TeraCota 2000

Service Guide

TeraView

Release History

Document Number	Revision	Publication Date
N/A	Rev 1	January 2023

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Printed in the United Kingdom.

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Contents

1. INTRODUCTION

1.1. About this Service Guide

This guide is intended for use by personnel trained by TeraView Limited in the service, configuration and support of TeraCota instruments. They must have received training and hold certification in Laser Safety. It is not intended that this manual forms a standalone course, and it is written as a reference document, not a training document.

1.2. PPE Equipment Required

This is the recommended Personal Protective Equipment list to be carried to site by TeraCota Service Personnel. This is in addition to any specific requirements imposed by the site.

- Steel toe-capped shoes/boots.
- Safety glasses.
- High visibility jacket.
- Paint suit.
- Hair net.
- LOTO padlock.
- Laser safety goggles
- Bump cap or safety helmet.
- ESD kit (wrist strap and cable).
- Antistatic gloves.

1.3. Tools Required

This is a general view of tools likely to be required for installs and services. Not all tools will be required for all systems or service activities.

- Large and small flat-blade screwdrivers.
- Large and small Posidrive screwdrivers.
- Miniature/watchmakers screwdriver set.
- Electric screwdriver / drill (for wooden crates).
- Full Allen Key Set Long handled/ball-driver: 1.5 mm, 2 mm, 2.5 mm, 3 mm, 4 mm, 5 mm.
- Regular ‘L’ Allen Key Set: 1.5 mm, 2 mm, 2.5 mm, 3 mm, 4 mm, 5 mm.
- Short/Stubby Allen Key set: 1.5 mm, 2 mm, 2.5 mm, 3 mm, 4 mm, 5 mm.
- Miniature Allen Key Set: 0.71 mm, 0.88 mm, 1.27 mm, 1.5 mm, 2 mm.
- Long handled Imperial Allen Keys: 1/16th, 0.050”.
- 2 mm Hex Key Thumbscrew (Thorlabs HKTS-5/64).
- End-cutters (e.g. for cutting cable ties).
- Long-nose pliers.

- Stanley knife.
- Scissors.
- Laser power meter (ideally Thorlabs PM100D).
- Laser power meter head (ideally Thorlabs S121C).
- Fibre Adapter for Laser power meter head (Thorlabs S120-FC).
- IR Viewing Card.
- IR viewer (e.g. IRV1-1700).
- Fibre inspection scope (e.g. Thorlabs FS201).
- Test Fibre.
- Fibre cleaning cartridge.
- Miniature torch/flashlight.
- Magnetic pick-up tool.
- Tweezers (curved & straight / long reach).
- Adjustable spanner/wrench.
- Mole grips (for water cooling pipes).
- Digital voltmeter (DVM) and probes. Extension probes.
- Syringe & small funnel (for filling and dosing cooling reservoir).
- Sensor Head Alignment Jig.
- Gold reference mirror.
- Alignment pin hole (2 mm) for TeraCota 2000 sensor head.
- Permanent markers (fine & thick).
- Tape measure & ruler.
- Fibre caps.
- Split conduit threading tools: 10 mm, 25 mm.
- Optical / lens cleaning tissues.
- Range of U.Fl and SMA test cables and adapters.
- BNC test cables and adapters.

1.4. Spares and consumables

This is a list of common spares and consumables that may be useful and can be carried in the service kit:

- Blade fuses: 1A, 3A, 5A, 10A.
- 20 mm cartridge fuses: 10 A.
- Roll of Copper Tape.
- Roll of Kapton Tape.
- Emitter and receiver cartridges.
- Batteries: AA, AAA, button cell (e.g. LR44).
- Cable ties.
- Bottle of superglue.
- Air duster can.
- Bottle of propanol (IPA).
- Bottle of coolant or distilled water.
- Rubber gloves (powder-free and ESD safe).

1.5. Stocked TeraCota Assembly Spares and Modules

These are larger or more expensive spares items that will be stocked at the discretion of the distributor, integrator or customer:

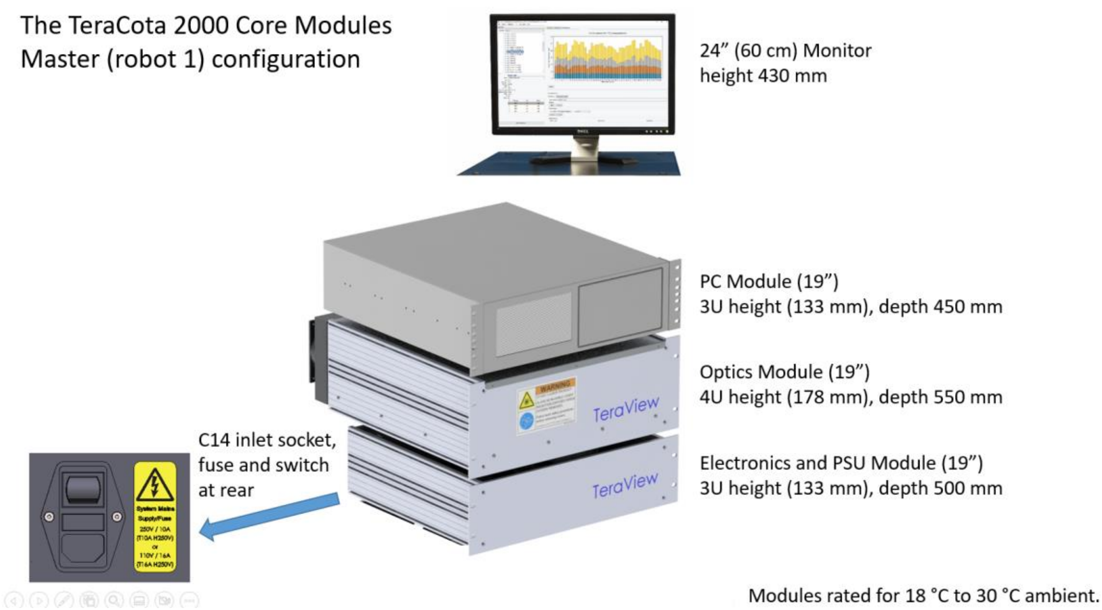
- 3U Rack PC – AMD Ryzen 9 3950X
- TeraCota Motherboard PCB
- DAM Board
- Power Supply
- Embedded PC
- Peltier Temperature Controller
- Head Alignment System
- Laser Head
- Motorised Stage (25 mm IKO)
- Diffraction Grating
- Fibre Splitter
- PCB assembly (12 V laser)
- TeraCota 2000 Sensor Head
- Cable Set for H.A.S.
- Cable Set for Sensor Head
- Armoured Fibre Set
- Optical Adaptor – Fibre Coupler

2. GENERAL LAYOUT OF THE TERACOTA 2000 MODULES

The TeraCota 2000 is a modular system that uses 19" rack mounted modules to support up to two terahertz sensor heads.

2.1. The core modules

The core modules are shown below. Note that one Electronics Rack assembly and One Optics Rack Assembly are require for each sensor.



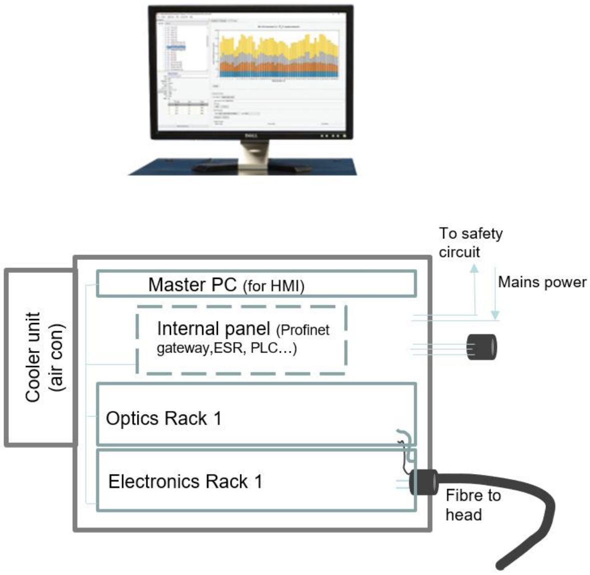
2.2. The cabinet

The modules are usually housed in a rack cabinet along with any other ancillary equipment. The cabinet may be supplied by TeraView, the integrator, or the end customer. It may or may not be air-conditioned, depending upon the ambient environment.

Note that if a cabinet is not air-conditioned, the equipment is rated to an ambient temperature of 18 to 30 C only. It must be open at the rear to allow the fans to extract heat, and at least 15 cm (6 inches) clear of any wall or other equipment.

Remember that air-conditioned cabinets are often interlocked. If they do not operate with the doors open, then care must be taken to allow adequate ventilation to prevent overheating, when working with opened modules.

Examples are shown below:


To safety circuit
Mains power
Master PC (for HMI)
Internal panel (Profinet gateway,ESR, PLC…)
Cooler unit (air con)
Optics Rack 1
Electronics Rack 1
Fibre to head

3. LASER SAFETY

3.1. TeraCota 2000 classification

The TeraCota 2000 core system is a CDRH Class 1, BS EN 60825-1/IEC 60825-1 Class 1 laser product. The enclosed optical system of the TeraCota 2000 contains a Class 3b ultrashort pulsed laser.

Class 3b lasers can cause severe eye injuries. CDRH regulations state that Class 3b lasers are those for which intrabeam viewing and the viewing of specular reflections is hazardous, but the viewing of diffuse reflections is normally considered safe. A Class 3b laser is not normally a fire hazard.

3.2. Responsibilities

Where a qualified and trained engineer is required to gain access to an operating laser (e.g. for alignment purposes), they must comply with local regulations and company policy in line with BS EN 60825-1. This includes, but is not restricted to:

- Maintaining communication and signage on customer sites (in local languages if necessary) to ensure that personnel in the surrounding area understand the hazard.

- Erecting physical screens or barriers where appropriate and restricting access and line-of-sight the laser area.

- Use of appropriate PPE (e.g. laser safety goggles) where appropriate.

- Not leaving an exposed laser unattended.

- Replacing covers and/or switching off the laser as soon as reasonably practical, minimising the time for which the hazard is present.

Service personnel must accept full responsibility for the safety of themselves and those working around them.

3.3. Access

Covers prevent access to the optical system and ensure safe and reliable operation of the TeraCota 2000. The covers are screwed in place and should only be removed using tooled-release by a TeraView Service Engineer.

Access to the system internals is gained by removing the front panel. This should only be performed by trained Service Engineers.

4. WORKING WITH ESD SENSITIVE COMPONENTS

Many of the electronic components used in the TeraCota instrument are sensitive to damage from electrostatic discharge (ESD). Such items include the laser, terahertz semiconductor devices, and the TEC controller PCB, amongst others.

4.1. What is ESD?

Electrostatic discharge is a sudden and momentary flow of electric current between two electrically charged objects caused by contact, an electrical short or dielectric breakdown. A buildup of static electricity can be caused by tribocharging or by electrostatic induction. The ESD occurs when differently-charged objects are brought close together or when the dielectric between them breaks down, often creating a visible spark.

ESD can create spectacular electric sparks (lightning, with the accompanying sound of thunder, is a large-scale ESD event), but also less dramatic forms which may be neither seen nor heard, yet still be large enough to cause damage to sensitive electronic devices.

ESD can cause harmful effects of importance in industry, including failure of solid state electronics components such as integrated circuits. These can suffer permanent damage when subjected to high voltages. Electronics manufacturers therefore establish electrostatic protective areas free of static, using measures to prevent charging, such as avoiding highly charging materials and measures to remove static such as grounding human workers, providing antistatic devices, and controlling humidity.

4.2. Protection during transit

Sensitive devices need to be protected during shipping, handling, and storage. The build up and discharge of static can be minimized by controlling the surface resistance and volume resistivity of packaging materials. Packaging is also designed to minimize frictional or triboelectric charging of packs due to rubbing together during shipping, and it may be necessary to incorporate electrostatic or electromagnetic shielding in the packaging material. A common example is that semiconductor devices and computer components are usually shipped in an antistatic bag made of a partially conductive plastic, which acts as a Faraday cage to protect the contents against ESD.

4.3. Working with ESD sensitive components

ESD protection is the process of helping to guard sensitive electronic devices and components against the potentially damaging effects of electrostatic discharge. Wherever you are in direct physical contact with electronics, circuitry and other high-tech assemblies, you will need to be aware of the potential impact of ESD events.

In short, ESD is effectively like a mini lightning strike on an electrical device. Depending on the amount of energy released and the sensitivity of the assembly involved, some ESD events can be entirely harmless. However, they can also cause a wide range of problems: reliability and performance issues, minor latent damage to individual components, melting/burnout, or even catastrophic failure of entire systems.

There are many facets to covering all the ESD protection basics. ESD safety means that all practical measures have been taken to keep the risk of an electrostatic discharge event to a minimum. These include:

- ESD control products
- Environmental factors
- ESD-safe clothing and workwear

4.4. ESD control products

Consider using wrist straps to ground yourself to an earthing point when working with the sensor head or inside the rack assemblies. Work slowly and methodically, allowing any static charge to dissipate. An ESD grounding clamp is used to connect equipment susceptible to a discharge event directly to the ground. Once suitably grounded in this way, the risk of ESD damage is greatly reduced.

They usually consist of a metal clip or static clamp attached to a length of cord, often tightly coiled and designed to stretch in use. At the other end is a grounding device, designed to be connected directly to the ground. The clamp attaches to the electrical component being worked on. This connection to the ground disperses any latent charge safely, without the risk of sudden arcing or shorting causing an ESD event. it provides a path of least resistance for any latent static charge that has built up through the movements of the wearer. This allows the static electricity to safely discharge to ground and minimises the risk of it arcing across from the operator to the component they are touching.

4.5. Environmental factors

In the absence of a conductive connection, the return current which inhibits charging is dominated by the conductivity of the air, which depends upon the relative humidity (RH). Workplaces and other indoor environments with a low relative humidity (RH) are at increased risk.

Since there’s less moisture vapor in the air, ESD is more common in environments with low RH. Normally, the airborne moisture helps to dissipate static electricity. Water is conductive, which allows electricity to travel freely throughout the air, minimizing ESD build ups. Humidity tends to be lower in cold weather or in winter, when extra care is needed.

If the RH is below 40% then increased care is required. 30% is usually defined as a safe working limit for handling ESD sensitive components.

4.6. ESD-safe clothing and workwear

ESD-safe shoes and anti-static shoes are terms that might often be used interchangeably, but there is technically a slight difference in definition. Both help to minimise the build-up of static electricity caused by the wearer moving around, by quickly conducting any latent charge to the ground.

However, fully ESD safe footwear does so at even lower resistances than more basic antistatic shoes, and as such, meets more stringent criteria for ESD control and cleanroom applications. Either type may be available or compatible with additional accessories like ESD shoe straps for additional grounding.

Clothing has a big effect on charging. ESD discharge can be prevented with special protective ESD clothing such as an ESD work coats or ESD shirts, Such clothing contains woven-in conductive fibres that discharge electrostatic electricity. Cotton or other natural fibres are preferable to synthetic materials (e.g. nylon).

5. GENERAL GUIDANCE FOR WORKING WITH OPTICAL FIBRES

5.1. Safety

Dispose of broken fibres very carefully – they can be sharp.

NEVER look directly at the end of a fibre (either with the fibre microscope or naked eye) when there is laser power coupled into the fibre.

5.2. Tools and Equipment

- Power meter with fibre connector.
- Fibre microscope.
- Propanol.
- Fibre cleaning cartridge.
- Permanent marker with fine tip.
- Rubber gloves.
- Air duster.

5.3. Overview of polarisation maintaining fibre used in TeraView systems

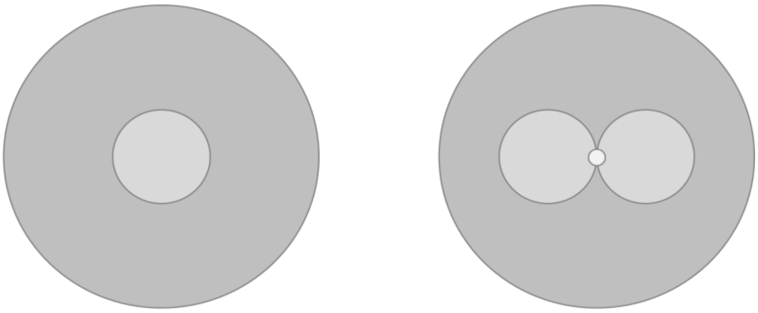
Any optical fibre transmits light (in our case, laser light) internally by total internal reflection with very low losses. For the lengths of fibres we use the absorption in the fibre is negligible: i.e. we can assume that 100% of the optical laser power *coupled into the fibre* is transmitted along it. The heavy losses tend to come when attempting to couple light into a fibre!

Disregarding the connectors at the ends for the time being, the type of fibre we use at TeraView is characterised by three parameters:

The fibre is specified as **single-mode**. This means that it is specific to wavelength (see core diameter, below) and hence other wavelengths won't propagate along the fibre. It also means that all the power travels down the fibre in single optical transverse mode, so (for example) it is not possible to 'see' images down the fibre, only a single point of light.

The core diameter is 5 µm and the cladding diameter is 125 µm, making this fibre suitable for the 780 nm wavelength of light we use.

The fibre is described as **polarisation-maintaining** because the polarisation (direction of the electric field vector) of the laser light is preserved along the whole length. We use 'Panda' type fibre, which has a 'preferred' direction of polarisation indicated by 'Panda eyes' in the cross-section'. These are clearly visible in a microscope.

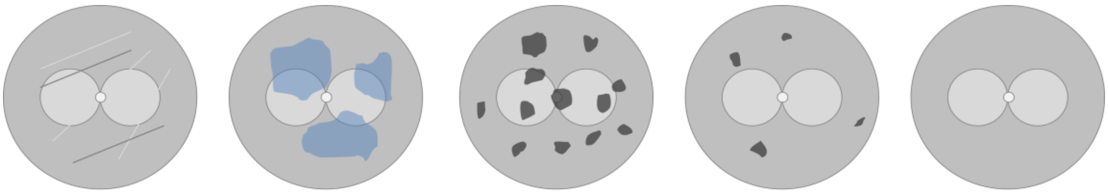


Non-PM fibre PM fibre

The outer jacket of the fibre is the only part of the structure that is visible from the outside – it may be thick, thin, blue, black, rigid, flexible, plastic or metal. It makes no difference to the fibre inside. In general to avoid damage, the fibre should not be bend to radii smaller than about 25 mm (50 mm bend diameter) for bare fibres and 100 mm radius (200 mm bend diameter) for armoured fibres.

5.4. Inspecting and cleaning tips of fibres

Regardless of the type of connector on the end of the fibre, it is important to inspect and clean the tip of the ferrules to ensure good coupling efficiency into the fibre. Use the handheld fibre microscope to view the fibre tip before using the fibre.



scratches | solvent stains | major debris (core blocked) | minor debris (core clear) | clean

If the Panda eyes are difficult to make out due to low contrast, then try rotating the ferrule back and forth as you observe – it is often easier to see a moving image than a static one.

Scratches: It is not possible to clean scratches from the tip without re-polishing the fibre (which cannot be done at site). Minor scratches outside of the core or panda eyes area will probably not do much harm. If the scratches are major, or cross the core, then consider rejecting the fibre. If in doubt, do NOT connect it face to face with another fibre, since the other face can be scratched by the first.

Solvent stains: These can be easily cleaned using the fibre cleaning cartridge, wetted with a little propanol, using very light pressure.

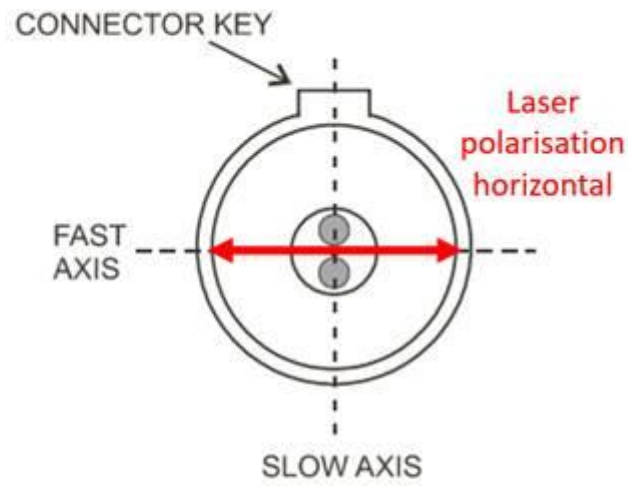
Major & minor debris: This can be either specks of dust / other debris on the surface, or pits and recesses in the tip. The former can be cleaned, the latter cannot. It is important to clean the tips for three reasons. First, the debris can block laser light, reducing the efficiency of coupling into the fibre. Second, it can absorb laser light and heat up, causing burnt-on damage that cannot subsequently be cleaned off. Thirdly, the damaged fibre may cause scratching or deposit debris onto any other fibre tip that it is brought into contact with. Cleaning should take place in the following order:

- A blast of air from the air duster.
- Dry wipe of fibre cleaning cartridge using light pressure.
- Wipe of fibre cleaning cartridge wetted with propanol using light pressure.
- Wipe of fibre cleaning cartridge wetted with propanol using heavier pressure.

Be aware that over-cleaning (or cleaning when not necessary) can often actually make the situation worse. Over time, lots of cleaning will tend to erode the tip of the fibre into a concave shape, leading to a significant loss of coupling efficiency. **Clean only when necessary, and as little as necessary**.

5.5. Polarisation alignment

TeraView instruments usually align lasers into fibres with the electric field polarization aligned along the fast axis, but the connector key aligned to the slow axis. As shown below:

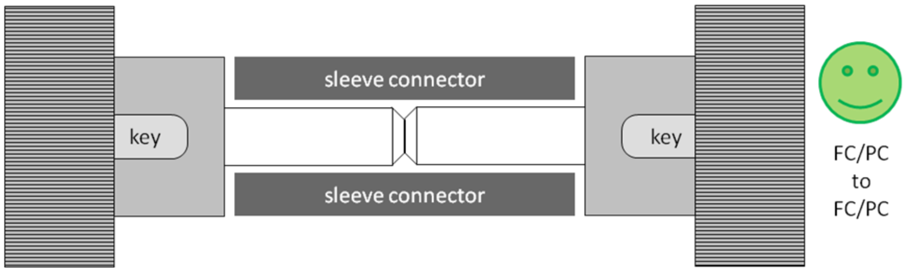


5.6. Coupling power into fibres from free space

Coupling from free space into fibre is done using fibreports. When connecting fibres into fibreports, the cleanliness of the fibre end facet is less important because the tip of the fibre is not actually in contact with another surface. Nevertheless, it is important to ensure that the core is clear, and it is good practice to wear gloves when handling fibre tips, to prevent the transfer of dirt or grease to the fibre. Use the fibre dustcaps whenever they are not in use. It should be possible to couple approximately 60% to 80% into an FC/PC fibre.

