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Spin sensitive bleaching of absorption in p-type GaAs/AlGaAs QWs

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We report on the first observation of the spin sensitive bleaching of heavy hole — light hole absorption in p-doped quantum-well (QW) structures. Due to selection rules as well energy and momentum conservation direct intersubband transitions induced by circularly polarized light depopulate and populate selectively spin states at certain energies in the valence band causing a monopolar spin orientation. Since the transition rate is proportional to the difference of populations in the initial and final states, the increasing selective population tends to equalize the differing transition rates and, hence, leads to a sublinear dependence of the absorption on the intensity. The bleaching is controlled by both the hole spin relaxation and the energy relaxation of photoexcited carriers. In contrast to circularly polarized light, optical transitions induced by the linearly polarized light are not spin selective and the saturation is controlled by energy relaxation of photoexcited carriers only. The experimentally observed difference between absorption saturation of circularly and linearly polarized radiation gives evidence for spin controlled relaxation and allows to distinguish between energy and spin relaxation.

The experiments have been carried out on p-GaAs/AlGaAs (311)-MBE-grown single QW and 20 QWs of 15 nm width as well as MOCVD-grown p-GaAs/AlGaAs multiple QWs with 300 or 400 wells of 20 nm width on vicinal (001)-substrates. The growth direction of the latter structures was tilted by an angle of 50 with respect to the [001]-crystallographic axis as has been verified by X-ray diffraction. Samples with free-carrier densities between 10^{11} cm^{-2} and $2 \cdot 10^{12}$ cm^{-2} were studied in the range from liquid helium to room temperature. As a terahertz radiation source a high power pulsed far-infrared molecular laser optically pumped by a TEA-CO_2 laser has been used delivering 100 ns pulses with intensity up to 1 MW/cm^2 at wavelengths $\lambda = 35$ μm, 76 μm, 90 μm, and 148 μm.

The nonlinear behavior of the absorption of intense terahertz radiation in the wavelength range between 35 and 148 μm has been investigated by application of the recently observed circular and linear photogalvanic effects [1]. The photocurrent has been measured in unbiased samples at two contacts placed along $[1\bar{1}0]$-crystallographic directions. Absorption of circularly and linearly polarized radiation results in a direct motion of free carriers in the plane of a quantum well perpendicular to the direction of light propagation. The photocurrent j is proportional to the light intensity at low power levels and gradually saturates with increasing intensity I as $j \propto (I/(1 + I/I_s)$ due to the absorption saturation. I_s is the saturation intensity which allows to determine relaxation times. Saturation intensities have been measured for a wide range of temperatures between 4.2 K and 300 K, hole densities, and photon energies, corresponding to different initial and final energy levels of holes. The experimentally obtained values varies from 30 kW/cm^2 to non-measurably large values at room temperatures. The magnitude I_s for the circular photogalvanic effect is generally smaller than for the linear photogalvanic effect. It varies with the radiation wavelength and increases with increasing temperature and doping density.

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