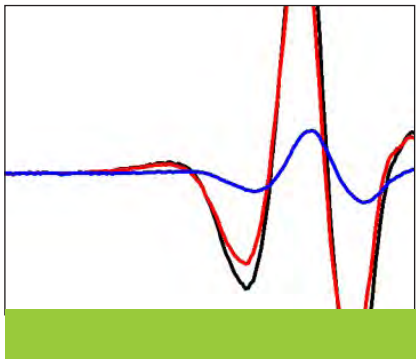
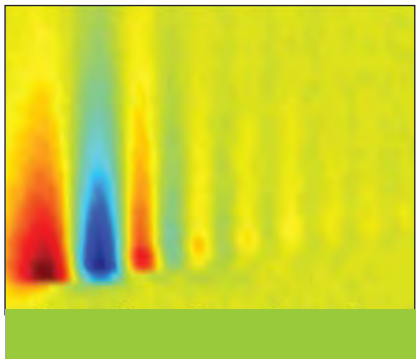
# HASSP-THz

- THz transmission spectroscopy system
- 1GHz spectral resolution
- Peak dynamic range greater than 60dB

## TECHNICAL DATA SHEET





Laser Quantum

# HASSP-THz


## High resolution THz spectrometer

## Overview

HASSP-THz is a time-domain THz transmission spectroscopy system with 1GHz spectral resolution and a spectral coverage of more than 6THz for scientific applications. The purged system has a peak dynamic range of greater than 60dB within only 1 minute of acquisition time. Video-rate spectroscopy (28 spectra per second) is performed at approximately 30dB peak dynamic range.

## Applications

**THz transmission spectroscopy**
HASSP-THz is used for THz transmission spectroscopy in scientific applications where ease of use, high precision and high spectral resolution are required. The ASOPS principle makes mechanical delay stages obsolete, there is no need to find a time-zero point. The absence of residual alignment errors and the long time-delay guarantee high precision and resolution.

**THz studies of dynamic processes**
HASSP-THz rapid data acquisition capability (up to 10,000 spectra per second at 1GHz resolution*) permit the investigation of dynamic processes and studies under rapidly varying environmental conditions.
*rapid data streaming capability provided by data acquisition board but not supported by HASSP-Scope software.

**THz imaging applications**
The rapid data acquisition capability of HASSP-THz makes very short pixel dwell times in spectroscopic THz imaging applications possible. Images can thus be acquired in a matter of a few seconds. An x-y-(z) scanning sample holder for imaging purposes must be provided by the customer.

## HASSP-THz technology

As enabling technology, HASSP-THz employs high-speed asynchronous optical sampling (ASOPS). High-speed ASOPS allows for a high scan-rate and a high frequency-resolution at the same time. This unique combination is impossible with conventional ultrafast time-domain measurement techniques based on a single femtosecond (fs)-laser and mechanical time-delay stages. High-speed ASOPS employs two separate fs-lasers whose 1GHz repetition rates are detuned by $\Delta f_R$=10kHz (2kHz with –GaP option) and thus deliver pump and probe pulse trains with a time-delay that is automatically ramped between zero and I ns at a rate given by $\Delta f_R$. A mechanical delay stage is not required.

HASSP-THz measures the transmission of a specimen by dividing the Fourier-transform of the transmitted THz radiation by a stored reference spectrum acquired without sample present at the interaction area. Transmission spectra are continuously displayed by HASSP-Scope at a user-definable update rate.

The signal-to-noise ratio of signals acquired by HASSP-THz is limited by detection shot-noise. It is thus directly proportional to the user-definable acquisition time. At video-rate (35ms per spectrum), the peak dynamic range is ~30dB. Higher values are accomplished by an increase in acquisition time. More than of 60dB can be achieved within just 1 minute.

A precision on the order of 150MHz has been demonstrated for HASSP-THz, a value that out-performs any other published time-domain spectroscopy instrument [G. Klatt et al., Opt. Expr. 17, 22847 (2009)].

# HASSP-THz components

HASSP-THz consists of different modules that are arranged on a breadboard with an enclosure. The components and their functionality are described in the following. See component specification sheets for details.

**Two Taccor-4 femtosecond lasers**
Taccor-4 is a femtosecond laser with 1GHz repetition rate. Each laser delivers more than 800mW of average power each with ≤30fs pulse duration. The two lasers deliver the pump and probe pulse trains, respectively.

