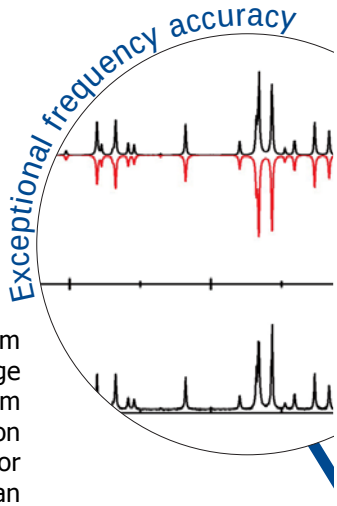
HASSP-THz

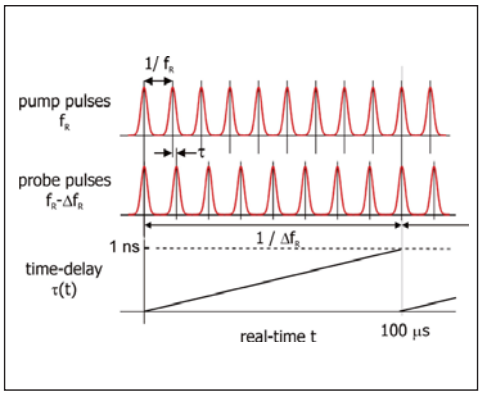
High resolution THz spectrometer

- Fully configured time-domain THz spectrometer
- Based on superior ASOPS technology
- 6.5 THz spectral coverage
- Up to 1 GHz resolution
- Ultra-rapid data acquisition (100 µs for single-scan trace)

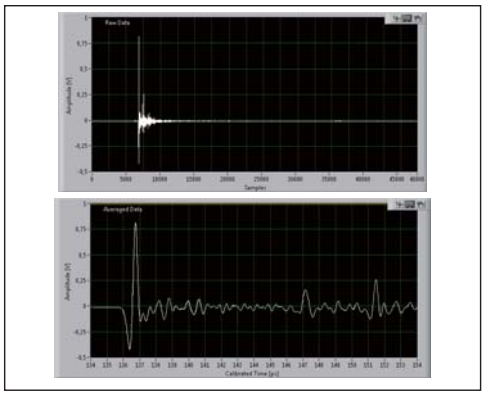


Overview

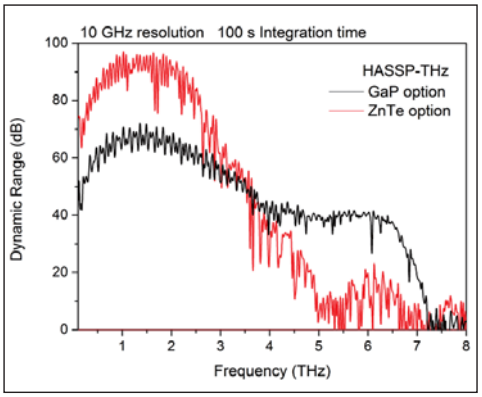
The **HASSP-THz** is a time-domain THz spectroscopy system with up to 1 GHz spectral resolution and a spectral coverage >6.5 THz for scientific applications. The modular system operates in transmission, reflectance or ATR mode. Transmission measurements are possible at a 500 µm focus. The purged or evacuated system has a peak dynamic range >90 dB with an acquisition time of only 100 seconds. Video-rate spectroscopy is typically performed at 60 dB peak dynamic range.



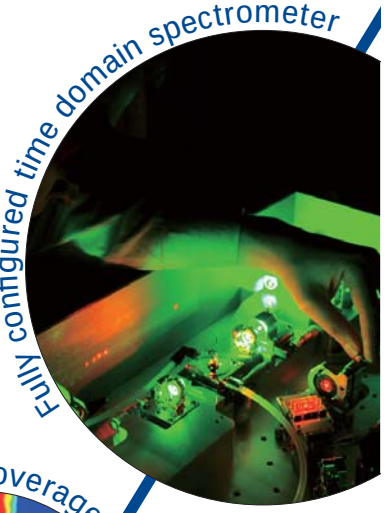
High-speed ASOPS scheme. The time delay between pump and probe pulses is scanned by slightly differing repetition rates (f_R~1 GHz). The difference Δf_R determines the scan rate, while the measurement window is given by the inverse of the repetition rate I/f_R=1 ns. Here, Δf_R is 10 kHz, i.e. the time-delay is repetitively ramped with a 100 µs period.