5.7. Coupling power from one fibre to another

When coupling power from one fibre to another, it is important to remember that the two faces will be in physical contact with one another, and hence the cleanliness of the facets is absolutely vital. Since all FC/PC fibre terminations are 'male', it is necessary to use a 'sleeve connector' (a.k.a. mating sleeve, connector, joiner, uniter) to make the join.



In practice, getting good coupling between two fibres seems to be dependent on manufacturing toleratnces. The specification for losses in the ideal case is less than -40 dB – corresponding to a coupling efficiency of over 99.99%. However, in practice, this can vary from a number indistinguishable from 100% down to 80% or worse. The recommended approach is:

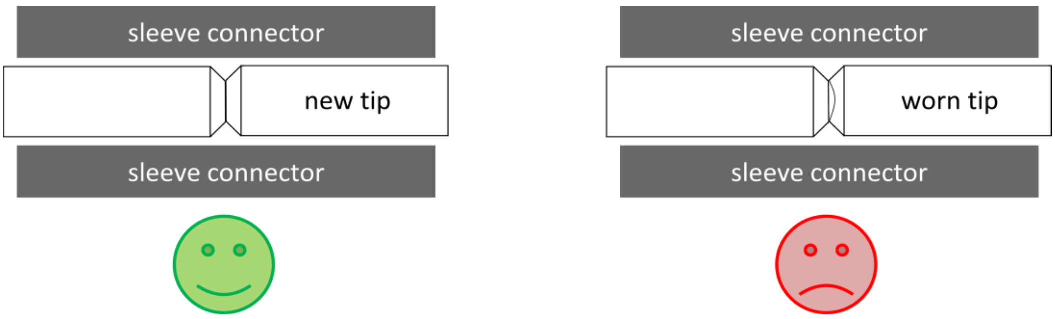
- Measure the power emerging from the source fibre, using the fibre attachment on the optical power meter. SWITCH OFF the laser.
- Examine both fibre tips to be connected, and clean ONLY if necessary.
- Ensure that the mating sleeve (connector, joiner, uniter) is clean by gently rubbing with a swab wet with a little propanol, then blow out any debris with the air duster.
- Insert the source fibre into the sleeve, being very very careful not to touch the metal face with the tip, and locate the alignment key into the notch on the sleeve. Tighten the housing thread finger tight.
- Insert the second fibre tip partially and rotate to align the key into the keyway on the mating sleeve. Then *gently but firmly* push the fibre fully into the sleeve: it will make contact and spring back a little. This is usually the state in which the best coupling is achieved.
- Switch on the laser power and measure the power transmitted by comparing this to the figure measured for the source fibre. If the fibre is connected to a device, this won't be possible, in which case try to obtain a THz signal on the screen.

- If the power / signal is not sufficient, then do NOT repeatedly make and break the contact, but withdraw the fibre, inspect (and clean if necessary) before trying again to make the join. It may take many attempts to get a good transmission, but take care to inspect and clean *both* tips between each attempt. If, after 10 attempts, there is no improvement in the transmission, then abort and try a different fibre.

It is occasionally possible that no good transmission will be achievable with any two given fibres, however many times it is attempted. This is usually attributed to one of the following reasons:

1. Broken fibre. This is usually very easy to diagnose, since an IR viewer will show a very bright intensity spot at the break point, with no light seen further down. This is usually accompanied by a kink in the fibre – note that no repair is possible – another fibre or device must be substituted. However, it is perfectly normal for some light to be lost into the cladding at strained lengths of fibre close to the connectors, or after coupling from a fibreport, and a green 'glow' for significant lengths of fibre is perfectly normal.

2. It is possible that permanent damage has been incurred to the fibre, even if the tips appear in good condition and free from debris. Two examples are a tip that has been worn into a concave shape by excessive cleaning (see figure), or a fibre where laser power has burnt debris into the fibre core.



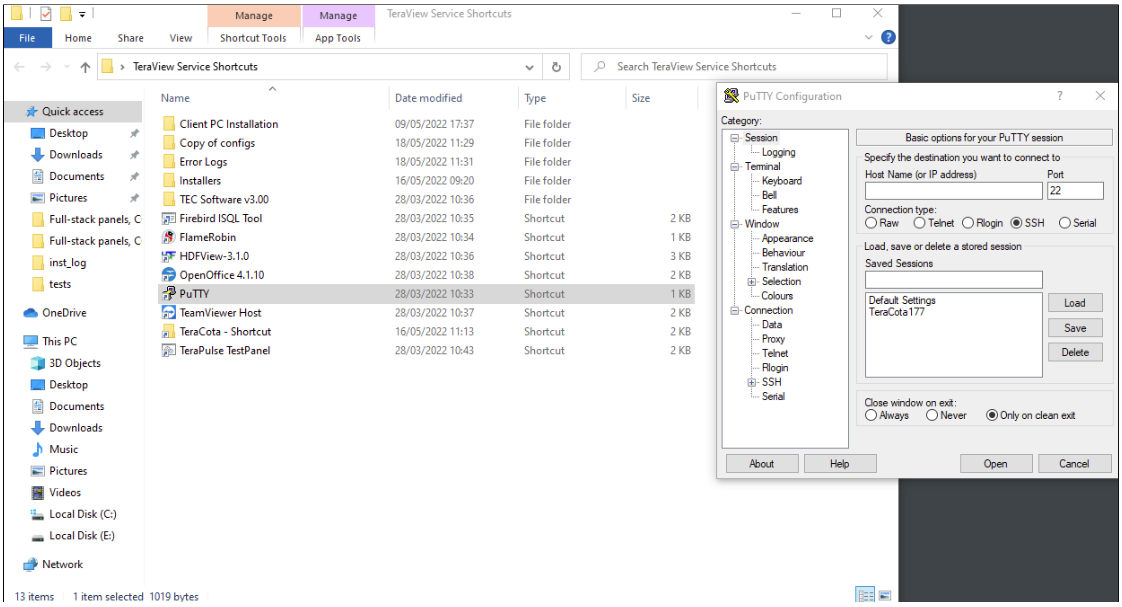
For builds, it may be necessary to purchase several fibres to the same nominal specification to ensure that at least one will achieve good coupling.

6. USE OF PUTTY TO CONNECT TO THE EMBEDDED INSTRUMENT

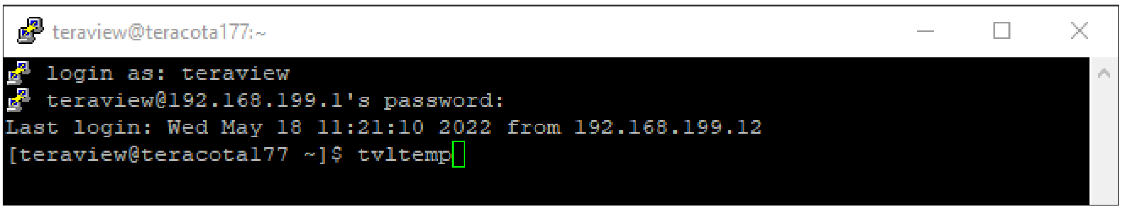
It is possible to use Putty from any Windows PC (usually either the Client PC on the system, or a personal laptop) to connect to the embedded PC in the instrument. This is useful if you want to check hardware, monitor the temperature controller, or turn the laser on for alignment purposes. Unlike using TestPanel or the TeraCota software applications, it does not require that peripherals are attached and working, nor that successful initialisation is achieved.

6.1. Opening a connection

To open a connection, run the Putty application from the desktop shortcut icon (commonly located in the 'Service' folder) or by typing it into the search bar.



If the TeraCota instrument is listed under the 'Saved Sessions' then double click on it to open the connection. If not, you can manually enter the IP address: 192.168.199.1



When prompted, the login name is 'teraview', with the usual service password.

6.2. Common commands

The embedded PC runs a Linux operating system. Common commands are:

- 'tvltemp' (returns the status of the temperature control service).
- 'tvltemp -s -25' (set target temp for laser baseplate to 25 degrees).
- 'tvlaser' (returns the status of the laser).
- 'tvlaser on' (turns on the laser).
- 'tvlaser off' (turns off the laser).
- 'sudo poweroff' (shuts down the embedded PC system).
- 'rpm -q tvlpulse' (returns current version of the embedded code).

```
teraview@teracota177:~
login as: teraview
teraview@192.168.199.1's password:
Last login: Wed May 18 11:21:10 2022 from 192.168.199.12
[teraview@teracota177 ~]$ tvltemp
[{'casting_temp': 24.500869750976562,
  'channel': 0,
  'current_lim': 4.0,
  'error_num': 0,
  'heatsink_temp': 21.21905517578125,
  'peltier_current': 0.18530738353729248,
  'peltier_voltage': 1.1609160900115967,
  'regulation': 'stable',
  'serial_no': 854,
  'status': 'run',
  'target_temp': 24.5},
 {'interval': 0}]
[teraview@teracota177 ~]$
```

```
[teraview@teracota177 ~]$ tvlaser
{'state': 'off', 'target': 'off', 'interlock': 'ok', 'elmo_state': 'standby', 'e
lma_state': 'standby', 'error_code': 0, 'error_msg': ''}
[teraview@teracota177 ~]$ tvlaser on
{'state': 'initialising', 'target': 'on', 'interlock': 'ok', 'elmo_state': 'stan
dby', 'elma_state': 'standby', 'error_code': 0, 'error_msg': ''}
[teraview@teracota177 ~]$
```

Warning: be aware that if you shut down the embedded PC from a remote connection, it is not possible to restart it without personnel at site to power cycle the core instrument.

7. USE OF TESTPANEL TO UPDATE THE CONFIGURATION

TestPanel is a service interface application which runs on the Client PC. It allows direct access to the TeraPulse embedded instrument for setup, optimisation and diagnostic purposes. Since it is possible to corrupt or damage the instrument by using this software without training, it is not usually available for use by the end customer.

7.1. When an update might be required

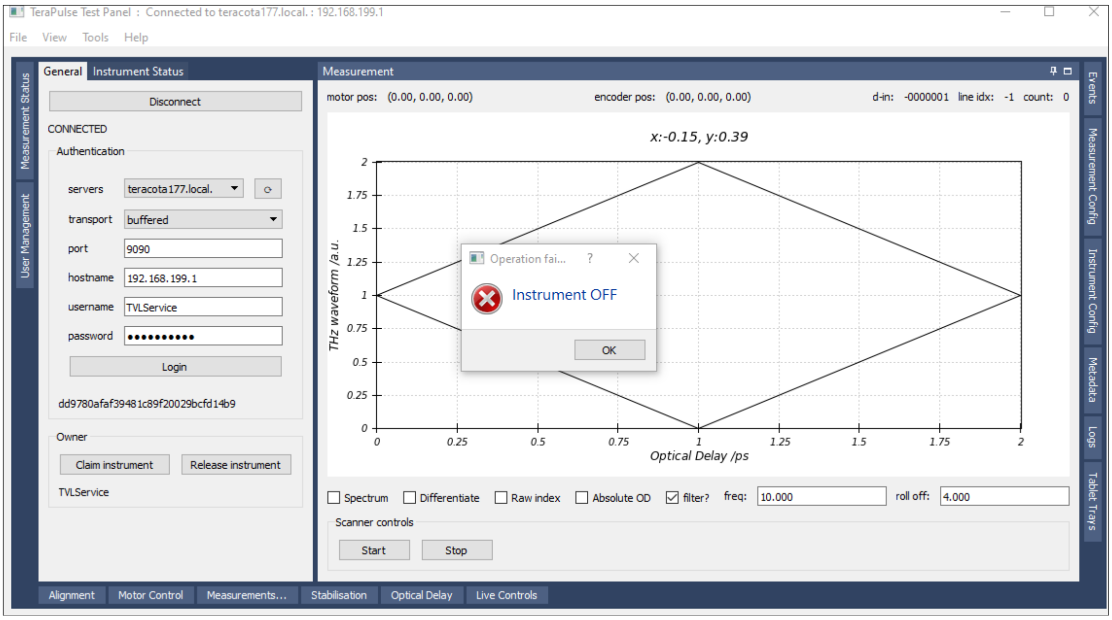
An update to the embedded instrument software is usually required every time a hardware intervention takes place, including swapping optical or THz components (e.g. the sensor head), laser realignment or terahertz signal optimisation.

7.2. Opening a connection using TestPanel

To open a connection, run the TestPanel application from the desktop shortcut icon (commonly located in the ‘Service’ folder) or by typing it into the search bar.

From the ‘General’ tab, ensure that the appropriate instrument name appears in the ‘servers’ box, and then enter the usual service password, and click ‘Login’.

Click ‘OK’ to close the pop-up box, and then ‘Claim Instrument’.

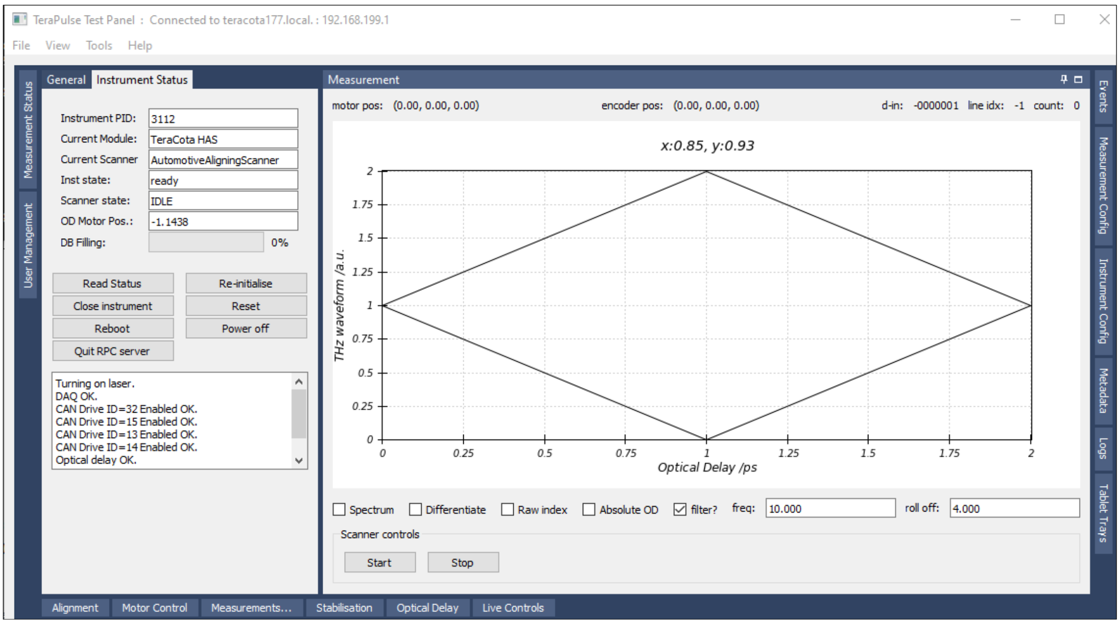


7.3. Initialisation

The initialisation process is internal to the embedded instrument, although it can be run from other applications (e.g. TeraCota) as a subset of their own initialisation routines. It establishes a connection to the hardware (including the peripheral board with communicates with the terahertz devices), turns on the laser, homes motor stages (including the head alignment system, if fitted) and checks that the laser baseplate temperature is stable.

From the 'Instrument Status' tab, click 'Re-initialise'. The status of the various hardware modules will appear in the left-hand panel as the individual services are initialised.

If there is an error or a failure of the instrument hardware, then it will usually become apparent now. The instrument will enter an 'error' state, with a description of the problem.



7.4. Instrument and Measurement configs

The Instrument and Measurement configurations are text files that may be viewed and edited from TestPanel using the corresponding tabs on the right of the screen.

The Instrument Config contains the parameters required to define and configure the hardware, and can only be changed in TestPanel (they are not written from external applications). Settings here should be changed with care, since it is possible to damage hardware if incorrect values are used (for example, increasing emitter bias, or setting the RSDL amplitude to a range that is too high).

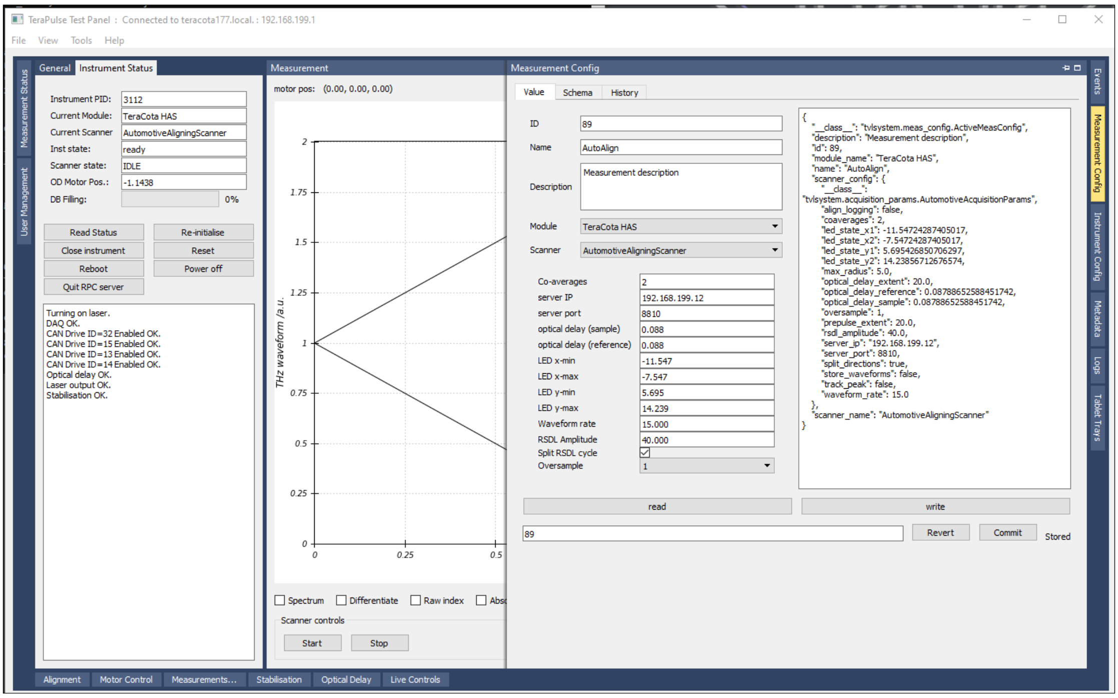
The Measurement Config contains the parameters required to define the waveform used in each measurement. These can depend upon the scanner type selected, and they *can* be modified by external software (e.g. TeraCota).

Both files are stored on the embedded PC (instrument). '*Read*' is used to read the file from the embedded instrument to TestPanel, and '*Write*' is used to write the file from TestPanel to the embedded instrument.

The Instrument and Measurement configurations are also specified in the TeraCota application configuration file (TeraCotaConfig.yaml) as IDs.

7.5. Starting the scanner

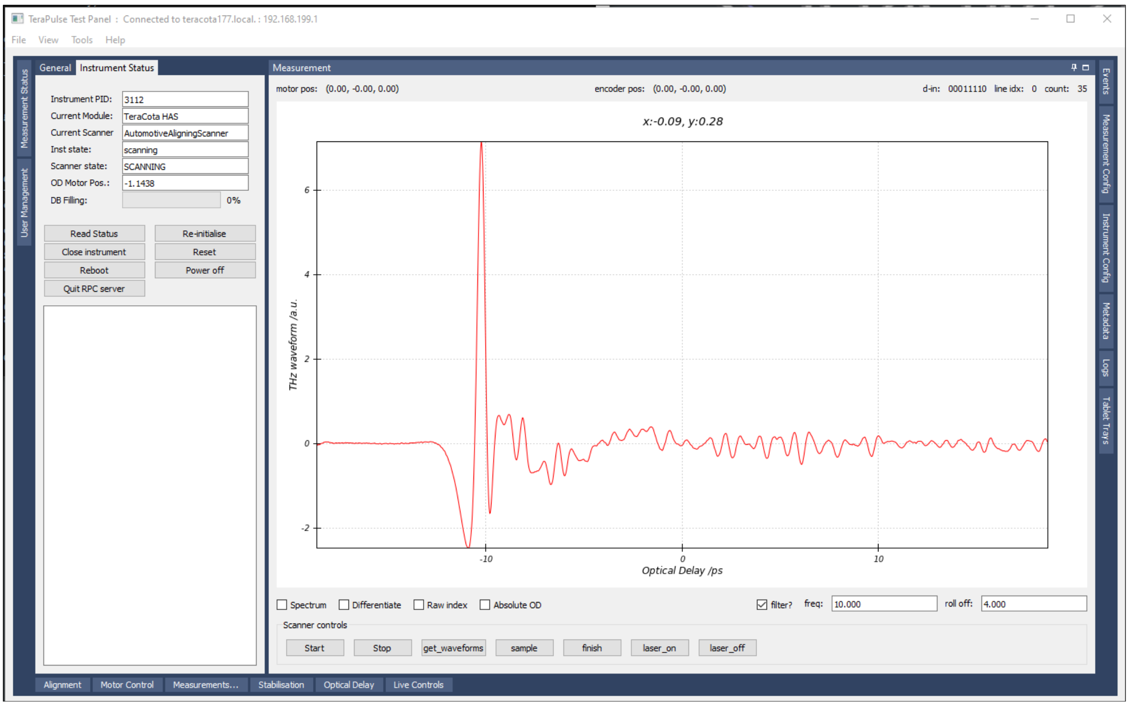
The scan service is accessed from TeraCota via server IP address, but when using TestPanel to run the scanner while TeraCota is not running, no server is present. Therefore it is necessary to (temporarily) delete the IP address from the Server IP box in the Measurement Config and click 'write'.



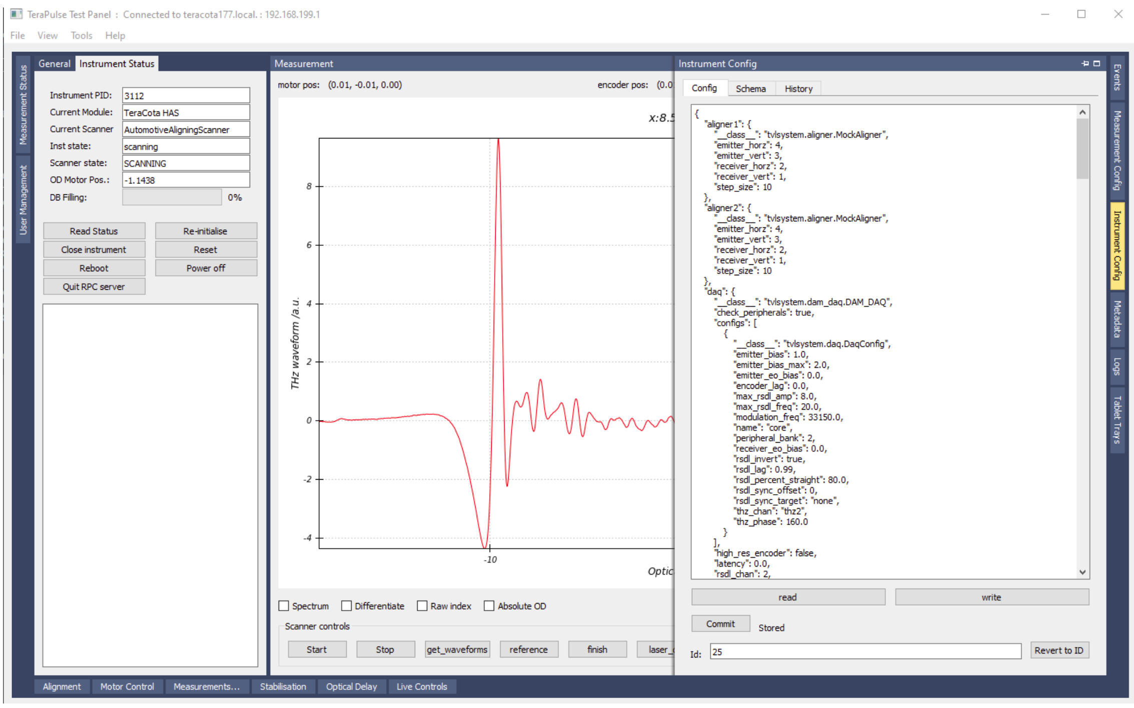
The scanner can now be run using the 'Start' button. If the measurement config is correct, the THz signal will be displayed in the main graph window.

