10. Infrared Nonlinear Optics

Academic and Research Staff

Prof. P.A. Wolff, Dr. R.L. Aggarwal, Dr. Piotr Becla, Dr. C. Jagannath, Dr. L.R. Ram-Mohan, Dr. Y.C.S. Yuen

Graduate Students

G. Boebinger, J. Warnock, S. Wong, E. Youngdale

10.1 Infrared Nonlinear Processes in Semiconductors

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Roshan L. Aggarwal, Peter A. Wolff, Chiravurri Jagannath, L.R. Ram-Mohan, Y.C. Sunny Yuen, Gregory Boebinger, Stephen Wong, Eric P. Youngdale

Four wave mixing spectroscopy[1] has been used to study the stress dependence of the ground state multiplet of phosphorus donors in silicon at 1.8 K, using a quantitative stress cryostat. For compressive force, F, along [100] or [110], the 1s(E) level splits into two singlet levels. These measurements determine the stress deformation potential constants, Ξ_u, characterizing the 1s — ground state multiplet. A direct measurement of the effect of uniaxial stress on the size of the envelope function should be possible via diamagnetic techniques.

Saturation behavior of the band-gap resonant optical nonlinearity at 10.6 μ in HgCdTe was studied[2] by degenerate four-wave mixing experiments over a wide range of laser intensities. The reflectivity saturates when the laser power density reaches 100 W/cm^2, and the third-order nonlinear susceptibility drops as the inverse of the laser intensity, thereafter. A theory of interband absorption at the pump frequency, due to state blocking, is in good agreement with the experiments.

Four wave mixing experiments were used to study[3] the variation of the third order nonlinear susceptibility, $\chi^{(3)}$, with difference frequency $\Delta\omega$ and laser intensity I in low carrier concentration HgCdTe crystals. At small $\Delta\omega$, $\chi^{(3)}$ is caused by nonparabolicity of free electrons generated by two photon absorption, with $\chi^{(3)}$ scaling as $(\Delta\omega)^{-1}$ and $I^{2/3}$. The $\Delta\omega$ variation of $\chi^{(3)}$ indicates that the electron thermalization time is longer than 8 psec. At large $\Delta\omega$, $\chi^{(3)} \simeq 3 \times 10^{-8}$ esu and is mainly due to valence electrons.

Three wave mixing, to generate far infrared radiation in the 100 μ range, has been investigated[4] in uniaxially-strained n-InSb. This work was stimulated by a recent observation of stress-enhanced, electron dipole spin resonance absorption in n-InSb. In the current work, two CO_2 laser beams, with difference frequency $\Delta\omega$ near the electron spin resonance frequency, were combined in a cold n–InSb crystal. The FIR signal at $\Delta\omega$ was enhanced by a factor of 10 with uniaxial stress; at the same time the spin resonance broadened substantially. Overall, the effect is smaller than anticipated and probably not useful for tunable FIR generation.

Measurements of the difference frequency dependence of $\chi^{(3)}$ have been used to determine[5] the light to heavy hole scattering rate in p–type GaAs. At 300 K the scattering time is $T = 1 \times 10^{-13}$ sec; it increases to 2×10^{-13} sec at 77 K. These values are in good agreement with those calculated for polar optic phonon scattering.

References

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