UNIVERSITÄT DUISBURG ESSEN

SFB 616

Time-Resolved Photoemission Microscopy of Plasmon Wave Propagation

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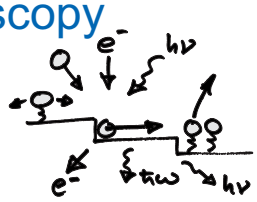

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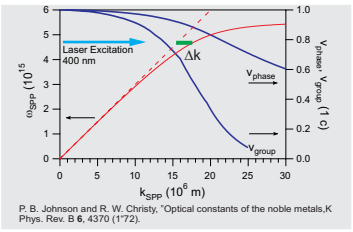
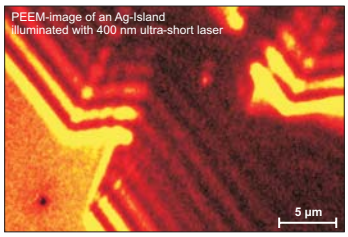
Motivation

- Surface Plasmon Polaritons (SPPs): propagating plasmon waves at surfaces
- In time resolved photoemission microscopy (PEEM) SPPs are imaged as a sequence of maxima and minima, some of which are shifted across the surface as function of the delay time.
- Gain understanding of the contrast mechanism and evaluate which properties of the SPP are accessible to PEEM.

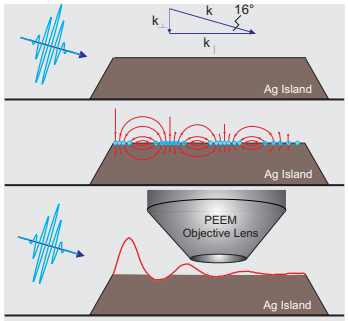


P. B. Johnson and R. W. Christy, "Optical constants of the noble metals,K Phys. Rev. B **6**, 4370 (1°72).

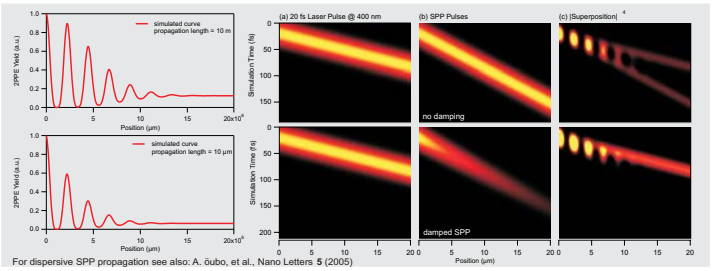


Imaging of Plasmon Waves in PEEM

- Illumination of surface with 400 nm ultra-short laser pulses.
- SPP is excited at the edge of the island.
- The superposition of lightwave and SPP results in a beating pattern.
- The PEEM detector integrates the superposition of light and SPP in time.
- Accordingly, the observed pattern in the PEEM corresponds to the slowly modulating componennt of the beating.
- The decrease of the beating amplitude has two origins:
  a) Damping of the SPP wave
  b) The loss of temporal overlap between lightwave and SPP

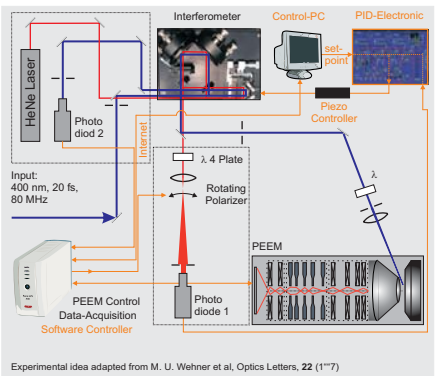


L. I. Chelaru, F.-J. Meyer zu Heringdorf, Surf. Sci. **601** (2007)
L. I. Chelaru, M. Horn-von Hoegen, D. Thien, F.-J. Meyer zu Heringdorf, Phys. Rev. B **73** (2006)

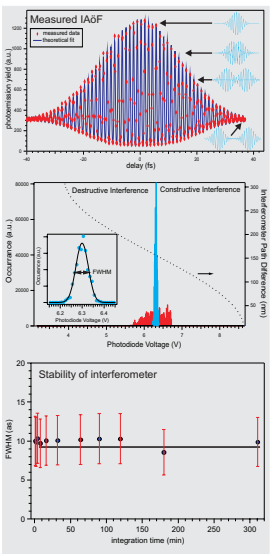


For dispersive SPP propagation see also: A. öubo, et al., Nano Letters **5** (2005)

Mach-Zehnder-Interferometer



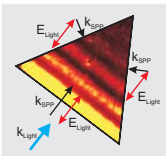
Experimental idea adapted from M. U. Wehner et al, Optics Letters, **22** (1°°7)



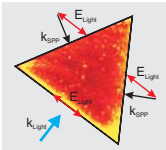
- Input: frequency doubled 20 fs laser pulses from a commercial Ti:Saphire oscillator with 80 Mhz repetition rate.
- Output: two pulses in a collinear arrangement with a known delay time in the attosecond regime.
- Stabilization: A cw HeNe-Laser beam is passed through the same optics as the blue laser pulses. Any change in the optical path within the interferometer changes the signal on the photo diode PD1.
- An analog, computer controlled feedback loop moves the piezo mirror, to maintain a constant signal on PD1.
- The setup has been proven stable within 15as over 300 minutes integration time.

