Femtosecond Microscopy for the Study of Meta-materials

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ABSTRACT

The understanding of the nonlinear optical properties and dynamics of meta-materials, constituted of arrays of nano-structures, requires studying their response on a broad spectral range, with a femtosecond temporal resolution and at the sub-micron spatial scale. For that purpose, we have developed a specific time resolved microscopy set-up consisting of two different microscopes operated in the visible or near IR. As it is well known, the optical response of an array of metallic nanostructures contains the information on both the individual objects, like their surface plasmon (SP) resonance, and on the diffraction pattern corresponding to the collective response of the array of dipoles. Typically, for nanostructures with an overall size of the order of 100 nm, spaced by a few hundreds of nanometers, the spectral resonances associated to the individual objects, lie in the visible spectrum and depend on their particular shapes. In addition, the collective response is situated in the near infra-red and the corresponding electric and magnetic modes have a strong polarization dependence upon the incident light. Our set-up consists in a pump-probe configuration with femtosecond optical pulses of ~100 fs. The pump pulses are either at the fundamental frequency (800 nm) or doubled (400 nm) in a BBO crystal. The time delayed probe pulses come from a super-continuum generated in a sapphire crystal and compensated in a prism line. The imaging is performed with an appropriate set of objectives and lenses, specially designed to avoid spatial chirping effects. The synchronous detection is performed either with photodiodes, by first selecting a narrow spectral range, or by a full spectral analysis on a spectrograph and CCD camera. We will present the performances of the apparatus and some preliminary results obtained on a 100x100 μm^2 array of u-shaped nanostructures (80 nm wide, 30 nm thick) spaced by 230 nm.

Keywords: Ultrafast spectroscopy, metamaterials, surface plasmon, femtosecond confocal microscopy.