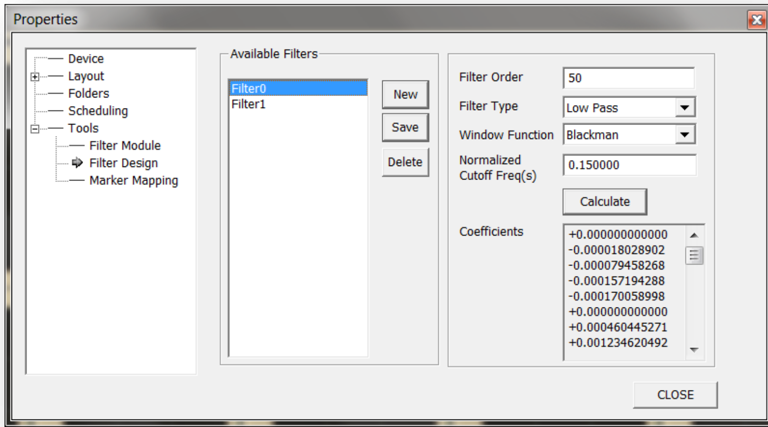
Optode_1 Optode_3 Optode_5 Optode_7 Optode_9

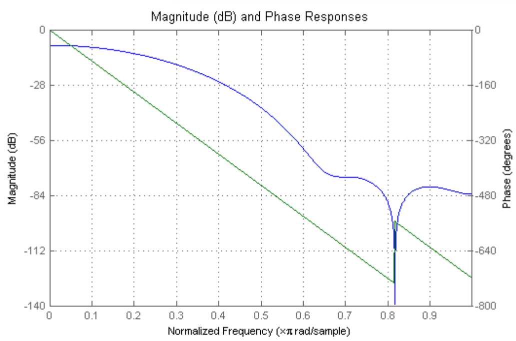
9.4. Filter Design

FIR (finite impulse response) filters can be designed and then applied to the input data at run-time. COBI has a filter module that is capable of designing any order of FIR filters using windowing. In the following figure, first COBI filter module (CobiFilter.dll) is selected as the “current filter module”.

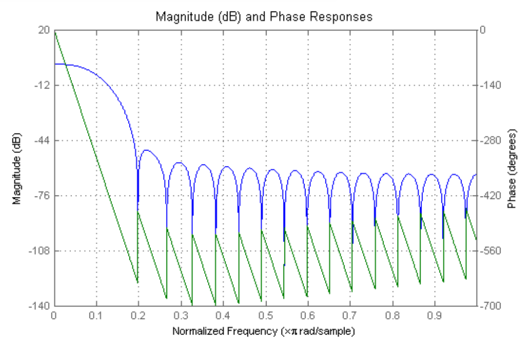


In the dialog below, an FIR filter can be designed by defining the type, order, window function and cut-off frequency. When the user press on the calculate button, the corresponding filter coefficients are calculated and saved for later use. For example, the Figure below shows two filters that have been designed with the COBI filter module. The first one is a 10^{th} order low-pass filter. The normalized cut-off frequency is 0.1 and Blackman Window has been used to calculate the coefficients. The second filter is a 20^{th} order low-pass, with the normalized cut-off frequency of 0.1 which uses a Hamming window. The frequency response of both filters has been presented in the following figure.

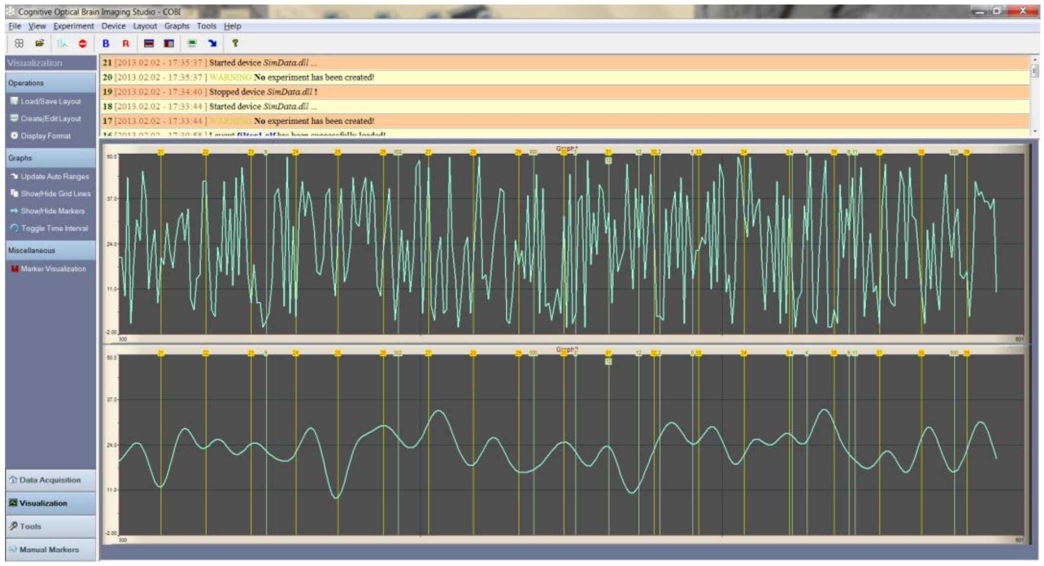




10th order, low-pass, Blackman windowed



20th order, low-pass, Hamming windowed



Noisy and filtered data (using run-time FIR filter)

10. fnirUSB.dll Properties

This section discusses the common settings and features of 'fnirUSB*.dll' variants that operate the fNIR Imager device. A variant of this is fnirUSBnet.dll that has similar features, see next section for more information.

Although each variant has specific additional features, all have common features. To see fnirUSB properties, click 'Device Settings' in the side pane of the COBI main window.