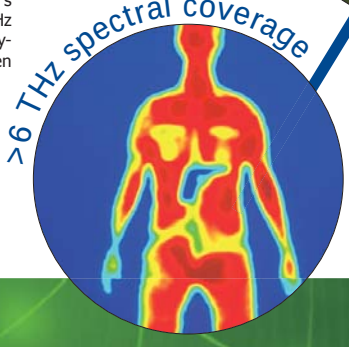


Screen shot of signal display field of **HASSP-Scope** software. The top graph shows raw data with 100 ms total acquisition time, the bottom graph shows a zoom into the main THz peak after additional averaging (total acquisition time 2 seconds). Water vapor was present for the displayed traces.



Typical THz sample spectrum shown for the ZnTe and GaP option. The vertical scale shows the spectral amplitude normalised to the noise floor above 7.5 THz. For acquisition times >1000 s a peak dynamic range of >100 dB can be achieved at 10 GHz resolution with the ZnTe option. Modulation is due to Fabry-Perot interference in the emitter substrate that cancels when referencing to an appropriate reference measurement.



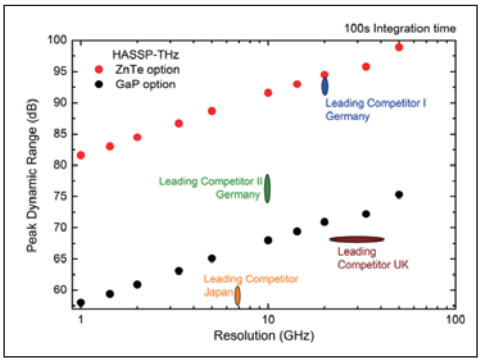


HASSP-THz technology

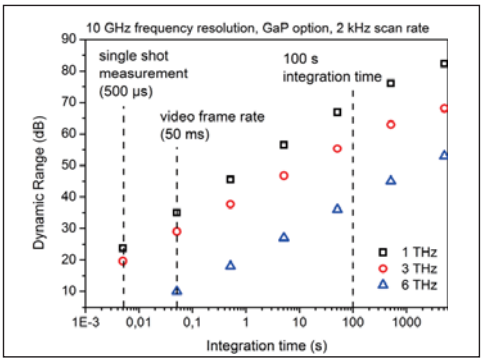
As enabling technology, the **HASSP-THz** employs high-speed asynchronous optical sampling (ASOPS). High-speed ASOPS allows for a high scan-rate and a high frequency-resolution at the same time. This unique combination is impossible with conventional ultrafast time-domain measurement techniques based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

The **HASSP-THz** measures the sample response by referencing the Fourier-transform of the transmitted or reflected THz radiation to a stored reference spectrum. Spectra are continuously displayed by **HASSP-Scope** at a user-definable update rate.

The signal-to-noise ratio of signals acquired by the **HASSP-THz** is limited by detection shot-noise. It is thus directly proportional to the user-definable acquisition time. At video rate, the peak dynamic range is ~60 dB (30 dB with GaP option). Higher values are accomplished by an increase in acquisition time. More than 60 dB can be achieved within just 100 seconds.

