Commissioning an EUV Mask Microscope for Lithography generations Reaching 8 nm

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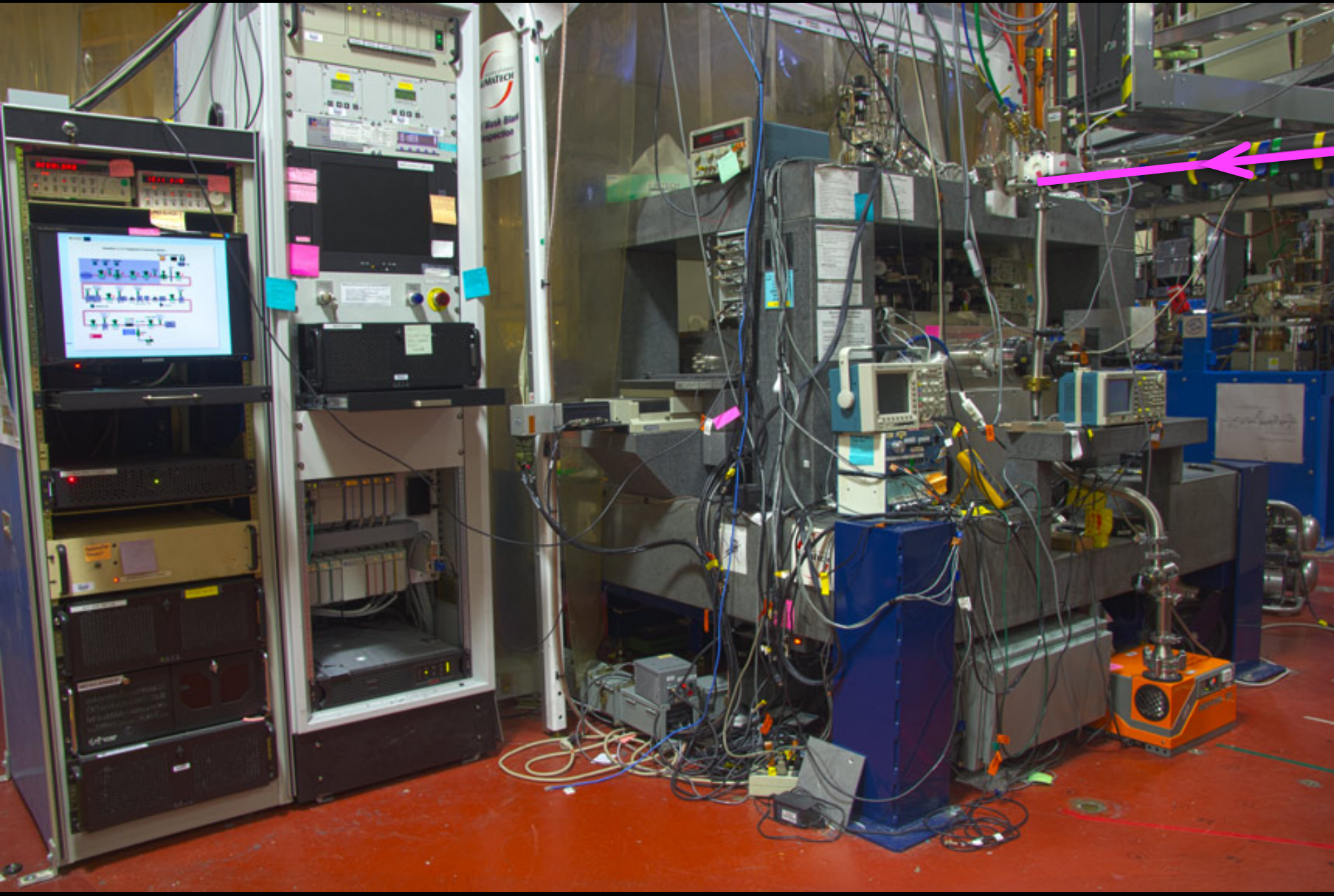
SHARP TEAM:
Science+: Kenneth Goldberg, Iacopo Mochi, Markus Benk, James Macdougall, Patrick Naulleau;
Engineering: Seno Rekawa, Arnaud Allezy, Dan Zehm, Erik Anderson, Weilun Chao, Farhad Salmassi, Michael Dickinson, Jason DePonte, Doug Van Camp, Bob Ghioroso, M. Gideon Jones, Liz Martin;
Controls Systems: Carl Cork, Will Cork, Vamsi Vytla, Jeff Gamsby, Hanjing Huang.



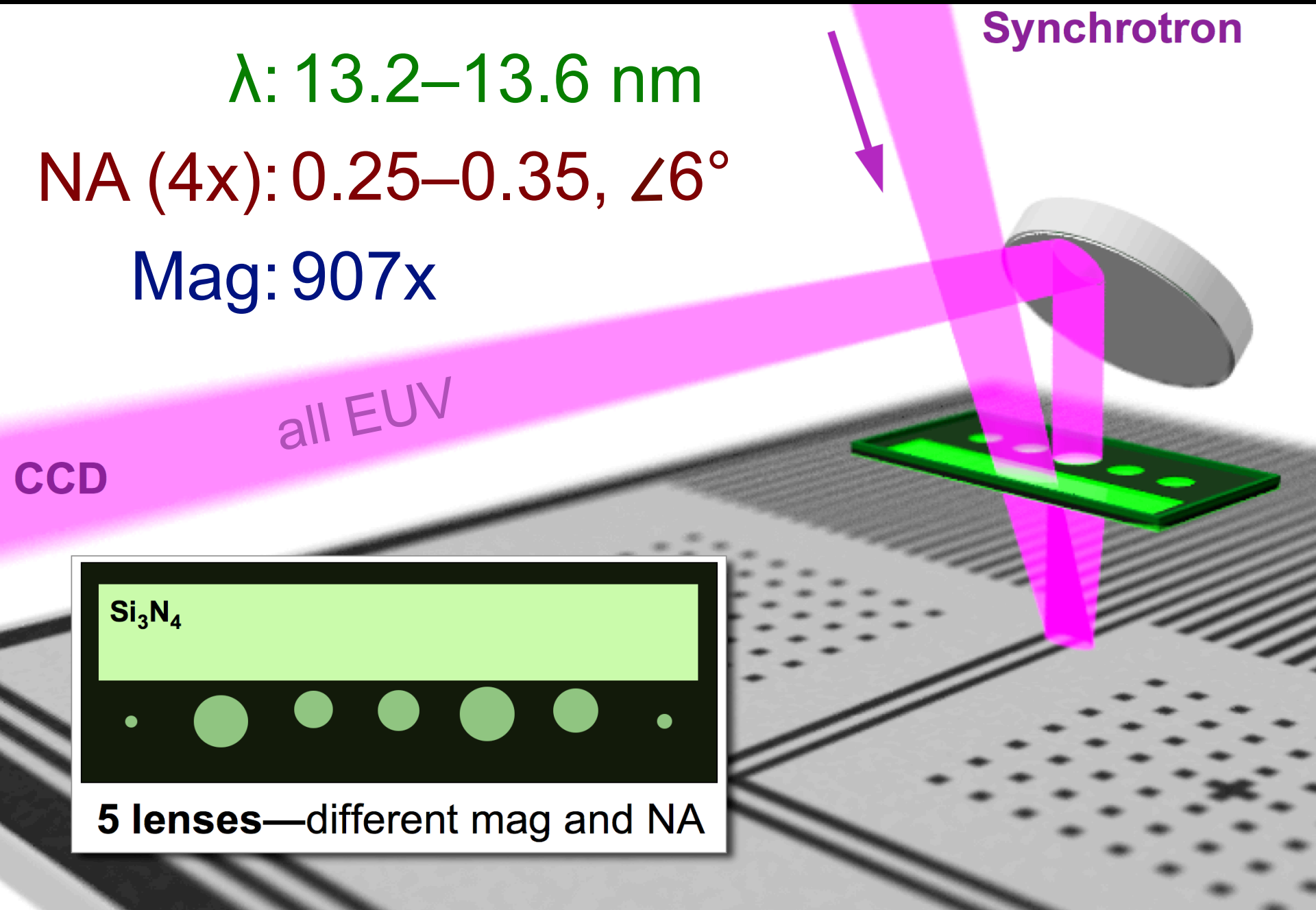
AIT: 2004–2012

The SEMATECH Berkeley Actinic Inspection Tool (AIT)

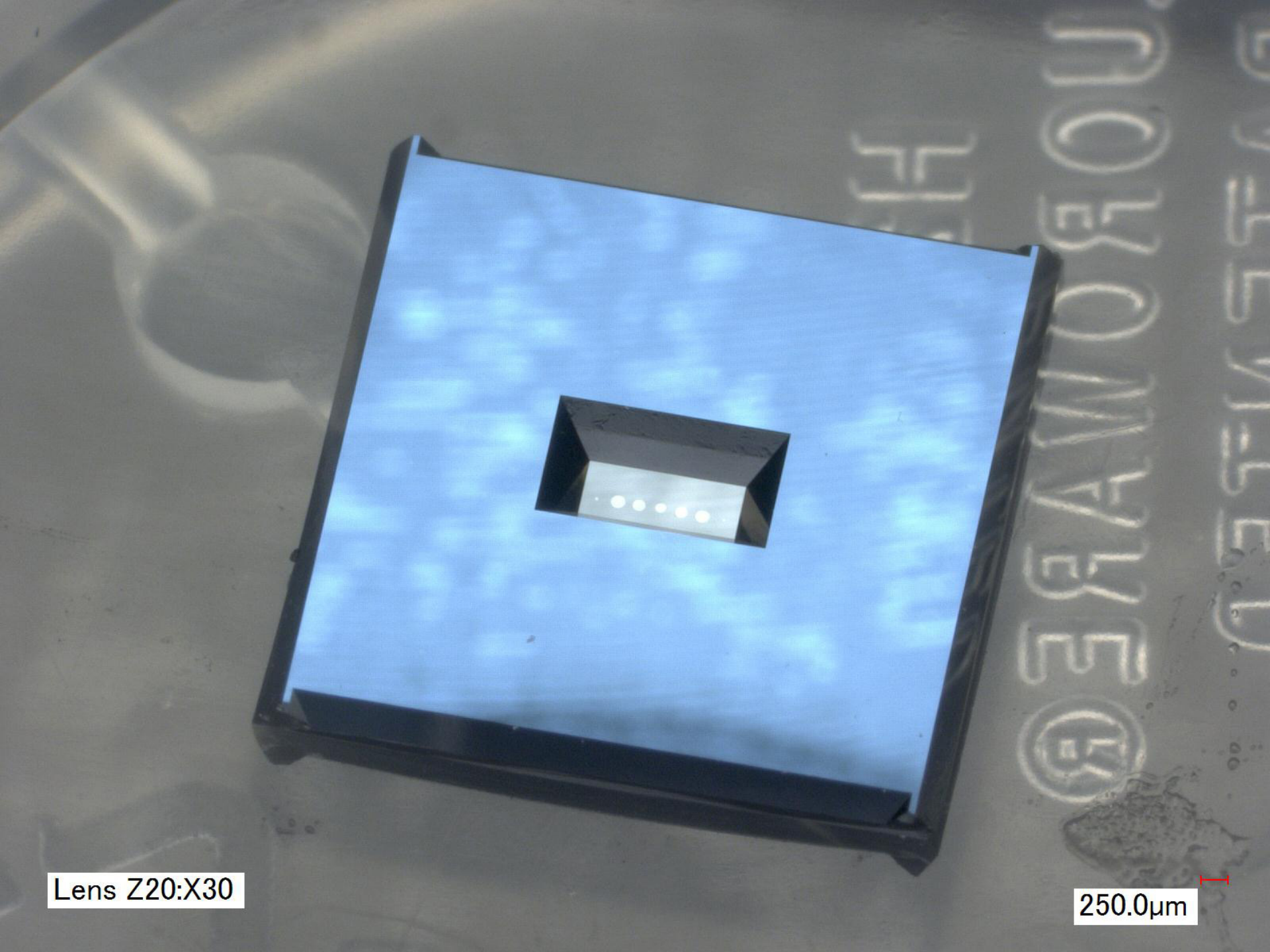
λ: 13.2–13.6 nm

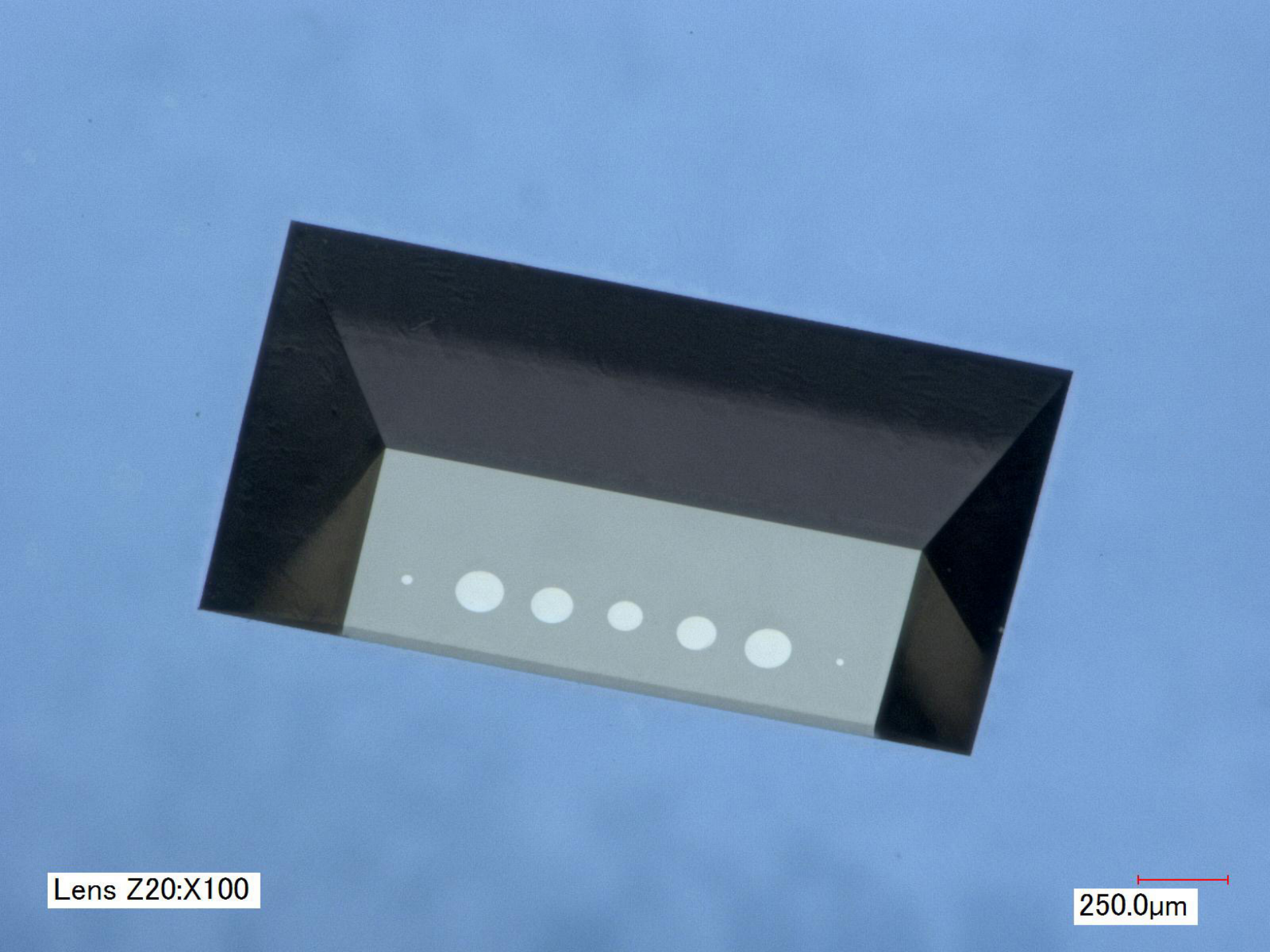
NA (4x): 0.25–0.35, ∠6°

Mag: 907x



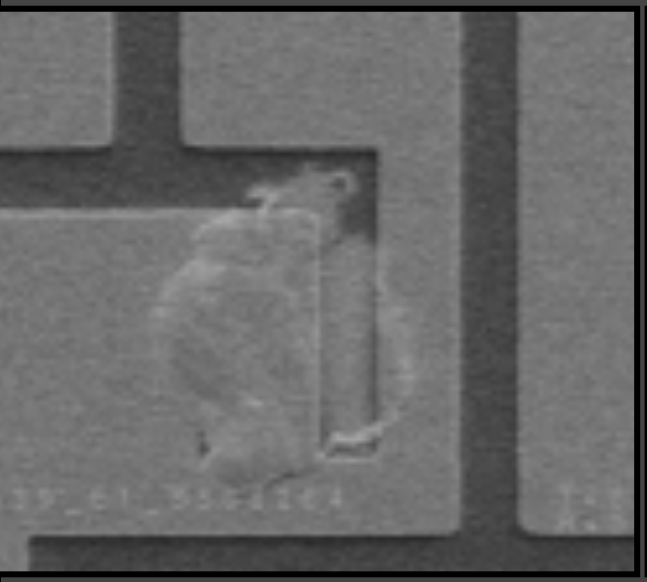
5 lenses—different mag and NA

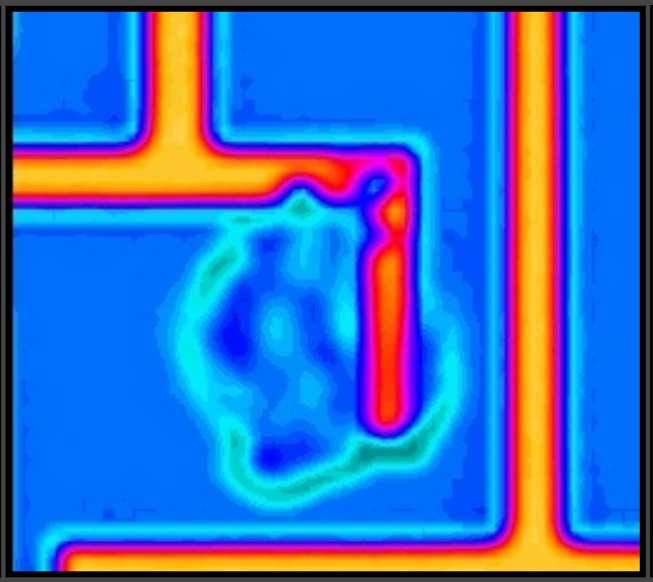

Lens Z20:X30
250.0µm

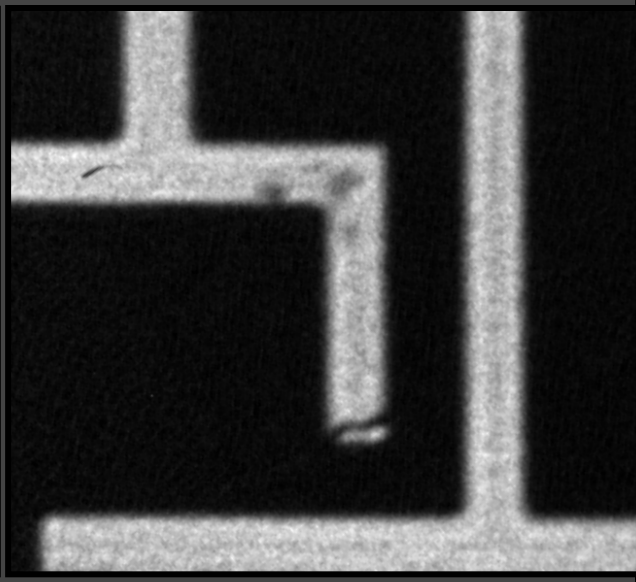

Lens Z20:X100
250.0μm

AIT

SEM **DUV** **EUV**



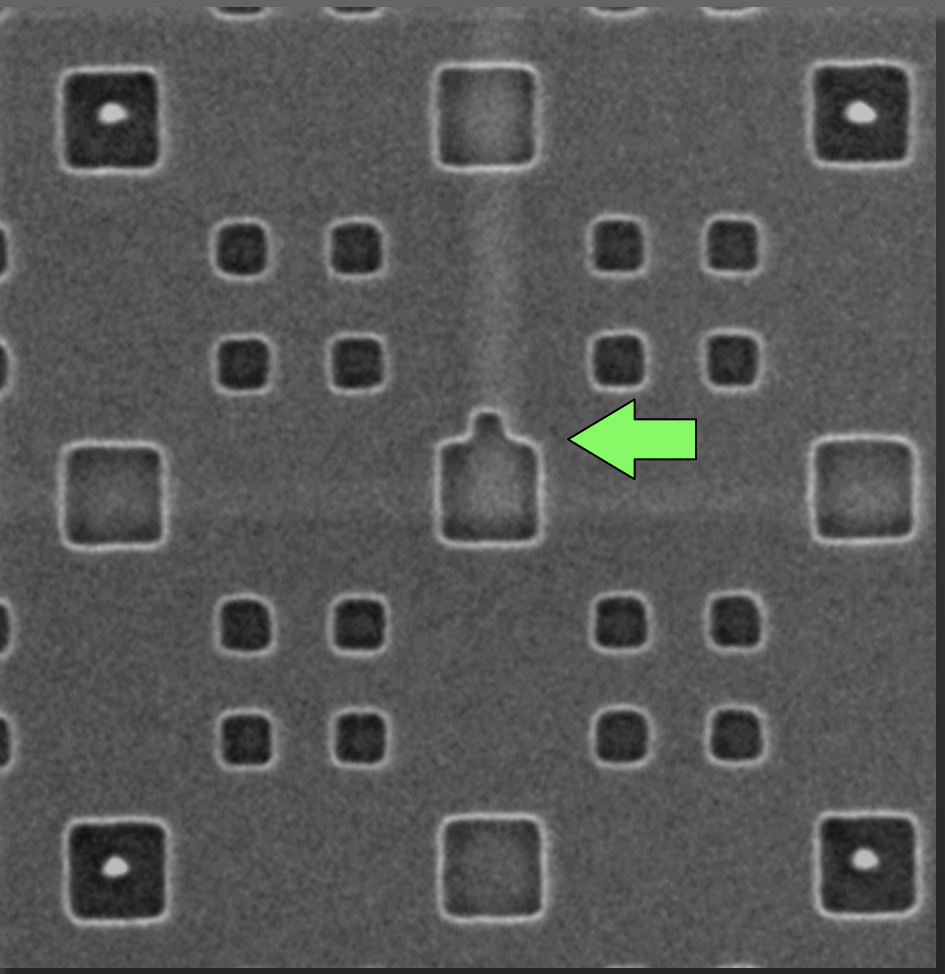


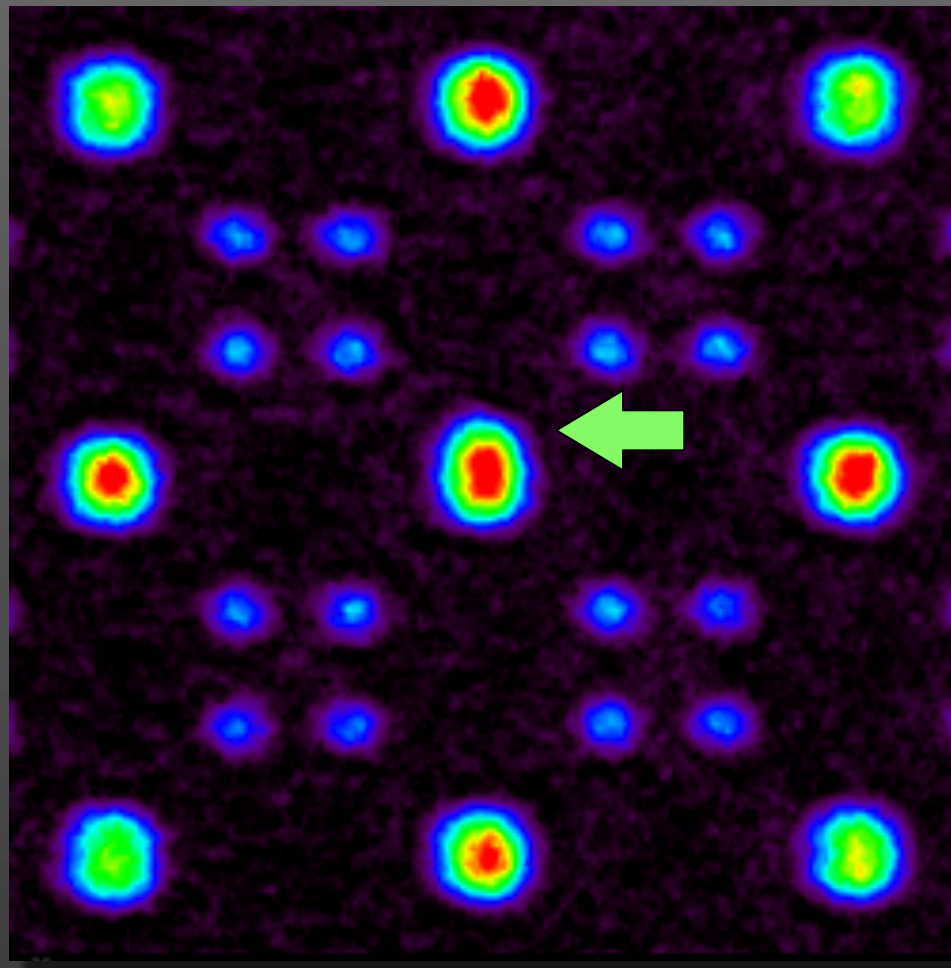


1 µm

Mochi, *SPIE* **7636** (2009)