When the scanner is running, the additional functionality of the TeraCota 2000 sensor head can also be accessed. The 'laser_on' and 'laser_off' buttons control the integral green laser pointer.

Close and open the intercept mirrors by clicking the 'Reference' button. This button toggles between 'Sample' and 'Reference'. Note that the button refers to the state accessed by clicking the button and NOT the current state of the instrument.



7.6. Changing the Instrument Config



The instrument config is specific to the particular configuration of the instrument: including the sensor head type. Once factory set, there are few parameters that will need to be updated in field service, and so any updates should be undertaken with great care, paying particular care not to disturb any punctuation. The most likely parameters that may need changing are detailed here:

THz phase ("thz_phase"): This parameter controls the phase difference between the 30 kHz emitter modulation and the demodulated receiver signal, as in a lock-in amplifier. The usual approach is to use the 'Live Controls' tab to adjust the phase parameter to minimise the terahertz signal amplitude, then add 90 degrees to the minimisation value.

Optical delay stage zero position ("optical_delay_zero"): This parameter sets the position of the optical delay stage in the emitter beam and should be set such that the instrument initialises with the terahertz pulse located at the correct position in the time domain, such that no further systematic offset is needed in either the Measurement Config or the Metadata tab. This value is given by the '*OD Motor Pos*' in the Instrument Status tab, and is in units of mm (NOT ps).

Terahertz signal scaling factor ("thz_scaling"): This parameter sets the scaling factor in the vertical (amplitude) axis for all pixels in the measured THz waveform. Usually set to a default of 1.0, it is occasionally useful to change it (to compensate for performance drift, or to normalise performance between two instruments, for example). Be sure to check the value of this parameter if using the apparent amplitude of the displayed terahertz pulse to assess the instrument performance.

Waveform minimum amplitude ("wfm_min_amplitude"): This parameter sets the minimum value of the terahertz amplitude required for the head alignment system (H.A.S.) to optimise the signal. If the signal is lower than this threshold, then the H.A.S. routine will return a 'low signal' error.

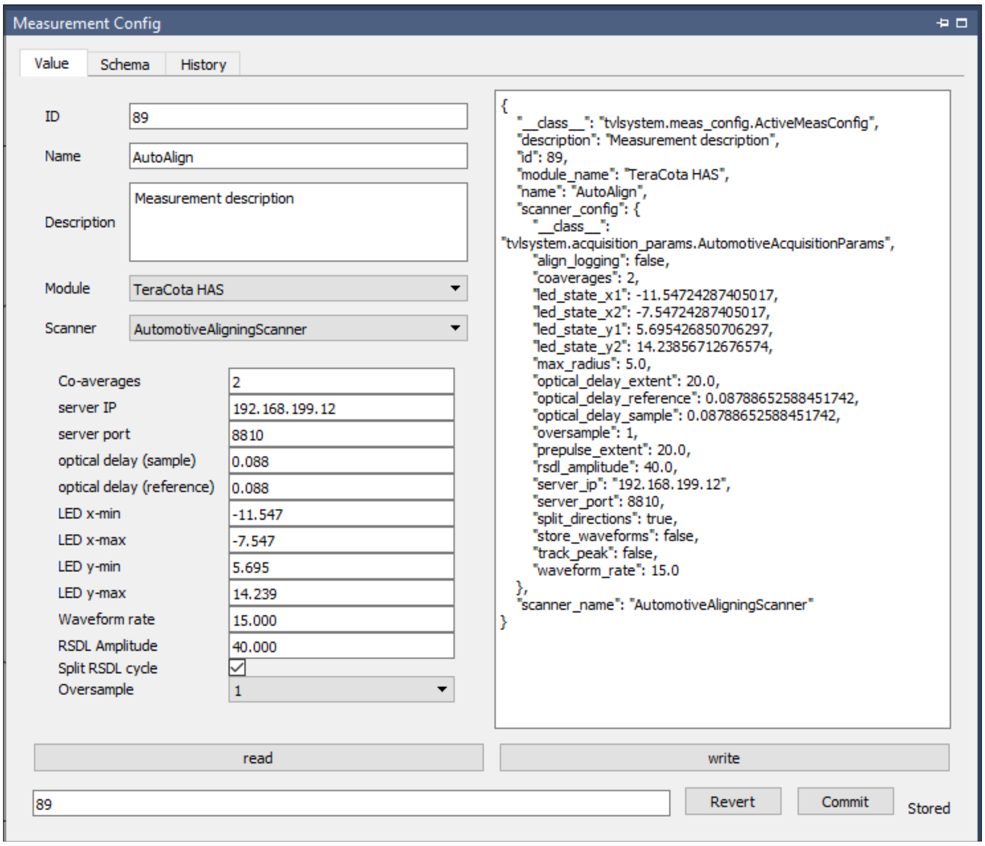
Rapid Scan Delayline Calibration ID ("rsdl_calibration_id"): This parameter selects which RSDL calibration to use when plotting the time-axis of the terahertz waveform. The default value is -1 (no calibration). This value will need to be incremented to the new value when a new RSDL calibration is taken.

Inside the modules for the H.A.S. motors for each axis:
"tmcm1240_a"
"tmcm1240_b"
"tmcm1240_c"
There is a **"zero_offset":** This parameter sets the offset required to allow the geometric / mechanic centre of travel of the H.A.S. stages to be set to the 0.0 definition of the origin in the control software. These values may need to be updated if the H.A.S. is repaired or replaced.

All changes to the Instrument Config or the Measurement Config will be persistent only when the changes are committed (click 'commit'). This will result in a new ID for the configuration (i.e. nothing is overwritten).

7.7. Changing the Measurement Config

The measurement config allows parameters specific to the measurement type to be controlled. For the TeraCota application specifically, most of these are fixed and should not change, because the TeraCota application has hard-coded expectations of the data format, etc.



One item that is useful is the control for the radius of the spiral (in mm) for the H.A.S search range.

"max_radius": 5.0,

The larger this value, the wider the search range of the H.A.S. and the more capacity there is to accommodate poor angular alignment, but at the cost of a longer alignment time. A smaller value speeds up alignment, but covers a smaller search range, with fewer points. Too small a range will result in too few points to reliably fit a surface to: the threshold will depend upon the level of the signal-to-noise, among other things. In practise, a good compromise appears to be approximately 3.5 mm.

Finally, the Measurement Config contains Optical Delay offsets for the reference and sample, that modify the ("optical_delay_zero") parameter in the Instrument Config.

"optical_delay_reference": 0.0,
"optical_delay_sample": 0.0,

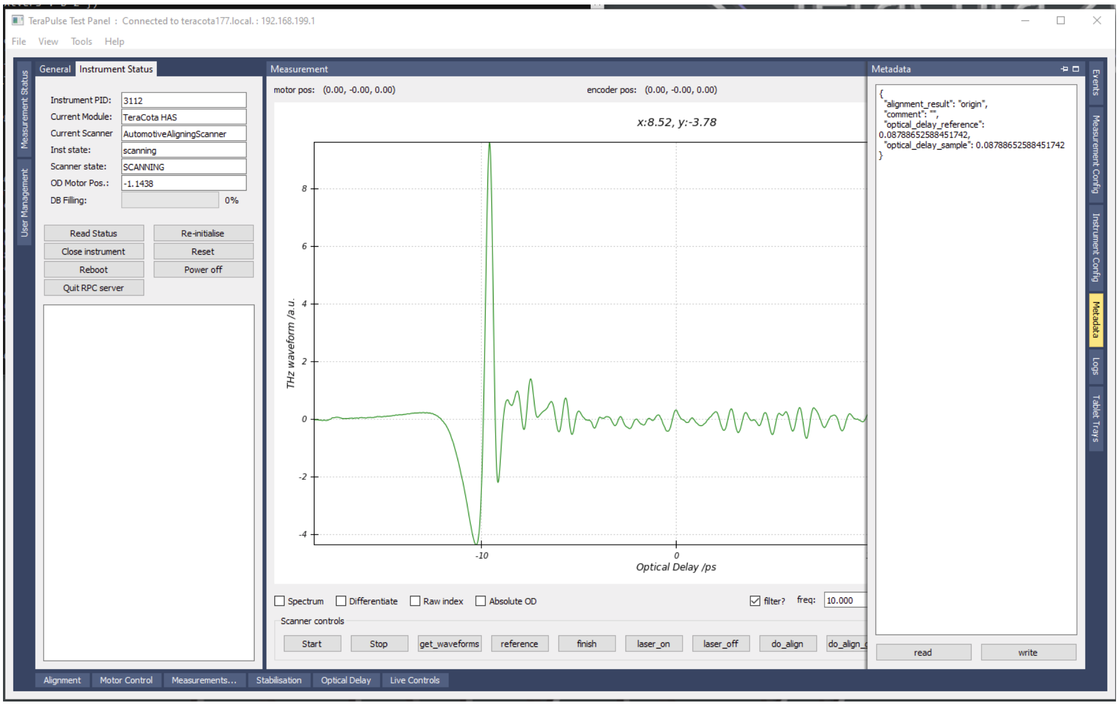
Unlike the ("optical_delay_zero"), these values are in units of ps. It is essential to ensure that the two values for reference and sample are identical to each other, because we don't want any motion of the optical delay stage between the sample and reference measurements (the existence of two separate parameters is historical). If the Instrument Config is set up correctly, then the "optical_delay_reference" and "optical_delay_sample" should both be set to zero.

Note that using the manual motor control in the Optical Delay tab only updates the optical delay position for the currently selected state (i.e. sample or reference).

7.8. The metadata tab

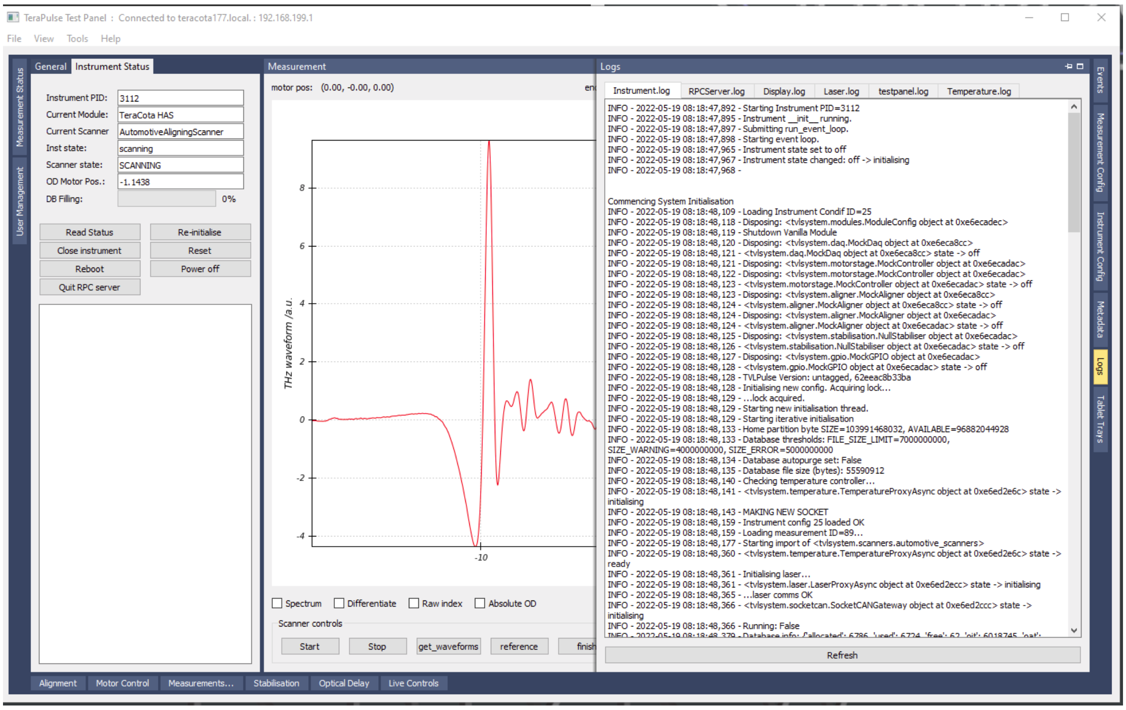
In TeraCota systems, the metadata tab contains further modifiers to the Optical Delay positions for both sample and reference, again in units of ps. TeraCota uses these offsets to compensate for unwanted shifts in the apparent waveform position (usually caused by mechanical factors such as fibre stretching, thermal expansion, etc).

Again, it is most important that these values remain identical for both sample and reference, and ideally 0.0 at the point at which the instrument is set up in TestPanel.



7.9. The logs tab

Any errors or hardware problems encountered by the TestPanel application are written to the log file, accessible from the Logs tab, on the right hand edge of the screen. This is a text file that can be manually copied to notepad, if necessary to report.



7.10. Common Update Procedures

The remainder of this section details common procedures that may be followed to update the Instrument or Measurement Configs following intervention. Most common service operations (e.g. parts replacement, optical alignment, THz optimisation etc) will refer back to this section.

7.11. Setting the Optical Delay Zero

1. With optical alignment complete, the software configuration can now be updated to fine-position the terahertz peak at the correct point in the time-domain scan window (usually at -10.0 ps). This update is required because each head or optical alignment state in the core will have slightly different optical and THz path lengths. Start TestPanel and log in to the instrument. Initialise the instrument. Remember to (temporarily) delete the IP address entry in the Measurement Config, to allow the scanner to run. This IP address is used by TeraCota to access the Measurement Config, but is not used whilst in TestPanel.

2. First, close the intercept mirrors to view the reference waveform. Find the pulse and be sure it is the principal (main) reflection, using the Optical Delay stage to navigate backwards and forwards along the time-axis as necessary.

3. In the Measurement Config, check that the "optical_delay_extent" and "prepulse_extent" are equal to each other, and half of the intended RSDL amplitude (for example: 22.5 ps). Check that the RDSL amplitude updates to the correct value (e.g. 45 ps).

4. Use Test Panel to move the optical delay line to get the 'reference' (mirrors closed) pulse peak to align to -10.0 ps. Zoom in and fine tune the stage position to locate the pulse peak at exactly -10.0 ps on the time axis. Note that for the TeraCota module type in TestPanel, the optical delay adjustment applies independently to the sample and reference 'states'. Thus the optical delay line may simultaneously move if the intercept mirrors are moved.

5. Record the OD Motor Position value (in mm) that appears in the box (top left panel) – you may need to click 'Read Status' to refresh it. If you have completed the optical alignment well, then this value should be close the centre of the stage value (0.0 for the IKO stage), within 5 mm is preferable.

6. Change the "optical_delay_zero" value in the Instrument Config to be this number you just recorded. Save the instrument config, and commit, generating a new ID number.

7. In the Measurement Config AND metadata, change the delay positions to 0.0. for both sample and reference. Save the measurement config, generating a new number. Reinitialise the instrument, and ensure that the measurement config values stay at 0.0 (this can be buggy sometimes), with the pulse at -10.0.

8. Once you have fully optimised in TestPanel, and are happy with the Measurement and Instrument Configs, then add the IP address back into the Measurement Config: *normally 192.168.199.100* but check against an older Measurement Config file. Then commit the new measurement config and note down the numbers of both the Instrument and Measurement IDs. Once the IP address is restored, you can no longer run the scanner in TestPanel. **Close the Instrument**, and then **exit TestPanel**.

9. Update the TeraCota Config.yaml file to request the Instrument and Measurement IDs you just set.

7.12. RSDL calibration

The rapid-scan delay line (RSDL) requires a valid calibration in order for the embedded instrument to be able to convert the voltage read back from the galvo encoder to a time-delay in ps. If the calibration is not correct, then the units of ps in the time axis, and hence the units of THz in the frequency-domain FFT axis will not be precisely calibrated. In turn, this will give errors in the thickness calculations and could produce distortion on the waveform. The simplest check for the accuracy of calibration is to compare the apparent location of water vapour absorption lines with the known standard. There is a simple viewer in the TeraCota application intended for this purpose.

To take a RSDL calibration using TestPanel, follow the following steps. You must first have completed the optical alignment and have a good terahertz pulse on the screen.

1. Clear the existing RSDL calibration by setting it to -1 in the instrument config.

2. Run the scanner, and close the intercept mirrors to view the reference signal.

3. Using the 'Live Controls', gently increase the RSDL amp until you hear a faint clicking or knocking sound (the galvo hitting the end stops). Immediately back off by 0.5 and record the value (the highest you can set in Live Controls before the RSDL starts knocking). This is the RSDL amp value to use in the calibration process.

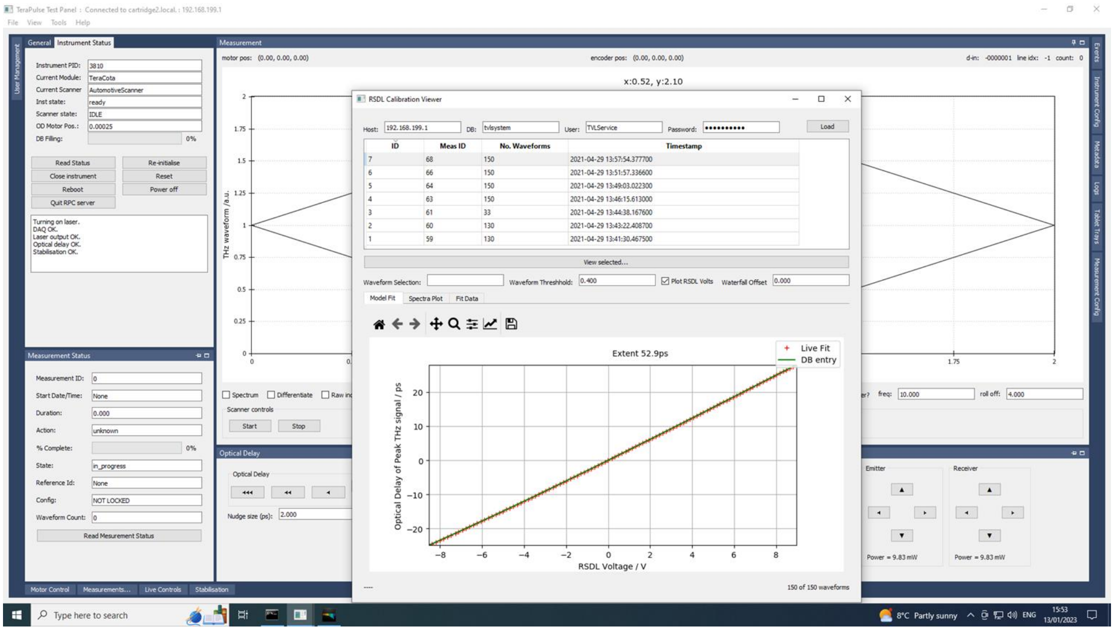
4. In the Measurement Config, select the RSDLCalibration as the scan type, and fill in the dialog box. The RSDLCalibrationScanner will step the static optical delay over the given range ('excursion') while collecting waveforms. At the end of the process, the calibration function will be calculated. This may take a few attempts to get it right. The TeraCota requires quite a precise OD offset setting to avoid the short stage from hitting the end stop. Try using:

   Co-averages = 5
   Wfm rate = 15
   RSDL amp
   OD offset = -10.0
   Excursion = 60
   Stepsize = 0.5

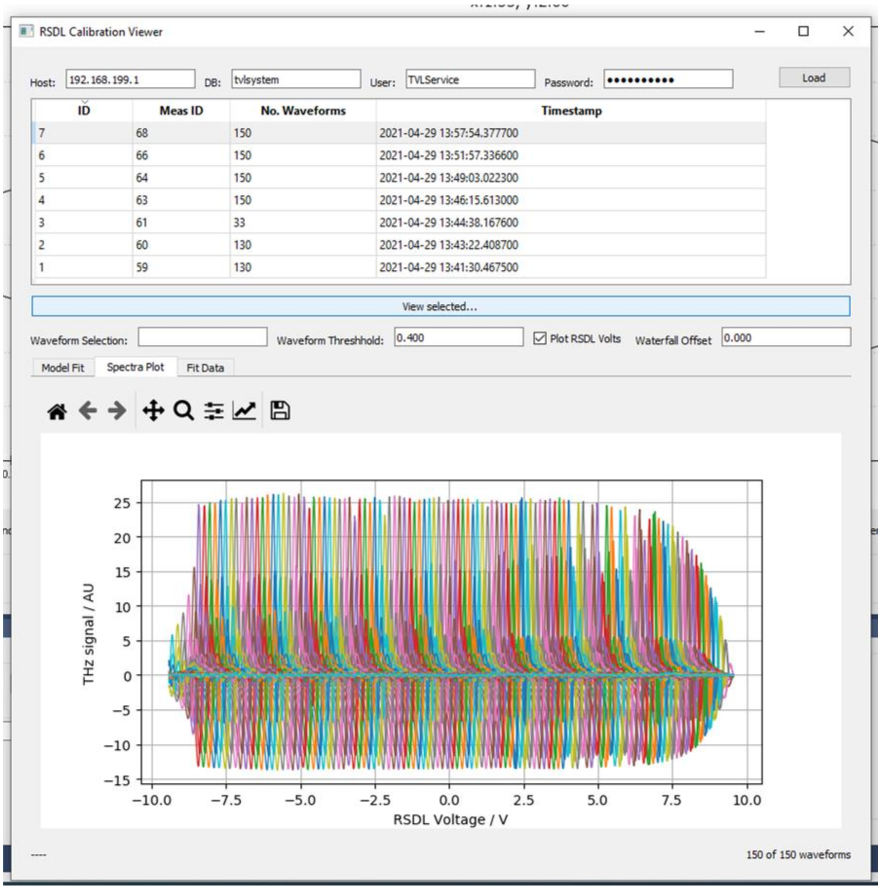
   Watch the calibration process on the screen closely, to ensure that you can see the pulse tracking from one edge of the RSDL window all the way to the other. If it stops or starts too early, then adjust the OD offset and increase the excursion accordingly and try again. Alternatively, if the scan fails, it may be that the delay stage has hit the end stop, in which case try to change the offset away from the limit, or reduce the excursion.

