Nanoscale Imaging of Plasmonic Structures with A Transmission Photoemission Electron Microscope

D.S.Pickard, Z.K. AI, V. Viswanathan, M.Mahmoudi, H.F. Hao, A.S. Yusuf
Plasmonics and Advanced imaging Technology Laboratory
National University of Singapore, Singapore 117576
pickard@nus.edu.sg

Control and manipulation of electromagnetic fields through excitation of surface plasmons is a promising method to concentrate and enhance the local fields over subwavelength dimensions. There are a diverse range of applications which could benefit from these intense, highly-localized fields; our interest lies in exploiting the fields to locally enhanced photoemission. Our aims are two-fold: 1) the development of high brightness electron sources with nanoscale emission areas and 2) the use of the plasmon assisted photoemission to provide a contrast mechanism for a high-resolution, nonperturbative imaging technique when coupled with a photoelectron emission microscope (PEEM).

Photoemission electron microscopes have already demonstrated both high spatial (< 20 nm) and temporal resolution (sub-fsec) in the imaging of plasmonic structures[1,2,3]. However, existing instrumentation has been limited to illumination conditions where the excitation light impinges on the front emission surface (reflection mode). This limitation prevents the study of two important classes of structures which are of interest to the nanophotonics community: sub-wavelength optical apertures and plasmonic excitations launched with attenuated total reflection (ATR, or Kretschmann coupling). Our efforts have focused on modifying an existing electron optical column (designed and presented by others, EIPBN 2001 and 2004) which features a transmission mode for illuminating the photocathode[4,5], Figure 1.

In this work, we present the results of imaging hotspots and the near-field distribution on sub-wavelength apertures. The apertures on aluminum films are patterned using a helium ion microscope, illuminated with a 257 nm laser source. Propagating surface plasmons and other optical phenomenon such as plasmon beaming and interference between the propagating modes arising from the array of complex aperture structures are observed, Figure 2. Control over the plasmon beaming through engineering of plasmonic structures and incident beam polarization have been demonstrated. These preliminary investigations promise exploration of complex resonant structures, interactions and phenomenon previously inaccessible to other techniques.

---

[1] M. Cinchetti *et al.*, Phys. Rev. Lett. **95** (2005) 047601
[2] A. Kubo *et al.*, Nano Lett. **5**, 6 (2005)
[3] M. Aeschlimann *et al.*, Nature **446**, 301-304 (2007)
[4] M. Mankos *et al.,* J. Vac. Sci. Technol. B **19**, 467 (2001)
[5] S.T. Coyle *et al.,* J. Vac. Sci. Technol. B **22**, 502 (2004)

