Generation and coherent control of all-optically induced single-color currents in (110)-oriented GaAs quantum wells

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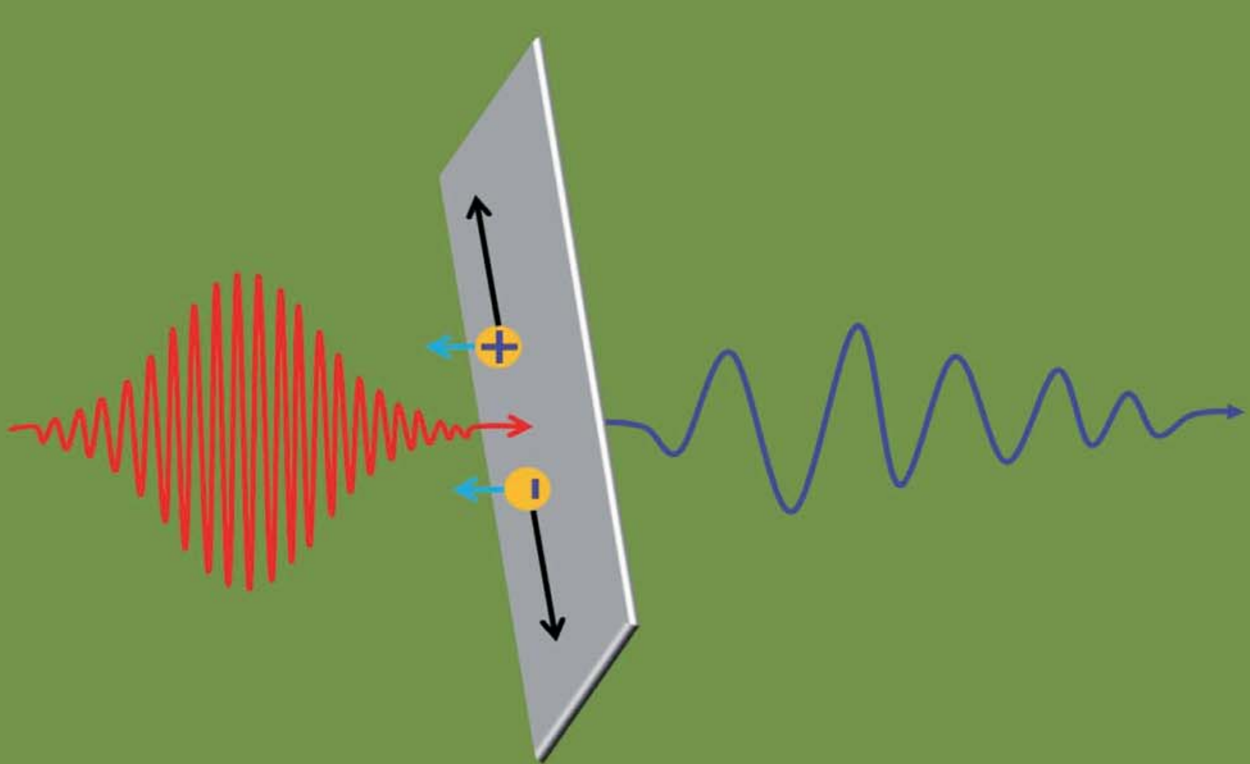

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“Science without religion is lame, religion without science is blind.” – *Albert Einstein*

Abstract

In the last few decades the study of ultrafast phenomena in GaAs gained worldwide attention showing potential for novel developments of ultrafast devices and techniques in metrology and communications. Possibilities for bandgap engineering, i.e., sophisticated techniques for crystal growth of lower dimensional structures propelled the GaAs research to a new realm of discoveries, e.g., quantum beating, spin-orbit interaction, and coherent control. In particular the control over the spin and drift of a coherently excited population became possible which triggered numerous studies of all-optically induced photocurrents to find applications in, e.g., spintronics, quantum computations, and the generation of THz radiation with a tailored spectrum.

In this thesis ultrafast all-optically induced photocurrents, namely shift and injection currents, are excited in (110)-oriented GaAs quantum wells by 130 fs optical pulses, which result in simultaneously emitted terahertz radiation. The terahertz radiation being a signature of the all-optically induced currents is measured using electro-optic sampling.

The excitation photon energy dependence of the shift and injection currents which exist in the quantum well region but not in the corresponding bulk structure of the (110)-oriented samples has been found to be strongly correlated to the bandstructure of quantum wells. However such correlation for the shift and injection currents differs remarkably and can be regarded as a characteristics signature. The shift current depicts a tremendous dependence on light-hole-exciton transitions showing huge enhancement at these transitions, whereas the injection current depends on free carriers, mainly heavy-holes. The shift current dynamics are found to be tremendously influenced by light-hole to heavy-hole intersubband scattering which becomes extremely fast when being assisted by LO phonon emission and results in a reversal of the shift current. On the other hand the study of the injection current dynamics shows that the carrier transport is tremendously influenced by light-hole and heavy-hole bandmixing which results in current reversals as well.

The dependence of shift and injection currents on the symmetry of crystal structures has been employed for the study of symmetry properties of (110)-oriented, nominally symmetric QWs. An out-of-plane asymmetry has been observed which proves that the nominally symmetric quantum wells are in reality asymmetric structures with different left and right interfaces. This is attributed to a different roughness of the interfaces.

Typically, the shift and injection currents constitute direct currents, i.e., flowing in one direction. In this thesis an in-plane coherent alternating photocurrent has also been observed which results from simultaneous excitation of heavy-hole and light-hole

states. The in-plane alternating photocurrent arises from an in-plane spatial separation of the periodic parts of the Bloch wavefunctions of the heavy-hole and light-hole states in (110)-oriented GaAs QWs. The observations are evidence for the existence of a substantial far-infrared transition-dipole moment between the heavy-hole and light-hole subbands for in-plane wave vectors.

The observations presented in this thesis considerably improve the understanding of optically induced currents and open new possibilities for further investigations. The all-optically induced photocurrents may be utilized for the down-conversion of encoded optical pulses into encoded terahertz pulses which may find its application in wireless terahertz communications. Moreover, the injection current investigations might pave the way to optically controlled pure spin current sources, hence applicable in spintronics. Finally, the observed in-plane alternating photocurrents might prove important for designs of far-infrared detectors, emitters, and amplifiers.

Advance publications relevant for the work discussed in this thesis

Journal:

[1] S. Priyadarshi, K. Pierz, U. Siegner, P. Dawson, and M. Bieler,“ All-optical generation of coherent in-plane charge oscillations in GaAs quantum wells,” *Phys. Rev. B*, vol. 83, pp. 121307(R), 2011

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[5] “THz spectroscopy of shift currents: a new tool for symmetry investigations of semiconductor quantum wells”, S. Priyadarshi, K. Pierz, A. M. Racu, U. Siegner, M. Bieler, “*Laser Optics Berlin, International trade fair and convention for optics and Laser technologies*”, (2010).

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