APPLICATIONS OF COMPLEX FIELD DECONVOLUTION USING DIGITAL HOLOGRAPHIC MICROSCOPY

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1. INTRODUCTION

The deconvolution of complex fields is a new post-processing method for quantitative phase microscopy [1]. Techniques like digital holographic microscopy (DHM) provide access to the complex wavefront. In particular, DHM holds the capability of imaging simultaneously amplitude and quantitative phase. We propose a method to improve the spatial resolution of such coherent microscopy systems by filtering of the coherent transfer function (CTF).
The 3D complex deconvolution is presented and potential applications shown.

2. RESULTS

A variety of transparent/semi-transparent samples are imaged in high-NA diffraction-limited optical systems using a transmission DHM setup.
In off-axis transmission configuration, a single sub-wavelength nano-metric hole on metallic films acts as a complex point source. The nano-metric apertures are drilled with focused ion beam (FIB) and inspected by scanning electron microscopy (SEM), as presented in [2]. The CTF itself can be acquired priorly by characterizing the imaging system with its complex point spread function, called ‘h’. It recasts into 3D frequency space by

$$c(\vec{k}) = \iiint_{-\infty}^{\infty} h(\vec{r}_2) exp[\mathrm{i}2\pi(\vec{k}\cdot\vec{r}_2)]\mathrm{d}x_2\mathrm{d}y_2\mathrm{d}z_2.$$

giving rise to the CTF, called ‘c’. The method of complex deconvolution can be expressed as the inversion of the coherent imaging equation [1]. Hence, the inverse filtering can be performed directly by dividing the two complex fields of the image spectrum ‘G’ and the CTF:

$$o(\vec{r}_1) = \iiint_{-\infty}^{\infty} O(\vec{k}) exp[-\mathrm{i}2\pi(\vec{k}\cdot\vec{r}_1)]\mathrm{d}k_x\mathrm{d}k_y\mathrm{d}k_z = \mathcal{F}^{-1}\left\{\frac{G(\vec{k})}{\tilde{c}(\vec{k})}\right\}.$$

Thus, it results in the object’s spectrum ‘O’, or the in real space, the object’s scatterers distribution ‘o’. The approach of complex deconvolution offers the advantage of directly correcting for phase aberrations within the CTF.
In order to suppress the noise amplification, the amplitude contribution in c may be filtered partially, resulting in $\tilde{c}$. This filter enables truncated complex deconvolution or pure phase deconvolution.
In summary, added frequencies lead to resolution improvements. In the same manner, its three-dimensional application gives rise to optical sectioning or de-blurred phase measurements.

3. REFERENCE

[1] Cotte et al., *Microscopy image resolution improvement by deconvolution of complex fields*, Opt. Express **18**, 19462-19478 (2010)
[2] Cotte et al., *Sub-Rayleigh resolution by phase imaging*, Opt. Lett. **35**, 2176-2178 (2010)