10.1. Marker Synchronization

fnirUSB.dll of COBI Studio can receive a synchronization (triggering) signal from an external system. These are different than **Manual Markers** as discussed on page 34. Sending synchronization signals (also called markers) allows comparing timing of a stimulus presentation with the fNIR data. fnirUSB.dll can receive and send markers through a standard serial port (RS232) or parallel port. For outgoing markers see Table 2 the end of this section.

Markers are displayed on the temporal graphs as vertical lines with labels. 'Marker Mapping' (by clicking on the side bar) can be used to give different colors and assign text labels to markers. See the sample graph with markers below.

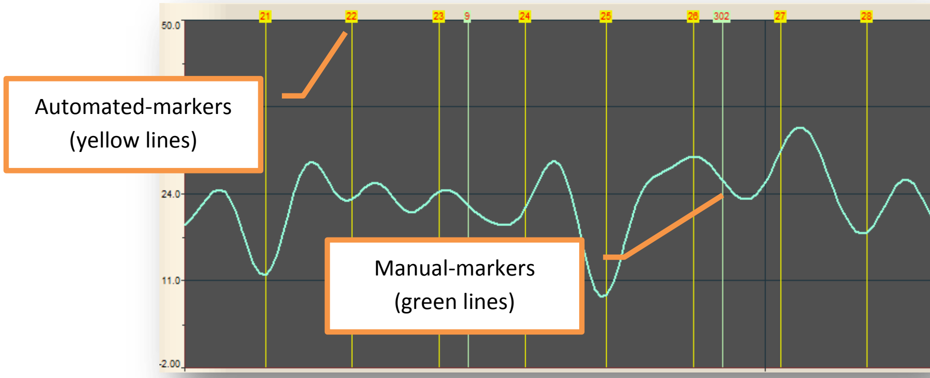
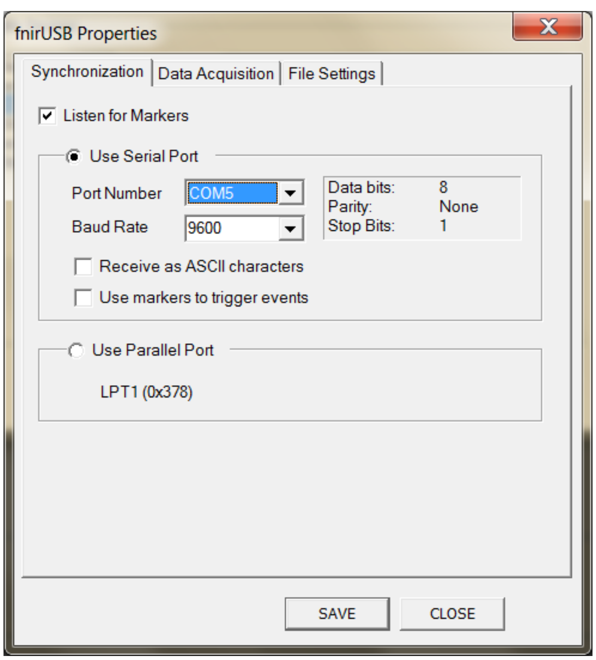


Figure 5. COBI graph with markers

The figure below displays the marker synchronization settings. First, check 'listen for markers' to enable signal reception. Then select a source (e.g. serial port or parallel port) to listen for markers. A serial port number is a computer dependent parameter that may be different on each computer, and if you have multiple serial ports each will have a different number. Available ports of a computer can be located by using the 'device manager' tool of the Windows operating system. For a proper connection via any port with a remote computer, the settings should be the same on both computers. More specifically, both computers should have the same parameters for the baud rate, data bit, parity and stop bits properties.

CAUTION! Markers are only listened when fnirUSB.dll is selected as the current device and started by clicking '**start current device**'. When fnirUSB.dll is started, it will inform the user if it is listening for markers in the message pane.



The following is a list of outgoing markers (and byte values) from fnirUSB.dll during data acquisition, if markers are enabled.

Table 2. Outgoing marker list

Event Name	*Byte Value*	*Description*
START	10	Data acquisition is started (user pressed start)
STOP	50	Data acquisition is stopped (user pressed stop)
BASELINE BEGIN	20	Baseline is started (user pressed baseline button)
BASELINE END	30	Baseline is complete
RECORD	40	Record button is pressed

10.2. Remote Control

Special Markers values can be used as commands to remotely trigger specific data acquisition events in COBI Studio (from another computer / stimulus presentation program) through serial port. To do that, enable "Use markers to trigger events" in fnirUSB device properties under synchronization settings tab. When this feature is enabled, COBI will screen incoming markers (each byte separately) and execute respective commands if the value matches. List of current command values are listed in Table 3 below.

Table 3. Marker values for remote control

Event Name	*Byte Value*	*Description*
COBI_RECV_EVENT_BASELINE_BEGIN	251	Baseline is started and ends in 10 seconds. (Simulates Baseline button press)
COBI_RECV_EVENT_RECORDING	253	Start recording data to file (Simulates Record button press)
COBI_RECV_EVENT_STOP	254	Data acquisition stops, experiment ends (Simulates Stop button press)

CAUTION: For remote control, device needs to be manually started (by clicking start device button) and a valid serial port should be enabled for marker synchronization. When the device is started, remote control markers can trigger recording of baseline and data and stop the device. However, commands should be received in the correct order, i.e. cannot record if baseline is not yet set. And record command should be sent at least 10 seconds after the baseline command.

10.3. External Trigger

fNIR device can produce digital TTL output signal through the BNC type output port (at the back of the device) to synchronize any external device with data acquisition events. Please see below for the photo of the trigger out port at the back of the device.