IBM Programmed Pattern Defects





SEM

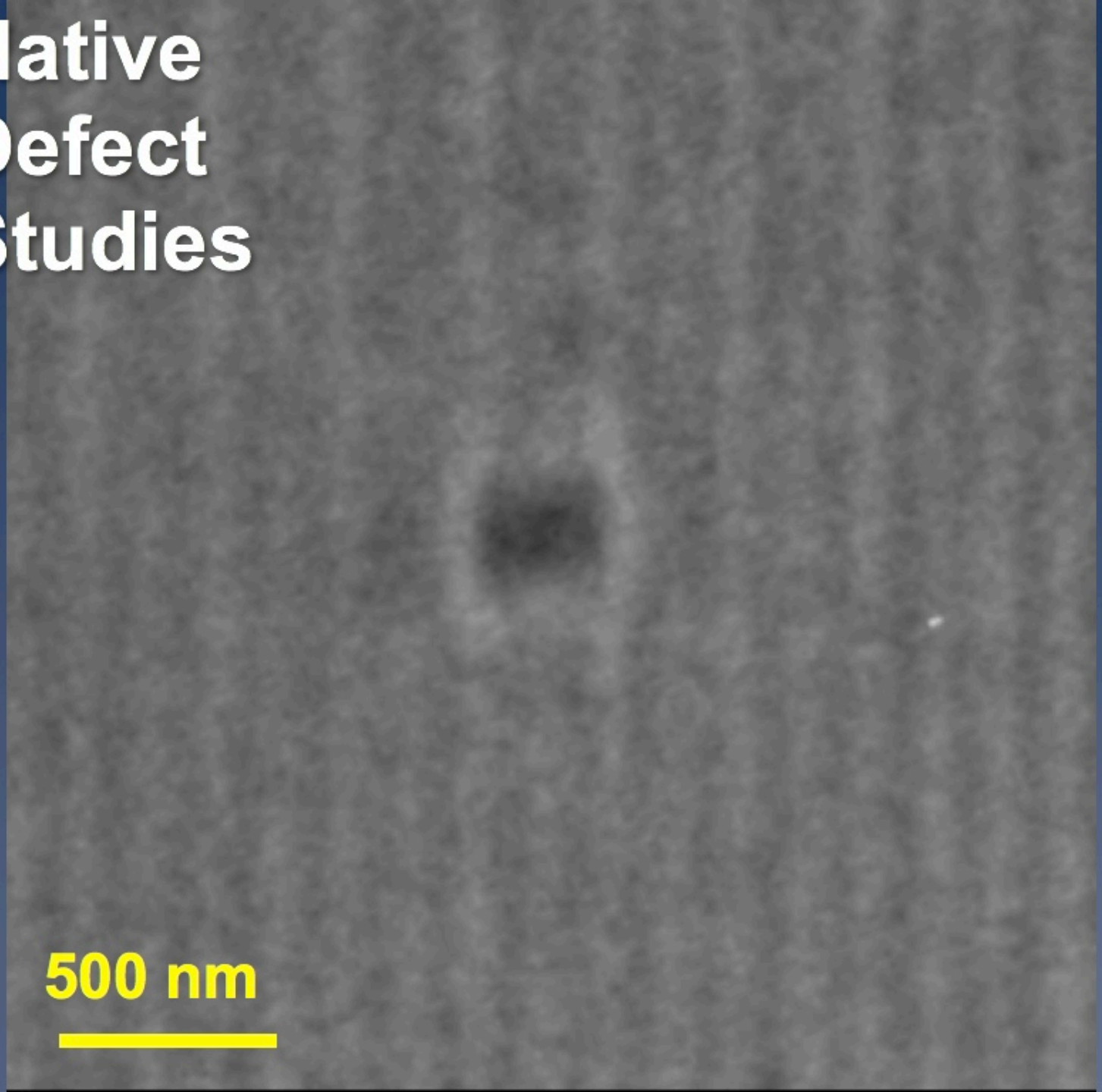
AIT (EUV)

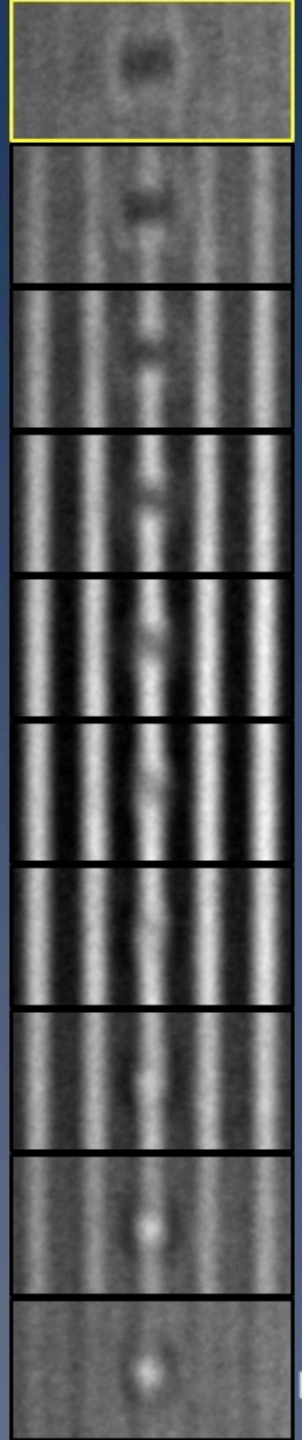
— 500 nm

Mask: SMOCOL2 / Gallagher, Badger, *unpublished 2011*

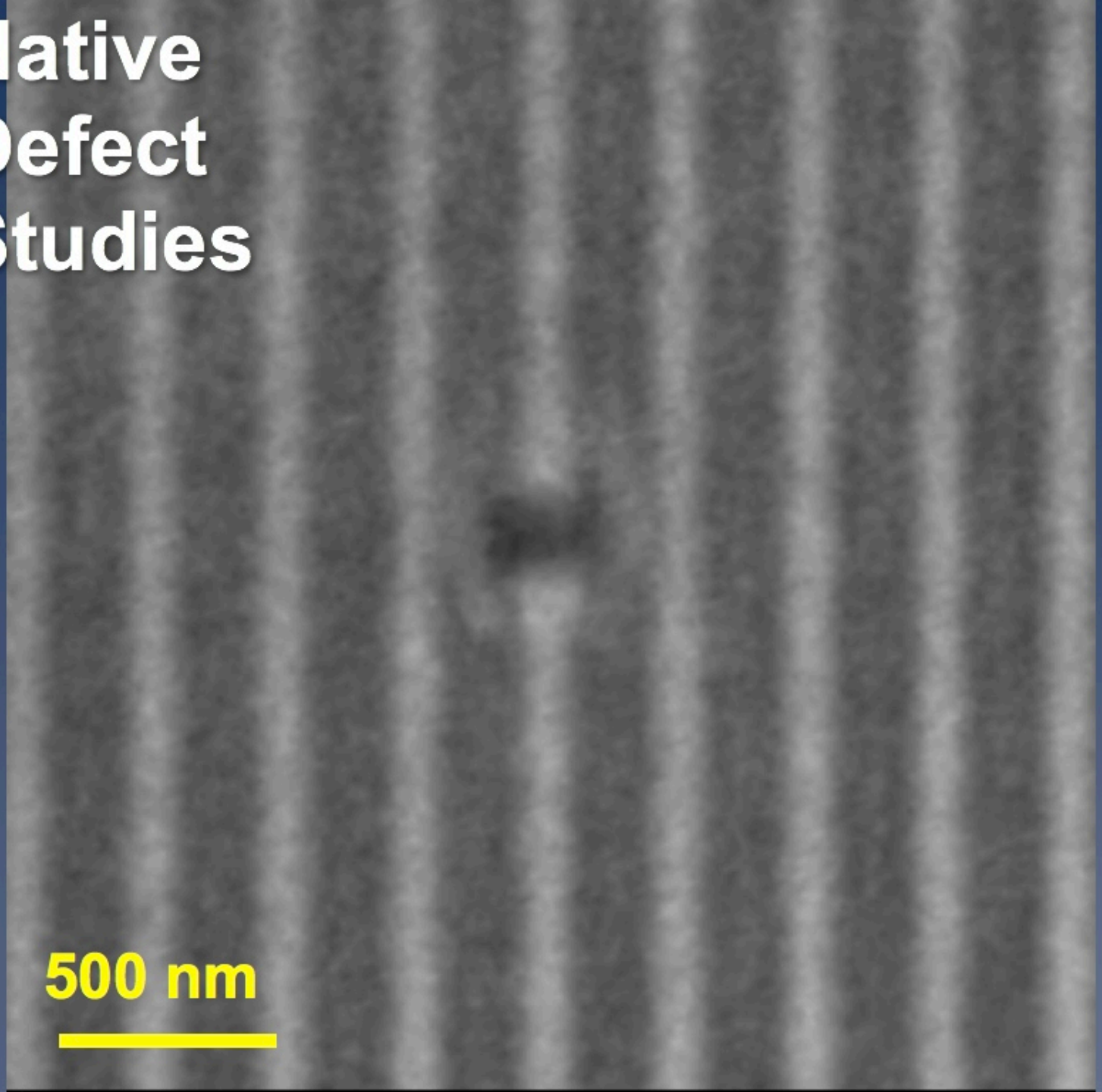
Defect A3-B30

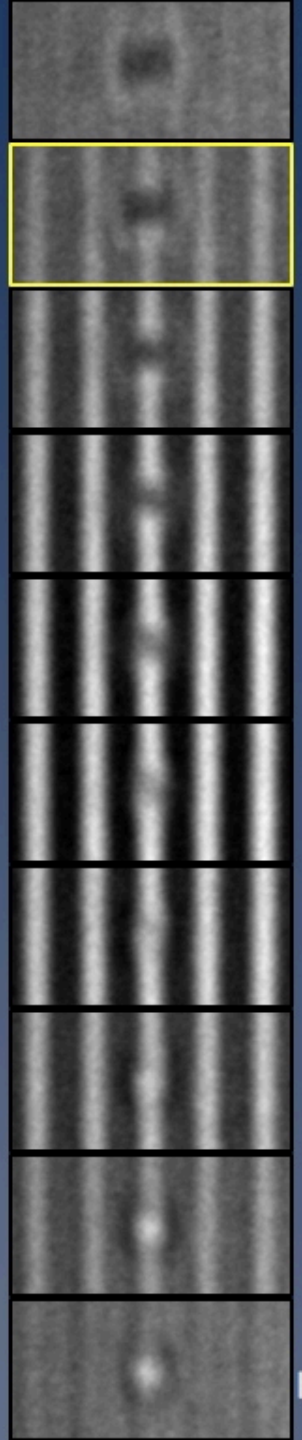
Native Defect Studies





Native Defect Studies





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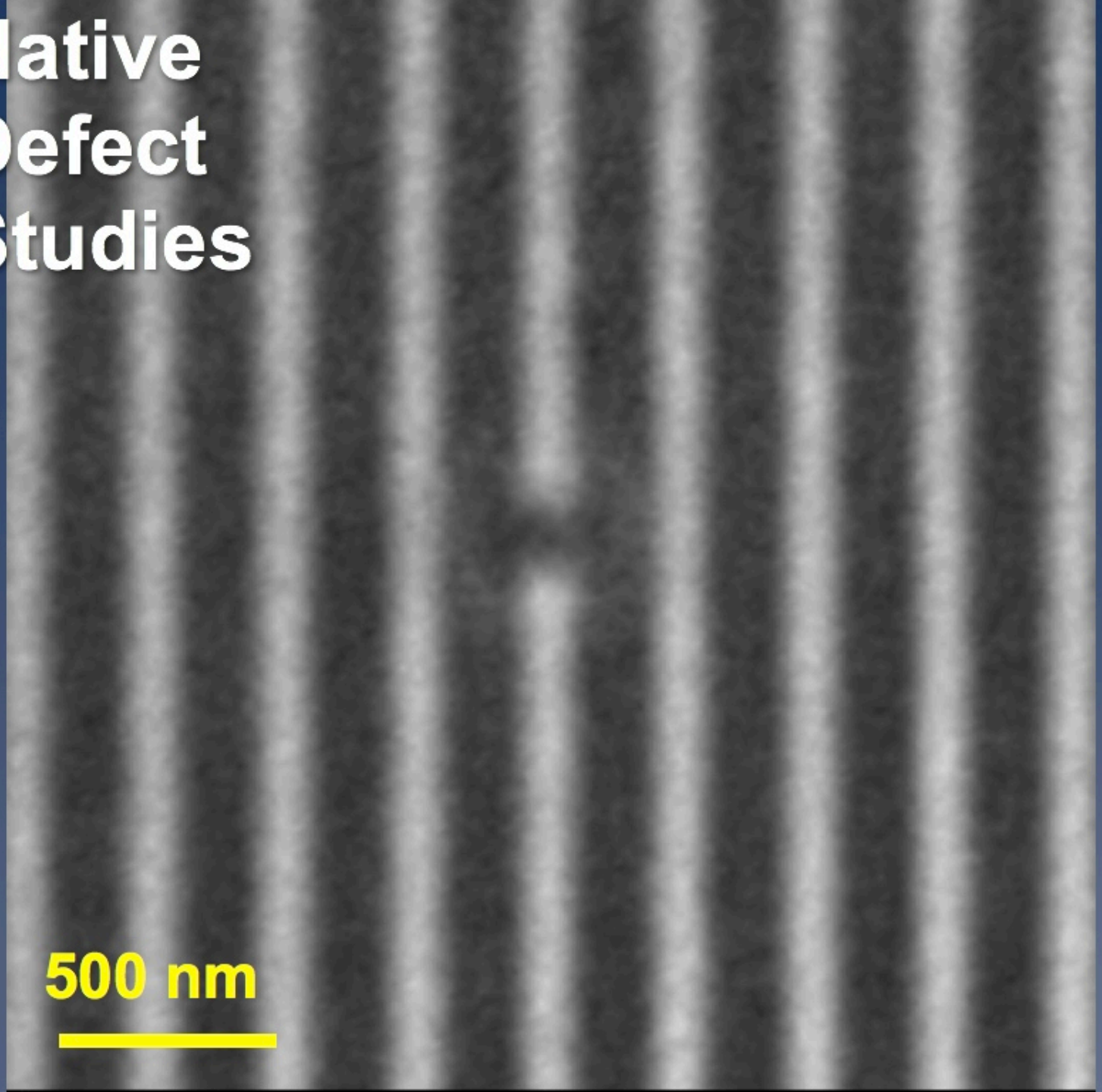

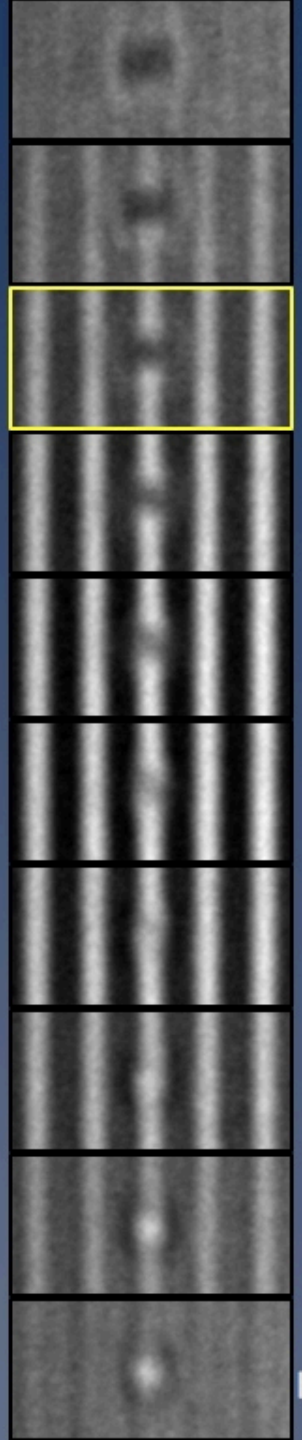

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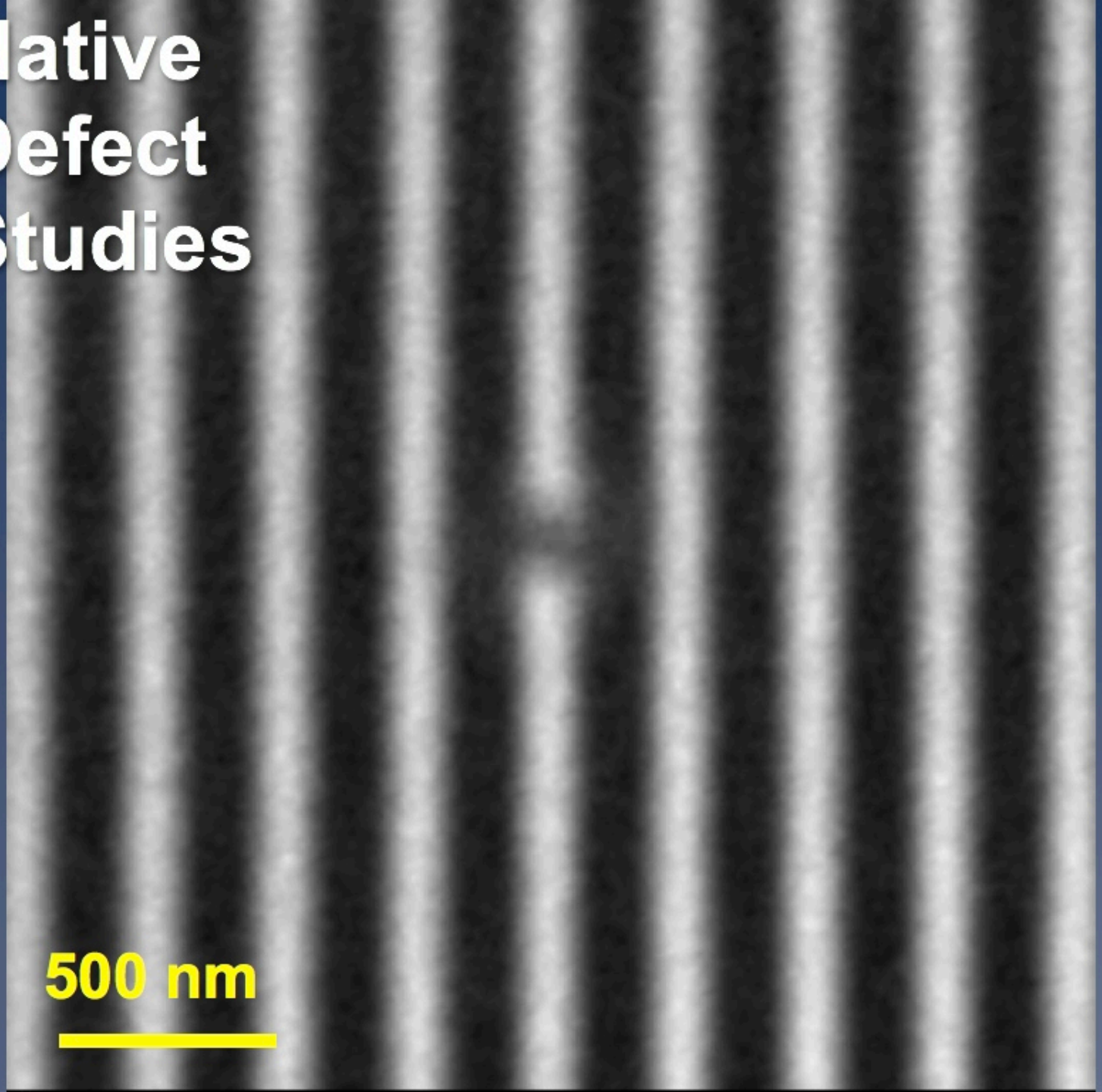

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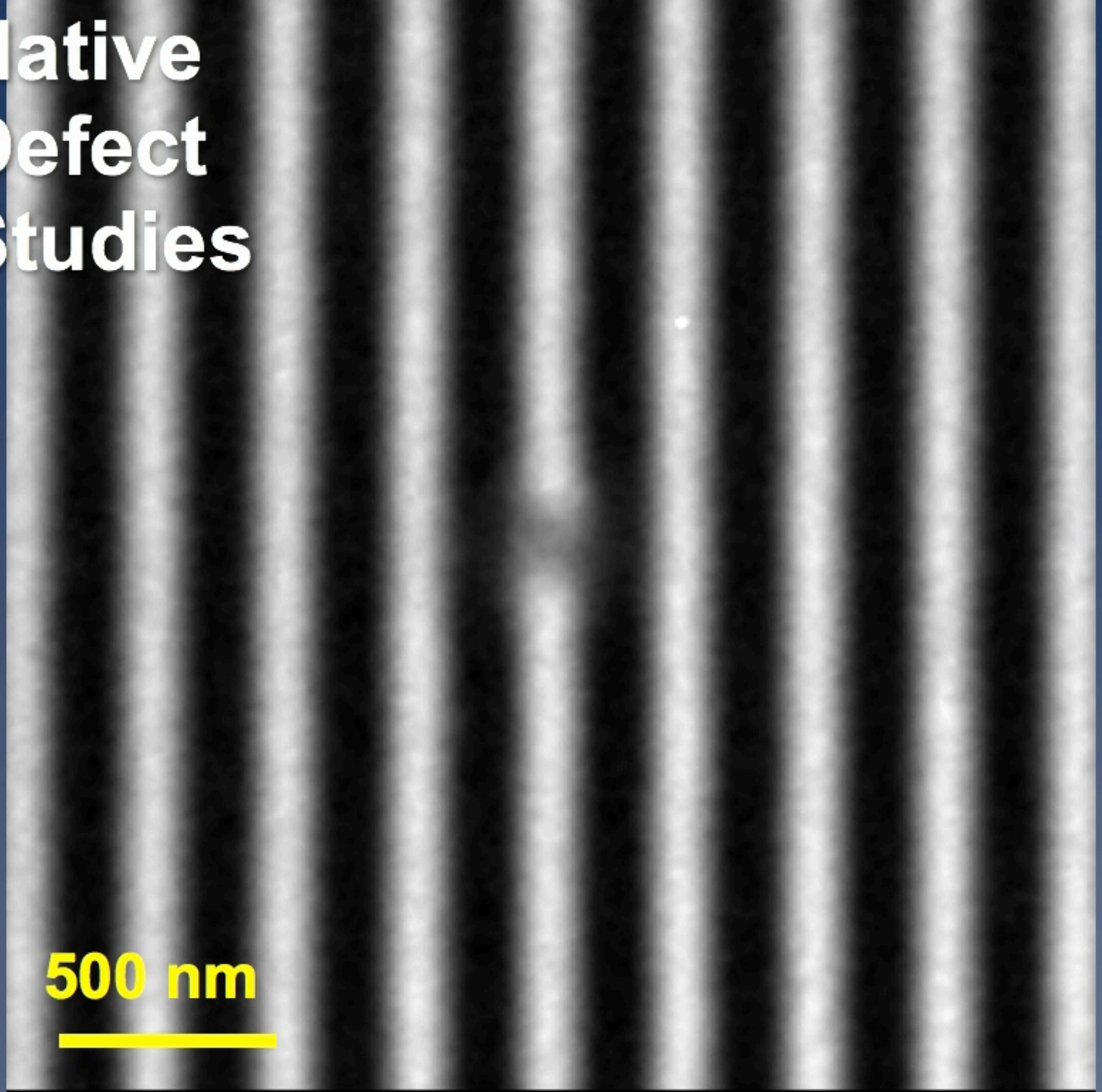

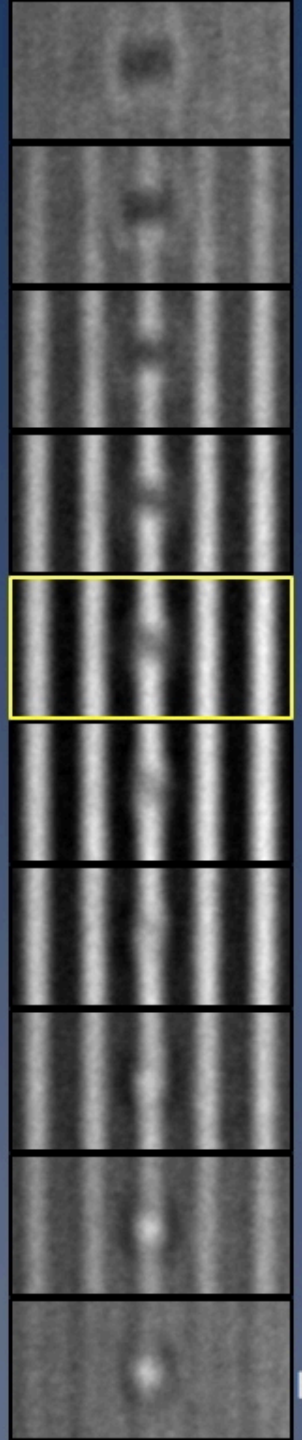

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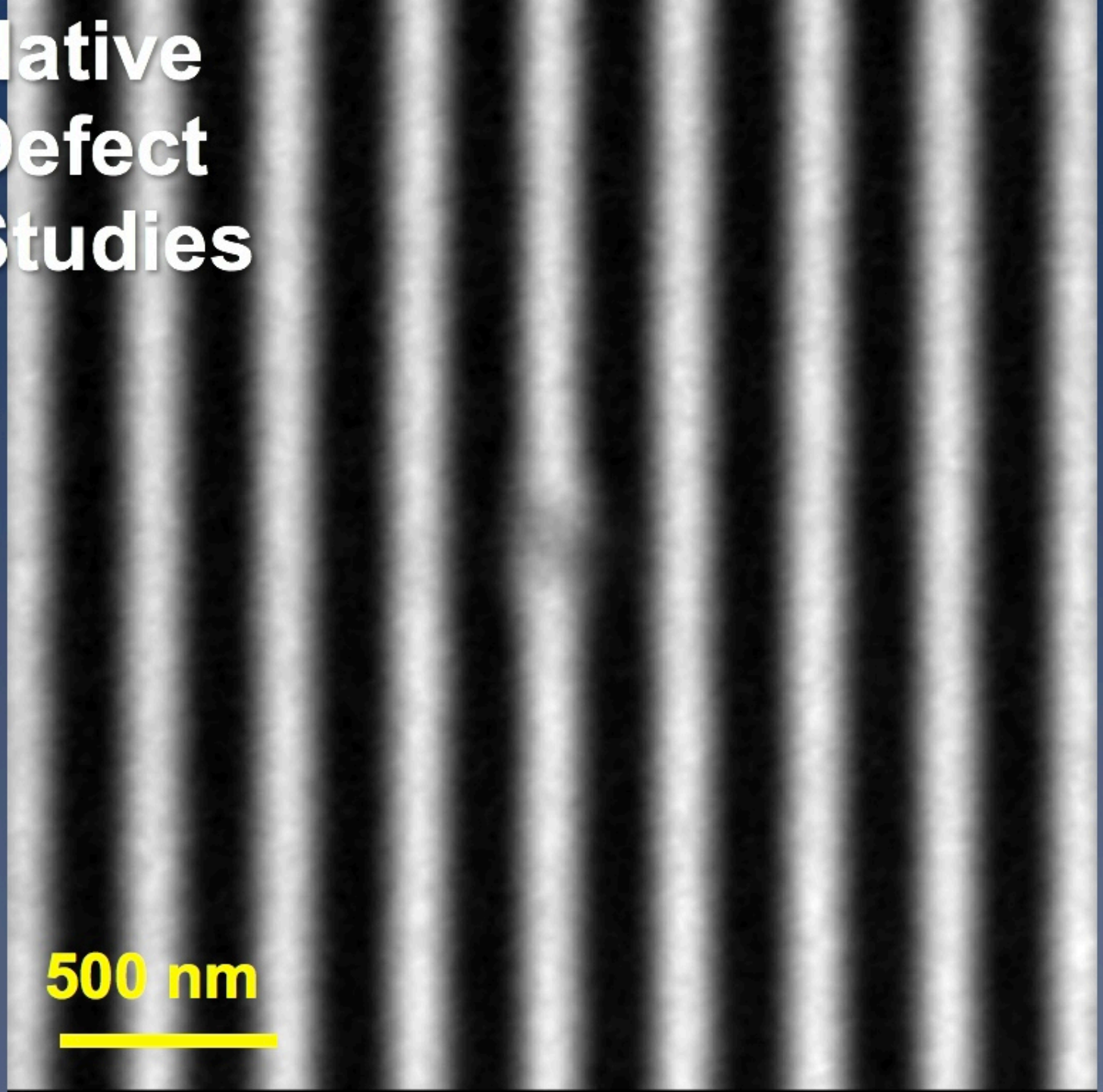

