A SHARPER LOOK AT EUV MASKS

Markus P. Benk,
K. A. Goldberg, I. Mochi, C. C. Lin*, P. P. Naulleau

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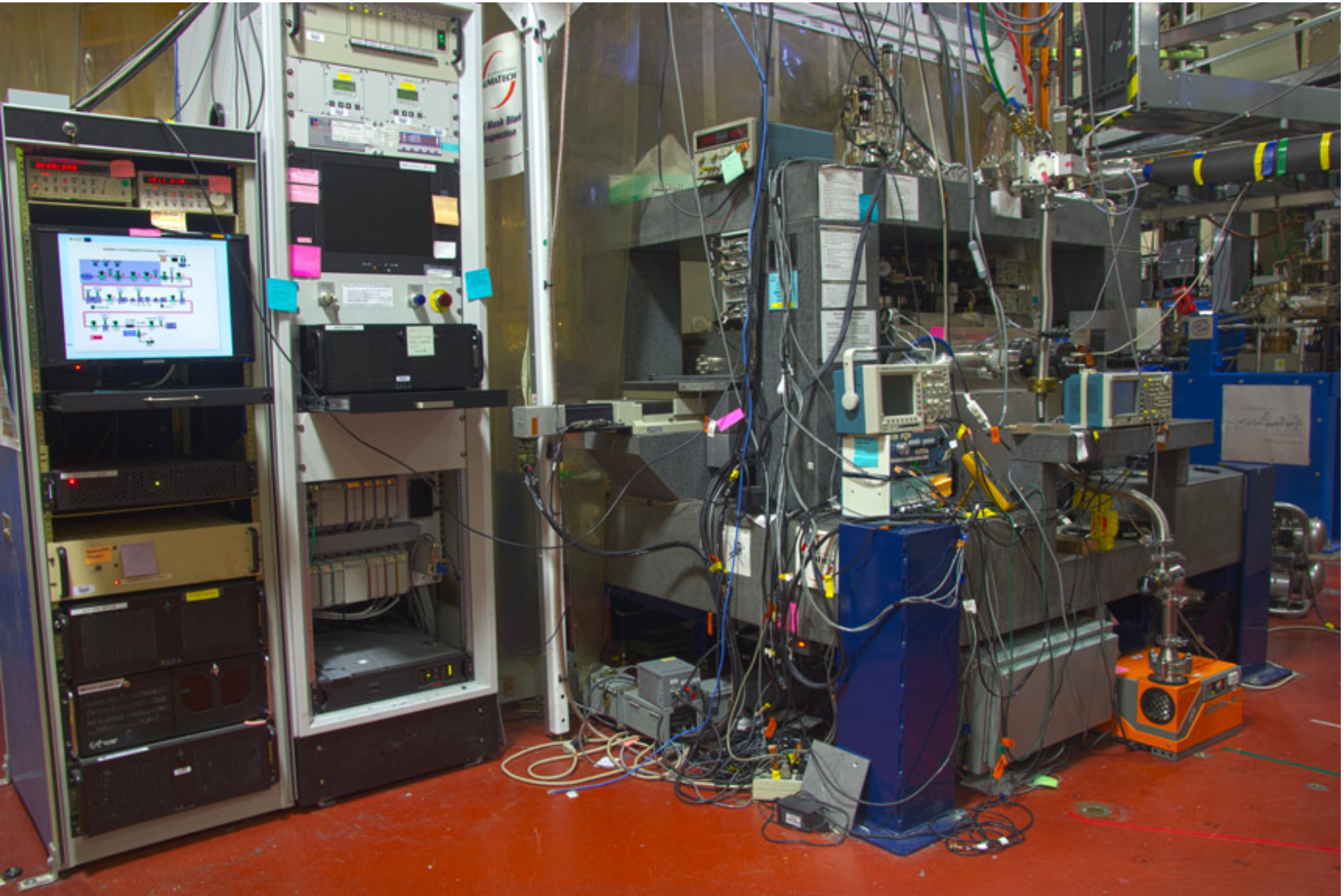
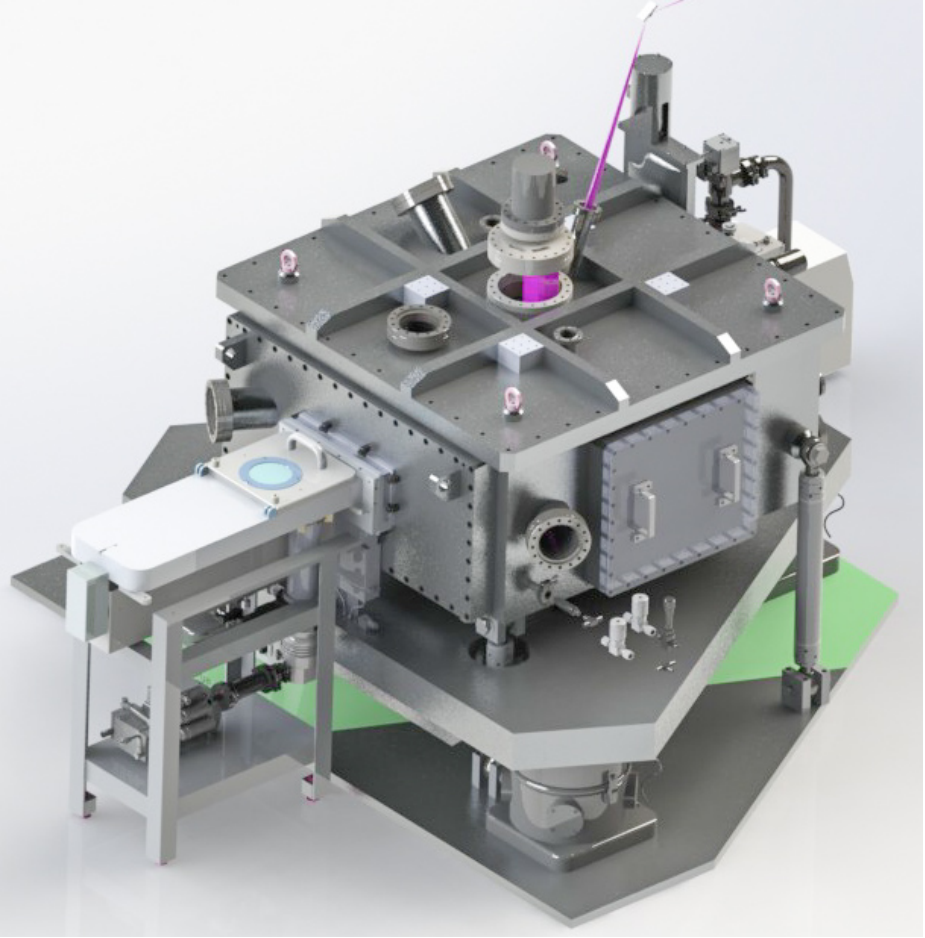
Berkeley Actinic Inspection Tool AIT



2004-2012

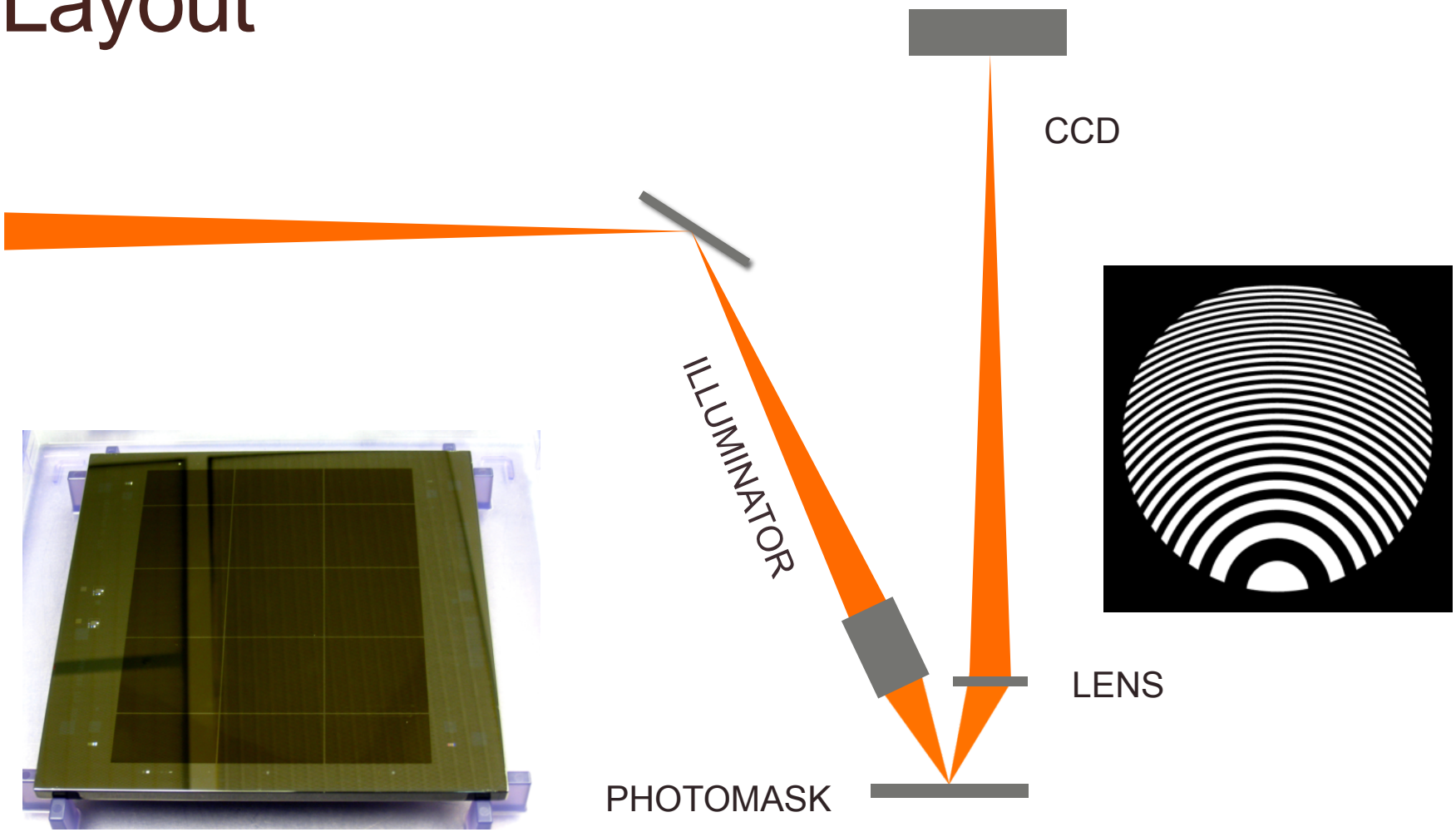
SHARP

SEMATECH HIGH-NA ACTINIC RETICLE REVIEW PROJECT

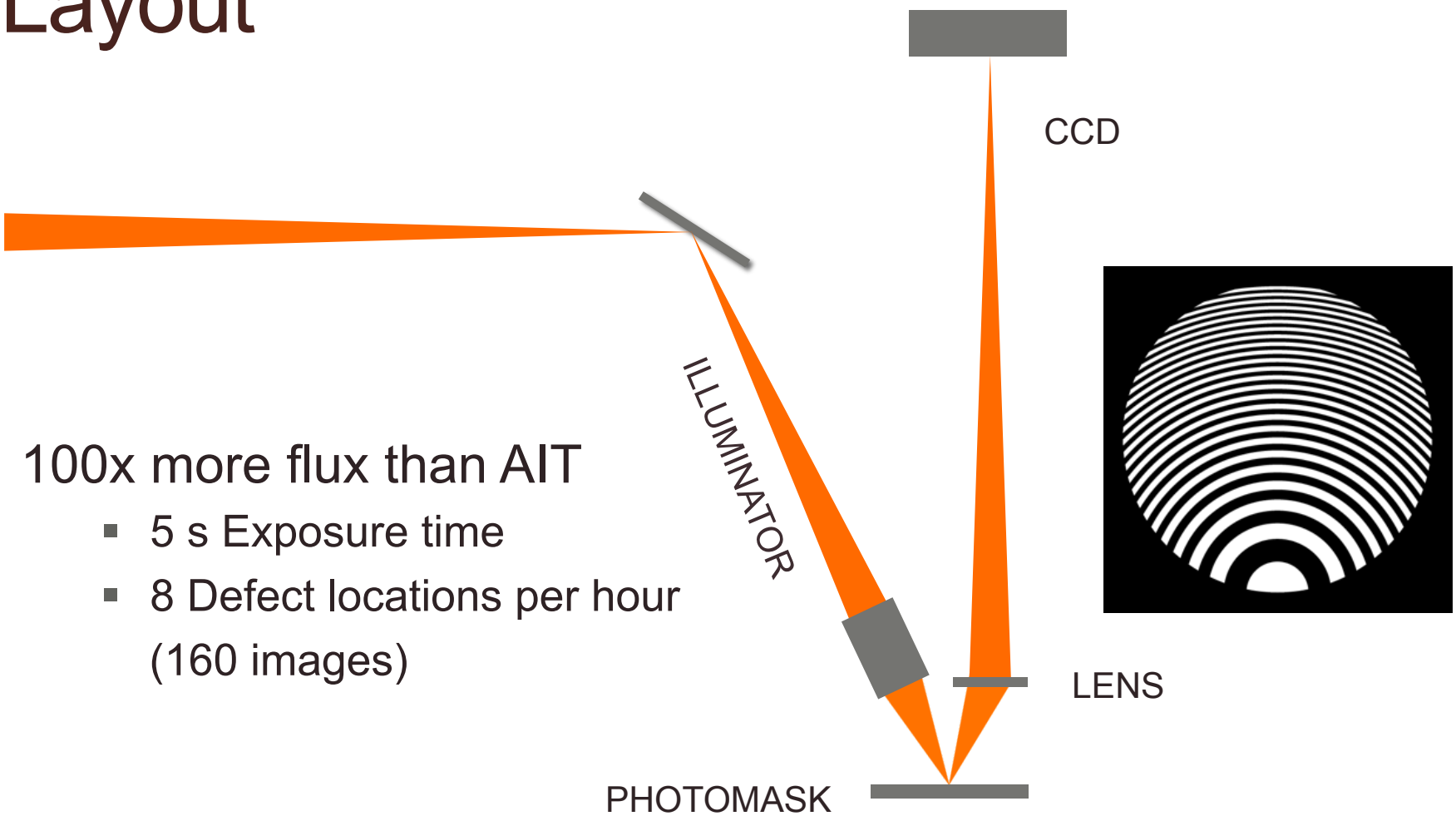


Source:	Synchrotron
Optics:	Zoneplate-lenses
4×NA:	0.25–0.625
Sigma:	Programmable
Navigation:	Full-mask xy
Stability:	Vibration Isolation

Layout



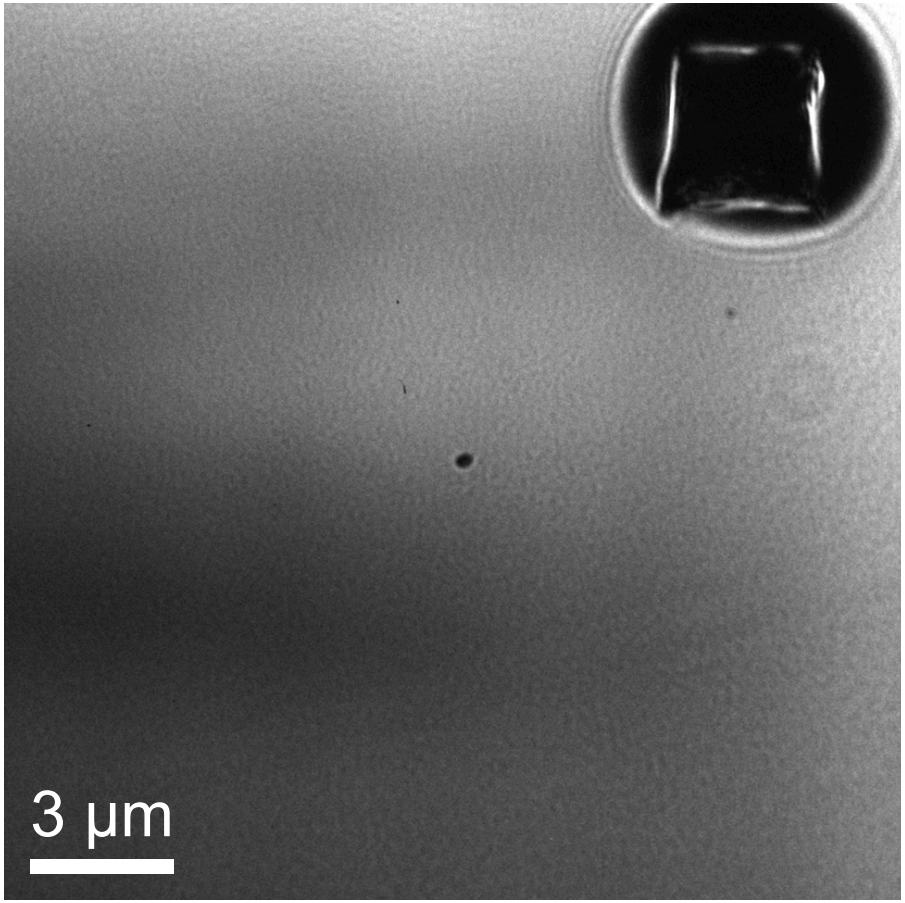
Layout



100x more flux than AIT

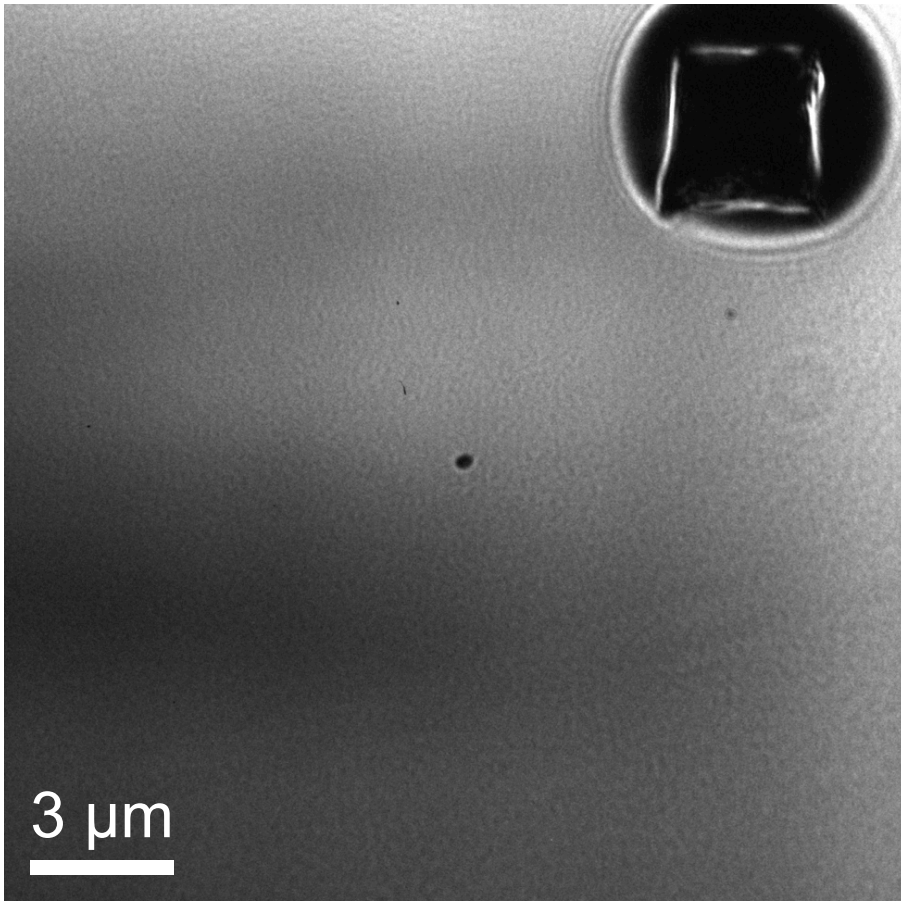
- 5 s Exposure time
- 8 Defect locations per hour (160 images)

Flux

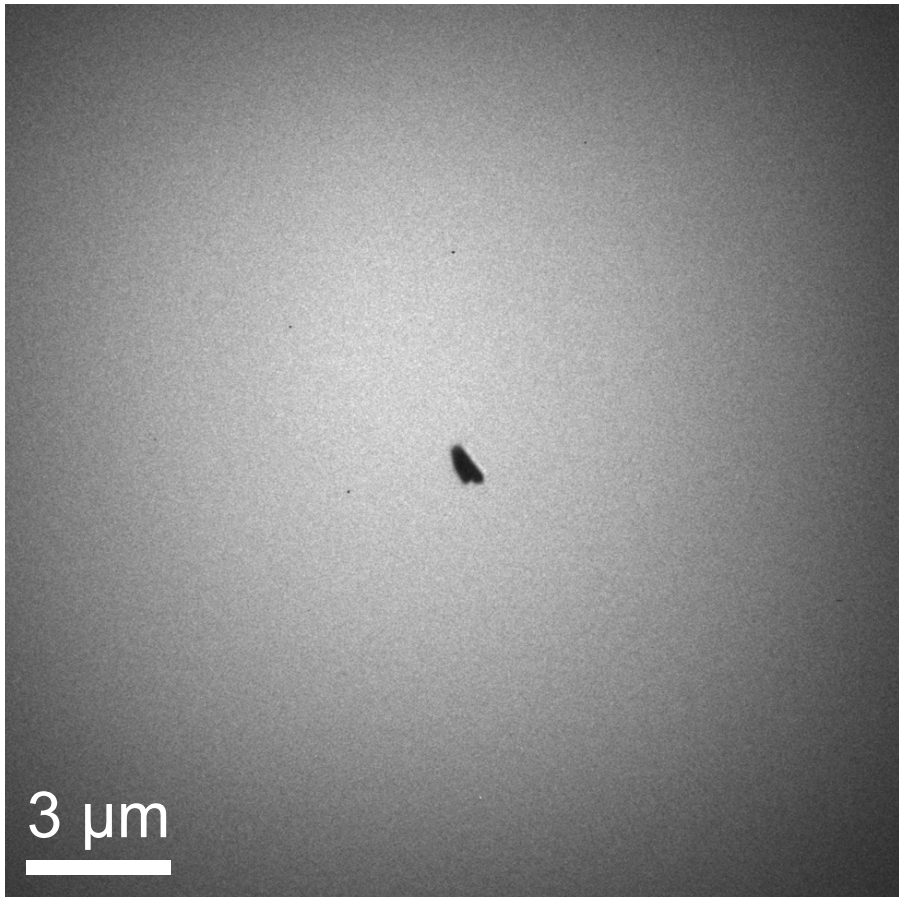


Blank multilayer: AIT
45s, 2.65k counts

Flux

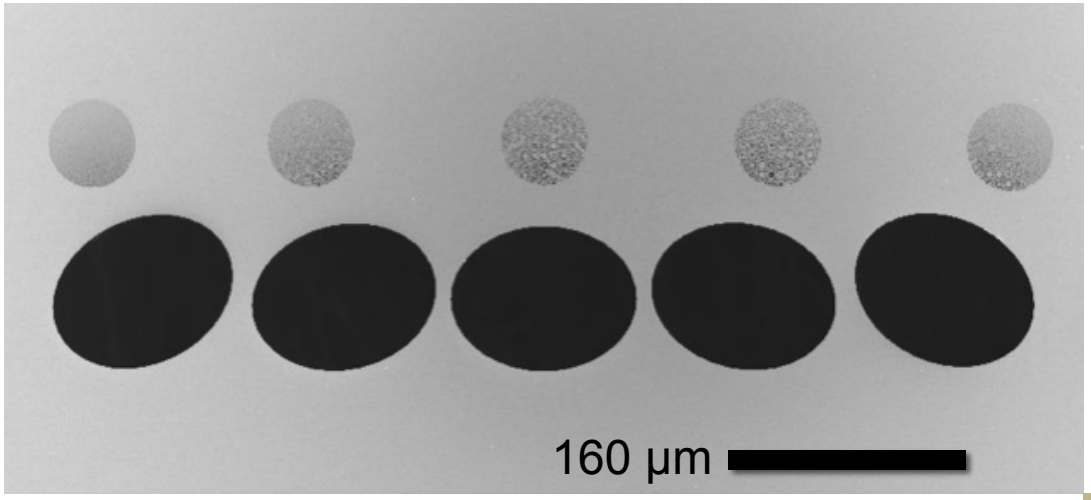


Blank multilayer: AIT
45s, 2.65k counts



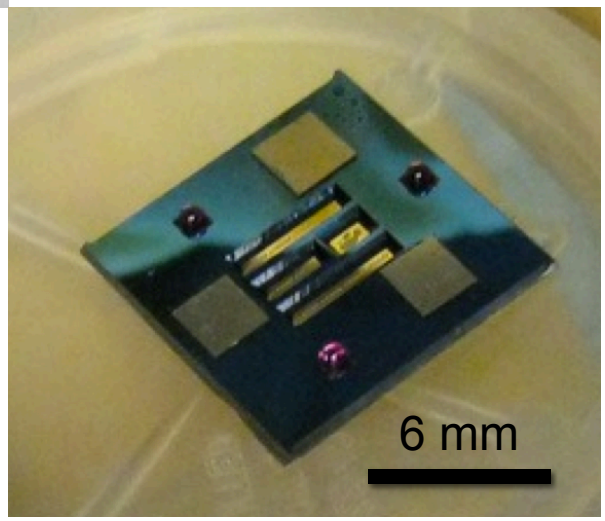
Absorber: SHARP
40s, 2.70k counts

Zoneplates



- 200 zoneplates
- 3 zoneplate chips
- 5 Azimuthal angles
- 0.25 to 0.625 NA
- 6° to 10° central ray angle

- Free-standing zones
- Magnetic mounting
- Kinematic positioning



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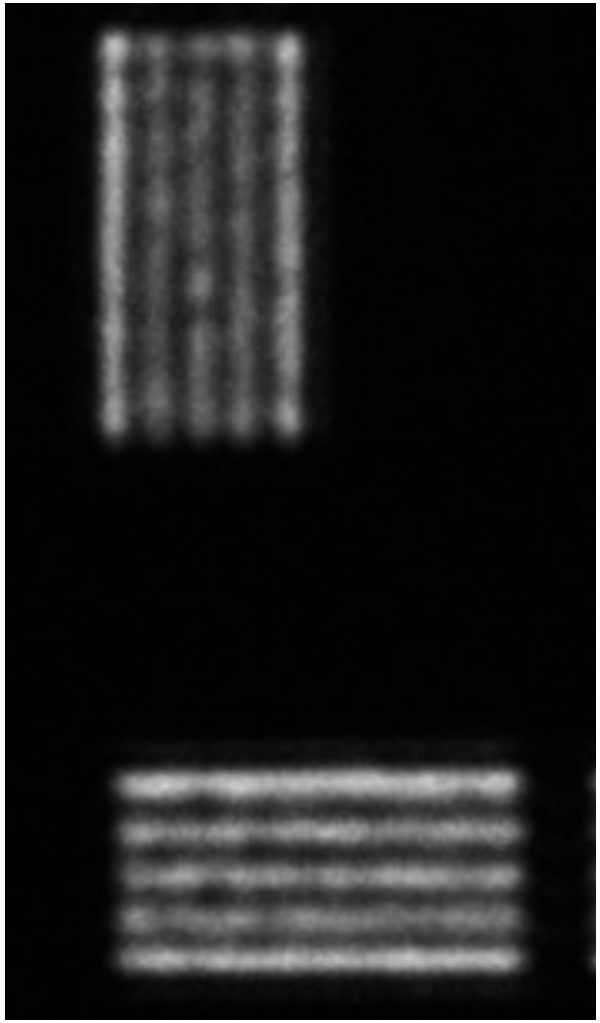
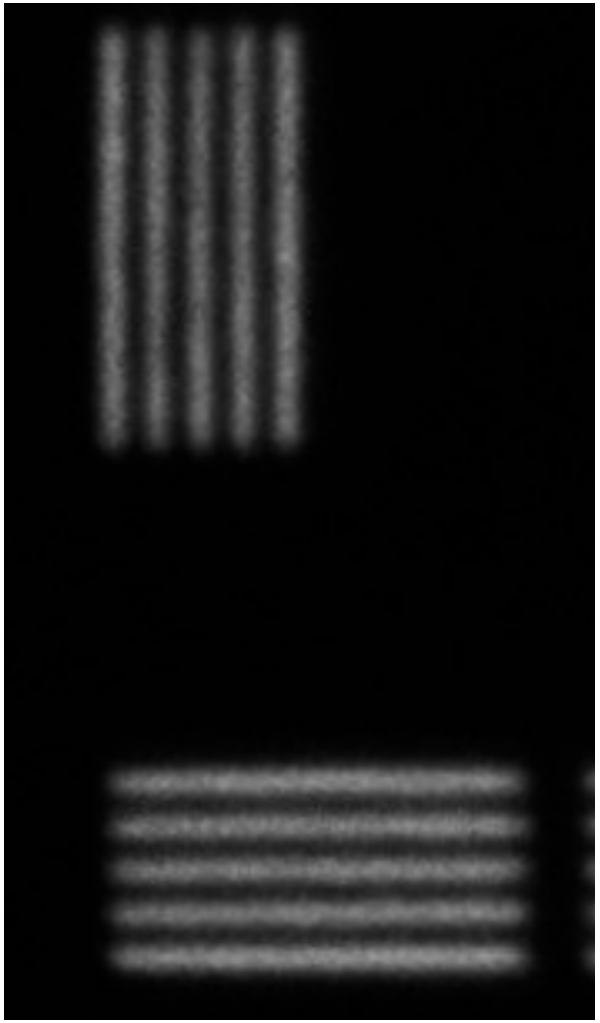
Illumination





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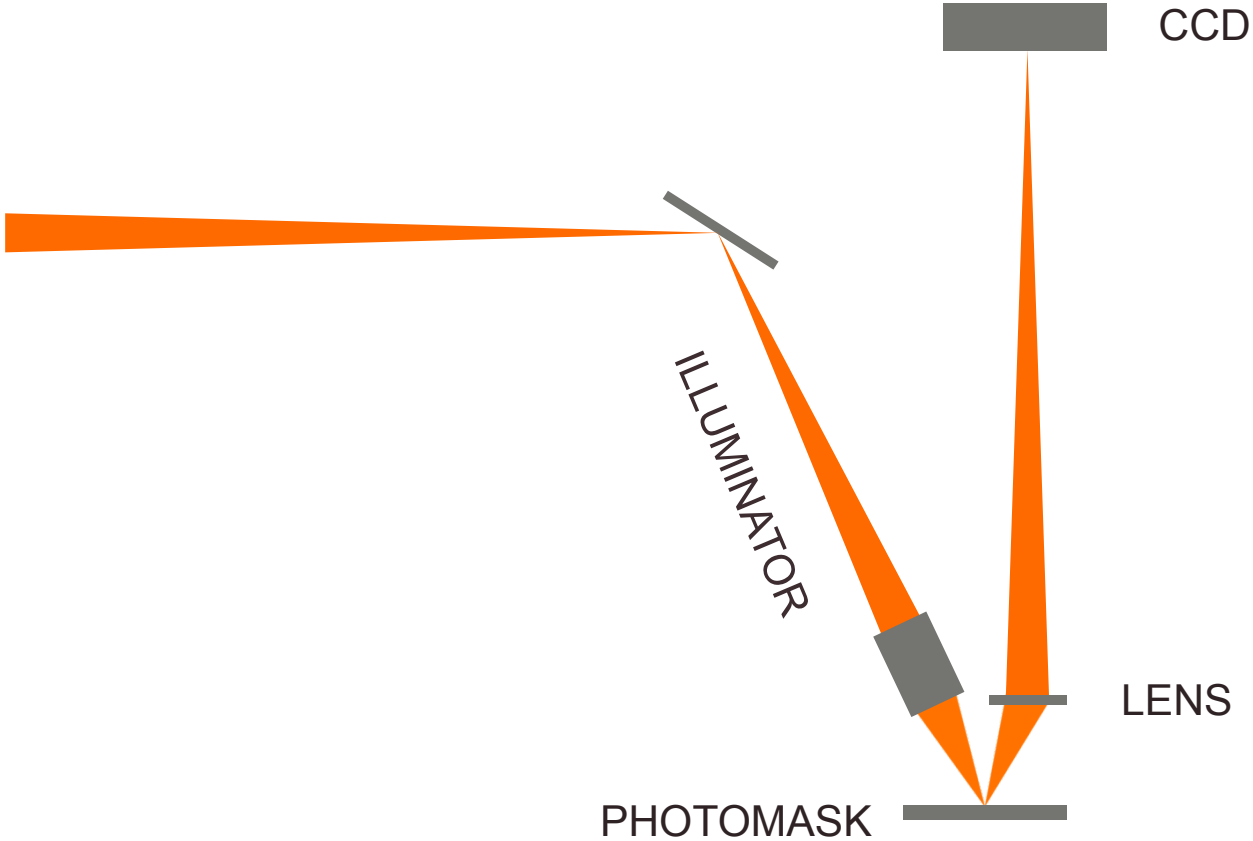
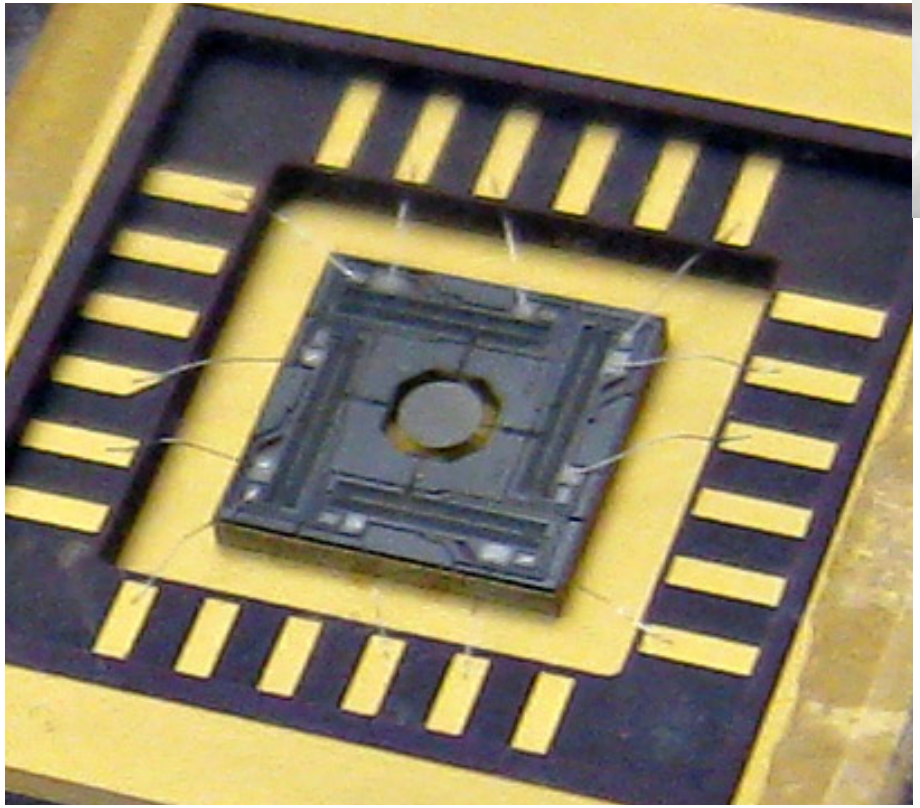
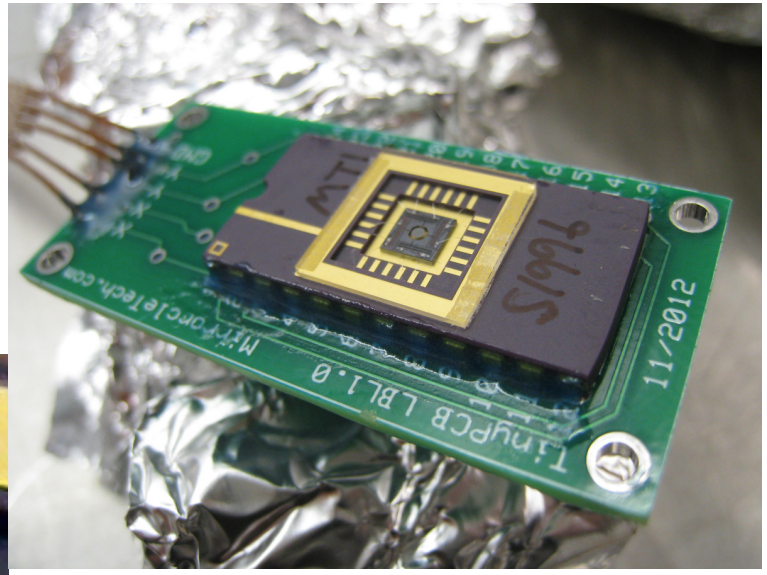