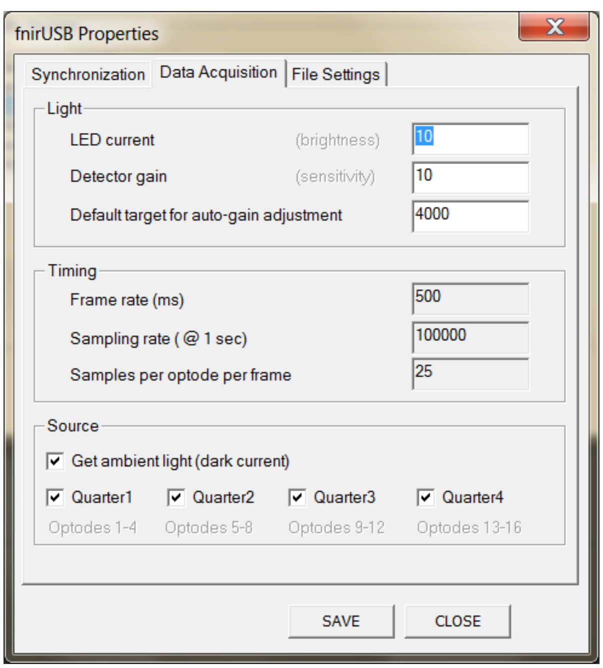
Trigger out port is a digital port and has two states: low (0 volts) and high (5 volts). The port is low all the time except when a special data acquisition events happens; when a pulse is generated on this port, first by switching the port status to high for 150ms (pulse length) and then switch back to low again.

A pulse is generated for all the following events device start, device stop, baseline begin, baseline end and record events (also listed in Table 2).

10.4. Data Acquisition Settings

This section displays advanced settings for the fNIR Imager. Timings such as sampling rate and frame rate are read-only. Two important parameters that can be modified are the LED drive current and the initial gain. Advised range for the LED current is between 5mA to 20mA depending on experiment conditions. And the initial gain should be 1, 5, 10, 15 or 20.

CAUTION: Please do not change LED drive current or gain default values unless you know exactly what you are doing.



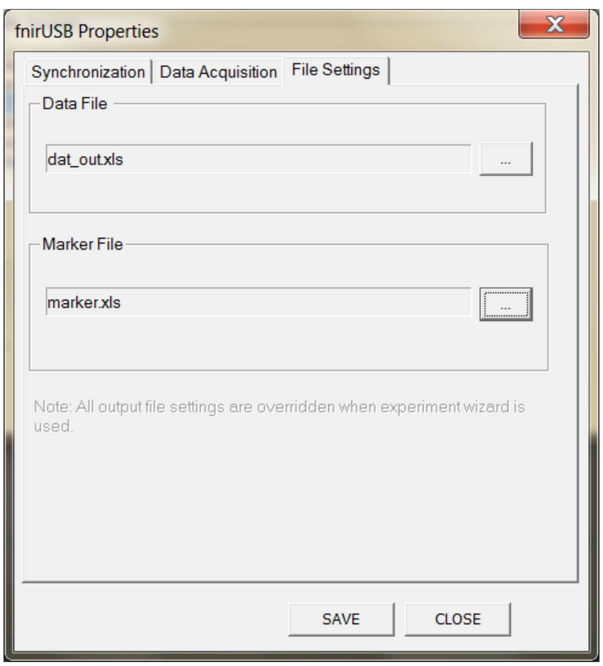
Within the 'Data Acquisition Settings' tab, 'Sampling Settings' group, contains checkboxes to enable or disable data acquisition from certain channels. If 'Get ambient light (dark current)' is not checked, only 730nm and 850nm wavelengths will be collected for each voxel, eliminating the ambient light. Data file structure will be the same but '-1' will be recorded for the ambient raw cell for all 16 voxels.

The second row of checkboxes enables of disables data acquisition from 4 quadrants separately. Quadrant 1 contains voxels 1 through 4; quadrant 2 contains voxels 5 through 8; quadrant 3 contains voxels 9 through 12; and quadrant 4 contains voxels 13 through 16. By default all of them are checked so all voxels are sampled. However, if the data acquisition computer does not have enough bandwidth, one or more of the quadrants can be disabled to maintain 2Hz sampling rate.

10.5. File Settings

This property allows the user to define the name and location of data files; e.g. fNIR files and marker files.

WARNING: These settings are overridden if an experiment is configured. See the experiment configuration section at page 30 for more information.



10.6. Data File Format

The file names and extensions depend on if the experiment is initiated at COBI. If so, fnirUSB.dll acquires fNIR data from the fNIR Imager and saves it to a "*.nir" file. Calculated oxy-Hb and deoxy-Hb (using selected baselines in Modified Beer Lambert Law) is saved to a "*.oxy" file. Marker data (if listening of markers is enabled) is saved to "*.mrk" file. All files are tab-delimited text files and can be opened directly by text editors or Microsoft Excel. If an experiment is not initiated at COBI, then the default file names will be “dat_out.xls”, “dat_out.xls.oxy” and “marker.xls”.

The figure on page 45, presents the fNIR data file and its components. The first two lines are the header followed by the date of the measurement. Next, the initial counter value of the high-resolution-timer is recorded, which is followed by its frequency. The frequency is used to convert the timer ticks to milliseconds.