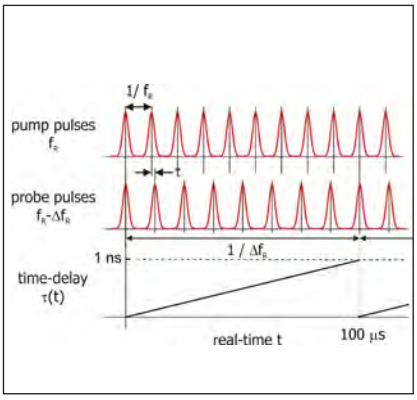
**TL-1000-ASOPS repetition rate offset stabilization unit**
The repetition rate offset stabilization unit TL-1000-ASOPS is used to phase-lock the pump laser to the probe laser with a +10kHz offset (+2kHz with –GaP option) as required for high-speed ASOPS. The time-resolution of the system is better than 60fs (typically 45fs) over the full 1ns time-delay window. The TL-1000-ASOPS unit also provides a TTL signal at the repetition rate difference to trigger the data acquisition hardware.

**TERA-SED3 large area THz emitter**
The pulse train from the pump laser illuminates a TERA-SED3 large-area THz emitter and launches a THz pulse into the spectroscopy system.

**THz interaction area and electro-optic detection**
The THz pulses are guided to the sample interaction area and from there to the (110)-ZnTe detector crystal (GaP with –GaP option) via off-axis parabolic mirrors. In the simplest configuration, the THz radiation is focused to a 0.5mm spot at the sample interaction area and measurements are performed in transmission geometry. Other geometries and solutions specifically tailored to meet customer requirements are possible. The entire area through which the THz radiation travels is contained in an enclosure which can be purged to minimise water vapour absorption. The pulse train from the probe laser is used to electro-optically probe the THz field via an electro-optic detector crystal. Our high-speed photoreceiver PR130 is used for detection.

**Data acquisition board and HASSP-Scope software**
The signal from the photoreceiver is sampled by a digitizer board at 125MS/s with 14 Bit resolution. Data acquisition is triggered by a square wave generated by the TL-1000-ASOPS unit or by an adjustable optically generated trigger signal which is synchronous with the time-delay ramping of the optical pulse trains. The real-timescale t is converted to a time-delay scale $\tau(t)$ by applying a scaling factor of ($\Delta f_R$/1GHz) to the time-axis of the acquired data. The data acquisition board has on-board capability of averaging over up to 1024 single-scan measurements. The time required for 1024 hardware averages is ~110ms (~550ms with -GaP option). The HASSP-Scope software displays the signal which is directly proportional to the detected THz field. HASSP-Scope also permits to acquire an arbitrary number of additional software based averages over the hardware-averaged traces in order to increase the signal-to-noise ratio. Live Fourier transform capability and displaying of transmission spectra is also provided.

a)

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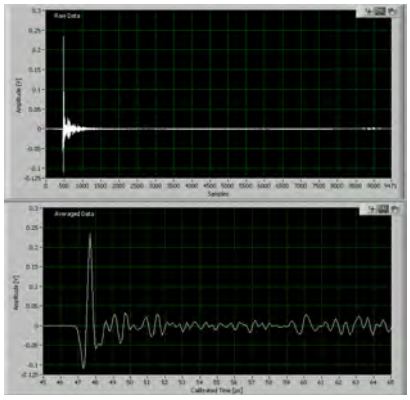

