Nondegenerate nonlinear refraction, absorption, and gain in semiconductors

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100-word abstract

The effect of intermediate-state resonance enhancement causes highly nondegenerate 2-photon absorption, 2PA, to be strongly enhanced in direct-gap bulk and quantum-well semiconductors. This enhancement leads to interesting applications of 2PA, such as mid-infrared detection and imaging. In the case of optically pumped semiconductors, the complementary process of nondegenerate 2-photon stimulated emission has also now been observed, leading to the possibility of large-gap devices with tunable mid-infrared gain. The enhancement of 2PA is accompanied by an enhancement of the nonlinear refractive index, n_2. This latter effect may lead to interesting optical switching paradigms.

250-word abstract

We have shown both experimentally and theoretically that the effect of intermediate-state resonance enhancement causes highly nondegenerate 2-photon absorption, 2PA, to be strongly enhanced in direct-gap semiconductors. Calculations indicate an additional 10x increase in this enhancement is possible for quantum-well semiconductors. This enhancement leads to interesting applications of 2PA, such as mid-infrared detection, where uncooled, large-gap photodiodes can rival the sensitivity of cooled MCT detectors (for short pulses). Additionally, mid-IR imaging and tomography based on this effect have been shown. Even larger enhancement of 3PA is calculated and observed. In the case of optically-pumped semiconductors, we have now demonstrated that the complementary process of nondegenerate 2-photon stimulated emission can be observed. Theoretically, this results in 2-photon gain (2PG) that is enhanced as much as 2PA, leading to the possibility of large gap devices with tunable mid-infrared gain. However, the effect of nondegenerate enhancement of 3PA can be detrimental to the observation of this gain. Additionally, by causality, Kramers-Kronig relations predict that the enhancement of 2PA is accompanied by an enhancement of the nonlinear refractive index, n_2, which is very highly dispersive in the region of 2PA. Our latest experimental results confirm this enhancement and strong dispersion.