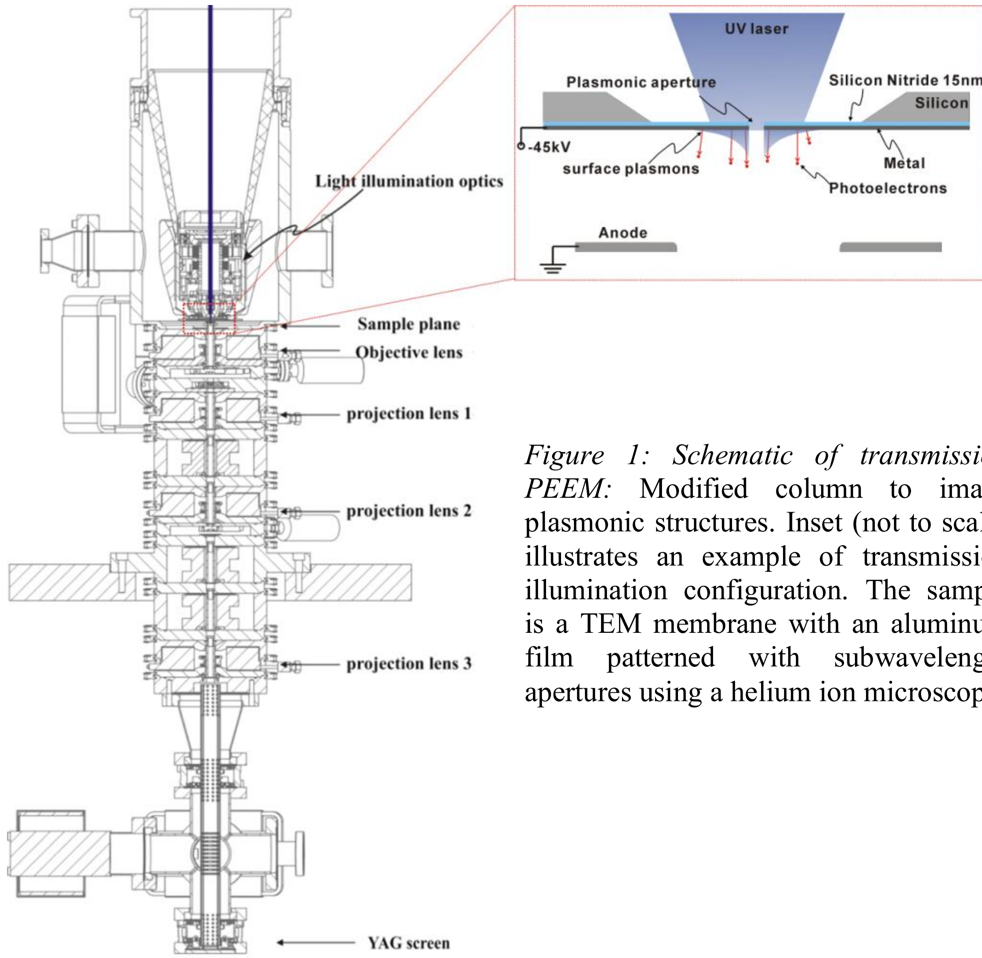

Figure 1: Schematic of transmission PEEM: Modified column to image plasmonic structures. Inset (not to scale) illustrates an example of transmission illumination configuration. The sample is a TEM membrane with an aluminum film patterned with subwavelength apertures using a helium ion microscope.

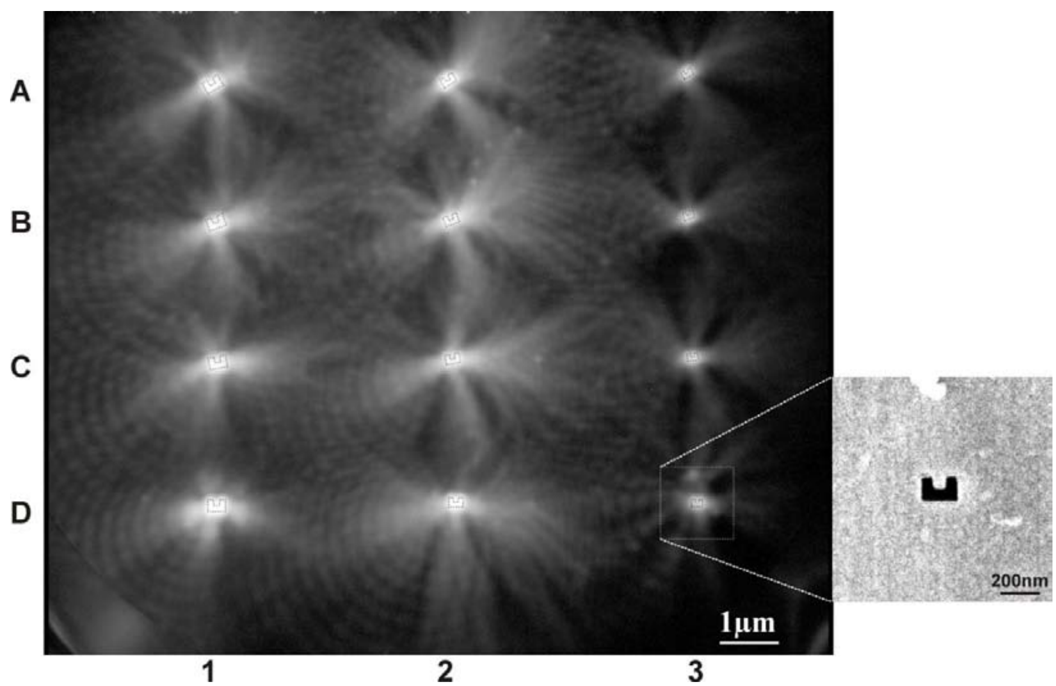

Figure 2: Plasmonic hotspots and complex near field interference between the propagating modes in an array of C-apertures: The columns 1, 2 and 3 consist of C apertures with the same critical dimension 100nm, 80nm and 60nm respectively but rotated over different angles. The structure was illuminated with UV laser source at 257 nm (4.8eV). The apertures were patterned on an aluminum film using a helium ion microscope (HIM). The inset shows a HIM image of the C aperture as patterned.