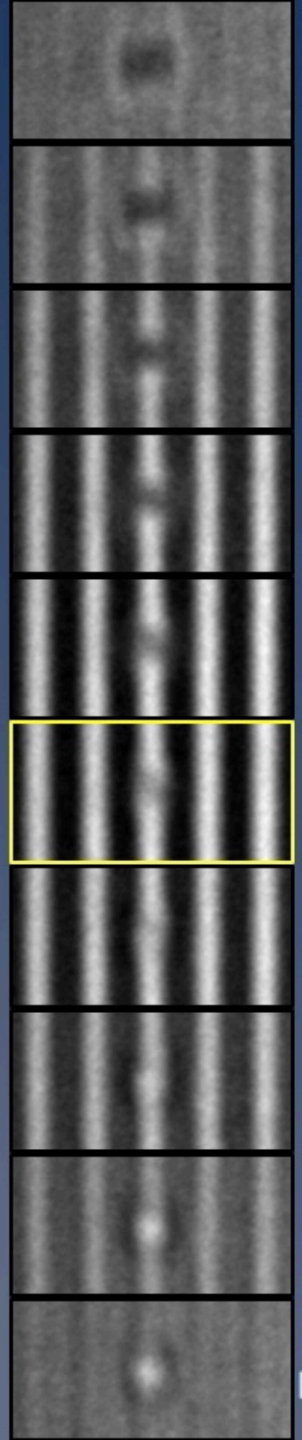

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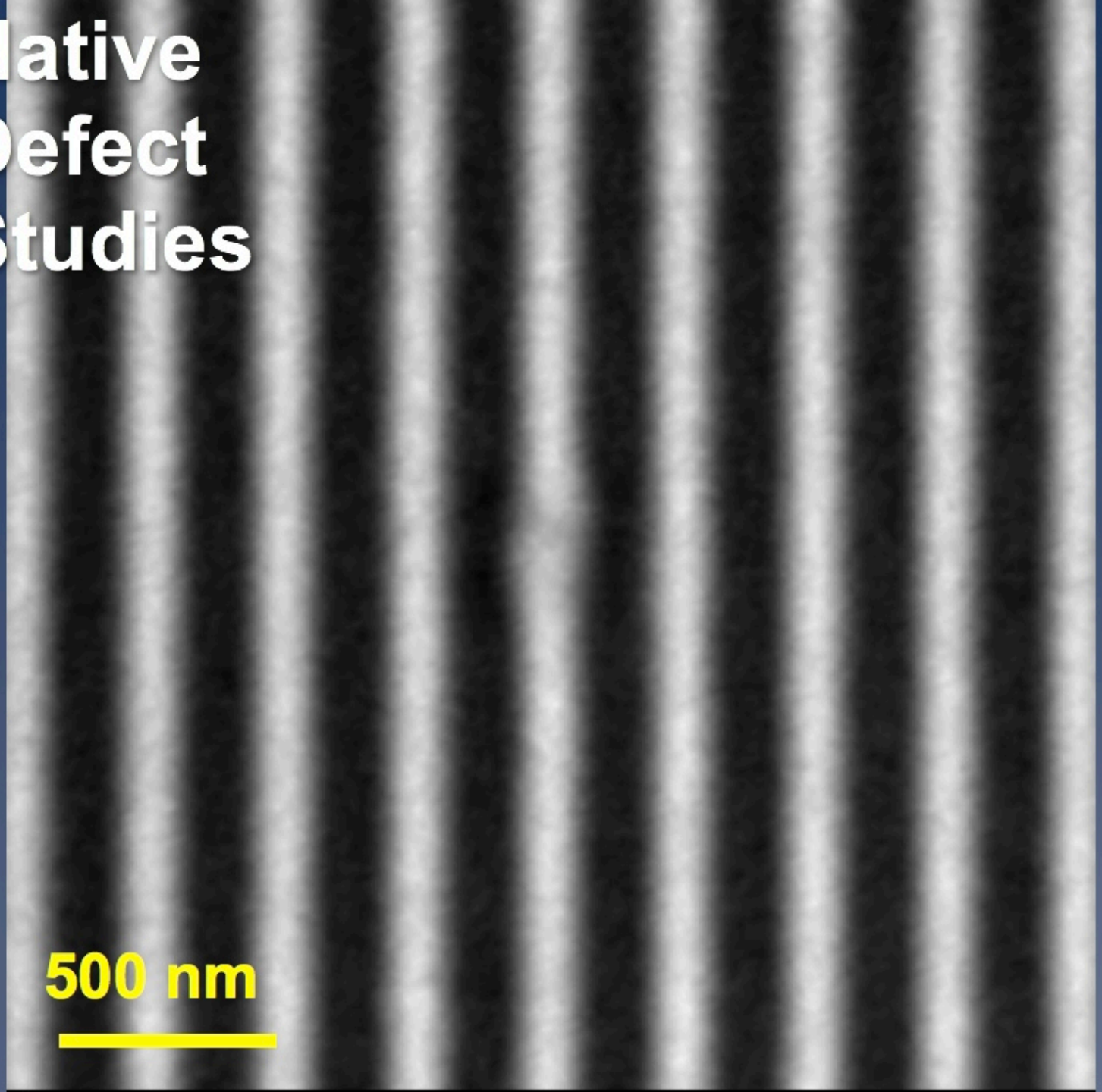

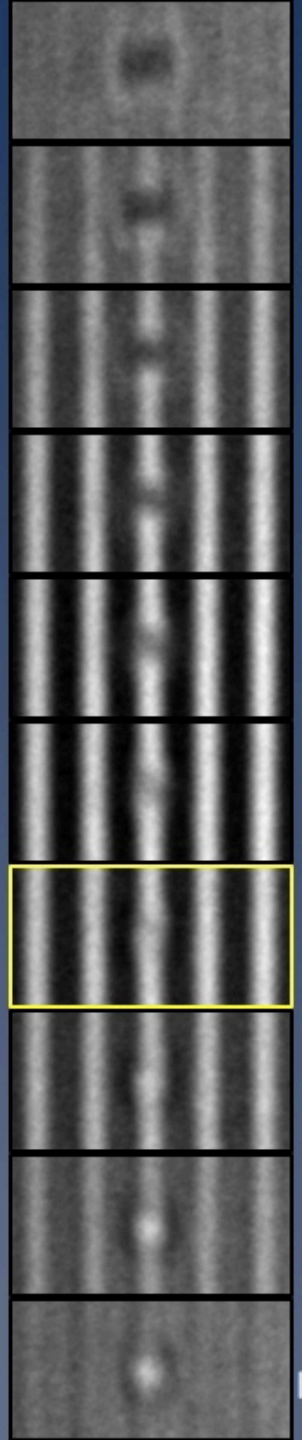

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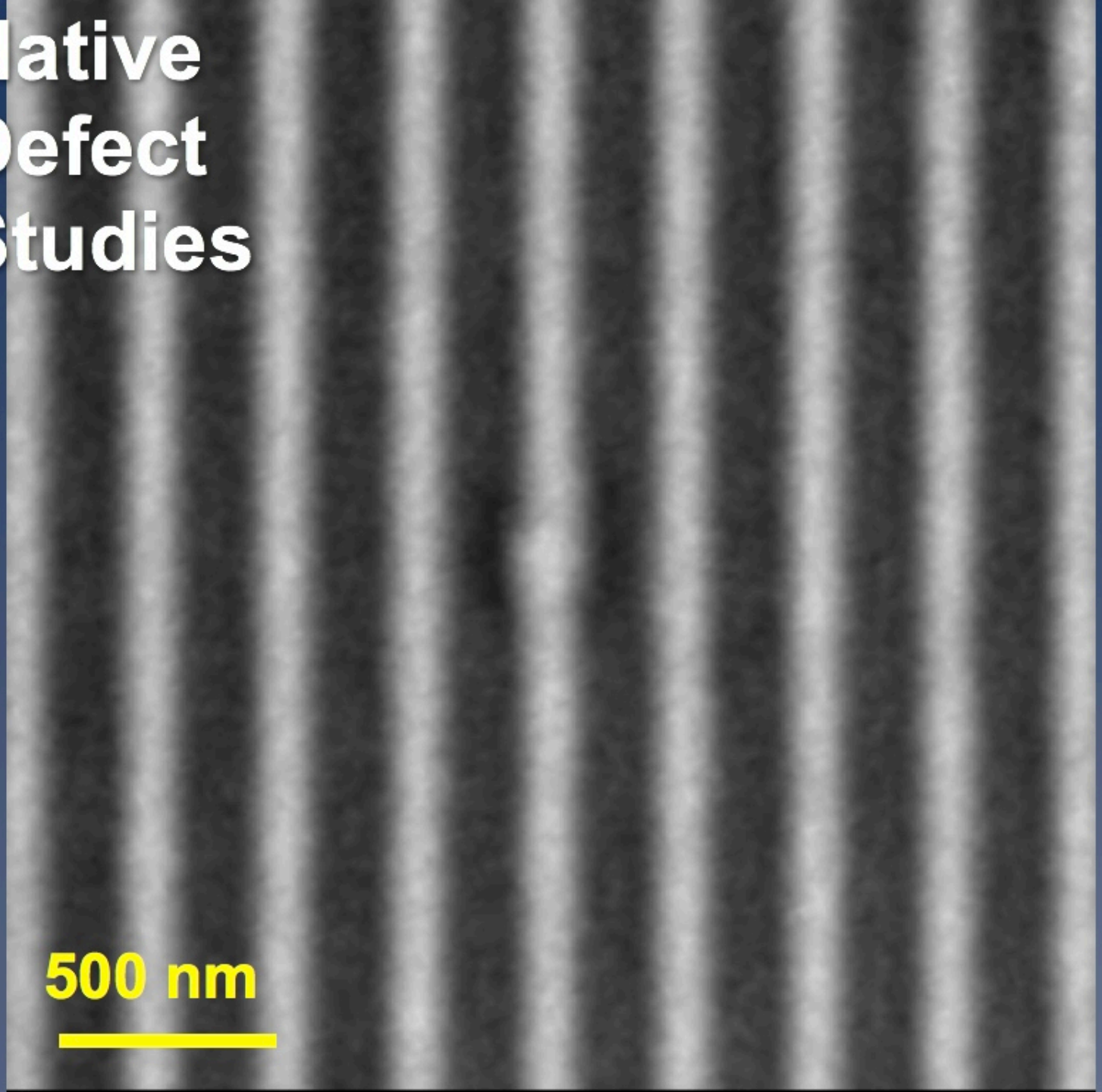

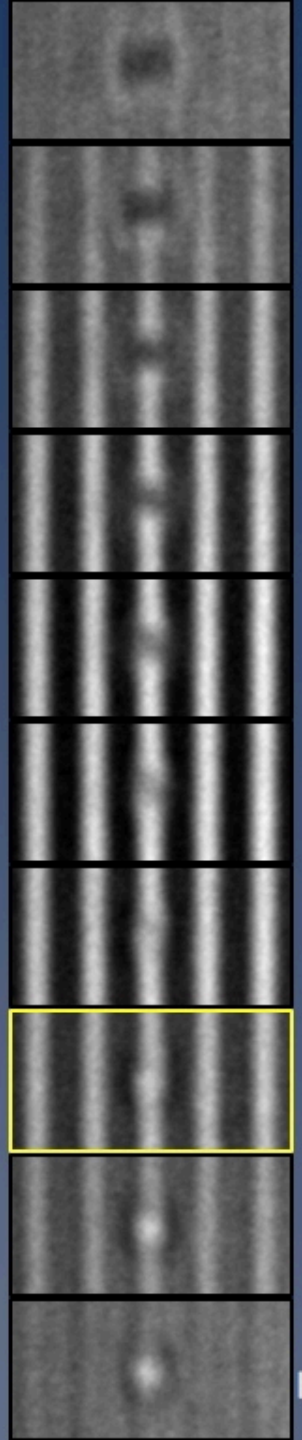

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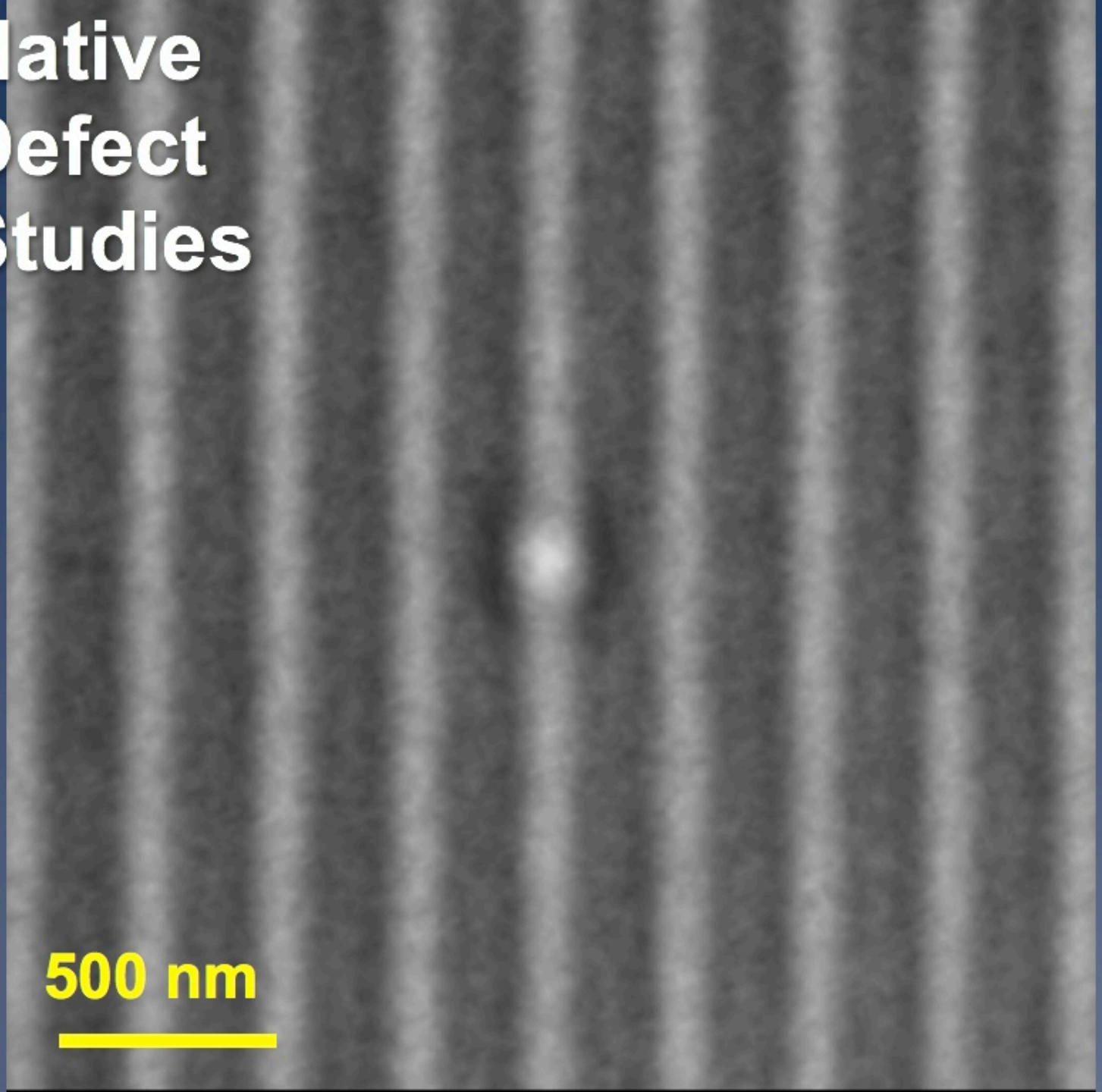

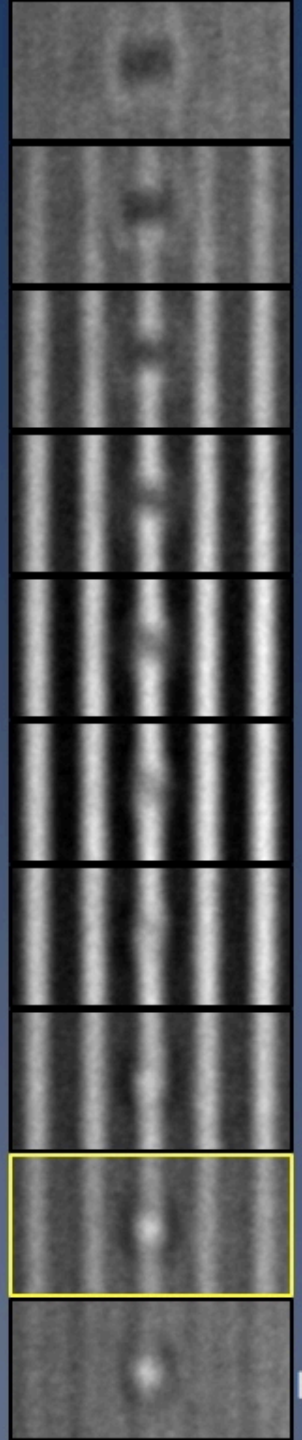

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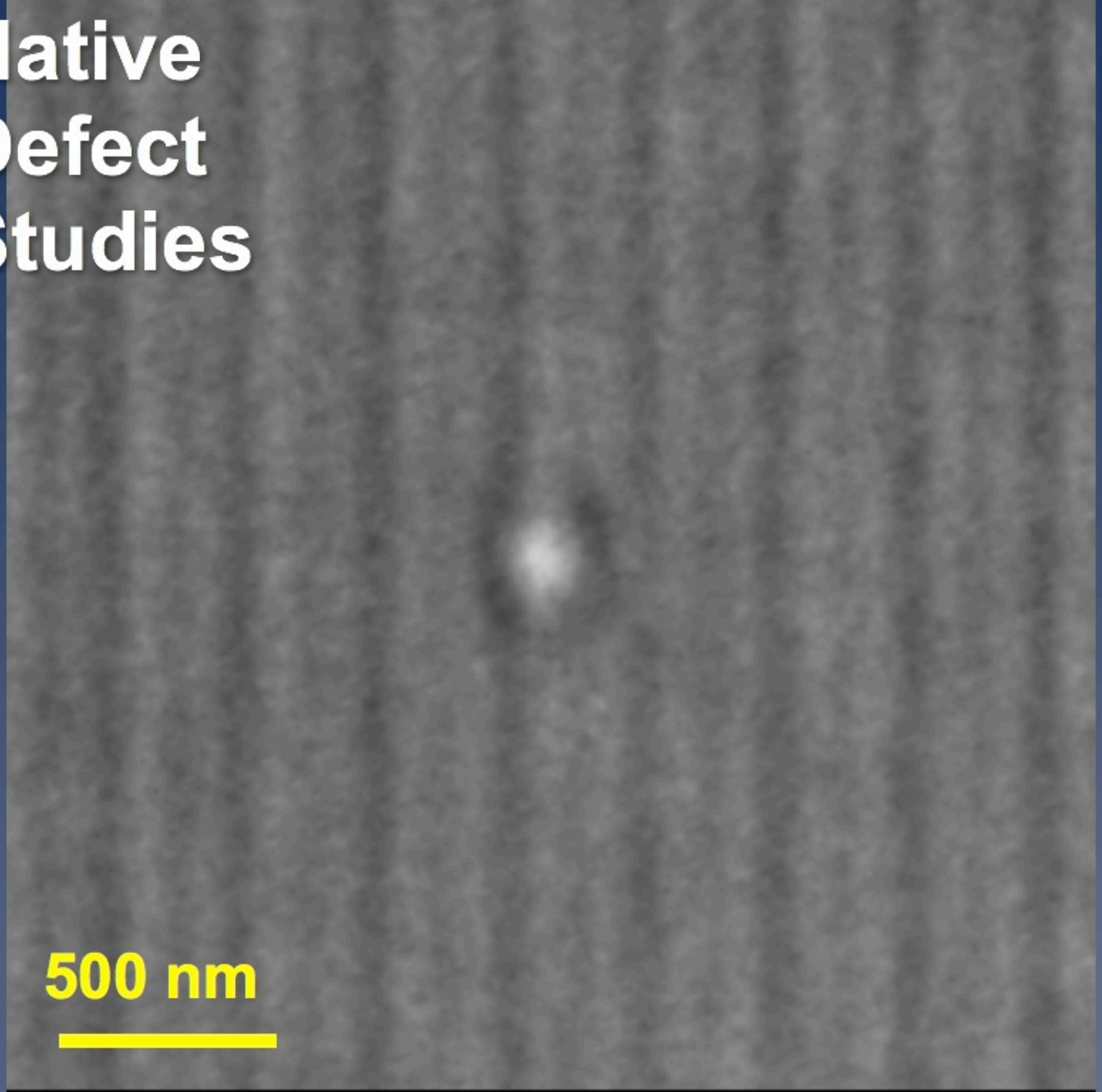
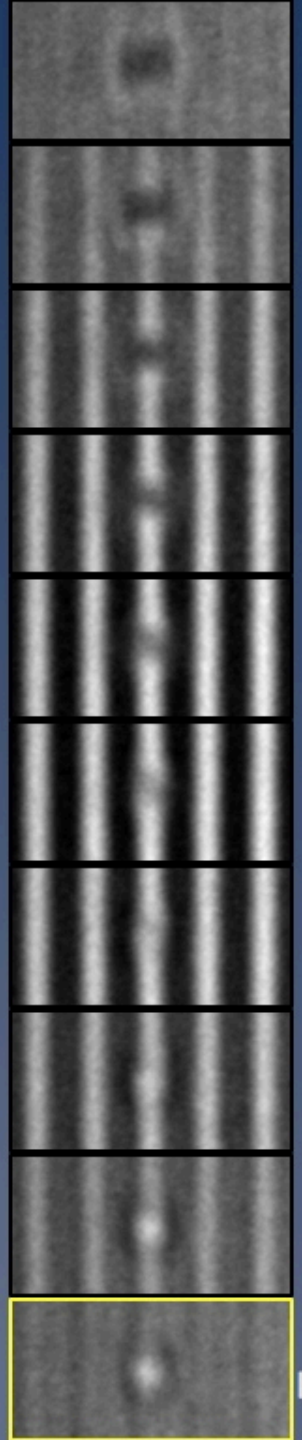
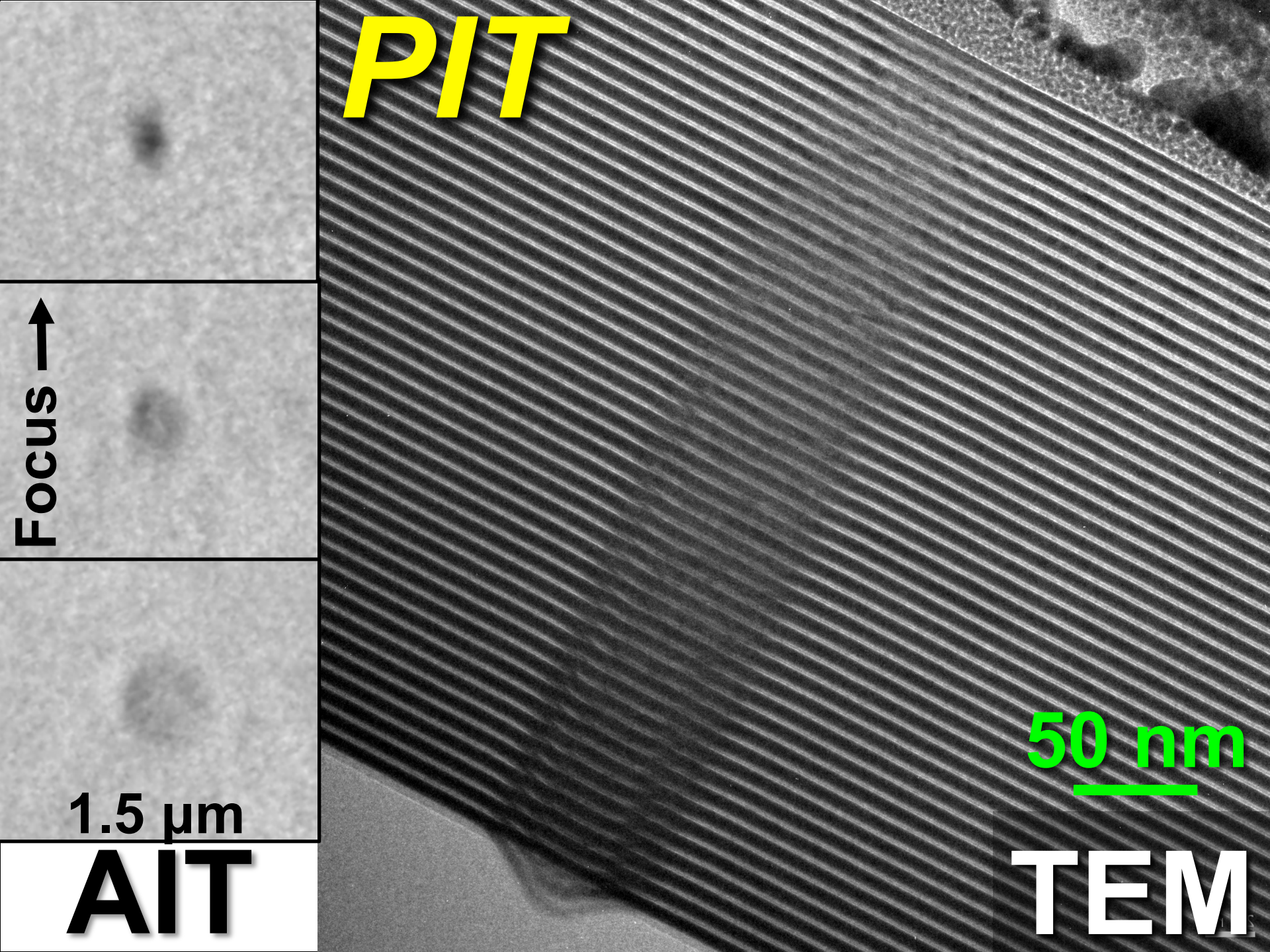
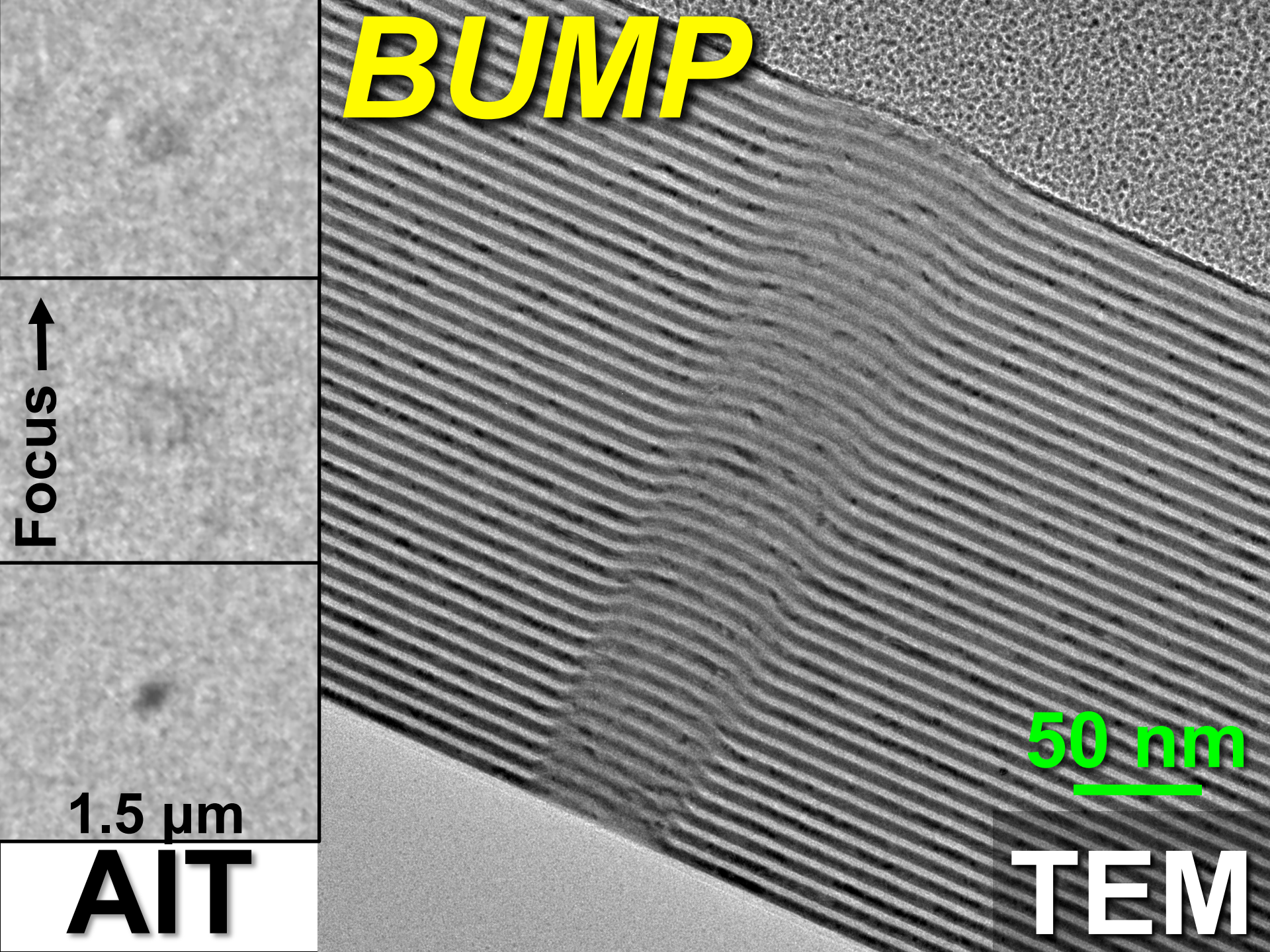
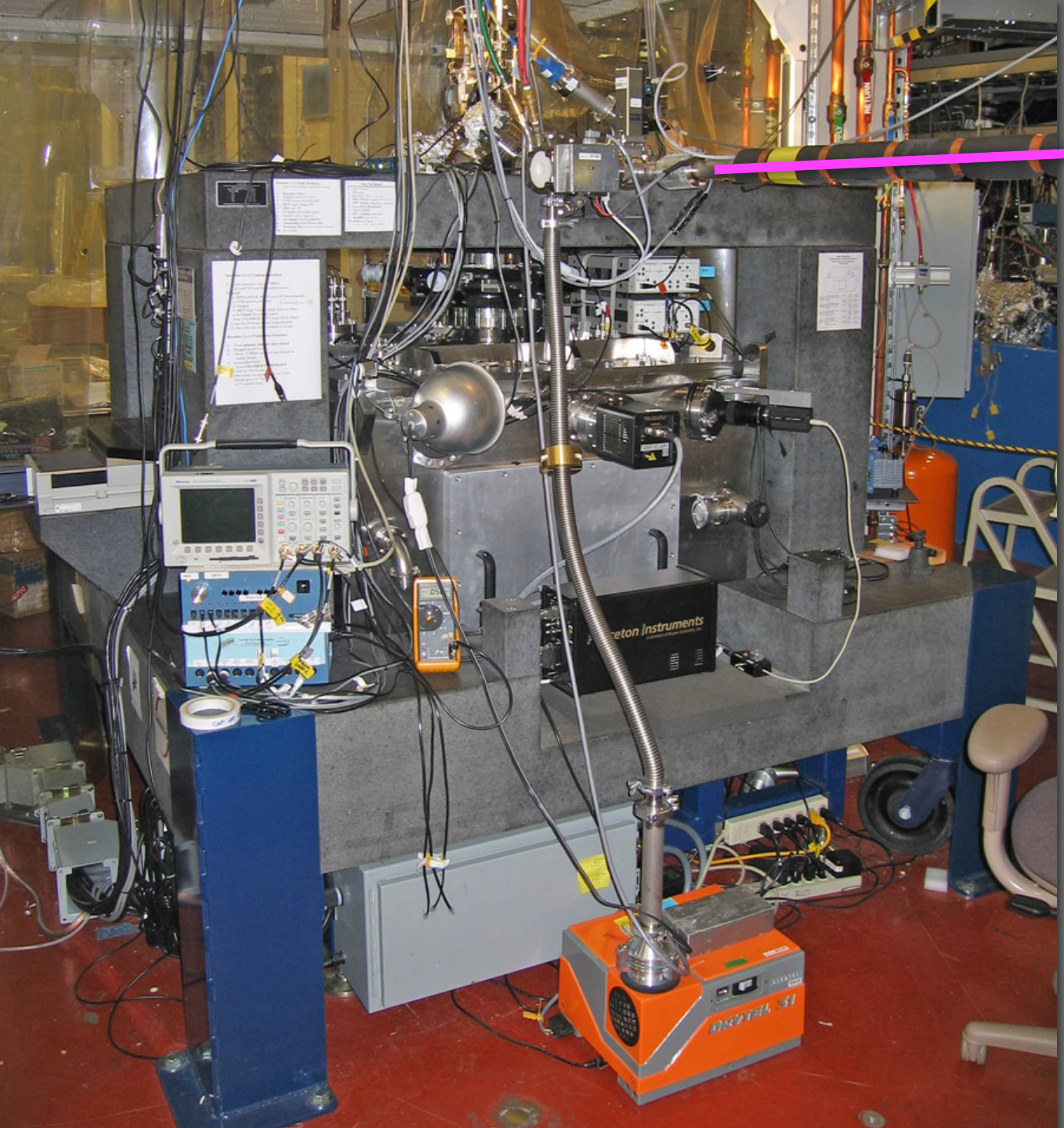


