Imaging Light-Matter Interactions using Low Kinetic Energy Photoelectrons

A. R. Kim,[1] A. M. Boehm,[1] M. Berg,[1] T. Ohta,[1] C. F. Doiron,[1] F. J. Vega,[2] J. Yu,[1] J. P. Klesko,[1] S. D. Gennaro,[1] F. Liu,[3] S. Smith,[1] R. G. Copeland,[1] C. K. Chan,[4] A. D. Mohite,[5] A. Cerjan,[1] T. E. Beechem,[2] M. B. Sinclair,[1] I. Brener,[1] R. Sarma[1]

[1] Sandia National Laboratories, Albuquerque, NM 87185
[2] Purdue University, West Lafayette, IN 479073
[3] Los Alamos National Laboratory, Los Alamos, New Mexico 87545
[4] University of Colorado Boulder, Boulder, CO 80301
[5] Rice University, Houston, TX 77005

In the photoemission process, the electromagnetic fields propagating within the material excite electrons above the vacuum level, with higher field intensity resulting in a greater number of photoemitted electrons. Photoelectron emission microscope (PEEM) directs the emitted photoelectrons onto an electron detector via electron optics that preserve their spatial origin. By extension, the spatial distribution of the electromagnetic field in engineered nanostructures, such as metasurfaces and photonic crystals, can be decoded from the photoelectron images.

In this talk, we will present results from three optical systems investigated using PEEM across a wide optical spectrum range. Using ultraviolet excitation, we examined Fabry-Perot resonances in thin film cavities of HfO_2 and SiO_2. The ultraviolet light is confined in oxides due to their refractive indices higher than that of the Si substrate in this wavelength range. We show that the cavity resonances enable us to visualize the nanometer-scale inclusions embedded in the oxides [1]. In the visible range, we examined dielectric metasurfaces of TiO_2 rods (i.e., meta-atoms) arranged in a square lattice. By comparing photoelectron images to finite-difference time-domain simulations, we determined the inelastic mean free path (IMFP) of the very low-energy (<1 eV) electrons to be ~35 nm. Because this IMFP is comparable to the height of the meta-atoms, the result highlights the sensitivity of photoelectron imaging to optical resonances supported within the meta-atom volume [2]. Extending to the near-infrared wavelength, we showed the polarization-dependent variation of the spectra of broken symmetry resonator metasurfaces. This work took advantage of potassium deposition on the surface to reduce work function, which enabled two-photon photoemission using near-infrared light [3]. In all three systems, we show exemplars where the real-space near-field variations are intertwined with their spectroscopic signatures. These results demonstrate the applicability of photoelectron imaging with sub-optical wavelength resolution to examine light-matter interactions in volume-type photonic resonances supported by dielectric nanophotonic structures.

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[+] Author for correspondence: tohta@sandia.gov