Super resolution microscopy using photonic nanojet

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Light-matter interplay is widely used for analyzing the topology of surfaces on small scales for use in areas such as nanotechnology, nanoelectronics, photonics and advanced materials. However, typical microscopy-based methods are limited in resolution to a value comparable to the wavelength, the so called Abbe limit. We present a way to go beyond this limit by employing small spherical lenses also known as photonic nanojets [1]. Such lenses couple light between a microscope objective and a surface in the near field with an effective probing width down to wavelength/15 [2], allowing for improved spatial resolution. Here we present the mathematical analysis method used for simulation of the optical response from a sub-wavelength line grating structure [3] and experimental results.

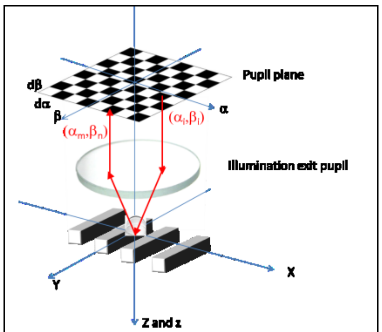

Figure 1 Illustration of the illumination geometry. The (m,n) diffraction order of the emerging wave from point (α_i,β_i) is observed at point (α_m,β_n) in the pupil plane

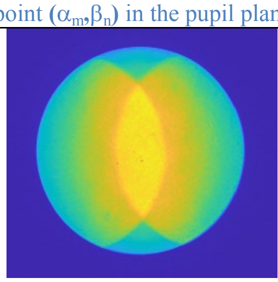

Figure 2 Diffraction pattern from 1D nanostructured grating

A rigorous simulator based on three-dimensional vector theory has been developed. The optical system consists of a standard microscope and a photonic nanojet lens. The system is represented by telecentrically conjugated pupil planes, see Figure 1. The focused light interaction with the photonic nanojet lens is handled analytically, and the rigorously coupled wave analysis method is used for numerical calculation of the response from the critical structure [3]. We demonstrate that for a plane wave incident on the structure with propagating vector $\mathbf{k} = 2n\pi(\alpha \quad \beta \quad \gamma)/\lambda$, the diffracted pattern can be expressed as a sum over all diffracted orders that fall into the area segment dαdβ.

$$\mathbf{E}^{diff}(\alpha,\beta)d\alpha d\beta = \sum_{m,n}\mathbf{E}^{m,n}\left(\alpha,\beta;\alpha_m,\beta_n\right)d\alpha d\beta$$

The field in image space coordinate system is obtained by performing a Rayleigh expansion of the diffract field transformed through the exit pupil for imaging. An experimental image of the diffracted pattern from a grating is shown in Figure 2.

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