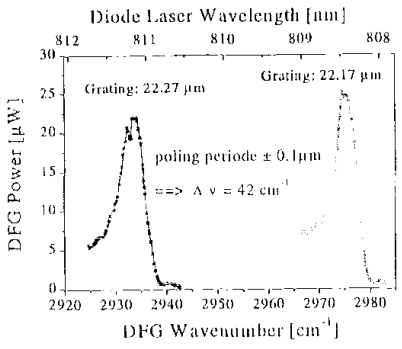

CThW5 Fig. 2. Power vs. wavenumber of the difference frequency laser for two different poling periods of the PPLN crystal. The temperature of the crystal is 20°C.

20.6 μm to 22.6 μm. Translating the crystal to the adjacent grating results in a frequency shift of 42 cm^{-1} as shown in Fig. 2.

The frequency range between the two peaks shown in Fig. 1 can be continuously swept by variation of the crystal temperature from 20 to 60°C with a rate of 1.6 cm^{-1}/°C. A spectroscopic important characteristic is the capability of fine frequency tuning. A fast change of the DFG wavelength with a rate of 0.013 cm^{-1}/V can be achieved by tuning the diode laser wavelength via tuning of the external cavity with a piezoelectric transducer. At a DFG wavelength of 3.35 μm high conversion efficiency of 0.2%/W is demonstrated, resulting in output power levels up to 27 μW. We expect to achieve even higher output power with a wave-guided PPLN which is currently under investigation.

In order to apply our DFG laser system for cavity leak-out spectroscopy the beam parameter of the laser has to be exactly determined because the beam has to be mode matched to the high-finesse cavity. The first spectroscopic results with our laser device in combination with a CALOS setup will be presented.

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Univ. Kaiserslautern, Germany

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CThW6 6:15 pm

Wide wavelength range picosecond table-top SFG spectrometer

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Since the first demonstration by Y.R. Shen, vibrationally resolved sum frequency generation (SFG) spectroscopy has become a powerful tool for investigation of molecules at surfaces and interfaces.[1] In SFG studies, the pulsed visible laser beam is mixed at the interface with the tunable IR beam. The majority of SFG experiments have employed mid-IR lasers at wavelength below 5 μm. At longer wavelength, especially over 10 μm, it becomes more difficult to generate sufficient infrared intensity.[2]

We have developed the picosecond table-top SFG spectrometer with a wide smooth tunability range of 2.3–10 μm. The accessibility of wavelength up to 16 μm is foreseen. For the sum frequency generation we use the second-harmonic (532 nm) radiation of EKSPLA PL2143B mode-locked Nd:YAG laser and mid-IR radiation of EKSPLA PG401VIR/DFG parametric generator. Active-passive mode-locked laser PL2143B generates optical pulses of three wavelengths: the fundamental Nd:YAG radiation (1064 nm), the second harmonic (532 nm) and the third harmonic (355 nm). The third-harmonic pumps LBO crystal-based optical parametric generator resulting radiation from 0.42 μm to 2.3 μm. Difference frequency generation by mixing of the 1.19–1.98 μm parametric radiation and 1.064 μm fundamental Nd:YAG radiation in $AgGaS_2$ crystal provides intense pulses in the range of 2.3–10 μm with the energies 400–70 μJ respectively. The using of GaSe crystal in difference frequency stage can extend spectrometer tunability range up to 16 μm. Typical parameters of pulses generating SFG signal are: energy of visible pulses (λ = 532 nm) ≈100 μJ, spot size 1.8 mm^2, pulse duration 20 ps; energy of IR pulses ≈100 μJ), spot size 0.28 mm^2, pulse duration 12 ps. Spectral resolution of the spectrometer, determined mostly by bandwidth of the parametric generator, is about 6 cm^{-1}.

The visible and IR beams are directed to the sample at the angles of $\varphi_{VIS} \approx 55°$ and $\varphi_{IR} = 62°$ respectively. The SFG signal is detected by photomultiplier after filtering via a holographic notch filter and monochromator. Out of plane two mirrors assembly changes the self-dispersion plane of SFG signal from horizontal to vertical. So this plane is made coincident with monochromator slits and allows to avoid the influence of self-dispersion when scanning of SFG spectrum. Two-channel detection with reference SFG signal generated in ZnSe is used in this system. This allows to reduce the influence of SFG pump beams instability and improves precision of experiment. Control of all spectrometer units and data acquisition is carried out by computer under LabVIEW software.

