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Plasmon Focusing on Single Crystalline Gold Platelets

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The manipulation of highly localized fields of surface plasmon polaritons (SPPs) forms the backbone for a vast field of applications. We investigate the SPPs excited on a single crystalline gold nanoplatelet milled with a plasmonic lens structure using a scattering type scanning near field optical microscope. SPPs are excited at different wavelengths in the visible regime employing a new tunable continuous wave source. Wave vector selection of the SPPs by the gold structures corresponded well with the numerically calculated dispersion relationship.

Background

Surface plasmon polaritons (SPPs) are electromagnetic excitations propagating along a metal-dielectric interface with an evanescent electric field perpendicular to the surface. Due to their local field enhancements, high sensitivity to surface inhomogeneities and the ease with which they can be manipulated, SPPs are excellent candidate's in many fields of application such as near-field imaging [1], surface enhanced Raman scattering [2], sensing, nanolithography, plasmonic based integrated circuits, memory devices [3] etc. One of the major requirements for such integrated optical devices and sensors is the possibility to focus the SPP fields to sub diffraction limit sized spots. A simple approach to achieve SPP focusing is the use of periodic circular slits (plasmonic lens) etched on metal films to guide the SPP waves to the geometrical centers of the structure [4,5]. A cw laser source is usually employed for exciting SPPs in such experiments.

Experiment

In our experiment we investigate the excitation and focusing of SPPs on a single crystalline gold (Au) nanoplatelet with a plasmonic lens structure milled on it. Figure 1 shows a scanning electron microscopy (SEM) and an atomic force measurement (AFM) image of a typical platelet. The excitation energies were chosen close to the SPP resonance according to the dispersion relationship as can be seen in Fig. 2. The dispersion relationship has been obtained by simulations for a 20 nm Au platelet on a SiO_2 substrate. The SPP fields were mapped by an apertureless scattering type scanning near field optical microscope (s-SNOM) [6]. The experimental setup can be seen in Fig. 3. A light source with appropriate polarization is focused onto the tip of the s-SNOM which raster scans the sample. The scattered light from the sample is directed back through the same pathway and is detected in the far field. Topographical and optical images are generated simultaneously. In order to map the SPP fields at several excitation energies close to the SPP resonance, a continuous wave source with

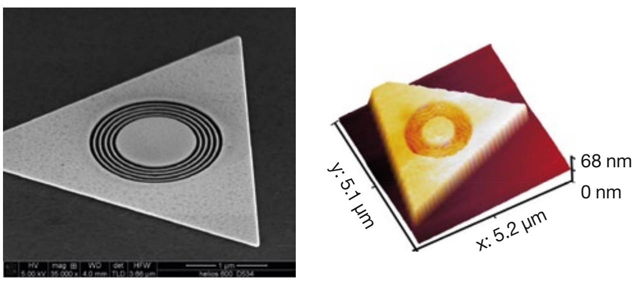


Figure 1: SEM and AFM images of a typical platelet which are triangular and hexagonal in shape.

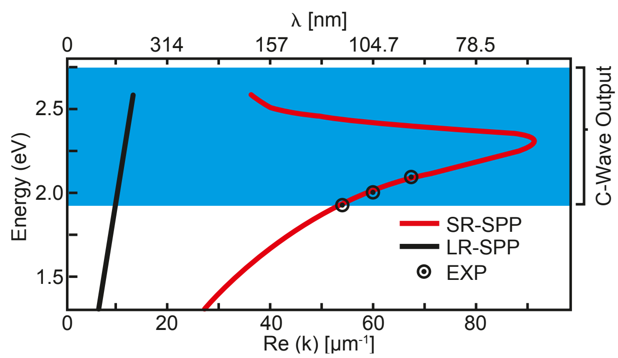


Figure 2: Plasmon dispersion relationship for a 20 nm Au platelet on a Si substrate coated with a 2.5 nm SiO_2 layer.

Figure 3: Experimental setup (s-SNOM): The incoming beam is split into two beams by the beam splitter (BS) partly sent to the reference mirror (M1) and partly focused to the tip via the parabolic mirror (M2). The tapping frequency of the tip modulates the nearfield signal. The backscattered field is collected and detected using a pseudo heterodyne detection scheme.

