Solid Immersion Optics for Surface Plasmon Excitation in a Transmission Mode Photoemission Electron Microscope

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Excitation and manipulation of surface plasmons has enabled the spatial control of electromagnetic fields beyond the diffraction limit. Several imaging techniques have emerged to characterize the near-field distribution of surface plasmons excited in various structures[1-2]. Photoemission microscopy has already been demonstrated as a non-perturbative parallel technique to observe surface plasmons with high spatial and temporal resolutions[3,4]. However, the reports so far employ instrumentation with illumination conditions where the excitation light impinges on the front emission surface (reflection mode). This configuration 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).

Last year, we presented our efforts on modifying an existing electron optical column[5,6] which features a transmission mode for illuminating the photocathode. The near-field distribution around sub-wavelength slits and apertures exciting surface plasmons under normal illumination with a pulsed UV laser source have been observed. In this current work, a complete redesign of the light optics to accommodate both normal and oblique illumination of the photocathode will be presented. The design features a solid immersion lens with an off-axis parabolic mirror in contact with the optical substrate to allow angles of incidence close to the critical angle and beyond. Details of the design implementation, current limitations and our initial studies with the modified configuration will be presented. Near-field distribution around holes and defects on aluminium films under different illumination conditions with complex interference patterns have been observed, Figure 1c,d. Further work on lithographically patterned structures and devices to engineer and manipulate the plasmon hotspots and propagation will also be presented. Our efforts also aim to demonstrate excitation of surface plasmons using Kretschmann coupling which would allow exploration of complex optical interactions and phenomena.

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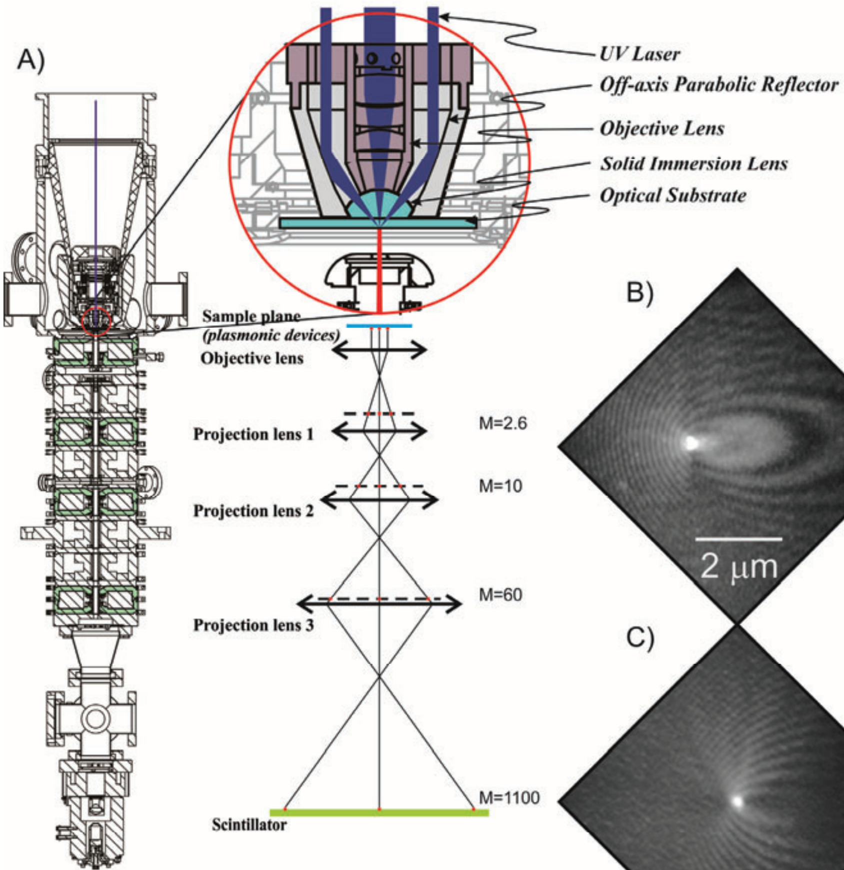

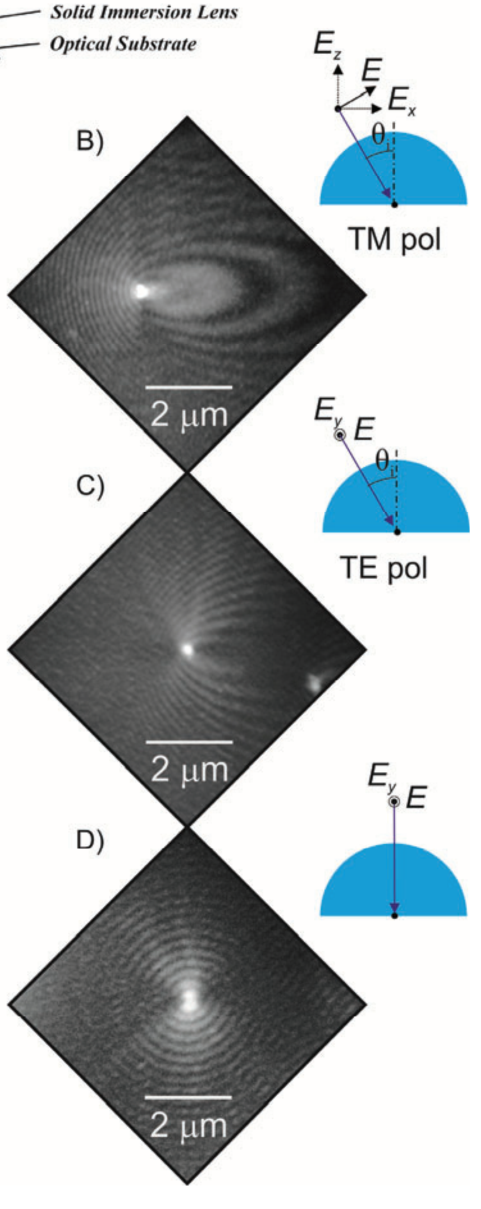

Figure 1. Transmission PEEM for Surface Plasmon Imaging:
A) Schematic cross-section of the PEEM column modified for imaging surface plasmons. The inset shows the schematics of the illumination scheme to enable oblique incidence using the off-axis parabolic reflector and normal incidence through the UV objective. The angle of incidence can be controlled from 30-50 degrees by translating the laser beam across the mirror surface. The excited surface plasmons decay to photoelectrons which are then accelerated down the electron optical column and imaged at the scintillator.

Near-field distribution of plasmonic fields and complex fringe patterns due to interference with the transmitted incident light source (257 nm UV laser) are observed in the micrographs. Surface plasmons are excited around a defect hole on an aluminium thin film under different illumination conditions – B) TM polarized and C) TE polarized at oblique incidence (θ_i =~30°) and D) normal incidence. The plasmon propagation is dependent on the polarization of the incident field as well as on the angle of incidence.