Fourier Ptychography Microscopy with the SHARP EUV Microscope for increased imaging resolution based on illumination diversity

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The SHARP EUV mask microscope has demonstrated **significantly increased spatial resolution** and **quantitative phase measurement** using an emerging microscopy technique called *Fourier Ptychography Microscopy* (FPM). FPM relies on SHARP's programmable illuminator and inherently high spatial coherence to image the mask sample from **many different angles of illumination**.

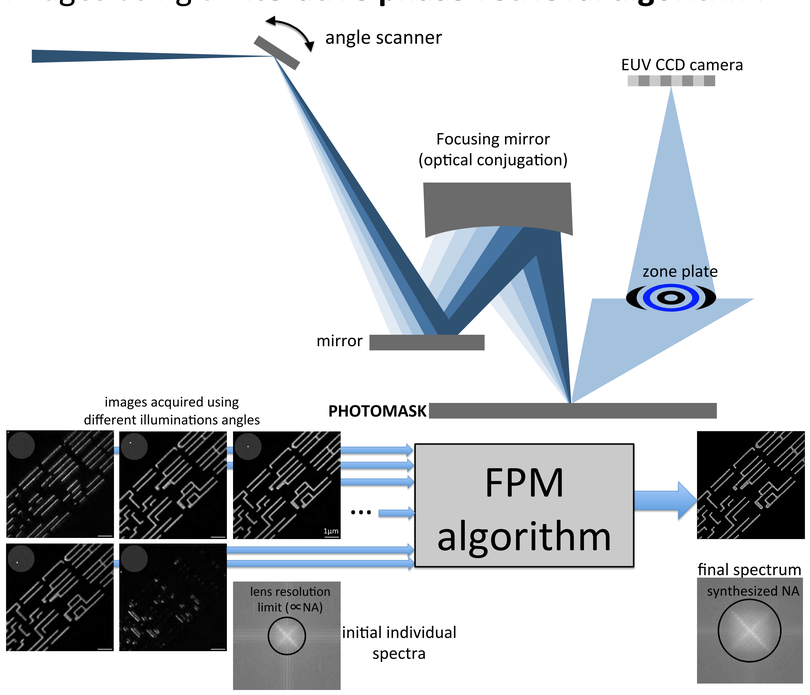
Images are reconstructed ptychographically, in the Fourier-domain, synthesizing an expanded numerical aperture with a real-space image that contains the complex field reflected from the mask. **We have recently demonstrated 50 nm resolution with a 0.33 4xNA lens.**

Introduction

SHARP is a synchrotron-based EUV zoneplate microscope that delivers at-wavelength aerial images of EUV photomasks. SHARP emulates current and future EUV printing tools and is used to research nearly every area of mask development. It features a Fourier Synthesis Illuminator capable of replicating any illumination condition.

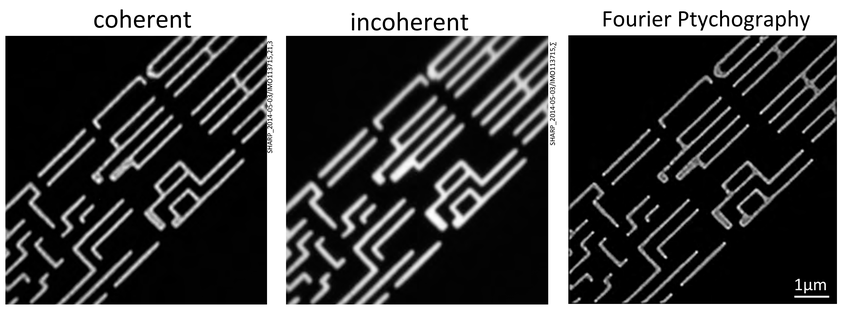
Principle

Fourier Ptychography consists in taking **multiple coherent images** of an object using **different illumination conditions**, and then recombining these images using an **iterative phase-retrieval algorithm**.

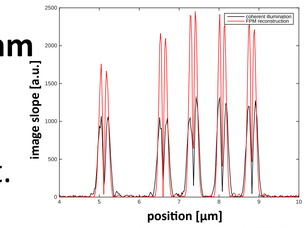


Increase in resolution

FPM synthesizes a higher-NA than the lens used to record the images.



This enables us to to reach **sub-40 nm resolution** (mask-side) with a 0.33 4xNA lens, compared to the conventional 82 nm diffraction limit.

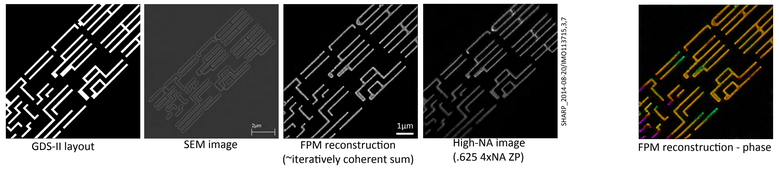


increase of line slope with FPM

Furthermore, the **field of view** and the **depth of focus** are increased compared to imaging with a higher NA lens; **lens aberrations can determined and corrected** during the reconstruction process [2].

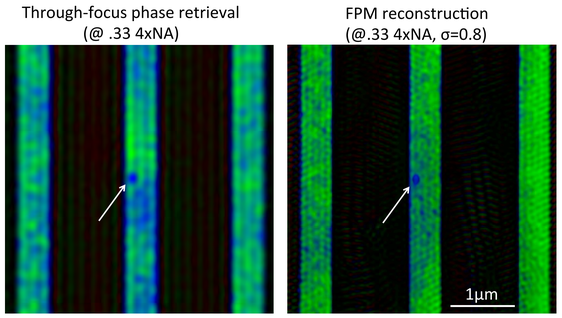
Validating data

FPM reconstruction is consistent with data acquired using other characterization techniques [3], with the advantage of being at-wavelength.

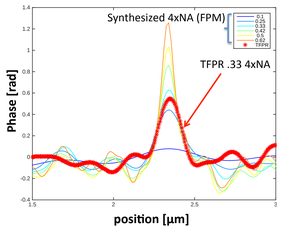


Phase defects characterization

The combination of all **the data yields quantitative phase information about the sample, point by point.**



amplitude (brightness) and phase (color) of a phase defect



influence of resolution on phase information

Compared with other phase retrieval techniques [4], the sharpness of phase information is increased. The **reconstruction of the actual angular spectrum** allows us to **perform numerical analysis** of the object (refocusing, restriction to various lens NAs, and the effect of various illuminations.)

Conclusion

FPM extends SHARP'S capabilities for EUV mask imaging, and allows us to achieve both increased resolution and quantitative phase measurement without requiring modifications to the existing hardware.

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References

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