The obtained spectra of model systems: octadecanethiol monolayers on gold and poly(3methylthiophene) on platinum, show high sensitivity of spectrometer in all tuning range and reproducibility of results.

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CThX 4:45 pm–6:30 pm
Room 104

THz Optoelectronics and Spectroscopy

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CThX1. 4:45 pm

THz spectroscopy with ultrahigh sensitivity

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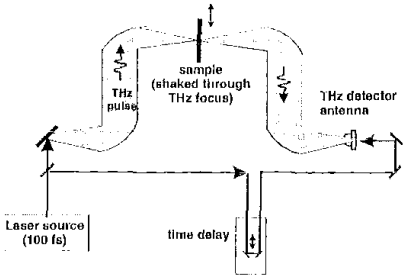
Although THz radiation has been used successfully for several applications[1,2] the signal-to-noise ratio is mostly restricted to 10^4 to 10^6 in intensity.[3] Especially for thin films of material the absorption and time delay of a THz pulse are mostly too low to be detected. We show a new method to enhance the sensitivity of THz spectroscopy to relative changes of 10^{-10} in intensity.

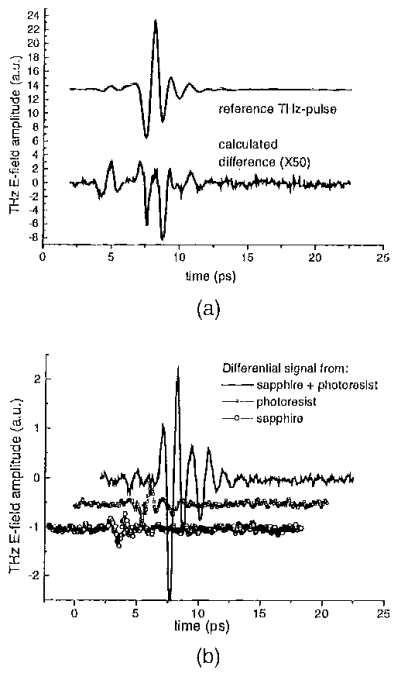
To demonstrate the capabilities of this new measurement technique, we spinned a photoresist (AZ 5214) with a constant thickness of 1.2 μm onto a sapphire substrate. From half of the sample the photoresist is removed, leaving a well-defined edge in the middle of the sample. This sample is placed in the focal plane of a focussed, pulsed THz beam which is detected by a photoconductive THz antenna (Fig. 1).

Figure 2(a) shows a reference THz pulse, which is transmitted through the sapphire substrate only. The difference between this reference pulse and a second pulse transmitted through sapphire with photoresist is also plotted as the lower curve. The calculated difference is not reliable because of high amplitude fluctuations and cannot be improved by longer averaging due to long-time fluctuations of the laser.

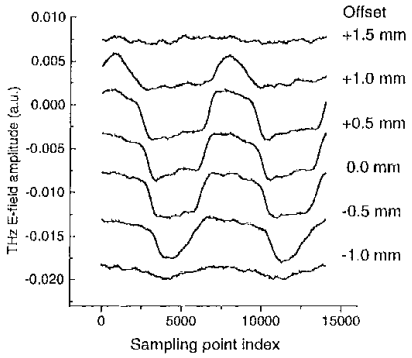
For the new differential measurement technique, the edge of the photoresist is rapidly moved ("shaked") laterally through the focus



CThX1 Fig. 1. Optical setup for investigating a sample with impulsive optically induced THz pulses.



CThX1 Fig. 2. (a) A THz reference pulse transmitted through sapphire and the calculated difference (multiplied by 50) between this reference pulse and a THz pulse transmitted through sapphire with photoresist on top. (b) Differential signals of three different sample positions are shown. Only when the edge of the photoresist crosses the THz focus, a significant signal can be detected.



CThX1 Fig. 3. Detected signal for a constant time delay. The sample is periodically moved across the THz beam with different offsets.

of the THz beam. Lock-in detection on the shaking frequency directly gives the difference between the signal with and without the photoresist [Fig. 2(b)]. Due to the rapid shaking the influence of the laser noise ($\sim 1/f$) can be considerably decreased. That difference signal is compared with two other signals taken with the same technique, but at other sample positions where the edge does not move into the THz beam. The small signal still left is mostly due to inhomogeneities of the sapphire or the photoresist.