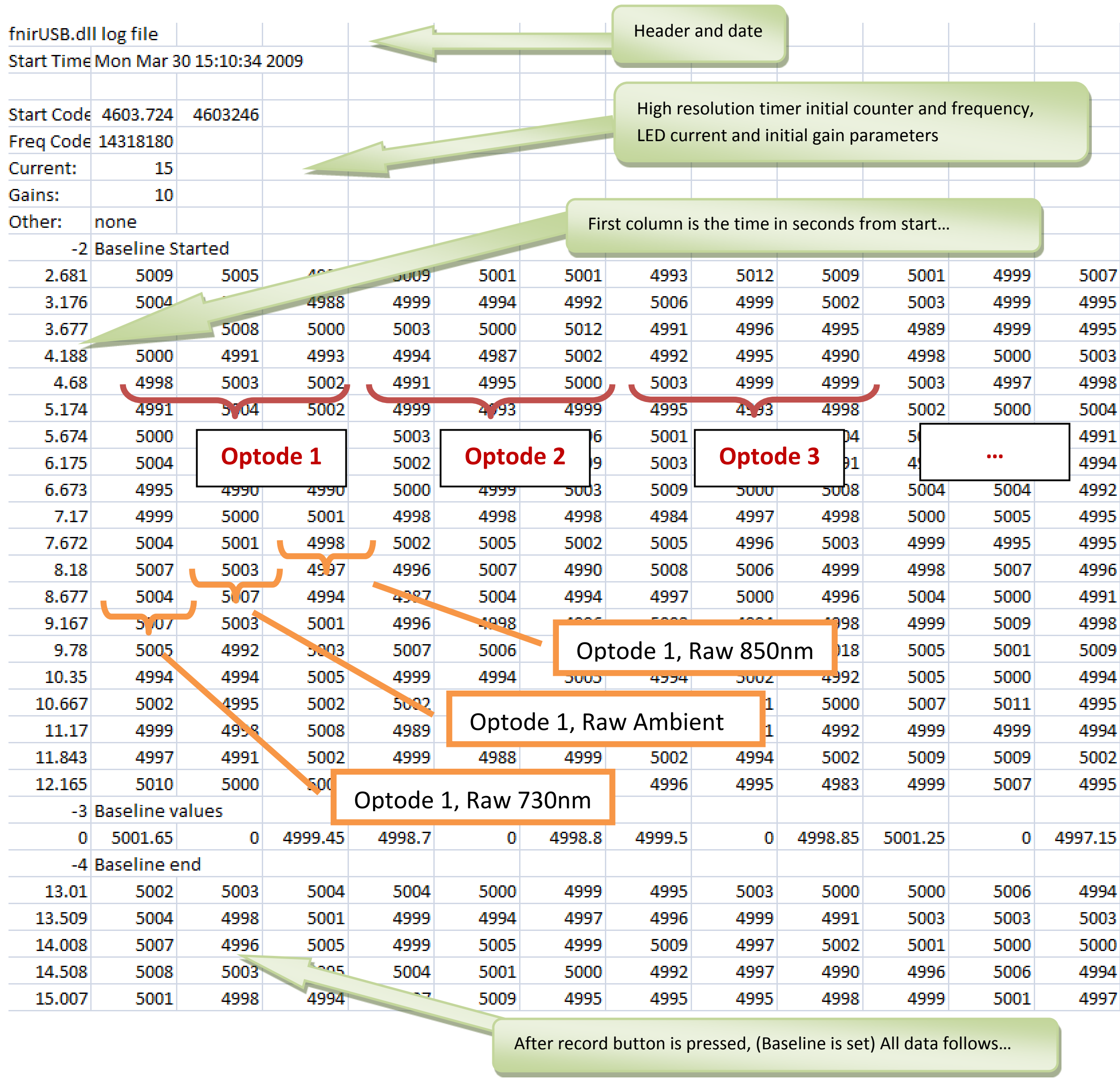
When the user starts the baselines, the line with “-2 Baseline started” is recorded along with 20 frames of data with each frame on a single row. After the baseline is complete (marked with -4), data is recorded only after the user clicked on “start recording”.

The first column in the data file is the time value in seconds from start of the current device. Then the rest of the columns contain the light intensity data for 16 voxels in 3 wavelengths. The second column (next to time column) is the data of voxel 1 – wavelength 730nm. The third column is voxel 1 – raw ambient data (the value would be negative unless ambient data collection is enabled in device settings). And the forth column is voxel 1 – wavelength 850nm. The next three columns are for voxel 2 with again 730nm, ambient light intensity and 850nm data, respectively. The grouping of 3 wavelengths continues for all 16 voxels. So, there are 49 columns in total (1 time column + 3x16=48 light intensity columns). In the current fNIR Imager, middle column (between 750nm and 850nm) for each voxel is the ambient light condition in which no LED is lit during its measurement. This will record ‘-1’ if ambient light acquisition is not enabled at the device settings (data acquisition tab>sampling settings).

The figure on page 46, presents the fNIR oxy data file and its components. The first two lines are the header followed by the date of the measurement. Next, the initial counter value of the high-resolution-timer is recorded and the frequency of it follows. The frequency is used to convert the timer ticks to milliseconds. These are the same as in the fNIR data file.