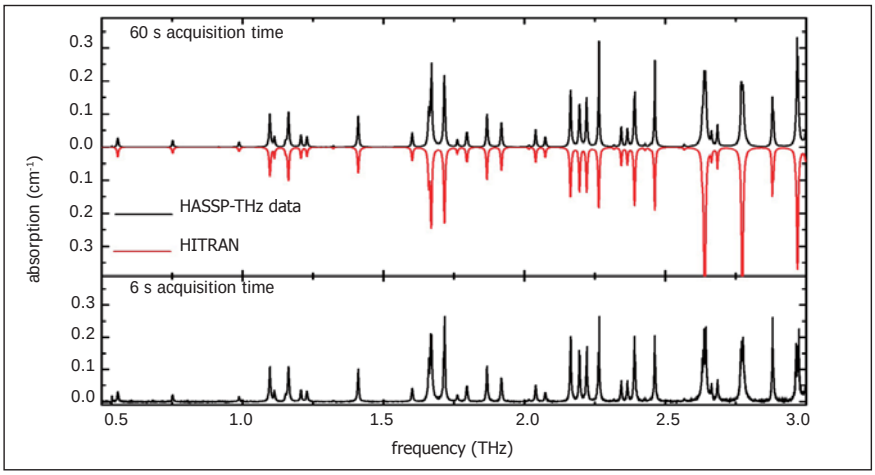


Typical peak dynamic range achieved with the **HASSP-THz** as a function of Fourier length analysis (frequency resolution). Please note that with the **HASSP-THz** system, the full 1 ns is always recorded so that the desired frequency resolution can be chosen when evaluating the data.



Typical dynamic range achieved with the **HASSP-THz** (with GaP option) as a function of integration time shown for three different frequencies: 1 THz, 3 THz and 6 THz.

A precision on the order of 150 MHz has been demonstrated for the **HASSP-THz**, a value that out-performs any other published time-domain spectroscopy instrument.



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

HASSP-THz components

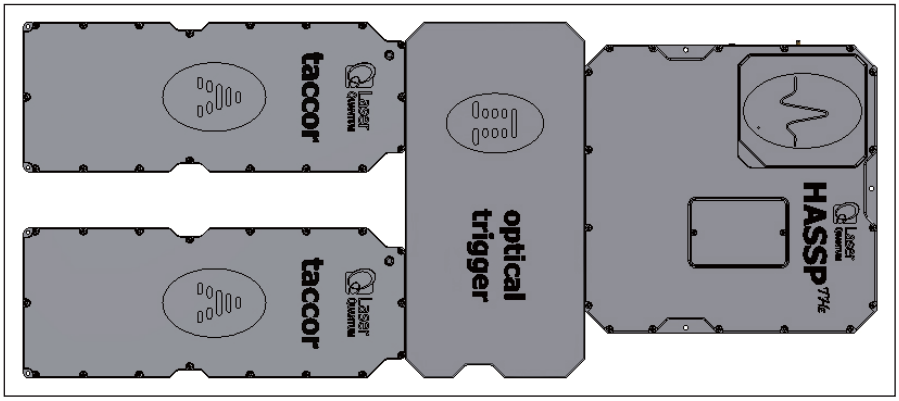
The **HASSP-THz** consists of different modules. The components and their functionality are described in the following. See component specification sheets for details.

Two taccor power femtosecond lasers
The **taccor power** is a femtosecond laser with 1 GHz repetition rate. Each laser delivers >800 mW of average power with <30 fs pulse duration. The two lasers deliver the pump and probe pulse trains respectively.

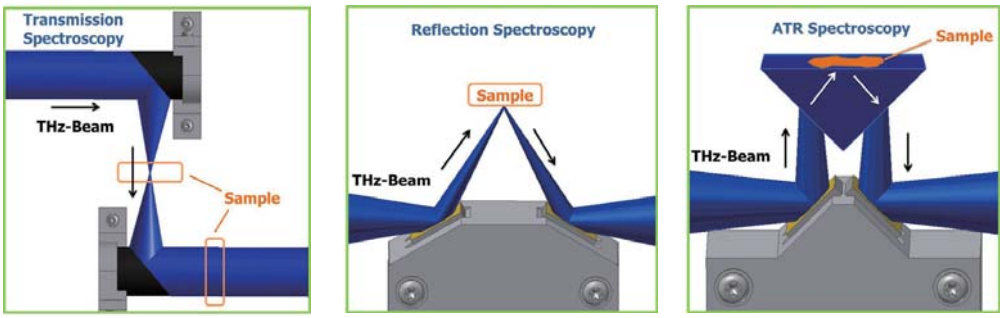
TL-1000-ASOPS repetition rate offset stabilisation unit
The repetition rate offset stabilisation unit **TL-1000-ASOPS** is used to phase-lock the pump laser to the probe laser with a +10 kHz offset (+2 kHz with GaP option) as required for high-speed ASOPS. The time-resolution of the system is better than 60 fs (typically 45 fs) over the full 1 ns time-delay window.