To prove that the differential signal originates from the photoresist, the THz transmission is taken for several different positions of the photoresist edge relative to the THz focus (Fig. 3) and a fixed time delay ($\Delta t = 7.75$ ps). Now the signal is acquired with the fast data acquisition PC-card AIXScan[@].[4]

Here one can directly see the amplitude difference between the transmission with and without the photoresist. If the sample is placed in such a way that the edge symmetrically moves through the THz focus (0 mm) a rectangular signal with a duty cycle of one is obtained. During the upper part of the signal the THz beam is only transmitted through sapphire, otherwise is has additionally to go through the photoresist. One can see that the duty cycle becomes smaller if the photoresist is moved further into the THz beam. When the edge of the photoresist does not cross the THz focus anymore the signal degrades to a flat line. This proves that the signal is due to an inhomogeneity of the sample which can only be caused by the edge of the photoresist.

In summary, we have demonstrated a measurement technique by which it is possible to enhance the sensitivity of a THz spectroscopy system from 10^6 intensity to 10^{10} by shaking a sample through the focus of a THz beam and using lock-in detection on the shaking frequency.

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4. AIXScan[@] the universal femtosecond daty acquisition system (GWU Lasertechnik Vertriebsges. mbH), http://ourworld-.compuserve.com/Homepages/gwu_umwelt/ultra_fa.htm.

CThX2 **5:00 pm**

Enhanced coherent THz emission from (100) GaAs in the presence of a magnetic field

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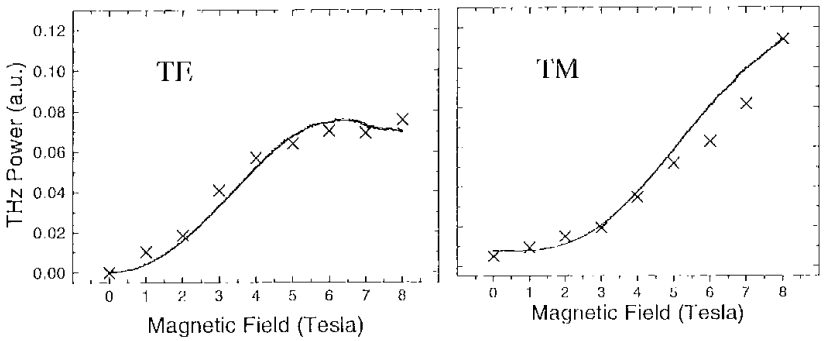
A terahertz (THz) field may be generated at the surface of a semiconductor by surface field photoconduction (SFP). In this process, photogenerated carriers are accelerated by the built-in surface field within the depletion region and their coherent motion results in the cooperative emission of THz radiation. A significant enhancement in the THz power generated by SFP has been observed when a magnetic field is applied to InAs.[1,2] In this experiment, we investigate the effects of magnetic fields up to 8T on the THz emission from a bulk (100) *n*-type MBE-grown GaAs sample (carrier density $n = 1^{*}10^{15}$ cm^{-3}). The sample was illuminated at an angle of 45° by a 70-fs pulse centred at 760 nm. The magnetic field was applied in the plane of incidence parallel to the reflected THz beam. The emitted THz radiation was measured both by an incoherent bolometer detection scheme and coherent free-space electro-optic (EOS) sampling.

The dependence of emitted power on magnetic field was measured at different sample temperatures in the range 5-300K; data in Fig. 1 refer to the TM and the TE polarizations of the THz field at 250K, the temperature which showed the maximum field-induced enhancement. Because only the surface field is present orthogonal to the crystal surface, the THz field at B = 0T is completely TM-polarized. With an increasing magnetic field, however, a TE component is also generated and an enhancement in both polarizations is measured. The TE component increases faster at smaller B-fields and peaks at B ≈ 6T whilst the TM component shows no saturation effect up to our maximum field of 8T. When the photon excitation energy is increased, the field-induced enhancement becomes larger (see Fig. 2) owing to a stronger absorption of the pump radiation at the crystal



CThX2 Fig. 1. TM and TE emitted THz power at 250 K. Solid lines represent bolometer data, crosses show EOS data (pulse squared amplitude is normalized to bolometer data).

Thursday, May 11