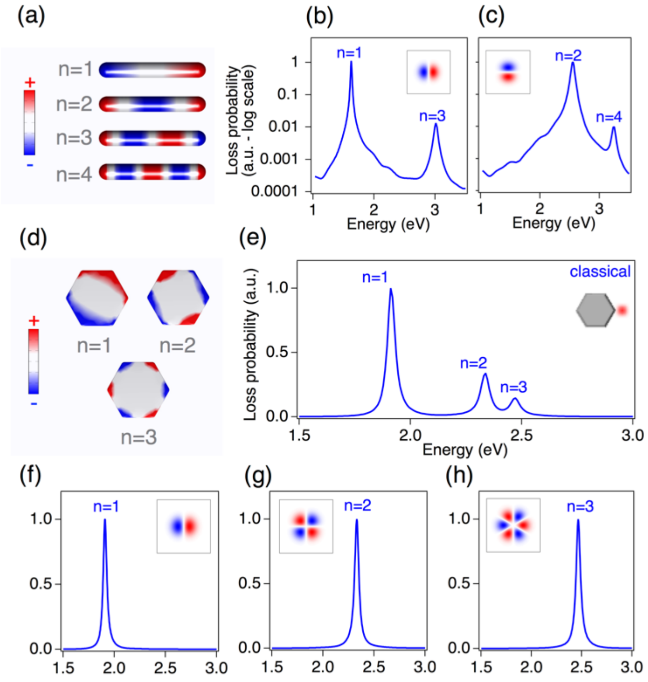
Theoretical and numerical study of the interaction between phase-shaped electrons and plasmonic modes

Lourenço Martins, H.[1], Guzzinati, G.[2], Verbeeck, J.[2] and Kociak, M.[1]

[1] Laboratoire de Physique des Solides, France, [2] EMAT, Belgium

Electron energy loss spectroscopy (EELS) in the low-loss region has attracted a large interest due to its efficiency in resolving plasmonic resonance at the nanometer scale [1]. However, standard low-loss EELS remained intrinsically unable to detect plasmonic optical activity. Nevertheless, phase shaped electron probes constitute a perfect candidate to overcome this limitation and measure the dichroic behavior of plasmons in an electron microscope - as recently pointed out through simulations by Asenjo-Garcia and García de Abajo [2]. Moreover, it has been recently demonstrated that such probes can be created in an electron microscope by tailoring the phase of the beam [3]. In the present work [4], we developed a semiclassical formalism describing the interaction between an electron probe with an arbitrary phase profile and a plasmonic mode. We showed that the equation ruling this interaction takes the elegant form of a transition matrix between two electron states mediated by the eigenpotentials of the plasmon modes. Important experimental inputs, such as convergence and collection angles, were considered. In this contribution, we will present the theoretical formalism and a wide variety of numerical studies of interactions between different nano-structures (e.g. helix, rod) and phase shaped electron probes (e.g. vortex beams, HG-like beams...), with a special emphasis on the experimental feasibility of the proposed geometries (see FIG. 1.)



[1] Nelayah et al, Nature Physics 3, 348-353, 2007.

[2] Asenjo-Garcia, García de Abajo, Phys. Rev. Lett. 113, 066102, 2014.

[3] Verbeeck et al, Nature 467, 301-304, 2010.

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Figure 1. (a) Four first plasmon eigenmodes of a 100 nm x 10 nm silver rod. We calculated the loss probability for an HG-wavefunction impinging at the center of the rod (b) parallel and (c) perpendicular to it . (d) Three first plasmon eigenmodes of a 100 nm x 5 nm silver hexagone. (e) Classical EELS spectrum In the semi-classical

limit, the loss probability has been calculated for an electron impinging at the center of the hexagone with a: (f) 2-lobbed, (g) 4-lobbed and (h) 6-lobbed wavefunction. Each of these wavefunctions has a spatial extension comparable to the hexagone's size.