5. When an RSDL calibration succeeds, the Instrument Config will be updated with the rsdl_calibration_id of the new calibration. This will

NOT automatically be committed to the inst-config, so I suggest clicking "commit" in the instrument config window just to be sure. The new RSDL calibration ID will also appear in the RSDL Viewer window, which can be opened from the 'Tools' menu in the top menu bar of the TestPanel application.



There are three tabs which can be used to view different aspects of the selected calibration. The most important value is the 'Extent' which gives the usable range of the RSDL travel.



The given value here is the maximum RSDL amplitude the calibration will permit. This should be >45 ps for a standard single-pass RSDL. If the calibration max range is <45ps, you may need to adjust the galvo head rotation to reduce the clipping at one end of the galvo excursion. Poor alignment into the fiberports can also limit the available RSDL range.

7.13. Updating the TeraCota Configuration file

1. The changes made using TestPanel will only be effective when running TeraCota if the configuration for TeraCota is updated to point at the new configurations. You must update the TeraCota.yaml with the new Instrument and Measurement Config values. This file is usually located in *C:\ProgramData\TeraView\Teracota.* Back up the existing .yaml file (it is not automatically version controlled) in case you need to revert. Then open the TeraCotaConfig.yaml in a text editor.

2. Update the Instrument and Measurement IDs to read the values you just set in TestPanel:

    - `terapulse_instrument_config_id:`
    - `terapulse_measurement_config_id:`

    Then save the file and close it.

Open TeraCota, and if all of the above has been done correctly, then it should automatically pick up all the various changes and initialise correctly with the pulse at -10.0 ps, and appearing just as it did in TestPanel.

8. REPLACING THE RACK PC (CLIENT/WINDOWS PC)

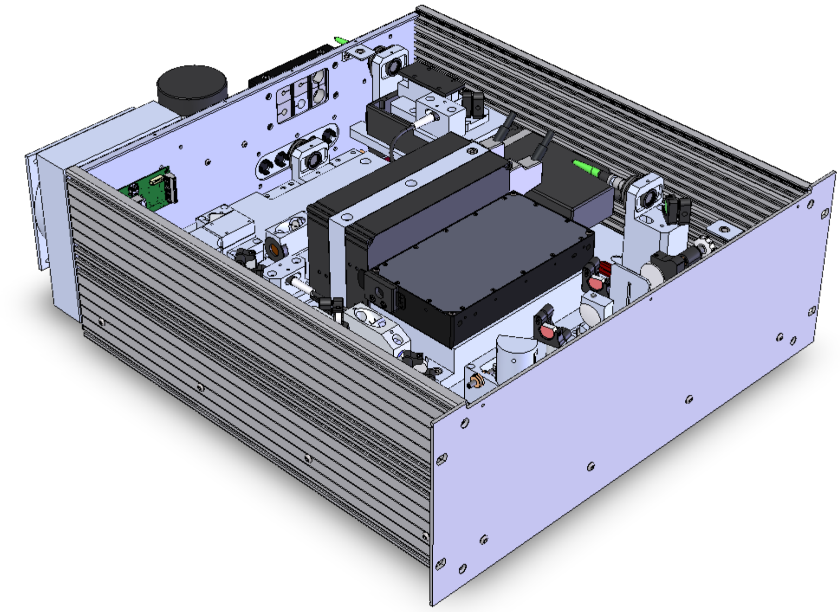
9. OVERVIEW OF THE OPTICS RACK ASSEMBLY

9.1. Access

1. Remove the four M6 screws that retain the tray in the cabinet, and gently slide it forward by a couple of inches, and test feel for any resistance that could be attributed to any cables getting snagged. It is best to move it forward a couple of inches at a time, and then check the back and sides each time that all cables are able to feed smoothly. It is necessary for the fibres to stay attached during this process so ensure there is enough length to allow this without straining them. It may be necessary to remove any cable ties that are managing any excess length.

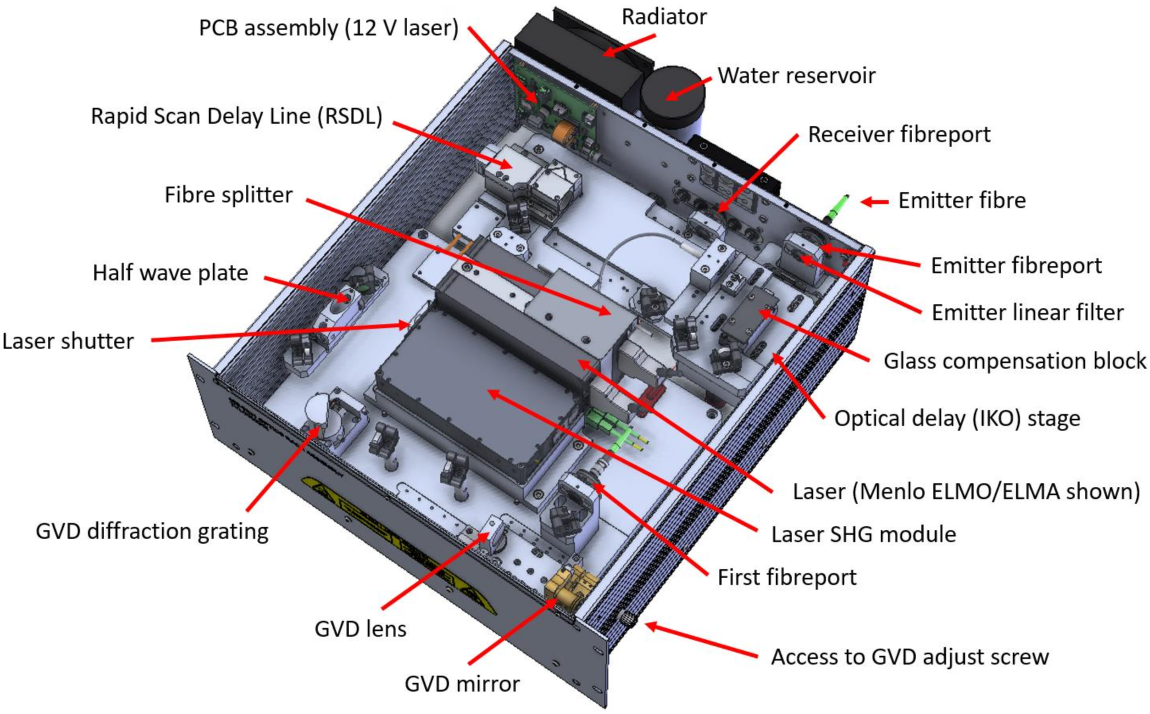
2. As the drawer moves forward, the inner rail and outer rail should both extend on both sides, so that the chassis can be fully removed to access the screws at the rear of the top cover. As soon as you can see these screws, it doesn't need to come further – there is no requirement to access the water cooling or fan. Be particularly careful not to snag the water reservoir or the overflow pipe on the chassis unit underneath – there is very little clearance. **Do NOT depress the metal push buttons on the side of the slide rails which emerge as the chassis is withdrawn. Doing so would release the chassis from the slide rails, potentially resulting in damage or injury as it falls.** The slide rails can be quite stiff, so be patient.

3. Once sufficiently withdrawn, use a 2 mm Allen key to remove the top cover, as shown. Remove the three screws on the front of the lid, and the four screws at the rear, and slide the thin top cover forwards to remove it, as shown. Do not touch any of the optical components inside.



9.2. Identification of internal components

The principal components in the Optics Rack assembly are as follows.



9.3. Nominal beam path

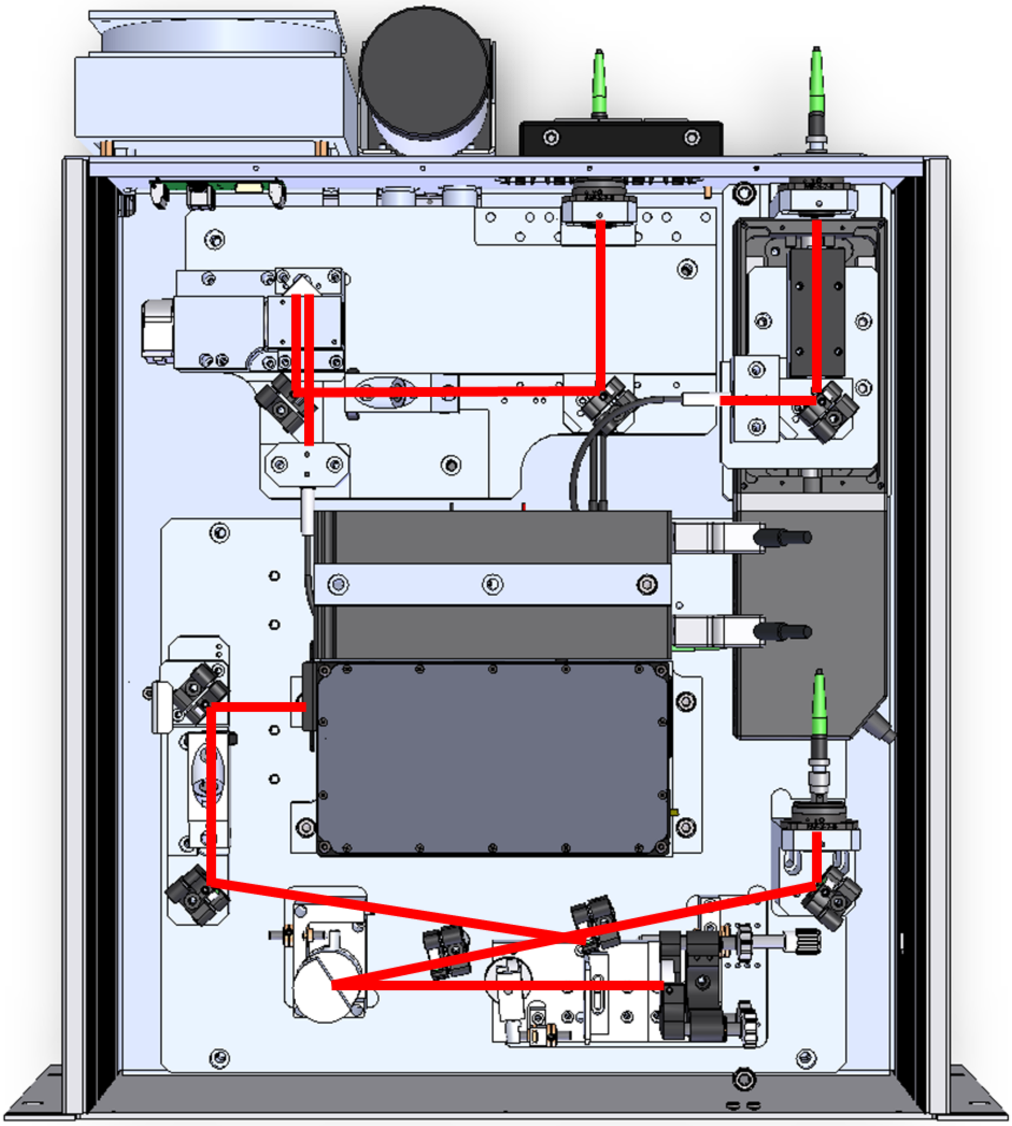
The design for the beam alignment is as shown in the following image. The free space part of the beam is in three separate sections, and it is important to understand that the three sections may be aligned completely independently, since the coupling direction into the fibre splitter does not affect the direction of the output from the two collimators.

The Laser Plate contains the beam path from the laser output, through a half wave plate set at 45 degrees so that the beam polarisation is swapped, with the electric field vector rotated from vertical to horizontal. After passing through the GVD assembly (four passes between the grating and mirror) it is coupled into the fibre splitter via a fibre port.

The fibre splitter splits the beam 50:50 between the two collimated outputs when the beam polarisation is aligned along the fast axis of the fibre.

The receiver collimator output of the splitter passes through the rapid scan delay line (RSDL) assembly before coupling into the receiver fibreport.

The emitter collimator output of the splitter passes through the glass compensation block (to provide an equivalent length of glass to that contained within the RSDL assembly), before coupling into the emitter fibreport.



9.4. Closing the Optics Rack Assembly

Slide the lid carefully back into position and screw the lid back on using the rear and front holes, and the domed M3 screws. Slide the tray back in as gently as possible, just an inch or two at a time then check for trapped cables or fibres at the back and sides. Be particularly careful that the bottom of the reservoir bracket or the overflow pipe don’t snag.

Once fully slid back, check the signal again to make sure nothing has been misaligned. Then screw the chassis to the cabinet front using the 4 M6 bolts.

10. GENERAL OPTICAL ALIGNMENT NOTES

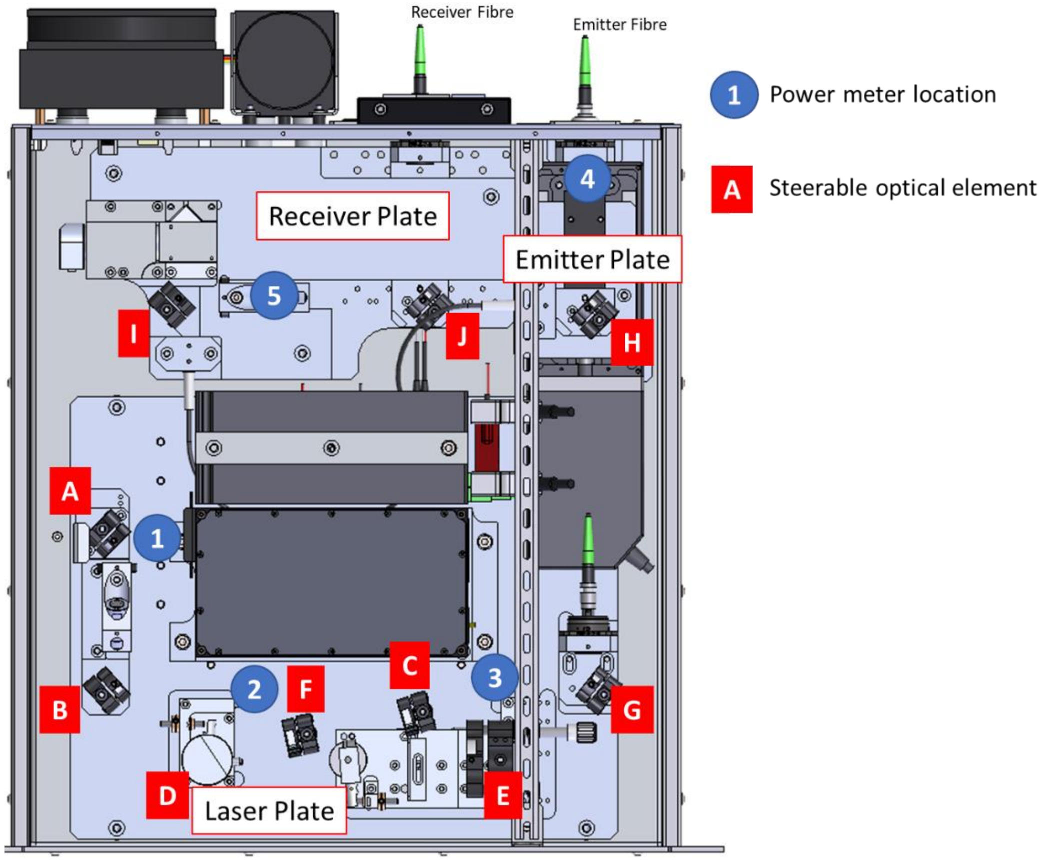
10.1. Powering up the Optics Rack Assembly

After any intervention, switch on the TeraCota core system via the switch at the back. It may need up to 30 minutes for the laser baseplate temperature to stabilise depending upon its initial temperature, before the software will allow you to initialise the system.

The temperature can be checked using '*tvltemp*' command in a Putty window.

10.2. Laser power measurement locations

The laser powers measured at TeraView (i.e. what you are aiming for) will usually be recorded from the FAT, SAT or the previous IQ. The measurement points are as follows:

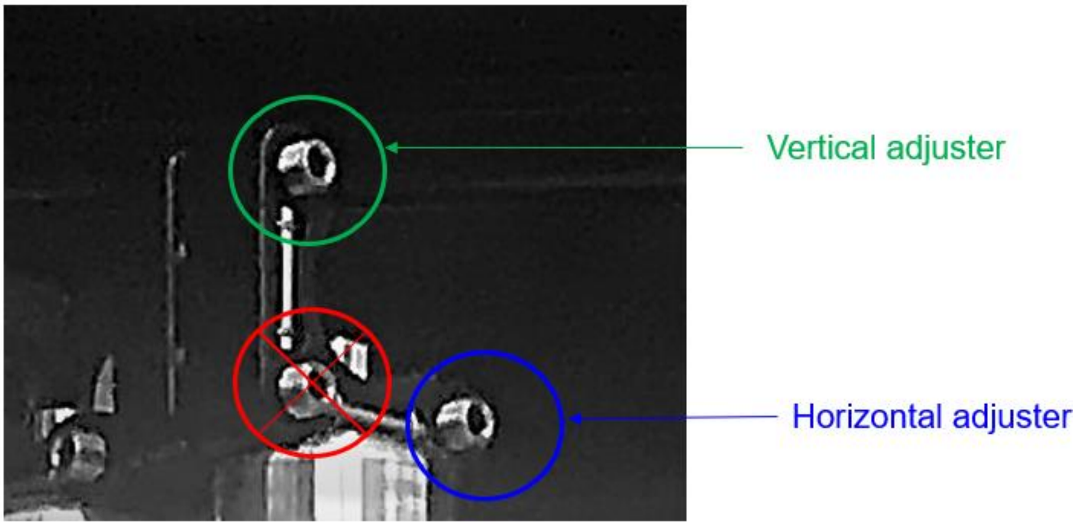


10.3. Alignment of the laser plate

The beam should hit the centres of mirrors B and G, and the power coupled through the fibre splitter can be measured at point 5 (the

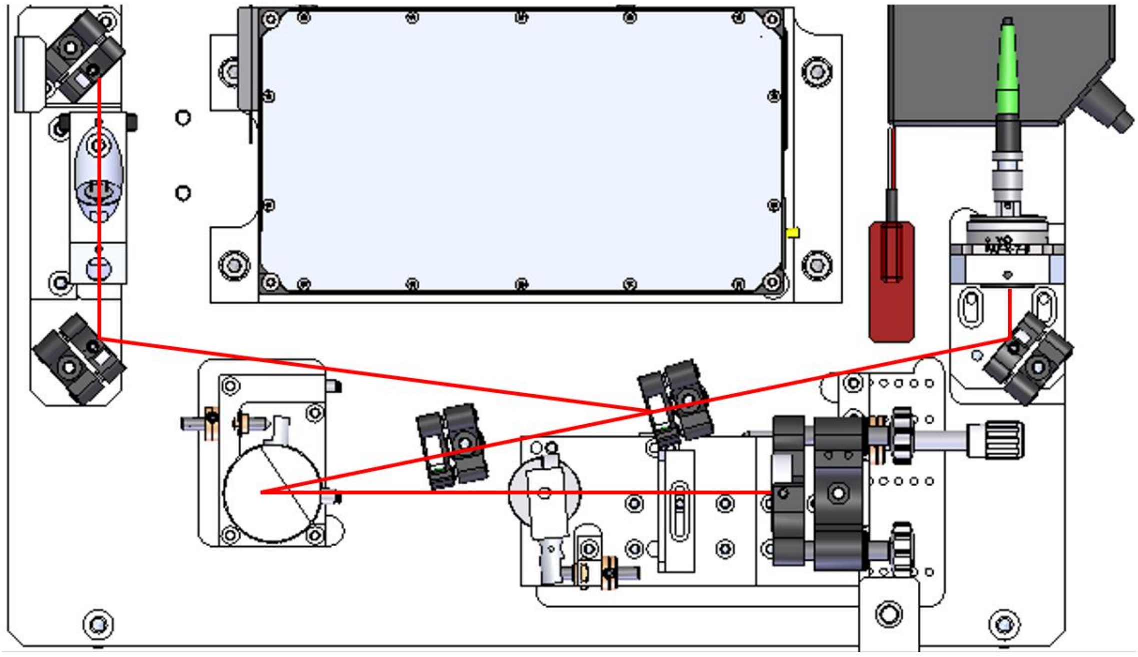
S121C power meter head sits quite nicely in the shallow groove). Use the power at 5 to optimise the first fibreport coupling by steering mirror G. If the beam does not hit the centre of G, or it is not possible to achieve good coupling by moving G alone, then it might be necessary to walk both F and G in order to get good power out.

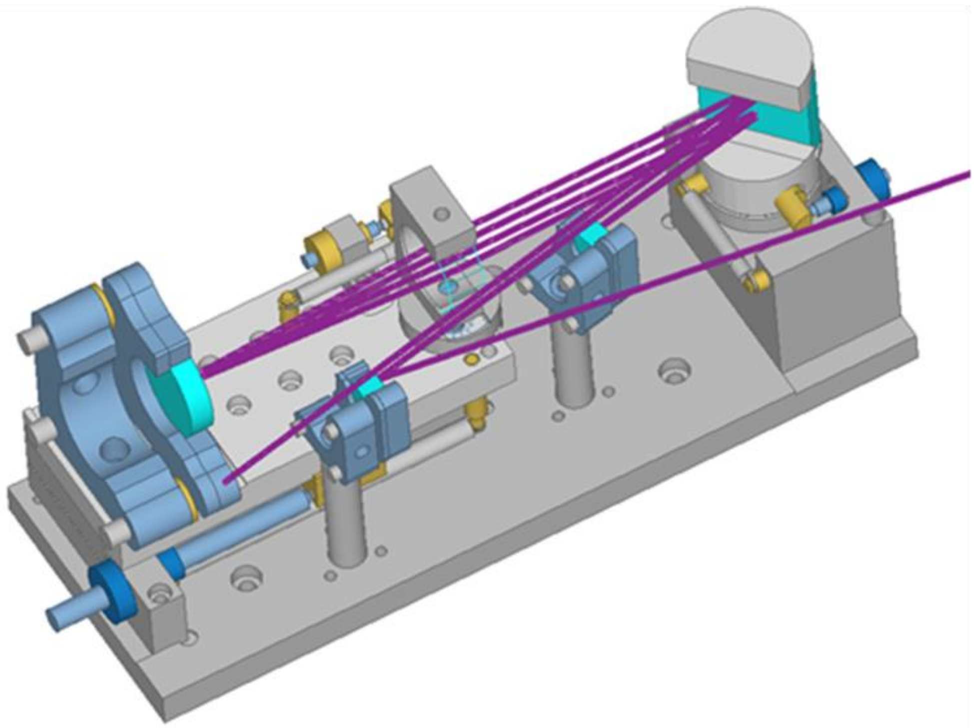
Mirror alignment is a practised skill, and all adjustments should be small. Use a lab book or notebook to record which mirrors are moved in which direction. This will help with retracing your steps if you find you are making it worse. The mirror mounts we use to adjust the beam position have three adjusters. We usually only use TWO of the adjusters to adjust the horizontal and vertical pointing of the reflected beam.



