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Patterns in Two Photon Photoemission Images of Light Diffracting Structures in Wave Guiding Transparent Thin Films

Sukhdeo Singh[1], Pradeep Kumar Choudhary[2], Shartendu Kumar Singh[3]

Author's Affiliations:
[1]Department of Physics, N.N. College, Singhara, Vaishali, Bihar 844126, India.
[2]Department of Physics, R.D.S. College, Muzaffarpur, Bihar 842002, India.
[3]Department of Physics, R.S.S. College, Chochaha, Muzaffarpur, Bihar 842001, India.

Corresponding author:
Sukhdeo Singh
Department of Physics, N.N. College, Singhara, Vaishali, Bihar 844126, India

E-mail:
madanjeebrabu@gmail.com

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Abstract

We have studied the patterns in two photon photoemission images of light diffracting structures in wave guiding transparent thin films. We first determined the wave numbers of guided modes that can be expected in dielectric thin films, then used Fraunhofer diffraction to determine the relative amplitude of modes excited at the periphery of the film where the in-coupling occurred. The evolution of waves in the film was then calculated using Fresnel-Kirchhoff integration, where the diffracting structure served as the aperature and a two dimensional, attenuated Green's function describes the guided mode fields at the vacuum interface. We used the results from this analysis to compute the photoelectron emission rate, which derived from the complex sum of surface fields and incident light. We studied two photonic structures in an aberration corrected photoemission electron microscopy using two photon excitation and compared the electron micrographs to field based calculations, where we found good agreement.

Keywords: Photo emission, wave guiding, thin films, guided modes, dielectric, diffraction, Fresnel-Kirchoff integration.

1. Introduction

Optoelectronics field has attracted considerable research interest following new materials developments and experimentation techniques with the emergence of nanoscale plasmonic and photonic devices there is a large interest for quantitative characterization. Scanning probe techniques particularly scanning optical microscopic, have largely been used to address these modes. Recently photoemission electron microscopy has been developed towards a level where images with high spatial and temporal resolution can be obtained [1-9] with the availability of ultra short high intensity laser pulses, even the infrared and visible spectral region can be routinely used in photoemission electron microscopy when multi photon excitations are utilized. This makes photoemission electron microscopy a potentially powerful tool for the study of all types of electromagnetic field excitations in materials with its excellent spatial resolution now approaching 5nm [10], photoemission electron microscopy may advance optical surface studies to scales well beyond standard optical microscopes and beyond currently available super resolution techniques. We have presented analysis of light propagation in non metallic transparent media observed in two photon photo emission at a wave length of 410nm. In photoemission electron microscopy the pattern is imaged with electron [11]. Since electrons are used to create the image in photo emission electron microscopy, the fundamental resolution limit is set by the electron as in other electron microscopies and is unaffected by the diffraction limit of the light used to illuminate the sample [12].

2. Method

Two photonic structures are assembly of holes and a single dielectric disc as shown in fig (1) were prepared by milling indium-tin-oxide thin film and glass substrate with an FEI strata 237 focused ion beam system. The indium-tin-oxide was chosen because its electrical conductivity was sufficient to prevent local changing after electron emission. The bottom portion of the first sample contained a gold nanowire that supported localized surface Plasmon resonances. An aberration corrected photoemission electron microscopy was used to image photoelectrons excited by 410nm laser pulses generated by spectra physics Mai Tai Ti, sapphire laser. The light pulses were up converted to 410nm with pulse energies of 2-nJ a 100-fs duration using a Del Mar photonics second harmonic generator. The laser was incident at 60^{o} with respect to the surface normal and had a spot size of about 100μm in diameter. We found that the two photon photoemission yield obtained with TM polarized light.

3. Results and Discussion

Guided wave refracted into the disc structure is shown in fig (1) converged at multiple foci, with the dominant focus attributed to the forward direction and a weaker, secondary focus from the reverse direction was found just below the primary focus. Bright line patterns diverged from the structure in fig (2) as a result of constructive interference between two or more holes. The presence of multiple wave guide modes leaded to the factitious appearance of beating in fig (1) and the line patterns in fig (2).

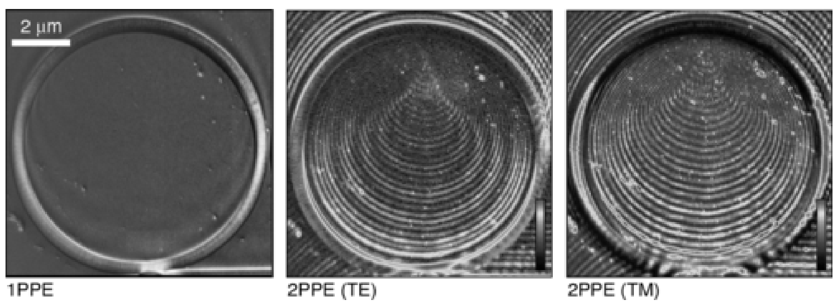

Figure 1: PEEM micrographs of a waveguide bounded by a circular groove. Light is incident from the bottom edge of the images. The 1PPE image shows the milled groove down to the glass substrate as a lighter shade. The 2PPE images show modulation in the surface electromagnetic field due to interference between incident and guided light.

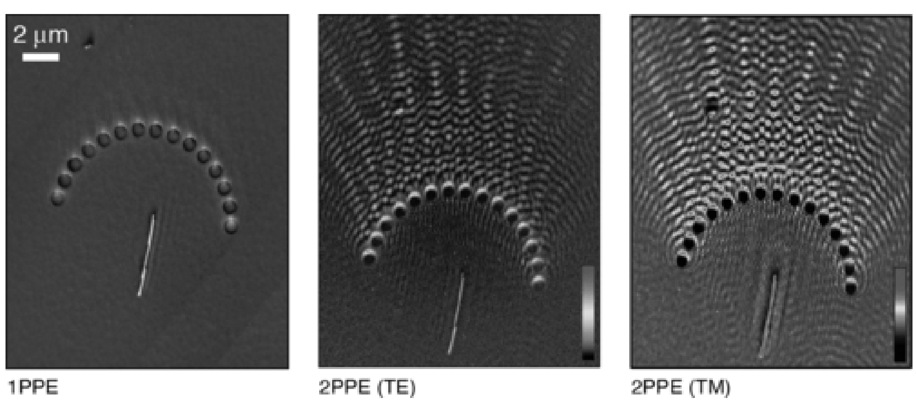

Figure 2: PEEM micrographs of a semicircle of holes. Light is incident from the bottom edge of the images.

4. Conclusion

We concluded that electromagnetic fields observed in photoemission electron microscopy are not significantly influenced by the photoelectrons. This is the advances compared to scanning probe technique where the presence of the probe technique where the presence of the probe often affects the signal. It was also found that n-photonic photoemission electron microscopy be developed as powerful visualization tool for the characterization of photonic and plasmonic structures where sub wavelength sensitivity, nanometer precision and details of near field behavior are essential.

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