Layout

M_a mirror

- 1 mm dia. flat Si substrate
- 1° range of incidence angles
- 10 bi-layer Mo/Si coating





- Mirrorcle
  - gimbal-less dual-axis, scanning MEMS device
  - 2 kHz scan rate

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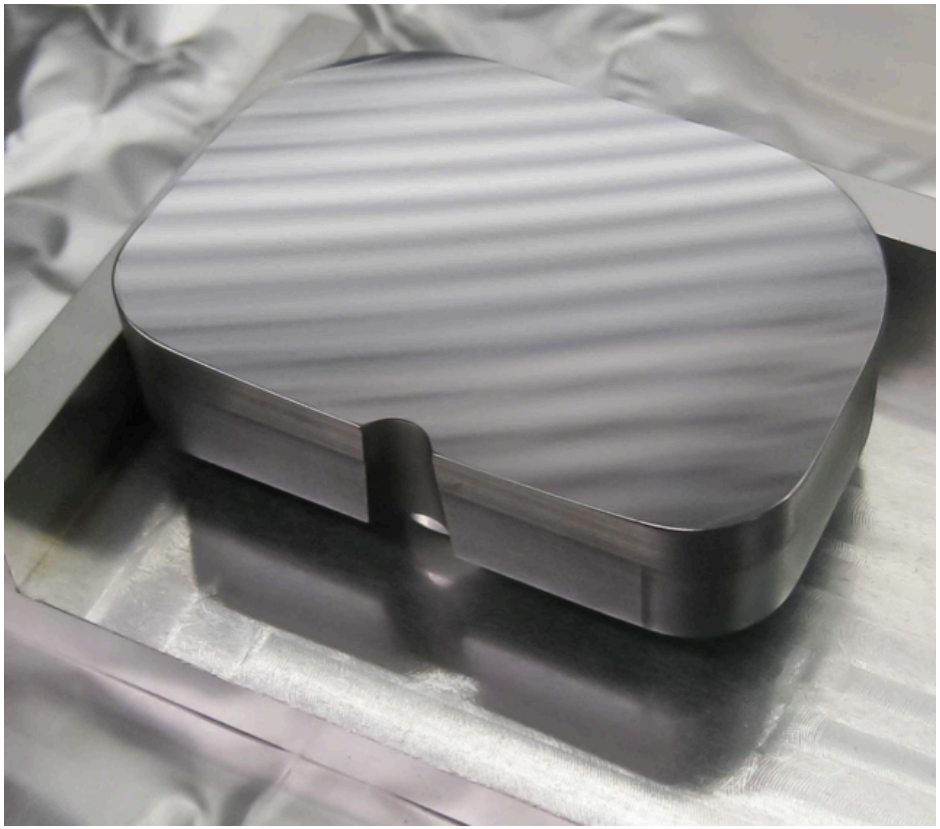
M_c mirror

- 48 mm x 35 mm poly Si
- ellipsoidal surface
- 10x demagnification
- 42 Mo/Si bi-layers
- 0.15 nm RMS roughness
- <25 µrad slope error

- Actuator
  - Piezo-driven dual-axis scanner
  - 200 Hz scan rate
  - 2 mrad scanning range



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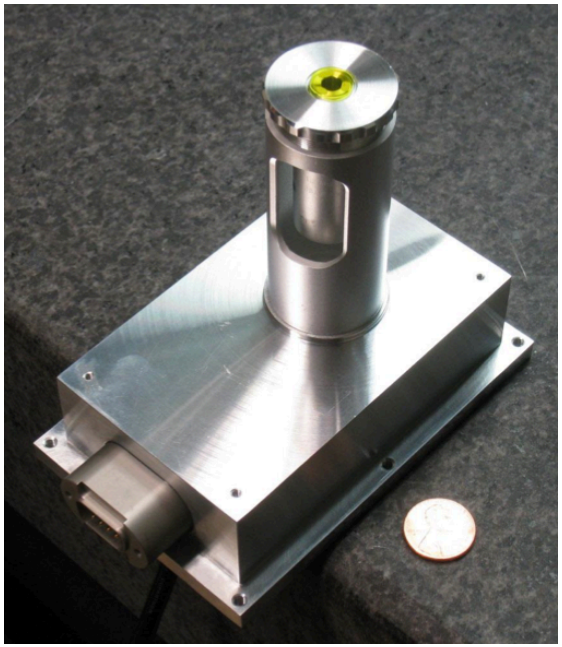
Assembly

Pupil-fill monitor

- In-vacuum YAG camera
- 2x magnification
- 2.1 μm per pixel



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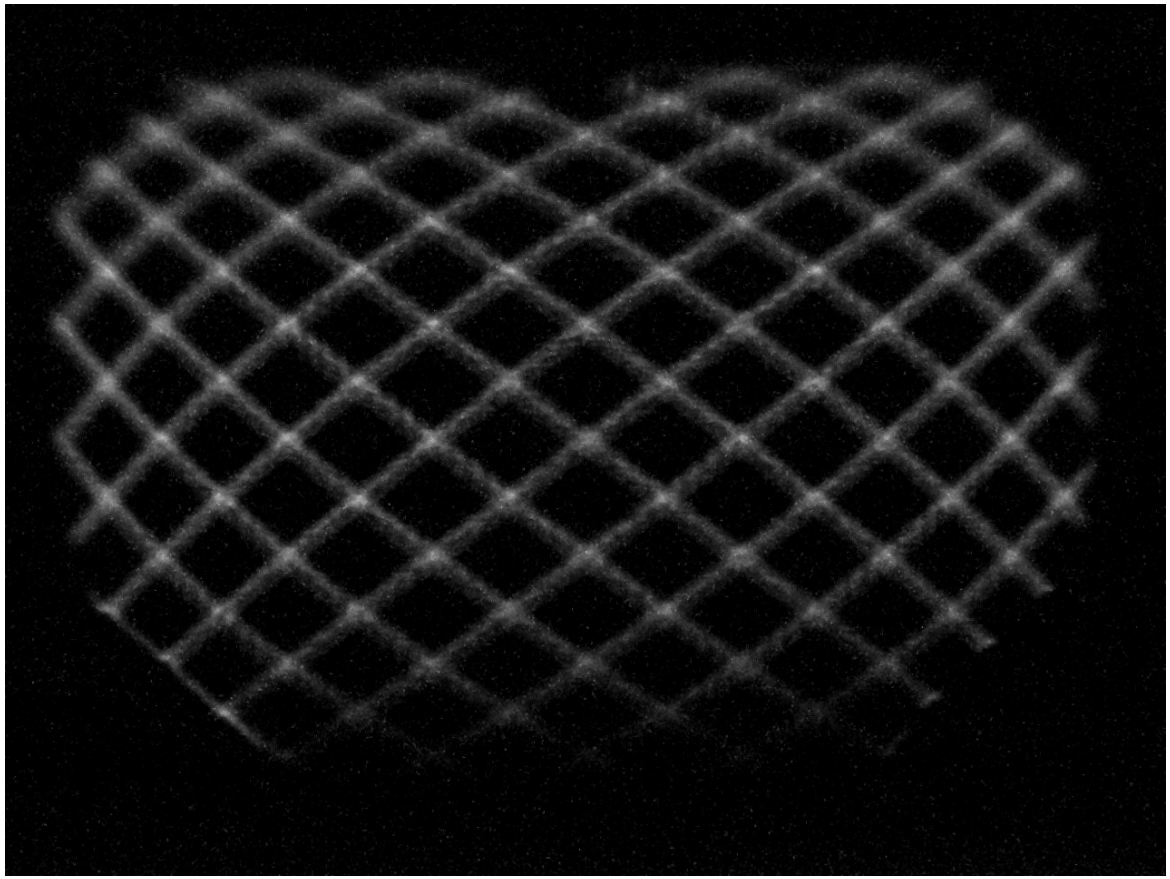
Pupil fill