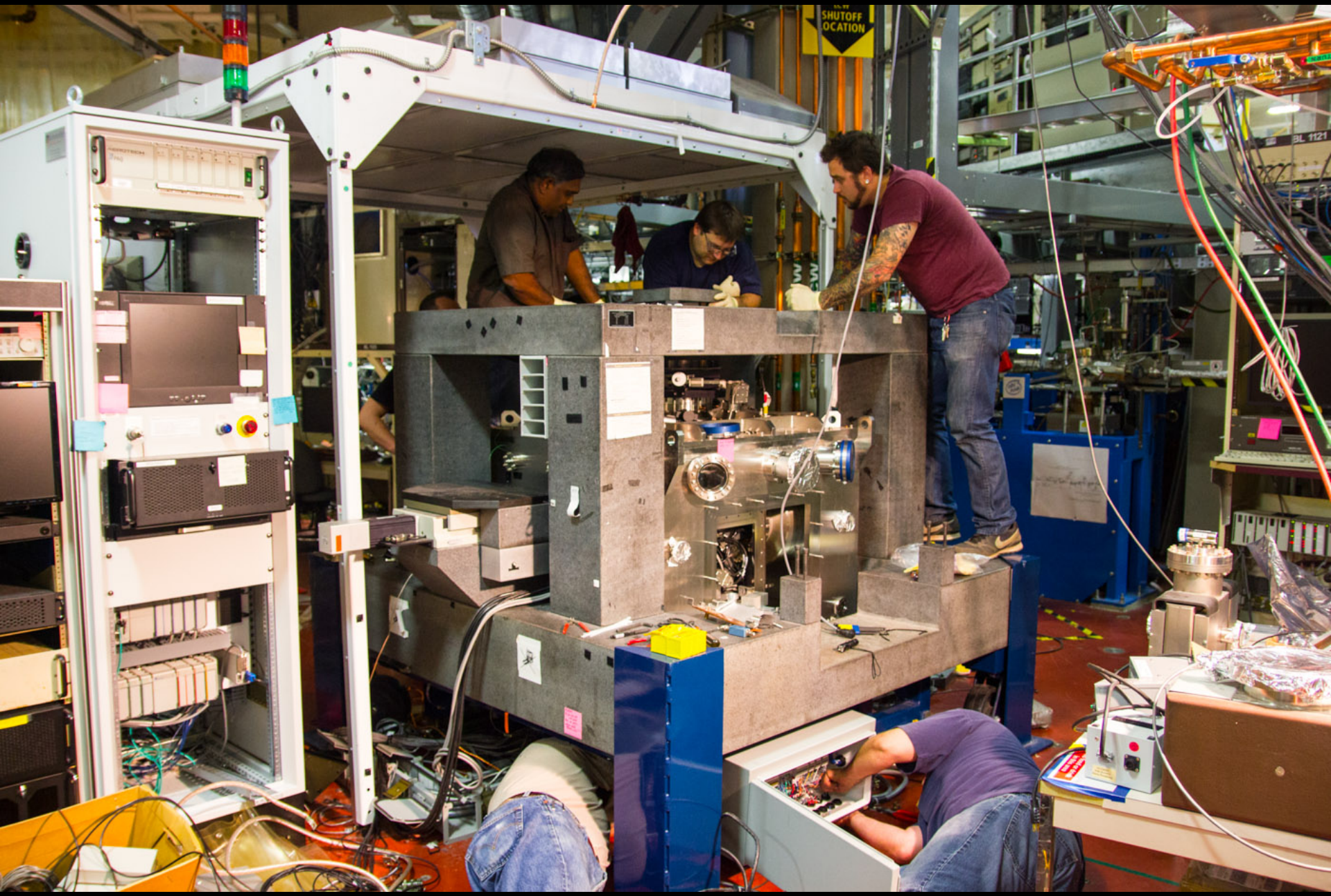



PIT
Focus
1.5 µm
AIT
50 nm
TEM


BUMP
Focus
1.5 µm
AIT
50 nm
TEM



The AIT


SHUTOFF
OCATION
BL 1121

EFFICIENT

lots of data per shift

COHERENCE CONTROL

emulate various tools

FLEXIBLE

lots of optical settings

EFFICIENT

lo ft

CO OL

em

FLEX

lots of optical settings

STABLE!