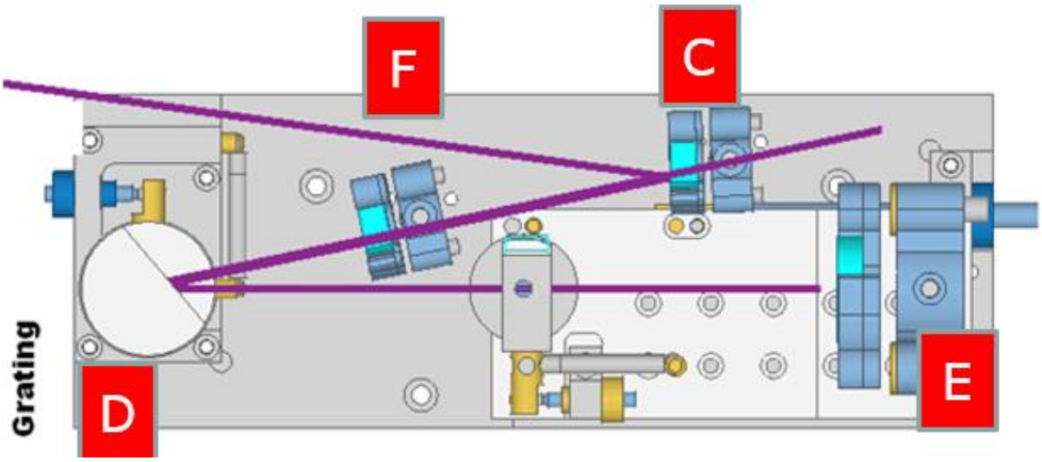
10.4. GVDc alignment

The Group Velocity Dispersion Compensator (GVDc or GVD) is the most complicated part of the free-space optics alignment. The beam path viewed from the top is shown below, however, note that each pass inside the GVDc is a different beam height above the base, as is clearer in the subsequent image.





1. It is unlikely that the GVDc alignment will be far from the previously aligned position, unless the laser has been changed. However, these notes should be sufficient for alignment from scratch. Align the GVD using an IR card and viewer. Adjust mirror B to position the beam on the extreme upper right corner of C.



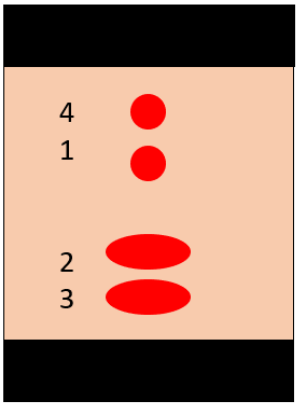
2. Adjust C to centre the beam on the grating horizontally. Adjust the vertical of C so the beam is ~1 mm beam height above the centre of the grating.

3. Adjust the angle of grating D to centre the beam horizontally on E.

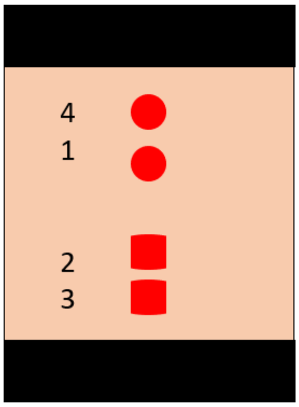
4. Adjust E so the beam is ~1 beam height below the first spot on the grating. Fine-tune the alignment of E to strike the extreme upper right corner of F. Adjust F so the beam is just above the bottom of the grating (~1 beam width gap above the metal frame) align vertically with the other spots.

5. Adjust F so the beam passed is centred on G. Depending upon the length of fibre, the GVD should have an efficiency of >80% (for short fibres ~3 m) ranging down to 30% at approximately 20 m. The beams should be aligned vertically on the grating, with the ordering as follows. The elongation of the lower two beam spots will increase with fibre length. For a short fibre system (e.g. 3 metres) the spots will appear circular, increasing to the illustrated 3:1 ratio for approximately 20 metres.

6. Note that instruments with more than approximately 9 metres of fibre length will usually have a slit installed between the lens and the mirror. The purpose of this is to act as a spatial filter to limit the bandwidth of the laser light entering the fibre, so to limit the temporal broadening due to the dispersion in it.



No slit



Slit in place

7. Alignment into the first fibreport is then achieved using mirror G, and if necessary, F. Once you have good power at position 5, then you can align into the emitter and/or receiver fibreports.

8. Fine tuning the GVD alignment (lens rotation, lens-grating separation) cannot be done by observing the power alone, since the pulse shape and bandwidth is not related to the power. Optimisation of these parameters can only be done using either an autocorrelator (e.g. for initial set up) or by observing the THz signal.

9. To maximise the THz signal, iteratively align the grating angle, lens angle, grating-lens separation, and the alignment into the first fibreport. Then optimise the slit position. These adjustments don't generally affect the laser power, but do optimise the pulsewidth, which might give a little more signal amplitude.

10.5. Fibreport alignment

10. Usually, there will be a THz signal to use as a reference when optimising a fibreport that is already almost aligned. In that case, only small adjustments of the last mirrors before the fibreports will be necessary. However, sometimes (e.g. after component replacement or a rough shipping) the misalignment into the fibre will be more severe, with no power coupled at all, and no measurable signal to optimise. In this case, first unplug the fibre and check you have laser power coming through the open fibreport.

11. Adjust the last two mirrors in order to obtain as round and bright a spot as possible through the fibreport when viewed using an Infra-red detector card.

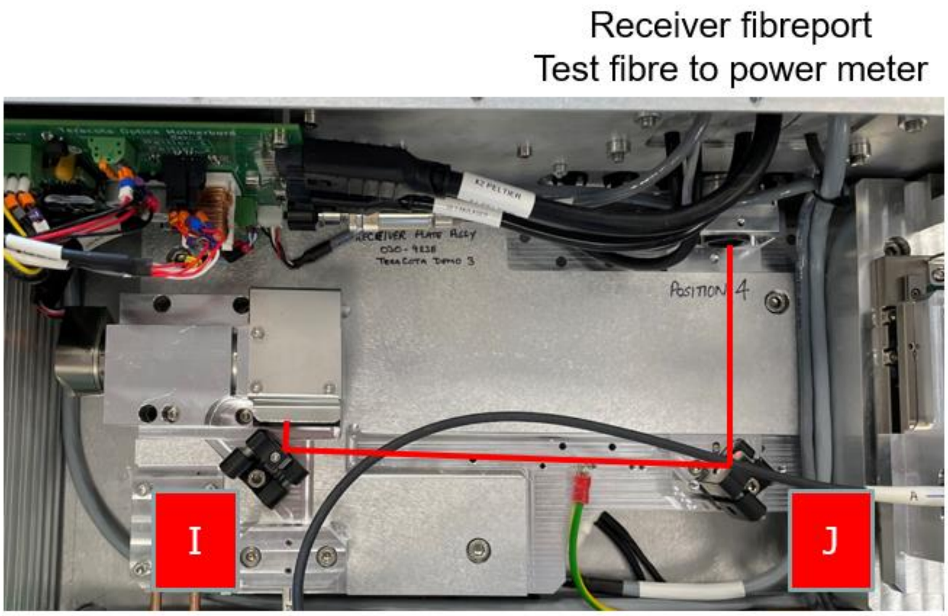
12. Once you have a beam coming through the fibreport lens, plug in a test fibre. Insert the fibre into the port and measure the power output at the end of the fibre using a power meter. This may be only microwatts. If no power is detected pull the fibre partly out of the port until a reading is seen on the power meter.

13. Maximise the output by 'walking' the beam using R1 and R2. Push the fibre gently and slowly into the port a few millimetres. Optimise the power output as before. Repeat until the fibre is fully located within the port.

14. Inspect the device fibre before reinstalling and clean if necessary. Screw the fibres up firmly (but do not over-tighten).

10.6. Walking the beam using two mirrors

When you walk the laser beam, you use two mirrors usually adjacent to each other. You will either walk in a vertical or a horizontal direction. For example, using two mirrors to walk into the receiver fibre port.



1. Place a hex key in mirror I and J vertical adjusters. Move mirror I key a small amount in a clockwise direction. Try to recover the power using mirror J key (this could be in either direction).

2. If the power improves continue moving mirror I key small amounts is clockwise direction and recovering with mirror J key until there is no improvement.

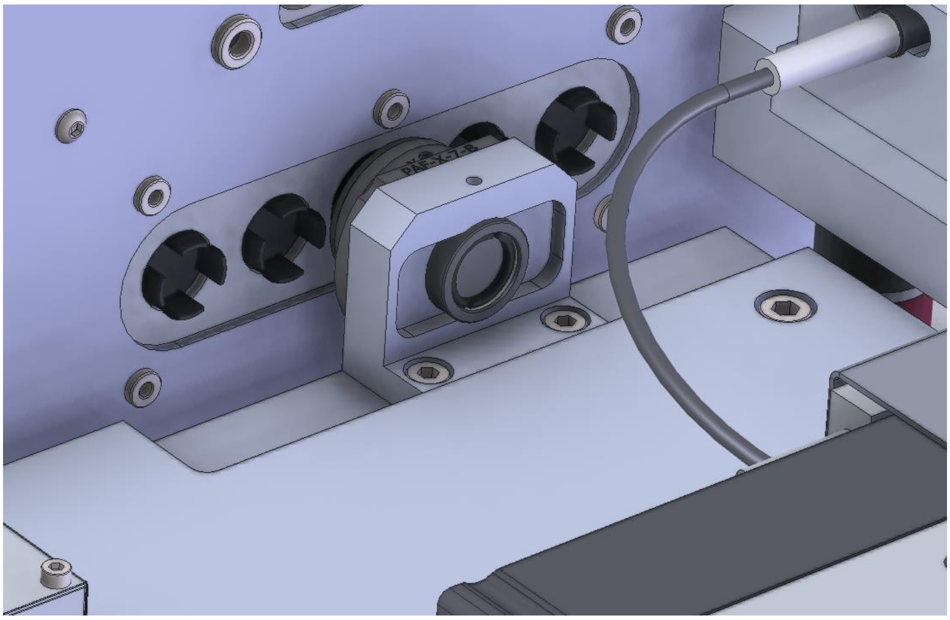
3. If the power doesn't improve after the first clockwise move of mirror I, move mirror I key in an anti-clockwise direction and recover with mirror J key. Repeat until there is no improvement.

4. Once this is complete apply the same procedure to the horizontal adjusters on I and J. If they are fiddly to reach, you will need short 2 mm Allen keys.

10.7. Linear filters

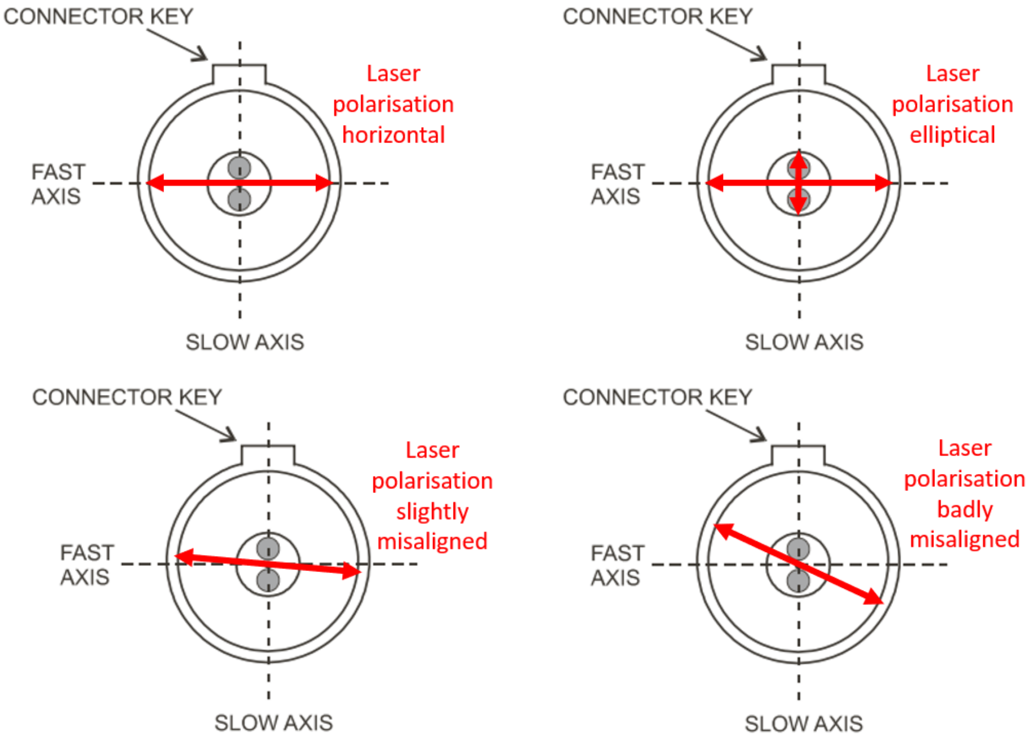
In front of each fibreport is an optional mount for a linear polarising filter. The purpose is to remove any orthogonal components of the laser polarisation when coupling into the fast axis of the fibre. This could occur if the beam polarisation has become slightly elliptical, for example, or not quite perfectly aligned to the horizontal plane. The symptoms of incorrect alignment will be a loss of power into the fibre, and pre-pulse or post-pulse artefacts in the THz signal caused by propagation of the laser in the incorrect (slow) axis.

To rotate the filter, usually whilst observing the THz signal, slacken the set screw at the top, and wearing gloves, rotate the filter with finger and thumb until the artefacts have been removed or minimised. Then tighten the set screw to lock the filter in position.



Unlike a half-waveplate, the linear filter does not rotate the polarisation, it only removes the component not aligned to the filter transmission direction (horizontal, in the images below).

The linear filter should always be aligned with the transmission axis parallel to the fast axis input, and NOT to maximise the transmitted power. If the laser polarisation is badly misaligned (for example, more than 20 degrees) then it should be corrected by optimising the alignment through the preceding free-space components, and/or rotating the collimator output. Using the linear filter to remove the orthogonal components of a badly misaligned beam will result in signal pre-pulse artefacts, and a loss of laser power.



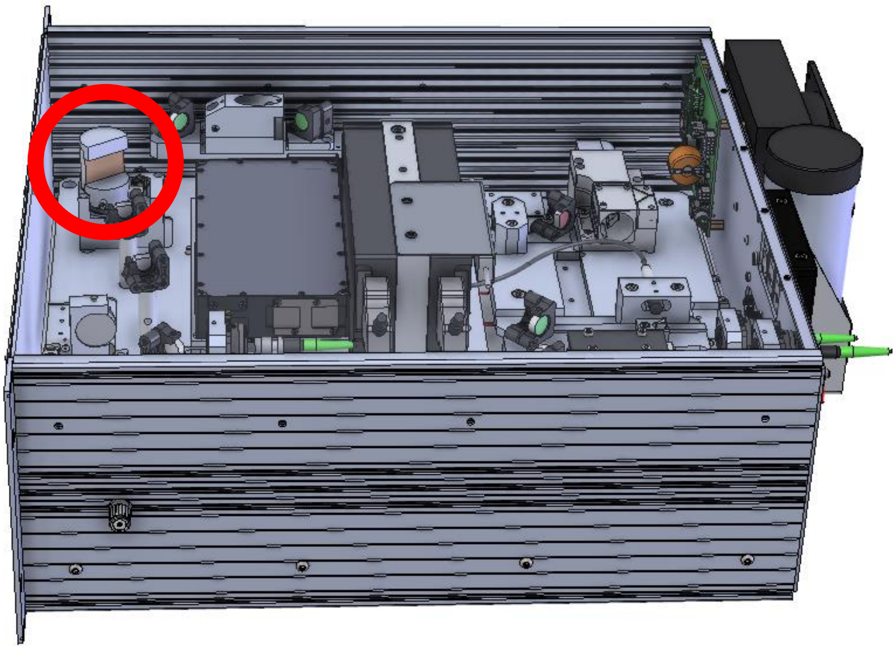
11. REPLACING THE GVD GRATING

The diffraction grating in the group velocity dispersion (GVD) compensator is prone to damage over time when used in high-humidity conditions, and natural wear and tear deterioration means that they are often required to be replaced approximately every five years. Sometimes, damage caused by manufacturing defects, accidentally touching the optical surface, or contamination with water, dust, solvents or mechanical debris means it may need to be replaced sooner.

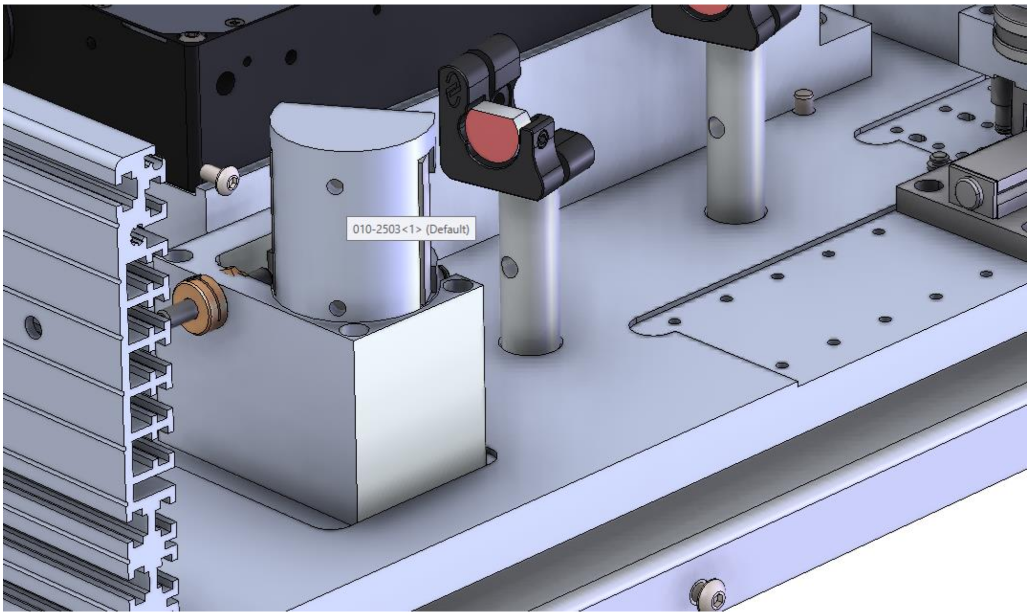
If a GVD grating is worn or damaged, then often it will be visible to the eye upon close inspection, resembling fading or a watermark. The main symptom is a loss of laser power as the reflectivity deteriorates.

11.1. Tools required

- Gloves,
- 2 mm Allen key.



The grating itself is clamped into the aluminium mount using two set screws to push the front face of the grating against reference surfaces at the top and bottom.



11.2. Procedure

Access the Optics Rack Assembly as outlined in a previous section.

3. Visually inspect the GVD grating, and measure the laser power entering and exiting the GVD assembly to estimate the transmission efficiency as a baseline for comparison. This can also be compared to previous records (the nominal efficiency depends upon the fibre length for which the GVD is compensating).

4. If the damage is local to a small area of the grating (e.g. where the laser beams are reflected) then it may be possible to move the grating sideways by a few beam widths, and restore the performance.

5. To remove or adjust the grating, loosen the two set screws from the rear of the grating holder, and slide the grating out sideways, using gloved hands. It may be necessary to rotate the grating holder slightly (against the return spring) in order to remove the grating completely.

6. Being careful not to touch the grating front surface, slide in the new grating. It MUST be inserted in the correct orientation, with grating surface at the front surface, and with the serial number written at the top. If the grating is not inserted the correct way around, the laser transmission will be very poor.

7. Replacing or sliding the grating will not have a large effect on the laser alignment, so only minor adjustments are expected, if any. By observing the terahertz signal, fine-tune the GVD alignment and re-optimise the bandwidth, by iteratively aligning the grating angle,

lens angle, grating-lens separation, and the alignment into the first fibreport. Then optimise the slit position.

8. Once the signal is optimised, replace the cover on the Optics Rack, as detailed in a previous section.

12. REPLACING THE LASER (MENLO LASER TYPE)

12.1. Tools required

- Metric allen key set
- End cutters
- Laser power meter
- Laser goggles

12.2. Removing the failed laser

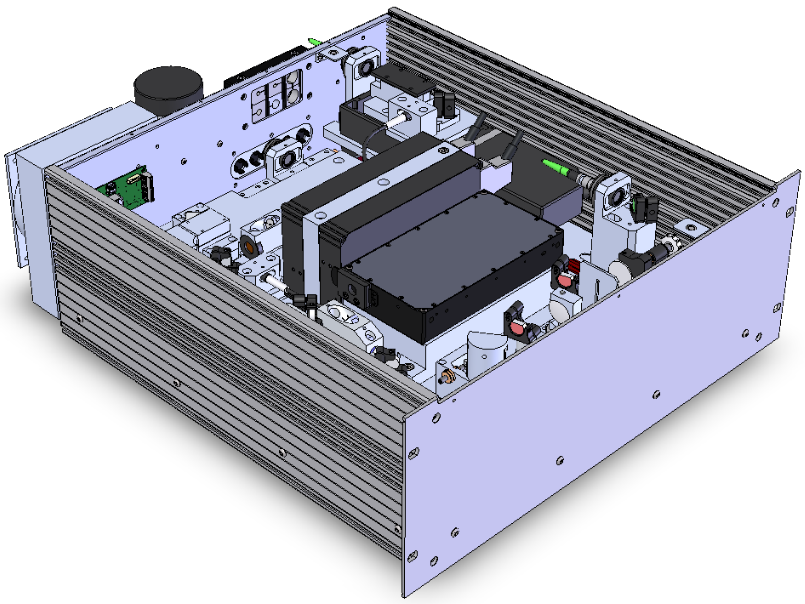
Please keep all fasteners and fittings safe, preferably in plastic zip-lock bags.

1. Exit the TeraCota application in the usual way, and close all TeraCota and TeraCota Launcher windows. This will put the main laser into standby mode. The PC itself may stay powered, and you can continue to use it to examine files.

2. Switch off the core unit via the switch at the back and unplug the cable. It should not be powered back up until the repaired laser is in place, so you may like to remove the cable, or put tape over the switch so it cannot be switched on accidentally.

POWERING UP THE INSTRUMENT WITH THE COVERS REMOVED EXPOSES THE USER TO A CLASS 3B LASER WHICH RISKS SEVERE EYE DAMAGE OR BLINDNESS.

