THz radiation from delta-doped GaAs

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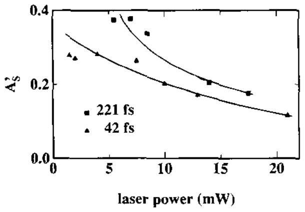

QWB5 Fig. 2. Power dependence of the normalised interface contribution A_S' measured at −4-V bias with a pulsewidth of 221 fs and 42 fs. The points are connected to guide the eye.

open circles present data at 0-V bias, the dots at −4 V.

Figure 1a shows a very clear bias dependence that disappears from 19-mW excitation as shown in Fig. 1b. The measured $I_{2\omega}$ curves can be fitted to Eq. (1) very well with A_B, A_S, and ϕ as fitting parameters. The bulk contribution A_B appears to be constant and insensitive to the applied bias voltage. This means that the bulk susceptibility is not affected by a depletion layer or injected carriers. The normalised interface contribution $A_S' = A_S/A_B$, depends on the effective electric field at the SB interface. A_S' appears to be proportional to the square root of the applied reversed bias and the zero-bias-bandbending, in accordance with the Schottky model. From Fig. 1b it can be seen that the bias dependence of A_S' is much smaller for higher average laser powers. This power dependence can be explained by the effect of carrier injection. If generated holes reach the Au layer, the charges will be compensated to a certain extent and thus the effective electric field will decrease. This decrease of the field takes place on a femtosecond timescale. This means that the power dependence of A_S' also depends on the width of the laser pulses. Figure 2 shows the power dependence of A_S' measured at −4-V bias with a pulsewidth of 221 fs and 42 fs. Monte Carlo simulations performed to calculate this power and pulsewidth dependence are in qualitative agreement with these observations.

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THz radiation from delta-doped GaAs

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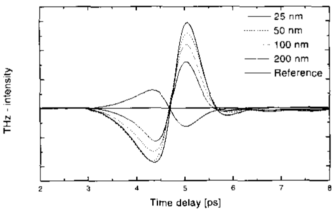
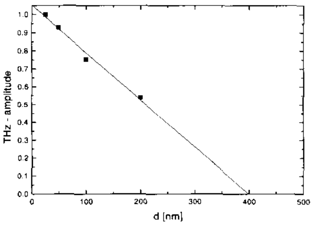
The emission of ultrafast THz pulses from semiconductor surfaces after femtosecond laser excitation was recently observed by Zhang and Auston.[1] Photoexcited carriers created near the surface are accelerated by the electric field present due to surface band-bending. The resulting photo current radiates an electromagnetic pulse possessing frequency components in the THz-regime.



QWB6 Fig. 1. THz-pulse radiated from the 4 delta-doped samples and the LEC GaAs reference sample with the Ti: sapphire laser operating at 830 nm.



QWB6 Fig. 2. Rms values of the THz-pulses emitted from the delta-doped sample relative to the d = 25 nm sample as a function of delta-layer depth. The line represents a linear fit to the data.

The presence of a delta-doped layer in the vicinity of the surface creates a very large field at the surface. These characteristics of the delta-doped structures make them very interesting as sources of THz-radiation, where both the high field and the high mobility should make the emitted THz amplitude greater than that emitted from bulk GaAs surfaces.

The delta-doped GaAs samples used in this work were grown by molecular beam epitaxy on Cr-doped semi-insulating GaAs substrates. The delta-doping was of *n*-type with Si as dopant. As reference samples we used a semi-insulating liquid-encapsulated Czochralski (LEC) GaAs sample. The fields present on both sides of the delta-doped layer are measured by photoreflectance.

The experimental setup used in the THz experiments is described in Ref. 2. THz signals radiated from the delta-doped samples upon laser pumping at 840 nm are shown in Fig. 1. The curves are labelled to indicate the type of sample. Also shown in a pulse radiated from the LEC GaAs reference sample. It is observed that the THz-pulses from the delta-doped samples show the opposite polarity of the THz-pulse emitted by the LEC GaAs sample. We also observe a decrease of the pulse amplitude as the distance from the surface to the delta-doped layer is increased.

The sign of the electric field radiated from the surface, and correspondingly the direction of the photo-current can be determined from the measured pulses by calibrating the response of the detection system with a biased THz-antenna. We find that the observed polarity of the pulses radiated from the delta-doped samples corresponds to a net current directed toward the substrate. This is consistent with the majority of the THz signal arising from the substrate side of the delta-doped layer.

We show in Fig. 2 the rms values of the THz-pulses emitted from the four delta-doped samples as a function of the position of the delta-doped layer. The straight line is a fit to the data and is explained in the following way: The source current responsible for the radiated THz-pulse originates from both sides of the delta-doped layer. Hence, the surface and substrate side contributions have opposite sign; the total THz signal is the sum of these contributions. As the distance from the surface to the delta-doped layer is increased the source current from the surface side is increased and the total THz-power is decreased.

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1. X. C. Zhang, D. H. Auston, J. Appl. Phys. **71**, 326 (1992).
2. J. E. Pedersen, I. Balslev, J. M. Hvam, S. R. Keiding, Appl. Phys. Lett. **62**, 1392 (1992).

QWB7 (Invited) 1000

Ultrafast coherent solid-state phenomena

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The progress of laser sources with subpicosecond pulse widths allows the preparation of coherent states in solid-state material and to study their dephasing in time domain. Of particular interest is the investigation of coherent phenomena in semiconductors and semiconductor heterostructures, revealing information on coherent electronic and vibronic states in these materials. Details on the generation and the dephasing of coherently excited phonons and electrons can be directly obtained in the time domain by pump–probe spectroscopy. Amplitude *and* phase of this motion can be simultaneously traced by electrooptic measuring techniques. Once the coherent state is prepared, it can be accurately controlled by further phase-sensitive excitation of the system.[1]

We review the results obtained in compound semiconductors and semiconductor heterostructures with a detection method that is based on the time-resolved optical modulation due to the Pockels-effect.[2] This technique has a high sensitivity towards internal polarizations associated with coherently excited LO-phonons and coherent electronic wavefunctions, e.g., Bloch oscillations in superlattices.

The time-resolved electrooptic detection of coherent longitudinal optical (LO) phonons in GaAs, which are launched by ultrafast screening of surface-space-charge fields, allows to display the dephasing in time domain with high accuracy and time resolution. Thus carrier-phonon interaction can be studied on a subpicosecond timescale directly for the first time. At low excitation levels, LO-phonons decay by the well known anharmonic coupling. With increasing excitation strength, however, carrier in-