Application of nondiffracting Bessel beams to optical lithography

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Abstract

Simultaneous enhancement of both depth of focus (DOF) and transverse resolution is an essential task in optical microlithography [1]. This report describes a new technique based on nondiffracting Bessel beams to increase both the DOF and transverse resolution power. It was shown by Durnin et al. [2] in 1987 that the Helmholtz equation for the free space propagation of light beams possess exact eigenmode solutions that describe beams that in principle can propagate indefinitely without any distortion due to diffraction. For beams of finite size it was demonstrated that the characteristics of nondiffraction could be achieved over finite distances. Since then several other papers have considered both the theoretical properties and experimental generation of such beams. We shall report on an experimental demonstration of a new Fabry-Perot interferometer based method to generate a nondiffracting Bessel beam. Due to the multiple reflections the interferometer can create several image points of a point like source. The projection lens superimposes these images and produces the final image. Our experiments have demonstrated that for appropriate phase conditions the depth of focus could be increased significantly and that the transverse resolution improved by a factor of 1.6 when this technique is used to image isolated patterns such as contact holes. Although these experiments were performed with visible laser illumination this method can be employed in 193nm lithography. Further experiments will be discussed that are concerned with demonstrating the applicability of this interferometric technique in a lithographic stepper using an appropriately coated pellicle placed between the photomask and projection lens.

1. M. Erdélyi, Zs. Bor, J. R. Cavallaro, G. Szabó, W. L. Wilson, C. Sengupta, M. C. Smayling and F. K. Tittel, Jpn. J. Appl. Phys. **34**, L1629 (1995).

2. J. Durnin, J. J. Miceli, Jr. and J. H. Eberly, Phys. Rev. Lett. **58**, 1499 (1987).

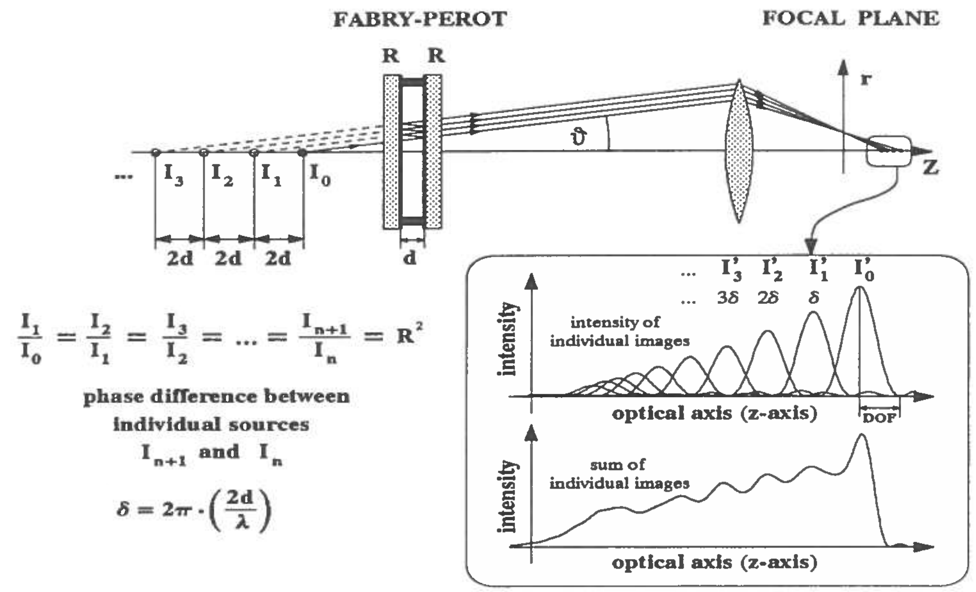

Figure 1: The image produced by the objective lens is the superposition of the images (I_0', I_1', I_2', ...) of the individual point sources.