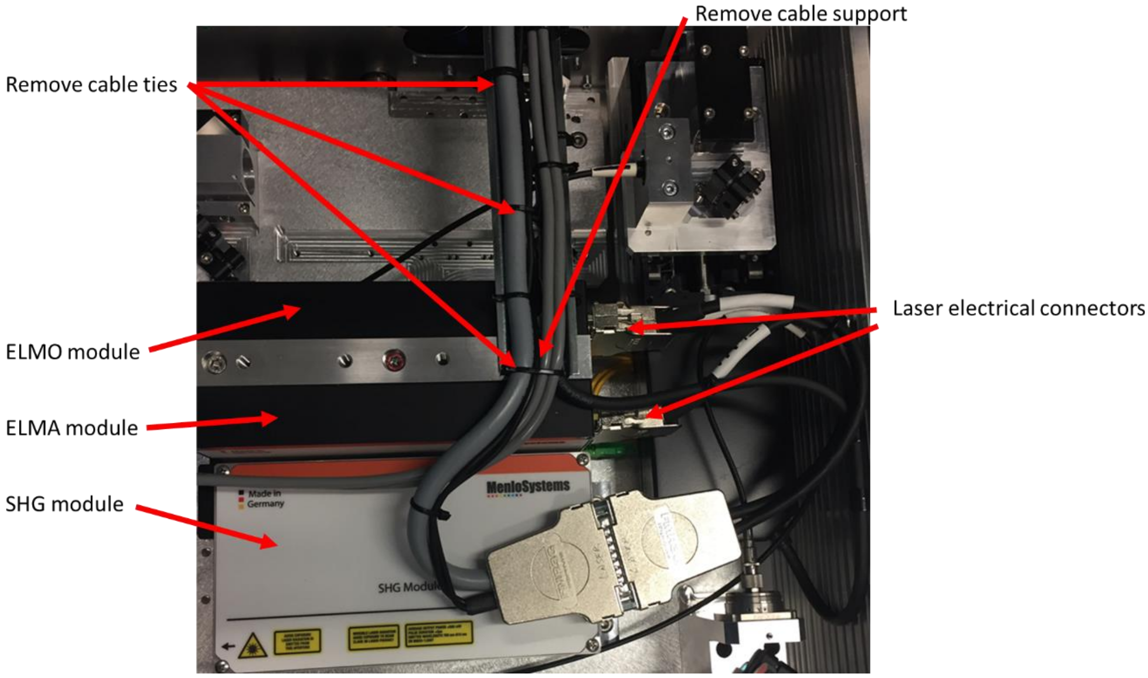
Open the Optics Rack Assembly as outlined in the previous section.



3. The laser units are the three black rectangular boxes in the centre of the tray. They all need to be removed and shipped for repair. There are cables (not shown in the CAD image above) mounted over the laser units, so there is some disconnection to do.

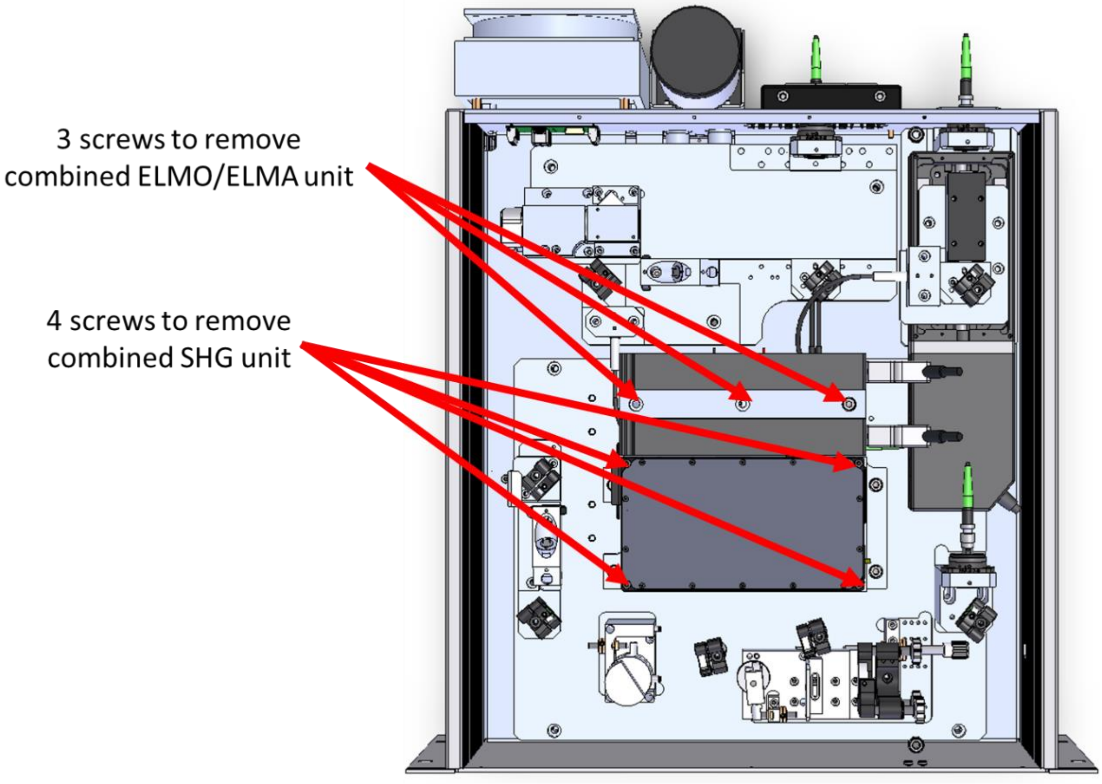
4. With reference to the photo below, carefully remove the plastic cable ties with end cutters to release the cables from the support rail. Remove the support rail from the top of the aluminium laser support.

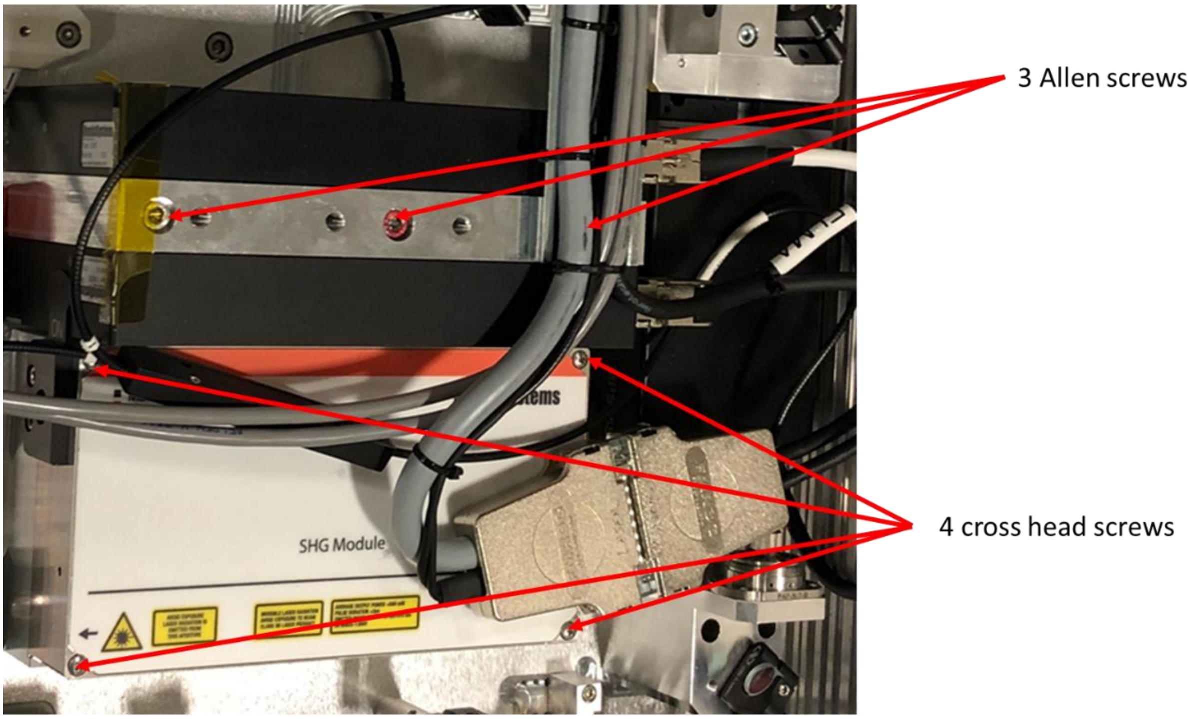
5. Disconnect the two electrical connectors, one to the ELMO and one to the ELMA module.



6. You do not need to disconnect any fibre optic cables. However, the yellow cable will continue to connect the ELMA and the SHG, so once they are removed, you will need to lift them all out together, and avoid snagging the fibre.

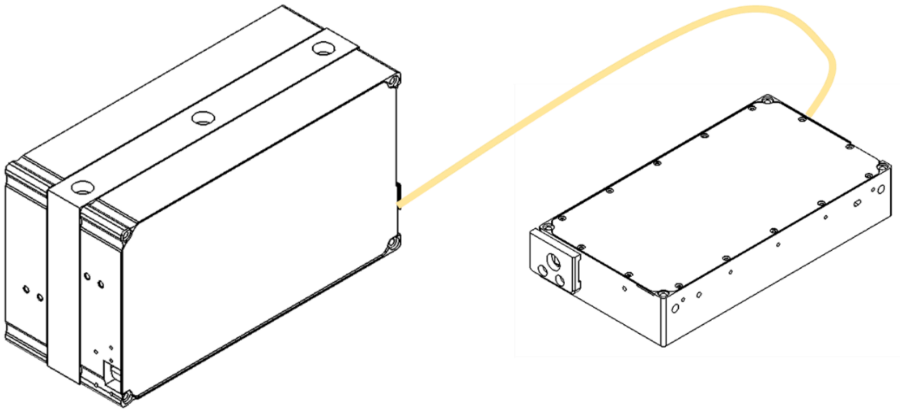
7. The laser modules can now be removed from the instrument optics plate by removing the seven screws as shown. The ELMO and ELMA units may remain attached to the central aluminium pillar for shipping. There is no benefit to returning the mounting baseplate under the SHG module, so remove only the small screws in the corners of the module itself, as shown by the arrows in the diagram. The underplate may remain screwed to the main optics plate. This will help with preserving the laser alignment when the repaired laser is replaced.



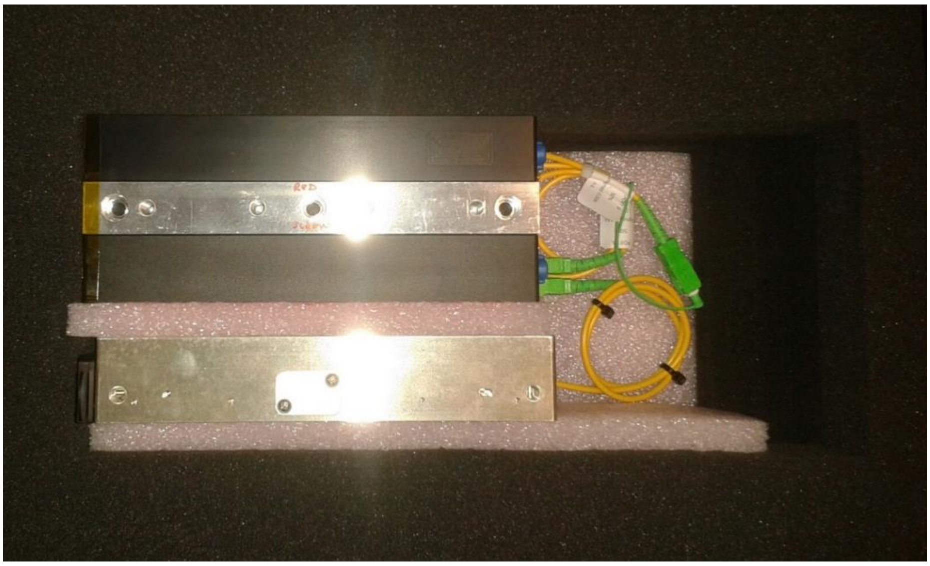


8. Once the laser is removed, temporarily replace the metal top cover to keep dust out – there is no need to replace all of the screws – just a couple will be sufficient.

9. The parts we expect to send back to the laser manufacturer are shown below:



The parts are packed into the same plastic case used for shipping the replacement laser. When packing, the parts most exposed to damage in transit are the connectors at the rear, and the fibre. You need to use the foam to prevent any movement of the laser components. As shown in the photo below. Use the pink foam to pack to prevent side by side motion, then use the large of foam to cover the fibres and prevent the laser from sliding backwards. Use extra foam between the laser top and the box lid, to ensure the laser cannot move up and down.



12.3. Installing the laser

If there is no baseplate to hold the high power SHG module to the ELMO/ELMA, they are connected by fibre, so be careful when removing from the box. They all need to come out together. Keep the blue plastic covers on the electrical connector to protect the laser from ESD until you are ready to connect the cables afterwards. **ESD damage might be a reason why the laser failures happen.**

1. The ELMO/ELMA pillar should be screwed down first.

2. The SHG sits on the metal platform on its side. Try to screw this down as accurately as possible against the side and back reference edges machined on the aluminium block. The better this is, the easier the alignment is going to be.

3. Connect the two electrical connectors, one to the ELMO and one to the ELMA module. Try to tuck the cables and fibres away as neatly as possible. The emitter arm of the fibre-splitter passes over the top of the laser as shown.

4. Bolt the cable support rail to the top of the laser pillar – this prevents the cables from dropping into the beam paths, or from pressing against the fibres. The cables need to be cable tied to the rail, as shown.

5. Before powering up the system, takes some time to double check that no cables are going to be snagged when the stage moves forwards and backwards, and that the fibres are not unduly stressed.

6. You'll need to make the area laser safe.

7. Switch the system on via the switch at the back of the PSU rack (bottom) module. Boot up the computer if it isn't already on. You may need to wait 15 minutes for the temps to stabilise.

8. Use the Putty window to turn on the laser. The laser should come on (green lights on ELMO & ELMA). Measure the laser power out of the laser, and record it. It should be > 140 mW.

9. Now the beam must be optically aligned through the GVD assembly and into the first fibreport.

    a. There is a slit between the lens and the end mirror, to filter the beam and make it more circular. You should be able to leave this in, unless the initial alignment is really so bad that it blocks the beam completely.

    b. The mirror on the post closest to the grating is also used to steer the beam into the fibreport, along with the mirror next the fibreport. This works fine because the magnification effect means that the adjustment needed to steer into the fibreport is absolutely tiny and has no effect on the alignment of the spots in the GVD.

10. There is room to put a free space power meter head after the RSDL in the receiver beam. This is easier than using a test fibre, because it is not necessary to unplug the fibre splitter.

11. Once you have optimised the power out of the fibre splitter, then there shouldn't be much realignment to do into the final two fibreports, because none of those components should have moved.

12. Run TestPanel and obtain the terahertz signal. Further optimisation can be done at this point. Because each individual laser may have its own beam profile, it may be necessary to adjust the GVD in order to obtain the best terahertz signal.

13. Once alignment is finished, slide the optics tray lid back on until it is fully sealed. If convenient, you could leave it for an hour or so for the temperatures to finally stabilise, then quickly do a final tweak into the fibreports.

14. Replace the covers as described in the previous section.

13. REPLACING THE MOTORISED STAGE (25 MM IKO)

14. REPLACING THE FIBRE SPLITTER

15. REPLACING THE PCB ASSEMBLY (12 V LASER)

16. CONFIGURING THE TERACOTA OPTICAL PATH LENGTHS

Because it is designed to be used with only one type of sensor head at a time, the TeraCota Optics Rack Assembly contains an optical delay line which is only 25 mm long, unlike the effective optical path adjustment of over 800 mm in the TeraPulse Lx. The lack of the optical delay line module is advantageous for reasons of stability, ease of alignment, and compactness, but does make setting the optical delay offset a bit more involved.

Assuming that the instrument was correctly set up in the initial build and commissioning phase, possible reasons for having to reset the optical delay offset in the field might be as follows:

1. The sensor head is replaced by another of nominally the same design, but different relative fibre lengths between the emitter and receiver fibres.

2. The sensor head optic is changed for one with a different focal length (and therefore THz path length).

3. One type of sensor head (e.g. TeraCota 2000 sensor head) is swapped out for another type (e.g. PolyScan head).

4. The fibre splitter is changed for a new one.

5. One or more of the external (armoured) optical fibres are changed, either due to replacing a breakage, or making changes to the total fibre length (e.g. extending fibres).

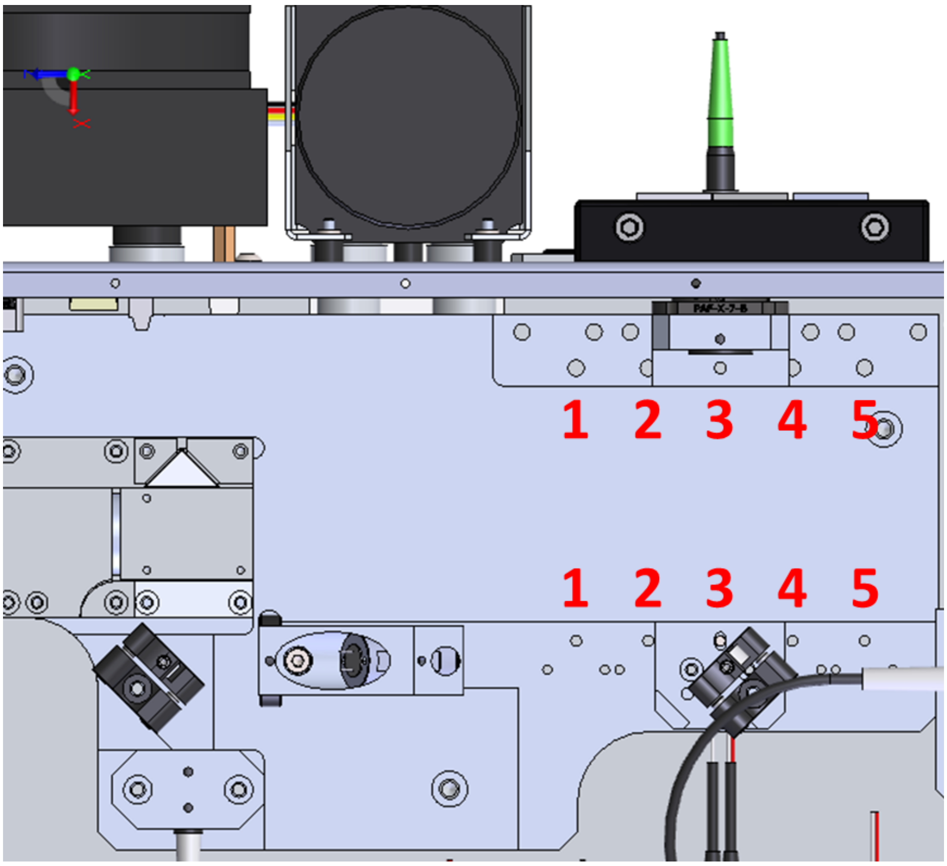
The fibre swaps are problematic because although the nominal length might be unchanged (e.g. 3.5 m), the manufacturing tolerances mean that the actual lengths may vary by several 10s of mm (e.g. 3527 mm or 3542 mm). While we measure and match fibres upon receipt, armoured fibres are harder to match in this respect, because the manufacturing tolerance is lower (and generally a function of fibre length) and because the serpentine nature of the fibre inside the armour jacket can make the true optical length hard to measure accurately.

Ideally, the instrument should be configured with the desired pulse position corresponding to an optical delay value that falls close to the centre of the 25 mm stage travel. This is to allow the RSDL calibration routine to be run (it is necessary to be able to move the pulse across the whole RSDL 'window'), but also to give some robustness against drift, fibre stretching, etc. The reason that the two fibres in a robot dress pack are routed together inside a 10 mm split conduit is to attempt to keep the strain in both fibres approximately equivalent, when the robot moves.

16.1. What can be adjusted?

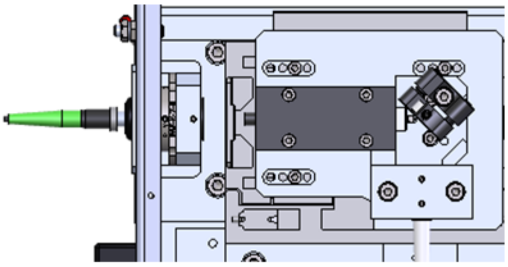
The TeraCota 2000/3000 Core Optics Rack Assembly contains some ways by which the optical delay offset can be adjusted.

- Moving the mirror and fibreport to one of 5 different options on the Receiver Plate Assembly, spaced by 20 mm.
- Substitution of different Emitter Plate Assemblies.
- Configuring the Emitter Plate Assembly to use one of 4 different hole sets, spaced by 5 mm.
- Fine adjustment by moving the fibre splitter collimators forwards or backwards in their vee grooves.

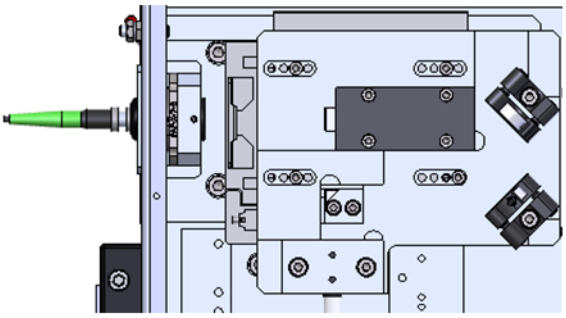


The receiver final mirror and fibreport are placed in one of five positions, with position 1 (closest to the RSDL) being the shortest path length, and position 5 (furthest from the RSDL) being the longest.

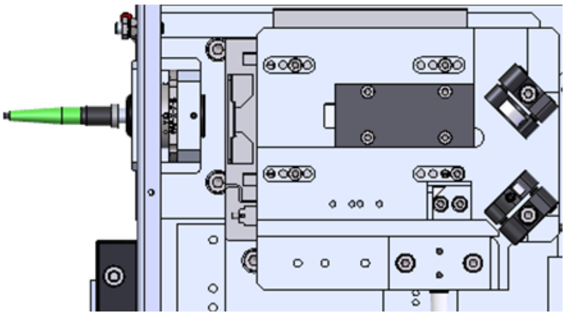
The three different types of Emitter Plate Assemblies are shown below. The relevant plate is defined by the type of sensor head attached.



