Dynamic approach to multi-photon absorption of semiconductors using a two-band model

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Abstract

The nonlinear optical response of direct-gap semiconductors is investigated by solving the semiconductor Bloch equations. In a perturbative treatment of the light fields we obtain multi-photon absorption coefficients as well as the corresponding higher-order corrections. Non-perturbative solutions in the strong-field regime show, e.g., Stark shifts and multi-photon analogues of Rabi oscillations.

Two- and multi-photon absorption (2PA/NPA) by semiconductors has been studied by a variety of theoretical approaches. However, still several fundamental aspects are not yet well understood, in particular, with regards to higher-order processes and the dynamical behavior.[1] The semiconductor Bloch equations (SBE) allow us to study these effects within the semiclassical approximation, when both the interband excitation and the intraband acceleration are taken into account.

We evaluate the SBE for two-band models and neglect many-body interactions for simplicity. The perturbative Bloch equations are solved analytically in the continuous-wave limit up to 7th order in the optical field. We confirm a previously found[2, 3] strong enhancement of NPA for non-degenerate excitation frequencies. In Fig. 1 the analytical results (dashed lines) are compared with numerical solutions for pulses of finite duration for a pump-probe scheme (yellow lines). The numerical results also feature higher-order corrections to each NPA. We demonstrate that their approximate shape can be predicted from the probe-frequency dependence of the NPA (dotted lines). Further aspects that are evaluated for pulses of finite duration are the dependencies on dephasing and relaxation, initial carrier densities, and the pulse delay.

In the high-intensity regime, dynamic saturation effects occur which are revealed by non-perturbative numerical solutions. In particular, we discuss NPA Rabi-like oscillations for a single strong pulse, as well as non-trivial transients for the strong pump/weak probe scheme.

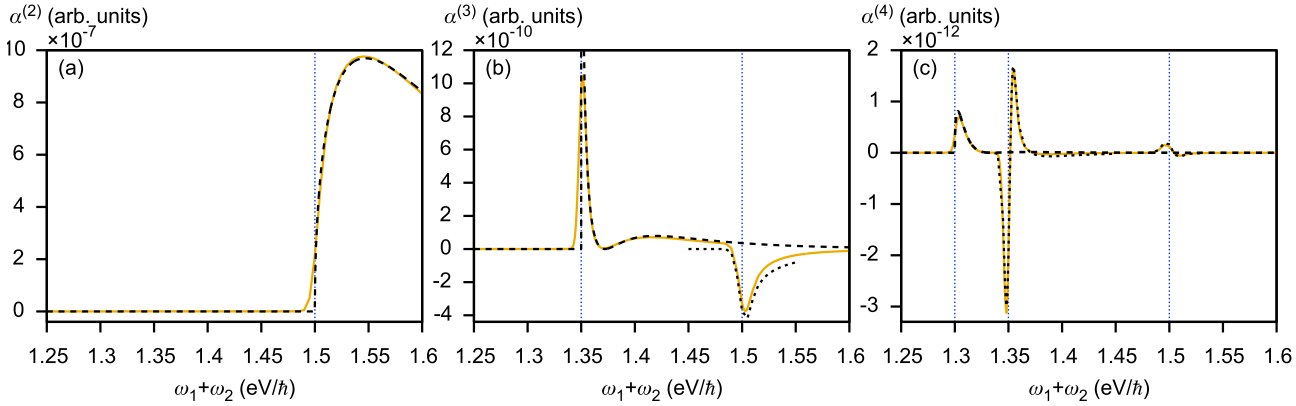

Figure 1: NPA coefficients $\alpha^{(N)}$ for N=2, 3, 4.[1] The probe frequency is fixed at $\omega_1 = 1.2\,\mathrm{eV}/\hbar$. The band gap resonances are indicated by vertical blue dotted lines. See text for details.

[1] W.-R. Hannes and T. Meier, *Higher-order contributions and non-perturbative effects in the non-degenerate nonlinear optical absorption of direct-gap semiconductors*, arXiv:1812.09171 [cond-mat.mes-hall] (2018).

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