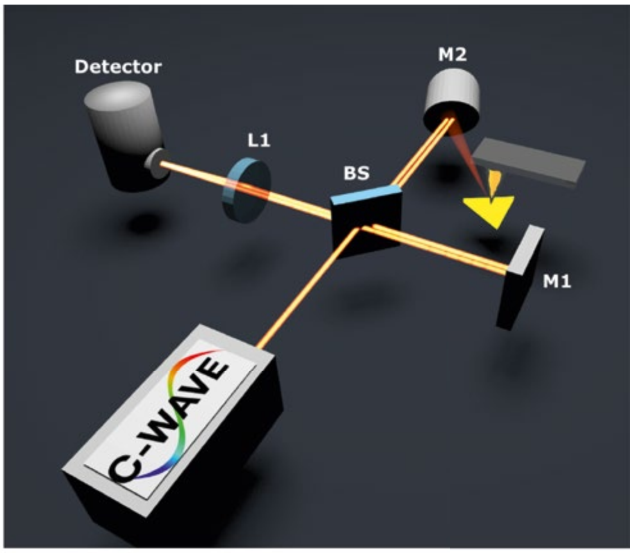
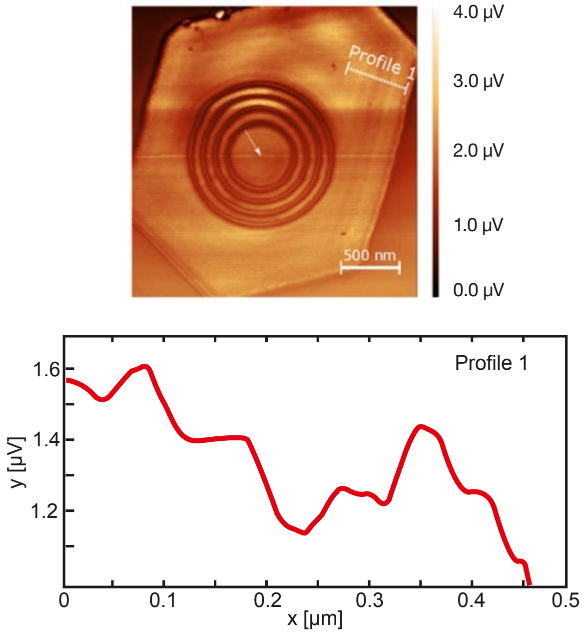


Figure 4: The fourth harmonic near field signal at 630 nm excitation and the corresponding line profile of the SPP waves near the edges of the platelet.



a tuning range between 450-650 nm is necessary. The C-WAVE by Hübner offers wavelength tunability in this range making it possible to conduct spectrally resolved measurements with a single light source. Wavelength switching is computer controlled: The wavelength is set in the GUI and C-WAVE tunes to the set wavelength automatically. The high output power, good beam quality and the narrow linewidths allows capturing of sharp images. No changes to the optical beam path were necessary after switching wavelengths owing to its high pointing stability.

Results

With the help of C-WAVE we were able to excite and probe the SPP fields at several excitation energies ranging from 530 to 650 nm. The fourth harmonic optical signal of the SPP field at 630 nm as well as the line profile of the SPP waves can be seen in Fig. 4. As the tip is operated in tapping mode the near field in the vicinity of the tip is modulated according to the tapping frequency. This enables to reach a higher signal to noise ratio in higher harmonics by filtering the unmodulated signal following a pseudo-heterodyne detection scheme [7]. SPPs excited at the edges of the platelet as well as the effect of the plasmonic lens structure on the direction of SPP propagation can be seen clearly in the figure. The wavelength of the SPP waves obtained from the experimental data matched well with the numerical predictions.

Outlook

Probing and manipulating SPP fields at resonance is an important aspect in many experiments designated to the improvement and development of many nanophotonic devices. Due to the strong dependency on the nature, dimensionality and geometry of the excitation medium, sources at different wavelengths are required in such experiments.

The C-WAVE offers a tuning in the visible (450-650 nm) and in IR (900-1300 nm) range, which are the most important regimes in most plasmonic experiments. The compact design, high spectral quality of the beam, wide tuning range and the ease and speed with which wavelength switching is achieved makes the C-WAVE a very convenient and easy to integrate tool for such experiments.

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