Superfocusing of light using a metallic/dielectric nano-optic lens

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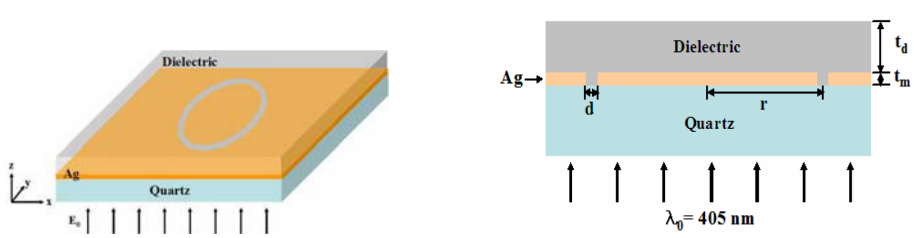
The study on super-resolution focusing or imaging beyond diffraction limit have attracted great attention for the application of nanolithography, bio imaging and optical data storage [1]. However, many studies on obtaining super resolution light spot have been achieved in near-field region and it is still big challenge to realize light spot with super resolution in far-field. In this study, using finite-difference and time-domain (FDTD) method, a Ag/dielectric superlens is proposed, which allows the enhanced evanescent waves or SPP wave to be propagated up to the distance of the mid-field, therefore, it makes possible the superfocusing of light at the extended focal length.

Our superlens consists of a quartz substrate coated with Ag thin film including subwavelength circular ring aperture. The deposition of dielectric material (dielectric constant=6.25, e.g. ZnS) is followed successively as shown Fig.1. The Ag film thickness, t_m and the dielectric layer thickness, t_d are fixed at 100 nm and 300 nm, respectively. The circular ring width, d is fixed at 150 nm and the radius, r is varied from 1 to 3 um. For three-dimensional simulation, a circularly polarized coherent plane wave, λ=405 nm is incident through the quartz substrate.

The numerical analysis indicated that the beam spot size (FWHM) of 156 nm is created for the focal length of 700nm as shown in Fig 2. Considering that the minimum of focused spot size depends on $0.61\lambda/NA$ corresponding to Rayleigh criterion, where NA is the numerical aperture, the effective NA of our superlens reaches up to 1.58. Moreover, the superfocusing beyond diffraction limit is found even at the extended focal length comparable to the distance of 8λ from exit plane. It is mainly because the dielectric layer in our lens acts as a waveguide to critically guide the energy of light to the center point [2]. Fig. 3 shows the effect of ring size on beam focusing. It is seen that the FWHM of the beam size with respect to the propagation length from the exit plane increases gradually as the propagation length increases and the beam size generally decreases as the radius of ring become large. Since the center intensity increases approximately linearly as the ring radius become large [3], it is apparent that the enhanced center intensity results in the superfocusing at the extended focal length.

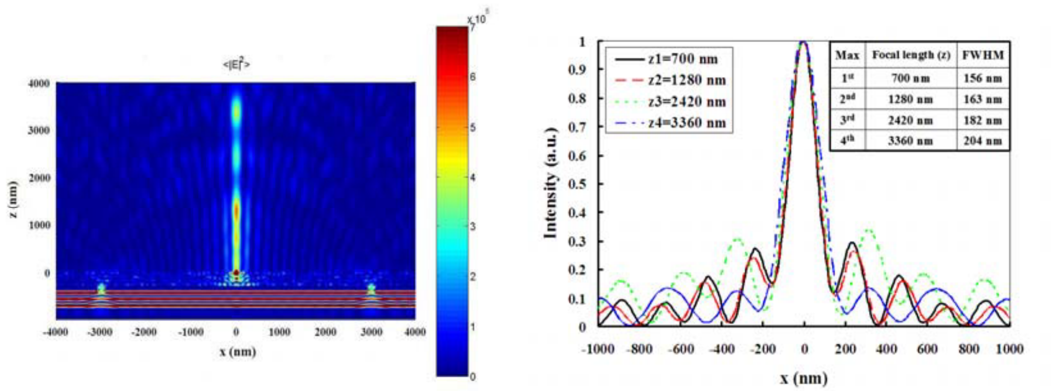
Therefore, our simple superlens has the promising potential for the real application to nanolithography and optical data storage.

[1] William L. Barnes, Alain Dereux , et al, Nature (London) **424**, 824 (2003)
[2] Kyu-Min Chae, Hyun-Ho Lee, Sang-Youp Yim et al, Opt. Exp. **12**, 2870 (2004)
[3] Zhaowei Liu, Jennifer M. Steele, et al, Nano Lett. **5**, 1726 (2005)



(a) (b)

Fig. 1. Schematics of the Ag/dielectric layered lens. It is illuminated by a plane wave with 405 nm wavelength. (a) Top view and (b) Side view.



(a) **(b)**

Fig.2 Simulation of Ag/dielectric layered lens. (a) The optical field exiting a lens at x-z plane, y=4um, (b) Comparison of the PSF (point spread function) at the different focal points.

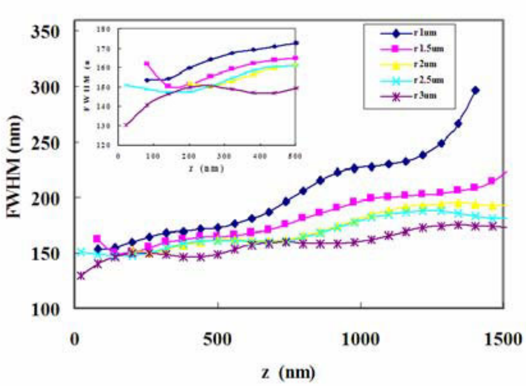


Fig. 3. Focusing characteristics with respect to the ring size at the Ag/dielectric layered lens. FWHM of the beam size in free space with respect to the distance from the exit plane are compared.