- Lissajous pattern on M_c mirror

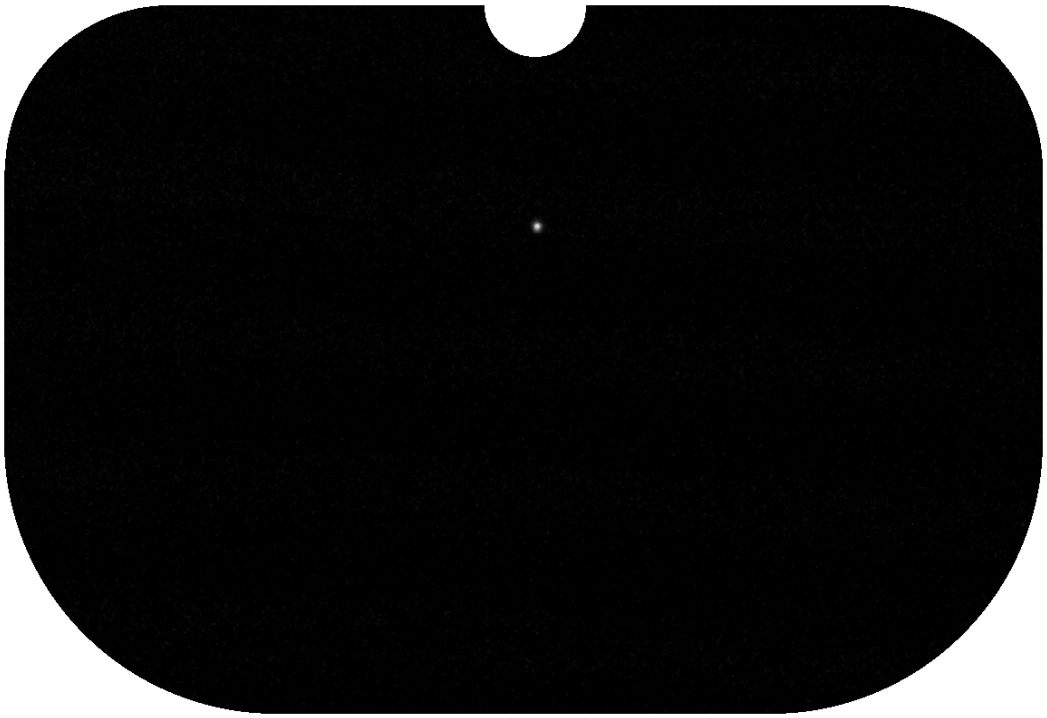


Pupil fill

- Lissajous pattern on M_c mirror

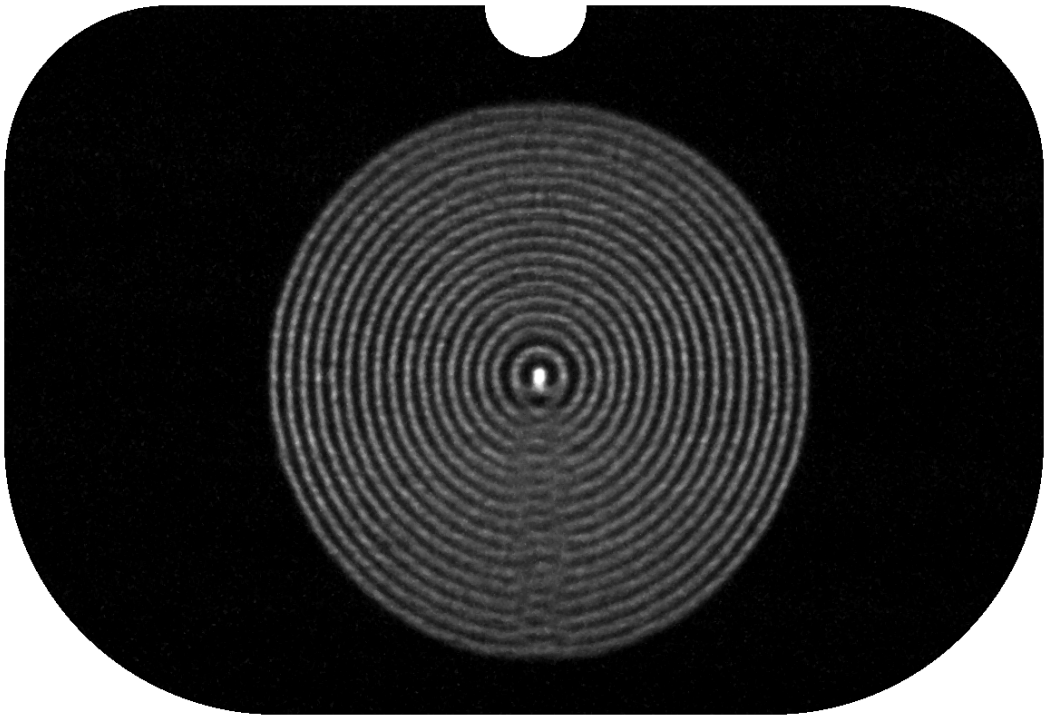
Pupil fill

- static beam



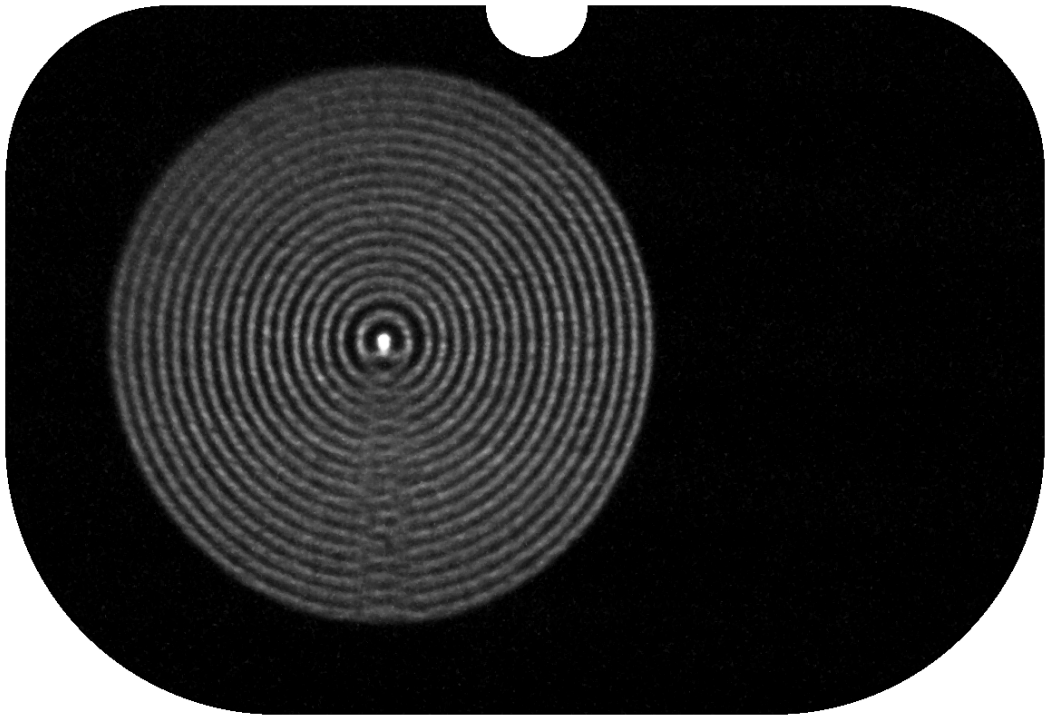
Pupil fill

- 0.625 4xNA
  10° CRA
  σ=0.8



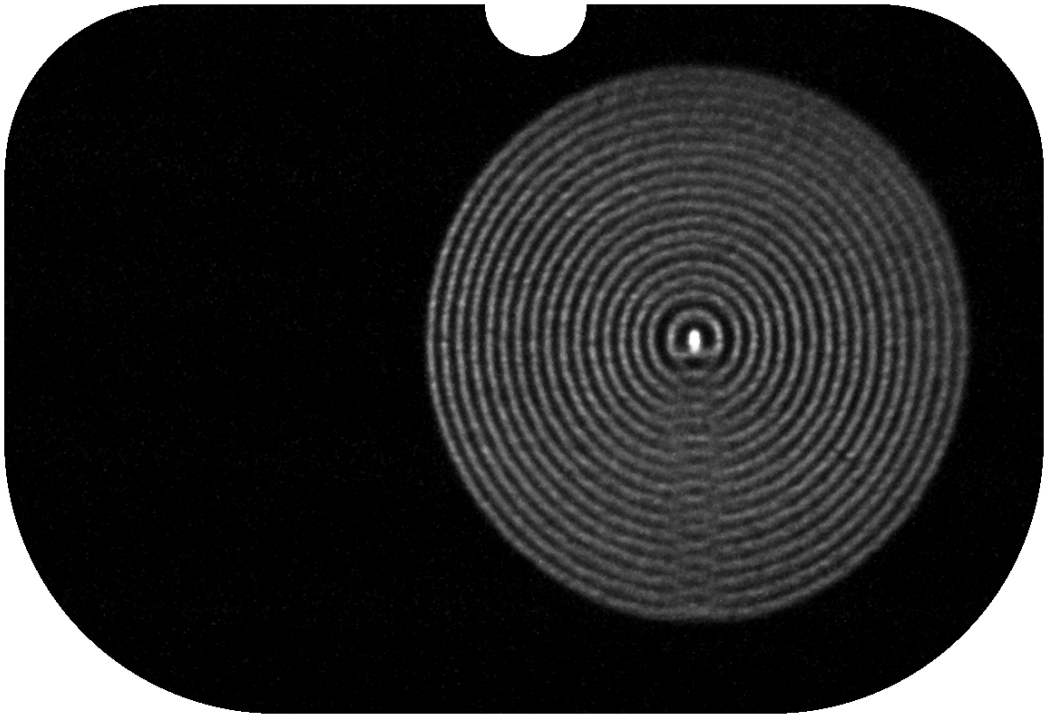
Pupil fill

- 0.625 4xNA
  10° CRA
  σ=0.8
  -25° azimuth



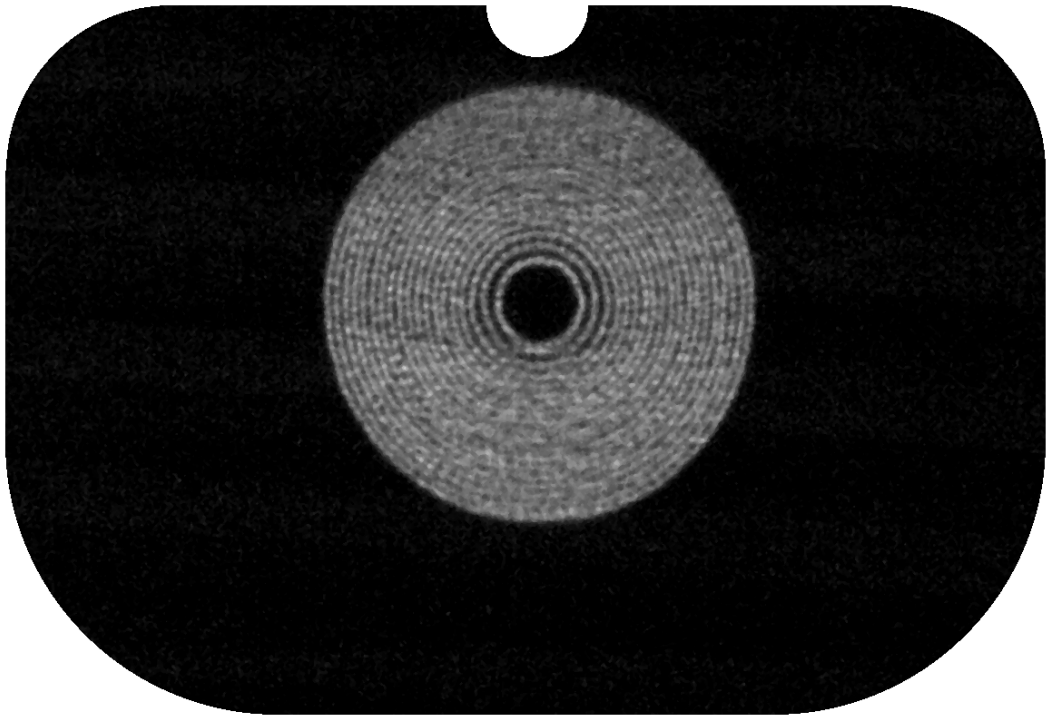
Pupil fill

- 0.625 4xNA
  10° CRA
  σ=0.8
  +25° azimuth



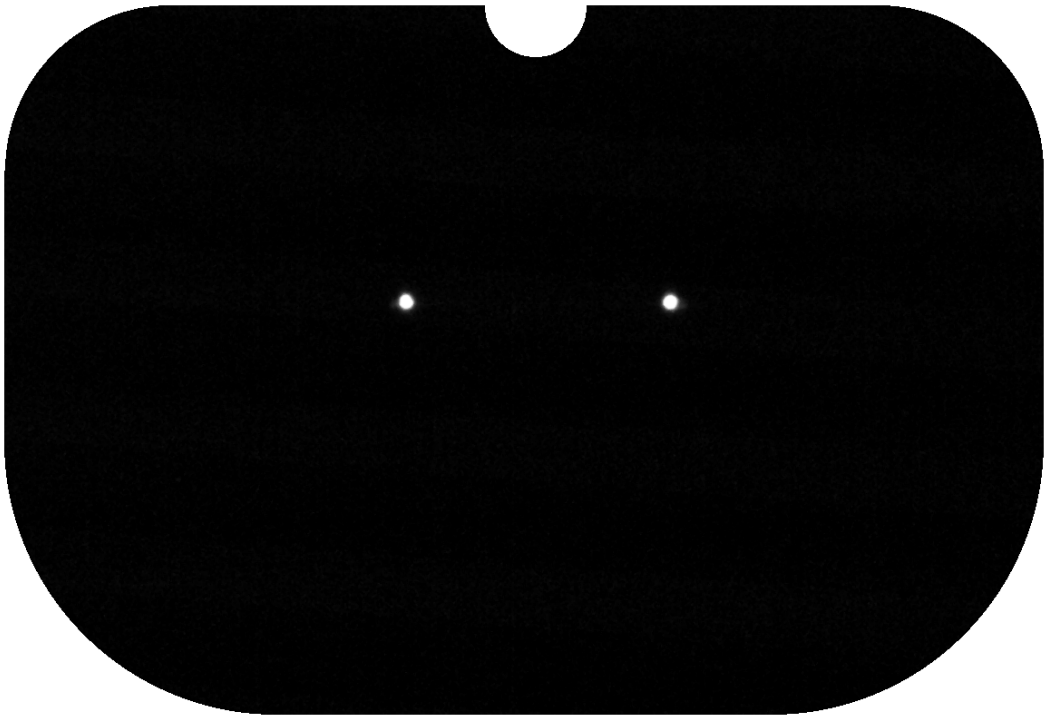
Pupil fill

- 0.5 4xNA
  8° CRA
  σ_1=0.2
  σ_2=0.8



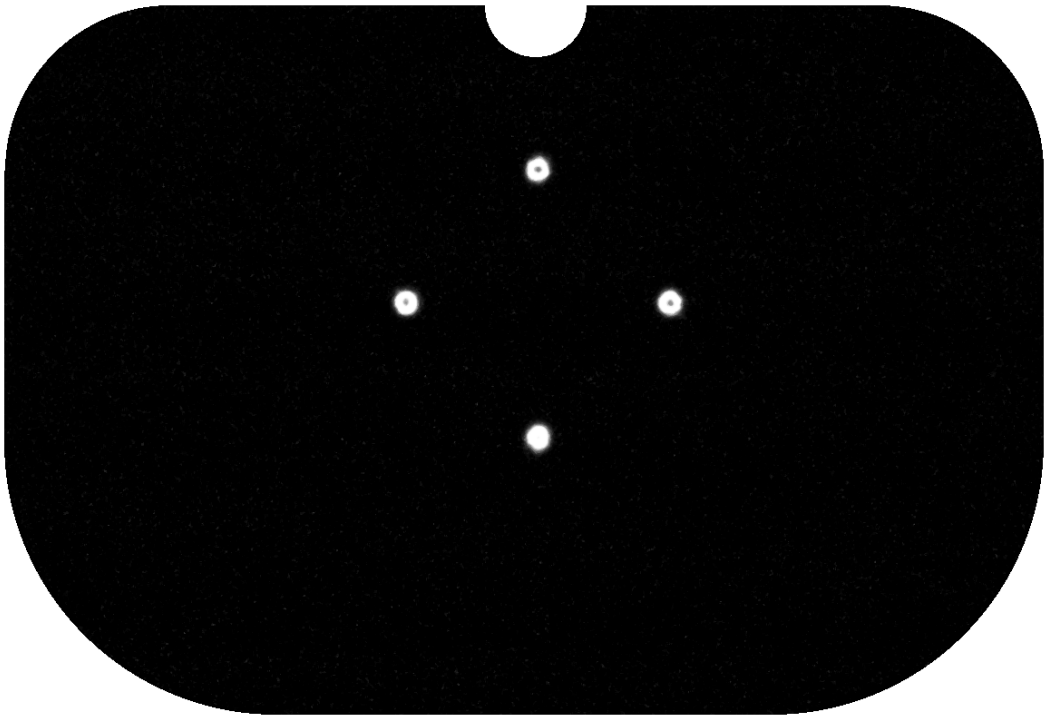
Pupil fill

- Dipole
  0.5 4xNA
  8° CRA



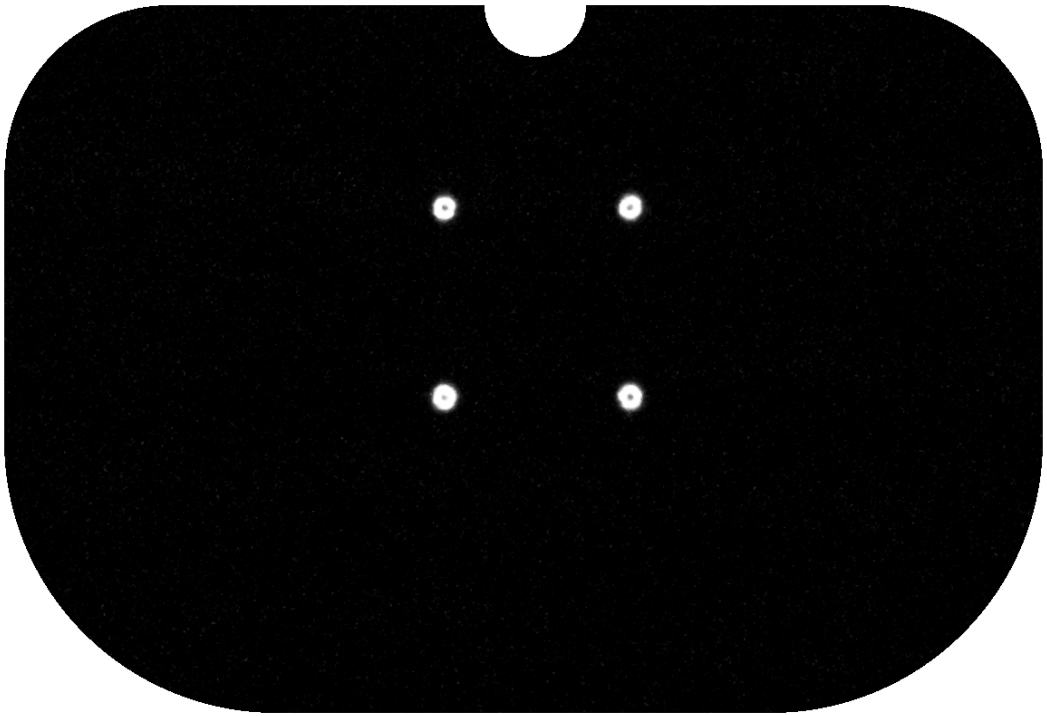
Pupil fill

- Quadrupole
  0.5 4xNA
  8° CRA



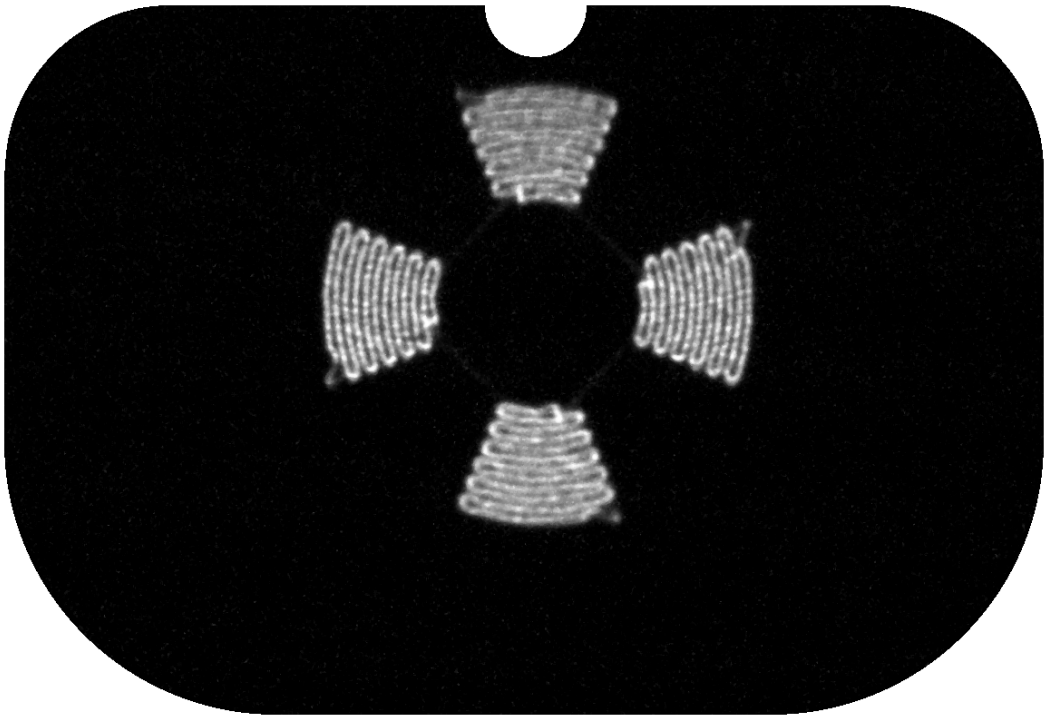
Pupil fill

- Quadrupole
  45°
  0.5 4xNA
  8° CRA



Pupil fill

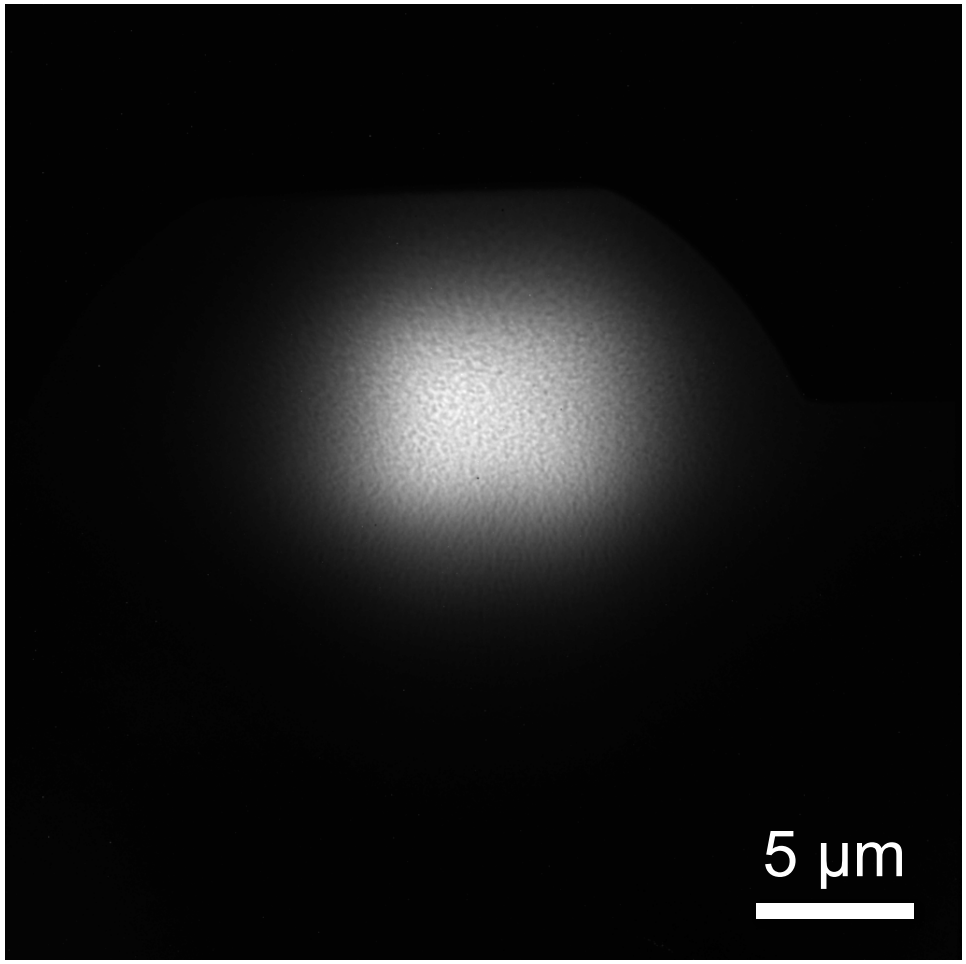
- Crosspole
  0.5 4xNA
  8° CRA



Uniformity

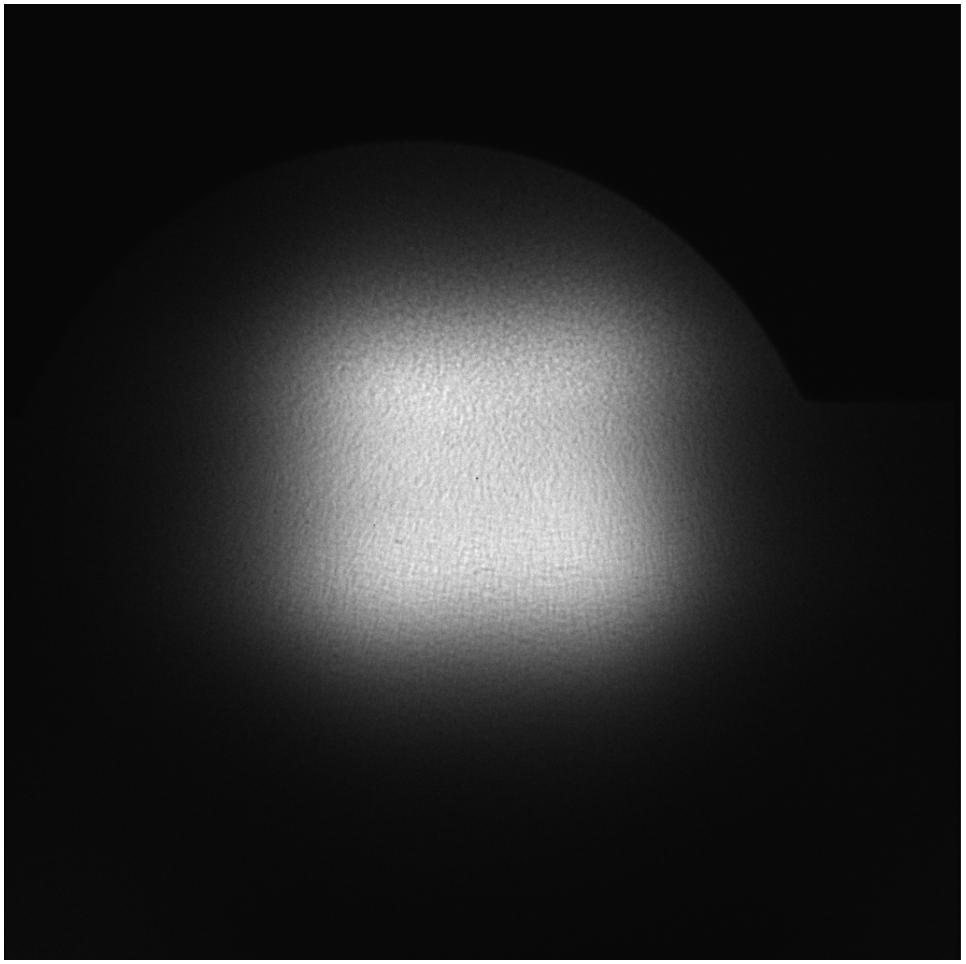
- No M_c scanning

- Image of mask blank surface
  σ=0.55
  900x mag



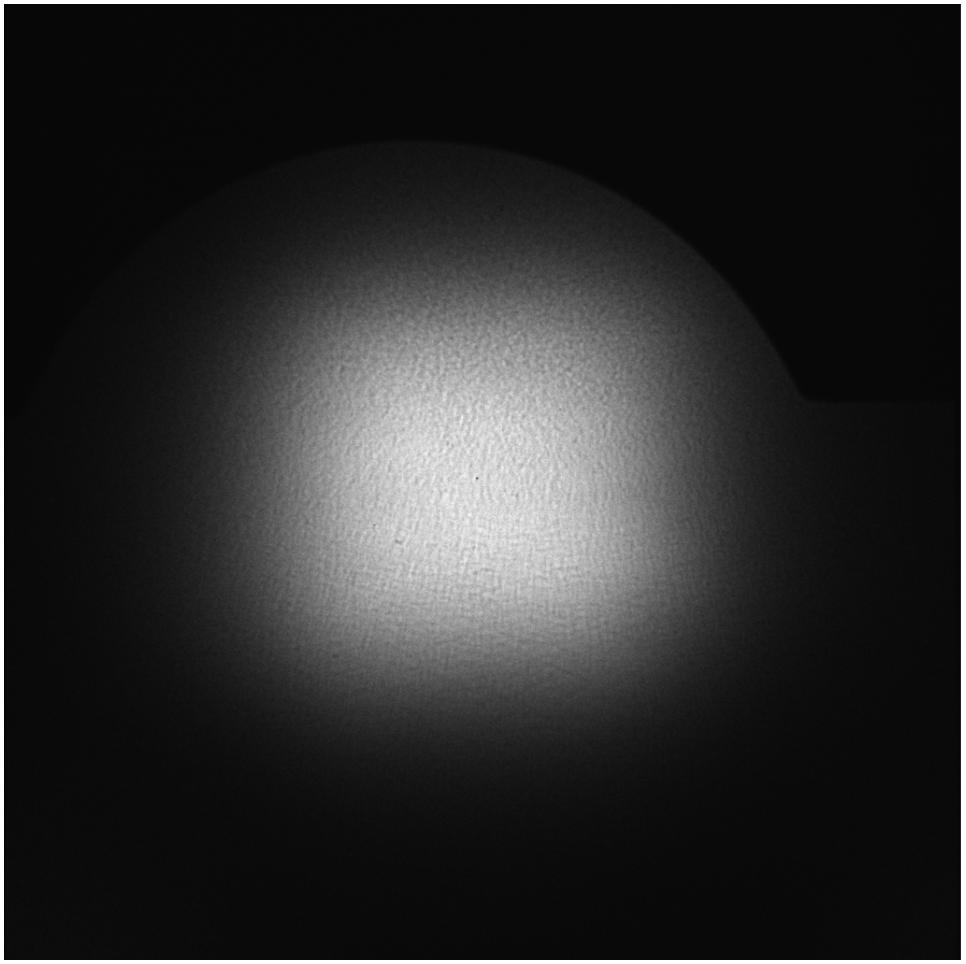
Uniformity

- Raster
  8 lines
  2 μm x 2 μm



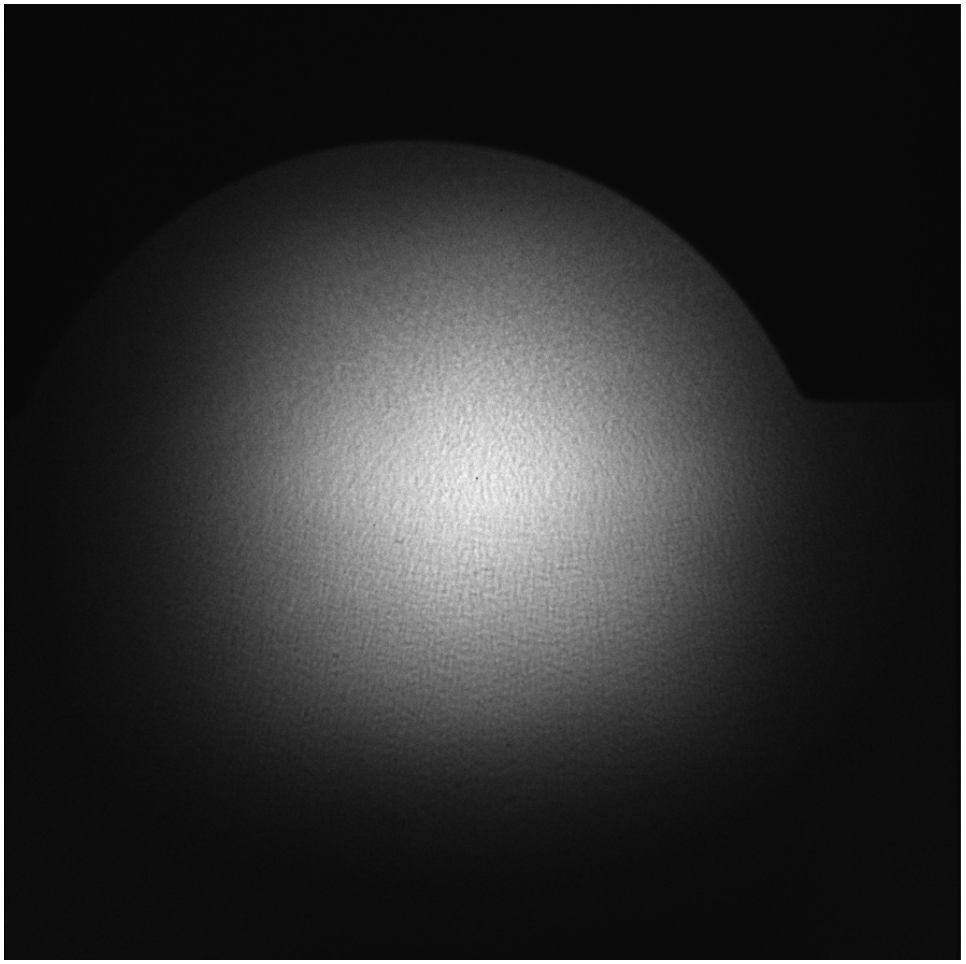
Uniformity

- Raster
  8 lines
  4 μm x 4 μm



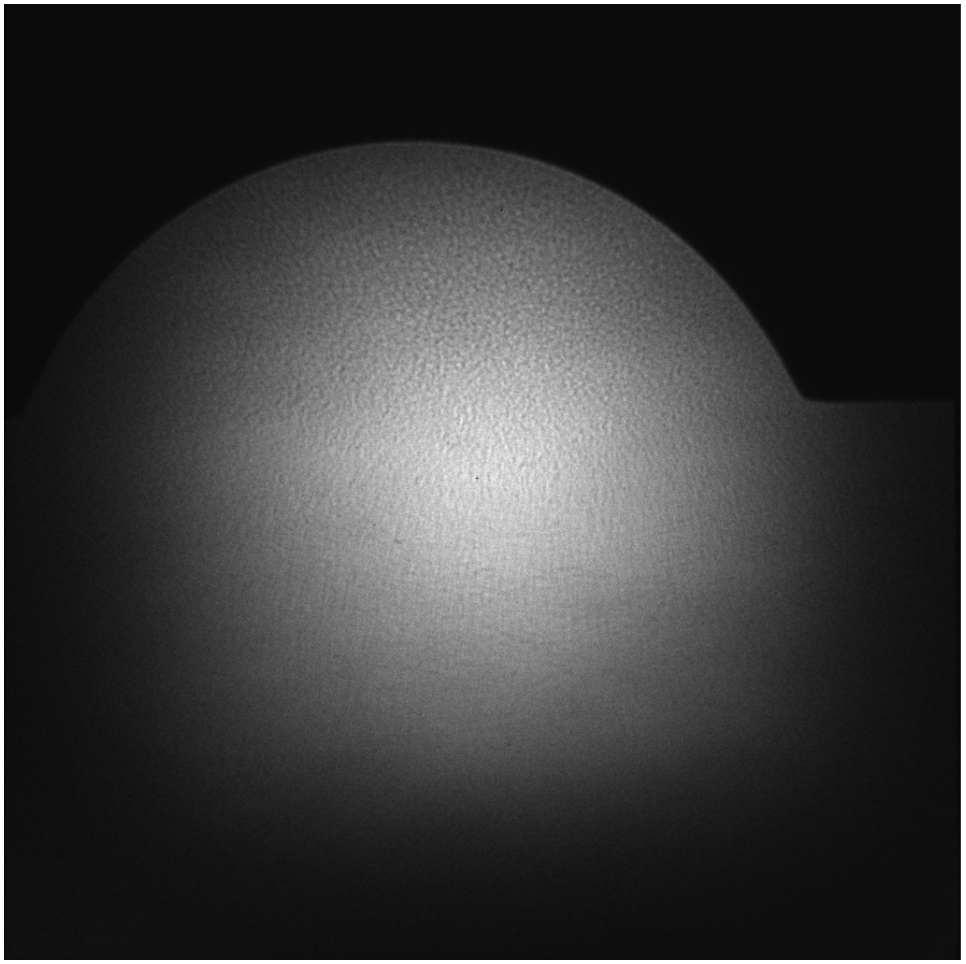
Uniformity

- Raster
  8 lines
  6 μm x 6 μm



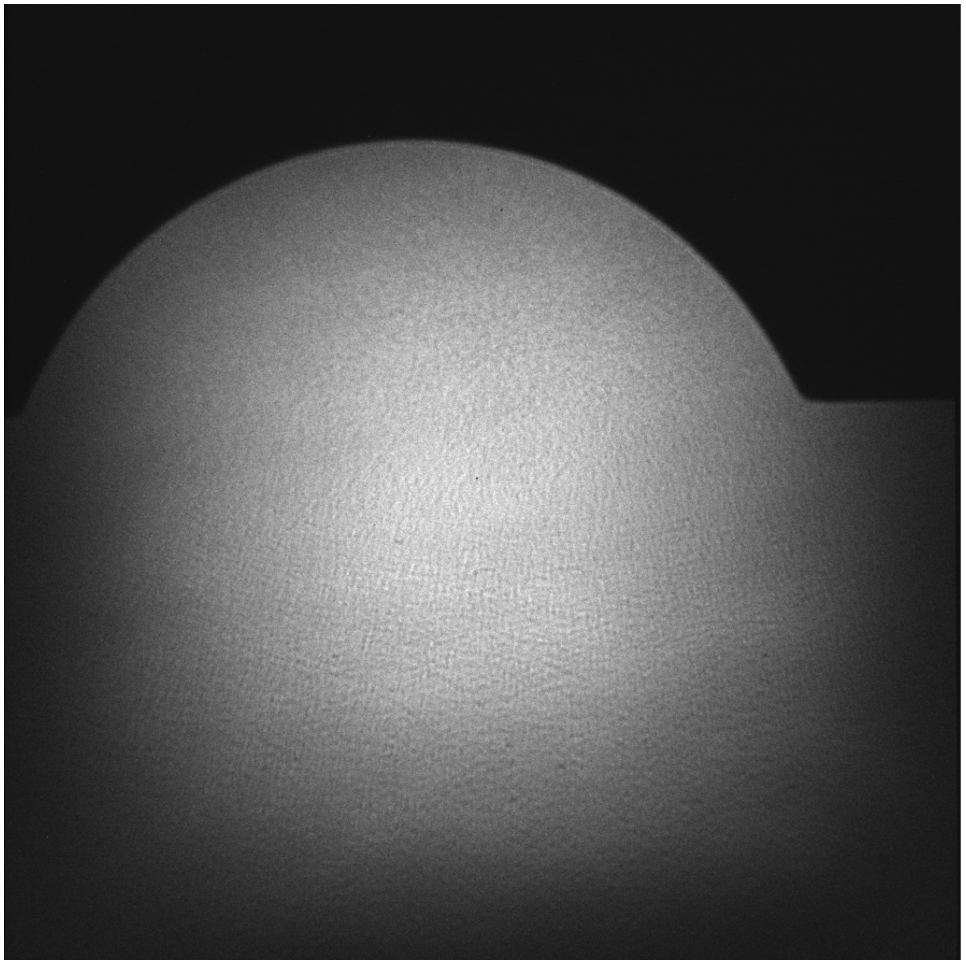
Uniformity

- Raster
  8 lines
  8 μm x 8 μm



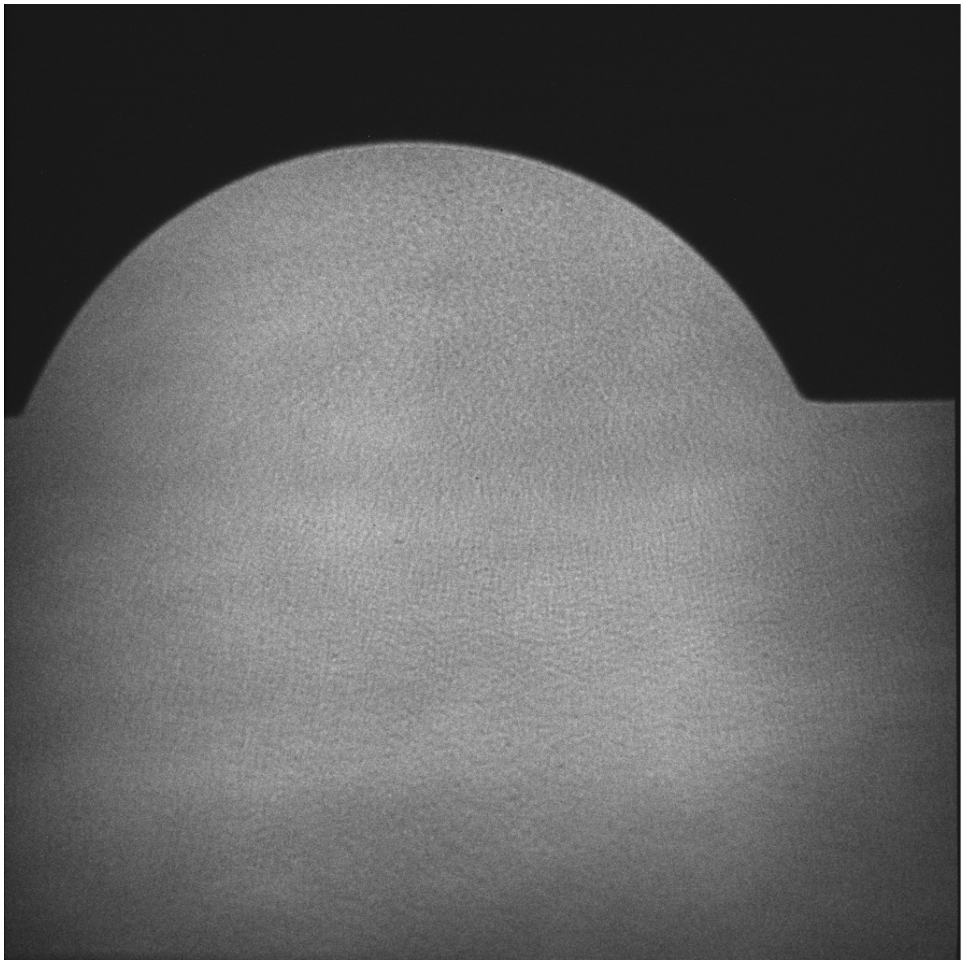
Uniformity

- Raster
  8 lines
  10 μm x 10 μm

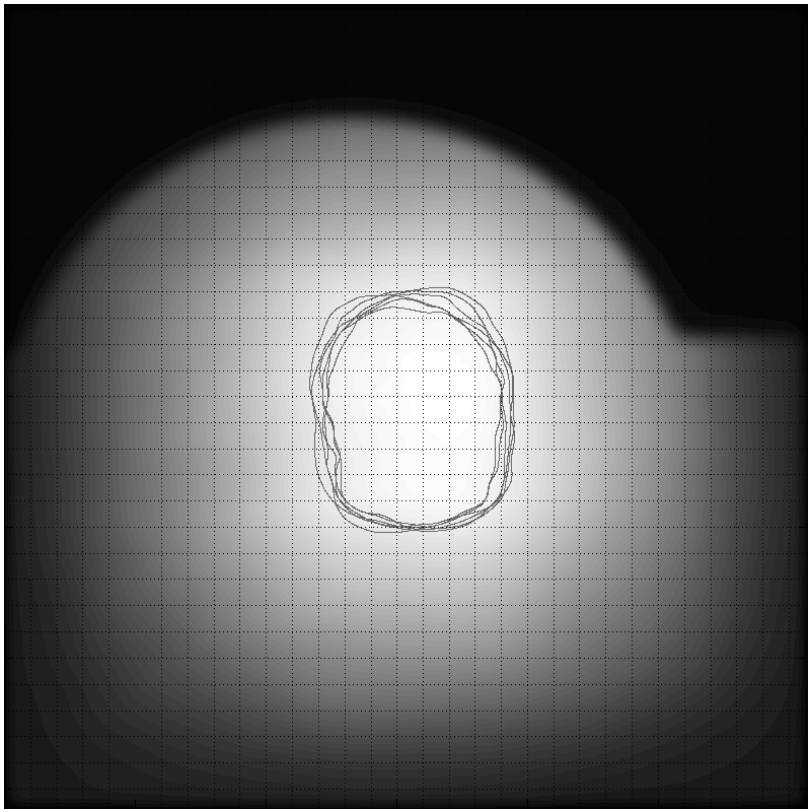


Uniformity

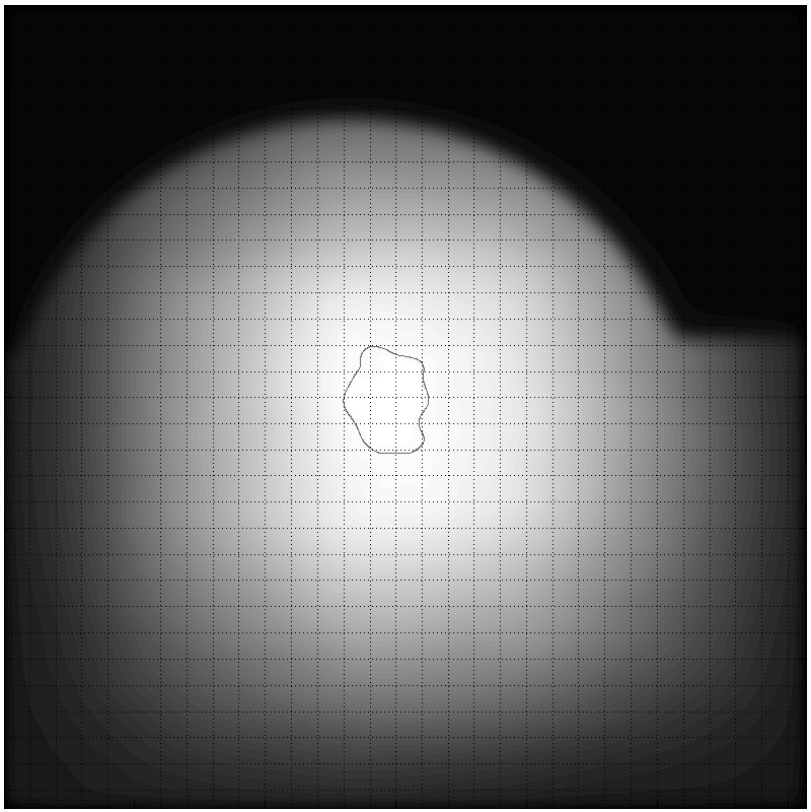
- Raster
  8 lines
  12 μm x 12 μm



Uniformity

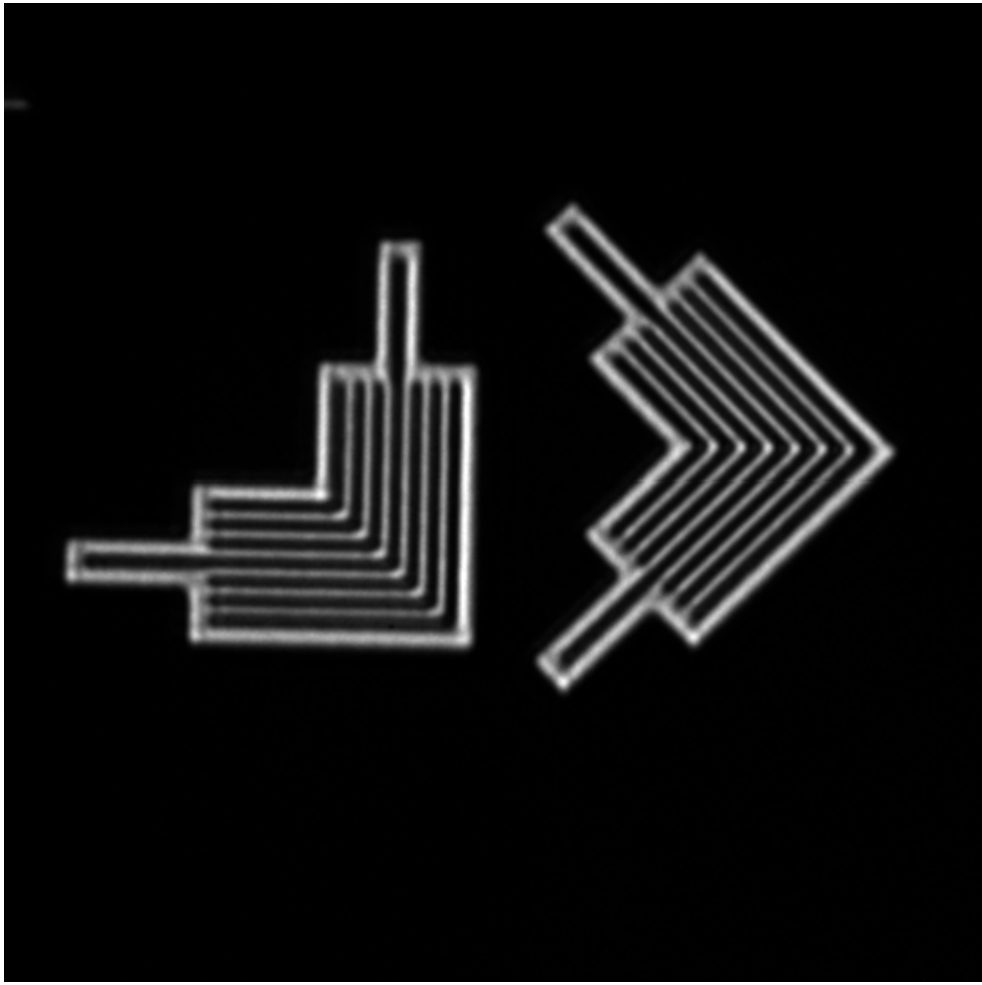


- 10% Uniformity region through-focus series



- 2% Uniformity region single image

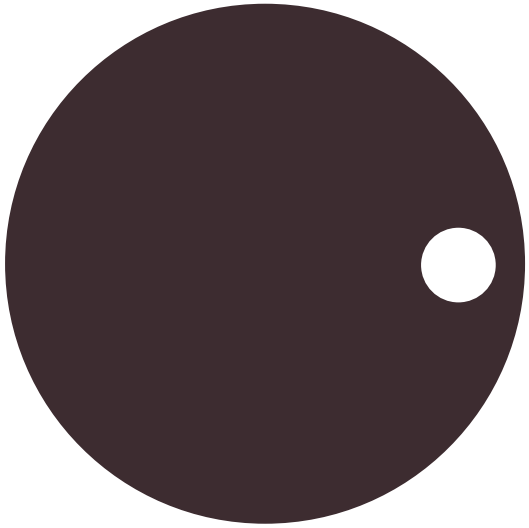
Pupil-fill

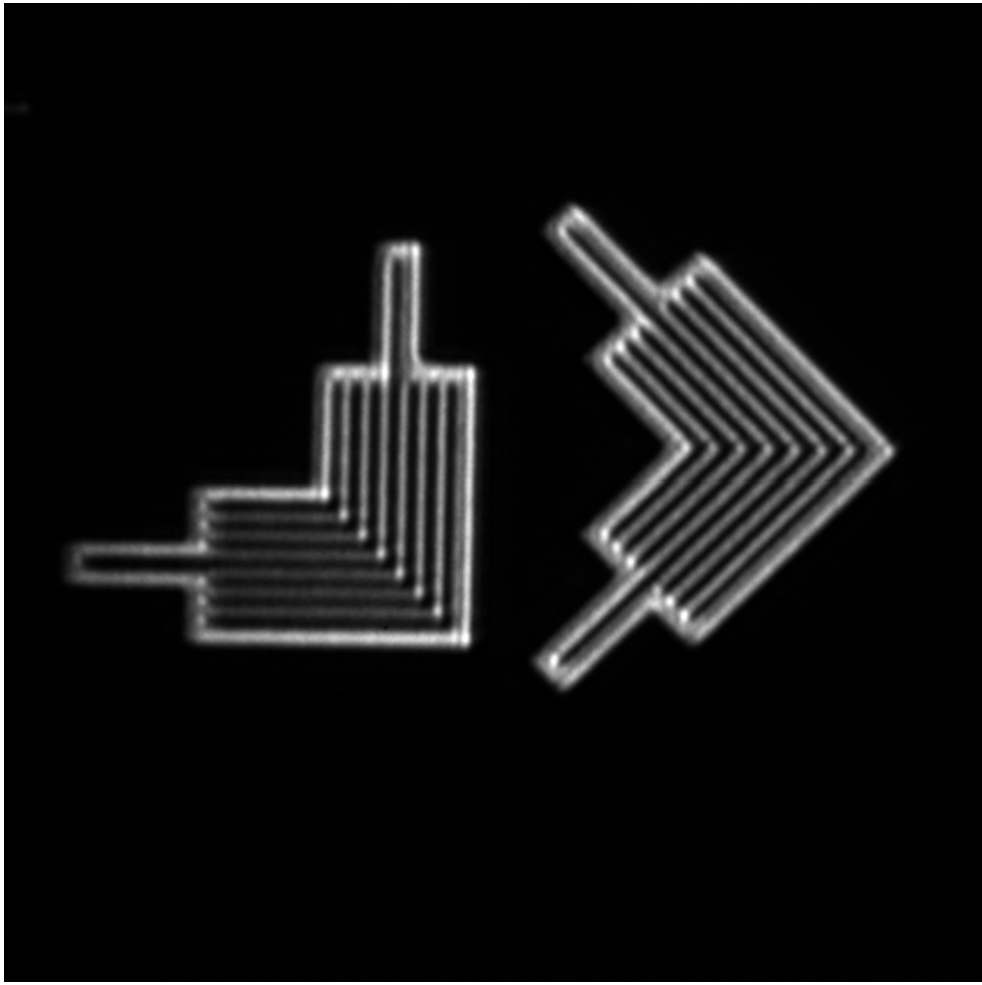


- 0.33 4xNA
- Ellbows,100-nm CD

Goldberg, *SPIE* **8880** (2013)

Pupil-fill





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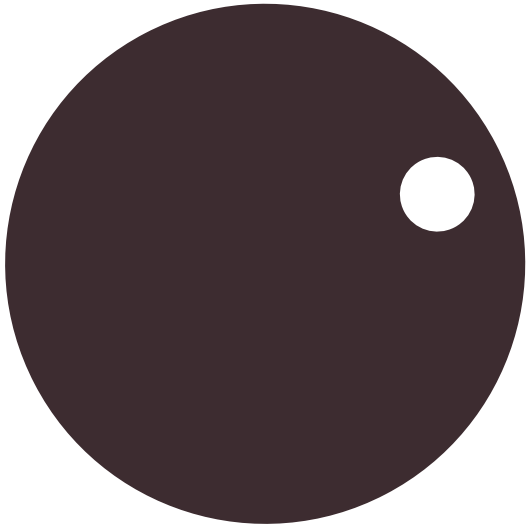

