Field-averaging micro lenses that synthesize highly uniform illumination in coherent EUV optical systems

Christopher N. Anderson (1), Patrick P. Naulleau (2), Paul Denham (2), Drew Kemp (2) and Senajith Rekawa (2)

(1) University of California, Applied Science and Technology

(2) Center for X-ray optics, LBNL

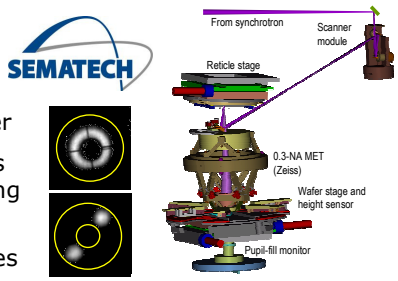
BERKELEY LAB

MOTIVATION

- Illumination uniformity and reproducibility in EUV microfield exposure tools is critical to many aspects of the EUV lithography development task.
- To address this concern, field-integrating fly's eye elements are often used in illuminator designs.

SEMATECH BERKELEY MET

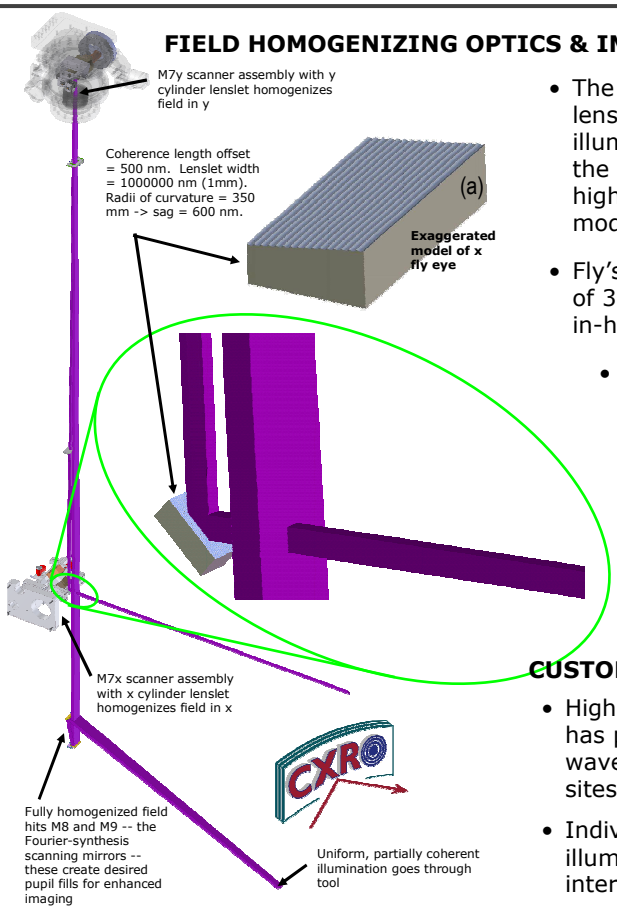
- 0.3 NA Zeiss optic in 5x reduction configuration
- 600x200 μm field size at wafer
- Support for arbitrary pupil fills with Fourier-synthesis scanning illuminator
- Ultrahigh resolution capabilities from a conventional projection EUV system



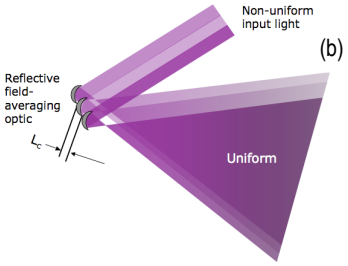
GOALS

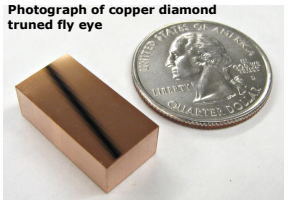
- Expand uniformly illuminated field size to match capabilities of MET projection optics (3-mm x 1-mm at mask)
- Enable programmable field size
- Maintain system throughput
- Maintain programmable coherence (pupil fill) functionality of the system

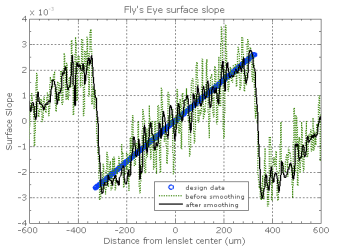
FIELD HOMOGENIZING OPTICS & IMPLEMENTATION AT EUV



- The field-homogenizing optic is an array of small lenslets that map sub-sections of an incoming illumination footprint to an overlap region wherein the expanded sub-fields are averaged to produce a highly uniform footprint. It is shown in reflection mode to the right.
- Fly's Eyes are designed to fill 1-mm x 1-mm subset of 3-mm x 1-mm field. Programmable scanners and in-house software create desired field fill patterns
  - Small NA of homogenizing optics does not affect our ability to controllably de-coherentize the illumination and achieve desired pupil fills
    - We've decoupled the Fly's Eye stage into a pair of orthogonal cylindrical lenslet arrays. At least five lenslets intercept the incoming illumination footprint in each imaging direction, mapping the uniform fill to the surfaces of the existing x and y Fourier-synthesis scanning mirrors.





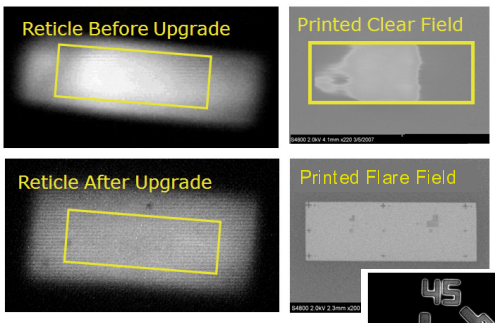


- In house smoothing renders diamond-turned surfaces suitable for multilayer deposition (see OP-P06).
- Diamond-turned optics by NU-TEK Precision Optical Corp in Aberdeen MD.

CUSTOM FLY'S EYE'S FOR COHERENT EUV

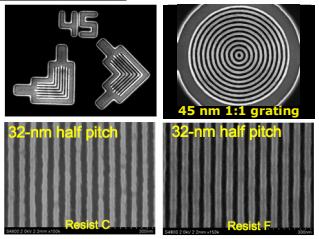
- High spatial coherence of synchrotron radiation has potential to cause interference between wavefronts emerging from different lenslet sites in Fly's Eye array
- Individual lenslets are offset by the 500-nm illumination coherence length to eliminate interference [see (a) and (b)].

POST-UPGRADE SYSTEM PERFORMANCE



- Before and after pictures of reticle field and printed clear fields show improved performance.
- Lithographically measured uniformity = 6.5% peak-to-valley across 9 points spanning the field

Printing data to the right is following the upgrade. Line-space data courtesy of Tom Wallow, AMD



CONCLUSIONS

- We've developed a field-averaging scanning-Fly's Eye stage enabling non-uniform, high-coherence sources to be used in applications requiring high illumination uniformity
- The system has been successfully integrated into the existing illuminator of the SEMATECH Berkeley MET and we report post-upgrade intensity uniformity across the 200x600 μm wafer-side field of view of 6.5%.

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 cnanderson@berkeley.edu