Type of presentation: Oral

IT-5-O-1642 Surface-plasmon-polariton coupling between adjacent submicron slits in a Au-film investigated by STEM-EELS

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Surface plasmon polaritons (SPP) and associated cavity modes (CM) were recently analyzed by STEM-EELS in submicron slits in thin metal films.[1, 2] Moreover, a strong enhancement of the CM was observed upon introduction of neighboring slits.[3] Such nanostructures exhibit extraordinary optical transmission, which is further enhanced due to SPP coupling between slits.[4]
In this work, EEL spectra were acquired in a monochromated FEI Titan^3 80-300. Background subtraction was performed by a fit to the ZLP tail. Slits with a size of 180 x 900 nm^2 were milled in a 200 nm Au-film by FIB milling. Numerical simulations were performed with the Discontinuous Galerkin Time Domain method adapted for EELS.[5]
Fig. 1a shows spectra acquired at 10 nm distance to the walls of a double slit (cf. dots in the HAADF STEM image). In addition to the Au surface plasmon (SP) at ~2.4 eV, signals at 0.5 and ~1.5 eV are resolved which correspond to the fundamental ω_1 and 3rd harmonic ω_3 of a CM hybridized with SPPs supported by the metal wall. A significant enhancement of ω_1 and ω_3 is found close to the inner wall. Also, ω_3 is red-shifted and the SP is reduced in intensity. Fig. 1b shows corresponding simulated spectra which agree well with the experiments.
The coupling was studied in double slits with inter-slit distances (p) of 280, 450, 900, 1080, and 1980 nm. Fig. 2a shows spectra acquired at 10 nm distance from the inner walls. For increasing p values, ω_1 is red-shifted from 0.5 to 0.4 eV and reduced in intensity, nearly vanishing at p=1080 nm. At an even larger p value, ω_1 is observed again at ~0.5 eV. Fig. 2b shows corresponding simulations agreeing well with the experiments. For p > 880 nm, a second signal at higher energy is observed which red-shifts and increases in intensity up to p=1580 nm. These two signals correspond to symmetric and anti-symmetric coupling of the hybridized SPP CM between both slits. At p=1080 nm, two weak modes are observed in the simulation which corresponds to the almost vanishing loss intensity in the experimental spectrum. For further increasing p the symmetric mode increases in intensity which is also observed in the experimental spectra for p=1980 nm. The latter effect impressively demonstrates the effect of coherent interference between SPPs of adjacent slits across the metal bar.

[1] I. Carmeli et al., Phys. Rev. B **85** (2012).
[2] B. Ögüt et al., ACS Nano **5**, 6701 (2011).
[3] R. Walther et al., arXiv:1212.1987 (2013).
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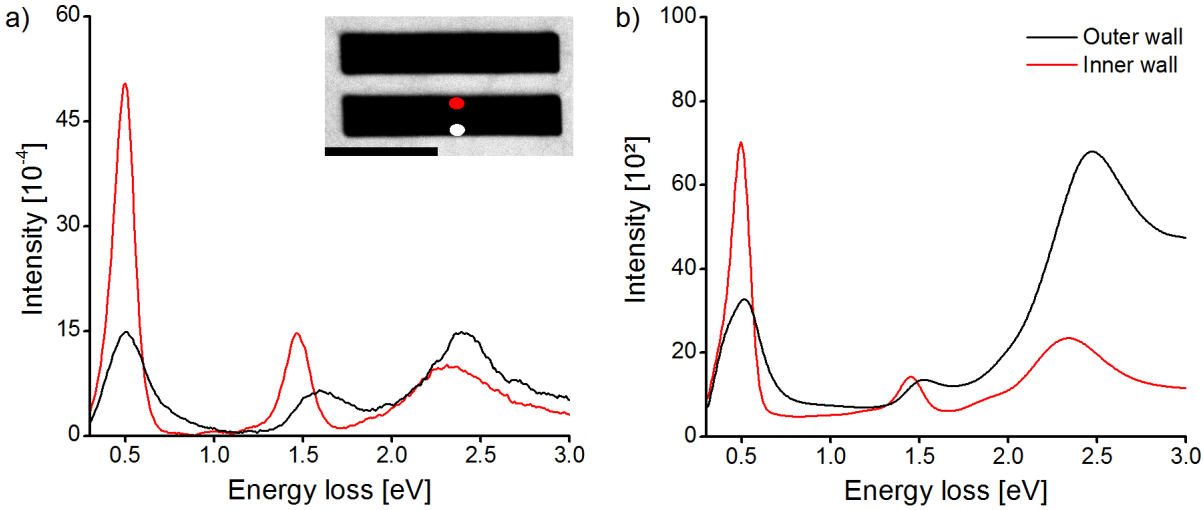

Fig. 1: a) Experimental and b) simulated EEL spectra at the outer (black line) and inner (red line) walls in a double slit system (cf. HAADF STEM image in inset). The scale bar corresponds to 500 nm.

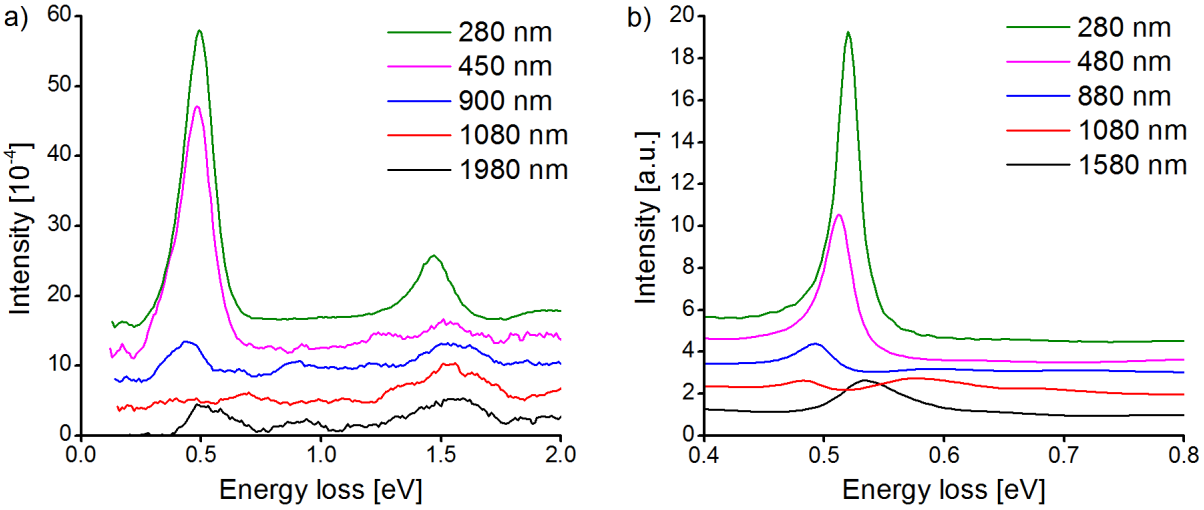

Fig. 2: a) EEL spectra from double-slit systems with varying p detailing the evolution of ω_1. The signal at 0.9 eV for p=1980 nm corresponds to the energy of ω_2. This signal was excited due to SPP coupling between the two slits despite having a node at the measurement position (see red dot in Fig. 1a).b) Simulated EEL spectra as a function for increasing p