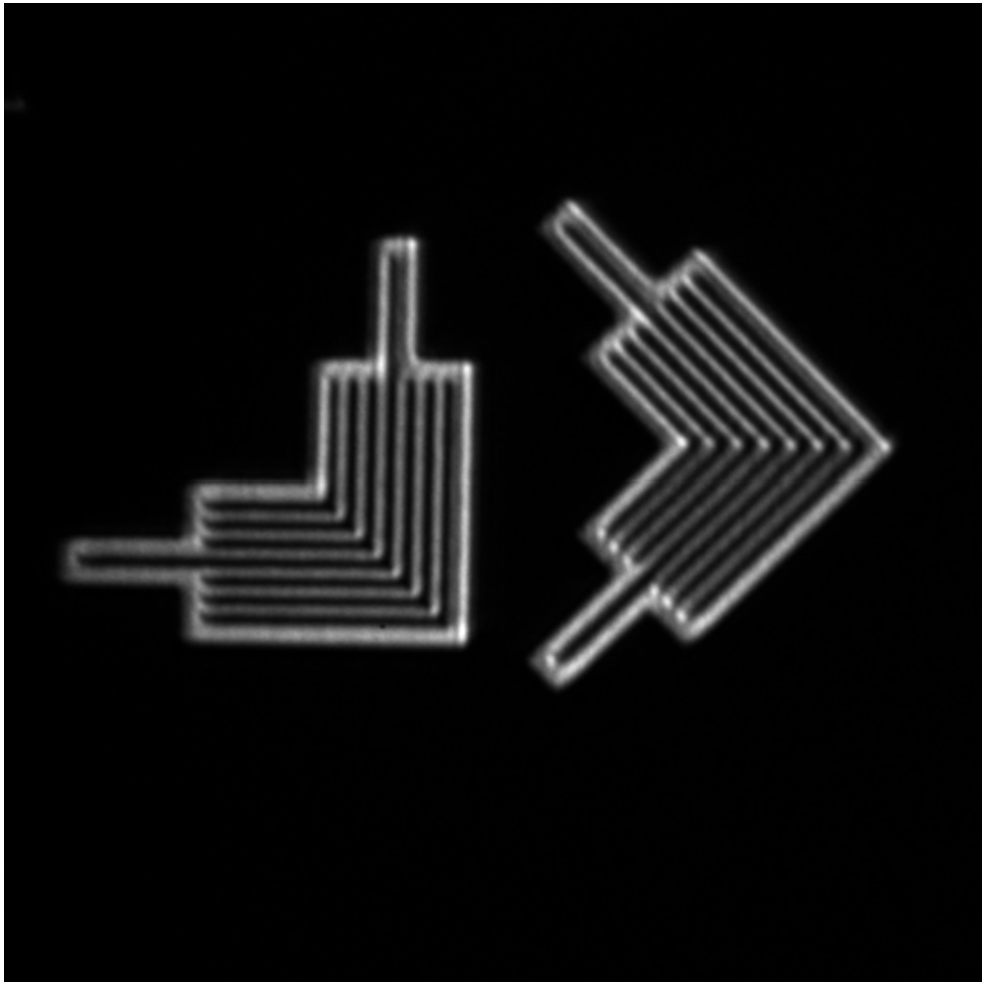

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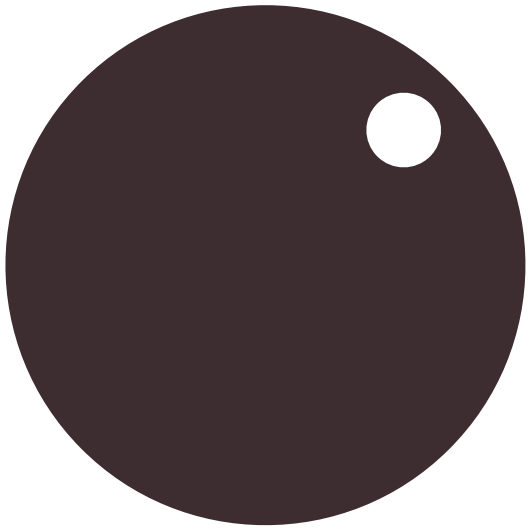

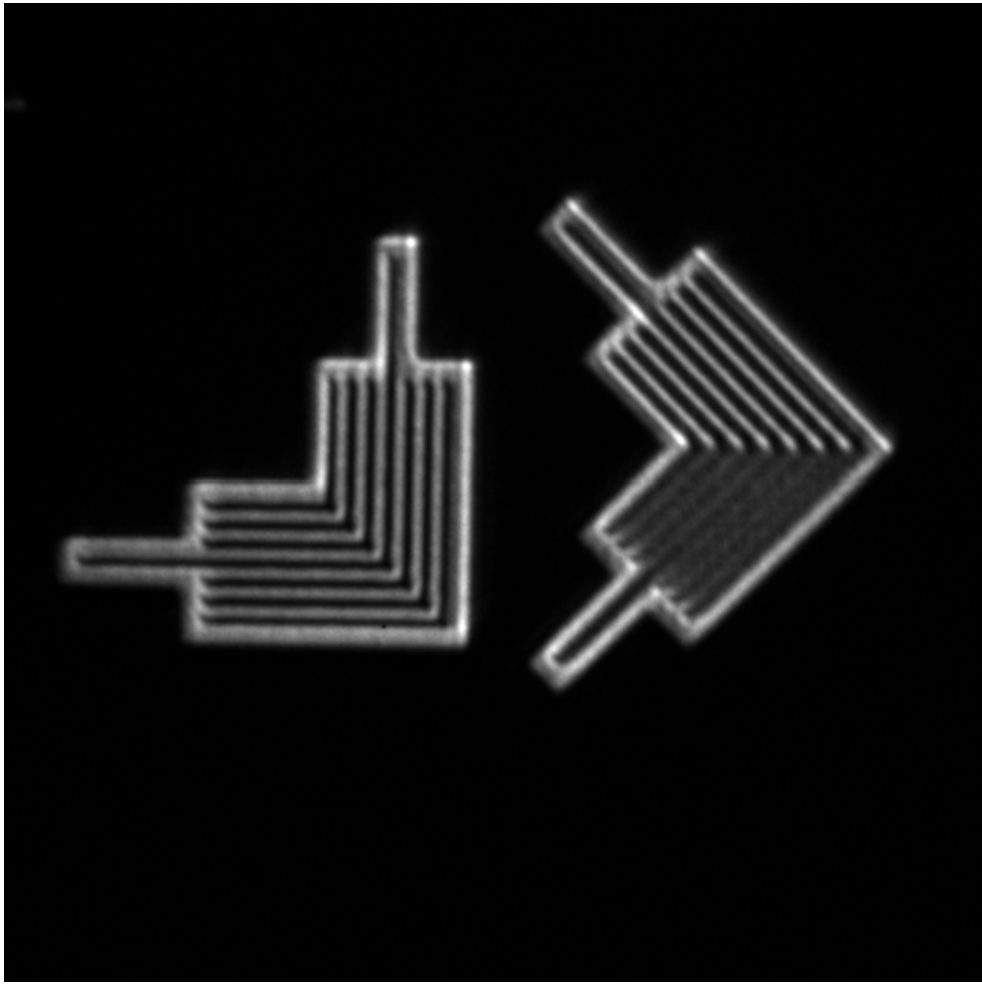

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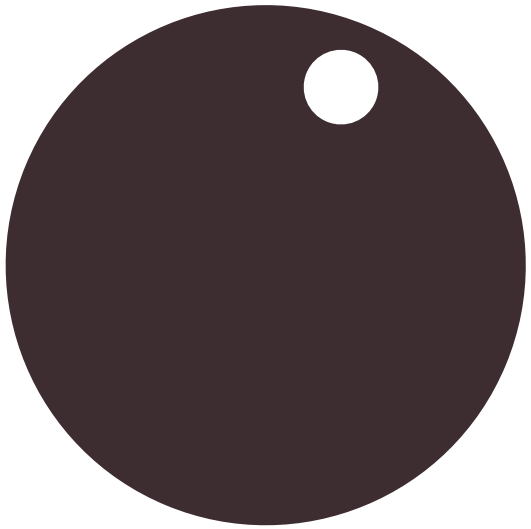
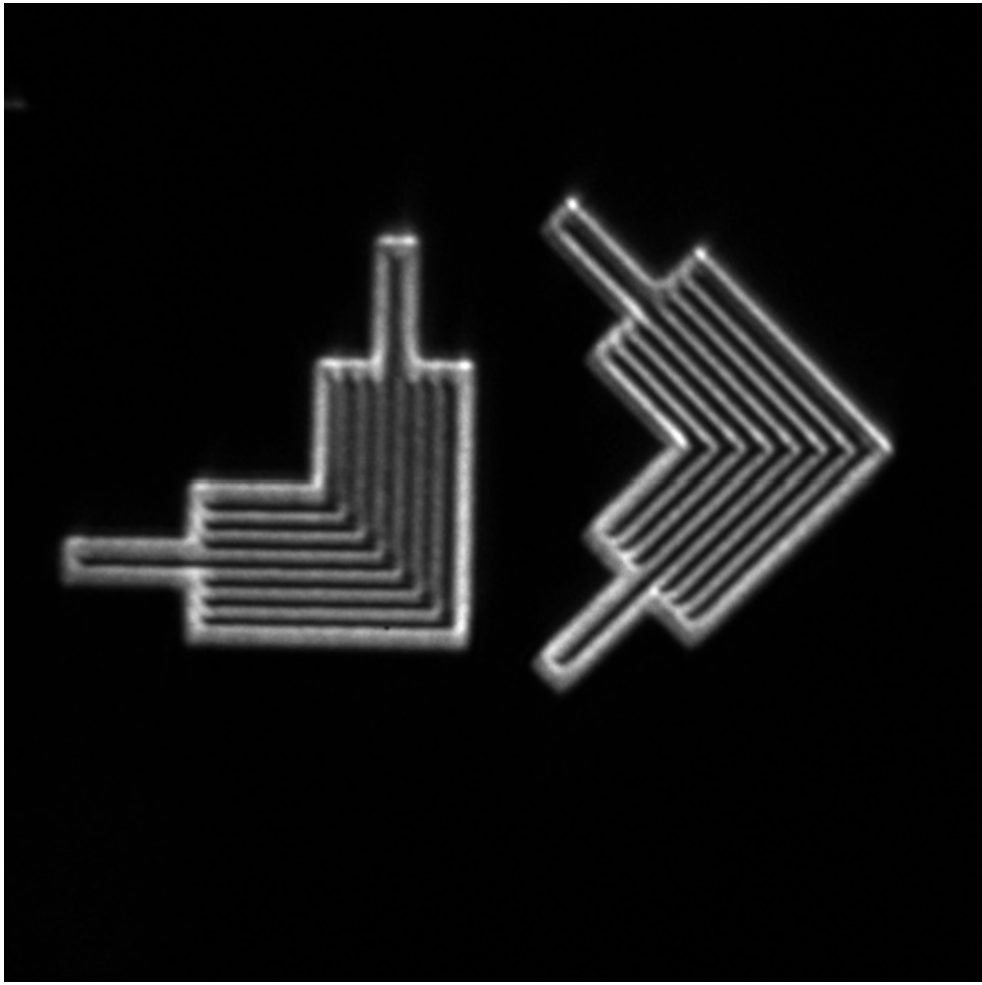
Pupil-fill





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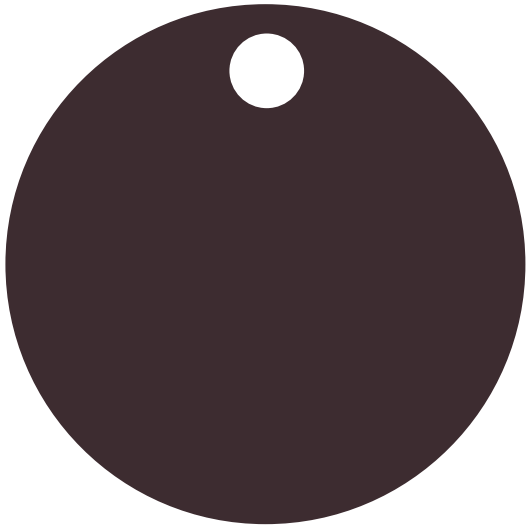
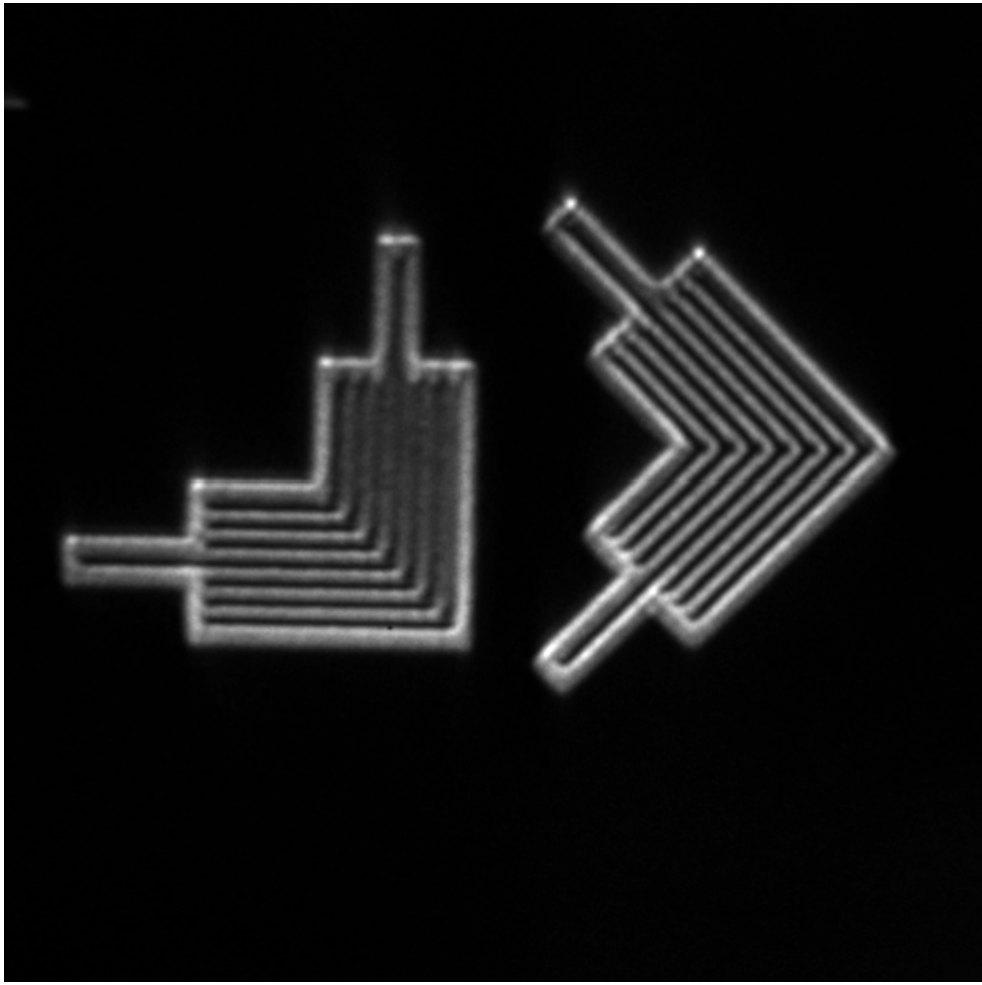
Pupil-fill





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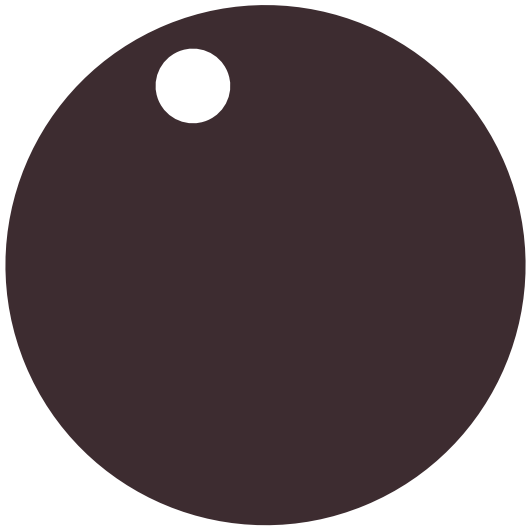
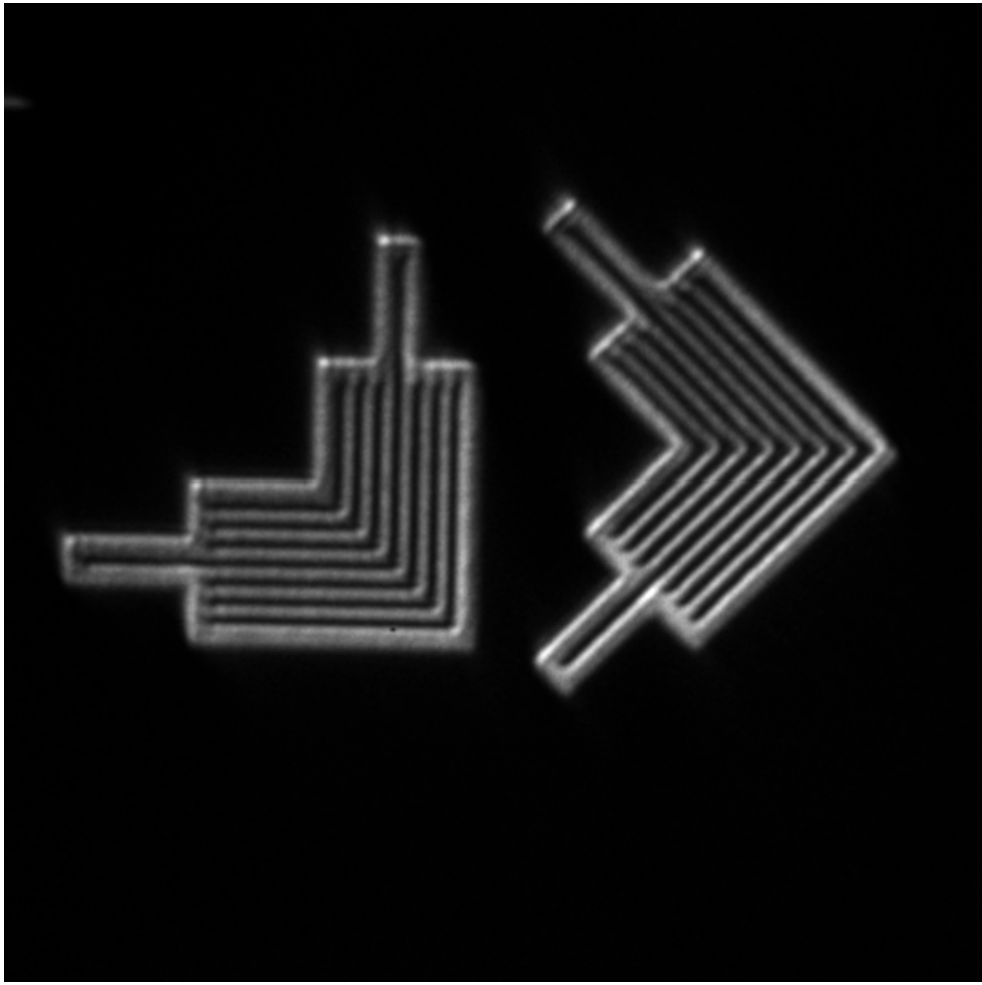
Pupil-fill





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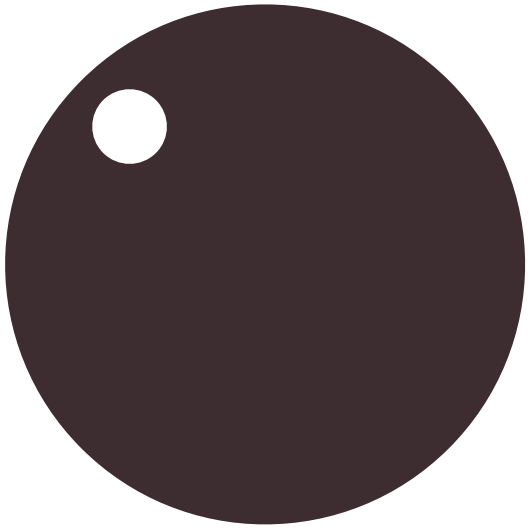
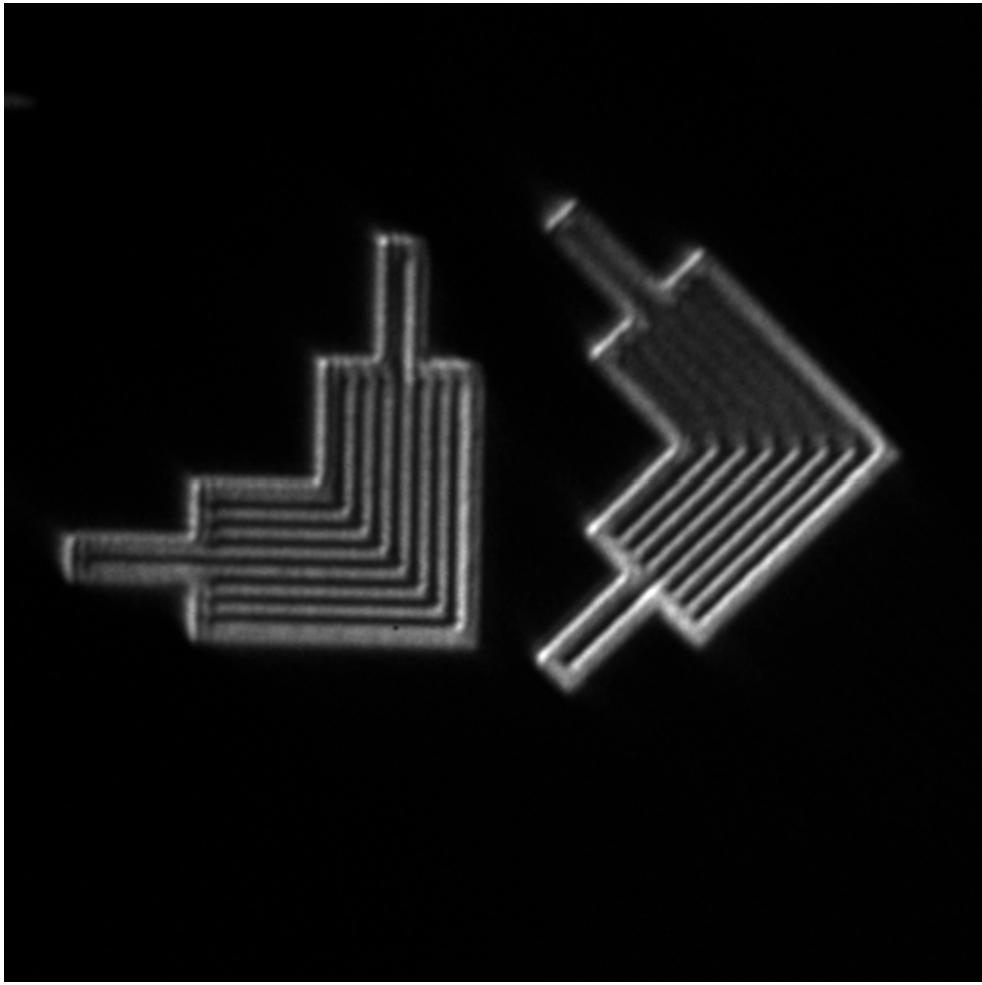
Pupil-fill





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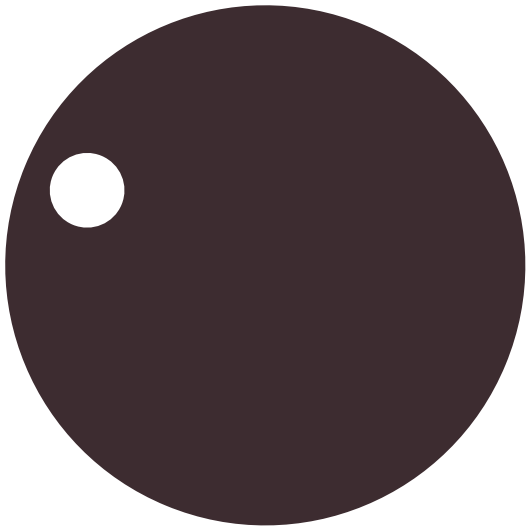
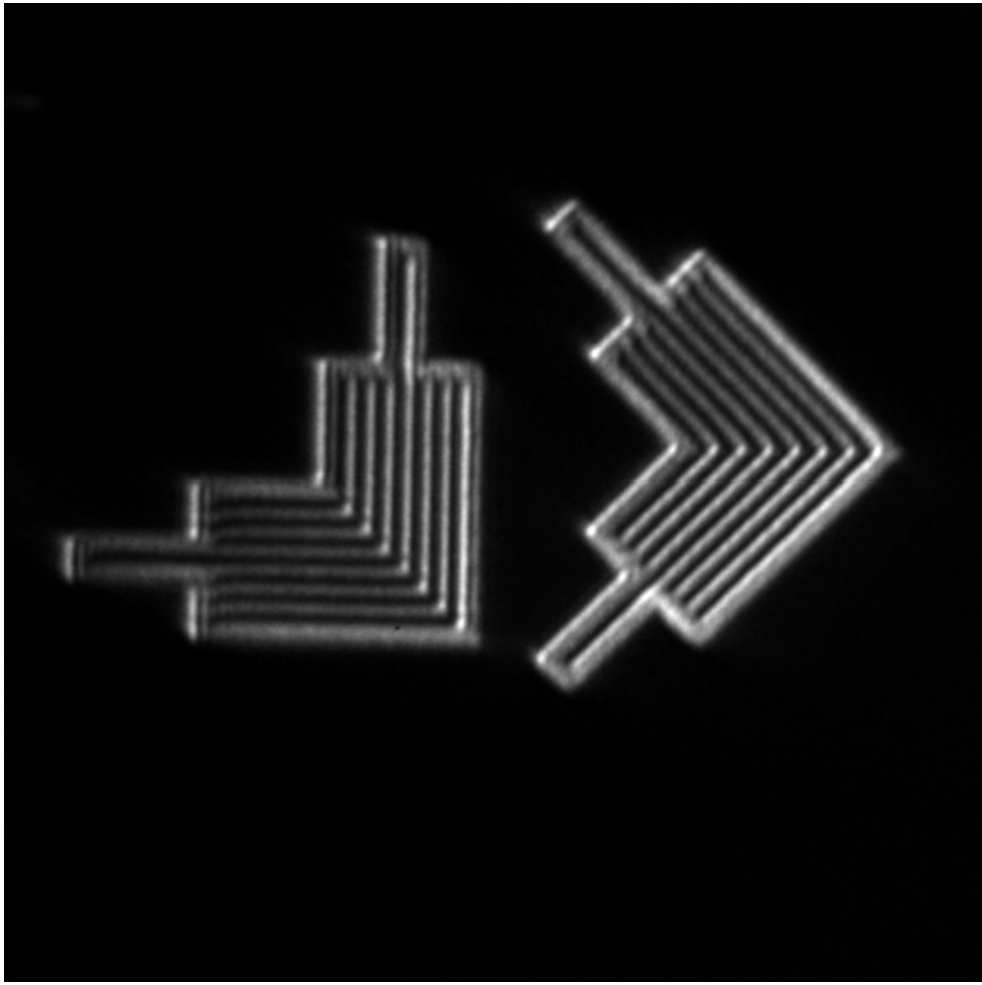
Pupil-fill

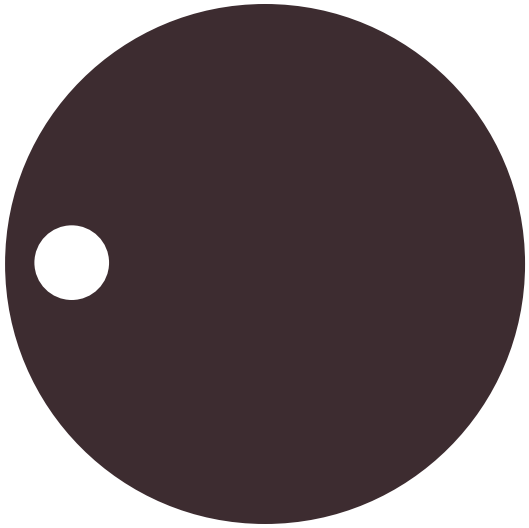


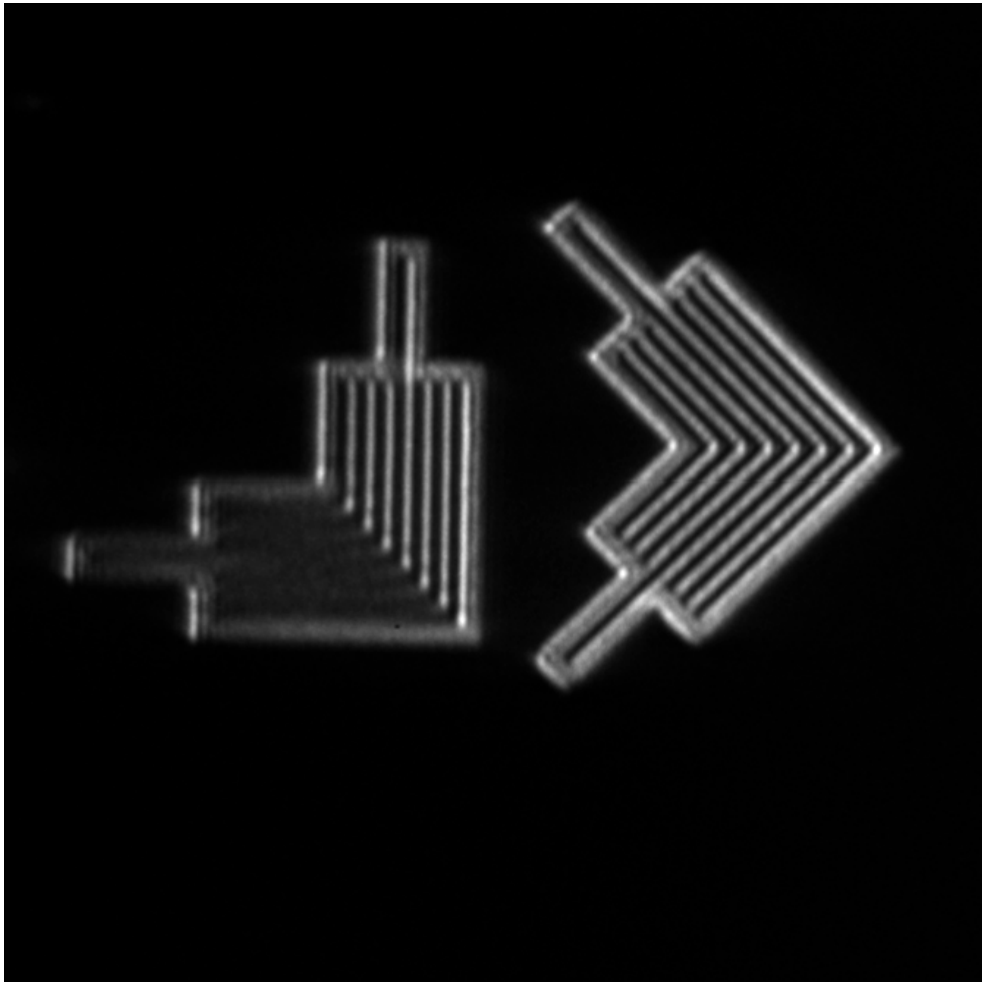


- 0.33 4xNA
- Ellbows,100-nm CD

Goldberg, *SPIE* **8880** (2013)

