# Ultra-enhancement of Photonic Nanojet in Multilayer Microspheres

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(poster presentation)

We present the first ultra-enhancement of photonic nanojet in the multilayer microspheres. Using finite difference time domain simulation with high resolution, we have investigated the electric energy distribution in the vicinity outside a multilayer microsphere. The composite microsphere consists of a core and several concentric shells. The enhancement of photonic nanojet depends strongly on the thickness of metallic shells. It becomes attainable to stretch the nanojet greatly. The multilayer microspheres promise exciting avenues to nanoscale optical imaging and ultracompact electro-optical devices.

Conventional lenses suffer the diffraction limit, because they are only capable of transmitting the propagating components emanating from the light source [1]. The evanescent waves carry subwavelength information about the object decay exponentially and are lost before reaching the image plane. In recent years, the physical phenomenon of photonic nanojets has been revealed by several papers [2,3]. Under plane wave illumination, the photonic nanojets are obtained on the shadow side of a dielectric microsphere. The nanojets have a subwavelength waist and a high intensity beam. This is a potential application to visible light detection of nanoscale targets.

The nanoscale detections have been limited by the short length of the nanojet, which allows it to interact with only near surface features. We are interested in applying far field projection property of the nanojet to achieve high spatial resolution of nanostructures. In this goal, a multilayer microsphere with metallic shell is proposed by the author. Figure 1 shows a schematic diagram of a multilayer microsphere for nanojet. The baby blue regions are dielectric materials and the blue regions are metallic shell. The refractive indices of the core, metal shell, and surrounding medium are $n_d$, $n_m$, and $n_s$, respectively. The diameter of microsphere is $d$ and the thickness of metallic shell is $t$. The focal length from the center of the microsphere to the point of maximum intensity of nanojet is $f$. The refractive index of the gold shell is $0.467 + 2.145i$ at the incident wavelength of 532 nm. Lightwave propagates from left to right at wavelength 532 nm. Consequently, we have made three-dimensional finite difference time domain computational electrodynamics modeling to investigate how a nanojet might be enhanced.

Figure 2 shows the power flow patterns of multilayer microspheres at different metal thicknesses. Figure 3 and Fig. 4 show the normalized intensity distribution of nanojet for multilayer microspheres along propagation axis (x axis) and transversal axis (y axis). The focusing intensity of the nanojet can be enhanced greatly at $t$ = 25 nm. The location and length of the nanojet can be extended at $t$ = 50 nm. Figure 5 and Fig. 6 depict the focal length and the full-width half-maximum of nanojet as a function of the metal thickness. It can be seen that the focal length and the full-width half-maximum increase as metal thickness increases. As a result, the focal length and the full-width half-maximum can be controlled by metal thickness.

[1] L. Novotny and B. Hecht, *Principles of Nano-Optics*, New York: Cambridge University Press, 2006.

[2] A. V. Itagi and W. A. Challener, *J. Opt. Soc. Am. A*, vol. 22, pp. 2847-2858, 2005.

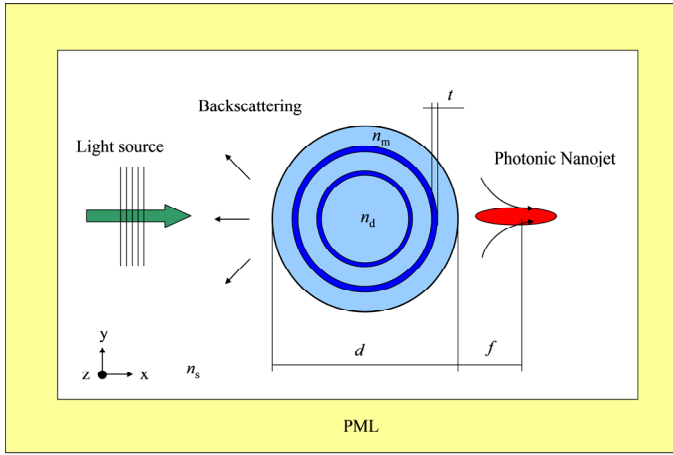[3] P. J. Ferrand et al., *Opt. Express*, vol. 16, pp. 6930-6940, 2008.

