Modeling of photonic nanojet emission from spherical nanoparticles using the 3D multiple multipole method

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Spherical micro and nano particles with different refractive indices under plane wave illumination have been studied by using the 3D multiple multipole (MMP) method. The intensity distribution that emerges in the vicinity of the particle’s rear boundary (with respect to its plane wave illumination) has resulted in a tightly focused photonic nanojet \cite{1, 2}. The resulting beam waist significantly undergoes the diffraction limit, where the nanojet emission extends over several optical wavelengths without suffering from significant diffraction providing a pencil-like area of high optical intensity. In our contribution, we report on the optimization of both the dielectric material and the particle shapes (oblate ellipsoids) in order to maximize the power confinement in the nanojet. Different 3D-MMP models are applied and discussed.

Fig.1: Nanojet emission from an oblate dielectric ellipsoidal particle \((n=2)\) illuminated by a plane wave from the left \((\lambda = 500 \text{ nm}; E\text{-polarization})\): a) The time-averaged Poynting field modeled with 3D ring multipoles. b) The Radiation pattern (intensity distribution in the “focal plane” against the lateral extent given in \(\mu m\)) showing a beam waist of \(W_{\text{FWHM}}=120 \text{ nm}\) for the particle’s major and minor axis of \(R_x=5 \text{ \mu m}\) and \(R_y=2.5 \text{ \mu m}\).

References


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**Results**

In the case of an oblate ellipsoid, an ellipse is rotated around its short axis. The optimized parameters of 2D model namely $R_x=5 \, \mu m$, $R_y=2.5 \, \mu m$ and $n/2$ are used to compute the waist size. The waist size is $W_{FWHM}=120 \, nm$. The mismatching error is 1.27% for the ring multipole ellipsoid and 53% for complex origin one.

**Conclusion**

3D MMP simulation has been done by using ring multipoles and complex origin and the difference between these two methods was compared. Comparison between oblate and prolate solution shows that they have nearly same waist for the same area, but the intensity for oblate by factor 1.5 is higher and the oblate one can be easily optimized for different major axis and refractive index. The waist is getting smaller by increasing major axis and refractive index. MMP method is difficult to set boundaries, sources and multipoles in correct positions, but as it is shown in the pervious section is quite fast and accurate.

**References**