Pupil-fill

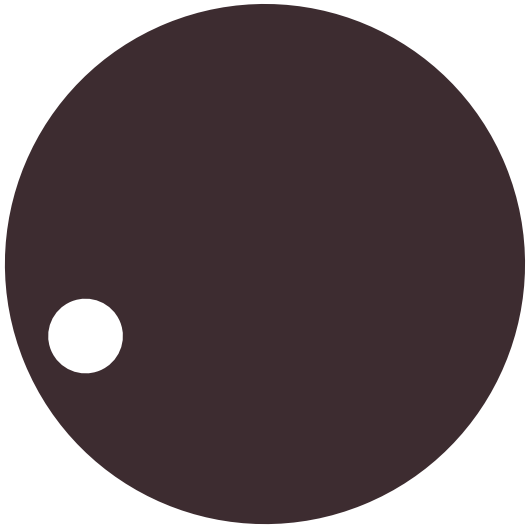


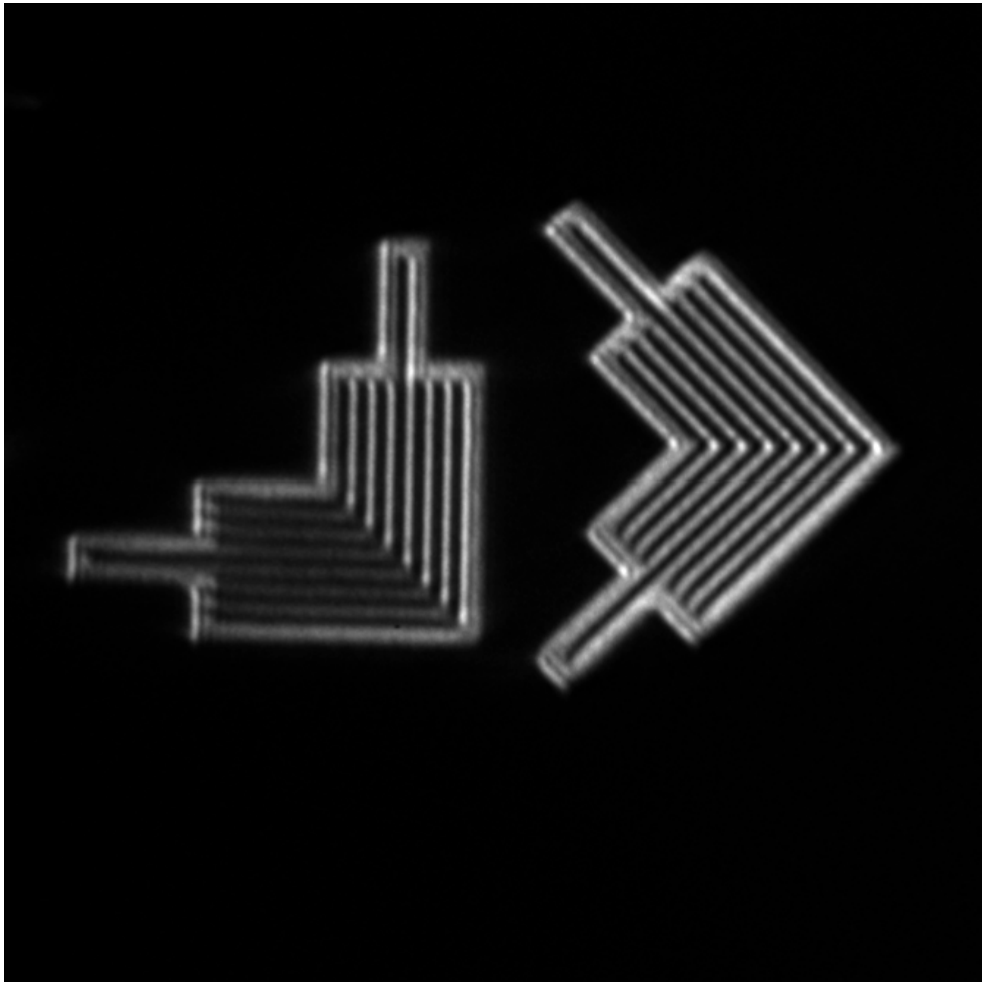


- 0.33 4xNA
- Ellbows,100-nm CD

Goldberg, *SPIE* **8880** (2013)

Pupil-fill

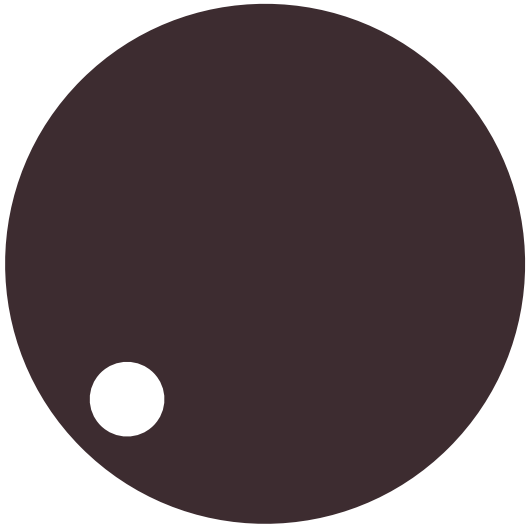


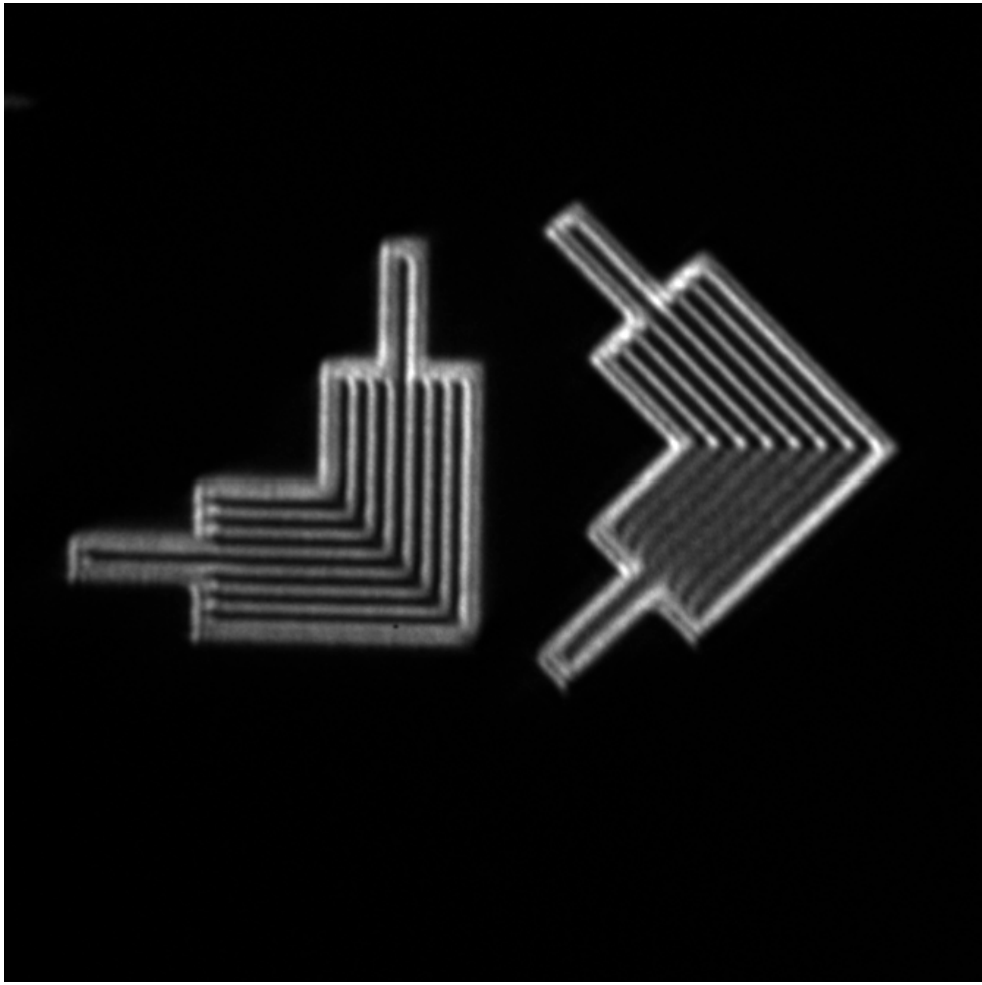


- 0.33 4xNA
- Ellbows,100-nm CD

Goldberg, *SPIE* **8880** (2013)

Pupil-fill

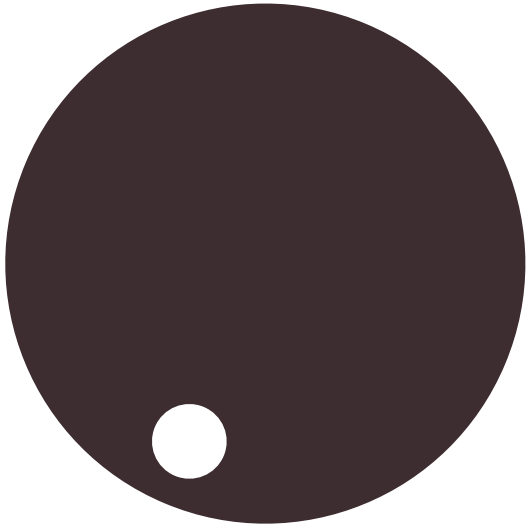


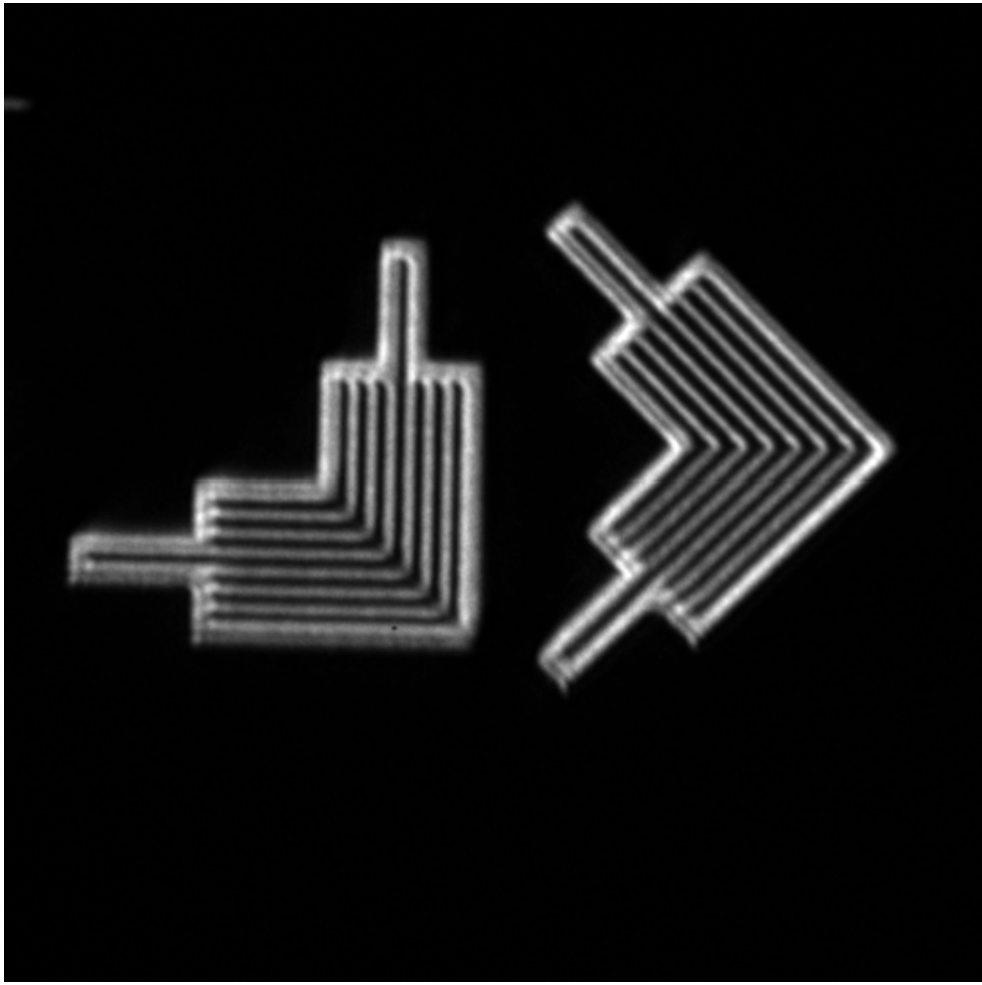


- 0.33 4xNA
- Ellbows,100-nm CD

Goldberg, *SPIE* **8880** (2013)

Pupil-fill

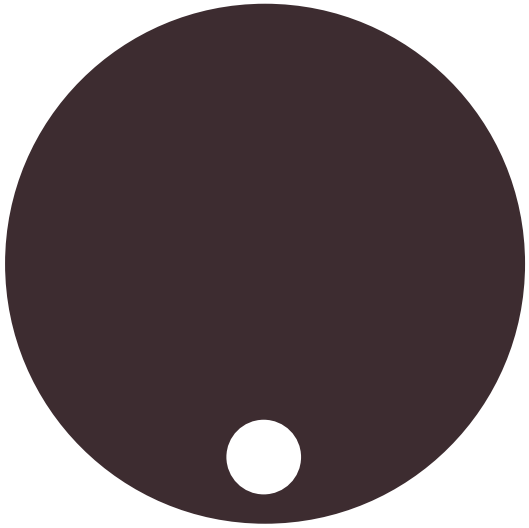


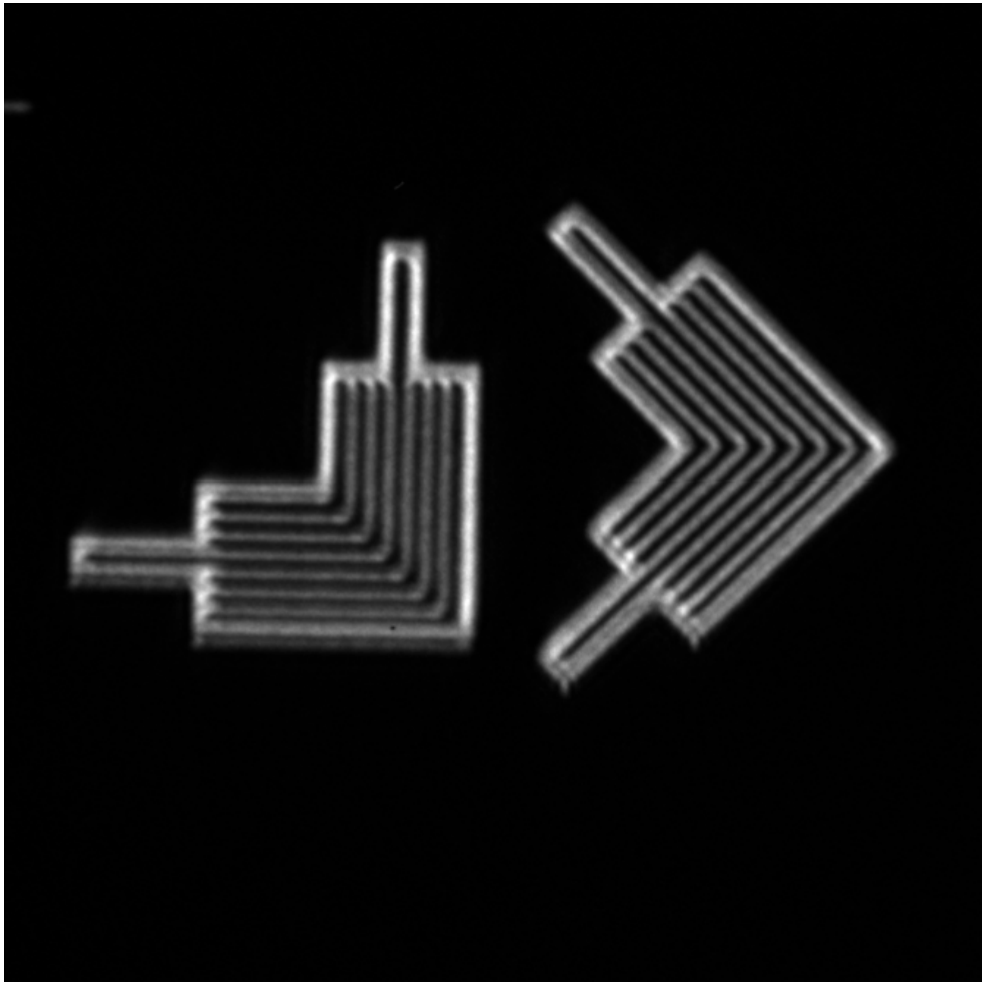


- 0.33 4xNA
- Ellbows,100-nm CD

Goldberg, *SPIE* **8880** (2013)

Pupil-fill

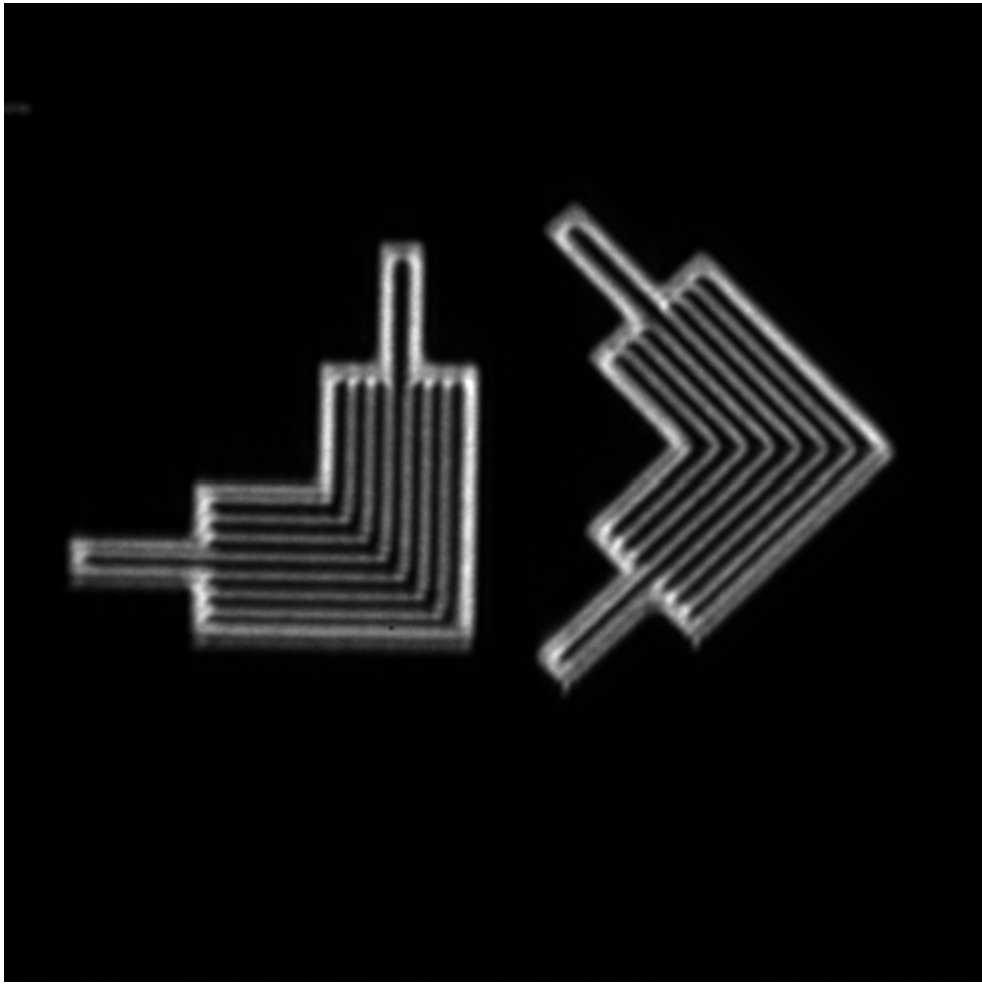




- 0.33 4xNA
- Ellbows,100-nm CD

Goldberg, *SPIE* **8880** (2013)

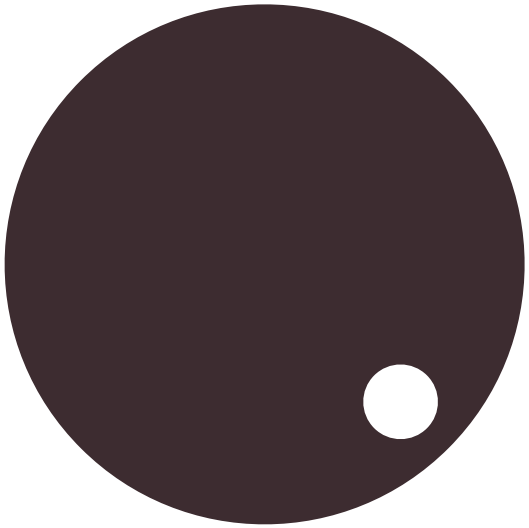
Pupil-fill



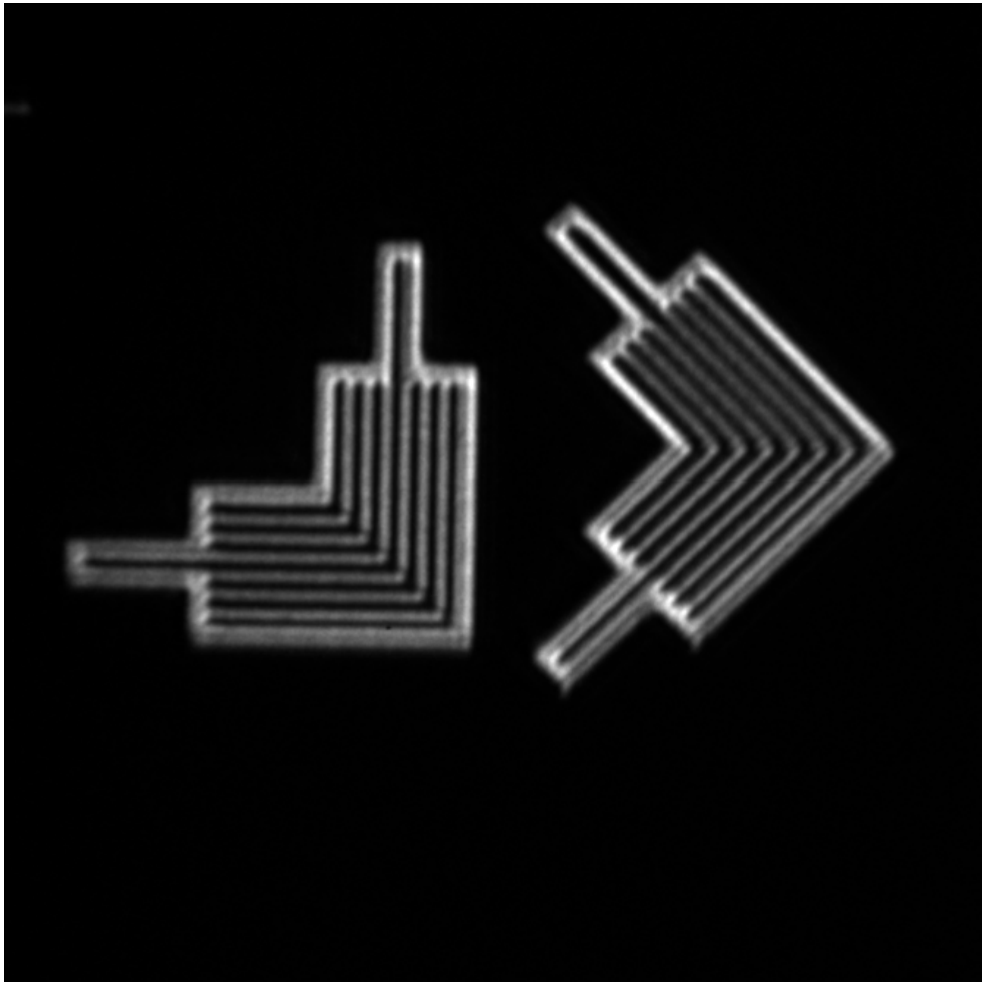
- 0.33 4xNA
- Ellbows,100-nm CD

Goldberg, *SPIE* **8880** (2013)

Pupil-fill



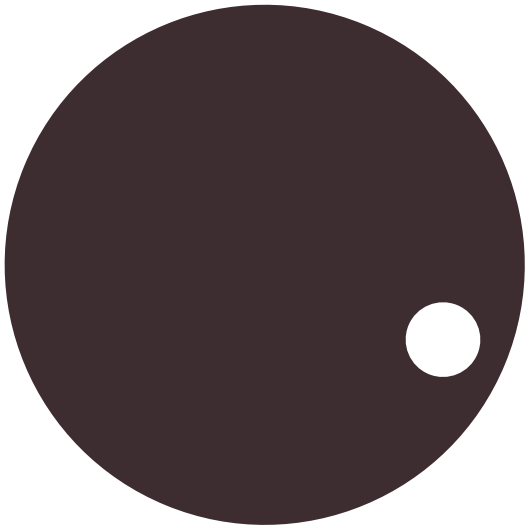
- 0.33 4xNA

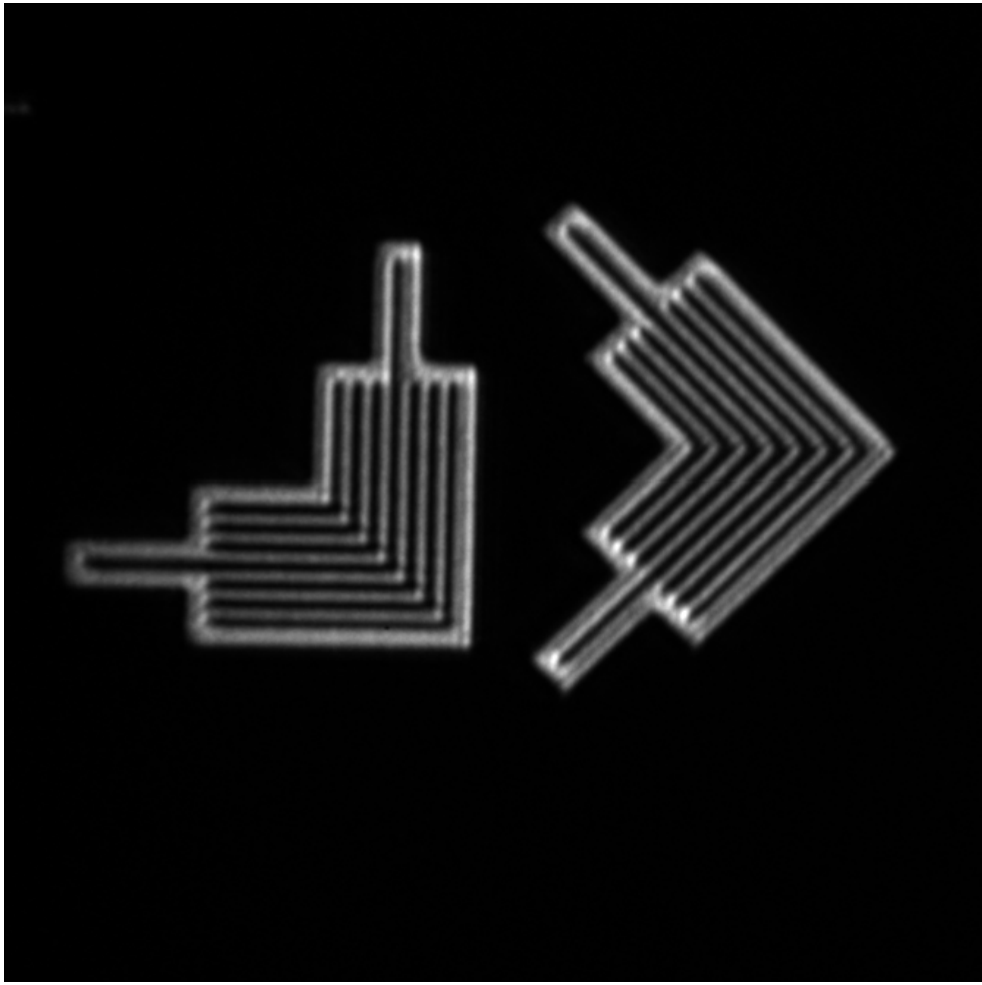


- Ellbows,100-nm CD

Goldberg, *SPIE* **8880** (2013)

Pupil-fill

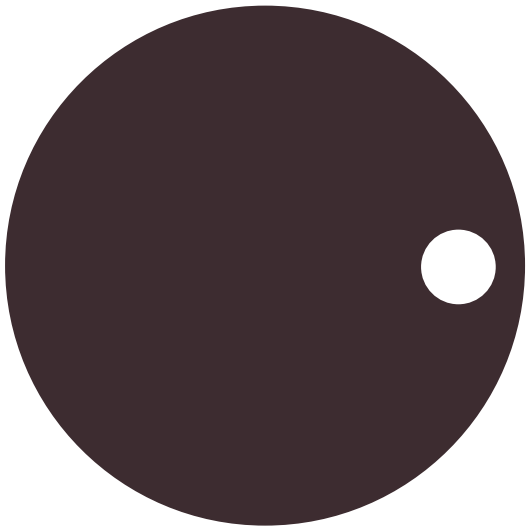


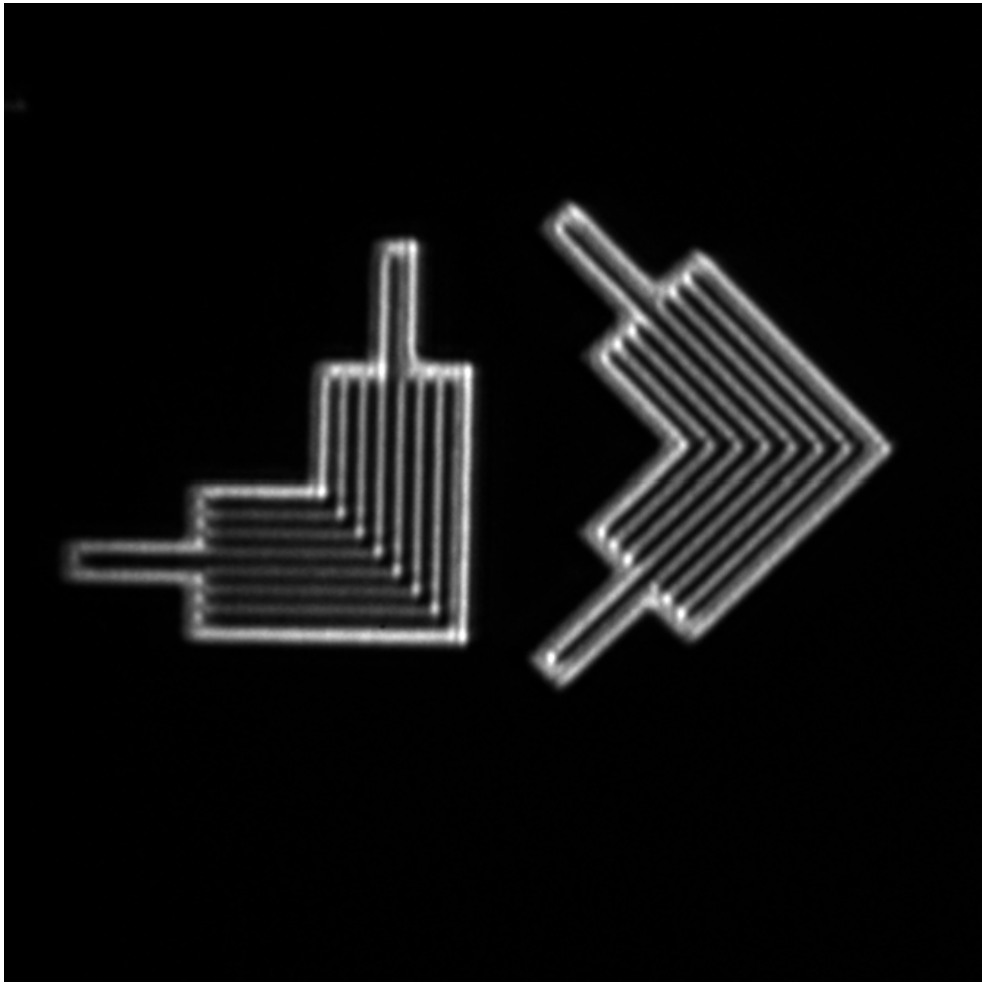


- 0.33 4xNA
- Ellbows,100-nm CD

Goldberg, *SPIE* **8880** (2013)

Pupil-fill

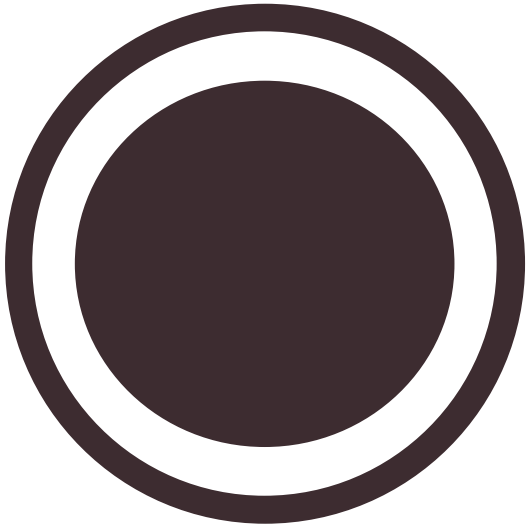


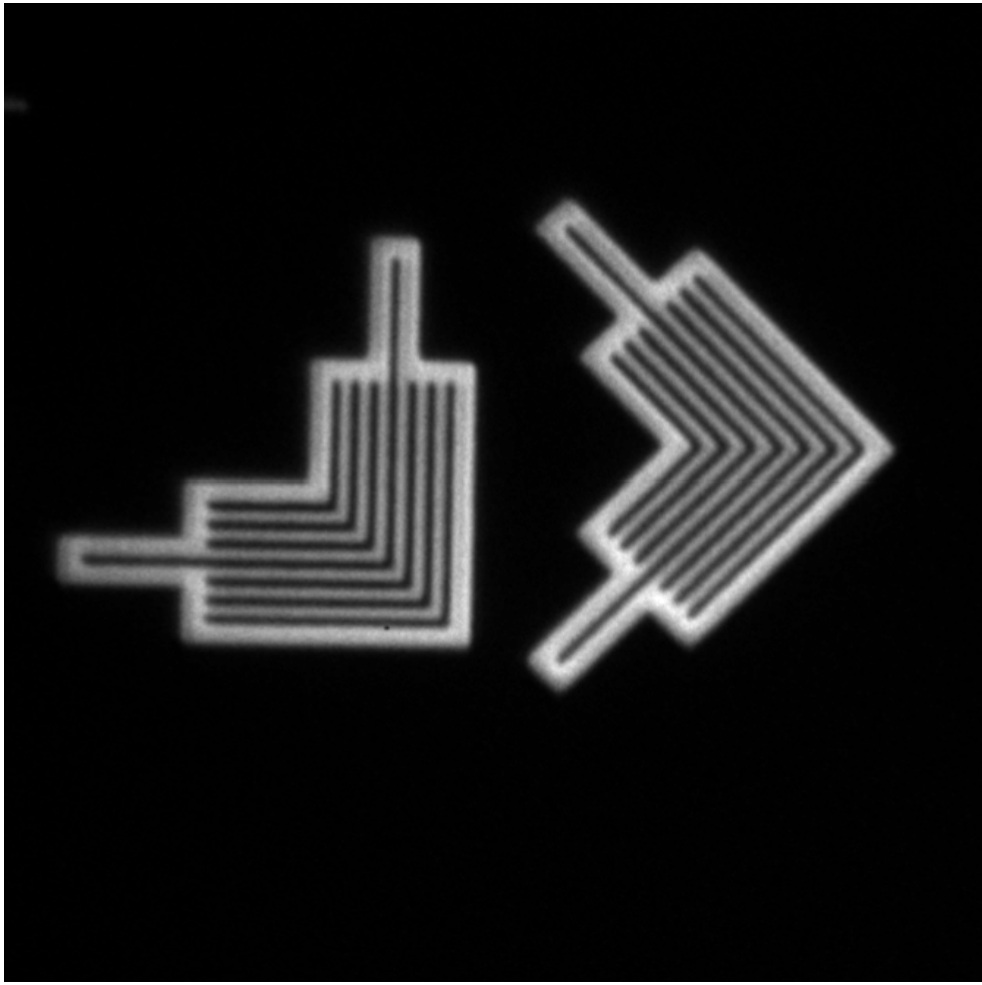


- 0.33 4xNA
- Ellbows,100-nm CD

Goldberg, *SPIE* **8880** (2013)