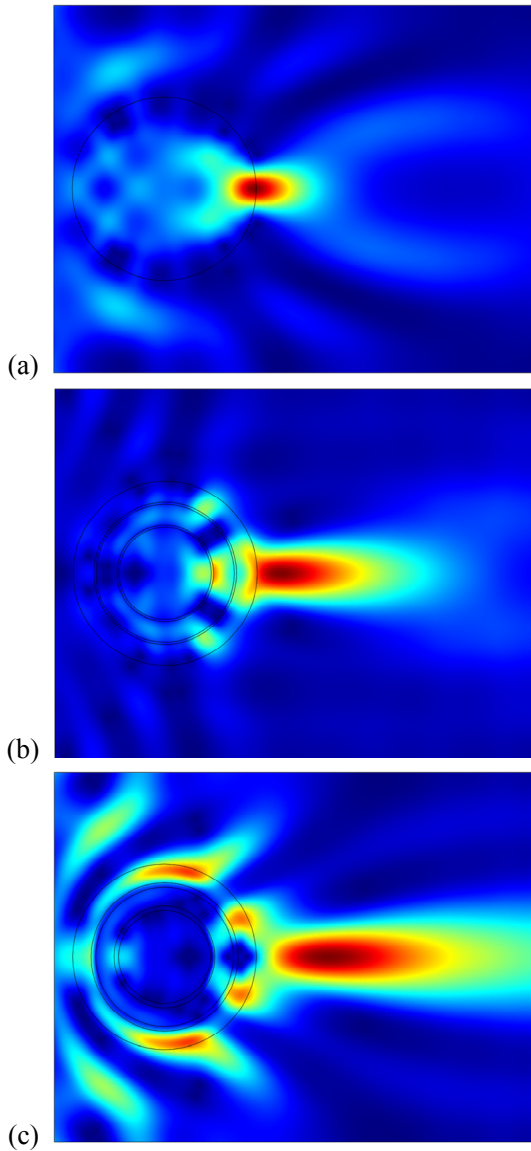Figure 1 Schematic diagram of a multilayer microsphere for nanojet.



Figure 2 Power flow patterns of multilayer microspheres at metal thickness (a) t = 0, (b) t = 25 nm, and (c) t = 50 nm.
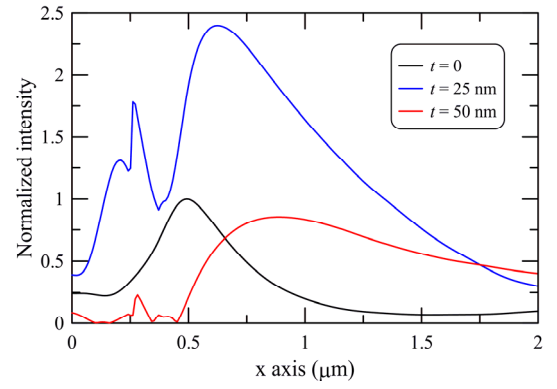


Figure 3 Normalized intensity distribution of nanojet for multilayer microspheres along propagation axis (x axis).
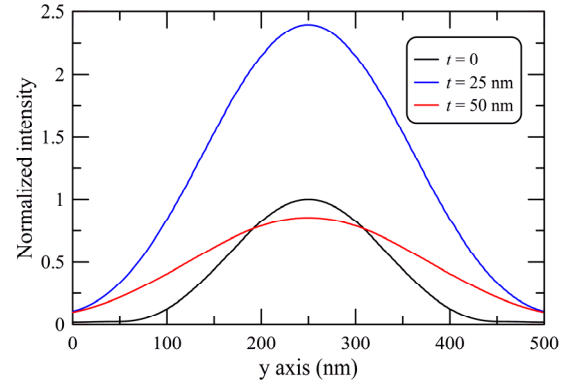


Figure 4 Normalized intensity distribution of nanojet for multilayer microspheres along transversal axis (y axis).
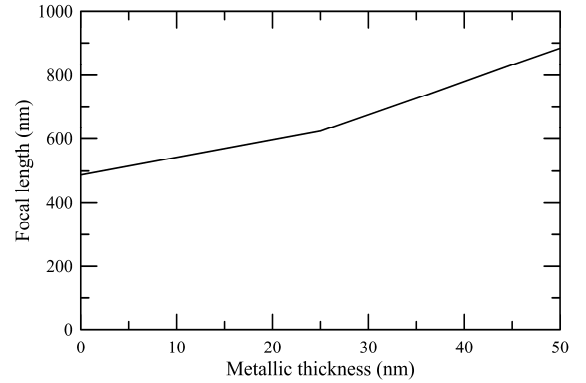


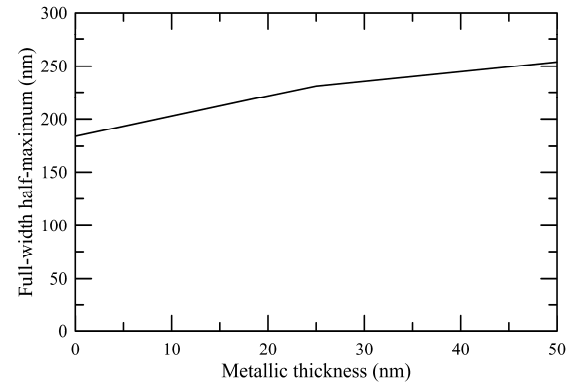Figure 5 Focal length as a function of the metal thickness.



Figure 6 Full-width half-maximum of nanojet as a function of the metal thickness.