DISTORTION CORRECTION IN IMAGING INTERFEROMETRIC MICROSCOPY AT THE 2/λ LINEAR SYSTMS LIMIT

Alexander Neumann, Yuliya Kuznetsova and S. R. J. Brueck
Center for High Technology Materials, University of New Mexico, Albuquerque, New Mexico, USA
E-mail: aneumann@chtm.unm.edu

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We have previously demonstrated a resolution approaching the linear-systems limit (λ/4) with a modest *NA* = 0.4 objective, using Imaging Interferometric Microscopy (IIM), which allows the acquisition of high-resolution images using low *NA* objectives combined with multiple exposures, off-axis illumination, interferometric reconstruction and digital image processing. This concept was introduced initially in the context of the formation of images in imaging interferometric lithography (IIL) [1].

Here we describe a methodology for image reconstruction for the distorted images that result from non-paraxial effects when illumination source and the image plane are tilted to access the highest available spatial frequencies of the image. We approach the theoretical linear systems resolution limit of ~λ/4 (a maximum spatial frequency of λ/2) by increasing the coverage of the spatial frequency space using multiple exposures as show in Fig.1. The two inner circles correspond to the spatial frequencies of 0.4/λ (*NA*/λ) and 0.8/λ (2*NA*/λ), representing the frequency space coverage of conventional coherent and incoherent illumination microscopy, respectively. The inner set of shifted circles in Fig.1 extend to a radius of ~1.2/λ (3*NA*/λ) [2]. Increasing the angle of the illumination beam can extend can extend the coverage of frequency space only up to (1+*NA*)/λ. Additional frequency space coverage is provided using a second pair of off-axis exposures with a tilted image plane, shown as ellipsoids due to the frequency spectrum distortion. We evaluate the mapping between the observed spatial frequencies in tilted/off-set image and actual frequencies in the object (Fig 2), propose a method of frequency restoration, and apply this method to experimental results, demonstrating improved image quality.

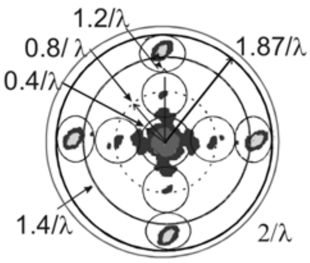

Fig. 1: Frequency space representation.

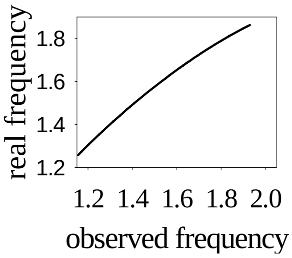

Fig. 2: Mapping between observed and real frequencies in object.

In the present experiments, the frequency space coverage extends to 1.87/λ, represented by the outer set of shifted structures in Fig. 1; or to a pitch of 340 nm using a 633-nm source. We show reconstructed images obtained after Fourier spectrum restoration for the case of a binary *x-y* sample geometry with a linewidth of 180 nm (λ/3.5) (Fig. 3). The limit of resolution with conventional illumination would be only ~ 0.6λ/*NA* (~950 nm). This technique will be useful for solving defocusing problems, mask inspection, biological research and other applications.

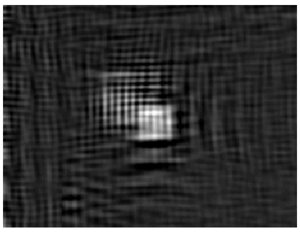

Figure 3: Reconstructed 180-nm image

References
[1] X. Chen and S. R. J. Brueck, Opt. Lett. **24**, 124 (1999).
[2] C. J. Schwarz, Y. Kuznetsova and S. R. J. Brueck, Opt. Lett. **28**, 1424 (2003).