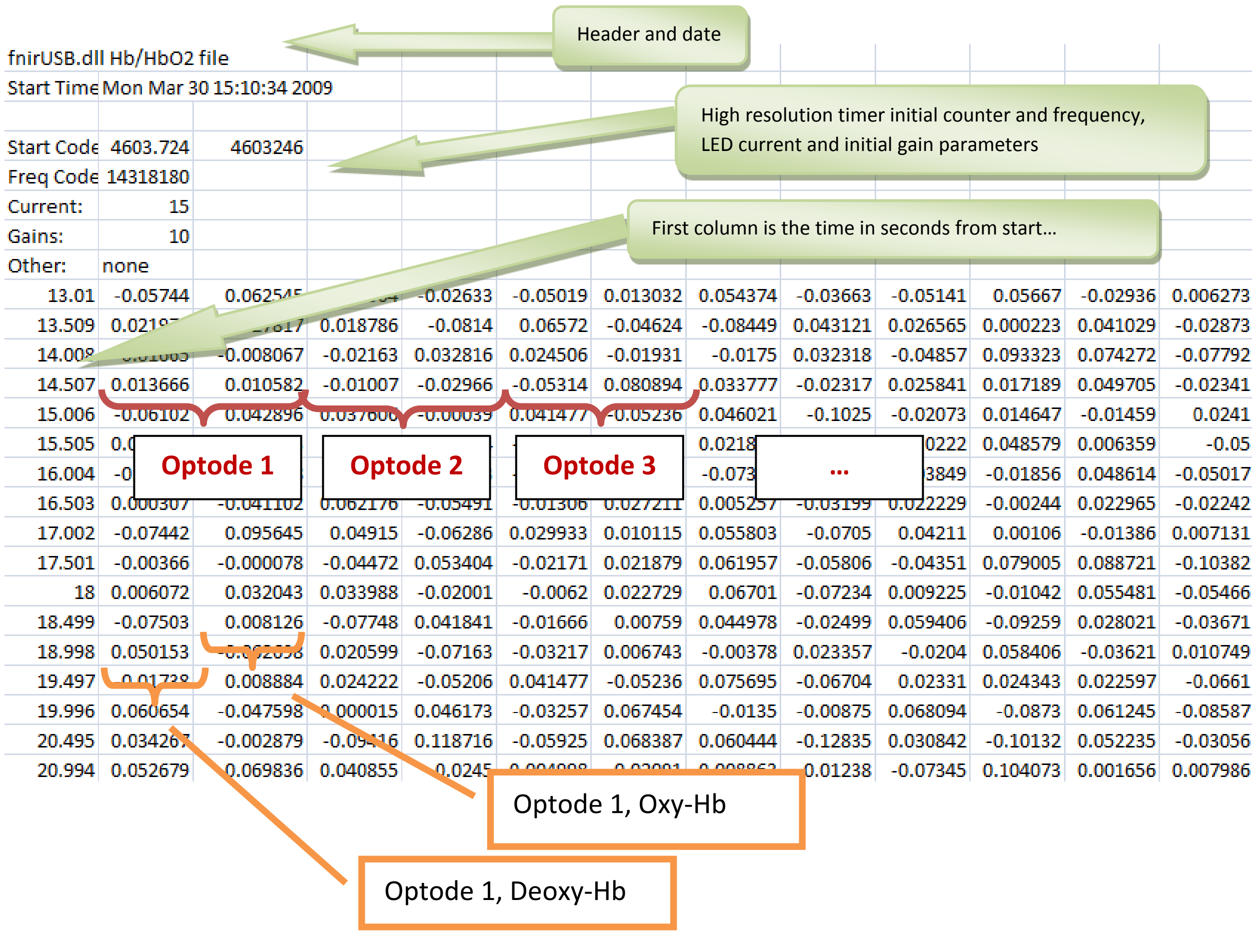
The first column in the data file is the time value in seconds since the current device has started. Then the rest of the columns contain deoxygenated hemoglobin (Hb) and oxygenated hemoglobin (HbO_2) pairs for all 16 voxels. So, there are 33 columns in total (1 time column + 2x16 Hb/HbO2 values).

10.6.1. fNIR Data File



fnirUSB.dll log file												
Start Time	Mon Mar 30 15:10:34 2009											
Start Code	4603.724	4603246										
Freq Code	14318180											
Current:	15											
Gains:	10											
Other:	none											
-2	Baseline Started											
2.681	5009	5005	[illegible]	5009	5001	5001	4993	5012	5009	5001	4999	5007
3.176	5004	[illegible]	4988	4999	4994	4992	5006	4999	5002	5003	4999	4995
3.677	[illegible]	5008	5000	5003	5000	5012	4991	4996	4995	4989	4999	4995
4.188	5000	4991	4993	4994	4987	5002	4992	4995	4990	4998	5000	5003
4.68	4998	5003	5002	4991	4995	5000	5003	4999	4999	5003	4997	4998
5.174	4991	5004	5002	4999	4993	4999	4995	4993	4998	5002	5000	5004
5.674	5000	[illegible]	[illegible]	5003	[illegible]	[illegible]	5001	[illegible]	[illegible]	[illegible]	[illegible]	4991
6.175	5004	[illegible]	[illegible]	5002	[illegible]	[illegible]	5003	[illegible]	[illegible]	[illegible]	[illegible]	4994
6.673	4995	4990	4990	5000	4999	5003	5009	5000	5008	5004	5004	4992
7.17	4999	5000	5001	4998	4998	4998	4984	4997	4998	5000	5005	4995
7.672	5004	5001	4998	5002	5005	5002	5005	4996	5003	4999	4995	4995
8.18	5007	5003	4997	4996	5007	4990	5008	5006	4999	4998	5007	4996
8.677	5004	5007	4994	[illegible]	5004	4994	4997	5000	4996	5004	5000	4991
9.167	5007	5003	5001	4996	4998	[illegible]	[illegible]	[illegible]	4998	4999	5009	4998
9.78	5005	4992	5003	5007	5006	[illegible]	[illegible]	[illegible]	[illegible]	5005	5001	5009
10.35	4994	4994	5005	4999	4994	[illegible]	[illegible]	[illegible]	4992	5005	5000	4994
10.667	5002	4995	5002	5002	[illegible]	[illegible]	[illegible]	[illegible]	5000	5007	5011	4995
11.17	4999	[illegible]	5008	4989	[illegible]	[illegible]	[illegible]	[illegible]	4992	4999	4999	4994
11.843	4997	4991	5002	4999	4988	4999	5002	4994	5002	5009	5009	5002
12.165	5010	5000	[illegible]	[illegible]	[illegible]	[illegible]	4996	4995	4983	4999	5007	4995
-3	Baseline values											
0	5001.65	0	4999.45	4998.7	0	4998.8	4999.5	0	4998.85	5001.25	0	4997.15
-4	Baseline end											
13.01	5002	5003	5004	5004	5000	4999	4995	5003	5000	5000	5006	4994
13.509	5004	4998	5001	4999	4994	4997	4996	4999	4991	5003	5003	5003
14.008	5007	4996	5005	4999	5005	4999	5009	4997	5002	5001	5000	5000
14.508	5008	5003	[illegible]	5004	5001	5000	4992	4997	4990	4996	5006	4994
15.007	5001	4998	4994	[illegible]	5009	4995	4995	4995	4998	4999	5001	4997

