Manual THz Kit 10XX

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DAQ	**D**ata **Ac**q**u**isition (System)
THz	Terahertz

1 Components

The THz Kit 10XX includes the following items:

- Pair of free space Terahertz (THz) antennas with hyperhemispherical Si-lenses[1]
  Plus collimating TPX lenses[1]
- Pair of fiber-coupled THz antennas with collimating Si-lenses[2]
- Delay line (matching the pulse propagation times of optical and THz beam path)
- Data acquisition system with pulse generator and lock-in detector
- T3DS Software provided on a USB flash drive

[1] Applies for the THz Kit 10XX with free space antennas
[2] Applies for the THz Kit 10XX-fo with fiber-coupled antennas

1.1 THz Antennas

The THz Kit includes a pair of free space (THz Kit 10XX) or fiber-coupled (THz Kit 10XX-fo) antennas.

Warning

The THz antennas have a designated maximum operating voltage and maximum optical power. Do not exceed these limits as this may cause permanent damage.

1.1.1 Free Space Antennas

The THz Kit with free space antennas offers the best possible performance. All elements of the THz beam path can be aligned independently and enable a detailed optimization.
But the laser and THz beam path are not independent. Any change of the principal arrangement of the THz antennas requires careful planning and adjustment of the laser beam path, too.

Figure 1: Free space antenna

1.1.2 Fiber-Coupled Antennas

The THz Kit with fiber-coupled antennas offers the highest flexibility. The arrangement of the THz antennas can be changed easily and remains independent from the laser beam path. This makes them an ideal choice for THz imaging (⇒ Imaging Unit).
But the fiber-coupled antennas offer less possibilities to optimize the THz signal. Combined with dispersion of the optical fiber[3] itself, the overall performance is reduced, in comparison to the free space antennas.

In order to keep the dispersion to a minimum, we recommend to use a pulse stretcher (@ 780 nm & 1.060 nm) or dispersion compensating fibers (@ 1560 nm).

Figure 2: Fiber coupled antenna

[3] Broadening of the laser pulse

1.2 Delay Line

The THz Kit contains a delay line with a travel length of 100 mm, which corresponds to a maximum time delay of about 650 ps. It is equipped with two mirrors.

Figure 3: Delay Line

Please use the provided cable to hook up the delay line to your computer. Subsequently, you will find the delay line (> active COM port) in the device manager.[4]

The delay line adapts the laser beam path of the emitter antenna and matches the pulse propagation time to the detector antenna.

Warning

For safety reasons you must never put your hand on the stage while it is moving. The linear stage can cause serious damage to your hand and fingers. Hence, before you can change the configuration on the stage, please always disconnect it from the power supply.

[4] After you installed the software package provided on the USB flash drive. Please check the manual for our T3DS Software for further details.

1.3 Data Acquisition System

The THz Kit contains a data acquisition (DAQ) system to drive the THz antennas. It encloses the pulse generator and lock-in detection.

Abbildung 4: Data Acquisition System

Please use the provided cable to hook up the DAQ system to your computer and switch it on. Subsequently, you will find the DAQ system (> NI-USB) in the device manager.[5]
Contact the green/yellow wire of the DAQ system to the ground in order to avoid electromagnetic interferences.

Please connect the BNC cables of the emitter and detector antenna to the corresponding port at the front panel of the DAQ system.

The DAQ system applies a voltage to the emitter antenna in order to create a THz pulse. The detector antenna converts this THz pulse back into a voltage and sends it to the DAQ system.

[5] After you installed the software package provided on the USB flash drive.
Please check the manual for our T3DS Software for further details.

Warning

The DAQ system can put out up to 20 V. Please make sure that the voltage remains within safe limits. Do not exceed the specifications of your antennas.

1.4 T3DS Software

The T3DS software controls the emitter voltage and records the signal of the detector antenna, while the delay line changes the emitter beam path length in order to match the pulse propagation times.
The time-domain graph is updated in real time. However, the frequency spectrum is calculated and displayed once the measurement has been finished.

Please see the manual for our T3DS and T3DS Calculator software in order to optimize the signal and operate the THz Kit successfully.