SHARP

SEMATECH HIGH-NA ACTINIC RETICLE REVIEW PROJECT

Source: Synchrotron

Optics: Zoneplate-lenses

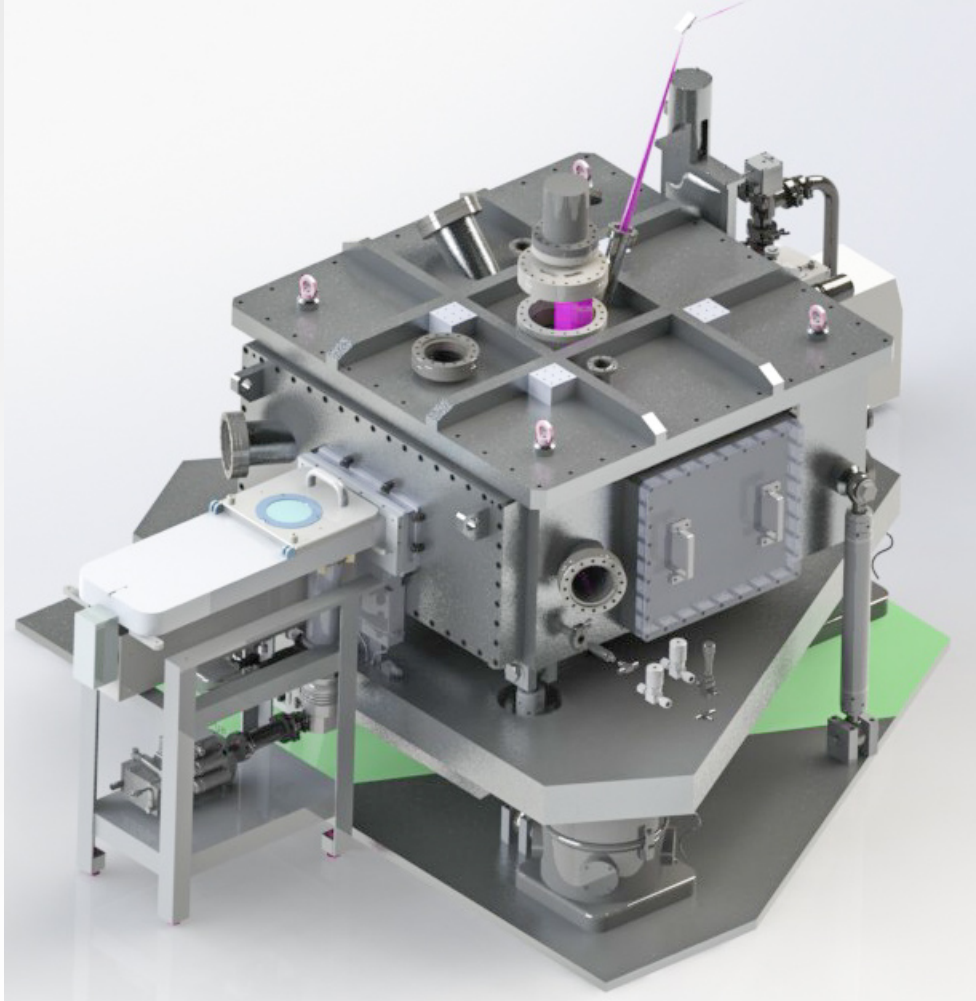
4×NA: 0.25–0.625

σ: Programmable

Nav: Full-mask *xy*

Speed: 5–10 series/hr

Vibration Isolation



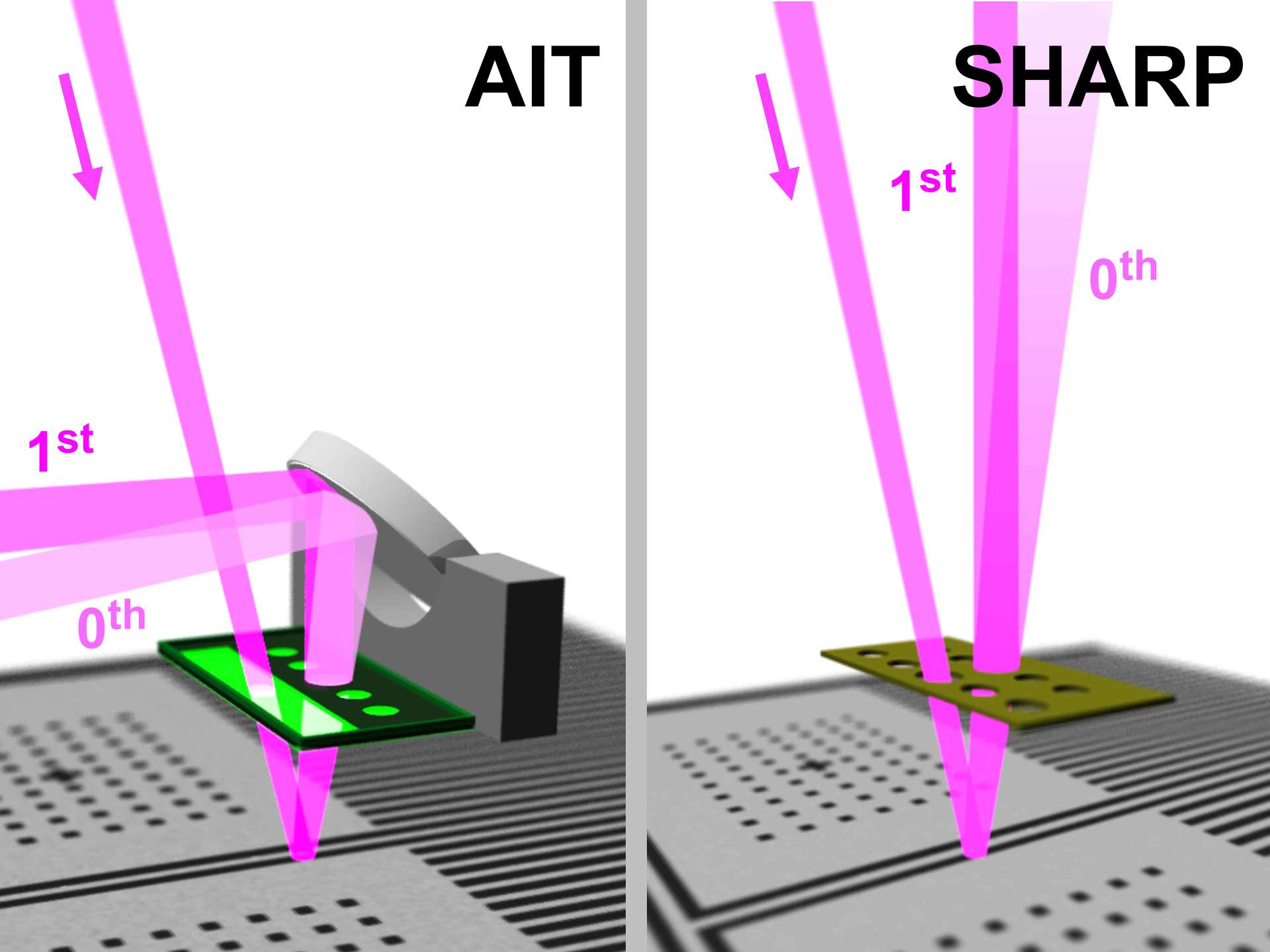
POWER

COHERENCE

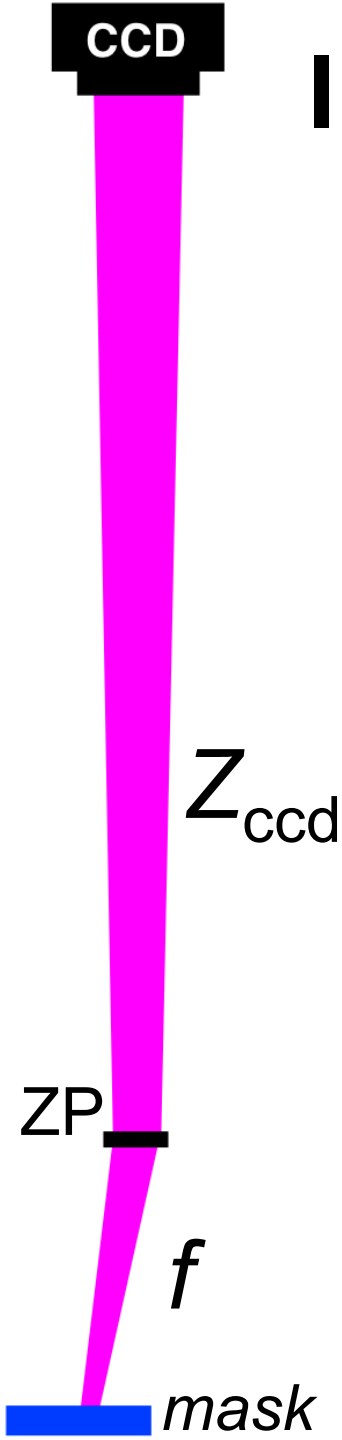
STABILITY

RESULTS

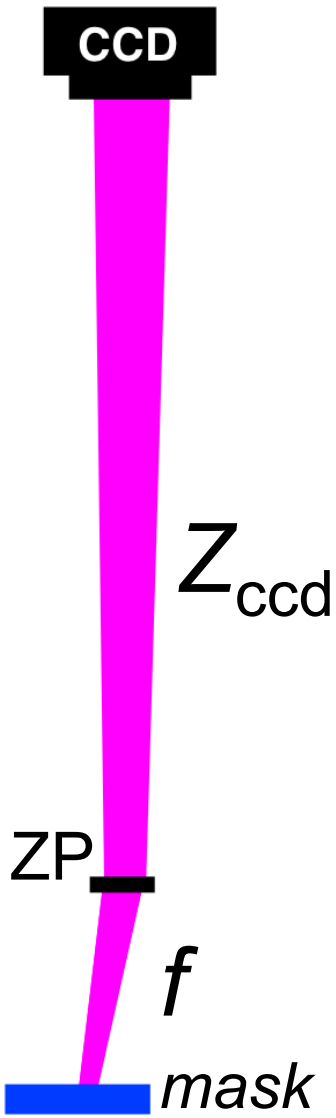
POWER


AIT
1st
0th
SHARP
1st
0th

Intensity ~ Bandwidth / Mag^2

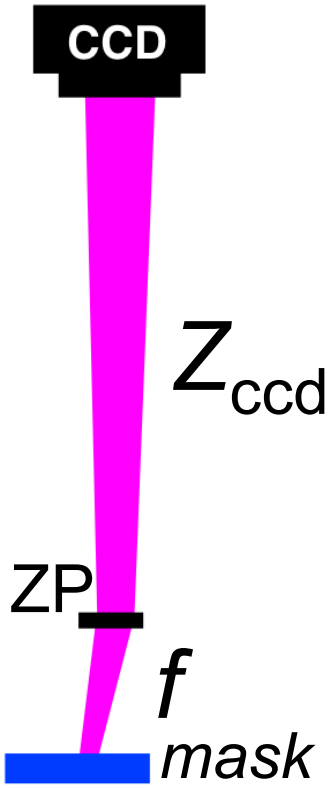


Intensity ~ Bandwidth / Mag^2

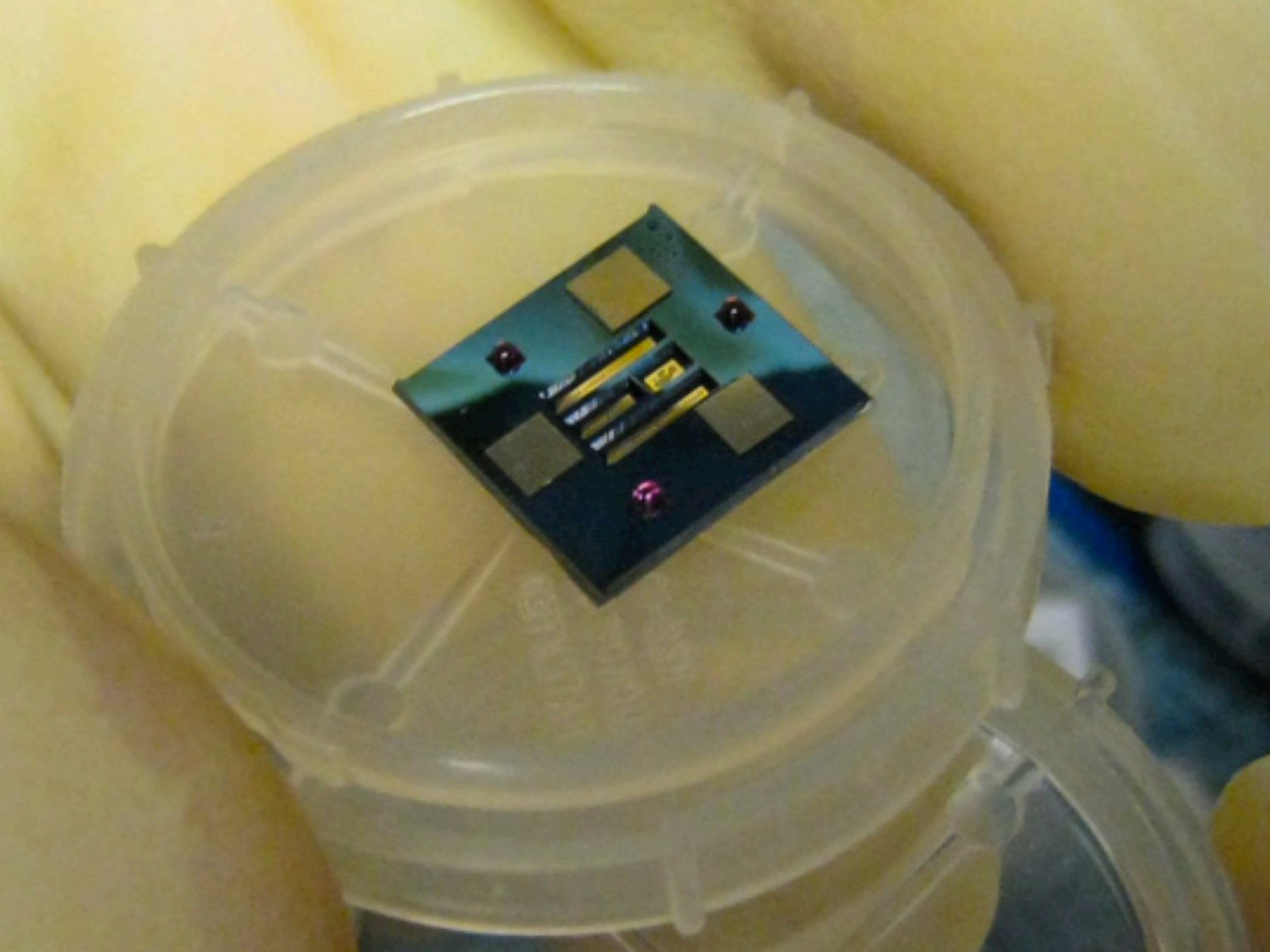


Intensity ~ Bandwidth / Mag^2

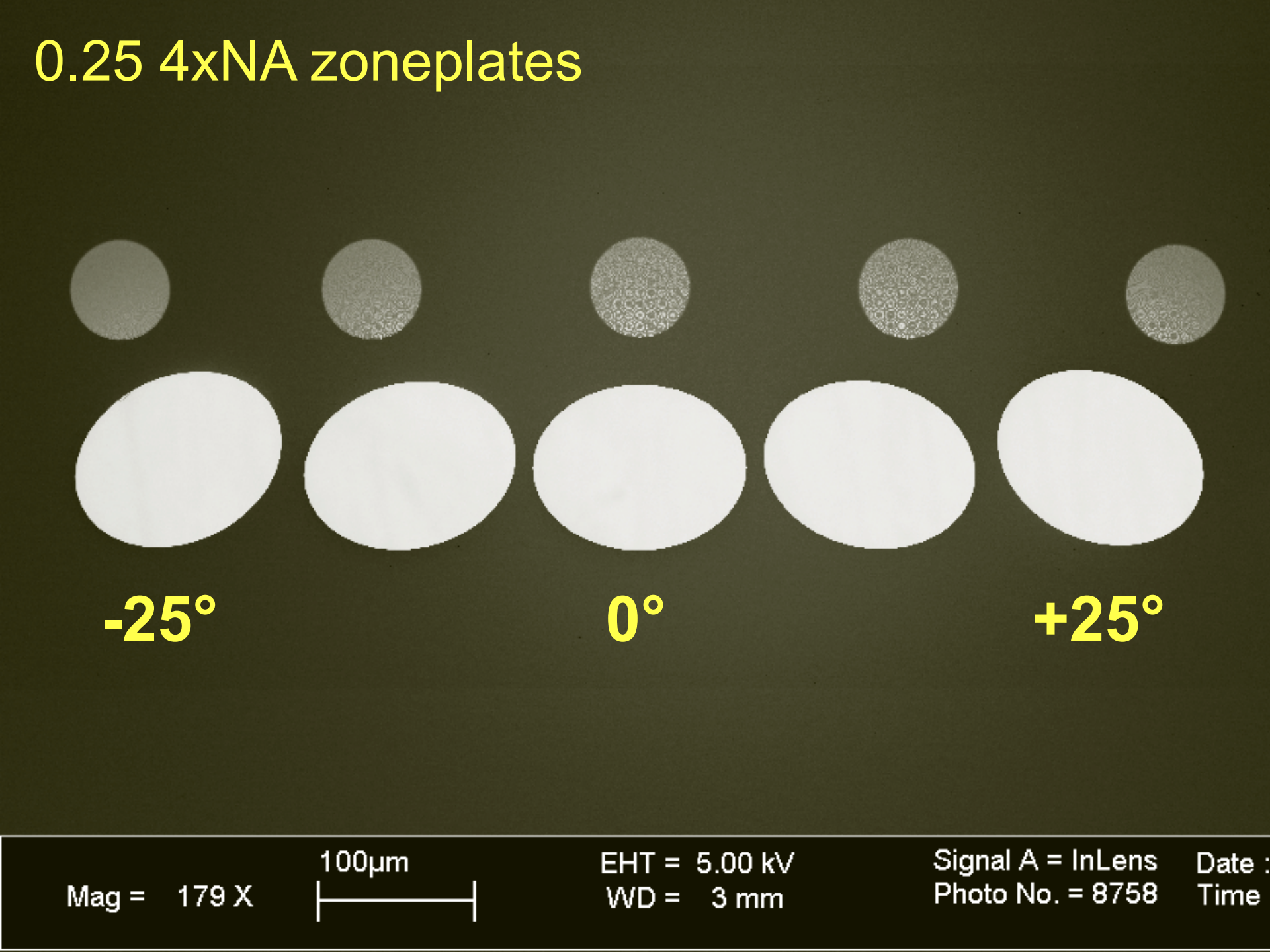
Reducing ƒ enables higher flux



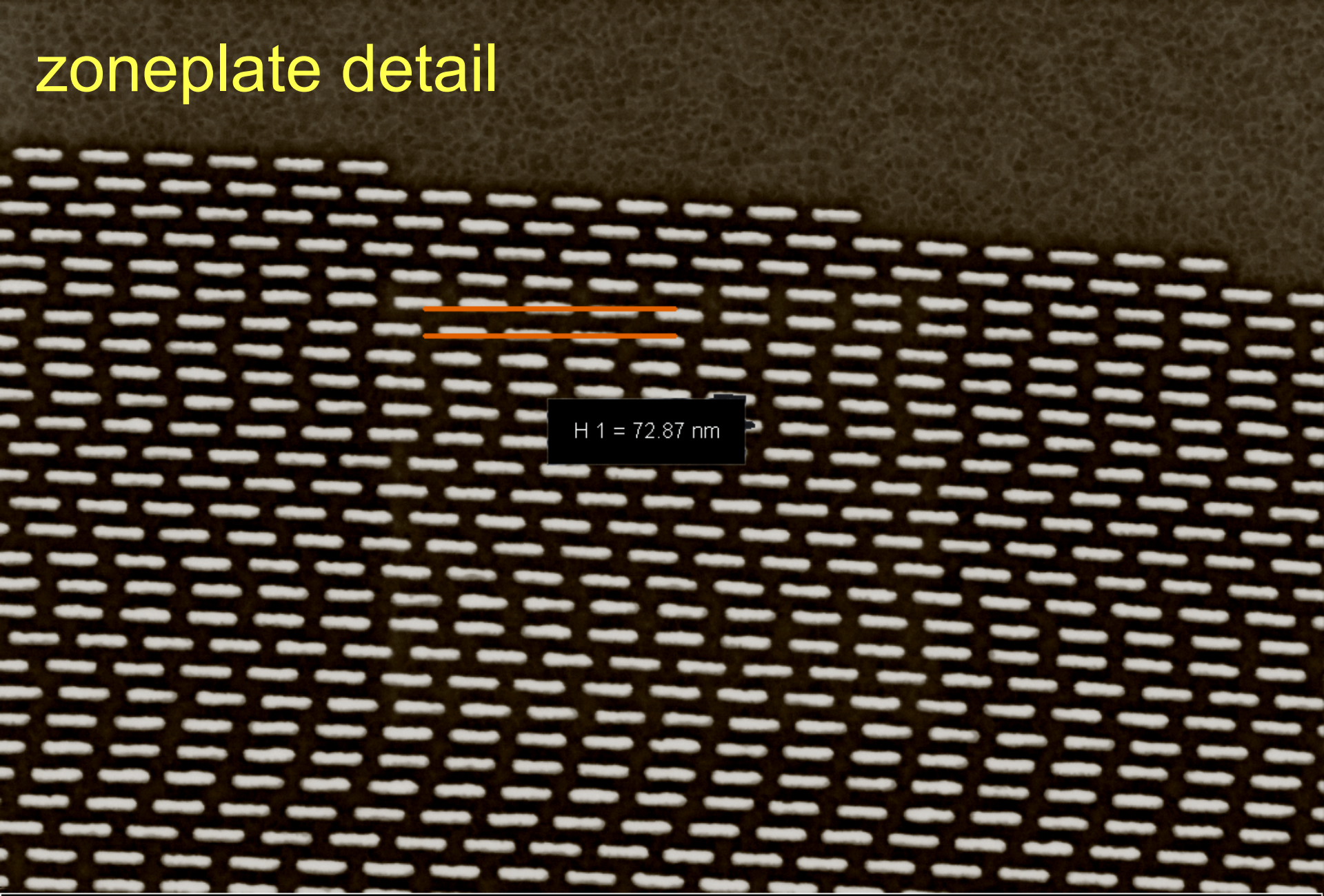
PATENTED
FLUOROWARE®
HSS-10



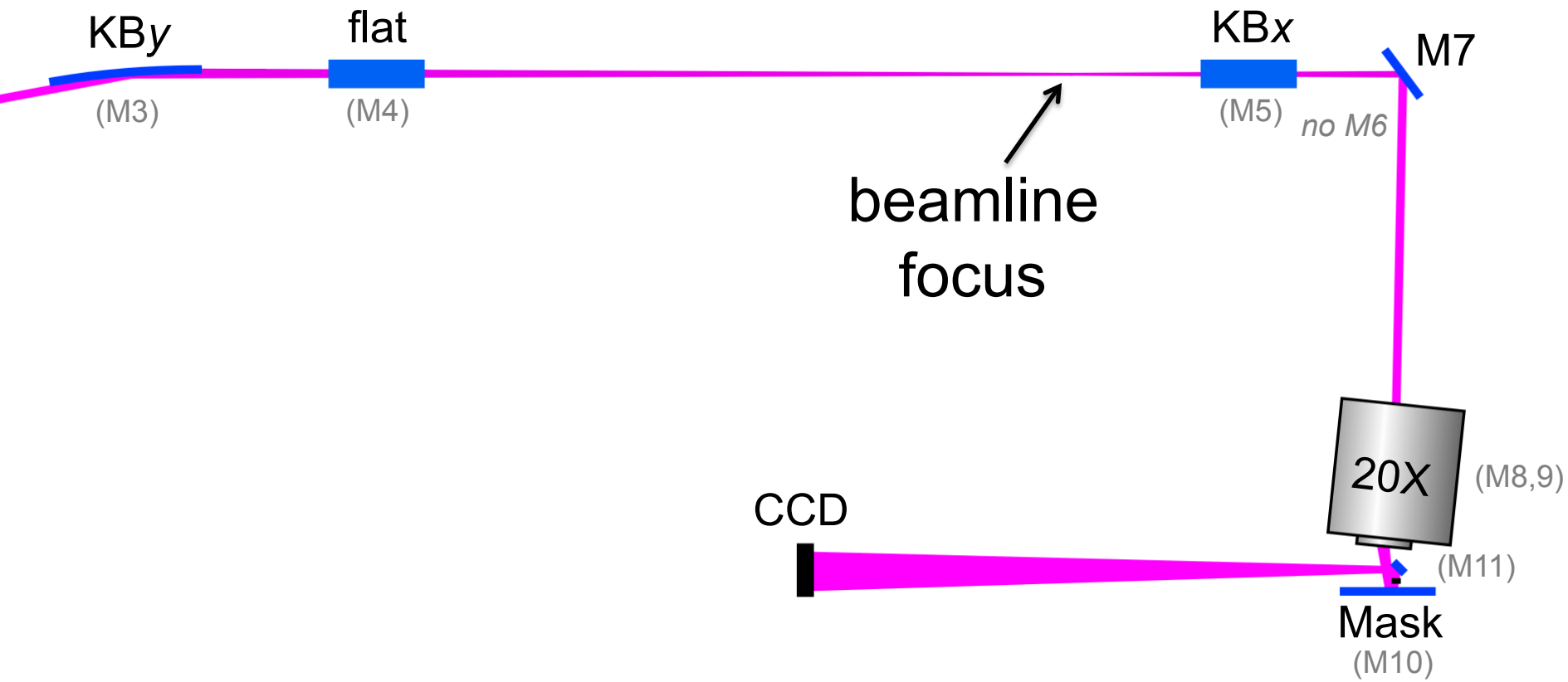
0.25 4xNA zoneplates



zoneplate detail



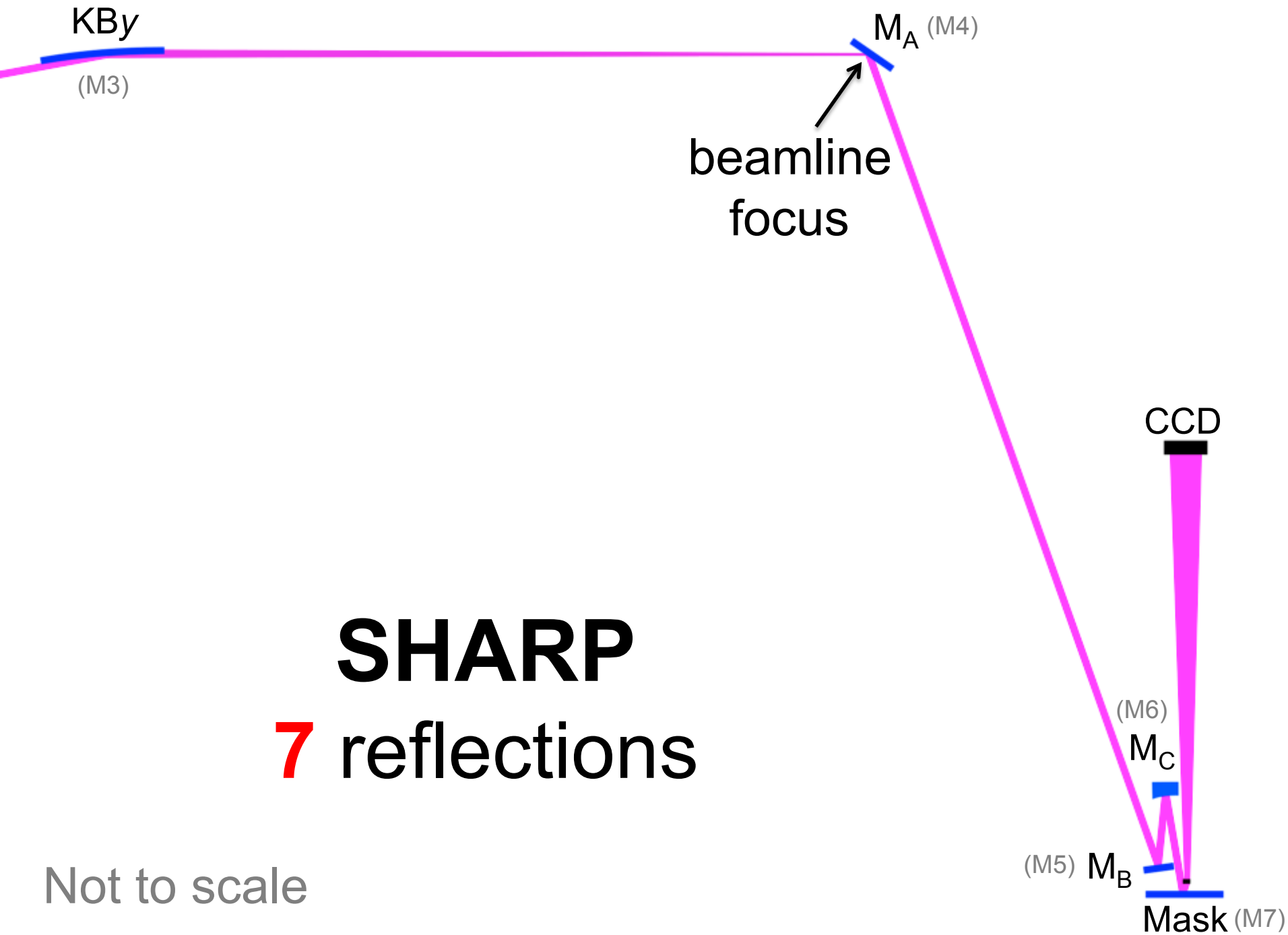
Mag = 50.00 K X
200nm
EHT = 5.00 kV
WD = 3 mm
Signal A = InLens
Photo No. = 8766
Date :11 Dec 2012
Time :13:29:34



