Highlighting excitonic optical properties of bundled carbon nanotubes to tailor novel nanomaterials-based devices

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The original excitonic optical properties of carbon nanotubes (CNT) [1,2] confer great potential on these 1D-nanomaterials for direct telecommunications applications around 1,55µm. Nowadays, all-optical regeneration of telecom signal, in high-bit-rate optical fibre transmission systems, need still more efficient optical devices, such as saturable absorbers (SA) with ultrafast optical response time and great ratio between ON/OFF states. Excitonic optical properties of nanomaterials- based SA, such as quantum wells (QW) nanostructures (2D-nanomaterials), have already demonstrated huge potential for such signal regeneration [3], in comparison to bulk materials. However, fabrication of these ultrafast 2D-nanostructures-based SA need complex and expensive growth technique, and QW-doping [4] or QW-irradiation [5] techniques have been developed to reduce typical nanosecond QW nanostructures optical response time down to subpicosecond range, required for high-bit-rate signal regeneration. Thus, ultrafast absorption dynamics and large 1D-excitonic nonlinearities of bundled CNT [6] make them intrinsically and potentially as prime candidate to replace QW-based SA. In this way, we have deposited CNT on glass, Si or photolithographied-InP substrates, from nitrogen-brushed NMP-dispersion containing CNT. We also extend the well-controlled microtechnology techniques developed for III-V semiconductor nanostructures-based devices (quantum wells, wires and dots) to CNT-based SA realization. Quality of technological process used for CNT deposition is analyzed by Scanning Electron Microscopy (SEM). Vibrational properties of CNT-based SA are characterized by Raman spectroscopy using 785nm-pump laser diode, and will be presented too. This invasive and useful optical experiment reveals vibrational modes and typical features of CNT [7]: radial breathing mode (RBM), defect-mode D and tangential modes G. The position of RBM mode provides first useful information, as it depends inversely to CNT-diameter [8]. This estimation of CNT-diameters provides first optical Van-Hove transition energy of semiconductor CNT, thanks to Kataura plot, which can be exploited for telecom applications near 0,8eV (1,55µm). Furthermore, the Raman spectra and SEM pictures show a relatively good reproductibility of our CNT-based SA, from fabrication (HiPCO from CNI *Inc.*) to deposit technological process.

Dynamics of nonlinear optical properties of CNT-based SA are highlighted by femtosecond-pulses cross-polarized degenerate pump-probe experiment. Figure 1 shows temporal evolution of normalized differential transmissions ($\Delta T/T_0$) of CNT-based and doped-QW-based SA for comparison (see ref [4] for details on doped-QW SA). A significant reduction of monoexponential response time by using CNT as efficient and relatively low-cost nanomaterials instead of doped-QW for SA applications is demonstrated (divided by ten factor), keeping an encouraging good contrast ratio for CNT–based SA. Studies on power and wavelength dependence of these excitonic nonlinear optical properties in telecom wavelength range (ultrafast response time and contrast ratio) are in progress.

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References:

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Figure:

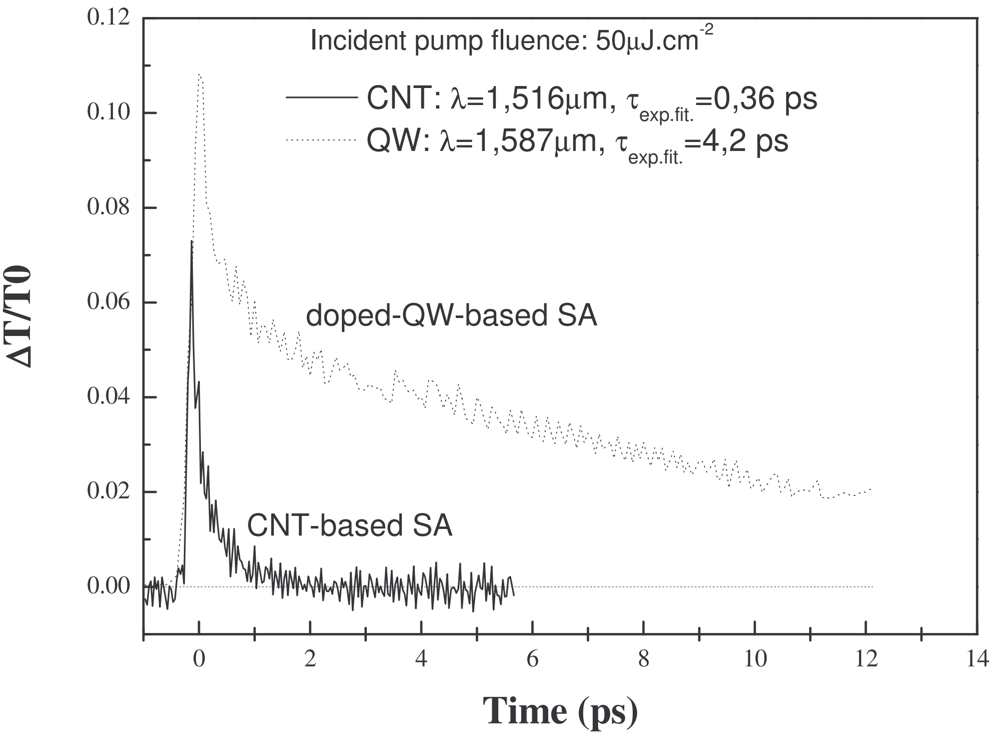

Figure 1: Ultrafast dynamics of CNT-based and doped-QW-based-SA. Degenerate pump and probe wavelengths, in resonance with first semiconductor nanomaterials optical transition, and fitted monoexponential response times are mentioned. Dashed line at zero level is a guide for the eye.