Generation of Plasmon-Vortex around a single elliptical nanohole in a gold film.

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Light carries both spin and momentum. Spin−orbit interactions (SOIs) of light come into play at the subwavelength scale of nano-optics and nanophotonics, where they allow to control the spatial degrees of freedom of light selecting the spin states of incident photons [1]. However, due to the small momentum carried by photons, the SOIs of light are extremely small hence their experimental observation is challenging. In order to explore such weak processes, plasmonic metamaterials are largely used, thanks to the flexibility of their structural design and to the enhanced subwavelength local field [2]. In this context, we study the SOI effects of an evanescent field scattered by an isolated elliptical nanohole in Au thin film by using a near-field scanning optical microscope (SNOM) working in transmission mode. The sample consists of a multilayer of metal films (titanium 1 nm, gold 88 nm and chromium 1 nm). Each layer was evaporated sequentially onto a glass cover slip using an Electron Beam Evaporator. An array of elliptical holes, with diameters of 130 nm and 80 nm on the long and short axis lengths respectively, were drilled by FIB. This simple procedure allows to construct a sample able to enhance the exotic optical phenomena, exploiting the rotational symmetry breaking due to the elongated shape of the nanohole. A plasmonic vortex mode is generated by illuminating the hole with an incident light beam without a spin state (linear polarization) in the near-field region. This observation relies on the unique ability of SNOM to provide information on both amplitude and phase of the electromagnetic near-field distribution [3]. The rotation direction of the vortex (right- or left-hand rotation) depends on the angle between the polarization direction of the incident field and the symmetry axes of the ellipse, which induce a spin-dependent splitting in the scattered field and controls its spatial distribution in near-field [4].

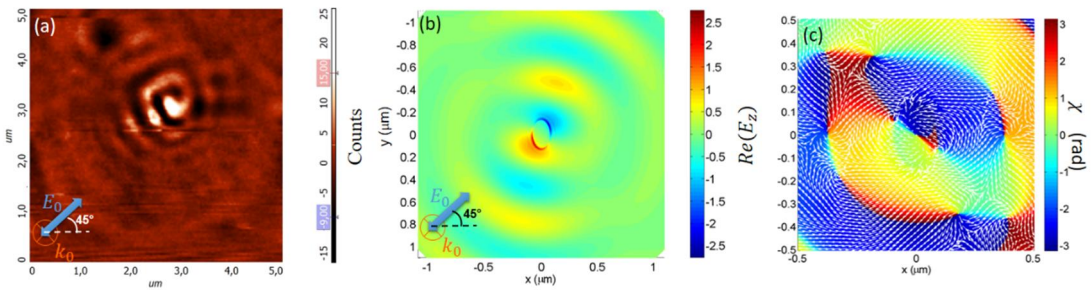

Figure: (a) SNOM image (scan area 5μm×5μm) performed using an incident beam at $\lambda_{exc} = 632$ nm with normal incidence and linear polarization at 45° on an elliptical nanohole in a thin gold film. In order to mainly detect the scattered contribution, a second linear polarizer, crossed to the first one, is placed in the collect optical path. (b) Near-field intensity distribution of $Re(E_z)$ around the elliptical nanohole illuminated by a plane wave at $\lambda_{exc} = 632$ nm, at 2 nm from the metal surface. Simulations are performed by FEM simulation. Size of nanohole: major axis a=130 nm, minor axis b=80 nm. (c) Spatial distribution (1μm × 1μm) of the phase variation of the z-component of the total field calculated by FEM simulations at 2 nm from the Au surface for an incident polarization direction at 45°. White arrows are the optical momentum vectors that evidence the formation of optical vortices around the phase singularities.

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