AIT

10 reflections

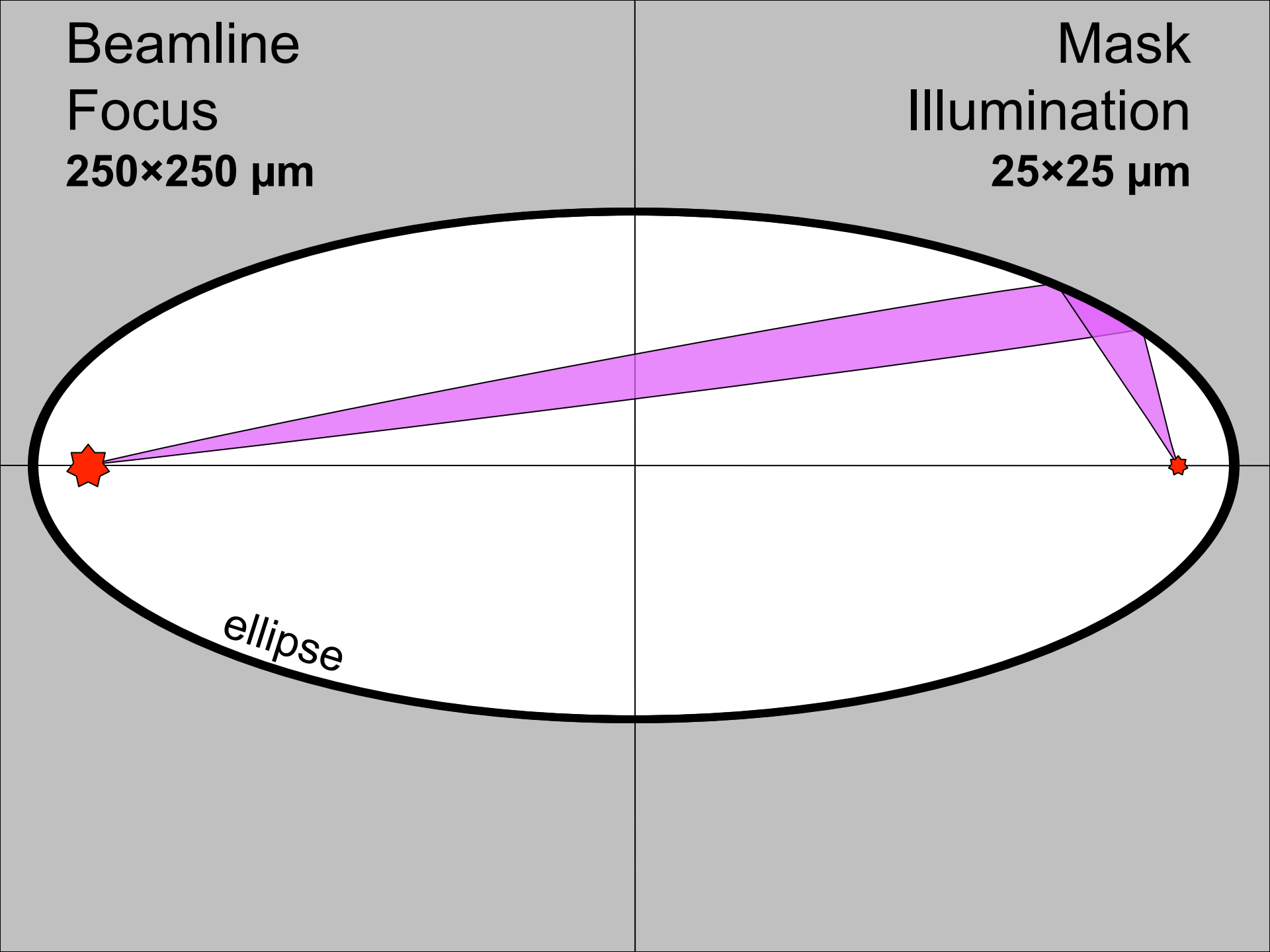
Not to scale



SHARP

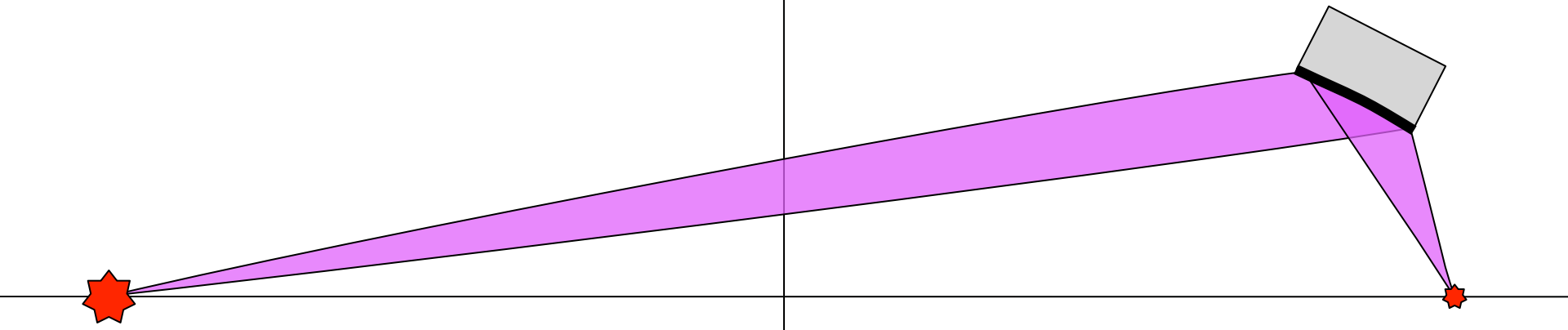
7 reflections

Not to scale

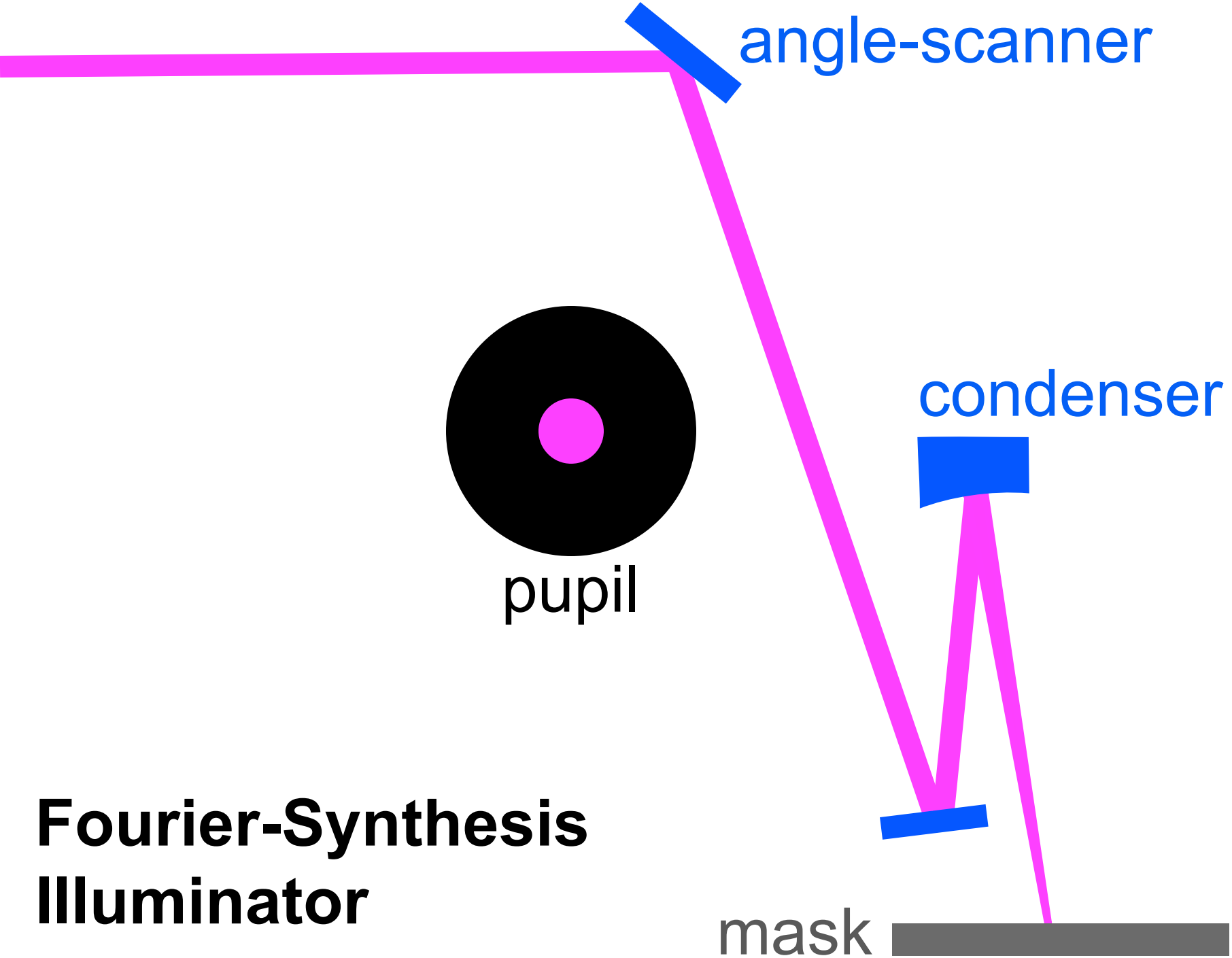

Beamline
Focus
250×250 µm
Mask
Illumination
25×25 µm
ellipse

Beamline
Focus
250×250 μm

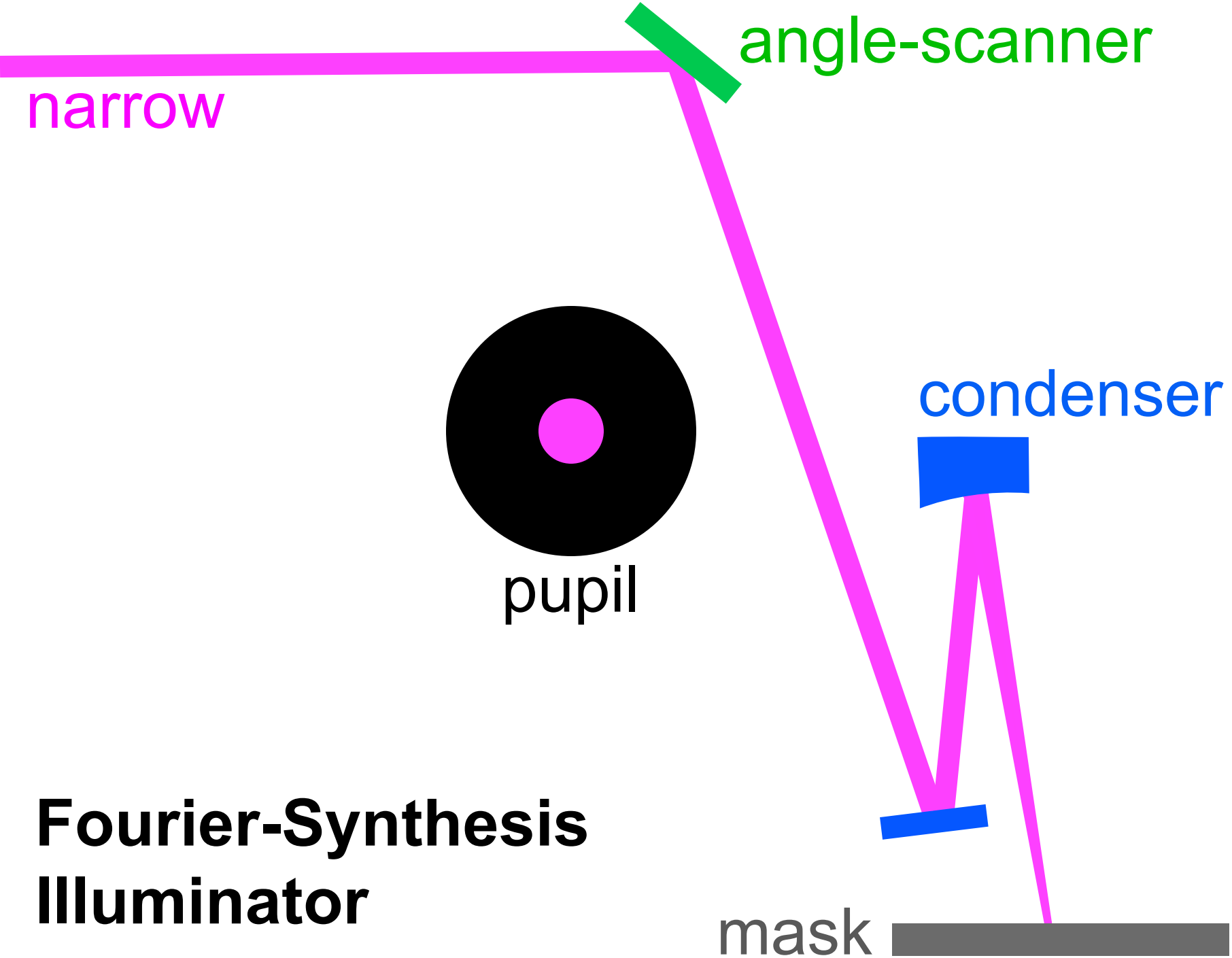
Mask
Illumination
25×25 μm



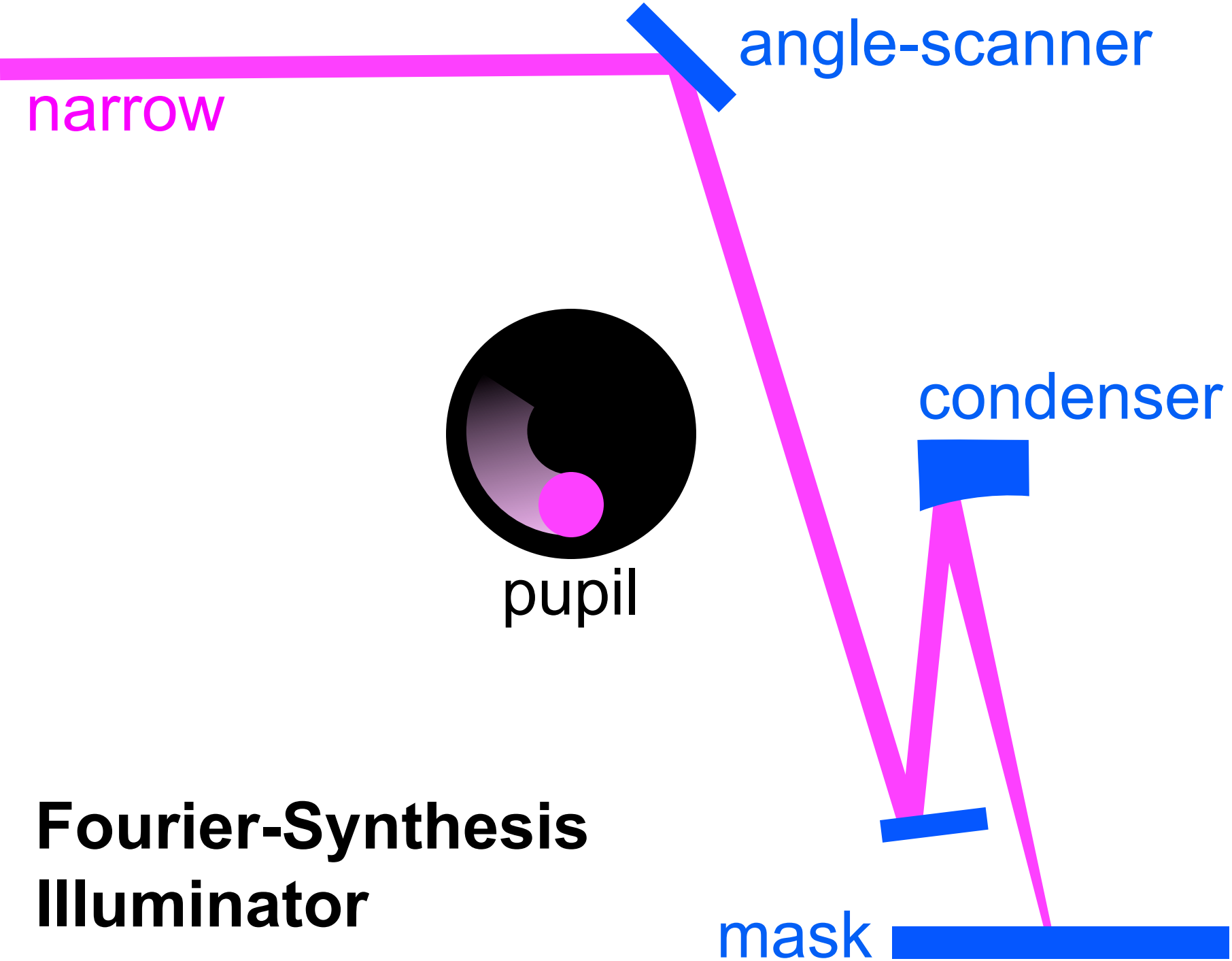
COHERENCE



Fourier-Synthesis Illuminator



Fourier-Synthesis Illuminator



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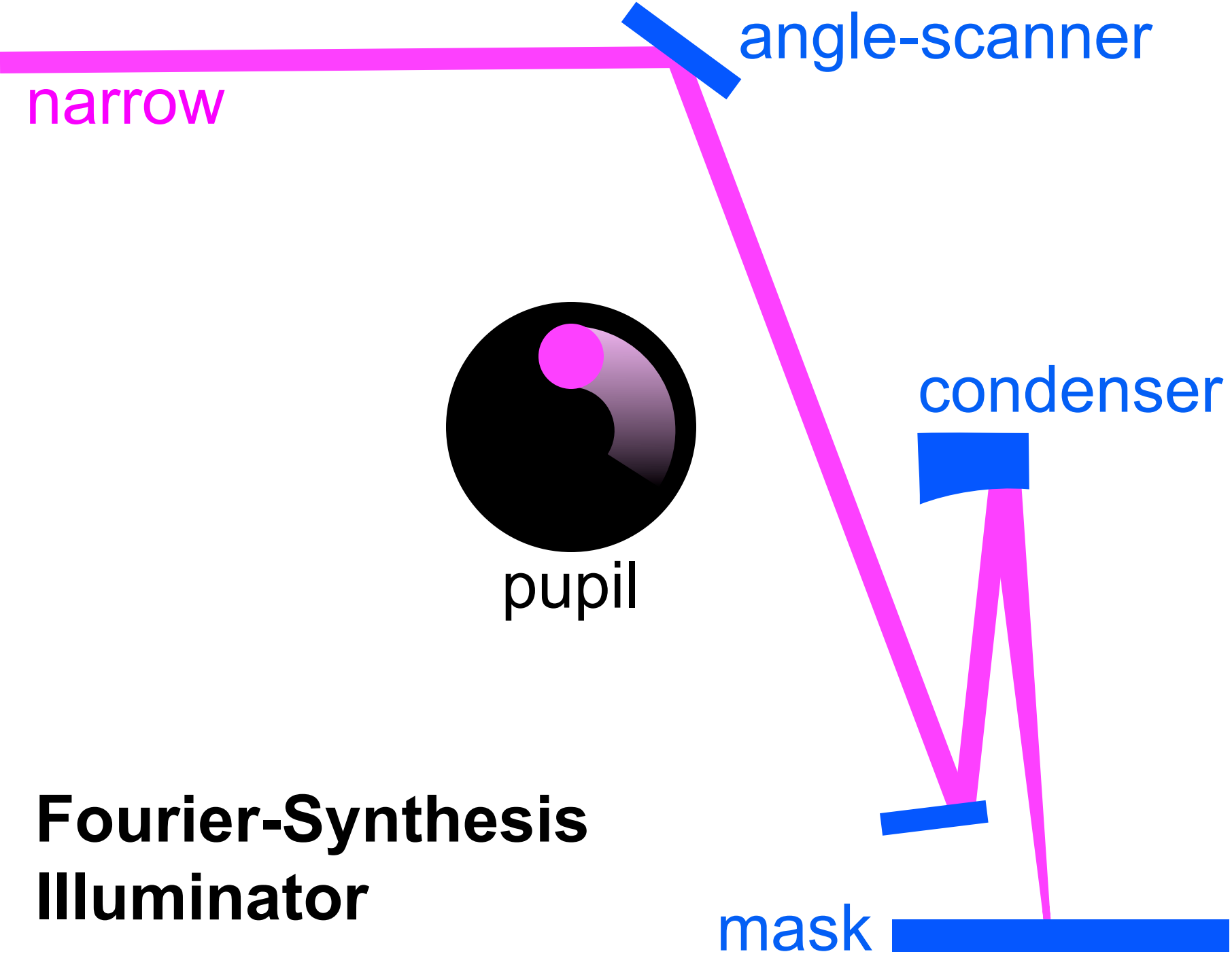
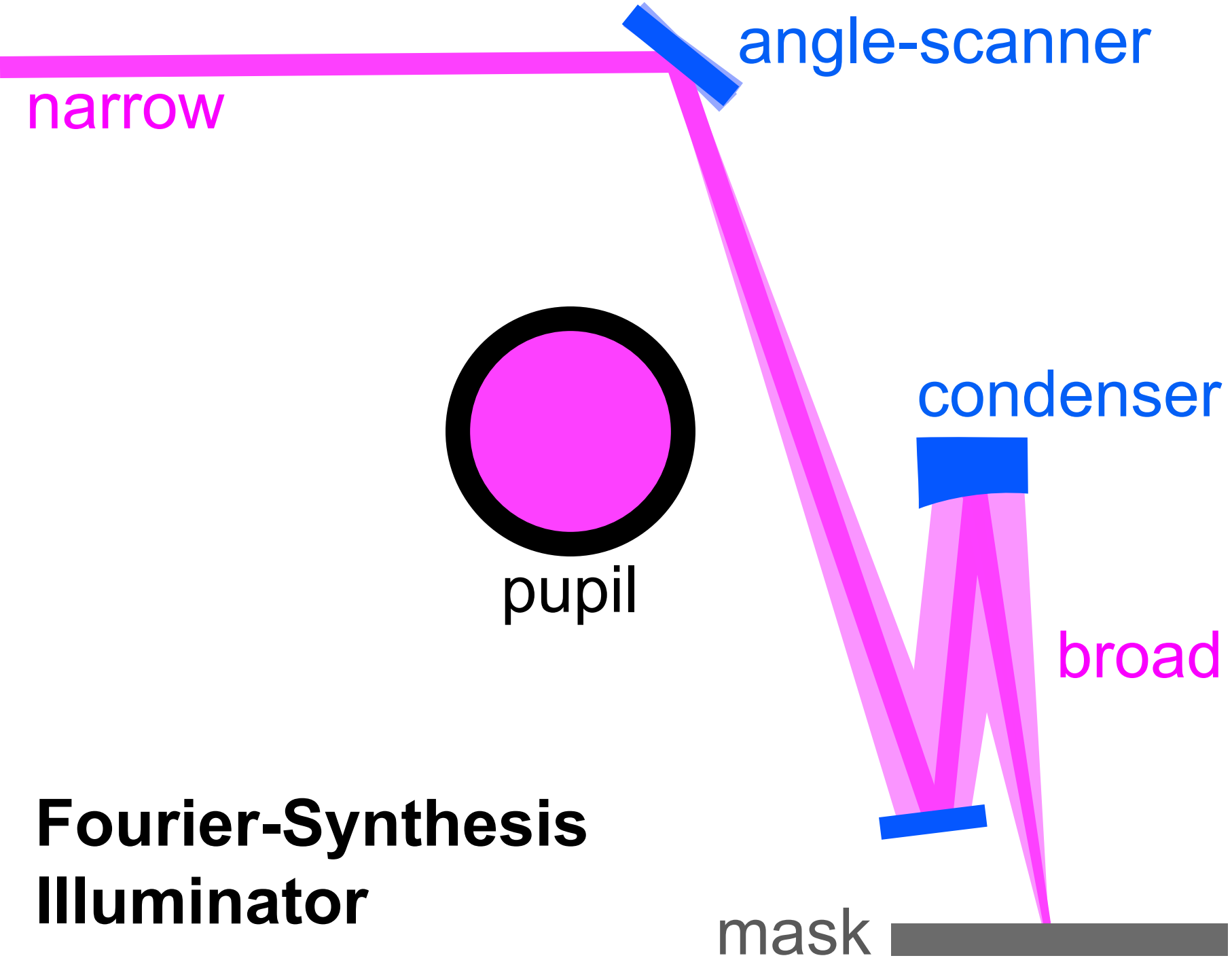
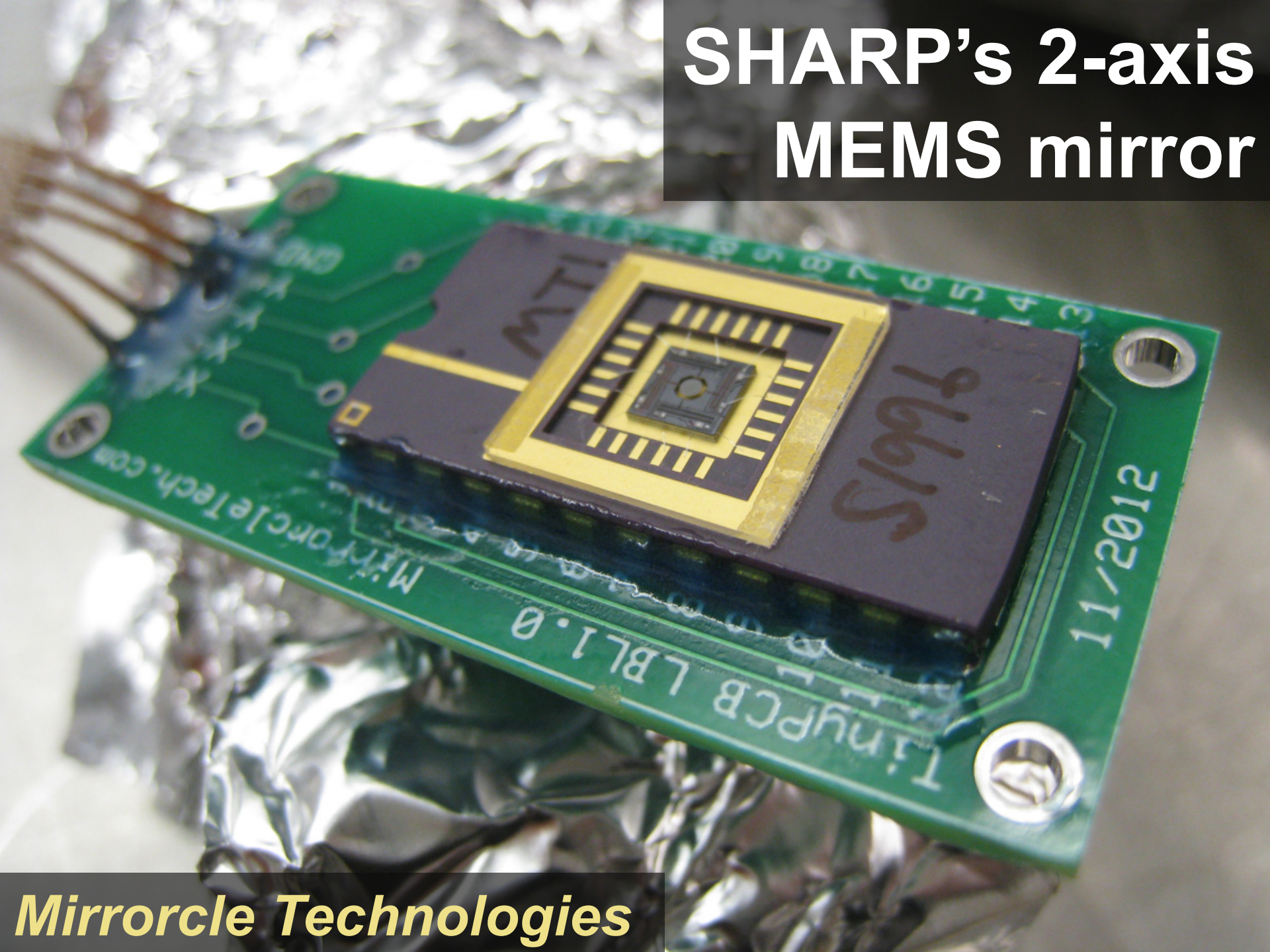