SPP Excitation and Propagation

- SPP excitation only possible whenever a component of the electric field of the laser pulse is perpendicular to the islands' edge.



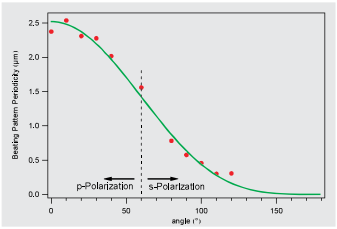
p-Polarization
In p-polarization, the SPP is started at the front edge of the particle, and the lightwave and SPP almost propagate in parallel.
Large Beating Wavelength

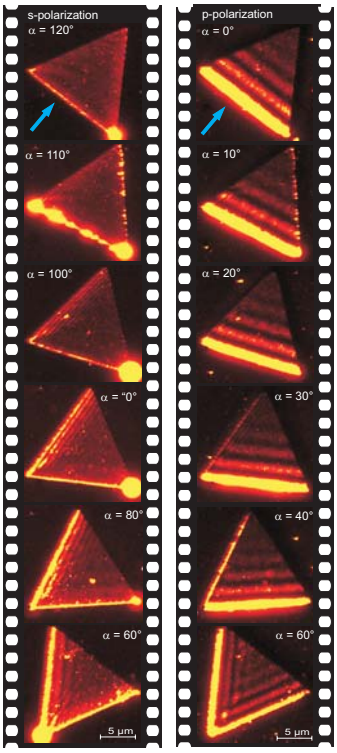


s-Polarization
In s-polarization, the SPPs are started at the back edge of the particle, and the propagation direction is not parallel to the laser pulse.
Small Beating Wavelength

- The observed wave length of the beat pattern depends on the angle between the k-vectors of lightwave and SPP wave.

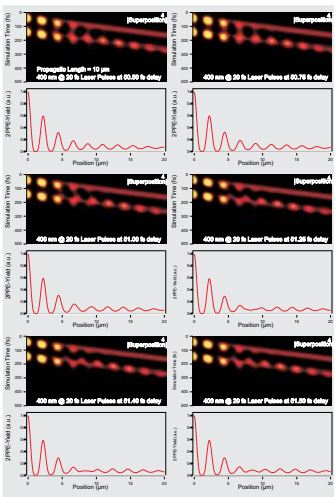
Frank-J.Meyer zu Heringdorf, N.M. Buckanie, L.I. Chelaru, N. Raß, EMC-Proceedings (2008)

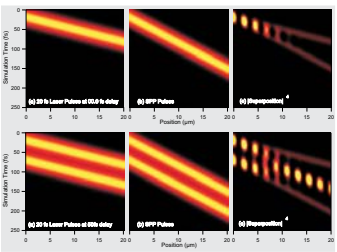




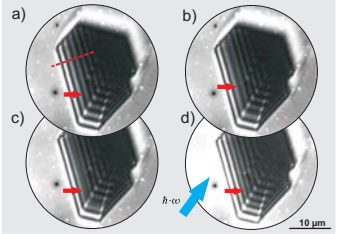
Time-Resolved Plasmon Propagation

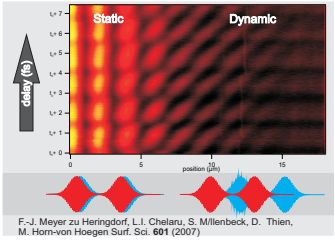
- In time-resolved PEEM, two regions of the beating patterns can be observed.
- Static Regime: At the beginning of the island we observe the superposition of each light pulse (pump and probe) with the surface plasmon wave that it generated.
- Dynamic Regime: After a few micrometers, the probe pulse interacts with the plasmon wave that was created by the pump pulse.





- The experimental data confirms the theoretically expected regimes
- In the static regime beating maxima do not move according to the delay.
- In the dynamic regime beating maxima move as a function of the delay time.





F-J. Meyer zu Heringdorf, L.I. Chelaru, S. Mllenbeck, D. Thien, M. Horn-von Hoegen Surf. Sci. **601** (2007)

Conclusion:

- PEEM is excellently suited to study Surface Plasmon Polaritons in Ag nanostructures.
- Time resolved and nonlinear photoemission techniques provide access to SPP damping, SPP propagation, and the dielectric function at the interface.