10.6.2. fNIR Oxy File



fnirUSB.dll Hb/HbO2 file												
Start Time	Mon Mar 30 15:10:34 2009											
Start Code	4603.724	4603246										
Freq Code	14318180											
Current:	15											
Gains:	10											
Other:	none											
13.01	-0.05744	[illegible]	[illegible]	-0.02633	-0.05019	0.013032	0.054374	-0.03663	-0.05141	0.05667	-0.02936	0.006273
13.509	[illegible]	[illegible]	0.018786	-0.0814	0.06572	-0.04624	-0.08449	0.043121	0.026565	0.000223	0.041029	-0.02873
14.008	[illegible]	-0.008067	-0.02163	0.032816	0.024506	-0.01931	-0.0175	0.032318	-0.04857	0.093323	0.074272	-0.07792
14.507	0.013666	0.010582	-0.01007	-0.02966	-0.05314	0.080894	0.033777	-0.02317	0.025841	0.017189	0.049705	-0.02341
15.006	-0.06102	0.042896	0.037606	-0.00039	0.041477	-0.05236	0.046021	-0.1025	-0.02073	0.014647	-0.01459	0.0241
15.505	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.048579	0.006359	-0.05
16.004	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-0.01856	0.048614	-0.05017
16.503	0.000307	-0.041102	0.062176	-0.05491	-0.01306	0.027211	0.005257	-0.03199	0.022229	-0.00244	0.022965	-0.02242
17.002	-0.07442	0.095645	0.04915	-0.06286	0.029933	0.010115	0.055803	-0.0705	0.04211	0.00106	-0.01386	0.007131
17.501	-0.00366	-0.000078	-0.04472	0.053404	-0.02171	0.021879	0.061957	-0.05806	-0.04351	0.079005	0.088721	-0.10382
18	0.006072	0.032043	0.033988	-0.02001	-0.0062	0.022729	0.06701	-0.07234	0.009225	-0.01042	0.055481	-0.05466
18.499	-0.07503	0.008126	-0.07748	0.041841	-0.01666	0.00759	0.044978	-0.02499	0.059406	-0.09259	0.028021	-0.03671
18.998	0.050153	[illegible]	0.020599	-0.07163	-0.03217	0.006743	-0.00378	0.023357	-0.0204	0.058406	-0.03621	0.010749
19.497	[illegible]	0.008884	0.024222	-0.05206	0.041477	-0.05236	0.075695	-0.06704	0.02331	0.024343	0.022597	-0.0661
19.996	0.060654	-0.047598	0.000015	0.046173	-0.03257	0.067454	-0.0135	-0.00875	0.068094	-0.0873	0.061245	-0.08587
20.495	0.034267	-0.002879	-0.09416	0.118716	-0.05925	0.068387	0.060444	-0.12835	0.030842	-0.10132	0.052235	-0.03056
20.994	0.052679	0.069836	0.040855	[illegible]	[illegible]	[illegible]	[illegible]	-0.01238	-0.07345	0.104073	0.001656	0.007986

10.6.3. fNIR Marker File

fnirUSB.dll marker file		
Listening from COM9 port		
Start Time	Mon Mar 30 15:10:34 2009	
Start Code	4603.724	4603542
Freq Code	14318180	
19.828	170	15
19.833	42	15
19.839	42	15
19.845	81	15
25.795	170	27
25.8	42	27
25.806	42	27
25.811	81	27
37.283	170	50
37.288	42	50
37.294	42	50
37.299	81	50
46.665	170	69
46.67	42	69
46.676	42	69
46.681	81	69
52.608	170	81
52.614	42	81
52.619	42	81
52.624	81	81
54.855	170	85
54.861	42	85
54.866	42	85
54.871	81	85

Header and date

Start codes are the same as recorded in the data file

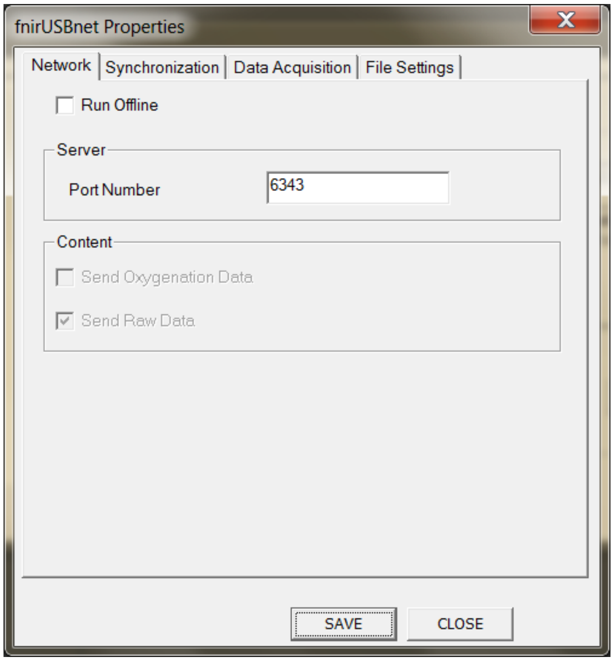
Frame number in fNIR data that this marker corresponds to.

Type of marker (1-255)

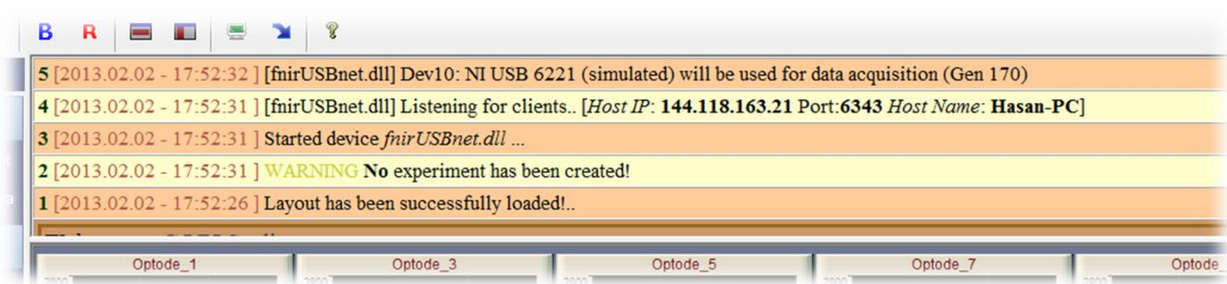
Time (seconds) of marker from start of experiment start

11. fnirUSBnet.dll Properties

This is a variation of fnirUSB.dll with the same basic functionality, but additionally fnirUSBnet.dll can broadcast the raw fNIR data over network. In the device settings dialog, there's an extra tab called 'Network Settings' as shown below. At this window, the device can be set to run online and offline. If the device is set to run offline, it is the same as fnirUSB.dll.

