Spectra-Temporal Dynamics of Carbon Nanotubes in Plasmonic Metamaterial

Andrey E. Nikolaenko, Mengxin Ren, and Nikolay I. Zheludev,
Optoelectronics Research Centre and Centre for Photonic Metamaterials, University of Southampton, SO17 1BJ, UK,
e-mail: aen@orc.soton.ac.uk, web: http://www.nanophotonics.org.uk/niz/
Francesco De Angelis and Enzo Di Fabrizio, Italian Institute of Technology, 16163 Genova, Italy

Abstract: By aggregating carbon nanotubes with plasmonic metamaterial we achieve giant optical nonlinearity with sub-500 fs response time. Dispersion of the optical response dynamics of this coupled exciton-plasmon system is studied for the first time.

Semiconducting single-walled carbon nanotubes (CNTs) possess unique nonlinear optical properties as they exhibit high third-order susceptibility. Recently we introduced Carbon Nanotube Metamaterial – a hybrid structure of photonic metamaterial and semiconducting single-walled CNTs where nonlinear optical response of CNTs is significantly (order of magnitude) enhanced through a strong coupling between the weakly radiating Fano-type resonant plasmonic modes of metamaterial and excitonic responses of CNTs [1].

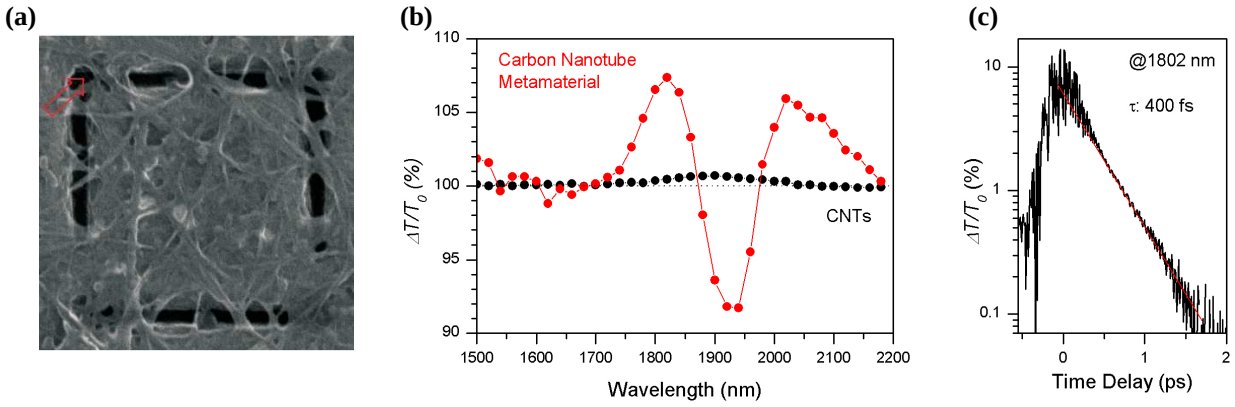

Fig. 1. (a) Helium ion microscope image of unit cell of the Carbon Nanotube Metamaterial, arrow pointing at a single nanotube crossing the slit. (b) Light-induced changes of transmission of the Carbon Nanotube Metamaterial, nonlinear response of CNTs on a silicon nitride membrane is shown for comparison. (c) Dynamics of the changes of transmission of Carbon Nanotube Metamaterial measured at λ = 1802 nm shows 400 fs dynamics.

Here we present a study of the response ***dynamics*** of optical nonlinearity in the Carbon Nanotube Metamaterial. Resonant exciton-plasmon coupling results in a complex spectral dispersion of nonlinear response of the Carbon Nanotube Metamaterial (fig. 1b) that was studied using a pump-probe technique with a 200 fs OPO system tunable through the entire spectral range covering excitonic resonances of Carbon Nanotube Metamaterial.

Typical optical response dynamics is shown on fig. 1c. We have found that response recovery time is sub-500 fs in the whole spectral range covering coupled exciton-plasmon resonance thus providing a very promising medium for various photonics applications including controlling light on the nanoscale.

[1] A. Nikolaenko, F. De Angelis, S. A. Boden, N. Papasimakis, P. Ashburn, E. Di Fabrizio, and N. I. Zheludev, "Carbon Nanotubes in a Photonic Metamaterial", *Phys. Rev. Lett.* **104**, 153902 (2010).