Immersion Optics for Excitation of Surface Plasmons in a Transmission Mode Photoemission Electron Microscope

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Control and manipulation of electromagnetic fields through excitation of surface plasmons is a promising method to concentrate and enhance the local fields over sub-wavelength 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 enhance 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, non-perturbative 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]. 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)[3,4] which features a transmission mode for illuminating the photocathode. Our work consists of two elements; the re-working of the electron optical column from a demagnification to magnification configuration (presented separately by Ai, Z.K., this conference), and a complete redesign of the light optics to accommodate both bright field and attenuated total reflection illumination of the photocathode (the subject of this paper).

Several approaches were explored to meet the ATR requirement, each with its own merits. However, our final design integrated a solid immersion lens with an off-axis parabolic reflector, which offered the best compromise in terms of beam placement accuracy, alignment of the light optical axis to the electron optical axis, range of angle of incidence, minimization of beam shift with beam incident angle (θ_i), and cathode substrate geometry, Figure 1. For a practical realization of this design a number of experimental challenges needed to be overcome. For example, the entire assembly requires precision motion to align to selected devices, but it is biased at the cathode potential (-50 kV), must be non-magnetic, operates over a broad range of illumination wavelengths, and most of the components are within UHV. We present the details of our design, anticipated performance based on optical simulations, Figure 2, as well as design compromises. This novel illumination system is currently being assembled, and we will report preliminary experimental results.

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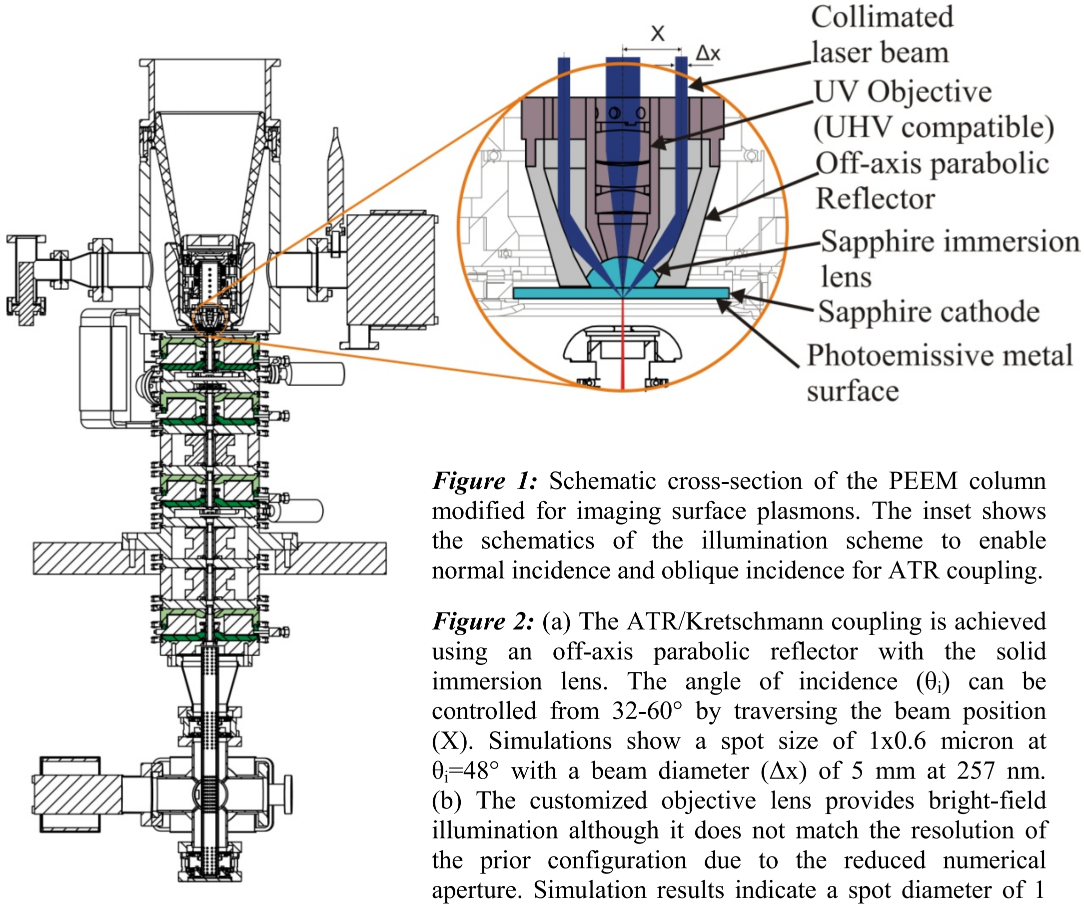

Figure 1: Schematic cross-section of the PEEM column modified for imaging surface plasmons. The inset shows the schematics of the illumination scheme to enable normal incidence and oblique incidence for ATR coupling.

Figure 2: (a) The ATR/Kretschmann coupling is achieved using an off-axis parabolic reflector with the solid immersion lens. The angle of incidence (θ_i) can be controlled from 32-60° by traversing the beam position (X). Simulations show a spot size of 1x0.6 micron at θ_i=48° with a beam diameter (Δx) of 5 mm at 257 nm. (b) The customized objective lens provides bright-field illumination although it does not match the resolution of the prior configuration due to the reduced numerical aperture. Simulation results indicate a spot diameter of 1 micron for a 5 mm beam at 257 nm