Focusing of Plasmonic Micro Zone Plate-based metallic structures covered by a dielectric layer

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Recent researches have shown the possibility of focusing surface plasmon polaritons (SPPs) on a planar metal film by guiding SPPs to the focal point of circular, elliptical and micro zone plate apertures. In case of a Fresnel zone plate, the maximum possible resolution depends on the smallest zone width which is the width of the outmost zone plate. Therefore, a micro zone plate (MZP) whose focal length is reduced to around $\lambda \sim 5\lambda$, mid-field region, is proposed to enhance the maximum possible resolution due to the reduction of the width of the outmost zone plate.[1] We present the method to decrease the spot size measured by full width at half maximum (FWHM) without aggravating transmission efficiency or signal contrast.

When the incident light impinges on the ring-slit entrance of the metal, it will couple into SPPs at the edge of the ring-slit entrance, and SPPs propagate along the slit with propagation constant associated with the slit width. When SPPs pass the metal slit, those decompose into two components at the exiting side. The first wave propagates toward free space through decoupling of the SPPs. The second wave propagates along the metallic-dielectric-air (MDA) interface.[2]

In this paper, we employ the finite-difference time-domain (FDTD) method to show the focusing properties of a plasmonic micro zone plate (PMZP) of MDA structure. A PMZP has much smaller zone area than that of a MZP. The design of a MDA structured PMZP consists of a silver film ($\varepsilon_{Ag} = -4.01 + j0.70$ at $\lambda = 405$ nm) covered by a Poly (methyl methacrylate) (PMMA) layer. The designed values are obtained from the classical equation of Fresnel zone plate using f = 1 μm and $\lambda_{in} = 405$ nm (Fig. 1). We investigate how changing the slit width, metal and dielectric film thickness of a positive micro zone plate affects the focusing properties, i.e., FWHM, transmission efficiency, and signal contrast. When a MDA structured PMZP has a half of zone area, the simulation predicts FWHM = 178 nm (effective numerical aperture = 1.39NA) and transmission efficiency ($T_{eff} = I_{max}/I_0$) = 22.7 in the Ag = 100 nm covered by PMMA = 50 nm (Fig. 3). This result reveals a focused spot size beyond diffraction limit in comparison to the conventional micro zone plate.

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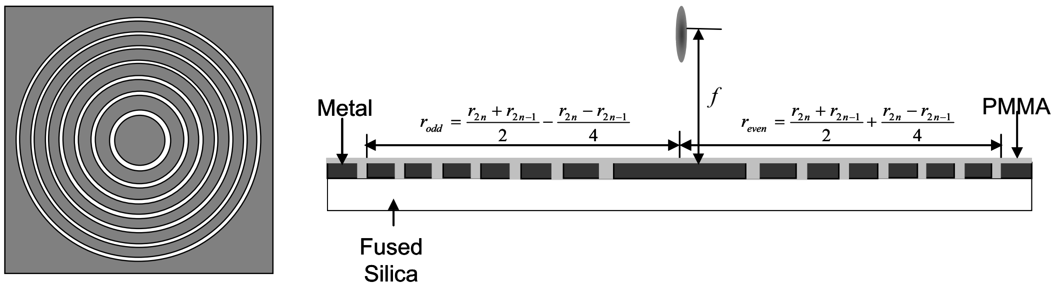
1 Y. Fu, W. Zhou, and L. E. N. Lim, Appl. Phys. Lett. **91**, 061124 (2007)

2 B. Wang and G. P. Wang, Appl. Phys. Lett. **88**, 013114 (2006)



(a) (b)

Fig. 1. (a) Top-down and (b) cross-section views of a MDA structured PMZP design (drawings are not to scale).

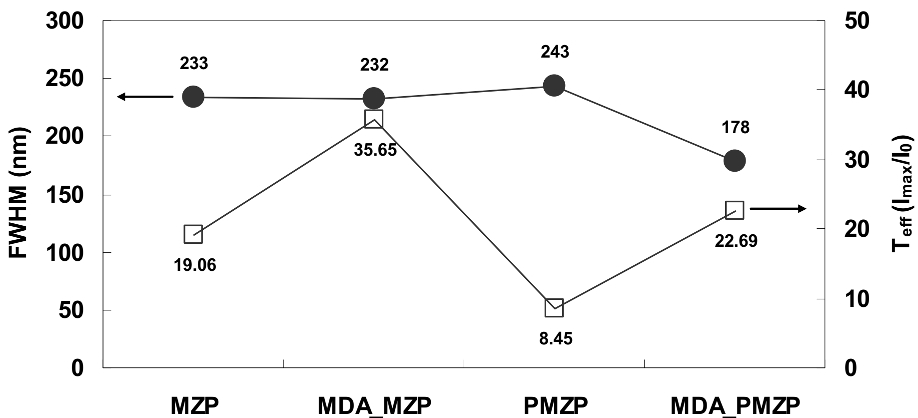
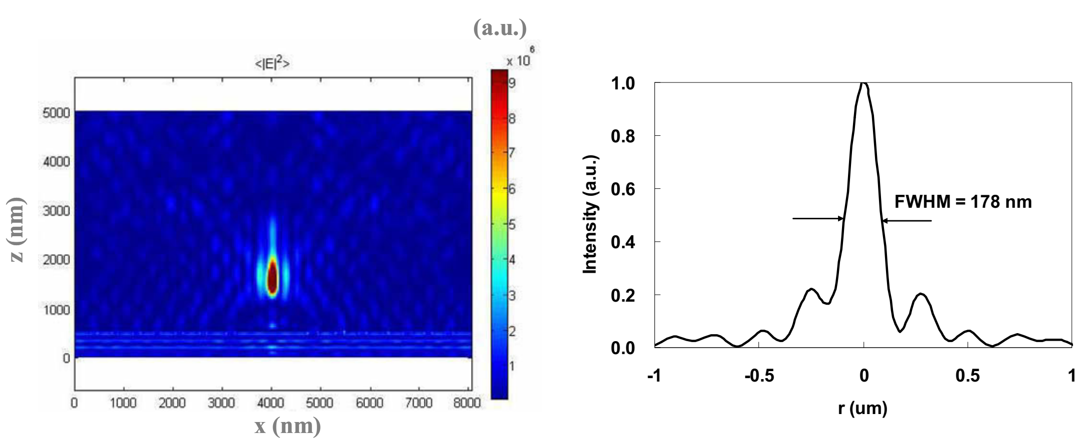


Fig. 2. Comparison of the FWHM and transmission efficiency ($T_{eff} = I_{max}/I_0$) at maximum intensity (I_{max}) for the different structures; micro zone plate (MZP), metallic-dielectric-air (MDA) structured MZP, plasmonic micro zone plate (PMZP), and MDA structured PMZP. t_{Ag} = 100 nm and t_{PMMA} = 50 nm are chosen.



(a) (b)

Fig. 3. (a) Optical field exiting a MDA structured PMZP and (b) the point spread function (PSF) at I_{max}.