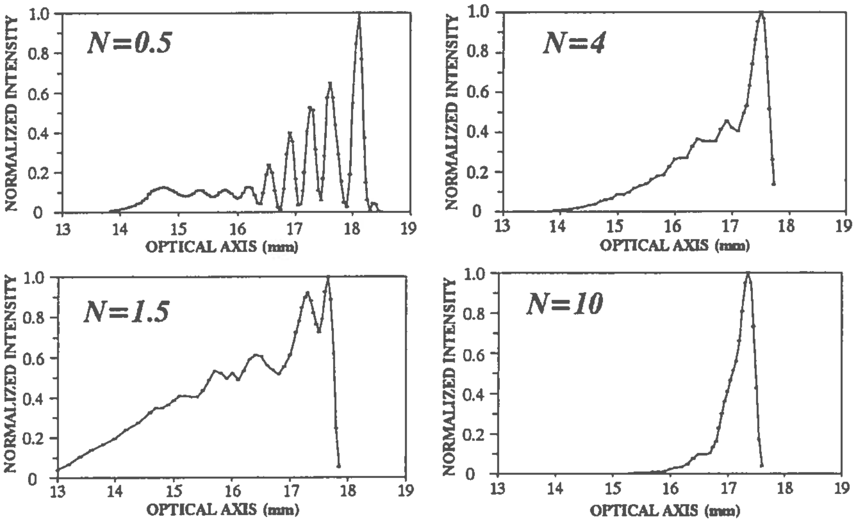

Figure 2: Intensity distribution on the optical axis for cases of different *N* values. The relative image density (N) shows the number of individual image points are in the range of one *DOF*.

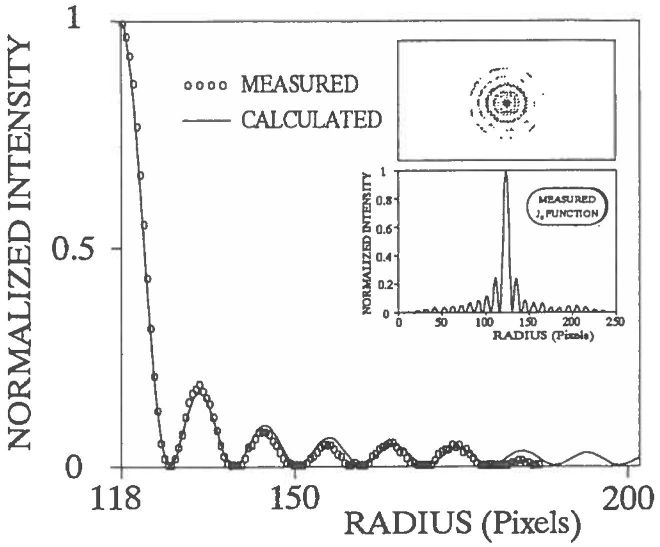

Figure 3: The measured intensity distribution perpendicular to the optical axis is quasi equivalent to a zero order Bessel function. The solid line shows the fitted curve to the measured intensity distribution (depicted by circles).

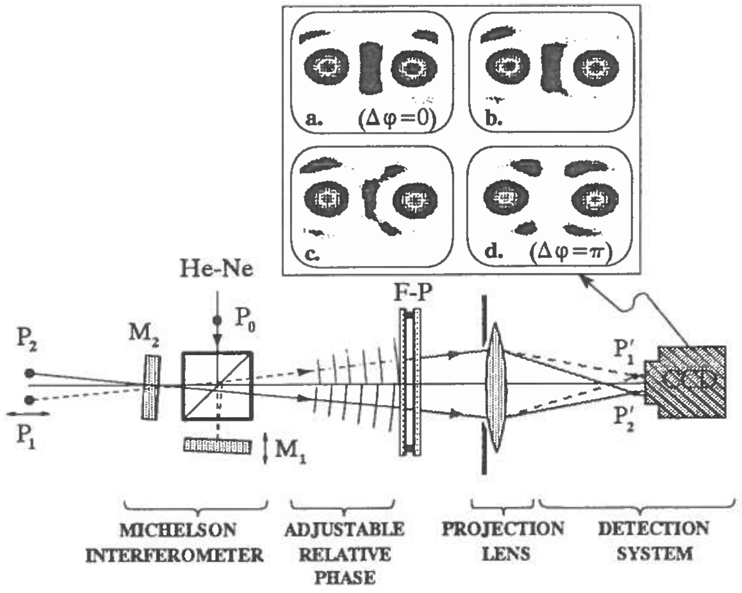

Figure 4: Imaging of two coherent point sources formed by a Michelson interferometer. The transverse distance and the relative phase difference between the sources was adjustable by translating and tilting the mirrors. The inset shows CCD images for different phase conditions.