2 How to build your THz Time-Domain Spectrometer

2.1 Preparation

2.1.1 Principal Configuration

Define your principal configuration in the first place in order to avoid any unnecessary alterations of the final system.

We recommend to plan with focusing TPX lenses[6] and to place the emitter and detector antenna accordingly. This way you can change between a focusing and collimating measurement setup on the fly. Just consider the time shift from the TPX lenses (~ 25 ps) between both setups.

2.1.2 Principal Beam Path

Draw a sketch of your principal beam path. Start with the laser beam fed into the system. Based on your laser you will need an adjustable mirror (free space output) or collimator (fiber output) and consider ...

- An **attenuator** to be able adjust the optical power of your laser
- A **beam splitter** (50/50) to generate the emitter and detector beam path
- The **delay line** (placed in the emitter beam path)

Warning

Since the THz antennas have a specific damage threshold you need to make sure that the laser meets the requirements and that the optical power on the antennas is within the specifications.

[6] e.g. LTA-D25.4-F32.5-M12.7 with a focal length of 32.5 mm

The distance of the emitter (E), detector (D) and THz (T) beam path has to meet the following criteria:

$$D = E + T$$

The THz (T) beam path consists of the geometrical and optical distance, measured between the PCA-Chip of the emitter and detector antenna. The optical distance is defined by the incorporated silicon and TPX lenses.

Table 1: Lens properties

	Free Space		Fiber-Coupled
	LSH-D12[7]	LTA-D25.4-F32.5[8]	LSA-D20[9]
Material	Silicon	TPX	Silicon
Refractive index	3.4	1.46	3.4
Geometrical thickness	7.1 mm	8.0 mm	13.8 mm
Additional optical thickness	17.04 mm	3.68 mm	33.12 mm

In general we recommend to plan with a THz beam path length of ~ 300 mm (free space) or ~ 245 mm (fiber-coupled) measured in air.

[7] Hyperhemispherical silicon lens
[8] Collimating TPX lens
[9] Collimating silicon lens

