1 Point Spread Function (PSF)

- Consider the set-up of Fig. 1. Replace the single dipole emitter by a pair of incoherently radiating dipole emitters separated by a distance $\Delta x = \lambda/2$ along the x-axis. The two dipoles radiate at $\lambda = 500$ nm and they have the same dipole strength. One of the dipoles is oriented transverse to the optical axis, whereas the other is parallel to the optical axis (z-axis). The two dipoles are scanned in the object plane and for each position of their center coordinate a signal is recorded in the image plane using a NA = 1.4 (n = 1.518), M = 100X objective lens.

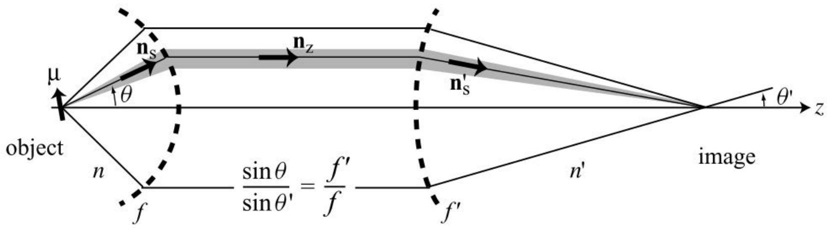

Figure 1: Configuration used for the calculation of the point-spread function. The source is an arbitrarily oriented electric dipole with moment μ. The dipole radiation is collected with a high NA aplanatic objective lens and focused by a second lens on the image plane at $z = 0$.

(a) Determine the total integrated field intensity (s_1) in the image plane.

(b) Calculate and plot the recorded image (s_2) if a confocal detector is used. Use the paraxial approximation.

(c) Discuss what happens in (a) and (b) if the dipoles are scanned at a constant height $\Delta x = \lambda/4$ above the image plane.

- A continuously fluorescing molecule is located at the focus of a high-NA objective lens. The fluorescence is imaged onto the image plane as described in section related to the PSF. Although the molecule's position is fixed (no translational diffusion) it is rotating in all three dimensions (rotational diffusion) with high speed. Calculate and plot the averaged field distribution in the image plane using the paraxial approximation.

- Calculate the longitudinal fields corresponding to the Gaussian field distribution given by the equation below.

$$E_x(x, y, 0) = E_0 e^{-\frac{(x^2+y^2)}{\omega_0^2}} \implies \hat{E}_x(k_x, k_y; 0) = E_0 \frac{\omega_0^2}{4\pi} e^{-(k_x^2+k_y^2)\frac{\omega_0^2}{4}}$$

Assume that $E_y = 0$ everywhere in space. Show how the longitudinal field evolves in transverse planes z = const. State the result in cylindrical coordinates as in the given equation.

$$E_x(x,y,z) = E_0 \frac{\omega_0^2}{2} \int_0^\infty e^{-k_\parallel^2 \frac{\omega_0^2}{4}} J_0(k_\parallel \rho) e^{ik_z z} \mathrm{d}k_\parallel$$

Plot the longitudinal field strength in the planes $z = 0$ and $z = \lambda$.

2 References

1. Principles of Nano-Optics (Second edition) by Lukas Novotny