TeraCota 2000
Emitter Plate Assembly

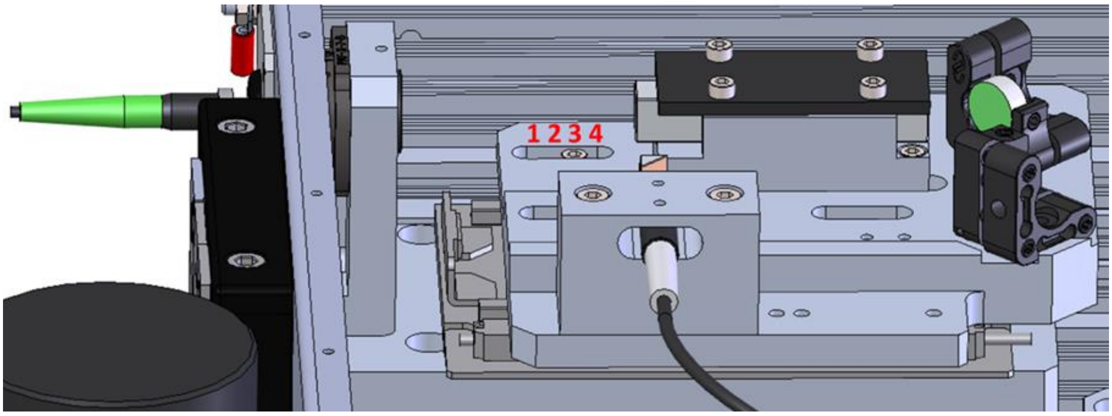


PolyScan Head
Emitter Plate Assembly



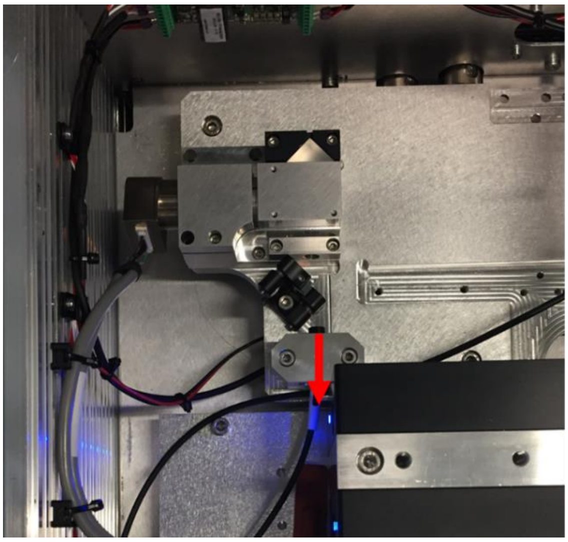
PolyScan SR Head
Emitter Plate Assembly

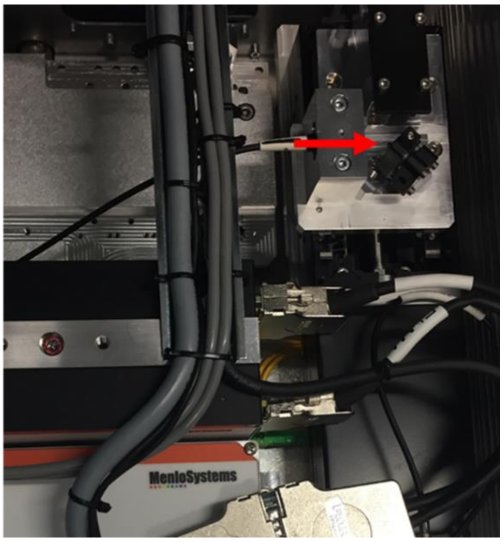
For each Emitter Plate type, there are four alternative options for the location on the stage plate. If changing these, be sure to check that there is no possibility that the stage metalwork or glass block can collide with the laser, cables or fibre port.



Finally, it is possible to make small adjustments by moving the emitter and or receiver collimators longitudinally in their vee-grooves, as shown below by the red arrows. Do this carefully to avoid rotating the polarisation alignment. As shown, increasing the receiver path length and/or decreasing the emitter path length will both move the THz pulse to earlier time (i.e. to the left in the RSDL window).

Conversely, moving in the opposite direction to the arrows below - decreasing the receiver path length and/or increasing the emitter path length will both move the THz pulse to later time (i.e. to the right in the RSDL window).





16.2. Optical alignment after path adjustment

1. Note that all adjustments will require a small amount of realignment back into the fibre ports. To avoid losing the THz signal altogether, if large adjustments are needed, then it is better to adjust in several steps, restoring the alignment after each step.

2. Further, any adjustment of the receiver plate which may affect the alignment through the RSDL assembly is very likely to require a new RSDL calibration.

3. Ideally, the pulse ought to be situated at the desired point in the time window (e.g. -10.0 ps for TeraCota) when the delay stage is close to the centre of its 25 mm travel. The aim is to adjust the path length enough to allow the pulse to be moved all the way across the RSDL window when the stage is moved. It isn't possible to run the RSDL calibration unless the pulse can span the whole window.

4. Once path lengths are correct, realign the emitter and receiver plates and finally optimise the fibreport coupling.

5. Next it will be necessary to update the instrument and measurement config parameters in TestPanel, to train the software on the new optical positions, as outlined earlier in this guide.

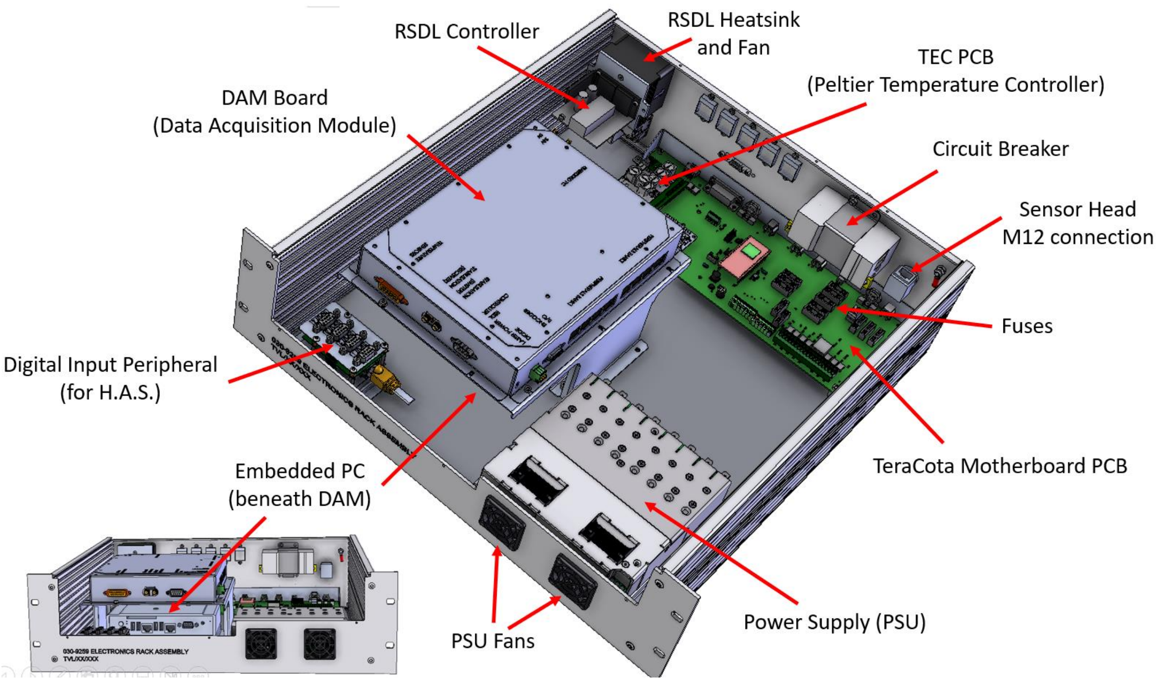
17. OVERVIEW OF THE ELECTRONICS RACK ASSEMBLY

17.1. Access

Access to the electronics tray is via the M3 screws along the front face. And rear of the lid.

17.2. Components

The components within the electronics rack assembly are identified as follows:



17.3. Electrical safety

Note that the cable running from the C13 inlet via the breaker to the PSU module is mains voltage (230 V or 110 V depending upon location). No work is to be carried out on high voltage components while the module is powered, except by personnel qualified to do so.

Remaining modules are powered by low voltage supplies (nominally 5 V, 12 V, 15 V, 18 V, 24 V or 48 V, and are clearly labelled at the PSU and at the motherboard PCB.

18. REPLACING FUSES

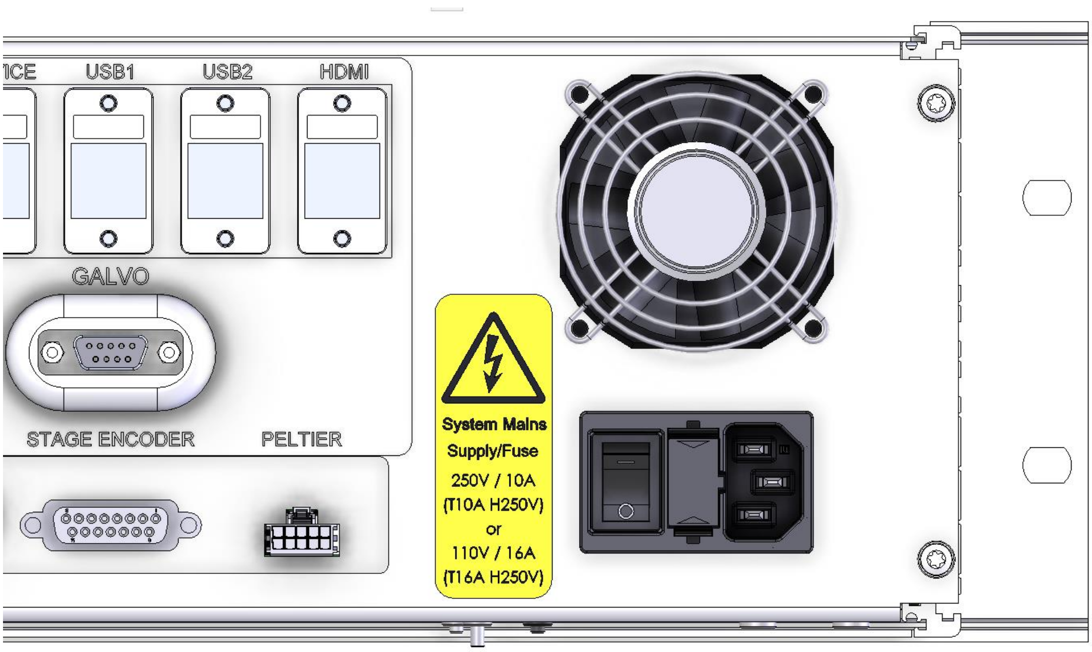
Fuses accessible to Service Engineers are located either at the mains power inlet at the rear of the Electronics Rack Assembly, or else on the motherboard PCB inside the Electronics Rack Assembly.

Note that fuses very rarely spontaneously fail. Often, they can blow during service interventions (for example, if you accidentally short two pins together whilst testing a cable). If there is no obvious stimulus, or a replaced fuse repeatedly blows, then it is a symptom of a different problem, which should be investigated.

18.1. Mains inlet fuse

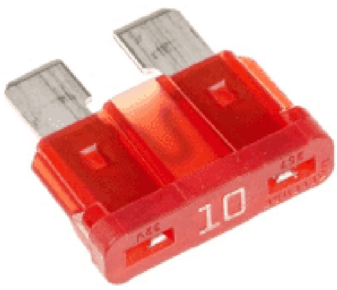
The fuse for the power to the entire core instrument is situated beside the C13 inlet at the rear of the Electronics Rack Assembly. Use a small flat bladed screwdriver to open the plastic cover, which holds the 20 mm cartridge fuse.

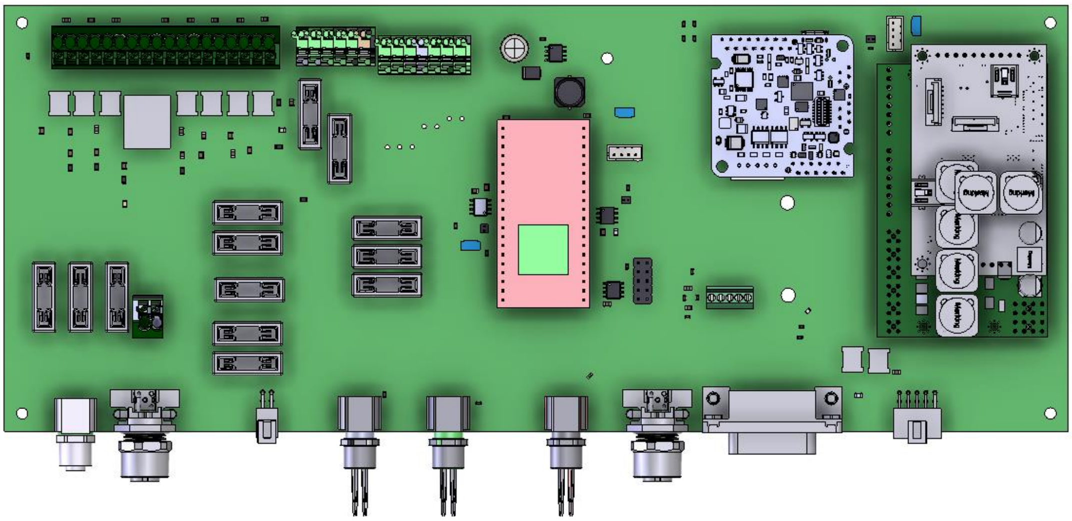
The appropriate rating is 10 A for 230 V systems or 16 A for 110 V systems.



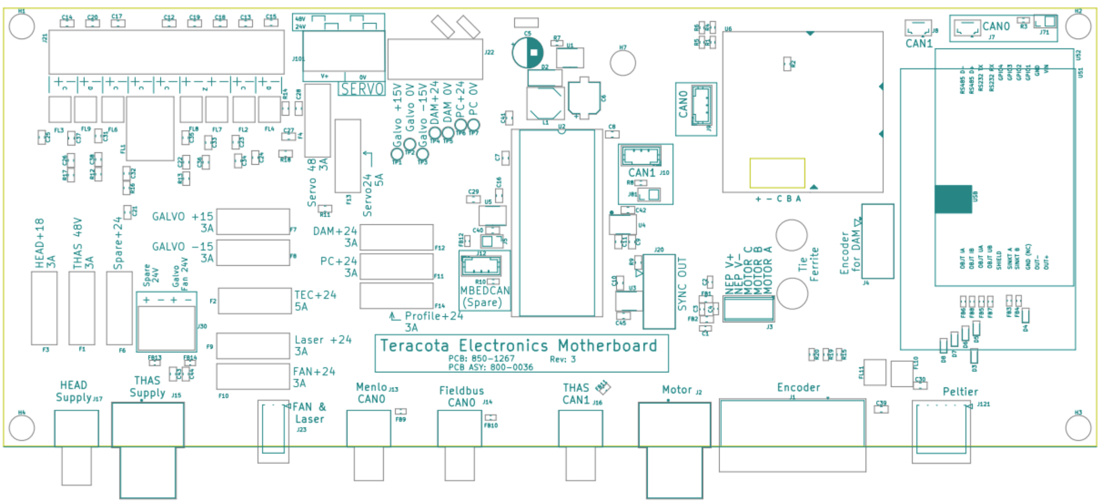
18.2. Motherboard PCB fuses

Individual components on the motherboard PCB are protected by their own fuses of appropriate ratings, usually 1 A (black), 3 A (violet), 5 A (tan) or 10 A (red). The fuses are blade (automotive) types.





The function of each fuse is printed on the PCB, laid out as shown.



19. REPLACING THE TERACOTA MOTHERBOARD PCB

20. REPLACING THE DAM BOARD

21. REPLACING THE POWER SUPPLY

22. REPLACING THE EMBEDDED PC

23. REPLACING THE PELTIER TEMPERATURE CONTROLLER

24. REMOVING THE TERACOTA 2000 SENSOR HEAD

24.1. Tools required

- long handled 4 mm Allen key,
- fibre dust caps,
- gloves,
- TeraCota 2000 Sensor Head transportation case (910-3200).

24.2. General process

The removal process for the TeraCota 2000 sensor head is slightly different, depending upon whether or not there is a Head Alignment System (HAS) module installed on the system. If there is ***NOT*** a HAS present, then **<u>steps 5 to 10 can be omitted</u>**:

10. Close the TeraCota application, or if using TestPanel, close the instrument. Shut down the embedded PC either by using 'Power Off' in TestPanel, or the 'sudo poweroff' command in a Putty terminal. Then turn off the main power supply to the core at the rear of the instrument. This ensures that the laser will be powered off and all power to the head is removed. The Client PC may stay powered.

11. Now, wearing gloves, unplug the two fibres. The optical fibres can be unscrewed ***<u>from the rear of the sensor head</u>*** by rotating the bezel anticlockwise on the FC/PC connectors. Once the white ferrule is visible, withdraw it cleanly and do not re-insert.

12. Inspect the tips using a fibre microscope. Clean them if necessary using the fibre cleaning cartridge. Use protective dust caps (see below for an example) to prevent damage to the optical fibre tips, and be careful not to touch the tips. The caps should be aligned with the keyway of the fibre connector aligned to the notch in the cap. The actual glass fibre optic core inside the armoured fibre cable is only 5 µm in diameter, so dirt or dust can impair the performance if the tip gets dirty or greasy. If you can't find the dust caps, put small clean plastic bags over the tips and tape in place.

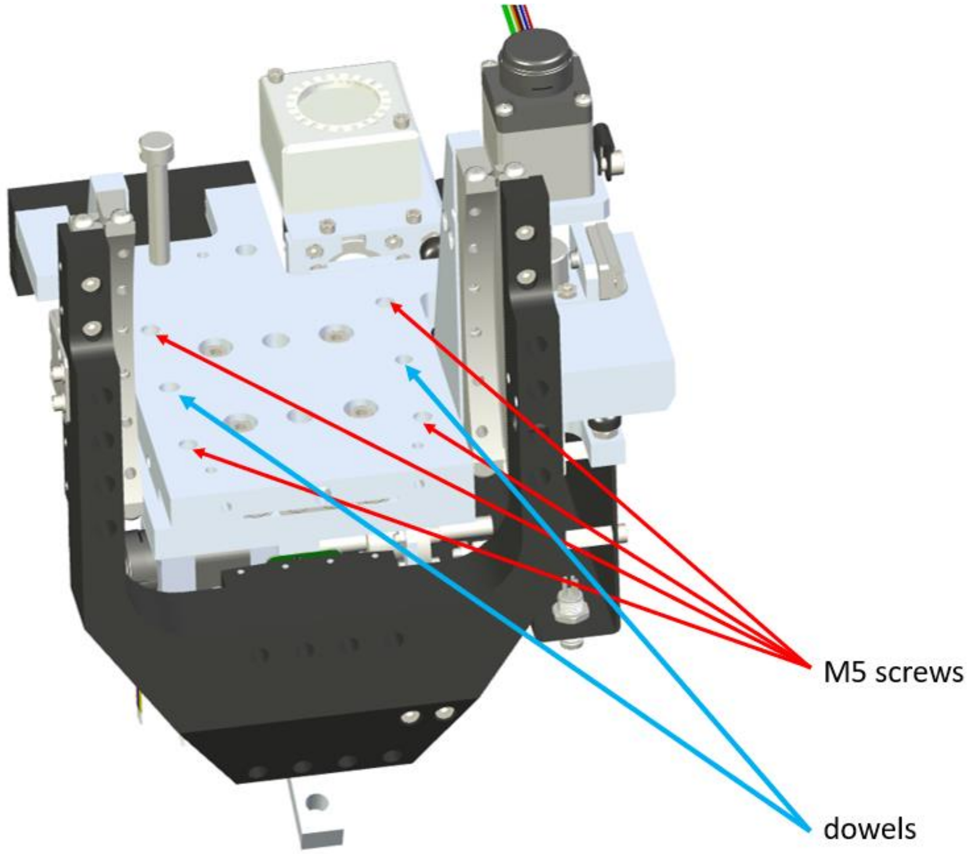
13. Next, unplug two electrical cables from the rear of the sensor head. When unplugging the M8 screw connector on the power cable, be sure to hold the connector body firmly so that only the bezel collar rotates (if the whole connector rotates there is a high risk of breaking the pins in the plug). The serial electrical cable has RJ45 connectors at its ends. It can be difficult to release the locking tab. If it is stuck do not force it out. Instead, use a small flat bladed screwdriver to gently depress the tab on the plug.

24.3. Removing the Sensor Head from the HAS module

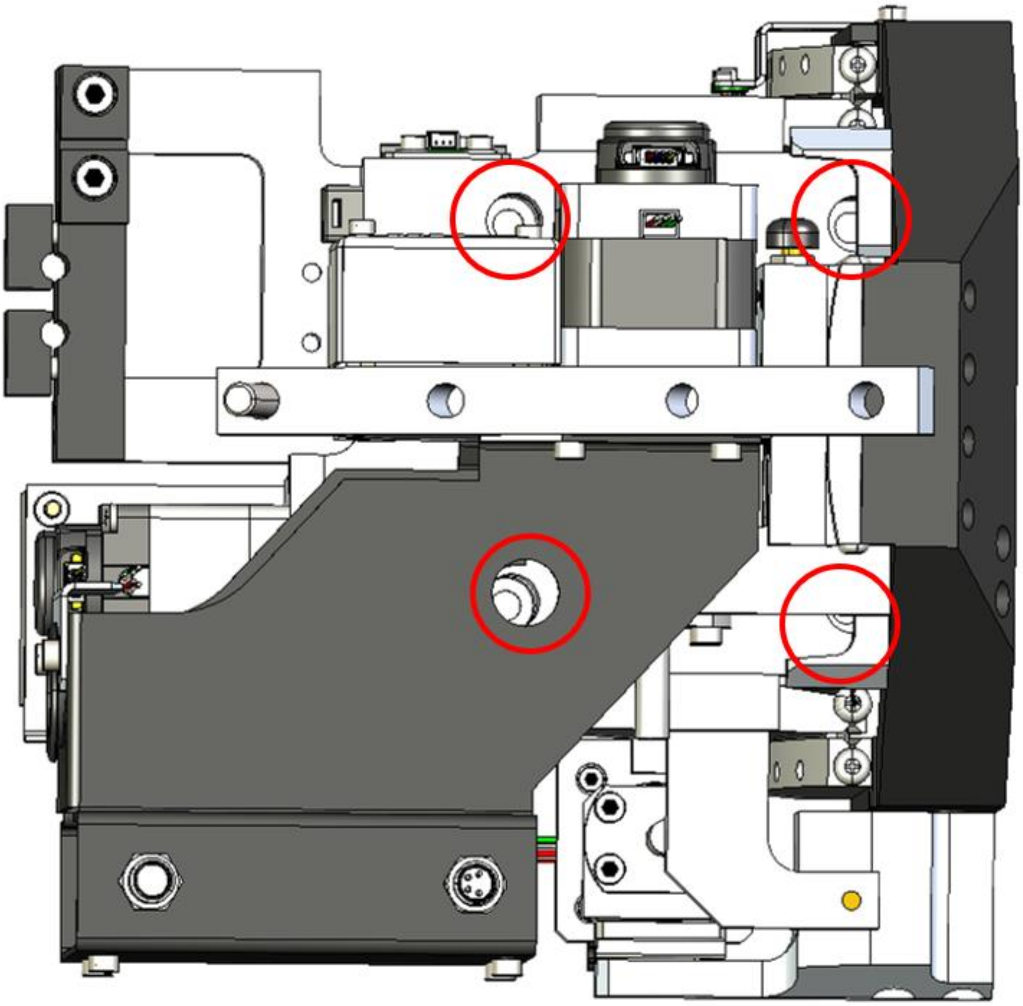
14. Do NOT unplug the two electrical cables to the Head Alignment System (HAS): these should be left in place.