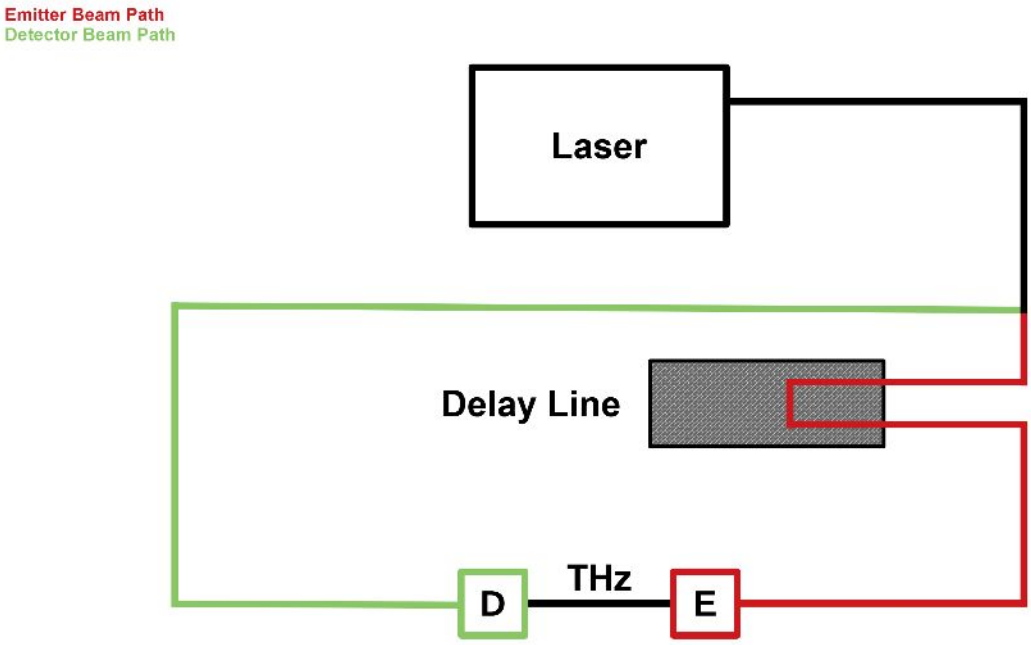

Figure 5: Principal setup of a THz spectrometer with free space antennas

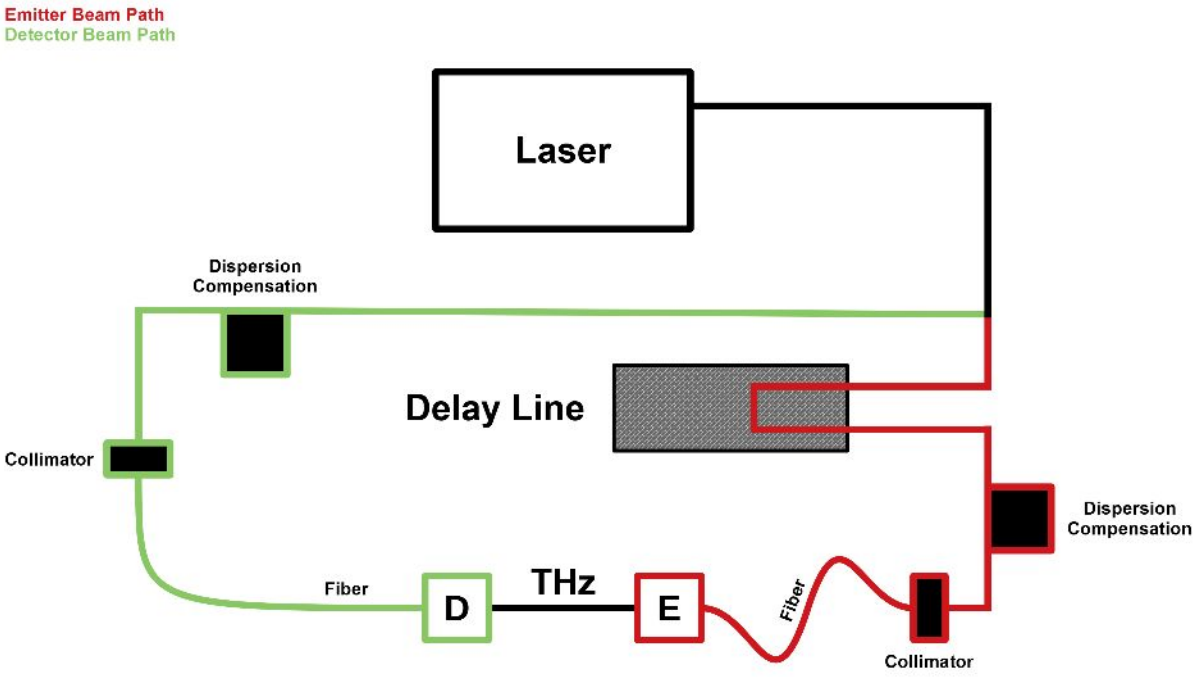

Figure 6: Principal setup of a THz spectrometer with fiber-coupled antennas

2.2 Setup

Recommended tools for the setup are:

- Laser viewing card[10]
- Infrared viewer[10]
- Optical power meter[10]
- Multimeter
- Adjustable aperture
- Aperture on a translation stage

Warning

You are working with invisible short pulsed laser radiation. Please follow all the safety measures recommended by the laser manufacturer. Any disregard may cause serious injury to your eyes.

2.2.1 Laser System

A careful setup of your laser system is crucial, since the laser beam has to be as parallel as possible to the optical table throughout the complete system.
Use the first mirror (free beam output) or the collimator (fiber-coupled output) and an aperture to dial in the desired beam height. Fix the height of the aperture and use it as reference for the rest of the setup.

Warning

Make sure that the laser beam entering the system does NOT damage the THz antennas. Set your power level accordingly in order to avoid damage to the antennas.

[10] Suitable for your laser wavelength

2.2.2 General Beam Path

Set up the optical elements as planned and measure the length of the overall beam path starting at the beam splitter. Position the delay line at around 25 mm of its travel length using the manual control knob.

