Extremely Nondegenerate Two-Photon Absorption and Sub-bandgap Detection in Semiconductors

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We have shown that two-photon absorption (2PA) coefficients in direct gap semiconductors may be greatly increased by using extremely non-degenerate photon pairs [1, 2]. This effect is due to the zero-frequency resonance enhancement of the dominant allowed-forbidden transitions in semiconductors, where the forbidden transition is an intraband or self-transiton and can be well described using a two parabolic band model [3]. Figure 1a shows the results of pump-probe experiments demonstrating that the nondegenerate 2PA coefficient is increased by up to 270 times the degenerate 2PA in ZnSe. Also shown are theoretical results using the two-parabolic-band model [3] which agree well with the experimental data.

This large enhancement of 2PA in the extreme non-degenerate case opens up the possibility of IR detection via two-photon excitation in direct-gap semiconductor based photodiodes. We have successfully demonstrated detection of infrared pulsed radiation (5.6 μm) using near-UV (390nm) gating pulses and vice versa in a commercial p-i-n GaN photodiode using pulses of approximately 200 fs duration [1]. In the case where the IR is used as the gating pulse the detected signal is essentially background-free. However, when detecting the IR pulse using an intense 390 nm gating pulse, a background is produced due to the unenhanced degenerate two-photon absorption of the gating pulse. Since this signal depends only upon the gating pulse irradiance, it can be easily discriminated by modulation techniques. Our results show that, when used in this mode, the uncooled GaN detector performs IR detection with sensitivites comparable to or even superior to that of conventional liquid-nitrogen cooled HgCdTe detectors (Figure 1b).

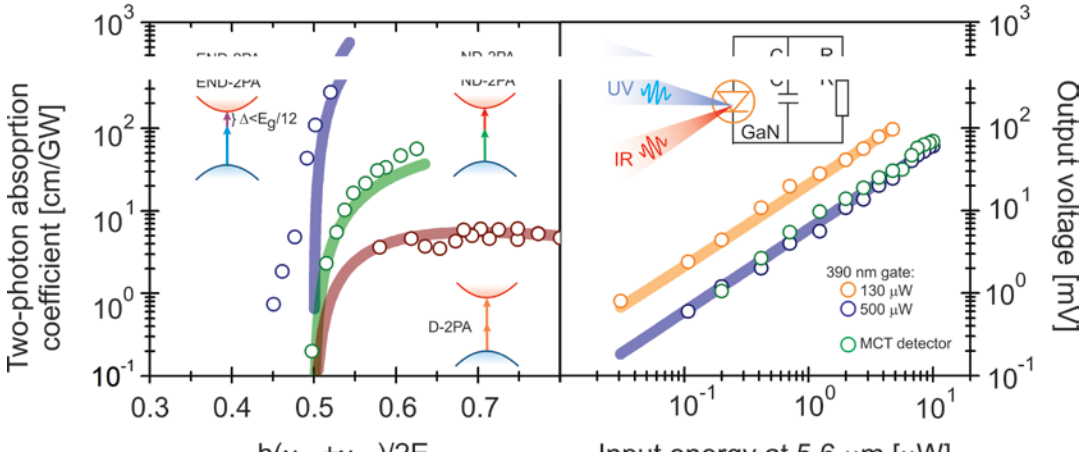

Fig1: (a) Femtosecond pump-probe results: D and ND 2PA coefficient of ZnSe versus the sum of pump and probe photon energies normalized to the bandgap: solid lines are theoretical model. (b) Log-log plot of the output voltage of a GaN diode vs. 5.6 μm (215 fs) input signal energy in the presence of temporally overlapped 390 nm gating pulses (100 fs) of various energies. The grey filled in squares show data for the MCT detector.

The availability of strong non-degenerate two photon absorption may lead to new applications and devices beyond IR detection. The enhancement seen in 2PA also applies to the inverse process of two photon gain, which has already been demonstrated in the near-degenerate case [4]. Additionally, with very large 2PA, one could

conceive of all-optical switching devices that operate purely on nonlinear absorption. [Is there a reference to ZEO-type switches we could use?]

References:

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