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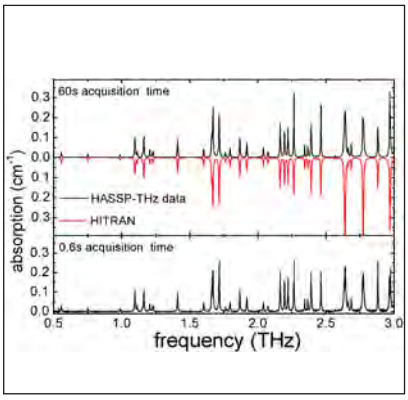
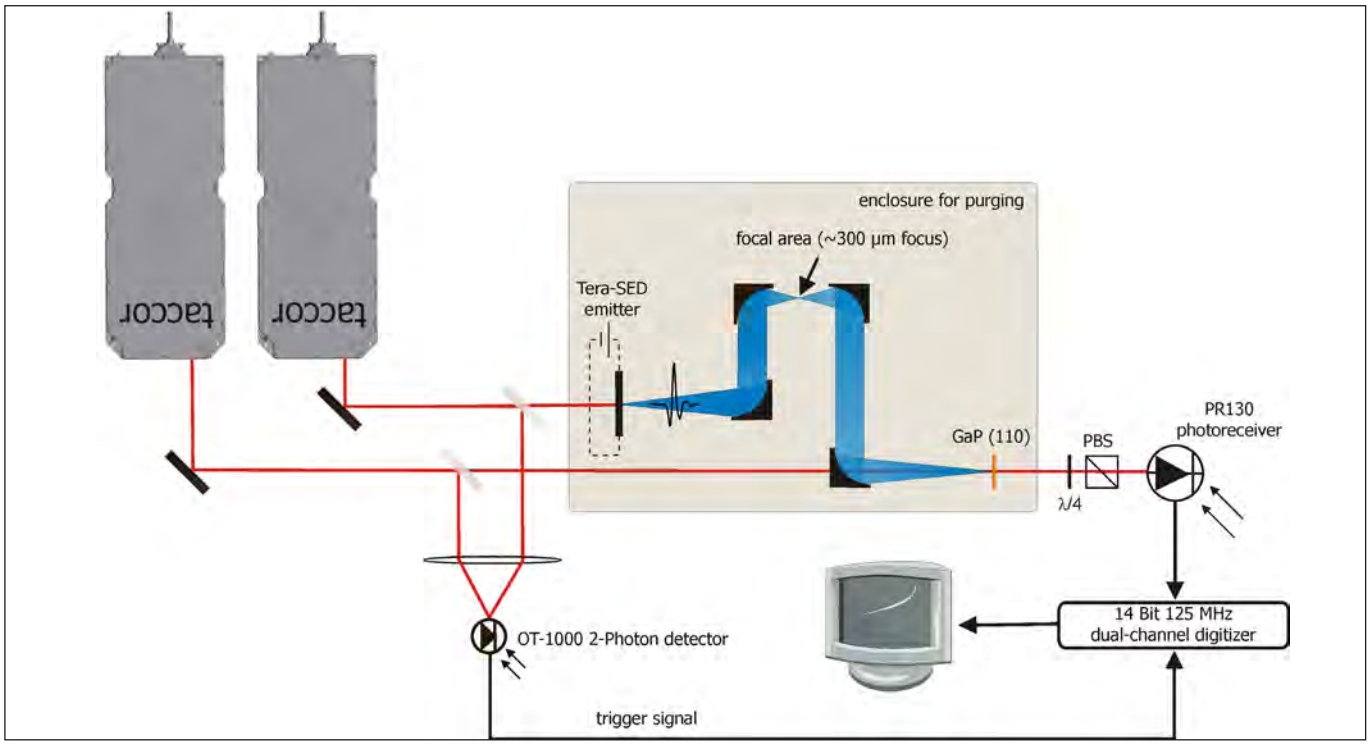



a) High-speed ASOPS scheme. The time delay between pump and probe pulses is scanned by slightly differing repetition rates ($f_r$~IGHz). The difference $\Delta f_R$ determines the scan rate, while the measurement window is given by the inverse of the repetition rate $I/f_R$=I ns. Here, $\Delta f_R$ is 10kHz, i.e. the time-delay is repetitively ramped with a 100µs period.

b) Screen shot of signal display field of HASSP-Scope software. Time-axis of raw data is scaled in samples, one sample equals 100fs time-delay (20fs with -GaP option). A zoom into the first ~20ps is shown for better visibility. Water vapour was present for the displayed traces. Upper panel: Hardware-based average over 1024 single scan traces displayed at ~10Hz update rate on the screen. Lower panel: Software-based average over 100 of the hardware-based averaged traces with increased signal-to-noise ratio.

c) Absorption spectrum of atmospheric air (black lines) compared to data compiled from HITRAN database for 60s and 0.6s acquisiton time.




Schematic of HASSP-THz. Optical femtosecond beam paths are red, electrical paths are black. TL-1000-ASOPS offset frequency stabilization unit is not shown.

## Technical Specifications*

| | HASSP-THz |
|---|---|
| Spectral coverage | 0.05-3THz<br>0.05-6THz with-GaP option |
| Frequency resolution | 1GHz (0.03cm$^{-1}$) |
| Scan frequency | 10kHz<br>2kHz with-GaP option |
| Time delay window | 1ns |
| Peak dynamic range @ 3 GHz resolution | ≤30dB @ 100ms acquisition time<br>≤60dB @ 100s acquisition time |
| Peak dynamic range @ 1 GHz resolution | ≤25dB @ 100ms acquisition time<br>≤55dB @ 100s acquisition time |
| Focal spot at sample area | Ø~0.5mm |
| Dimensions (main spectrom-eter unit) | approx. 90x150x30cm$^3$ |
| Sample holder | to customer specifications |
| Power requirement | 110 - 230V single phase<br>50-60Hz |
| Operating temperature | 15°C-25°C |

between 0.5 and 1.5THz, lower at other frequencies, reduced by 5dB with - GaP option

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