Wafer metrology via automatic differentiation-based reflection ptychography on a EUV High Harmonic Generation platform

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As the semiconductor industry progresses toward sub-nanometer manufacturing, it increases the demands for metrology. EUV diffractive imaging offers a promising option for future metrology applications. We report on a reflective ptychographic imaging system using an EUV high harmonic generation setup at 18 nm, with multi-wavelength, multi-mode ptychographic reconstructions of gold-titanium patterned samples at a resolution of 50-by-100 nanometers.

The presented EUV beamline is based on high harmonic generation (HHG) driven by a 100 W Ytterbium-doped fiber laser, producing harmonics up to the Soft X-ray regime. A narrow band at 18 nanometers is selected using multi-layer mirrors and focused onto a gold titanium patterned sample, with diffracted light captured by an EUV sensitive camera.

In this work, we implement our ptychography algorithm on a Tensorflow-based platform to enable gradient computation via automatic differentiation (AD), which allows us to take advantage of advanced momentum-accelerated optimizers and integrated GPU acceleration functionality. We demonstrate ptychographic reconstructions of a gold titanium patterned silicon wafer, achieving a resolution of 50 nm perpendicular to the tilt direction and 100 nm in the tilted direction. Due to the instability of the HHG source, both multiple wavelengths and multiple spatial modes must be involved in the reconstructions, leading to a total number of 200 million variables being optimized. A complex-valued reflection function can be retrieved, and the height of the structures can be determined by classifying the substrate and the patterned structures in an amplitude-phase histogram, leading to a measured height of 23.2 nm comparable to the designed 20 nm.

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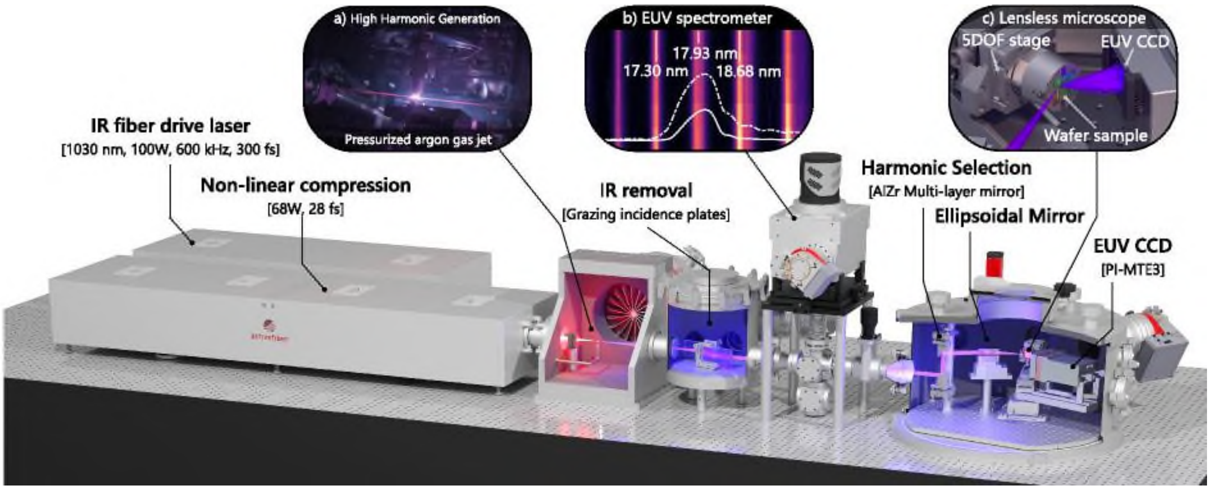

Fig. 1. A 100 W average power laser (λ = 1030 nm) emitting pulses of 300 femtoseconds at a rate of 600 kHz, which are compressed to 28 femtoseconds. Focusing the IR beam in a 10 bar Argon gas jet, results in higher harmonics down to the EUV regime efficiently. Two multi-layer mirrors select a narrow bandwidth around 18 nanometer which is focused onto a sample. Far field diffraction patterns are captured by a CCD.

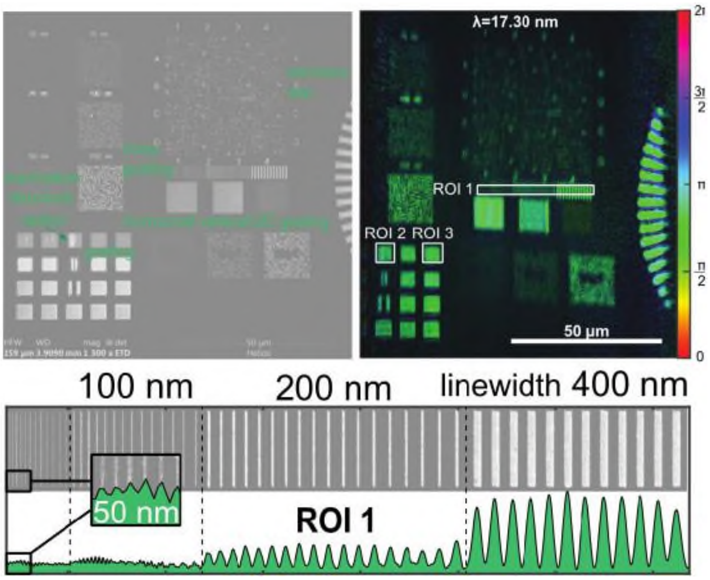

Fig 2. *Top-left:* An SEM generated reference of a silicon wafer, patterned with AuTi structures of 20-nanometer height. *Top-right*: A detailed reconstruction of the object, where the hue denotes the phase, and the intensity signifies the amplitude. *Bottom*: A chirped grating located in ROI 1, revealing reconstruction down to a precision of 50-nanometer linewidth.

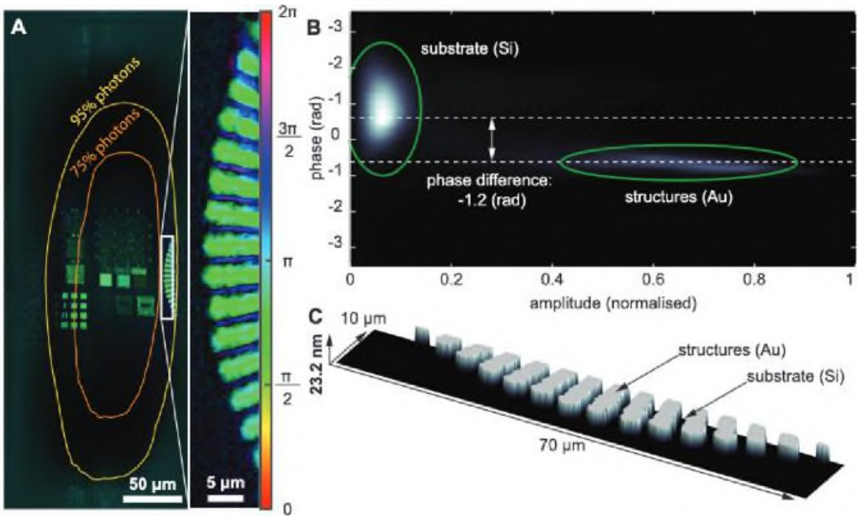

Fig. 3. It is possible to obtain a complex reflection function through ptychography, where the amplitude and phase are represented by intensity and hue respectively. The height of the patterned structures can be determined by classifying the substrate and structures in an amplitude-phase histogram.