15. Switch on the core unit via the switch at the back and re-connect to the instrument in TestPanel. The HAS should initialise before an error appears. The purpose of this is to energise the HAS motors, and return them to their home positions. This makes it much easier to access the screws required to release the sensor head.

16. The head can now be mechanically dismounted from HAS by unscrewing the four bolts on the underside. This can be a little tricky to access, so consider moving the robot to the most convenient position. Usually, the best orientation is with the Sensor Head upright, and at head height, such that you can access the screws from underneath, while gravity holds the head in place. For context, this is what the HAS looks like from the top, without the head in place.



17. To access the screws, you MUST use a long shaft Allen key (4 mm) to reach up through the lower plate. There are access holes or slots for each screw, as shown below. If you use a ball-end driver, then it will accept a slight angle, as required. Be very careful not to disturb or break any wires that might be in vicinity. As you undo each screw, gently lower it down out of the hole using the tip of the Allen key. If you lose it inside the mechanism, it may be difficult to retrieve, and potentially cause the HAS stages to later jam.



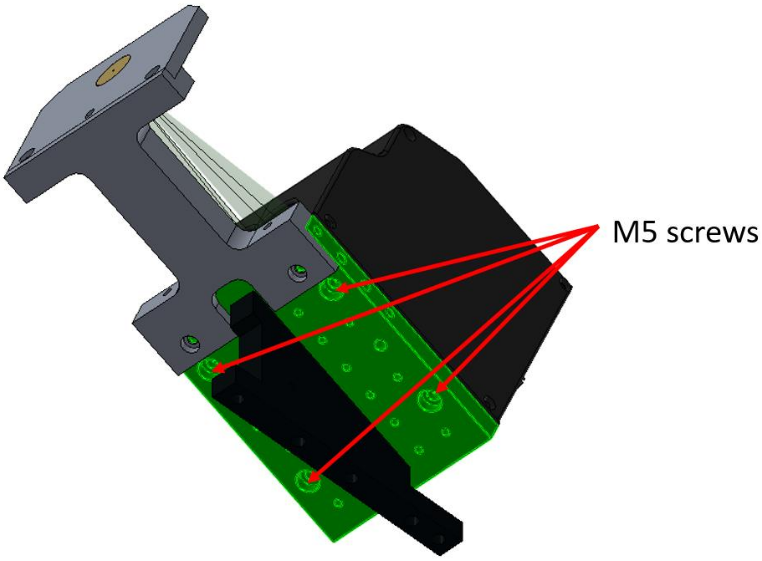
18. After the four screws have been removed, the sensor head may be lifted from the stand. Be sure to retrieve the two dowel pins.

19. As before, close the instrument and embedded PC (either by using 'Power Off' in TestPanel, or the 'sudo poweroff' command in a Putty terminal) and switch off the core unit via the switch at the back and unplug the cable. It should not be powered back up until the repaired head is in place, so you may wish to remove the cable, or put tape over the switch so it cannot be switched on accidentally.

24.4. Removing the Sensor Head without the HAS module

20. If no HAS is present, then the four M5 screws may be easily removed to release the head from the interface plate, using any 4 mm Allen key, see below.

21. There is no need to remove or return the interface plate (shown here in green), nor the Sensor Head Alignment Jig (if present).



22. Unplug the power cable to the core system. It should not be powered back up until the repaired head is in place, so you may wish to remove the cable, or put tape over the switch so it cannot be switched on accidentally.

24.5. Packing the Sensor Head for return to TeraView for repair

23. Carefully place the sensor head in padded foam in a sturdy box. Ideally, use the transport case provided. If this is not available, use a sturdy cardboard box with rigid foam to brace the frame against the inside of the box. The parts most exposed to damage in transit are the connectors at the rear.

25. INSTALLING THE TERACOTA 2000 SENSOR HEAD

25.1. Tools required

- Long handled 4 mm Allen key,
- 2 mm keys for alignment,
- Gloves,
- Laser power meter,
- Fibre inspection ‛scope.

25.2. General process

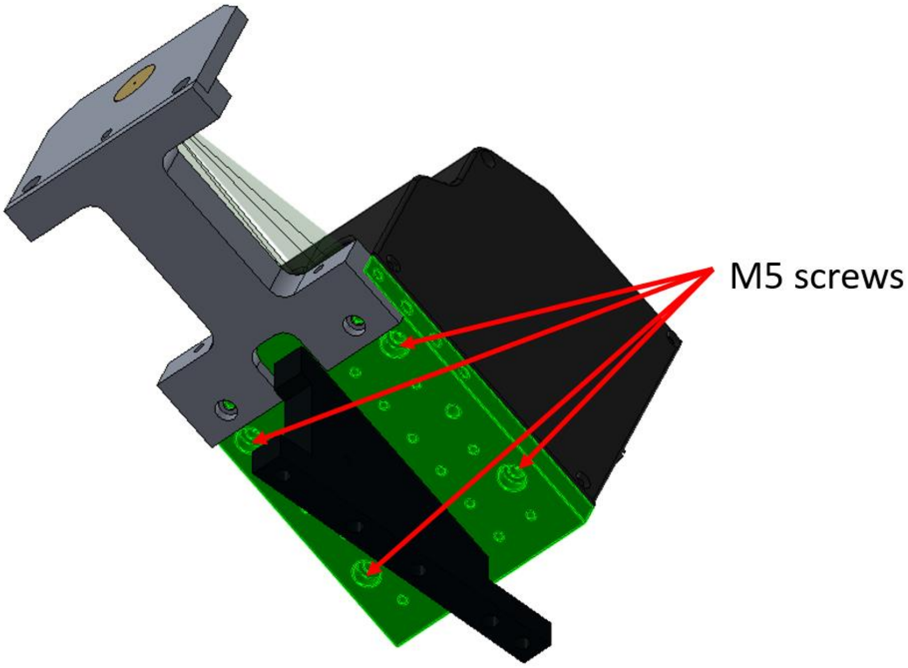
The installation process for the TeraCota 2000 sensor head is slightly different, depending upon whether or not there is a Head Alignment System (HAS) module installed on the system. If there is ***NOT*** a HAS present, then **steps 4 to 9 can be omitted**:

9. Ensure that the TeraCota core system is powered off.

10. For a robotic system, begin by moving the robot to the most convenient position. Usually, the best orientation is with the Sensor Head upright, and at head height, such that you can access the screws from underneath, while gravity holds the head in place.

25.3. Installing the Sensor Head without the HAS module

11. If no HAS is present, then the four M5 screws may be easily added to secure the head to the interface plate from the underside, using any 4 mm Allen key, see below. Ensure that both 5 mm diameter x 10 mm long dowel pins are inserted into the base of the Sensor Head prior to mating. This will ensure that the alignment is perfectly preserved, avoiding the need to re-teach the robot positions.

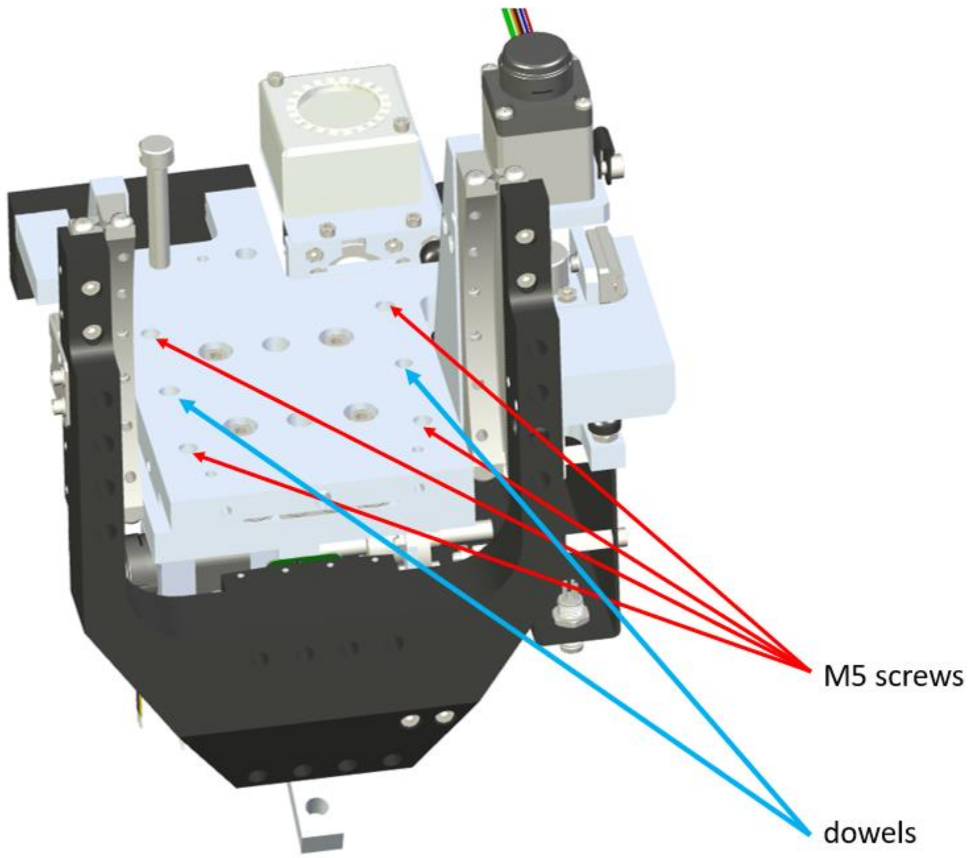


25.4. Installing the Sensor Head onto the HAS module

12. Switch on the core unit via the switch at the back and connect to the instrument in TestPanel. The HAS should initialise before an error appears. The purpose of this is to energise the HAS motors, and return them to their home positions. This makes it much easier to access the screws required to install the sensor head.

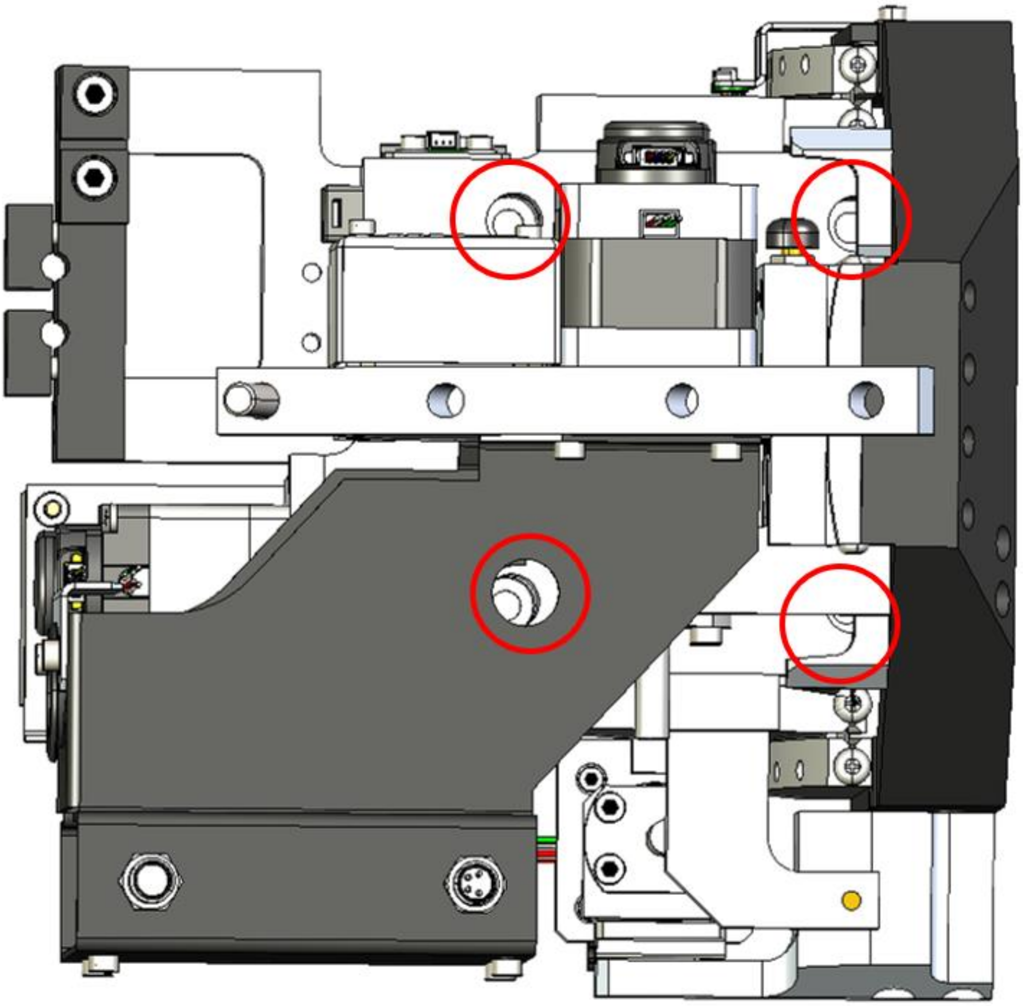
13. While the laser is on, but the fibres are still unplugged from the head, use the laser power meter to verify that there is laser power coupled out of the fibres. There should typically be approximately 5 mW from the emitter fibre, and typically 2-3 mW from the receiver fibre, although the latter will likely have been optimised according to the fibre length in that particular system.

14. The head can now be mechanically mounted onto the HAS by screwing in the four bolts on the underside. This can be a little tricky to access. For context, this is what the HAS looks like from the top, without the head in place. Ensure that both 5 mm diameter x 10 mm long dowel pins are inserted into the base of the Sensor Head prior to mating. This will hold the head in the correct position while each screw is tightened in sequence.



15. To insert the screws, you MUST use a long shaft Allen key (4 mm) to reach up through the lower plate. Cut a square approximately 30 mm by 30 mm from the corner of an optical lens cleaning tissue, and place it over the ball end of the Allen key. This will better grip the screw head. There are access holes or slots for each screw, as shown below. If you use a ball-end driver, then it will accept a slight angle, as required. Be very careful not to disturb or break any wires that might be in vicinity.

16. For each screw in turn, secure it to the ball driver using the tissue, then gently feed it up through the lower plate, until it begins to engage in the upper plate. For access points, see the drawing below.



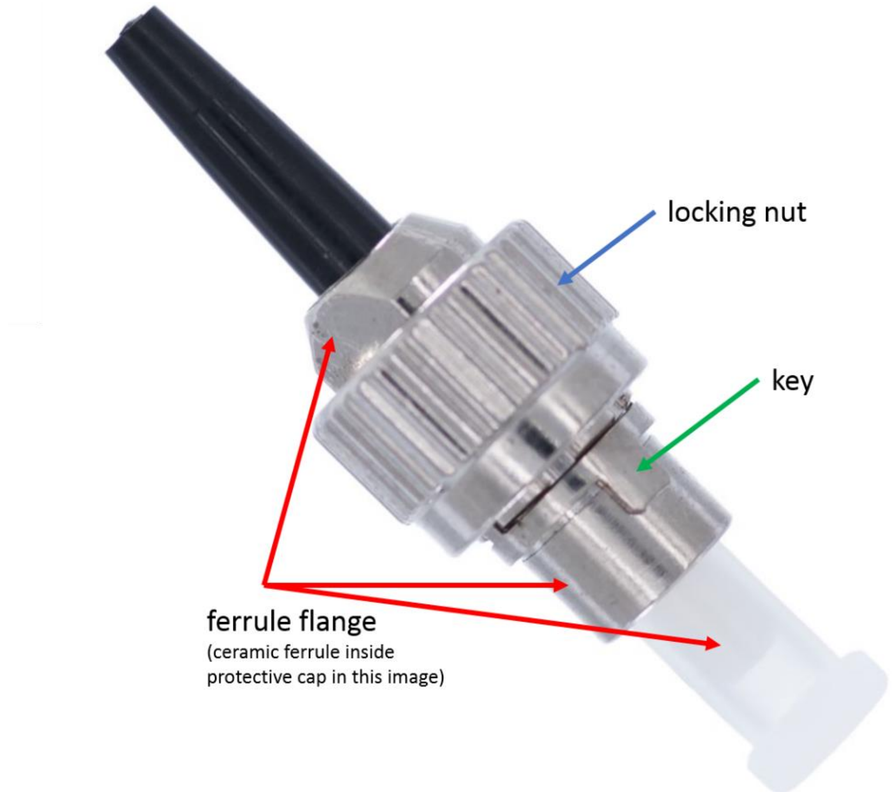
17. Once the Sensor Head is installed onto the HAS, using TestPanel, close the instrument. Shut down the embedded PC either by using 'Power Off' in TestPanel, or the 'sudo poweroff' command in a Putty terminal. Then turn off the main power supply to the core at the rear of the instrument. This ensures that the laser will be powered off and all power to the head is removed. The Client PC may stay powered. **Plugging in the power supply plug to the head while the system is energised will damage the delicate electronics components within the head.**

25.5. Connecting the fibres and cables

18. Now, wearing gloves, plug in the two optical fibres. It is important to get them the correct way around: red for the emitter and blue for the receiver. First, remove the dust covers, and then inspect the tips using a fibre microscope. Clean them if necessary using the fibre cleaning cartridge. The actual glass fibre optic core inside the armoured fibre cable is only 5 μm in diameter, so dirt or dust can

impair the performance if the tip gets dirty or greasy. The mating of the connectors relies on a clean physical contact between the two fibre glass cores. In theory there will be a degradation in coupling efficiency every time they are mated and disconnected, so we want to try to do this process as cleanly as possible.

19. The optical fibres can be screwed in by carefully inserting the white ferrule. To connect, locate the ceramic ferrule into the receptacle as accurately as possible to avoid contaminating the tip. Push in until the key makes contact with the mating sleeve ring. Then rotate until the key aligns to the notches in the receptacles, allowing you to insert further. Once fully home, rotate the locking nut bezel clockwise on the FC/PC connectors until it is finger-tight.



20. Next, plug in the two electrical cables from the rear of the sensor head. When plugging the M8 screw connector on the power cable, be sure to hold the connector body firmly so that only the bezel collar rotates (if the whole connector rotates there is a high risk of breaking the pins in the plug).

25.6. Updating the core system for the new head

21. Switch on the TeraCota core system via the switch at the back. It may need up to 30 minutes for the laser baseplate temperature to

stabilise depending upon its initial temperature, before the software will allow you to initialise the system. The temperature can be checked using '*tvltemp*' command in a Putty window.

22. Start TestPanel, and log in to the instrument. Initialise the instrument. Remember to (temporarily) delete the IP address entry in the Measurement Config, to allow the scanner to run. This IP address is used by TeraCota to access the Measurement Config, but is not used whilst in TestPanel.

23. Start the scanner, and then close the intercept mirrors by clicking the 'Reference' button. This button toggles between 'Sample' and 'Reference'. Note that the button refers to the state accessed by clicking the button and NOT the current state of the instrument. Find the pulse and be sure it is the principal (main) reflection, using the Optical Delay stage to navigate backwards and forwards along the time-axis as necessary. Note that the head alignment is generally very stable, so if there is good laser power in the fibres (see step 5, above) then you would reasonably expect to see a good signal immediately – there's not much you can realign if you don't.

24. Fine tune the stage position to locate the pulse peak at approximately -10.0 ps on the time axis. This update is required because each head has slightly different optical and THz path lengths. Note that for the TeraCota module type in TestPanel, the optical delay adjustment applies independently to the sample and reference 'states'. Thus the optical delay line may simultaneously move when the intercept mirrors are moved.

25. OPTIONAL: For best results, at this point the optical alignment of the Optics Rack Assembly in the TeraCota Core System may be fine-tuned. This will optimise for slight variations in the fibre lengths inside the replacement head, and optimise the laser power for the individual terahertz devices inside the head. Follow the optical alignment instructions given in an earlier section.

26. It's possible, though unlikely, that the replacement head will require an optical delay position that is beyond the end stop – or uncomfortably close to it – in order to locate the pulse peak at the correct position. This will only occur if the emitter and receiver fibres inside the TeraCota 2000 Sensor Head are not well matched. In this instance, refer to the separate section to reset the optical path length setting, and note that if any adjustment is made to the receiver collimator position in the vee groove, then a new RSDL calibration will likely be required.

27. Finally, make any adjustments to the instrument software configuration, as detailed in the TestPanel section of this guide, and ensure that a new Reference Calibration is taken in TeraCota.

26. REPLACING THE HEAD ALIGNMENT SYSTEM

27. CONFIGURING AND UPDATING THE TERACOTA SOFTWARE

27.1. Updating the Reference Calibration in TeraCota

This is the file that relates how the internally sampled beam from the reference mirrors compares to the signal reflected from an external calibration object (and to define 100% reflectance). To do this update:

1. Place the circular gold mirror in the usual place and align the robot/head to see a reflected pulse from the mirror, roughly in the middle. Set the calibration to NN (or 'None'), and (if the H.A.S. is fitted) measure an AutoAlignPoint. With the robot static in this optimised position, click 'Goto AutoAlignPoint' to move the alignment back to the optimised position, and use the TeraCota UI to stop the THz beam.

2. From the menu "*Instrument >> Instrument Settings…*", open the "*Ref. Calibration…*" tab. Click on "*Clear Reference Calibration*". Leave the dialog box open. From the menu "*Instrument >> Scans >> Run Optical Delay Alignment…*" followed by "*Instrument >> Scans >> Run Reference Calibration…*". The instrument will collect data: this should take about 10 to 20 seconds. Be sure not to disturb the instrument while it is collecting data. Save the file in the "*Refcals"* folder. We would typically name it by date and Sensor Head Serial Number, with 3 repeats, suffixed by a letter. e.g.: *0365_2018_08_08a.refcal*.

3. Check in the displayed report that the water vapour lines visibly line up with the vertical reference lines in the frequency domain plot. This indicates that the RSDL calibration is valid. If the absorption lines do not align, then it will be necessary to recalibrate the RSDL.

4. Click on "*Load Reference Calibration*", and select the file you just created. Click on '*Save hardware config*" at the bottom of the dialog box. Close the dialog box. Close down the TeraCota software completely, and relaunch in the usual way. The instrument is now ready for use.

28. APPENDIX A: LASER POWER RECORD SHEET

System Type:	TeraCota 2000/3000	**Serial Number:**	
Laser Power Meter ID:		**Sensor Head ID:**	
Date:		**Completed by:**	

TeraCota 2000		
Position – not all locations are required. Depending upon the nature of the intervention, **some of the optional positions might be too invasive** to a working system.	**Laser Power (mW)**	
	Emitter	**Receiver**
Out of Laser		
Into GVD		
Out of GVD (no slit) - optional		
Out of GVD (2.7 mm slit inserted)		
Into first fibreport (use test fibre) - optional		
Before final fibreports		
Coupled into fibre - optional		

Notes

29. APPENDIX B: IQ REPORT FORM