Pupil-fill



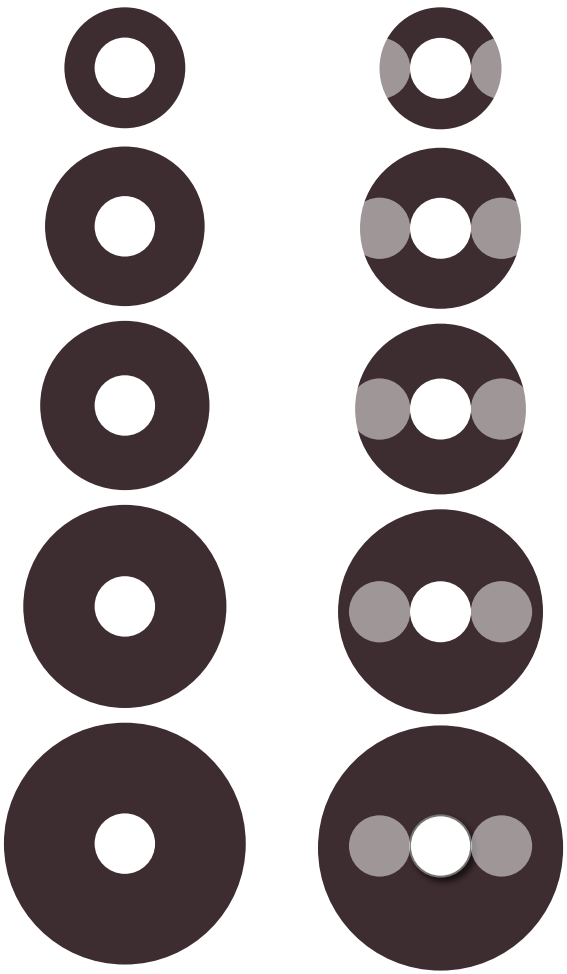


- 0.33 4xNA
- Ellbows,100-nm CD

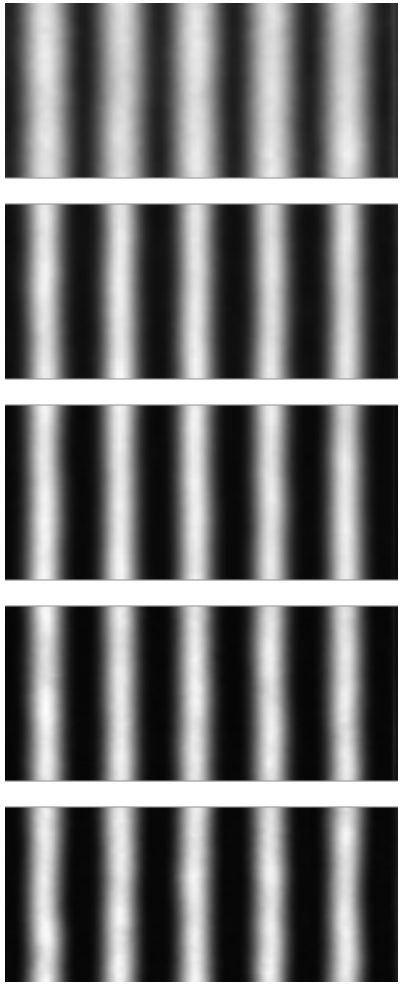
Goldberg, *SPIE* **8880** (2013)

Numerical Aperture

4xNA	σ
0.25	0.50
0.33	0.38
0.35	0.36
0.42	0.30
0.50	0.25

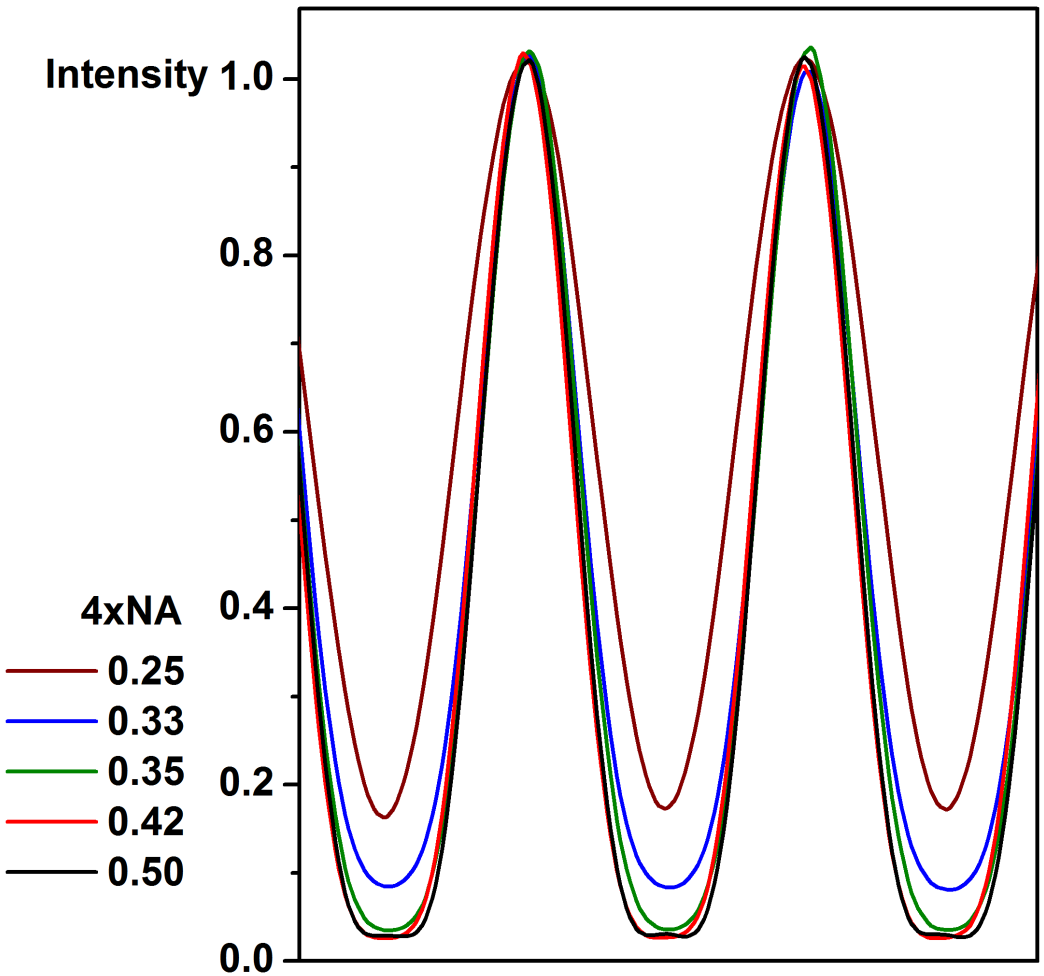


110-nm CD

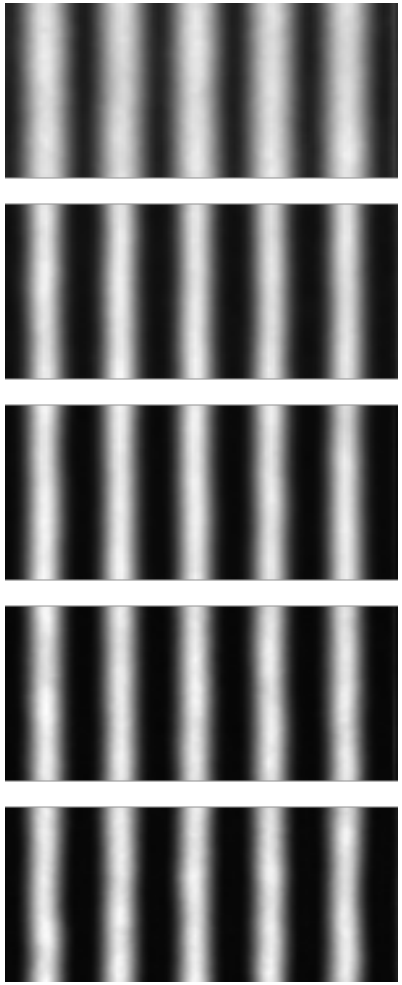


Goldberg, *SPIE* **8880** (2013)

Numerical Aperture

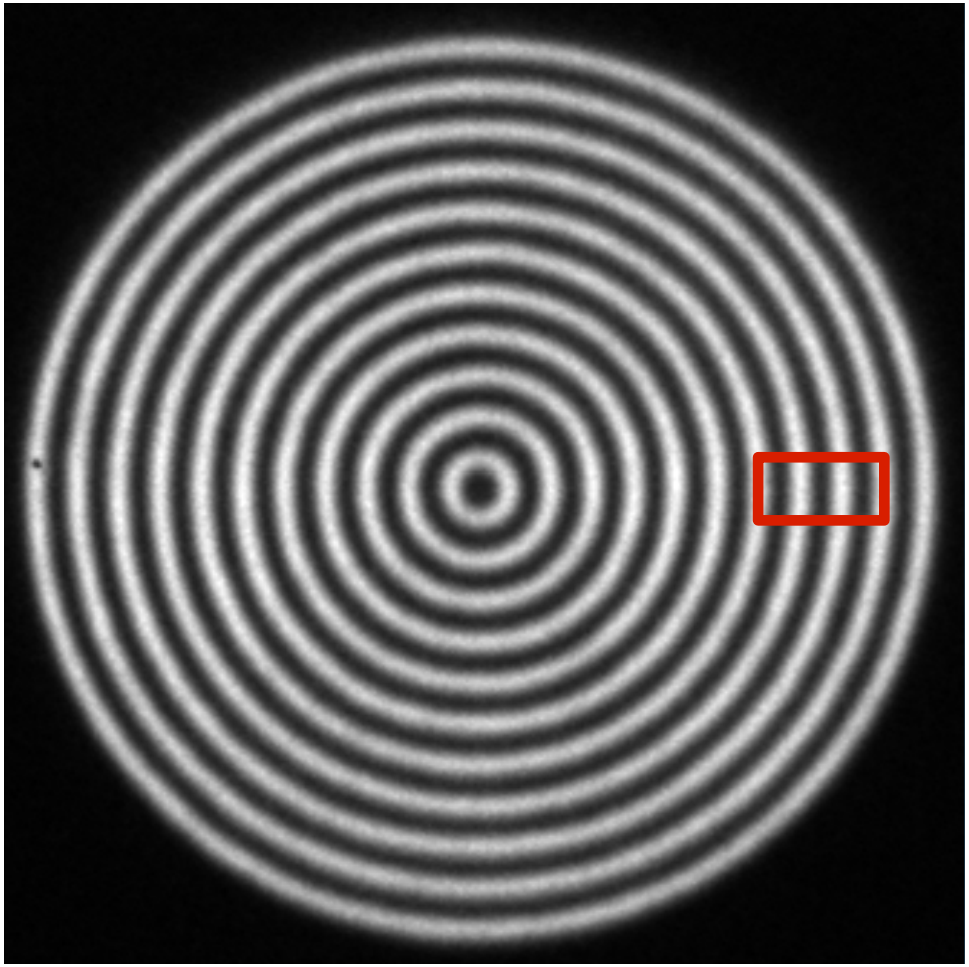


110-nm CD

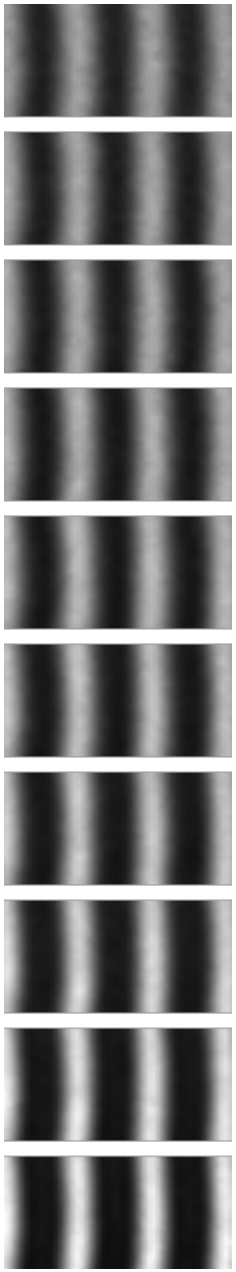


Goldberg, *SPIE* **8880** (2013)

Illumination Coherence



110-nm CD 0.33 4xNA



1.0

0.7

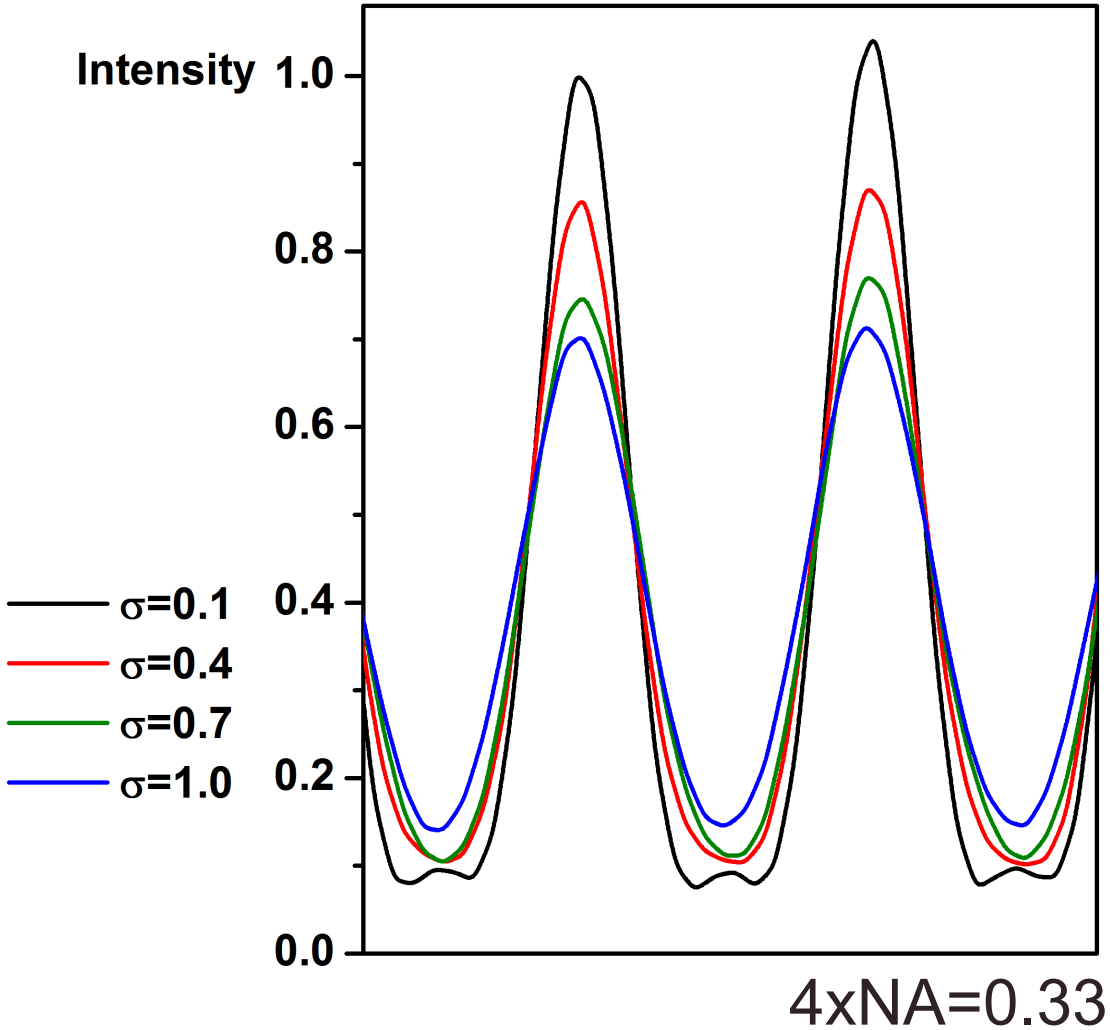
0.4

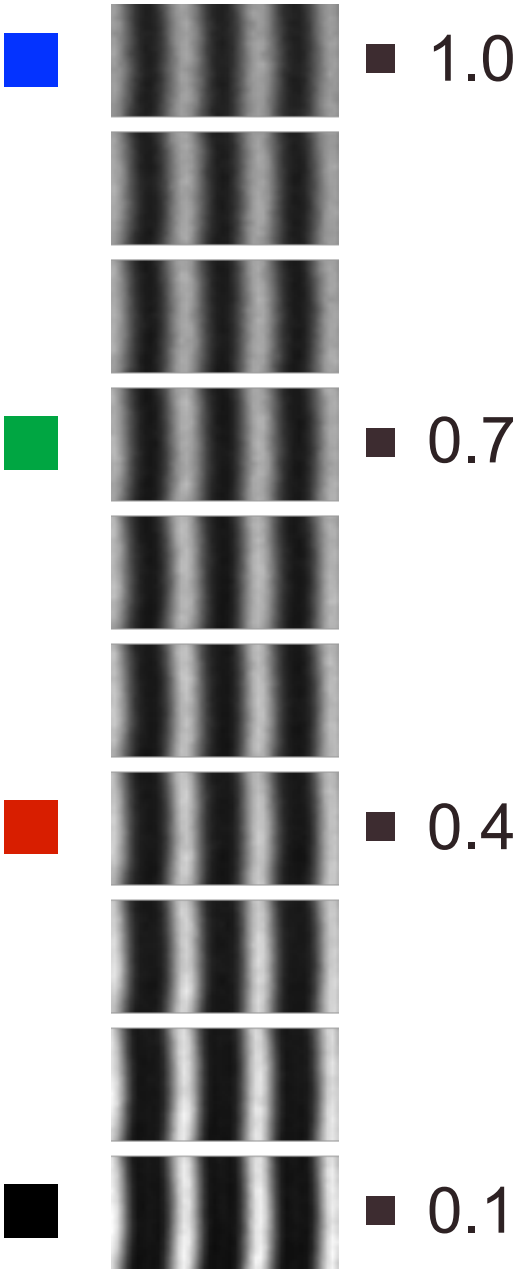
0.1

σ

Goldberg, *SPIE* **8880** (2013)

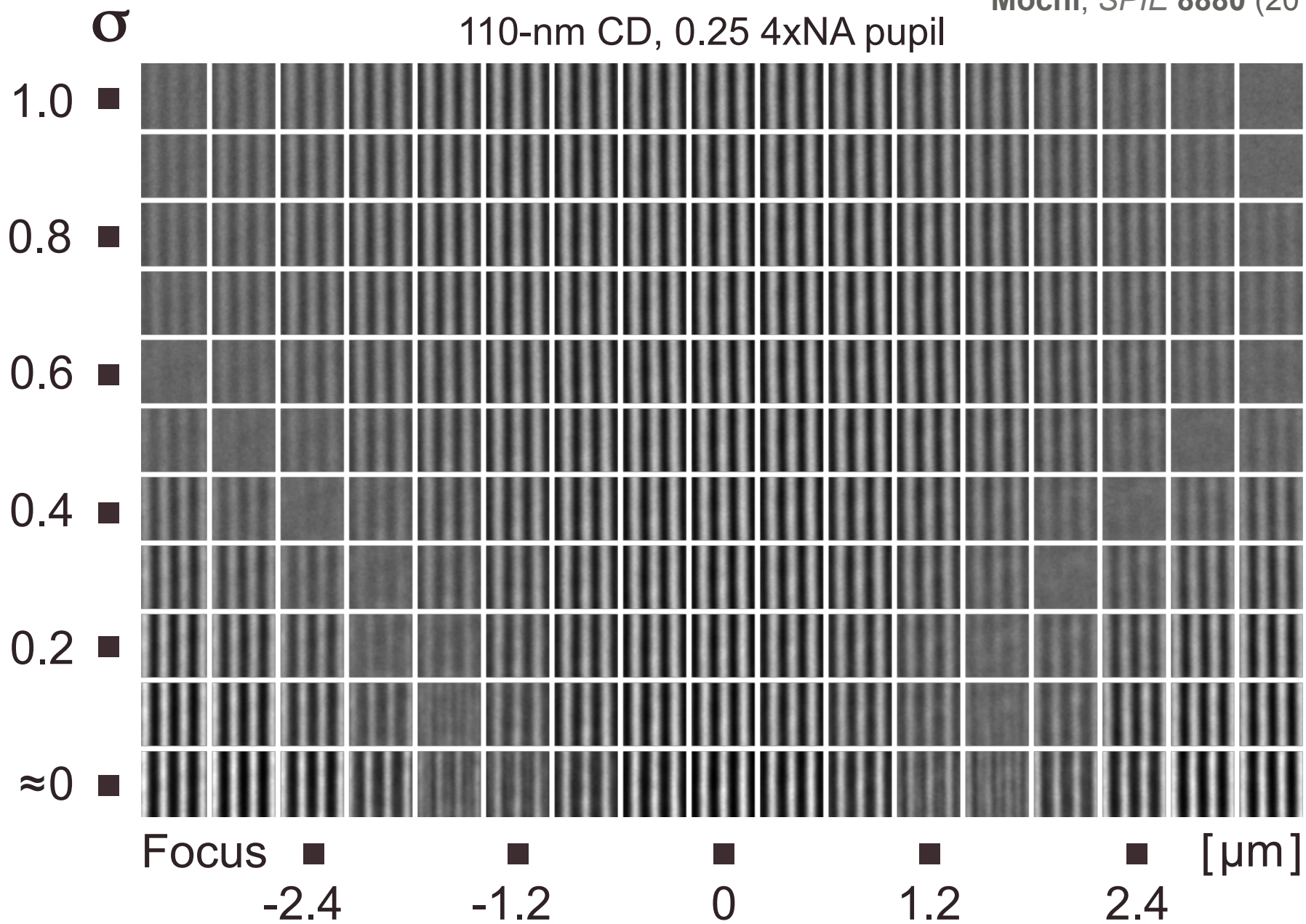
Illumination Coherence





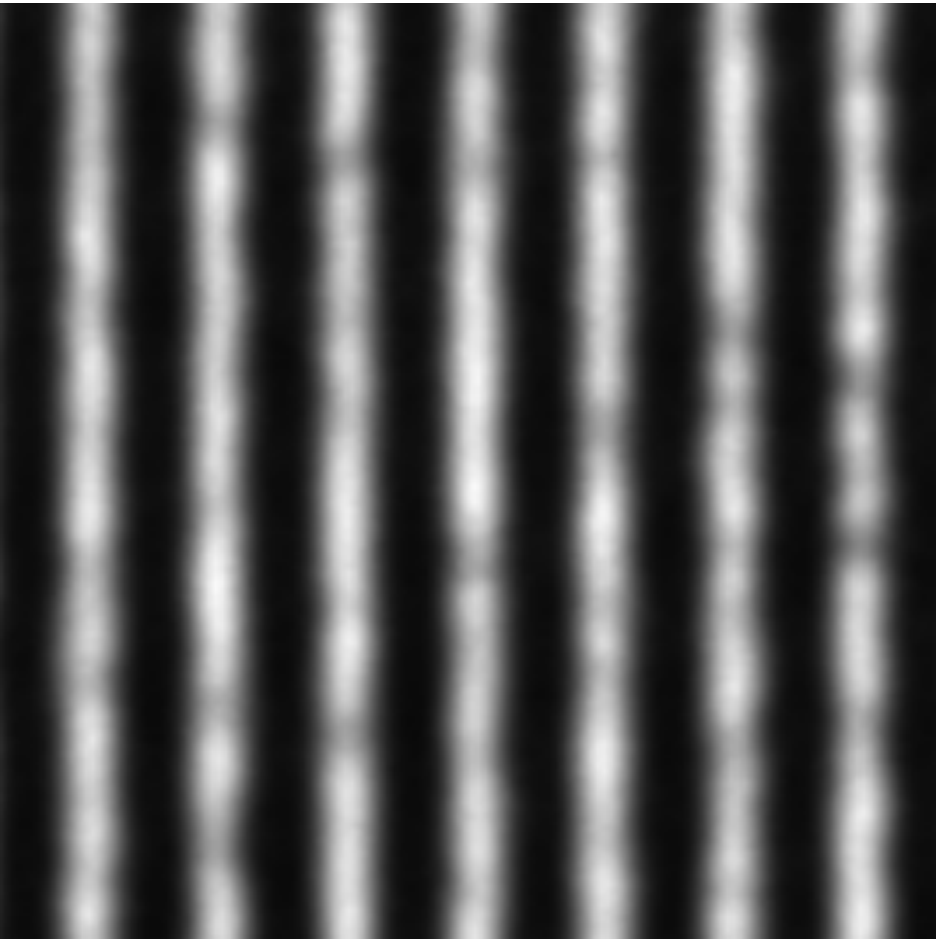
Goldberg, *SPIE* **8880** (2013)

Mochi, *SPIE* **8880** (2013)

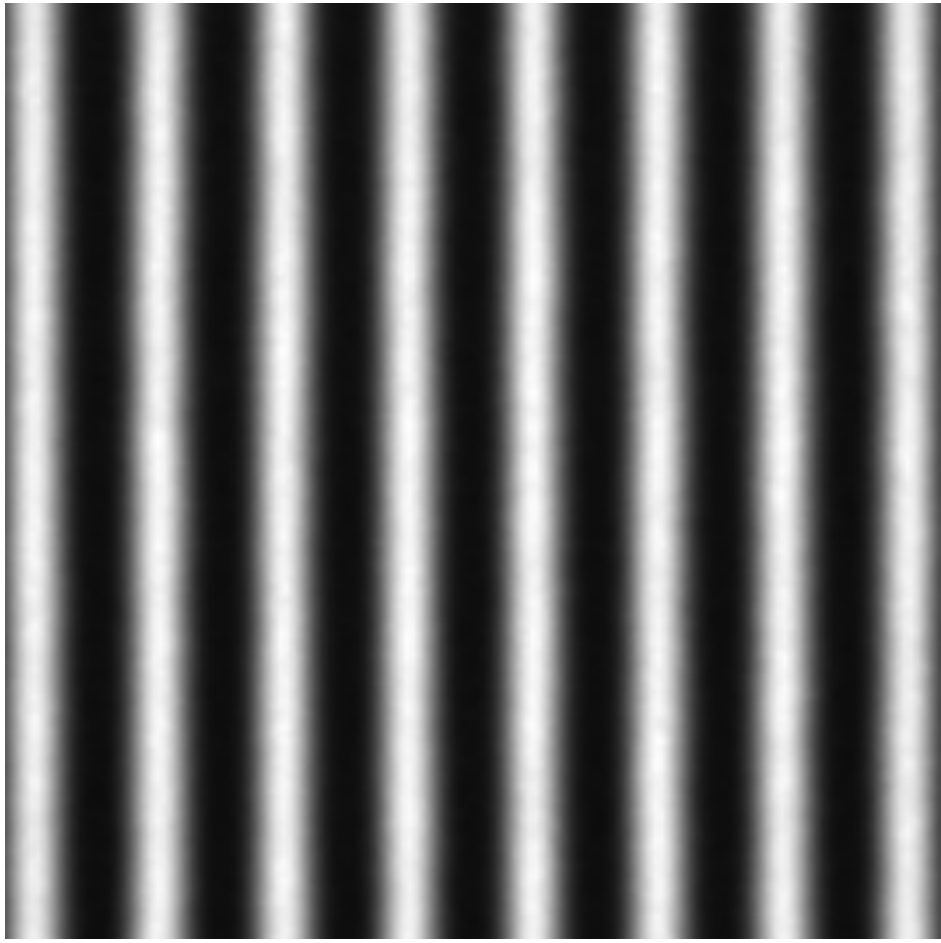


Goldberg, *SPIE* **8880** (2013)

Line-Width Roughness



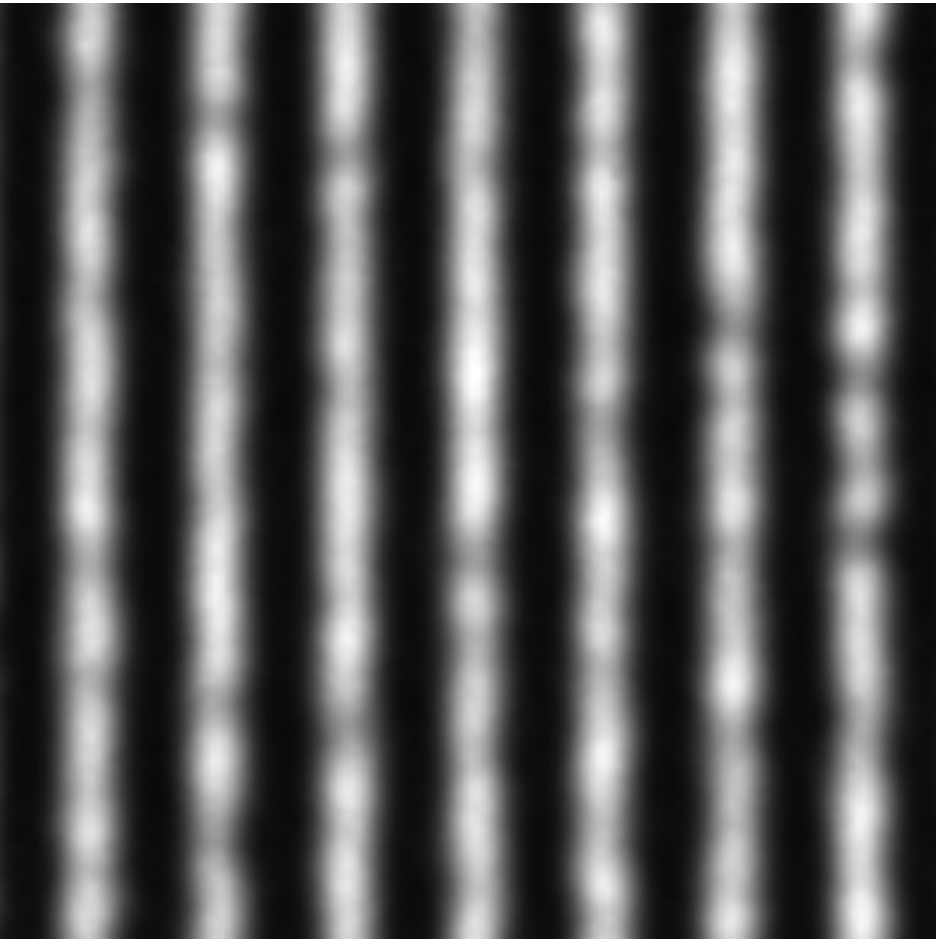
2 µm x 2 µm



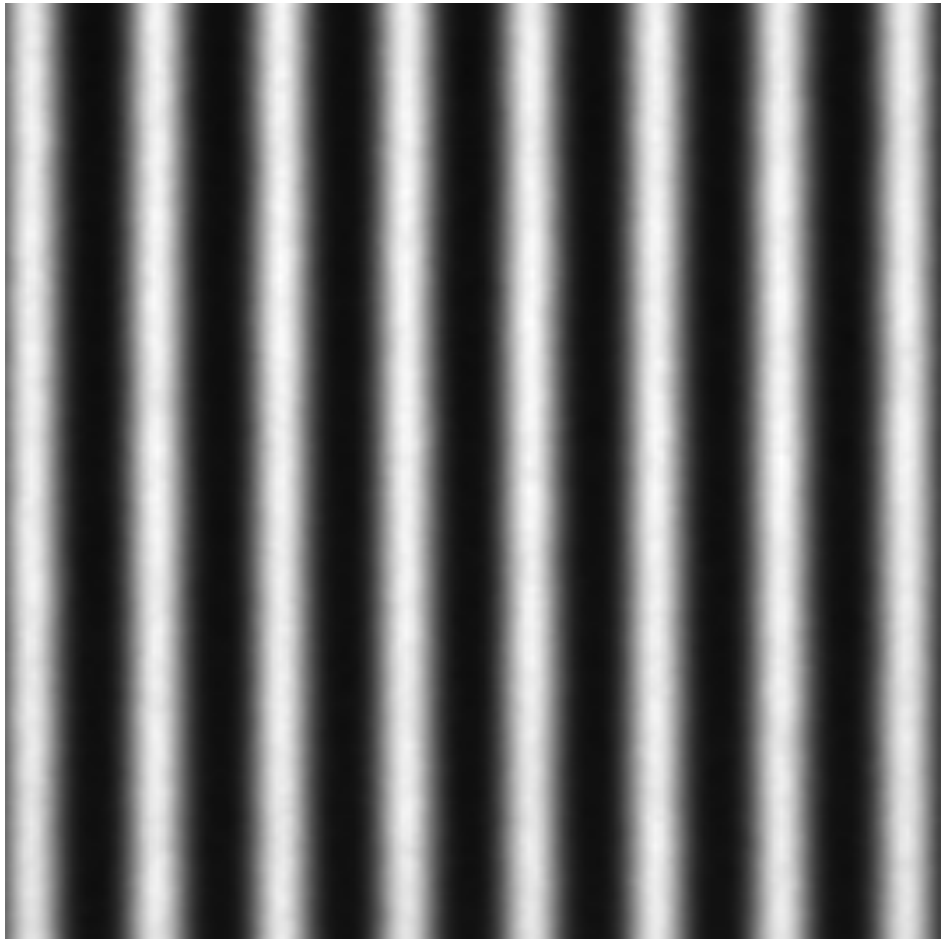
132-nm hp

Goldberg, *SPIE* **8880** (2013)

