Grating-assisted optical diffraction tomography with near-field resolution
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Developing sub-100 nm optical imaging systems stirs a lot of interest in biology and nanoscience domains. In addition to fluorescence and near-field microscopes, a novel imaging technique, known as optical diffraction tomography (ODT), is now addressing the issue of three-dimensional imaging with sub-wavelength resolution. Its main interest is that it does not require fluorescent samples nor a probe in the vicinity of the sample [1]. ODT consists in illuminating the sample from many different directions and collecting the diffracted field under many scattered angles. Contrary to optical microscopy, in which the object is formed by lenses, ODT relies entirely on a numerical inverse procedure for reconstructing the map of permittivity of the sample from the data of the scattered field. Indeed, under weak scattering approximation, one can show that the diffracted field is proportional to the spatial Fourier transform of the permittivity of the sample, $\varepsilon(k_{\text{diff}}-k_{\text{inc}})$ where $k_{\text{inc}}$ is the wavevector of the incident plane wave and $k$ is the wavevector of the detected diffracted field. Hence, the reconstruction procedure is relatively easy and the higher the spatial frequency of the incident wave, the better the resolution of the system.

To ameliorate the resolution of ODT while maintaining the far-field detection and illumination, it has been proposed recently to illuminate the sample with evanescent waves by depositing the objects on a prism [3]. This option has led to total internal reflection tomography (TIRT). The expected resolution in TIRT is limited by the refraction indices available to $0.6 \lambda/(n+1)$, namely $0.2 \lambda$ for $n=2$. To overcome this limit, we propose, in this work, to deposit the objects on a periodically nanostructured substrate, which generates waves with arbitrarily large wavevectors, and to adapt the ODT principles to this configuration [4]. To generate a high frequency field, we have considered a thin metallic film supporting plasmons and deposited on top of it a phase grating whose period has been chosen to excite the plasmon. Note that these high frequency plasmon are difficult to excite because of their high losses. We have simulated rigorously the field diffracted by the a-periodic sample deposited on the periodic substrate with a numerical technique based on the coupled dipole theory [5]. Then, we have developed a simple iterative inversion scheme, using the extended Born approximation to reconstruct the map of permittivity in a bounded domain above the grating from the diffracted field data. We show that the resolution of the images is improved in a spectacular way as compared to that obtained with classic TIRT. Details of length 40 nm are visible with an incident wavelength of 500 nm.

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