Fourier-Synthesis Illuminator



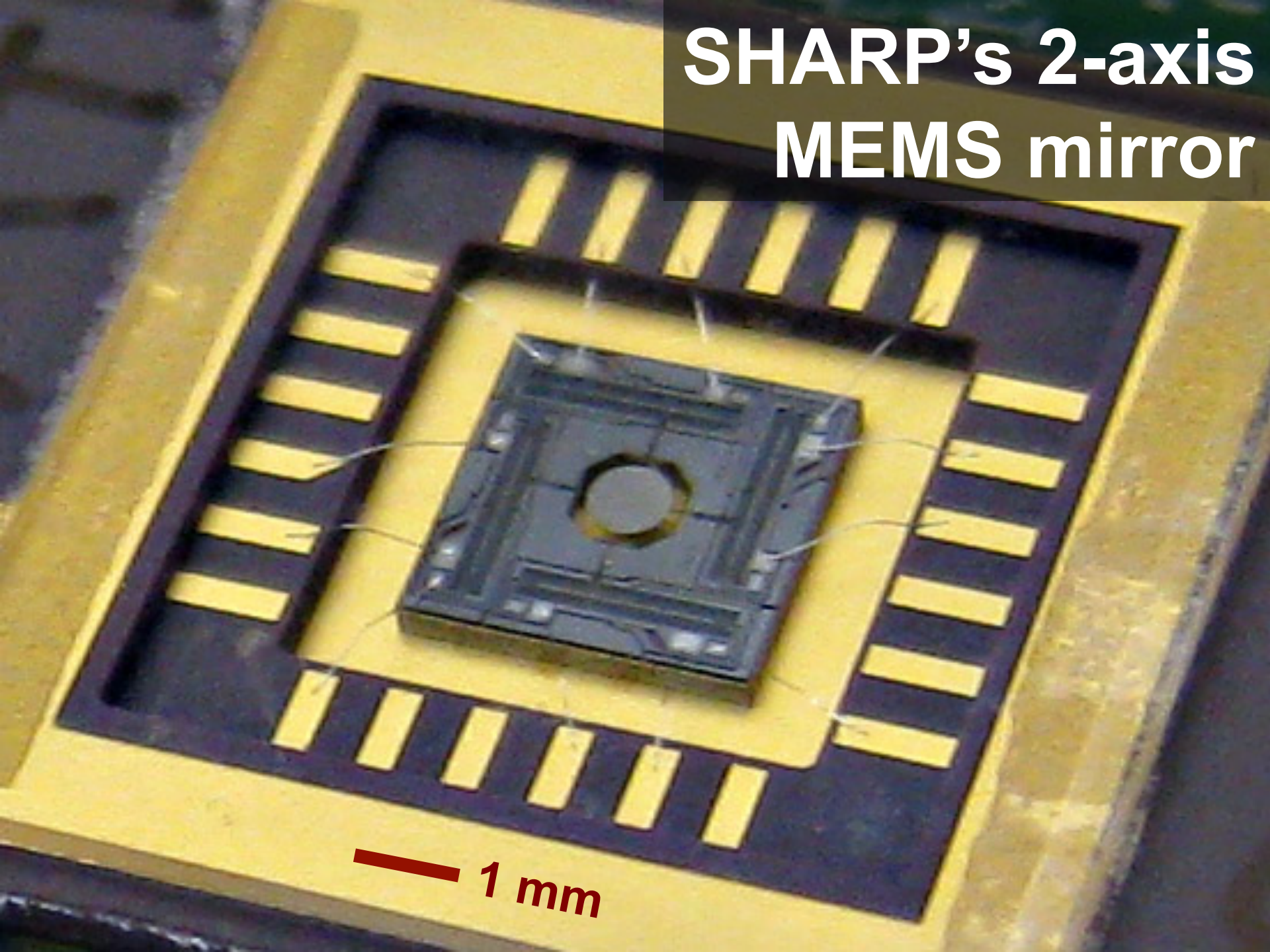
Fourier-Synthesis Illuminator

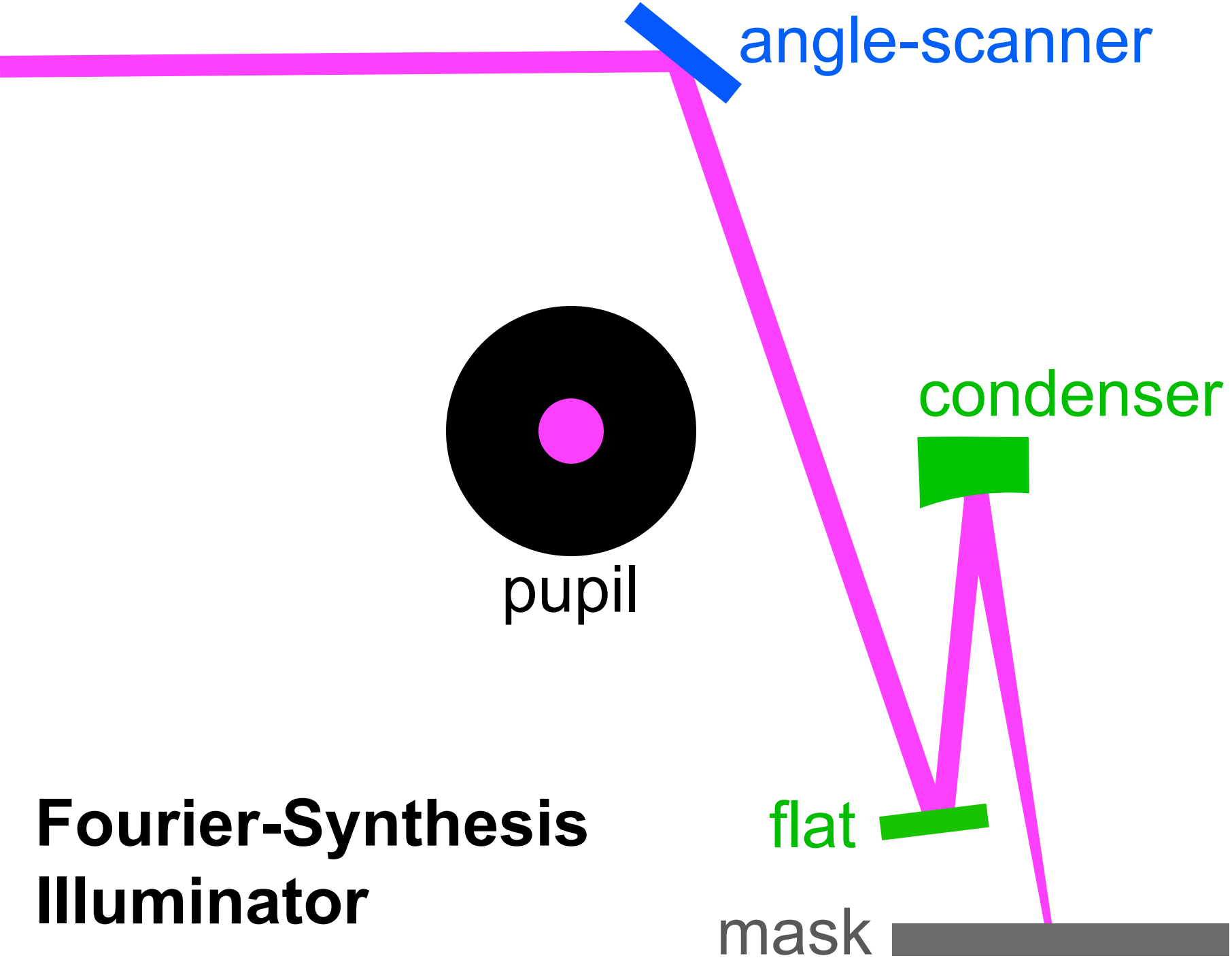
SHARP's 2-axis MEMS mirror



Mirrorcle Technologies

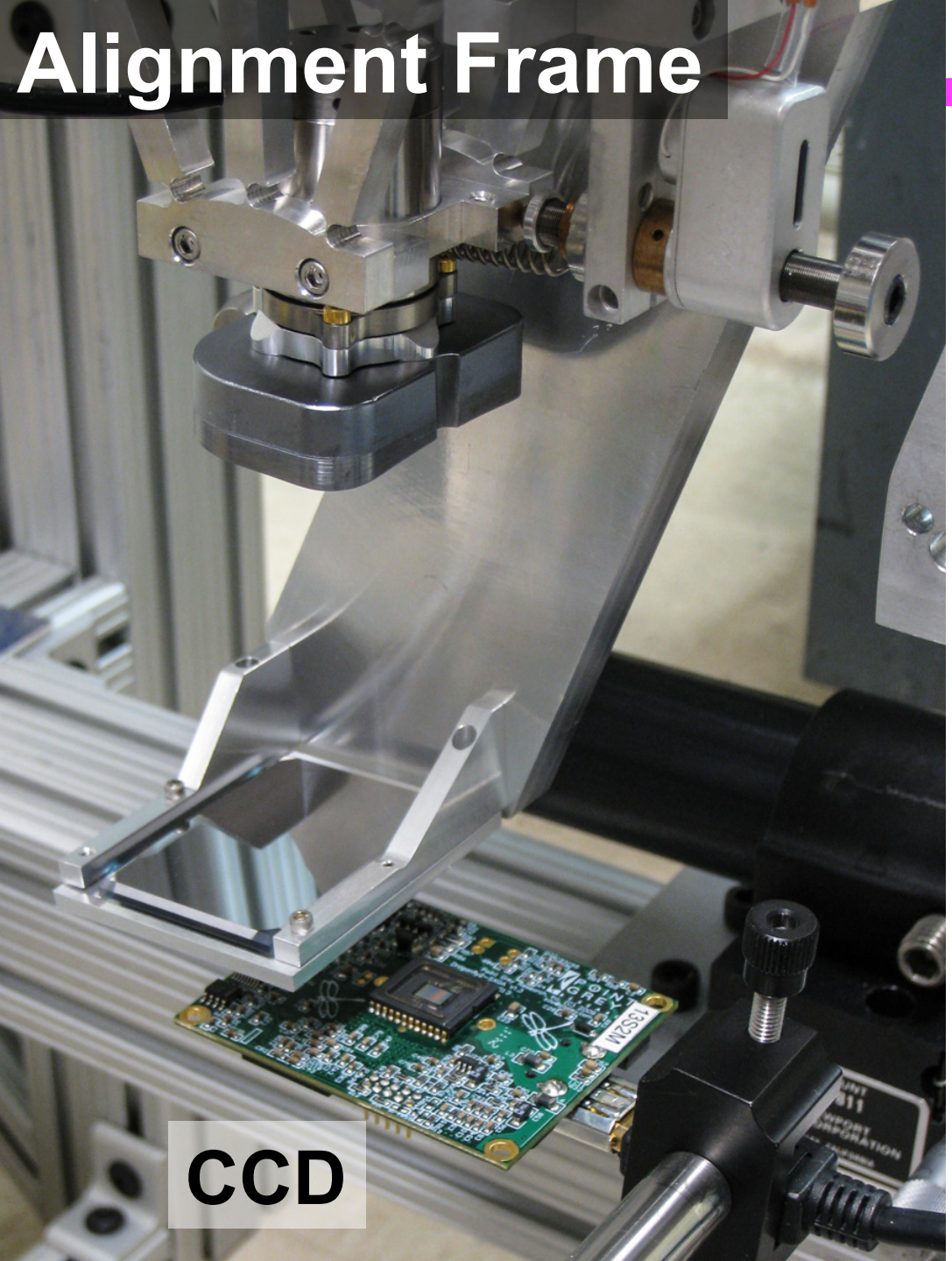
SHARP's 2-axis MEMS mirror

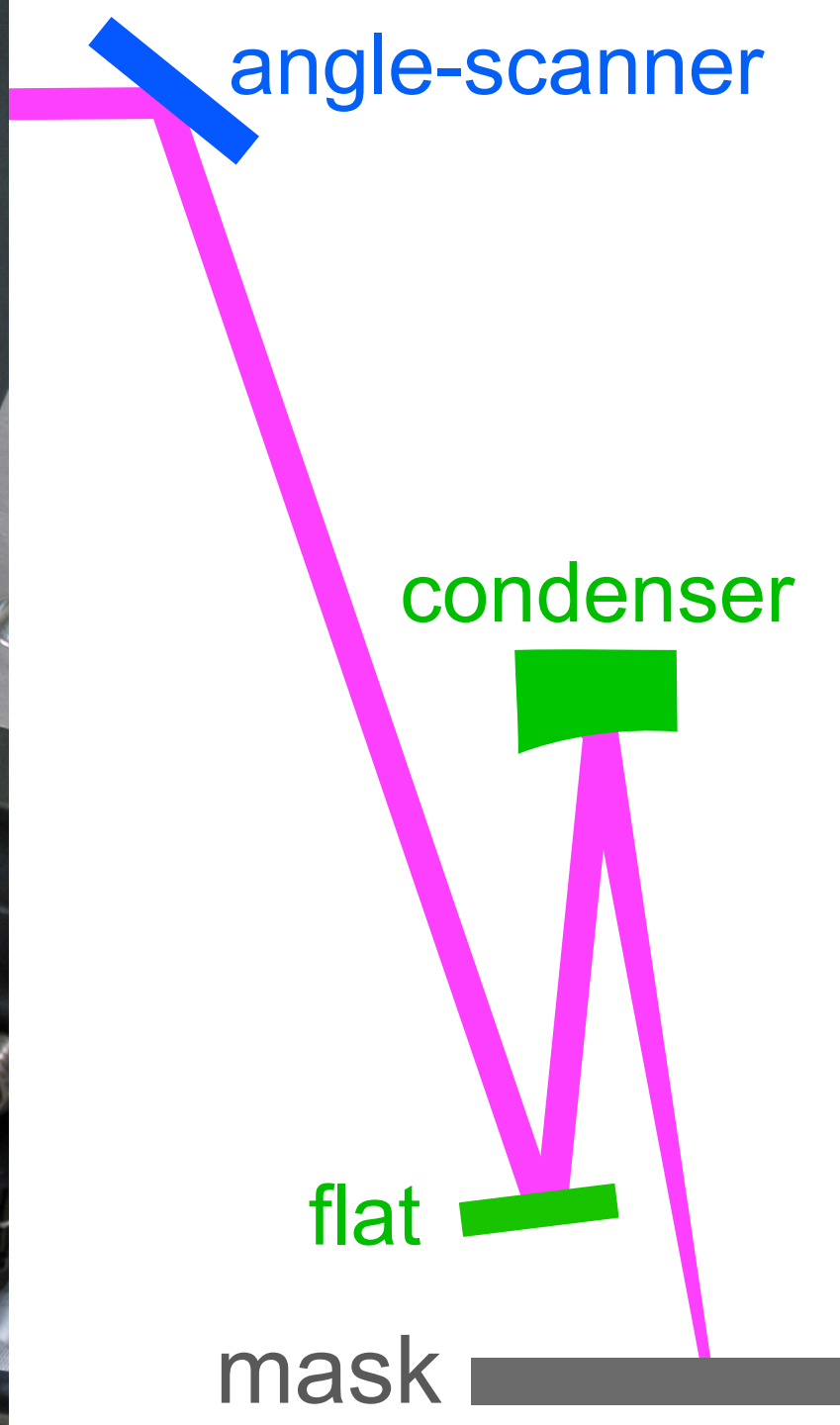




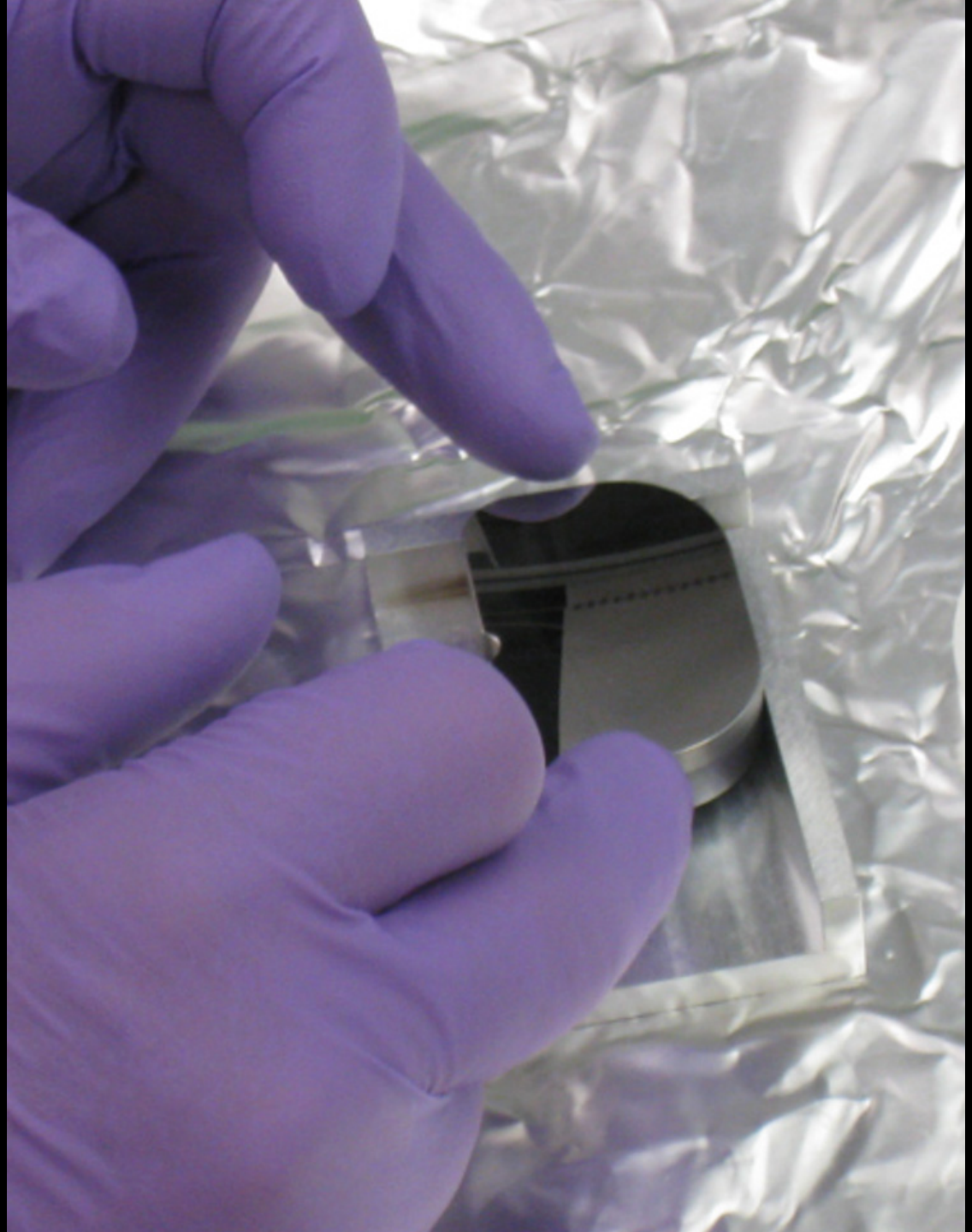
Fourier-Synthesis Illuminator

Alignment Frame

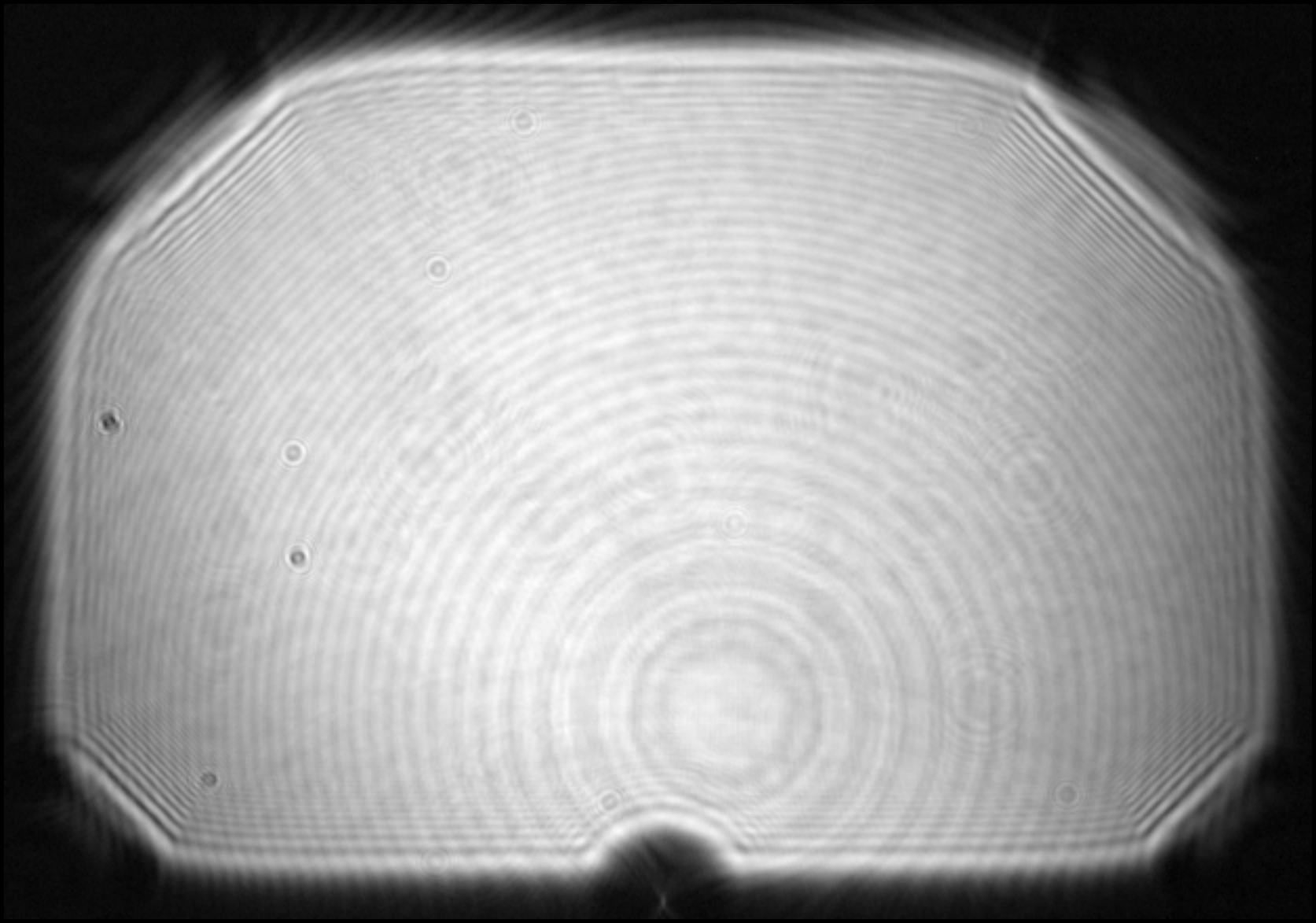




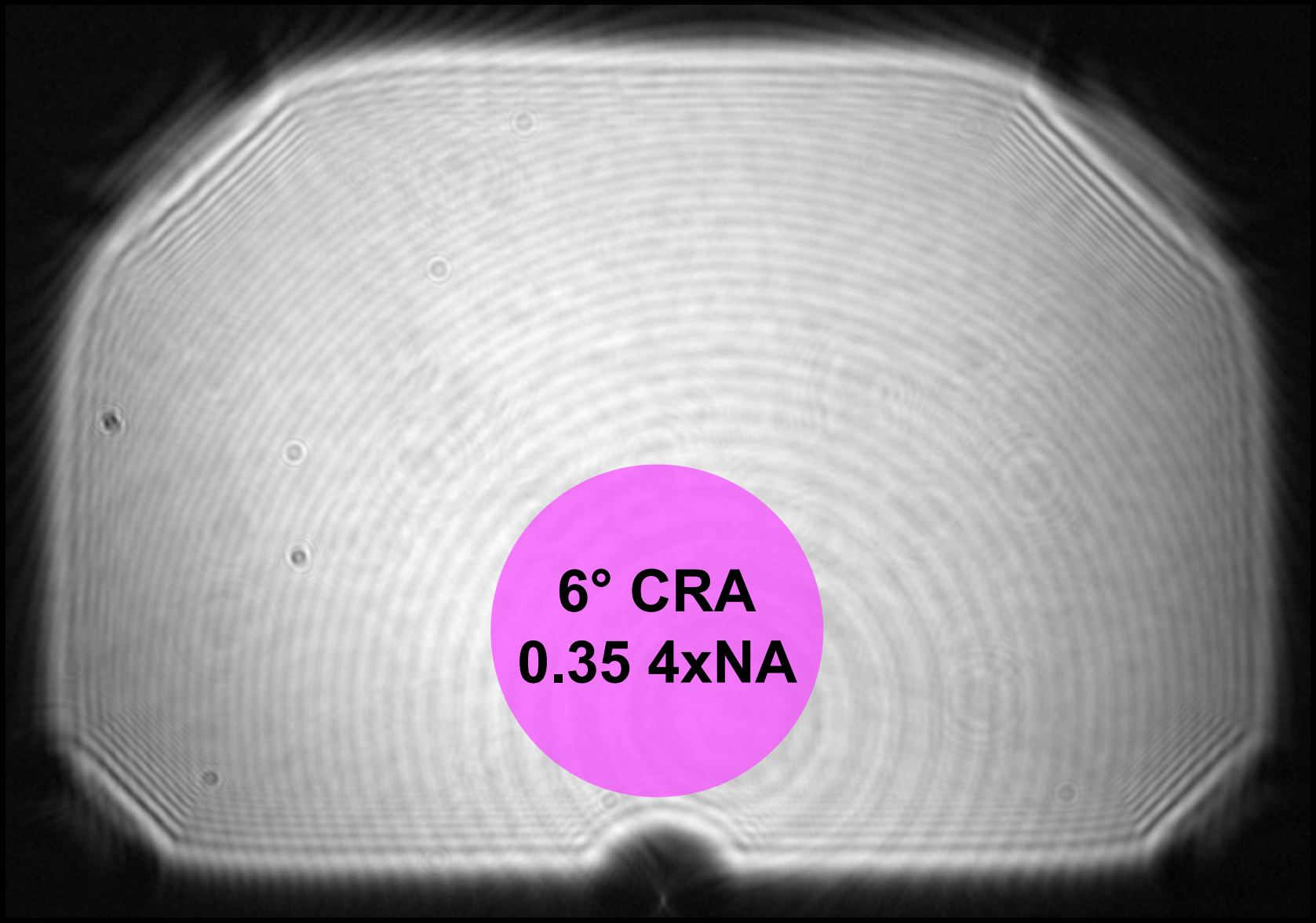
SHARP
Condenser
L-3 Tinsley



Pupil-Fill Monitor



Pupil-Fill Monitor



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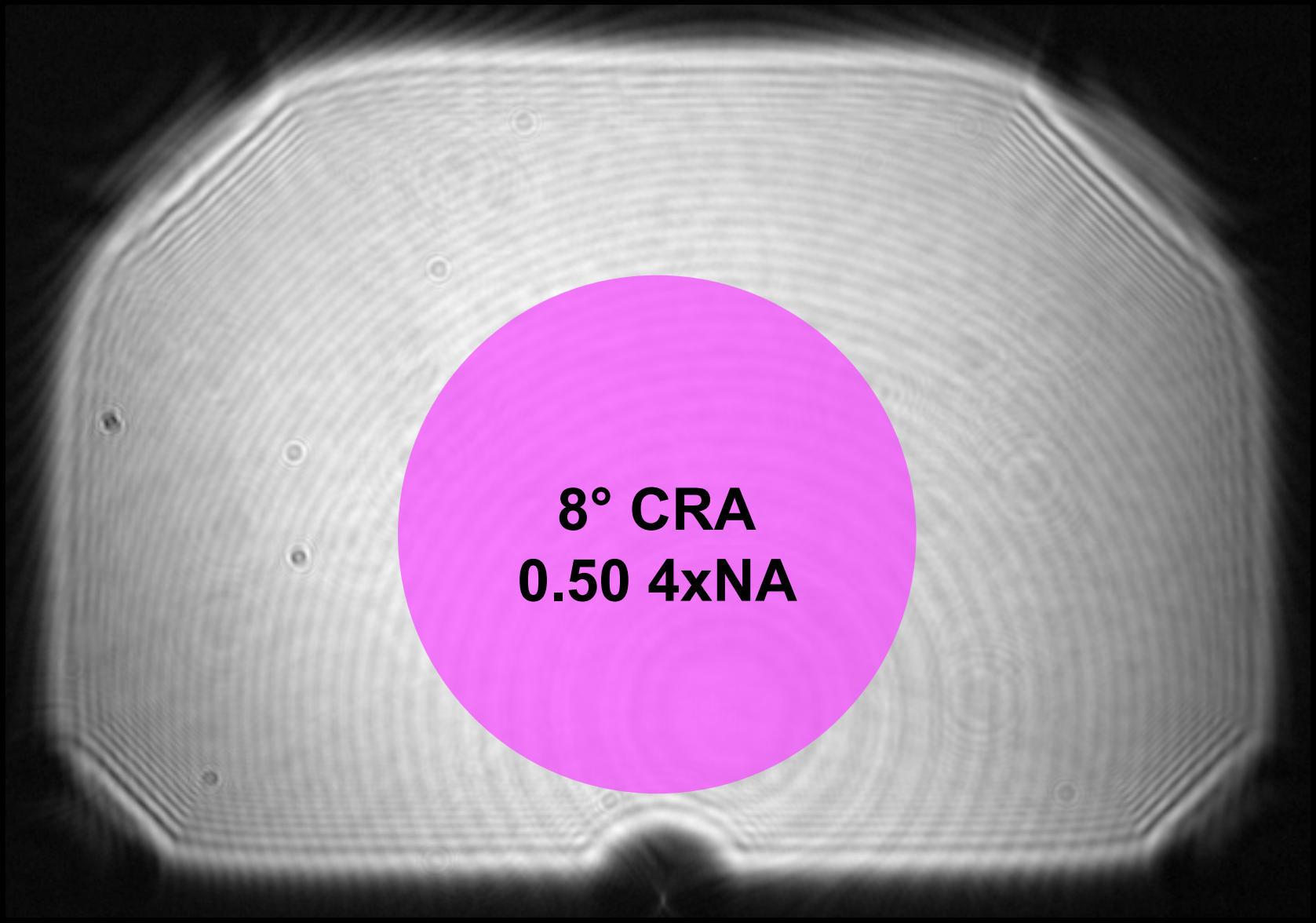
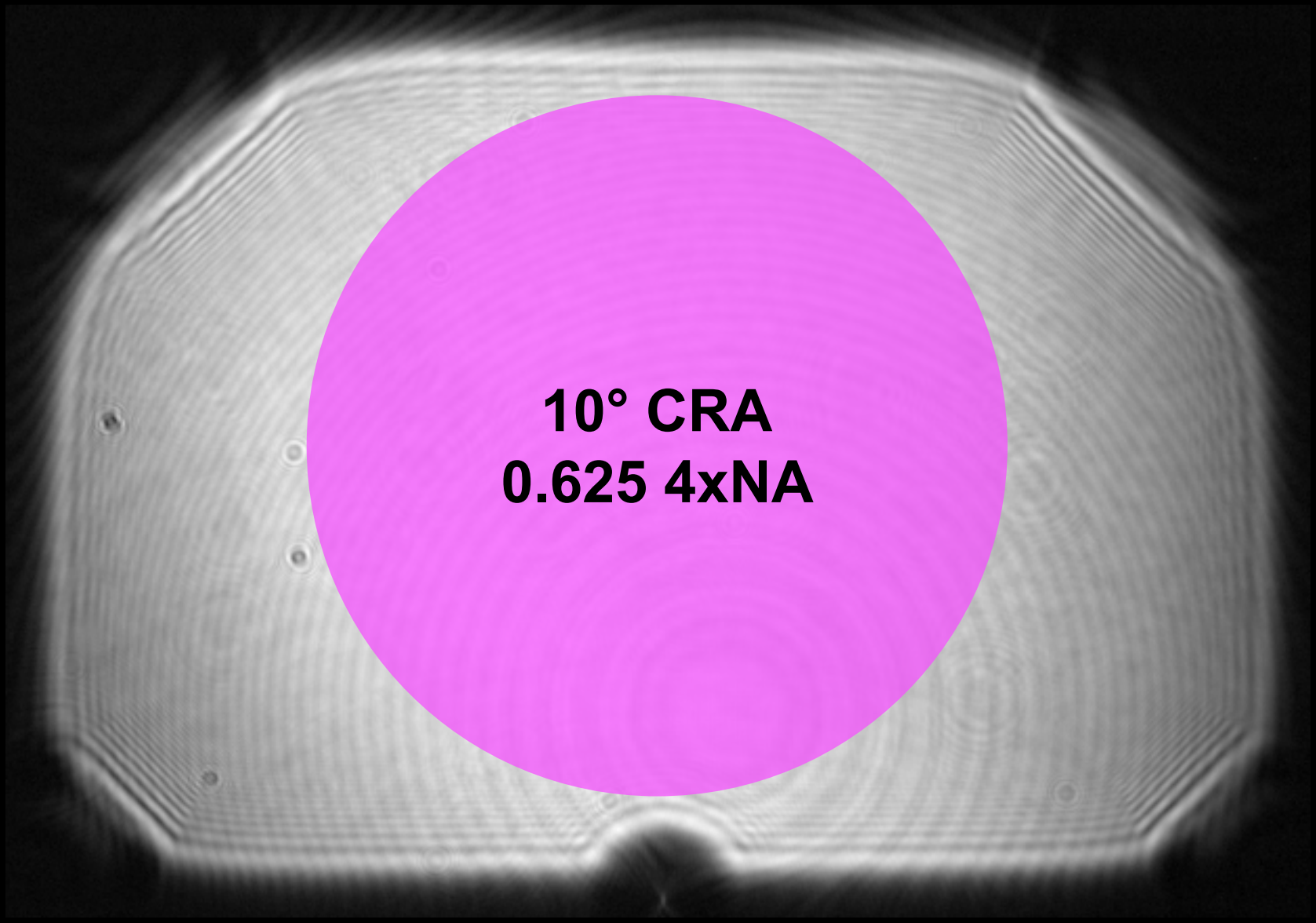


Pupil-Fill Monitor



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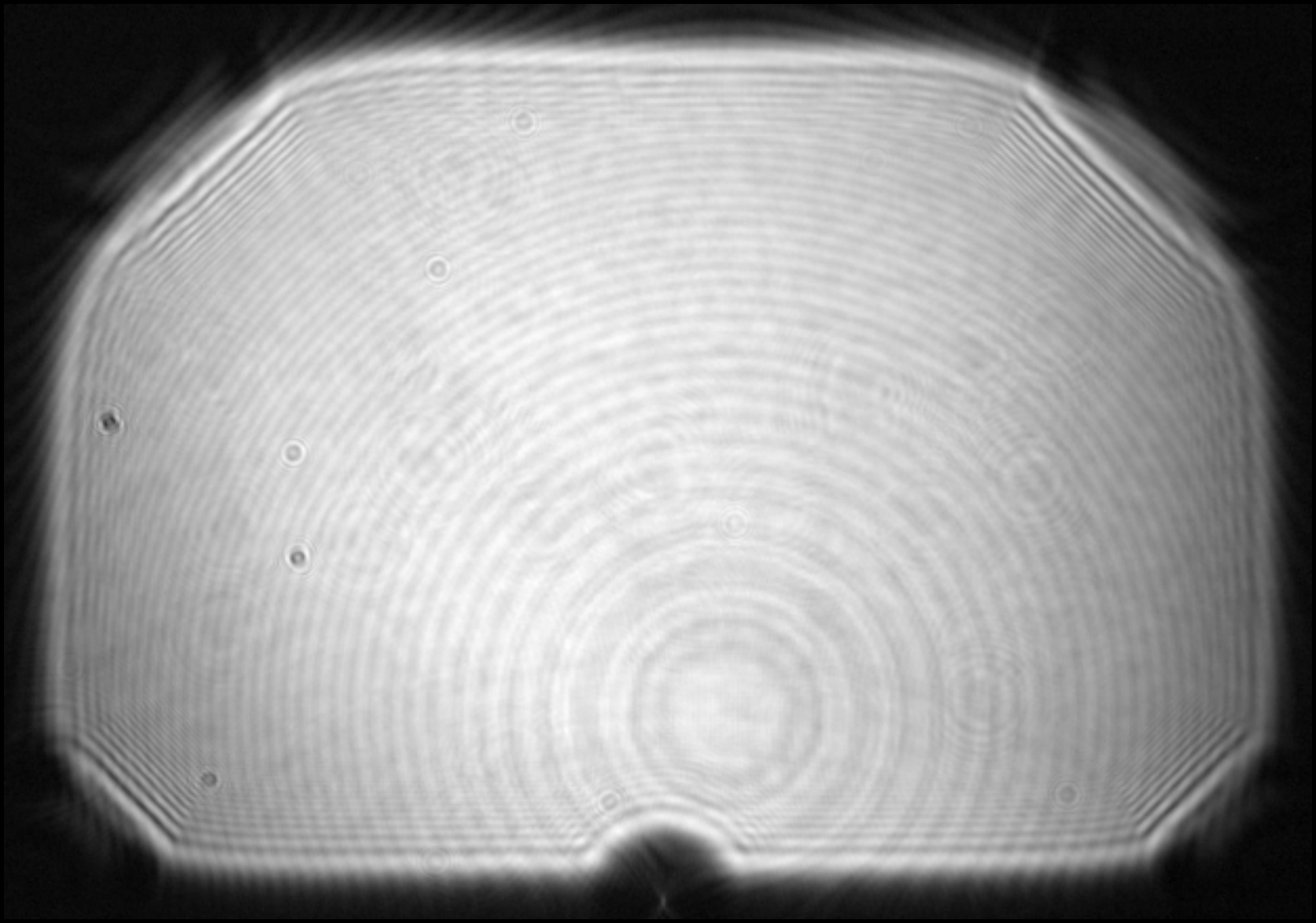