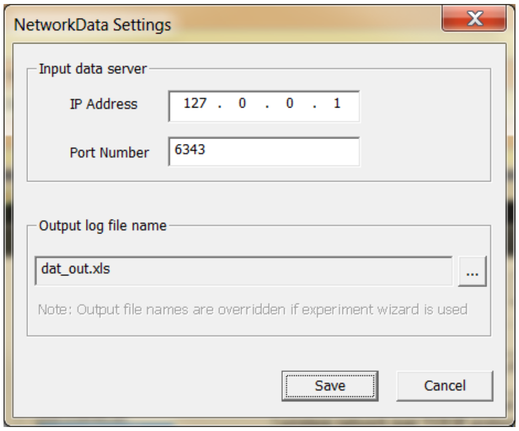


When the device is started to run in the online mode, the message pane displays the IP and port numbers through which the clients can connect to the device. This information is required on the receiving side at the remote system. The default port number is 6343.



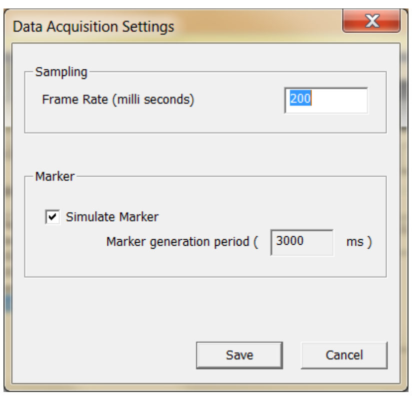
12. NetworkData.dll Properties

This COBI device receives data from network that are broadcasted by fnirUSBnet.dll as described above. The device settings dialog allows entering IP and port numbers of a remote COBI system. The received data can be logged (if baseline is set and record button is pressed) and the log file name can be changed from the settings dialog as shown below.



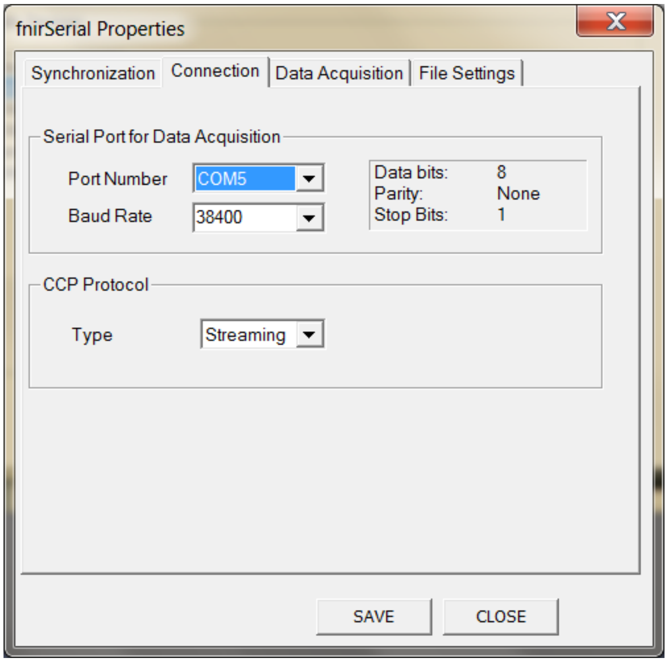
13. SimData.dll Properties

This is test device that created artificial data in form of varying types of sinusoidal and random signals. The frame rate in milliseconds can be set at the settings dialog. Also, SimData.dll can be set to simulate receiving markers if 'Send marker' is set.



14. fnirSerial.dll Properties

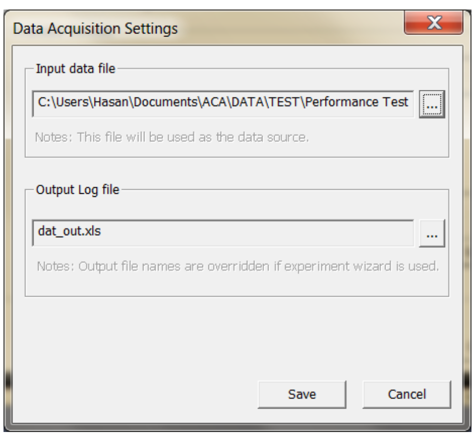
This section discusses the common settings and features of 'fnirSerial.dll' that operate the wireless fNIR Imager device. Other properties such as file format, marker synchronization settings, etc are same as fnirUSB.dll as both share common features. To see fnirSerial properties, click 'Device Settings' in the side pane of the COBI main window while fnirSerial.dll is selected as current device.



The “Connection” settings indicates the virtual com port established after installation of the wireless received driver (as explained in section 4.2). This is port not for markers or time synchronization. Use “Synchronization settings” tab for configuring marker recording.

15. fnirFile.dll Properties

This COBI device allows reading previously recorded fNIR data files to COBI. In the settings dialog, input file name can be set and also the log file name can be changed as shown below.