Line-Width Roughness



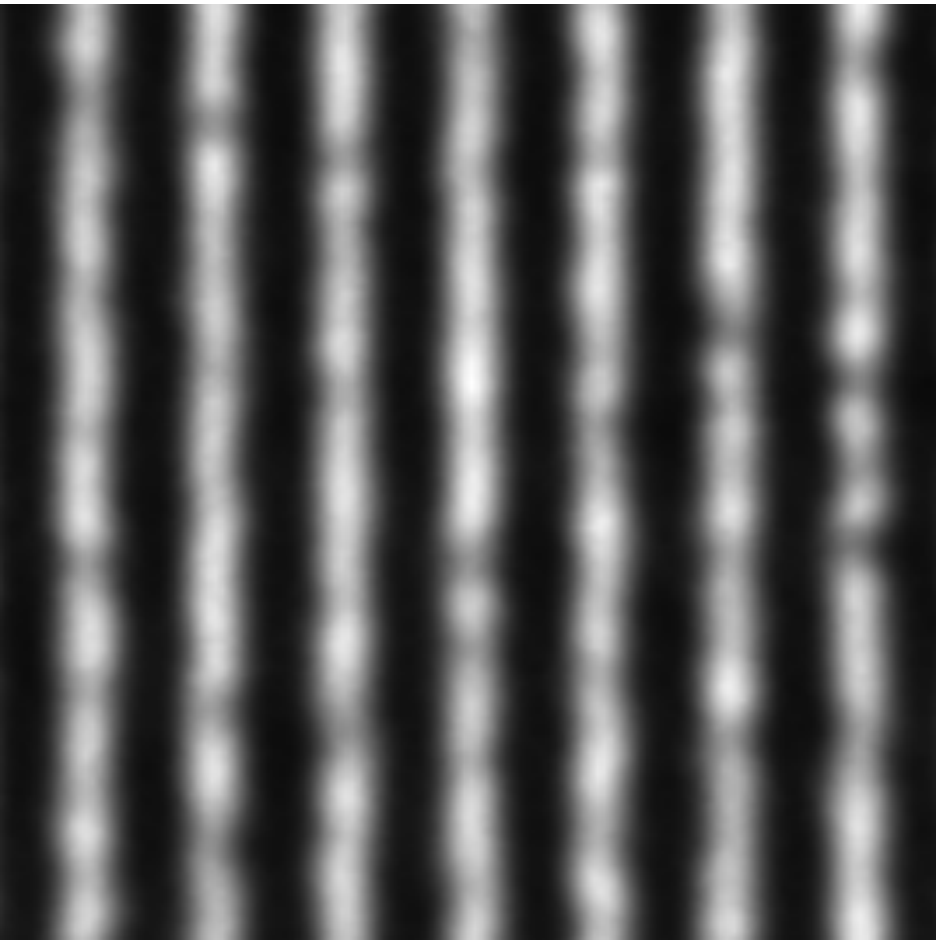
2 μm x 2 μm



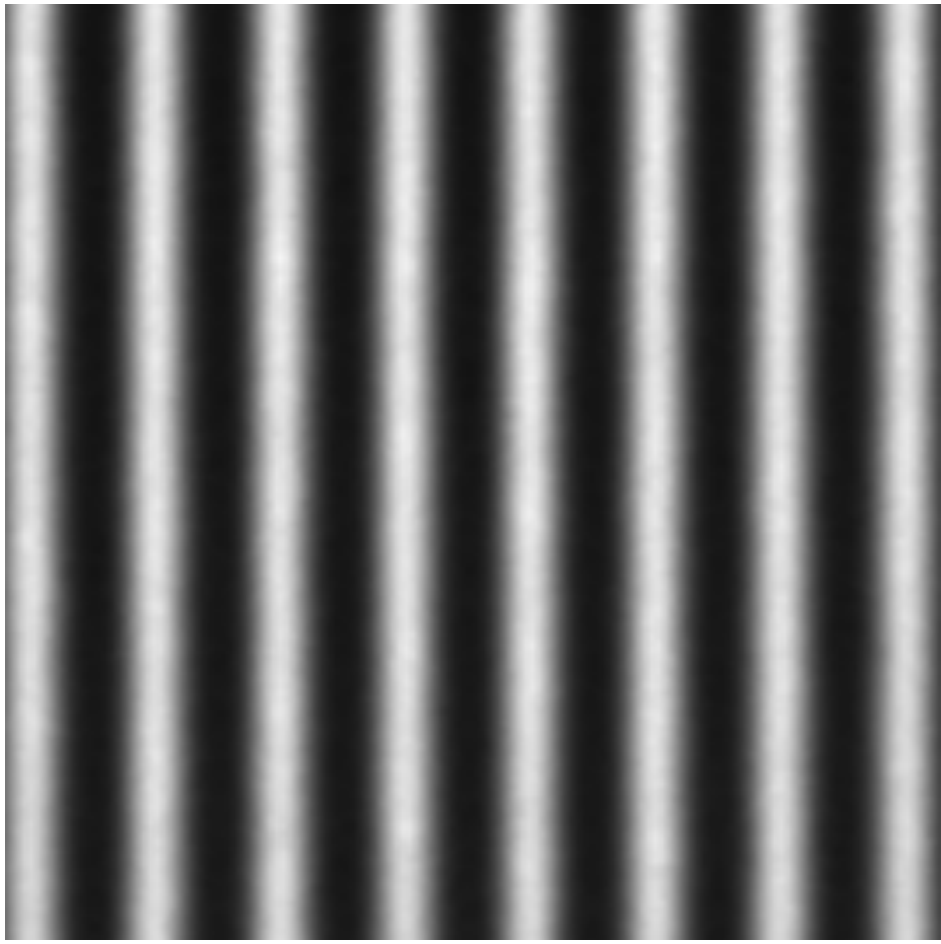
132-nm hp

Goldberg, *SPIE* **8880** (2013)

Line-Width Roughness



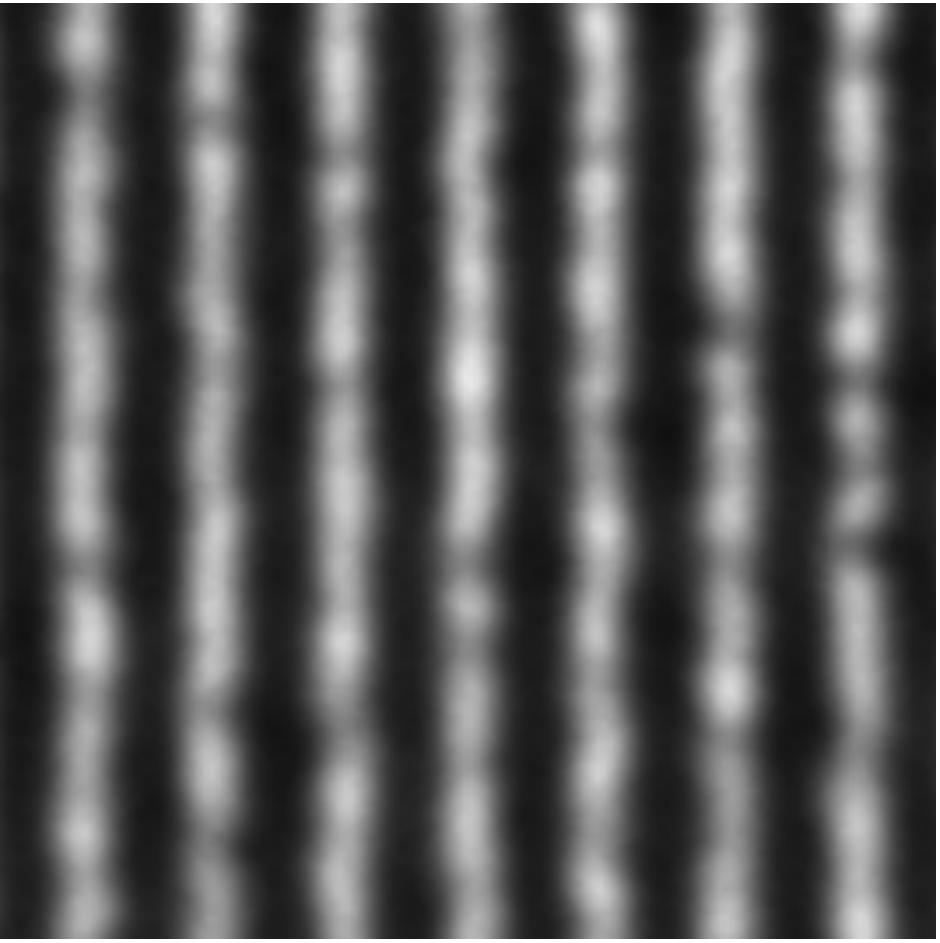
2 µm x 2 µm



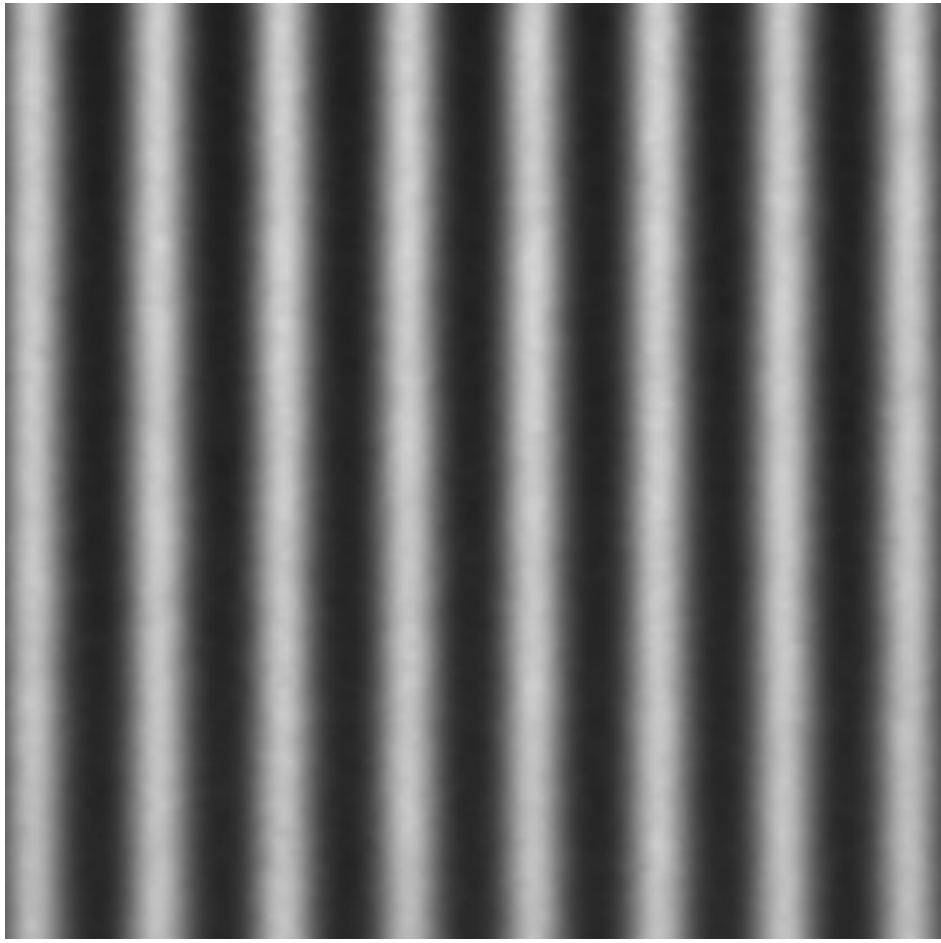
132-nm hp

Goldberg, *SPIE* **8880** (2013)

Line-Width Roughness



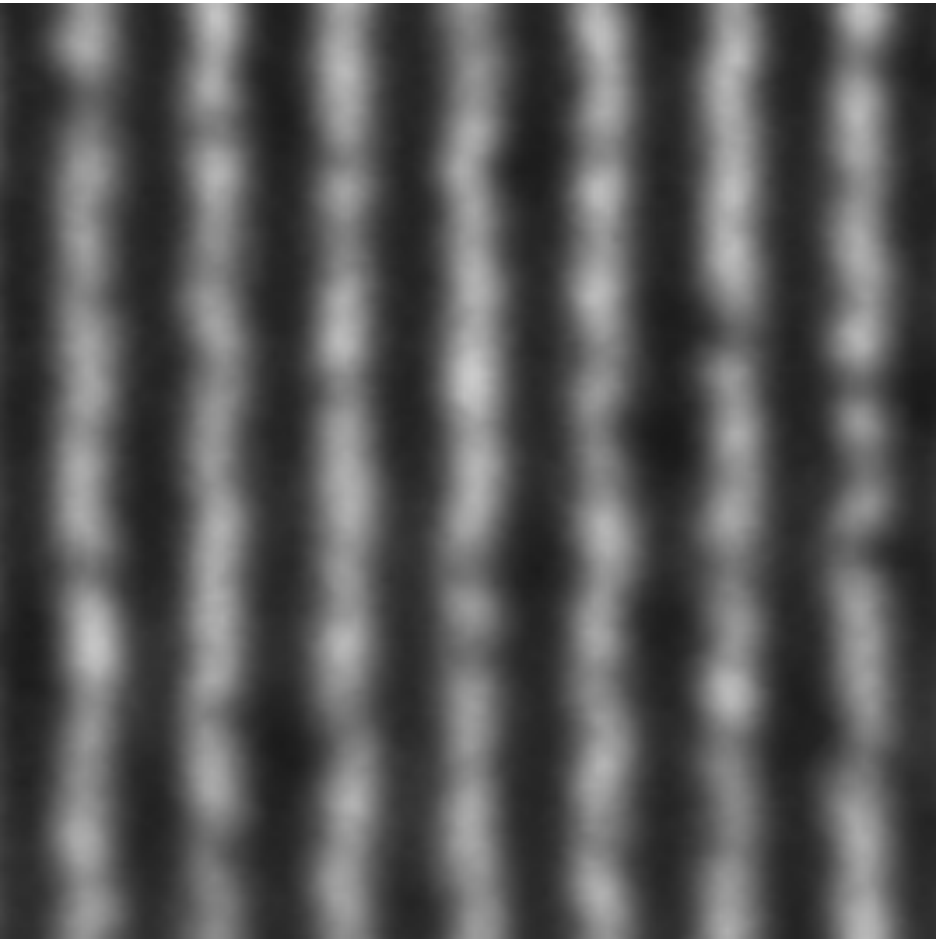
2 µm x 2 µm



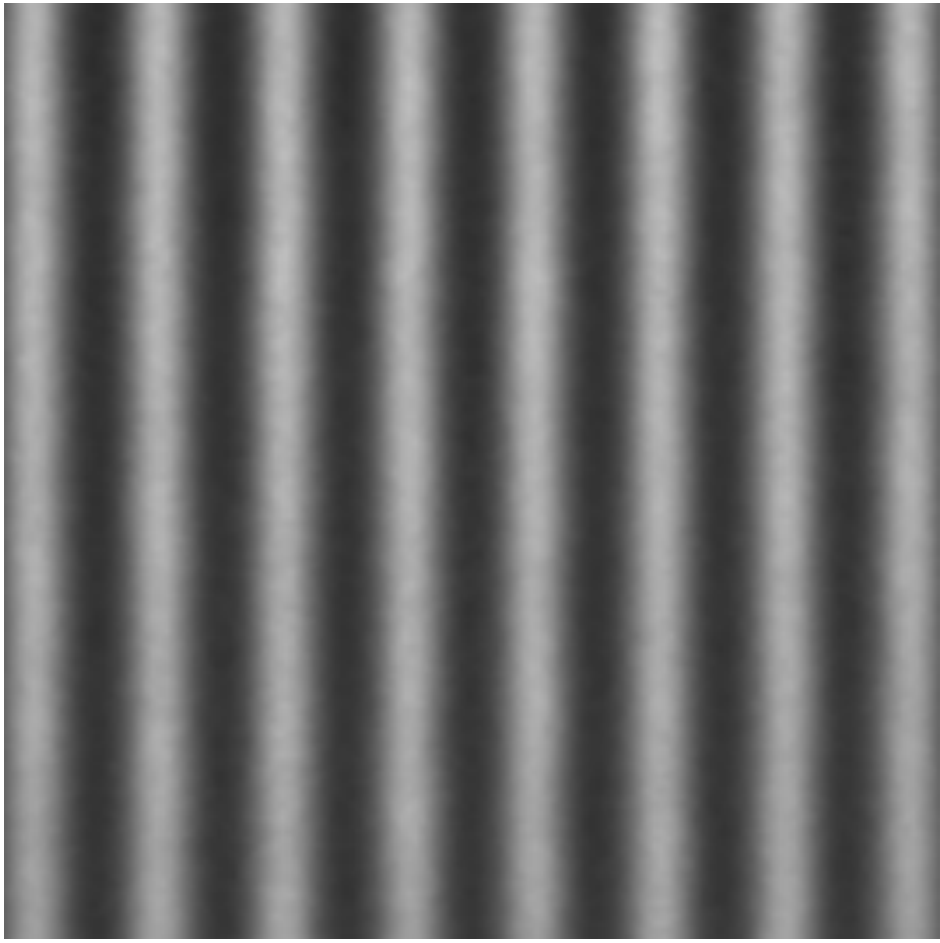
132-nm hp

Goldberg, *SPIE* **8880** (2013)

Line-Width Roughness



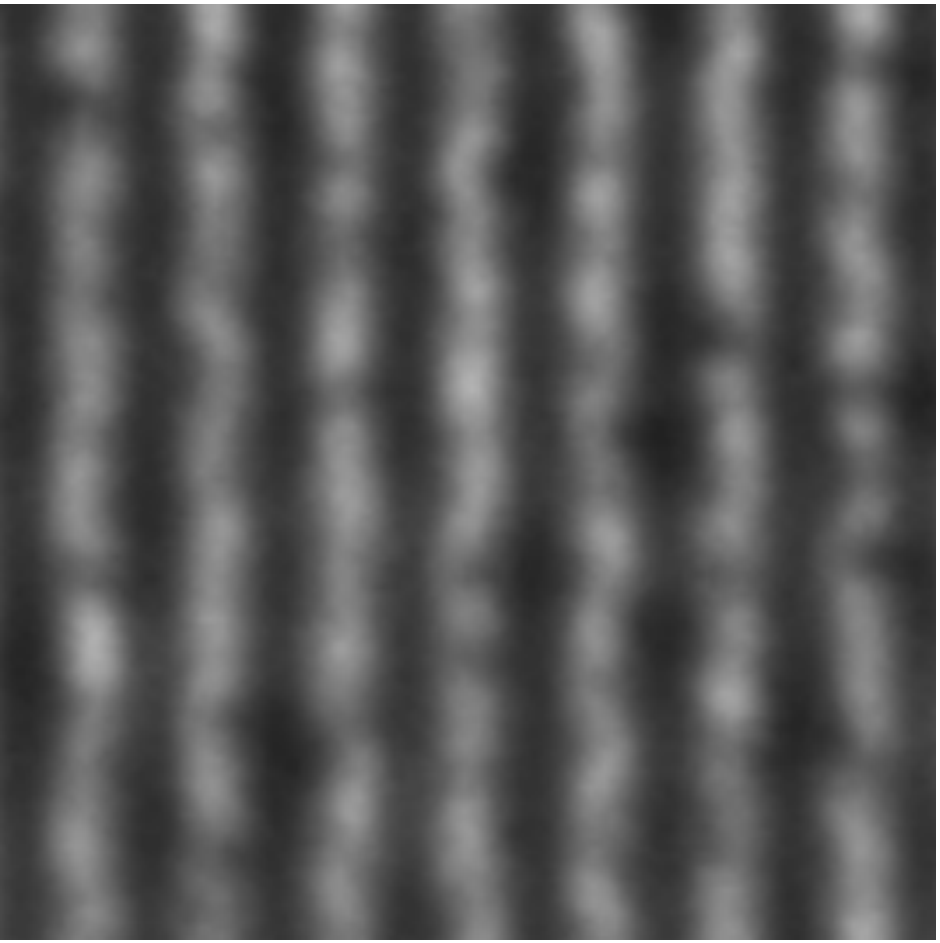
2 µm x 2 µm



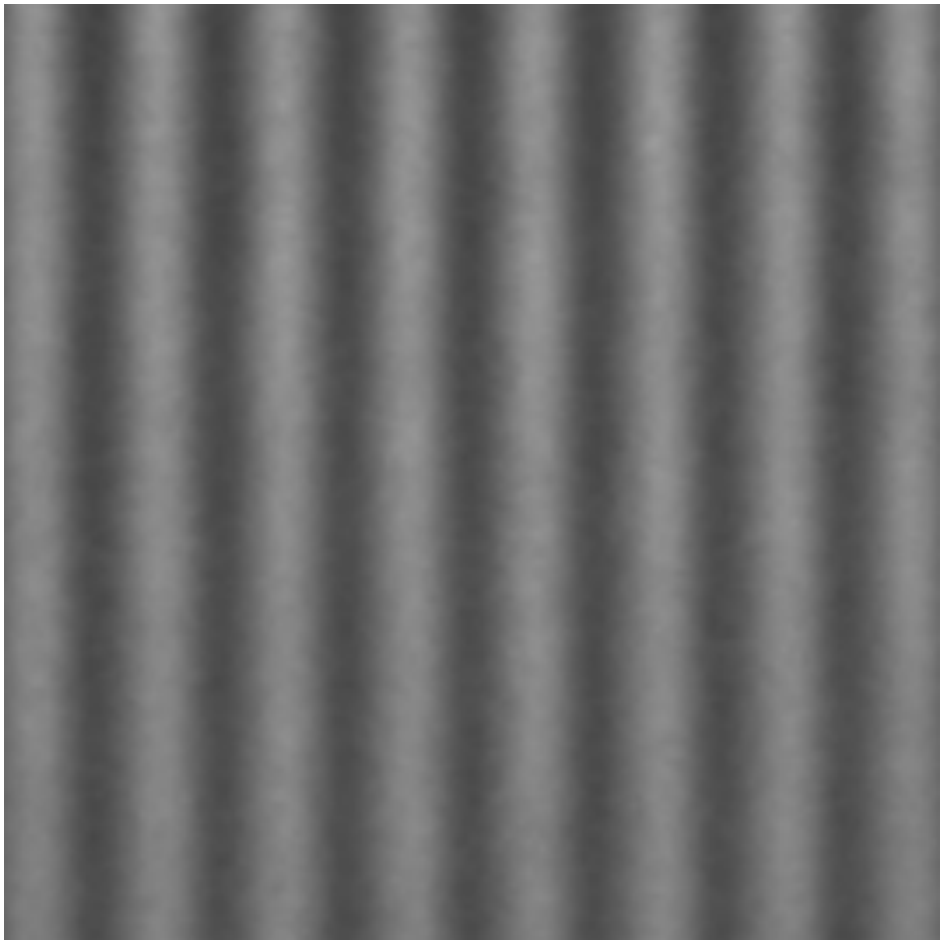
132-nm hp

Goldberg, *SPIE* **8880** (2013)

Line-Width Roughness



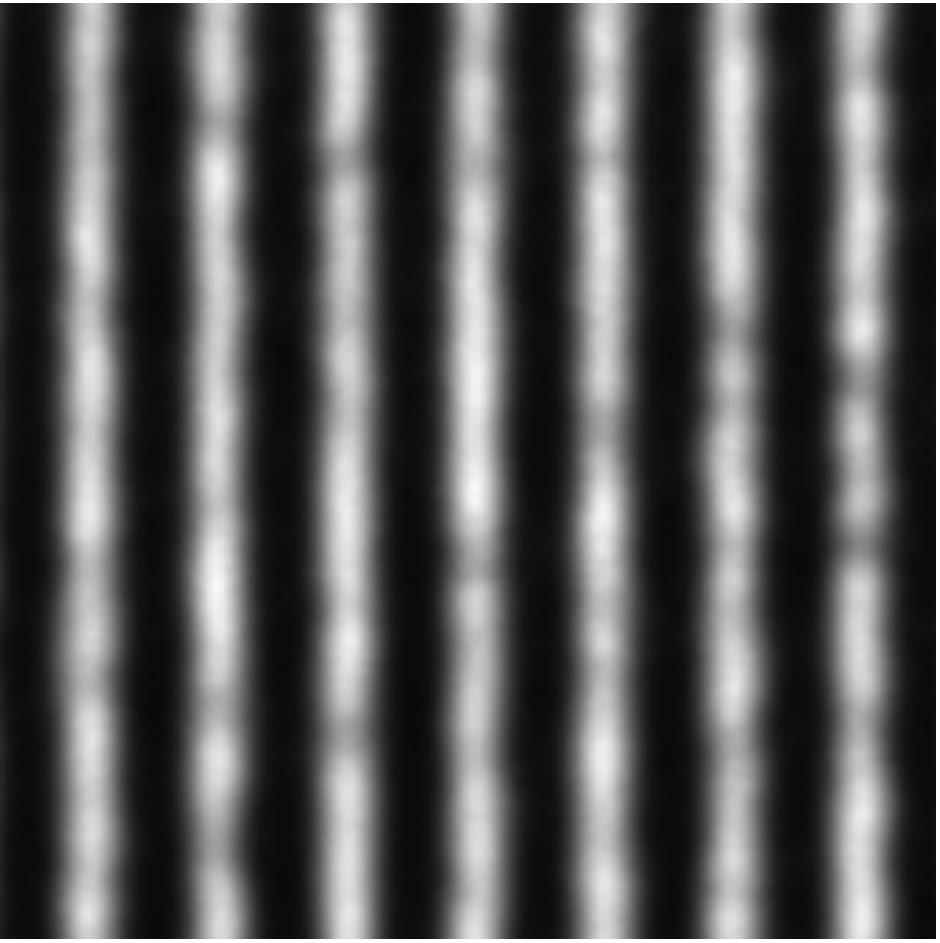
2 µm x 2 µm



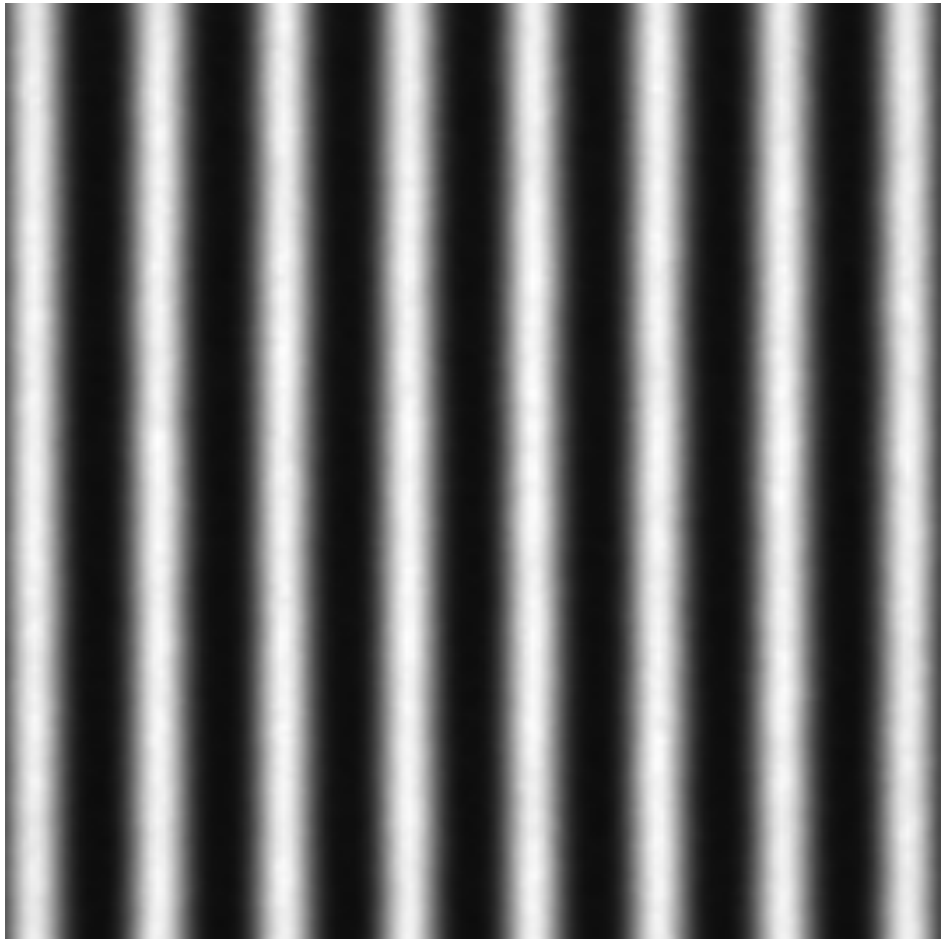
132-nm hp

Goldberg, *SPIE* **8880** (2013)

Line-Width Roughness



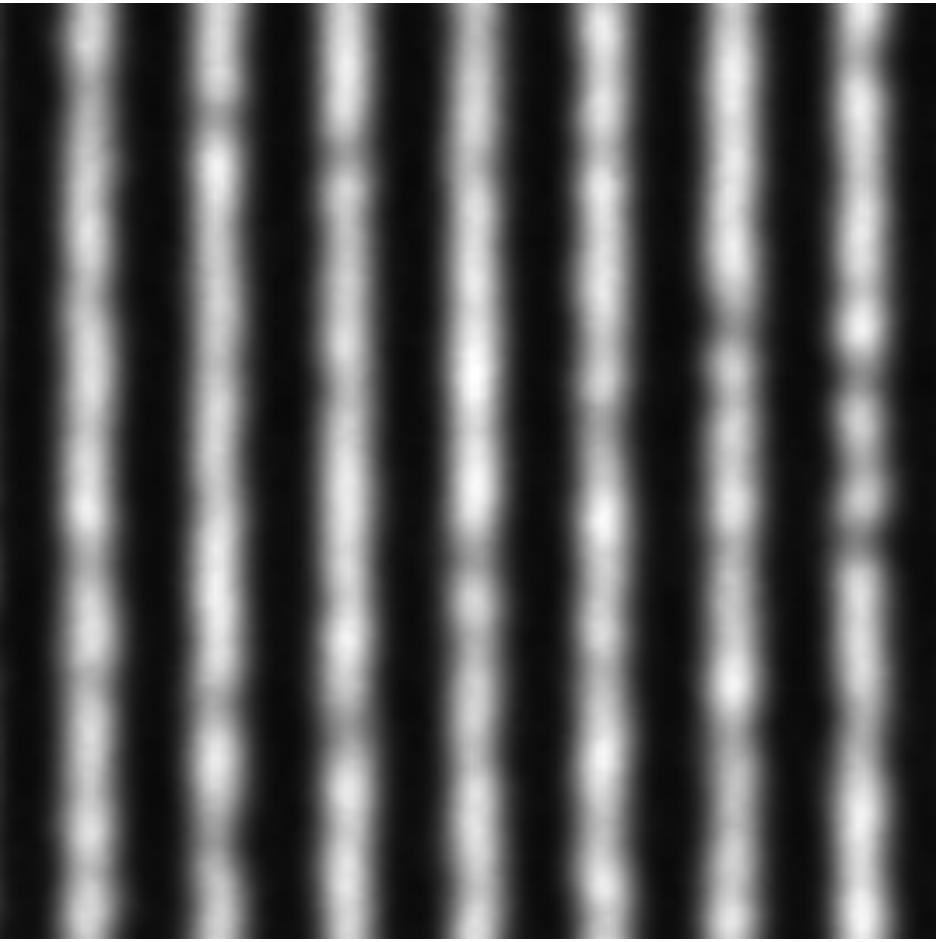
2 µm x 2 µm



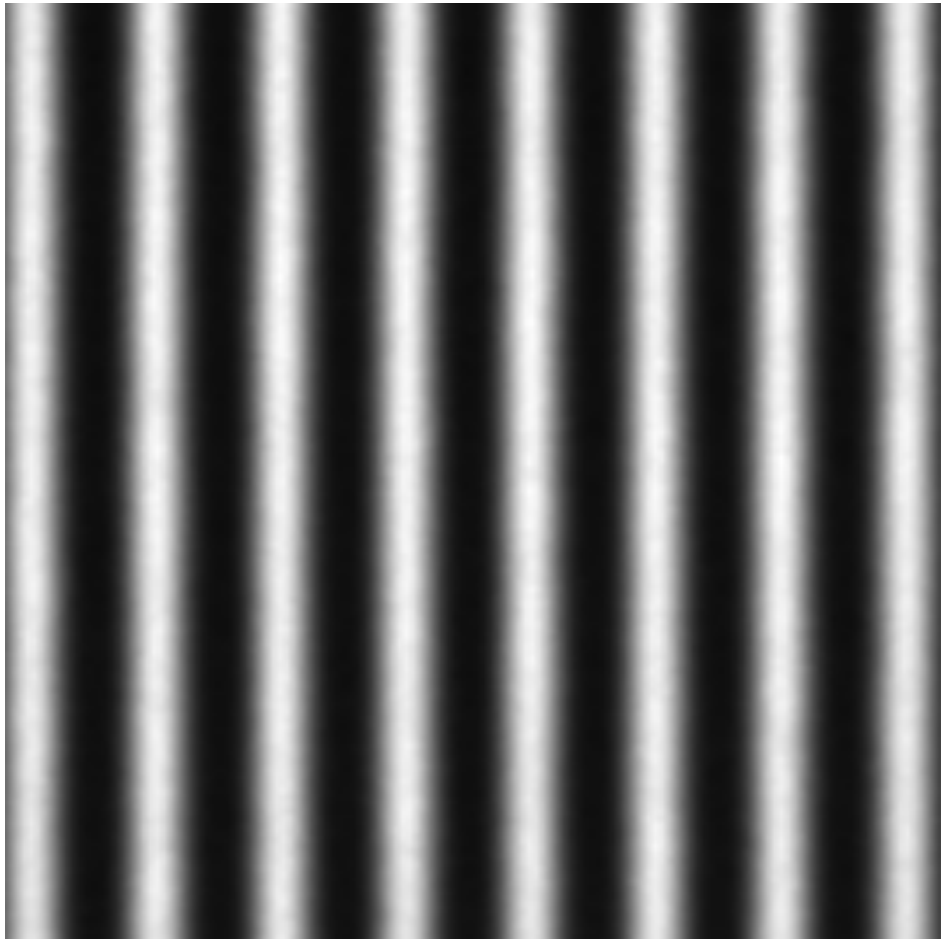
132-nm hp

Goldberg, *SPIE* **8880** (2013)

