Femtosecond imaging of surface plasmon polaritons by PEEM.

Atsushi Kubo[1,2] and Hrvoje Petek[1]

1. Department of Physics and Astronomy, University of Pittsburgh, Pittsburgh, Pennsylvania 15260 USA
2. PRESTO, Japan Science and Technology Agency, 4-1-8 Honcho Kawaguchi, Saitama, Japan

By combining a photoemission electron microscope (PEEM) with an interferometric time-resolved pump-probe light excitation, we explore dynamics of surface plasmon polaritons (SPPs) at <10 fs temporal and 60 nm spatial resolution. SPPs are propagating electromagnetic waves at metal-dielectric interfaces. Recently, optical properties of SPPs such as propagation, focusing, reflection, and interference in optical elements of sub-micron to microns scales have been studied intensively, because of their potential applications for integrated optical circuits on sub-wavelength scales. In such 'plasmonic' devices, digital information will be transferred by a sequence of SPP wave packets which are launched by ultrashort light pulses. Understanding of dispersive and dissipative properties of SPP wave packets in plasmonic elements is indispensable to utilize them for information processing. However, while static profiles of SPPs have been studied, the dynamical property, which requires <10 fs temporal resolution, has not been revealed.

We use 10 fs, 400 nm femtosecond laser as the excitation source. Phase correlated pump-probe pulse pairs are generated with the delay time (τ_d) defined to ± 0.025 fs, using a Mach-Zehnder interferometer. Taking PEEM pictures, while advancing τ_d with an increment step of 1/4 optical cycle of the 400 nm carrier wave (= 0.33 fs), we obtain movies of SPP propagation.[1] Pump-probe pulse pairs launch SPPs in silver films at film discontinuities formed by focused ion beam lithography. SPP wave packets propagating at the silver-vacuum interface make a spatially inhomogeneous modulation of a polarization field as a consequence of interference with the light-induced polarization. PEEM reveals the spatial map of the polarization field (P) via imaging photoemission current ($\propto P^4$) which is caused by two-photon process. The pattern and the intensity of PEEM images changes as τ_d increases on account of the SPP motion: SPP propagation from a line source is imaged as an advancing oscillatory pattern for which wave front proceeds at the SPP group velocity. We will demonstrate some movies of SPP evolution in patterned silver films.

[1] A. Kubo, K. Onda, H. Petek, Z. Sun, Y. S. Jung, H. K. Kim, Nano Lett. **5**, 1123 (2005)