Adjust each optical element and ensure the correct beam height (⇒ reference aperture) throughout the system. Start with the beam splitter and make sure that the power level of both laser beam paths is equal.

Please take great care at the alignment of the delay line. It is crucial that the laser beam is aligned parallel to the movement of the delay line. The recommended procedure is as follow:

- Adjust the incoming laser beam
  - Adjust the laser beam height (⇒ reference aperture)
  - Adjust the horizontal alignment of the laser beam
    - # Position an aperture on a translation stage on the delay line and minimize the variation of the optical power throughout the travel
    - # Small distance between the mirror and aperture ⇒ Alignment of the aperture
    - # Large distance between the mirror and aperture ⇒ Adjustment of the mirror

- Position the first mirror (deflecting the beam at 90°) on the delay line
  - Adjust laser beam height (⇒ reference aperture)
  - Adjust the horizontal alignment of the laser beam

- Position the second mirror (deflecting the beam at 90°) on the delay line
  - Adjust the laser beam height (⇒ reference aperture)
  - Adjust the horizontal alignment of the laser beam
    - # Position an aperture on a translation stage behind the delay line and minimize the variation of the optical power throughout the travel
    - # Small distance between the mirror and aperture ⇒ Alignment of the aperture
    - # Large distance between the mirror and aperture ⇒ Adjustment of the mirror

This iterative process can be very time consuming, but ensures proper THz measurements. Ideally, the change of the optical power throughout the travel of the delay line remains blow 10 %.[11] The last (~) 10 mm before the two end positions are less critical and larger changes are acceptable.

Proceed with the setup of the remaining optical elements and ensure the correct beam height (⇒ reference aperture).

In a setup with free space antennas it is important that the last section of the laser beam(s) towards the emitter and detector antenna are as collinear as possible.
In case of fiber-coupled antennas the emitter and detector laser beam path remains independent.

With all optical elements in place (and the delay at around 25 mm of its travel length) you have to verify the length of the overall beam path starting at the beam splitter. The difference between the emitter (E) plus THz (T) and the detector (D) beam path (see section 2.1.2) should be below 20 mm. Otherwise you have to adjust the beam path accordingly. In this case we recommend to reposition the mirror(s) of the detector beam path.

2.2.3 Free Space Antennas

Before you insert the THz antennas you have to dial in the recommended power level using the attenuator.

Position the emitter antenna in the beam path and use an IR viewer and multimeter to match the laser beam and antenna gap. Make sure that the PCA-Chip remains perpendicular to the laser beam. Insert the focusing lens and adjust its orientation (right/left & up/down) and focus (distance) in an iterative process. Make sure to choose a lens with a suitable focal length in order to get a laser spot that roughly matches the size of the antenna gap[12].

Repeat the procedure with the detector antenna.

[11] In- & outward travel
[12] e.g. ~ 6 µm for a 5 µm x 10 µm gap

2.2.4 Fiber-Coupled Antennas

Connect a multi-mode fiber to the collimator of the emitter antenna and your power meter. Adjust the last mirror and the collimator in order to maximize the optical power (~ 100 %[13]). Proceed with a single-mode fiber[14]. Now, the adjustment of the last mirror and collimator will be way more delicate. Once the fiber-coupling has been optimized (~ 80 %[13]), use the attenuator to dial in the recommend power level.
Connect the emitter antenna to the collimator and check the illuminated resistance. For the best results you may need to realign the last mirror and collimator slightly.

Repeat the procedure with the detector antenna.

Warning

Do NOT detach the optical fiber from the antenna!

2.3 THz Signal

Connect your THz Time-Domain Spectrometer to your computer and power supply using the provided cables and switch the DAQ system on. After you installed the software package, you will find the DAQ system (> NI-USB) and the delay line (> active COM port) in the device manager.

Finally you can start the T3DS software and do the fine optimization. Please check the also provided software manuals for further details.[15]

[13] X % of the optical power measured in front of the collimator
[14] Choose a single-mode fiber with the same mode field diameter as the fiber of the antenna
[15] Please check the manual of our T3DS Software for further details

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