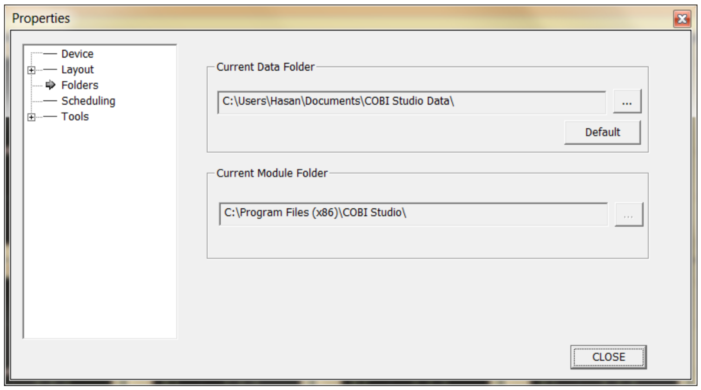


16. COBI Data Folder and Files

All recorded data files are saved in the COBI Folder, which can be opened by the ‘Open Folder’ button on the main toolbar. (See page 32). COBI Data folder is located by default at “My Documents>COBI Studio Data” of the current windows user. COBI saves files in tab separated text format so they can be opened by any text editor such as Notepad and also Microsoft Excel. fNIR Data file format is explained on page

45 and fNIR marker file format is explained on page 47. The default file name for a data file is 'dat_out.xls' and for a marker file is 'markers.xls' respectively. These names can be changed from the 'File Settings' tab of 'Device Settings' dialog of each device.

CAUTION! When experiment mode is enabled (See page 30), all file names settings are automatically assigned.



Below is a list of data files for 2 sessions in the COBI data folder. The first session was recorded with experiment mode on and files are named automatically. The 'HA_0_0_03301510.nir' is the fNIR data file. The marker file has the same name but an extension of 'mrk' and the log file also has the same name but an extension of 'log'. When experiment mode is not set, as in the second session, the three data files formed are 'dat_out.xls' (that is fNIR data file), 'win_out.xls' and 'marker.xls' (that is fNIR marker file).

Name	Date modified	Type	Size
cobi.dat	3/30/2009 3:35 PM	DAT File	26 KB
HA_0_0_03301510.log	3/30/2009 3:11 PM	Text Document	1 KB
HA_0_0_03301510.mrk	3/30/2009 3:11 PM	MRK File	1 KB
HA_0_0_03301510.nir	3/30/2009 3:11 PM	NIR File	37 KB
dat_out.xls	3/30/2009 3:09 PM	Microsoft Office Exc...	1 KB
marker.xls	3/30/2009 3:09 PM	Microsoft Office Exc...	1 KB
win_out.xls	3/30/2009 3:09 PM	Microsoft Office Exc...	1 KB

17. Troubleshooting

Description	Action
fnirUSB.dll and its variants are not in the available device list of COBI	The National Instruments USB driver is not installed or needs to be re-installed. Go to 'Add/Remove Programs' in the control panel of the Windows operating system and check to see if National Instrument is listed. If so, uninstall it, restart the computer and re-install the driver.
COBI adapter 'fnirUSB.dll' fails to start…	Make sure that the fNIR box is powered and connected to the computer. Wait a few seconds after device is connected to computer. If the problem persists, try using different USB ports of the computer.
Raw signal values are too high (>4000mV)	The sensor pad is not in good contact with the subject's forehead. Tighten the probe.
Raw signal values are too low (<400mV)	1) The sensor pad is on something other than skin. Move the probe off of hairs, eyebrows, etc. 2) There's no power to the fNIR Imager. Check the connection the electrical outlet. Check the power box to see the power is on.
Receive a warning message while using fnirUSB.dll: "Cannot maintain sampling frequency".	This warning indicates that the USB bandwidth and/or computational power of the computer may not be adequate. Even with the warning message, data acquisition can continue and data can be recorded with the best possible sampling even though it is slower than 2Hz. If there are any unnecessary applications running, closing them before starting data acquisition may help. Also, if there are any extra devices connected through USB ports, removing them before data acquisition may help to improve performance. Also, try changing sampling settings within fnirUSB.dll device settings under 'data acquisition settings' tab. One option is to unselect 'get ambient light' option. This will disable collecting raw ambient light for each voxel so only 730nm and 850nm data will be collected for each voxel. Another option to improve sampling frequency (controlled from sampling settings) is removing quadrants (groups of voxels) from data acquisition scheme. By unselecting one or more quadrants, required USB operations at each period will decrease so sampling frequency will improve (especially for slower computers).
Receive error messages on the message pane and data acquisition is not continuing	Close the application and restart.

Receive error message “cannot open specified layout file”	This message indicates that the layout file selected to be loaded at start-up is not found or cannot be accessed. Start-up layout file setting can be accessed from left-hand side menu, “Layout Operations” and under “Start-up settings”.
During data acquisition, after baseline is started, receive message “baseline XX lambda 730/850 changed to 1”	This message indicates that channel specified by XX contains noisy/problematic data that is not usable in baseline, and thus replaced by 1 just for oxygenation data view. Please check your sensor, cables and/or connections and verify sensor is positioned properly on the subject.

18. Appendix: Specifications

1. Physical Specifications
   1.1. Dimensions of Probe: 18x6x0.8cm
   1.2. Probe Materials: Foam & Wire
   1.3. Number of detectors: 10
   1.4. Number of light sources: 4
   1.5. Light-Source Separation: 2.5 cm

2. Sample Rate Specs
   2.1. Sample rate = 25,000 samples/second or A/D Conversion every 40 microseconds
   2.2. 250 samples per LED wavelength per detector = 10 milliseconds
   2.3. 2 wavelengths per detector = 20 milliseconds
   2.4. For 16 channels = 320 milliseconds for one whole sample
   2.5. Period is set to 500ms (full image rate = 2 Hz)

3. LED Specs (Epitex L6X730/6X850)
   3.1. 2 wavelengths: 730, 850nm (+-15nm)
   3.2. Max continuous current/relative power at each wavelength
   3.3. 730: 75ma/90%
   3.4. 850: 100ma/100%

4. Opto101 Photodiode Specs:
   4.1. Active area: 2.3x2.3mm
   4.2. Unit to unit detection variation +-5%
   4.3. Non-linearity: .01% of full signal
   4.4. Bandwidth 14kHz
   4.5. Voltage output Vs. Temperature: 100ppm/C
   4.6. Dark Current: 7.5mv