THz spectroscopy module
The THz spectroscopy module is based on a robust housing machined from a solid aluminium block. It contains all THz beam guiding optics and can be hermetically sealed to support either evacuation or purging with inert gas to eliminate the influence of water vapour. The electro-optic detection unit resides in a separate compartment isolated from the THz area. THz generation and detection with the femtosecond pulses from the two **taccor** lasers are based on the **Tera-SED3** emitter and a (110)-ZnTe detector crystal (GaP with GaP option), respectively. The basic module allows installation of a sample holder in the ~0.5 mm large THz focus and perform transmission spectroscopy. Additional module extensions permit reflectivity spectroscopy and ATR spectroscopy.

Data acquisition and HASSP-Scope software
The THz signal is digitised at 125 MS/s with 14 Bit resolution, permitting shot-noise limited detection. Data acquisition is triggered by an adjustable optically generated trigger signal which is highly synchronous with the time-delay ramping of the optical pulse trains and therefore permits high time-resolution and therefore a spectral coverage of >6.5 THz. The data acquisition board has on-board capability of averaging up to 1024 single-scan measurements (hardware averages), each one lasting only 100 µs (500 µs with GaP option). The **HASSP-Scope** software displays the THz signal. **HASSP-Scope** also permits the acquisition of an arbitrary and user settable number of hardware and subsequent additional software based averages in order to optimise dynamic range for a given sample. Live Fourier transform capability and displaying of transmission/reflectivity spectra is also provided.



Schematic of **HASSP-THz** in the transmission spectroscopy configuration. The **TL-1000-ASOPS** offset frequency stabilisation unit is not shown.



Available interchangable spectroscopy configurations for **HASSP-THz**.

HASSP-THz

Applications

THz spectroscopy

The **HASSP-THz** is used for THz 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. Please note in order to enable a spectroscopic analysis with high spectral resolution it is crucial to perform a reference measurement with a suitable reference sample.

THz studies of dynamic processes

The **HASSP-THz** rapid data acquisition capability (up to 10,000 single-scan traces per second at 1 GHz resolution*) permits 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 the **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. A suitable x-y-(z) scanning sample holder for imaging purposes must be provided by the customer.

Specifications*

	HASSP-THz	
	Standard configuration (ZnTe EO crystal)	High bandwidth configuration (GaP EO crystal)
Spectral coverage	0.05-3 THz	0.05-6 THz
Frequency resolution	1 GHz (0.03 cm^{-1})	1 GHz (0.03 cm^{-1})
Scan frequency	up to 10 kHz	up to 2 kHz
Time delay window	1 ns	1 ns
Frequency accuracy	<500 MHz	<500 MHz
Peak dynamic range @ 10 GHz resolution (standard transmission mode)[1]	≥90 dB @ 100 s acquisition time ≥70 dB @ 1 s acquisition time	≥60 dB @ 100 s acquisition time ≥40 dB @ 1 s acquisition time
Peak dynamic range @ 1 GHz resolution (standard transmission mode)[1]	≥80 dB @ 100 s acquisition time ≥60 dB @ 1 s acquisition time	≥50 dB @ 100 s acquisition time ≥30 dB @ 1 s acquisition time
Focal spot at sample area	Ø~0.5 mm	Ø~0.5 mm
Dimensions (main spectrometer unit)	approx. 60x120x30 cm^3	approx. 60x120x30 cm^3
Sample holder	Standard sample holders available, custom holders supported	Standard sample holders available, custom holders supported
Power requirement	110 - 230 V single phase (50-60 Hz)	110 - 230 V single phase (50-60 Hz)
Operating temperature	15°C-25°C	15°C-25°C

* Laser Quantum operates a continuous improvement programme which can result in specifications being improved without notice.
[1] The peak dynamic range is reduced by 5dB when ATR or reflection module is mounted.

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