Picosecond-class nonlinear refractive-index recoveries in quantum-dot waveguides measured with a heterodyne pump-and-probe technique

Masanori Honma[1], Ferran Salleras[1], Jun Sakaguchi[1], Yoshiyasu Ueno[1], Nobuhiko Ozaki[2], Yoshiaki Takata[2], Yoshinori Kitagawa[2], and Kiyoshi Asakawa[2]

[1]Department of Electronic Engineering, University of Electro-Communications, Chofu, Tokyo

[2]Center for Tsukuba Advanced Research Alliance (TARA), University of Tsukuba, Tsukuba, Ibaraki

e-mail: honma@ultrafast.ee.uec.ac.jp

The present progress in the growth and fabrication of nano-structures, including photonic crystals (PCs) and quantum dots (QDs) [1], is spurring novel all-optical devices with ultrafast and ultralow-energy operation in compact photonic integrated circuits. PC waveguides have high optical confinement and slow light effect which can enhance the optical nonlinearity of QDs (low saturation energy due to high density of the states). The saturation of the QD absorption induced by a strong pump pulse produces a corresponding change in refractive index for any signal detuned from the pump (through Kramers-Kronig relations), resulting in a phase shift. This phase shift can be employed in interferometric configurations acting as intensity modulators or optical switches. Recently, switching operation has been demonstrated in a 2D symmetric Mach-Zehnder interferometer consisting of PC waveguides with embedded QDs [2].

This year, we have started building up a sub-picosecond two-color heterodyne pump-and-probe setup for characterizing those PC/QD waveguides. Fig. 1 contains the schematic view of the proposed setup. An optical parametric oscillator (OPO) delivers 150fs pulses centered anywhere between 1.3 and 1.6μm. The OPO signal is split into two beams in a polarizing beam splitter (PBS). The first beam, i.e. the pump beam, is sent to a delay stage and then injected into the PC/QD waveguide. The second beam is spectrally broadened in a single-mode fiber (SMF, zero dispersion at 1.3μm) through self phase modulation. A band pass filter (BPF) slices the generated super-continuum to obtain sub-ps pulses with a different color than the pump pulses. After the BPF, a beam splitter (BS) separates the probe and reference beams. The probe frequency is modulated by an acoustic optical modulator (AOM) and then injected collinearly with the pump pulses (both TE polarization) into the PC/QD waveguides. The reference frequency is shifted by another AOM. After crossing the PC/QD waveguide, the modulated probe and the reference are mixed in the BS. A PIN photodiode and a lock-in amplifier detect the resulting beat signal.

In the symposium, we will present the measured dynamic range of our scheme and its dependence on the reference pulse energy. The first measurements of pump induced refractive index change (i.e. phase shift) in a semiconductor optical amplifier will also be presented.

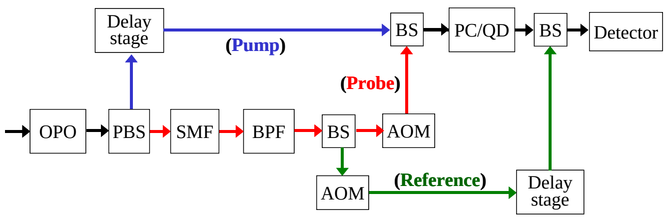

Fig. 1. Schematic view of the two-color sub-picosecond heterodyne pump and probe setup.

References

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2. H. Nakamura *et al.*, Opt. Express **12**, 6606 (2004); K. Asakawa *et al.*, New J. Phys. **8**, 208 (2006).