Line-Width Roughness



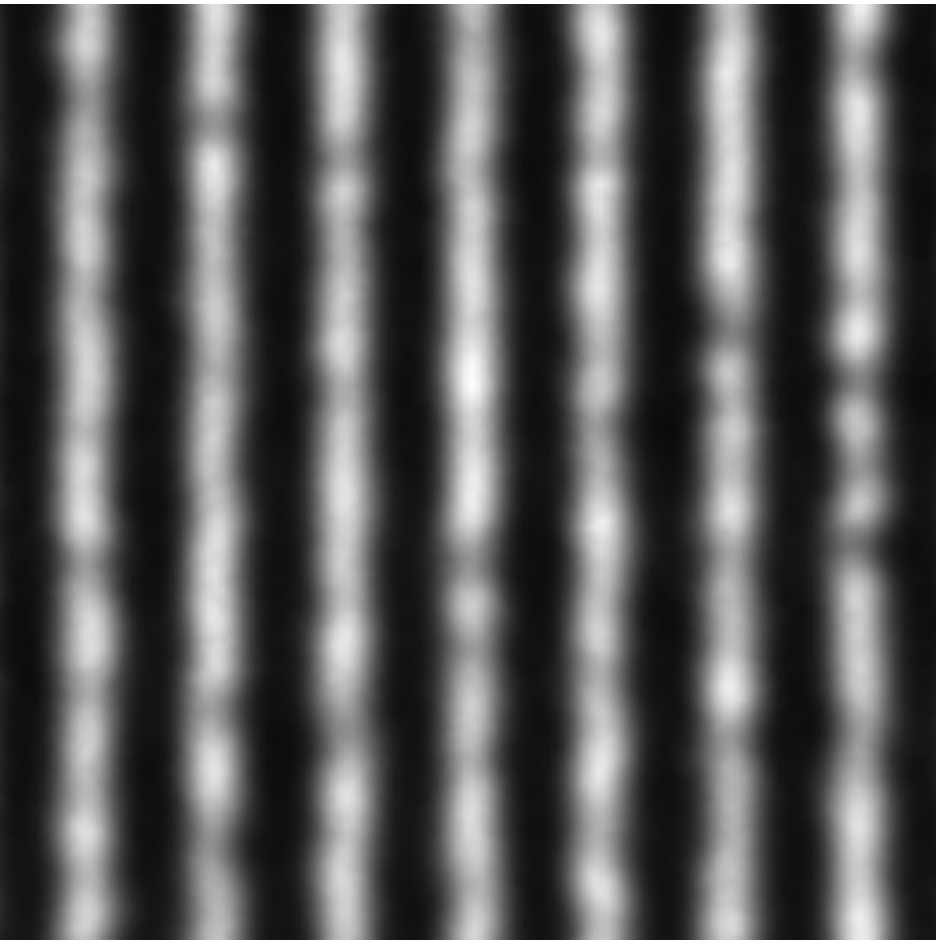
2 μm x 2 μm



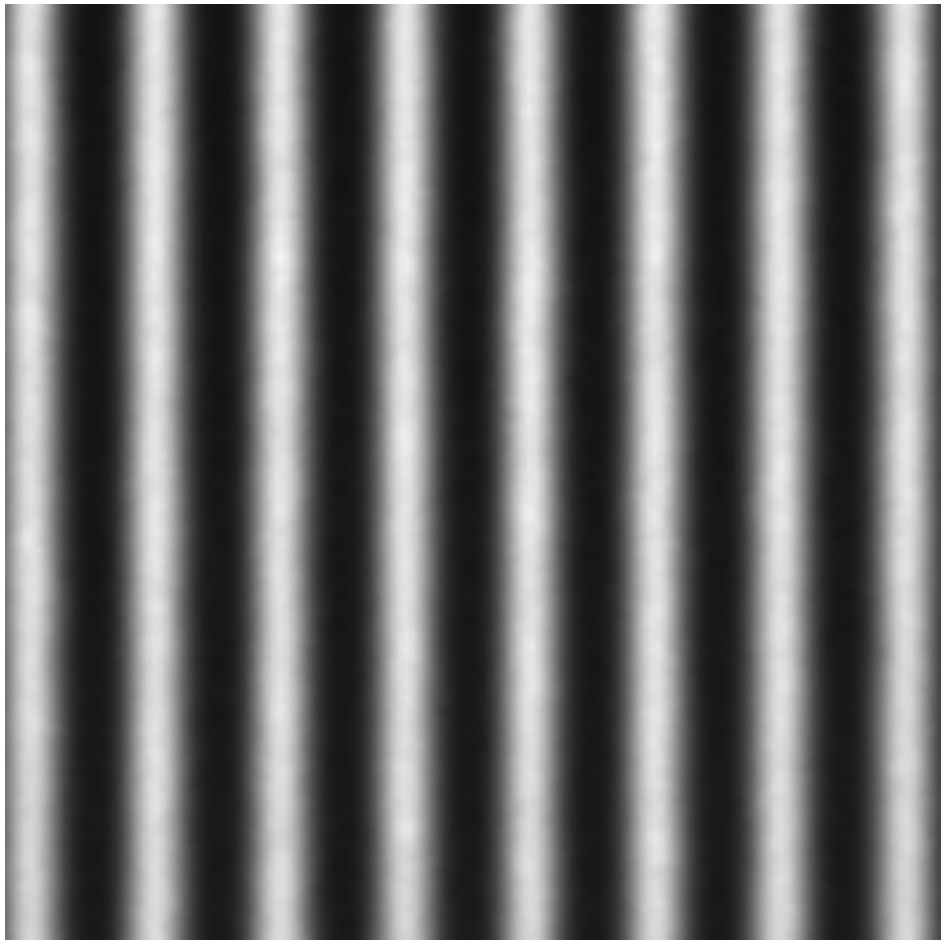
132-nm hp

Goldberg, *SPIE* **8880** (2013)

Line-Width Roughness



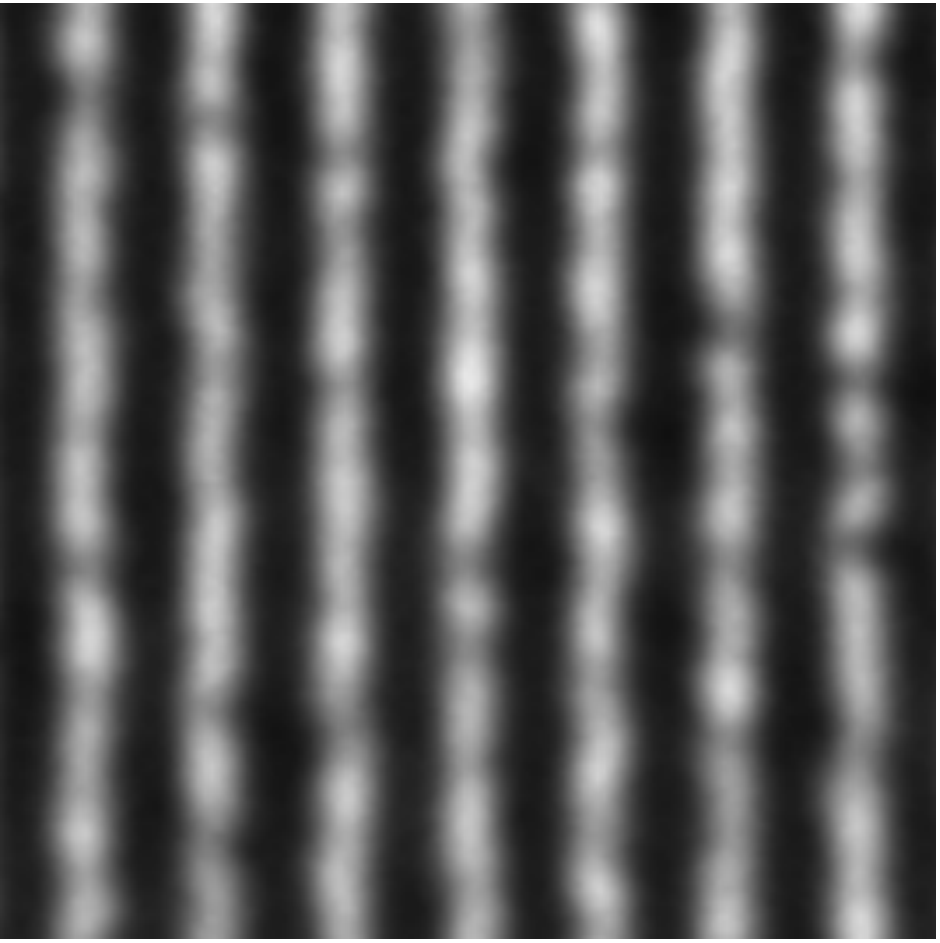
2 µm x 2 µm



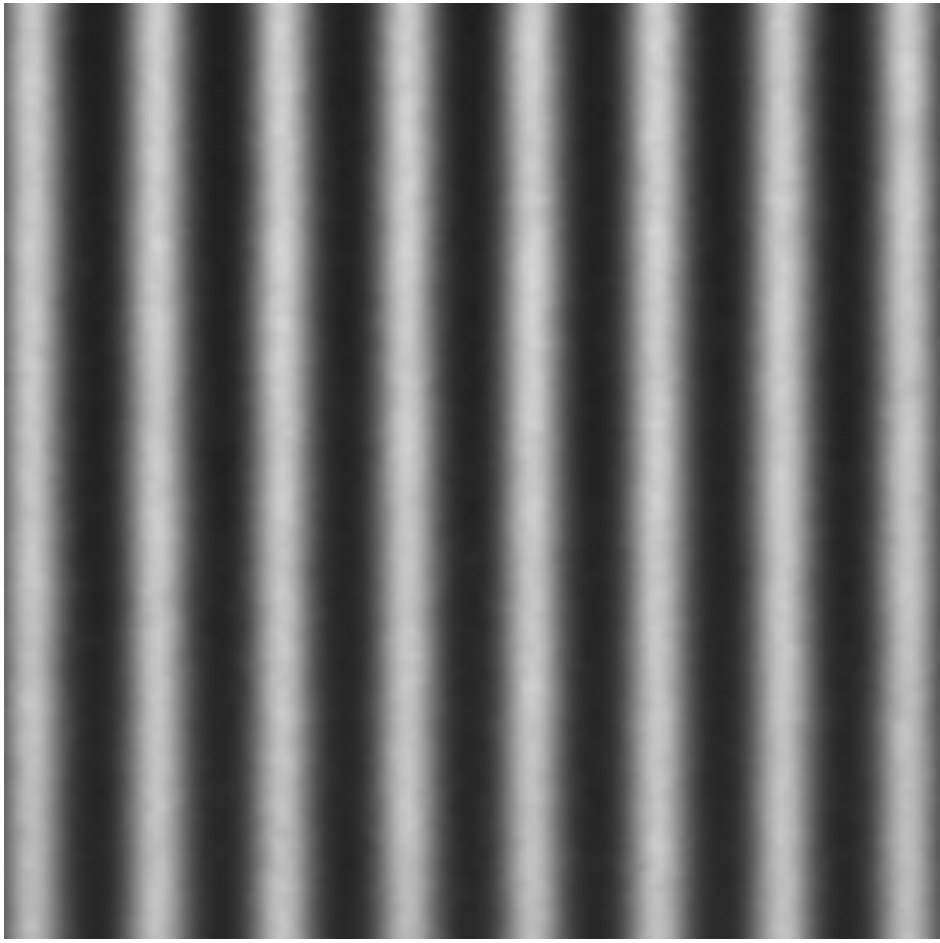
132-nm hp

Goldberg, *SPIE* **8880** (2013)

Line-Width Roughness



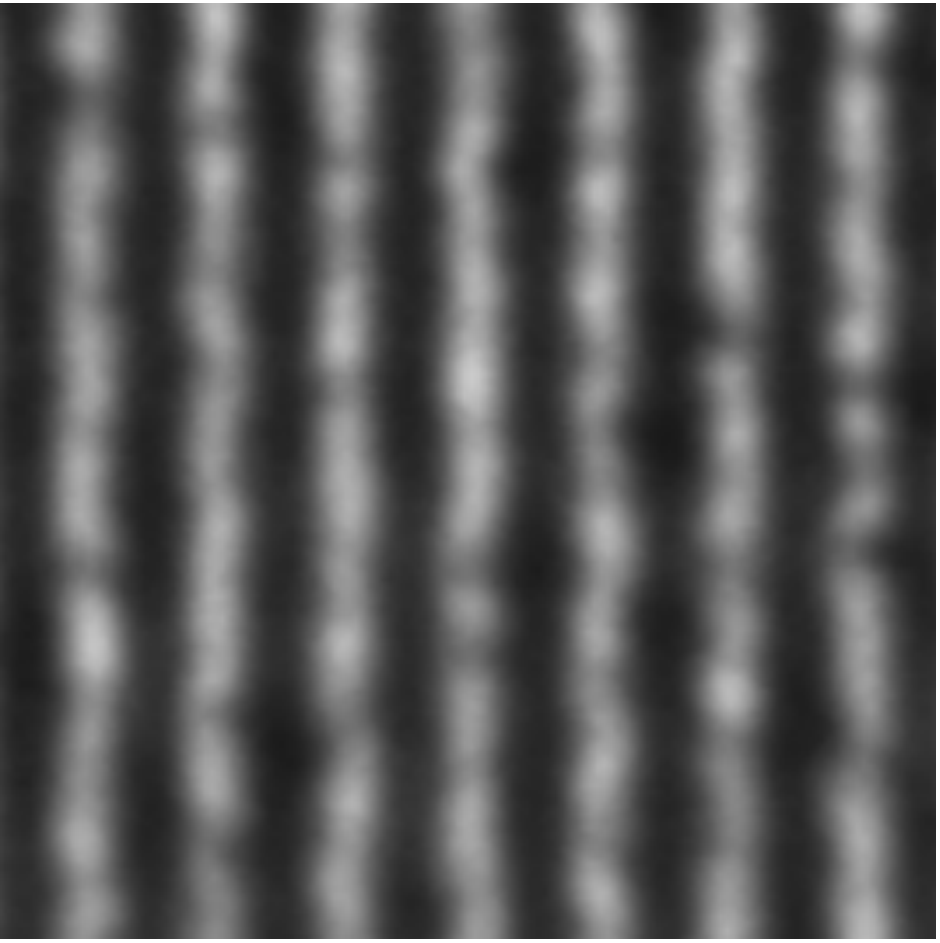
2 µm x 2 µm



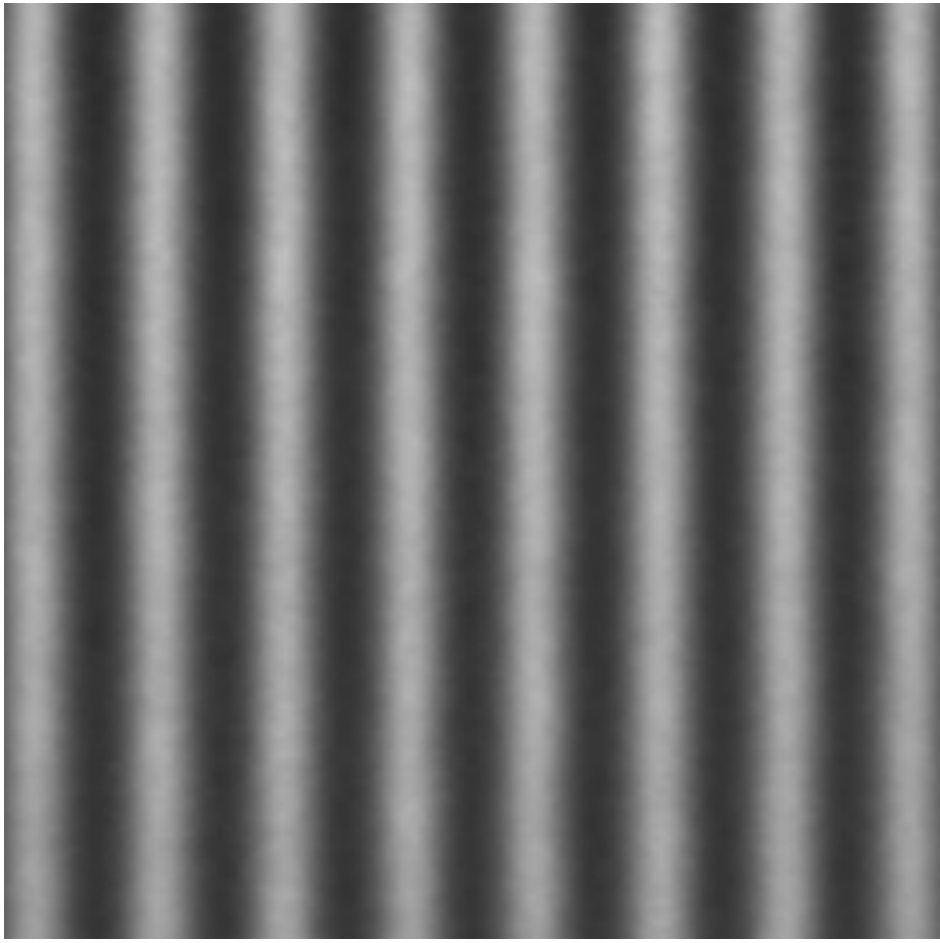
132-nm hp

Goldberg, *SPIE* **8880** (2013)

Line-Width Roughness



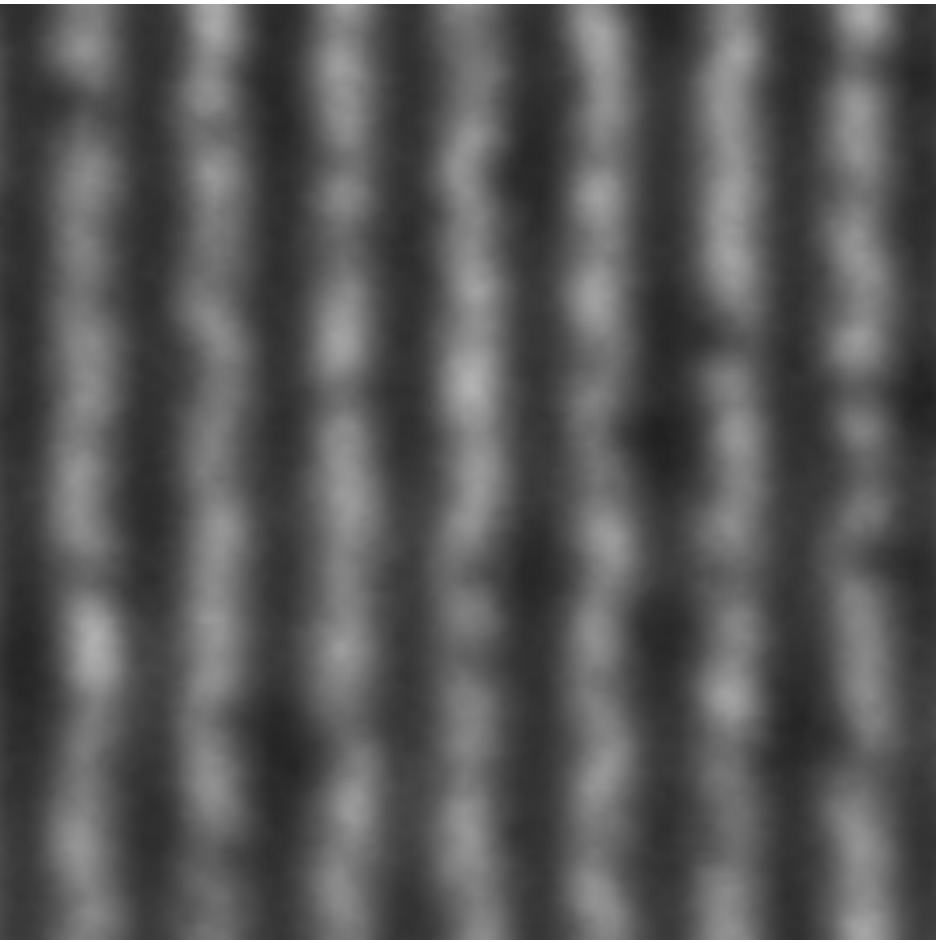
2 µm x 2 µm



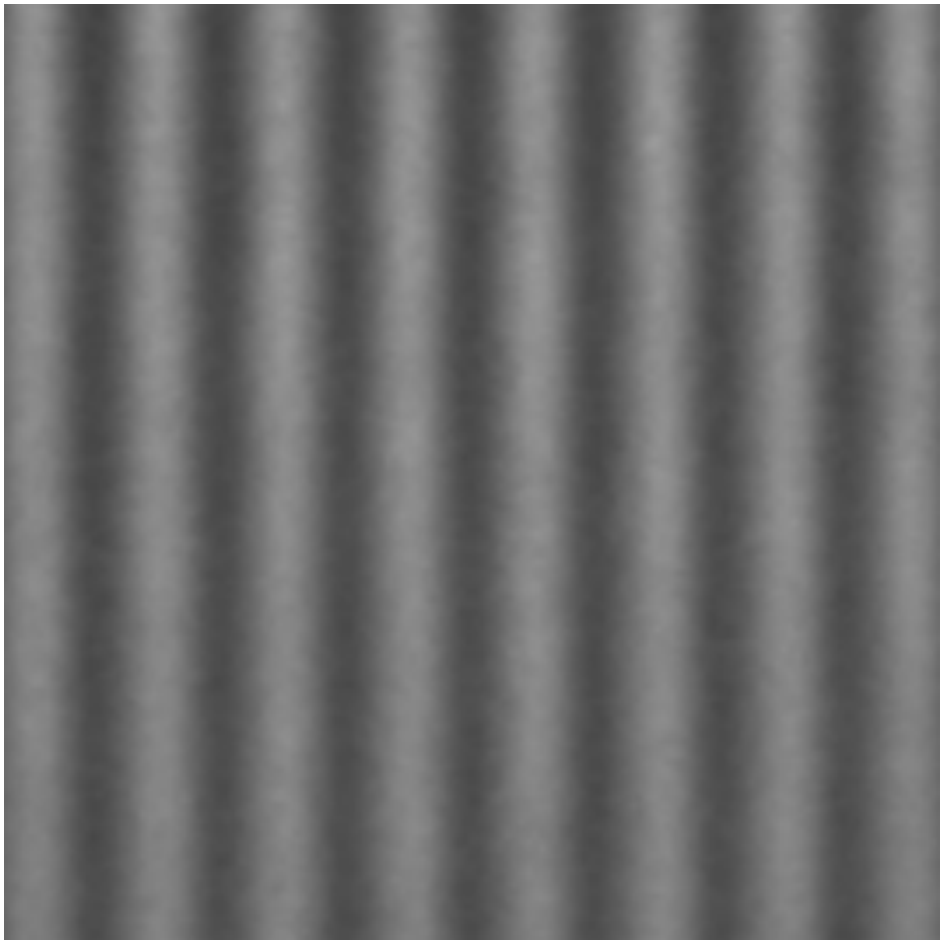
132-nm hp

Goldberg, *SPIE* **8880** (2013)

Line-Width Roughness



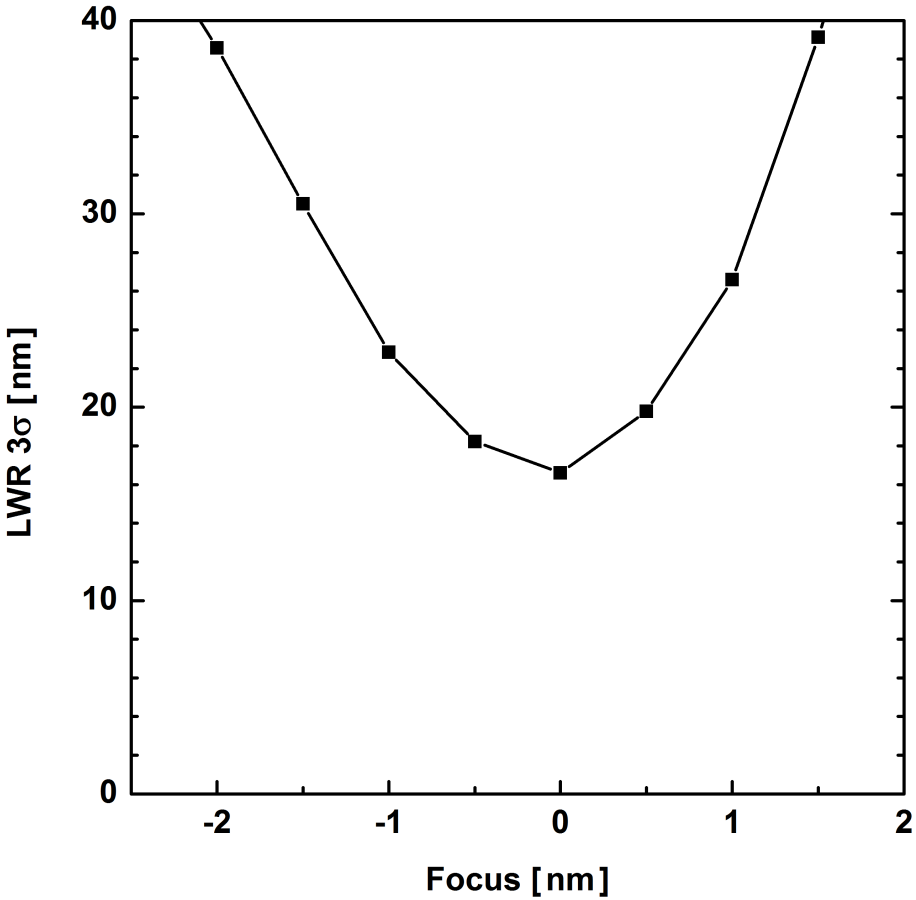
2 µm x 2 µm

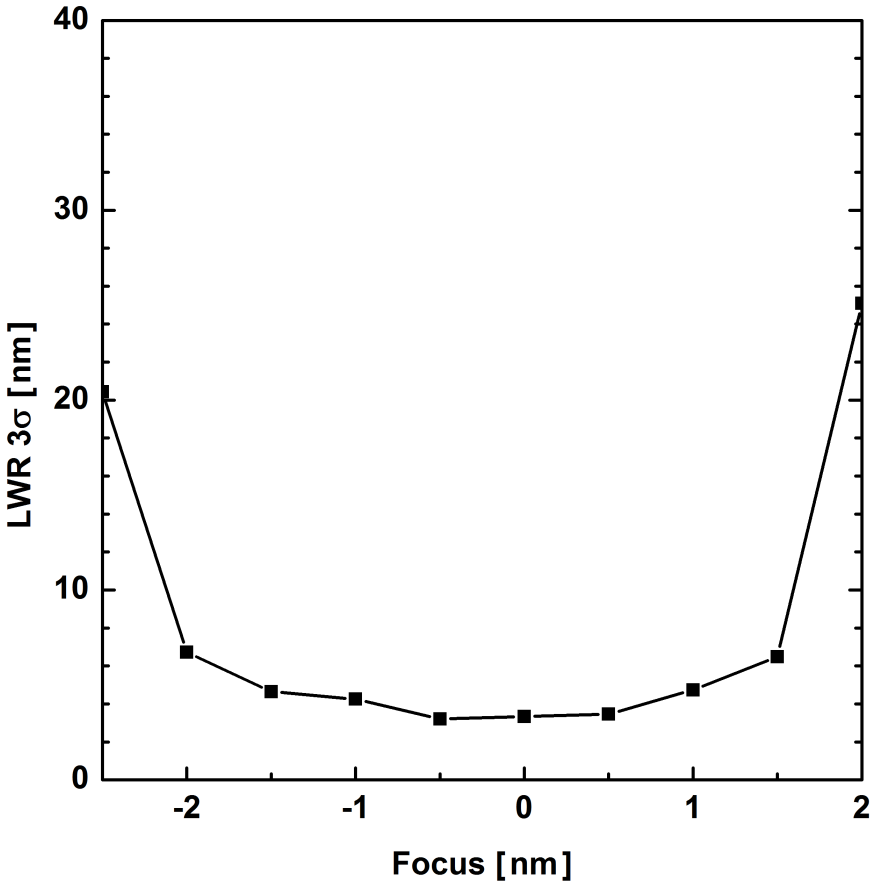


132-nm hp

Goldberg, *SPIE* **8880** (2013)

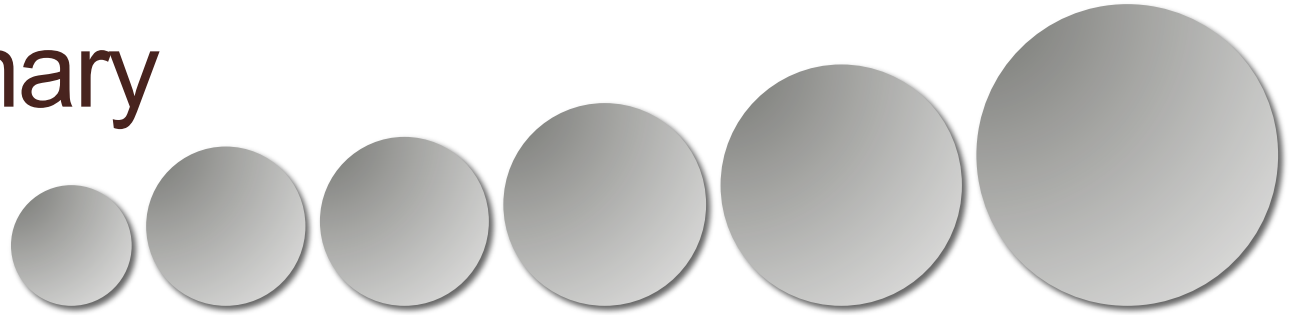
Line-Width Roughness





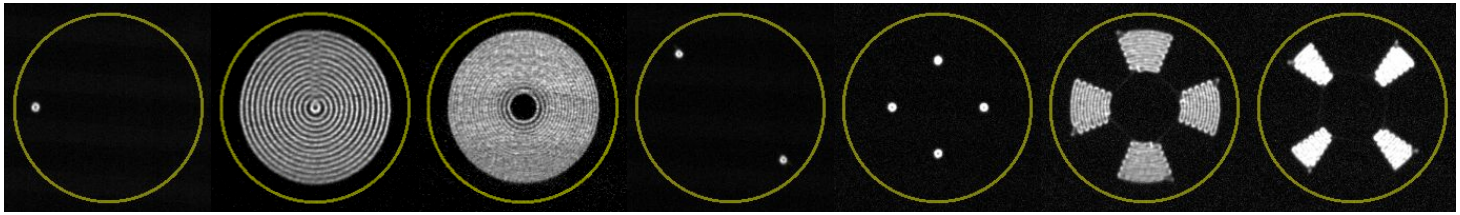
Summary

NA

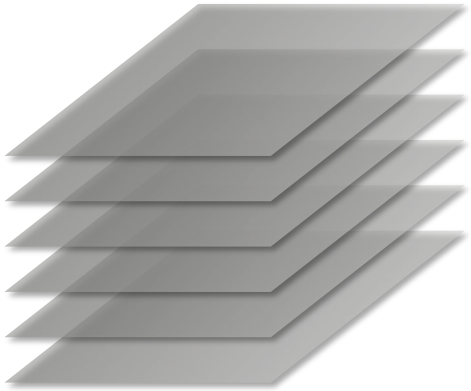


(4x) 0.25 0.33 0.35 0.42 0.50 0.625

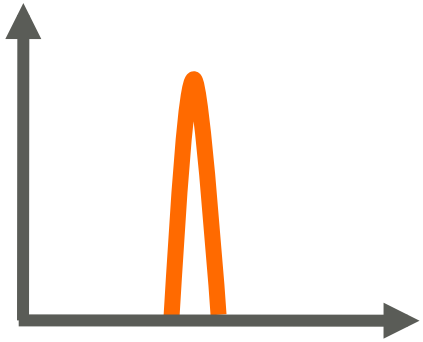
σ



z



λ



13.5 nm

T

8 points/h

Summary

- Acknowledgement

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Thank you!