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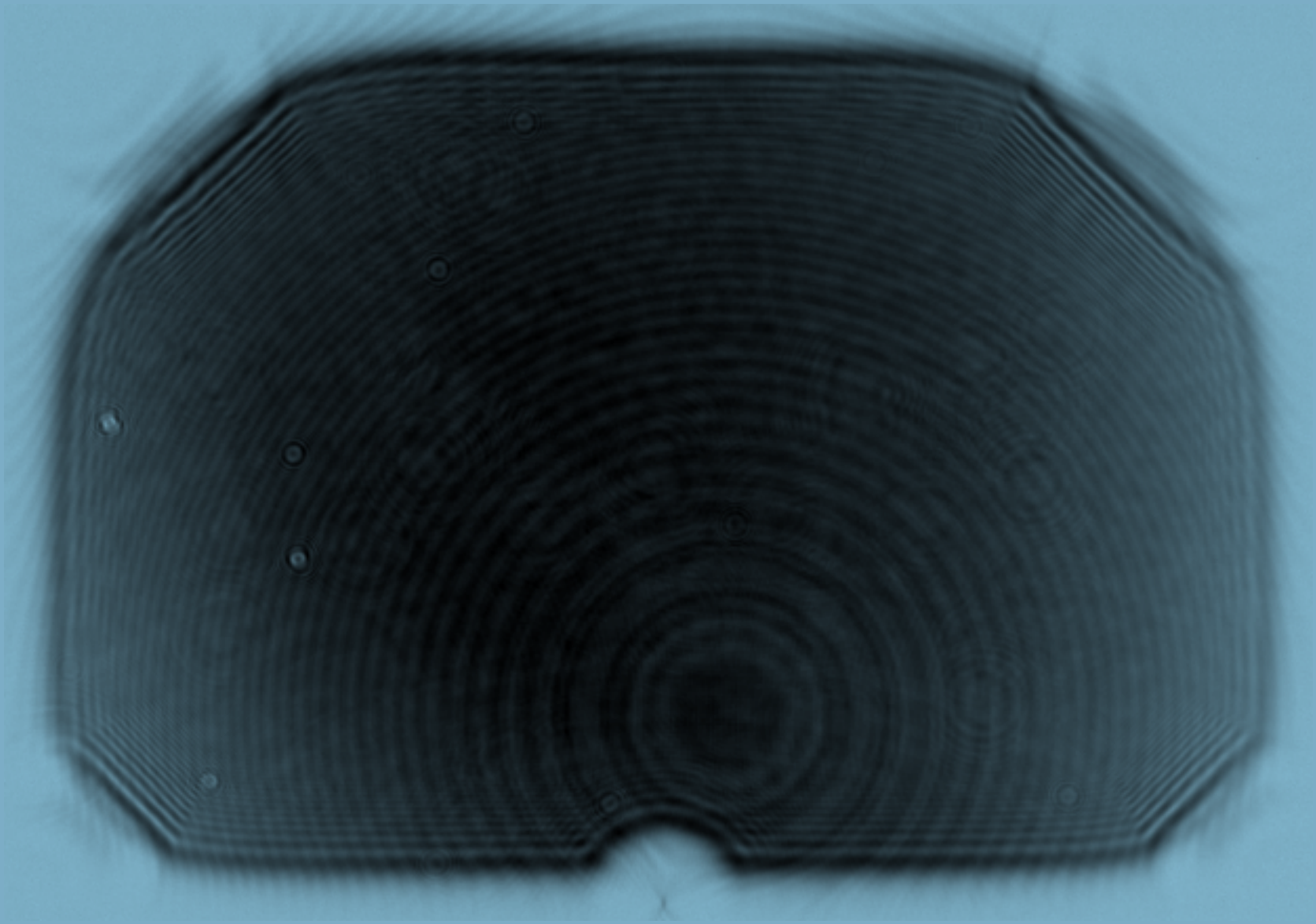

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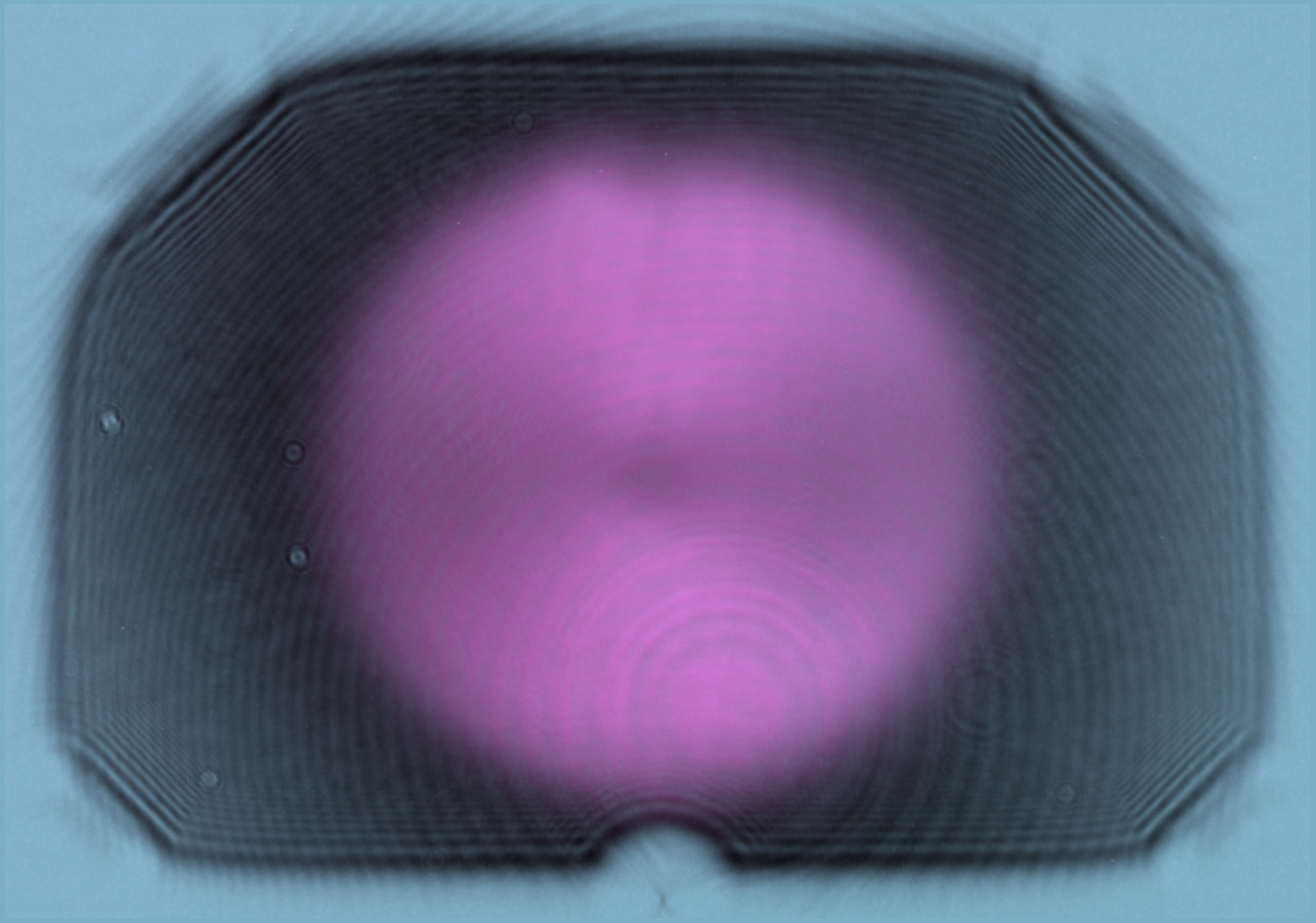

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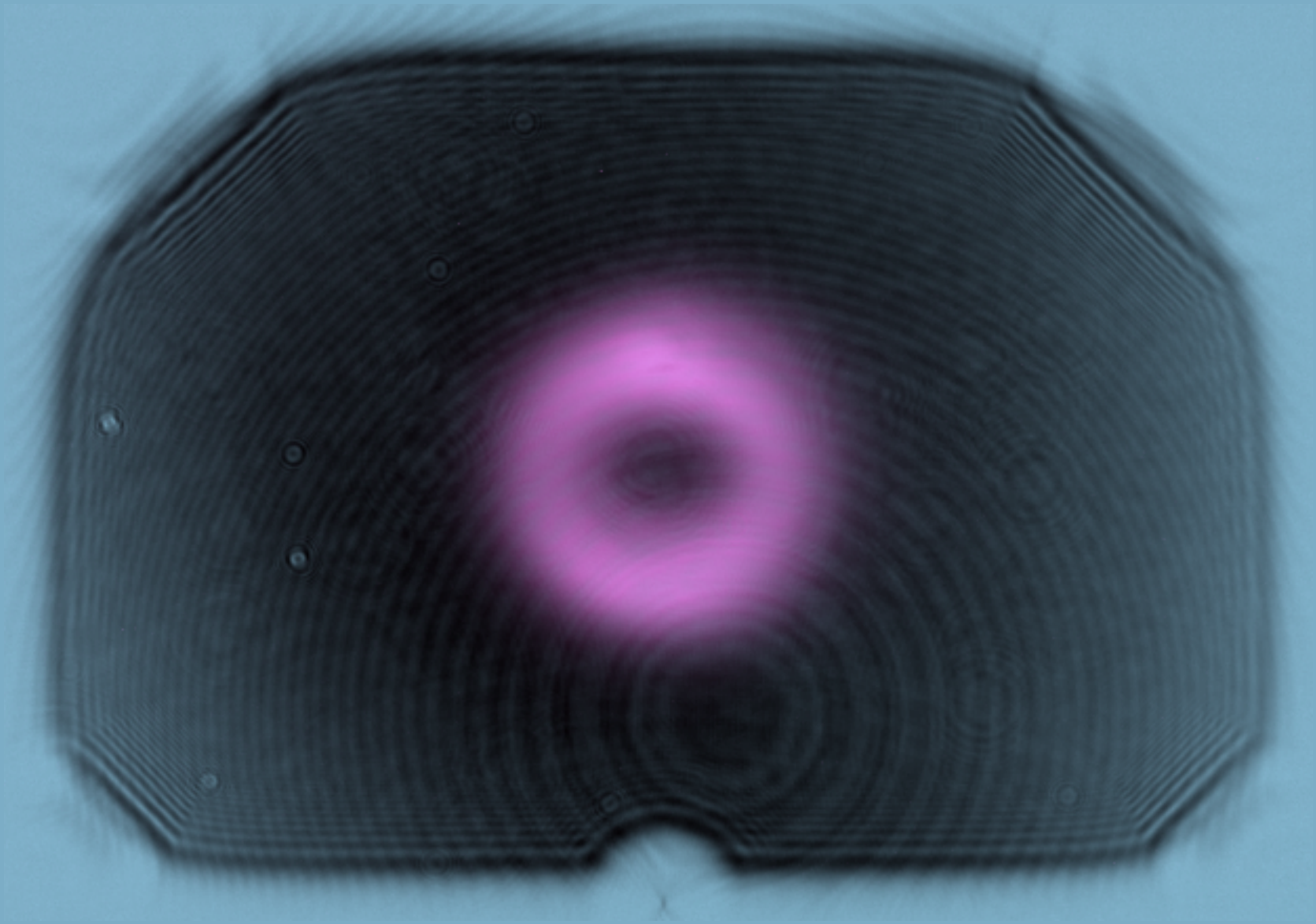

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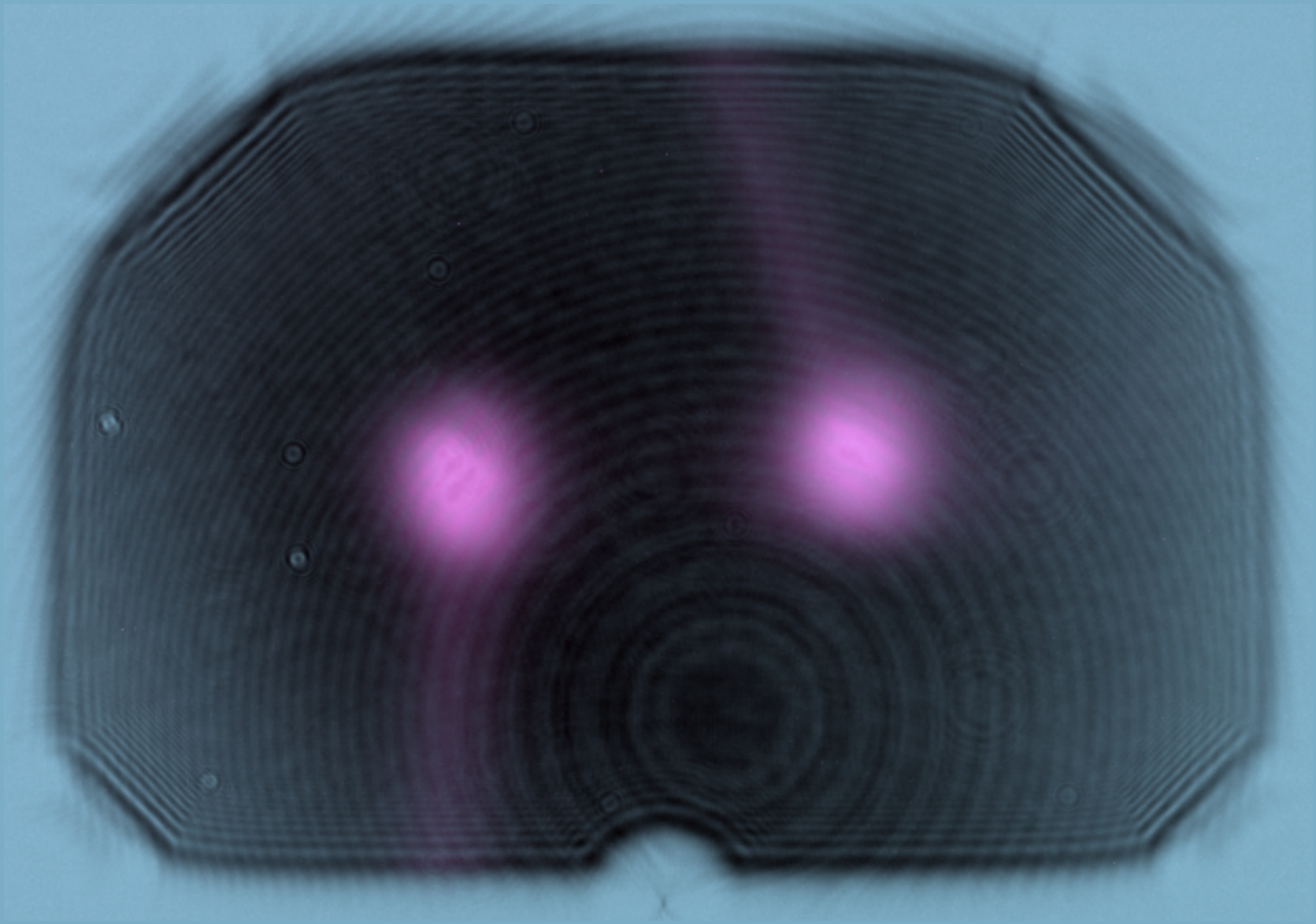
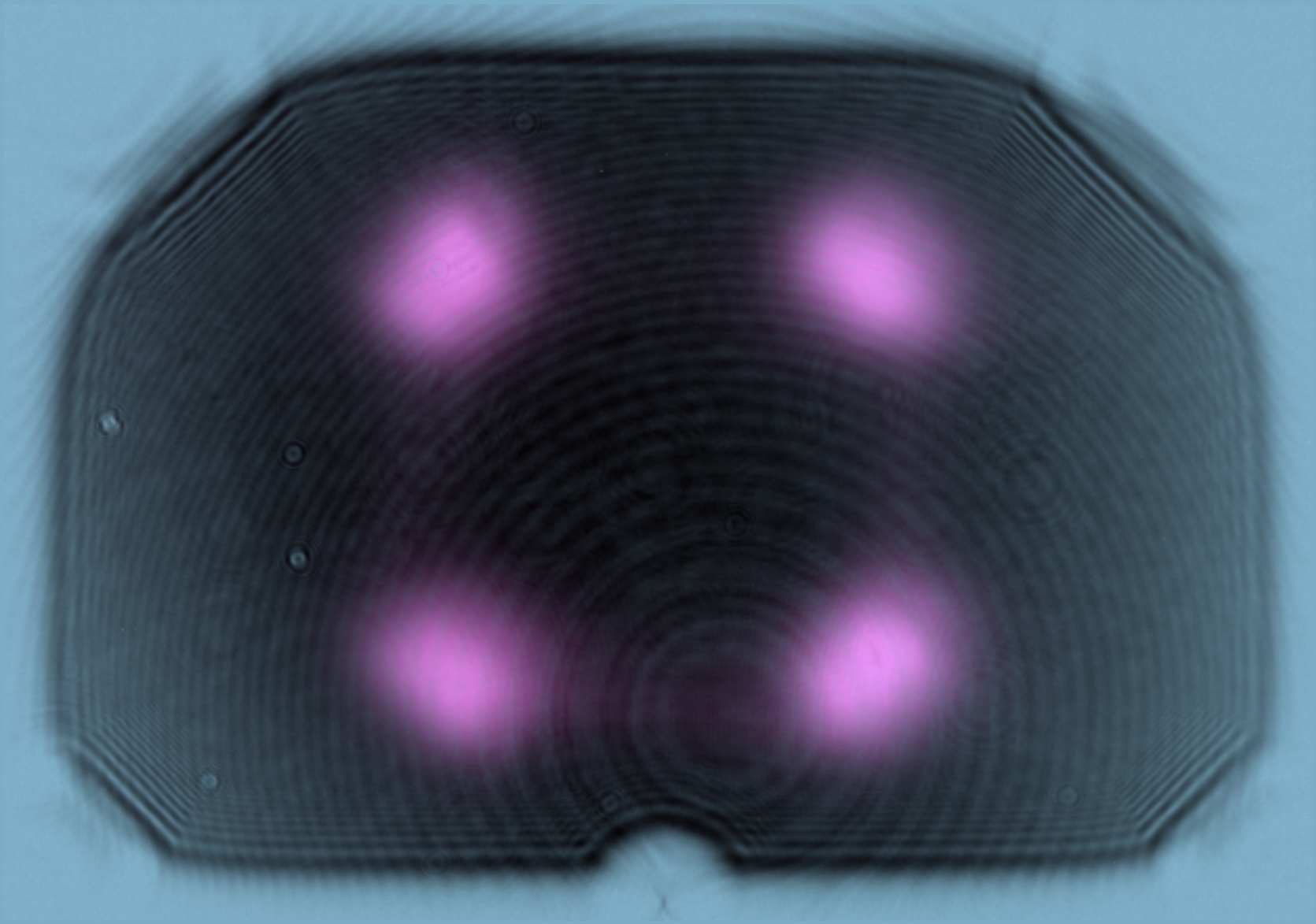
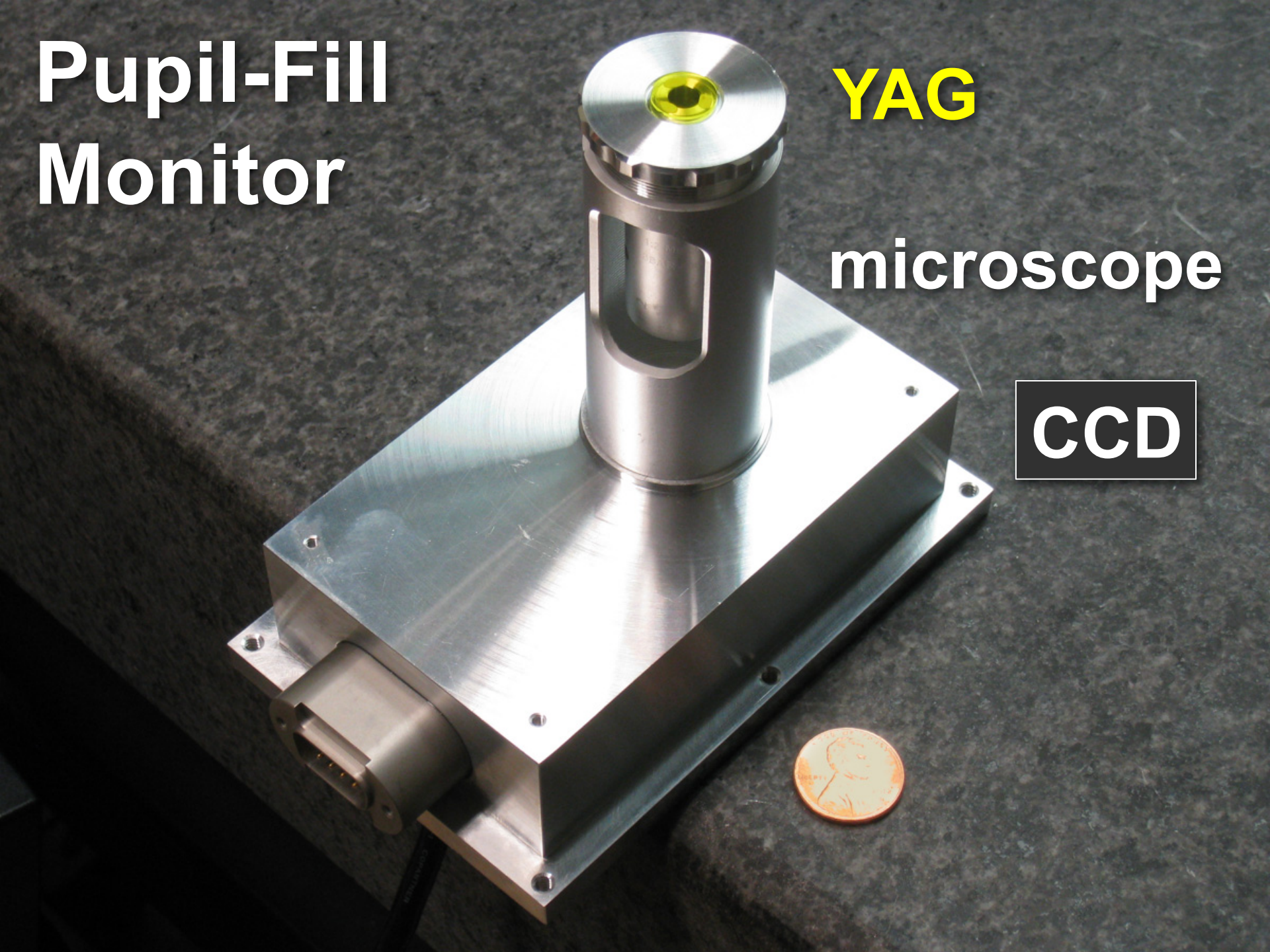


Pupil-Fill Monitor




Pupil-Fill
Monitor
YAG
microscope
CCD

Pupil-Fill Monitor

image

focused in the mask plane

100 μm

Pupil-Fill Monitor

image detail

450 nW @ the mask

focused in the mask plane

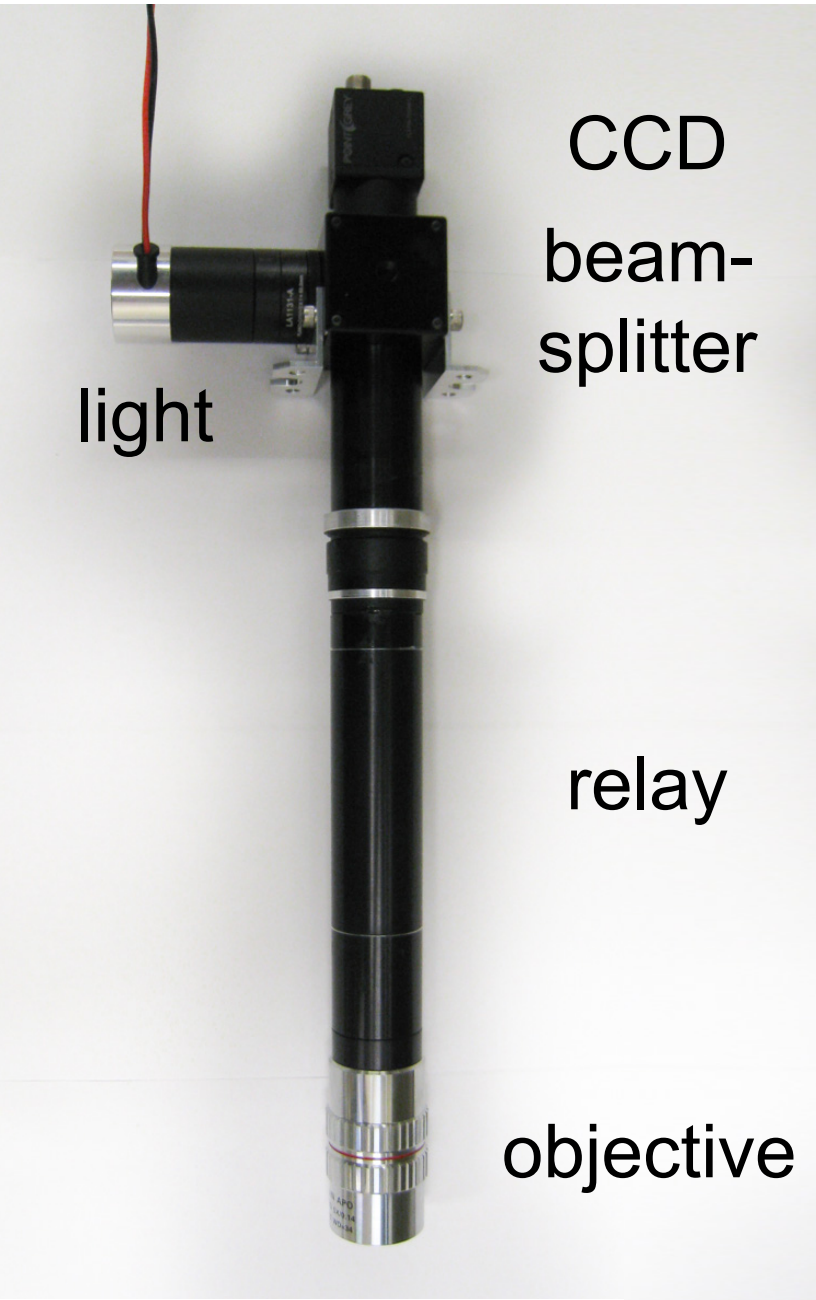
100 μm

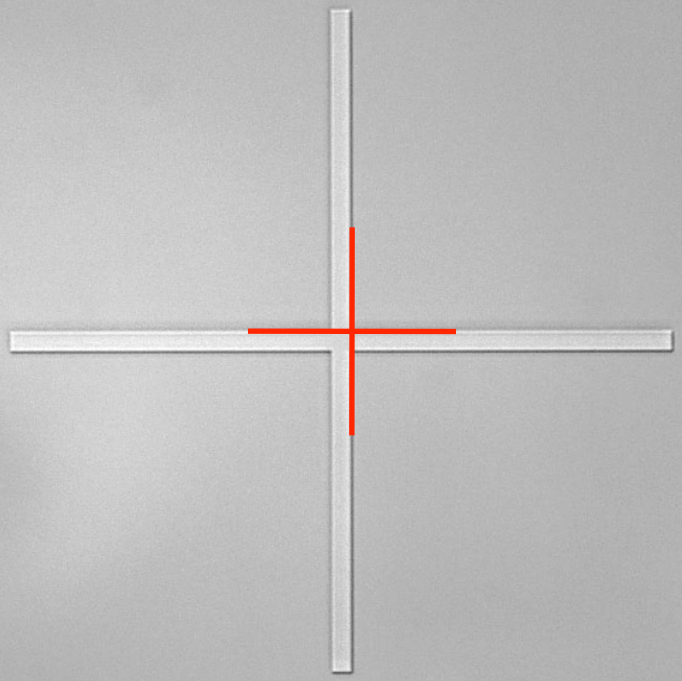
in-situ visible-light microscope

relay lens
external CCD

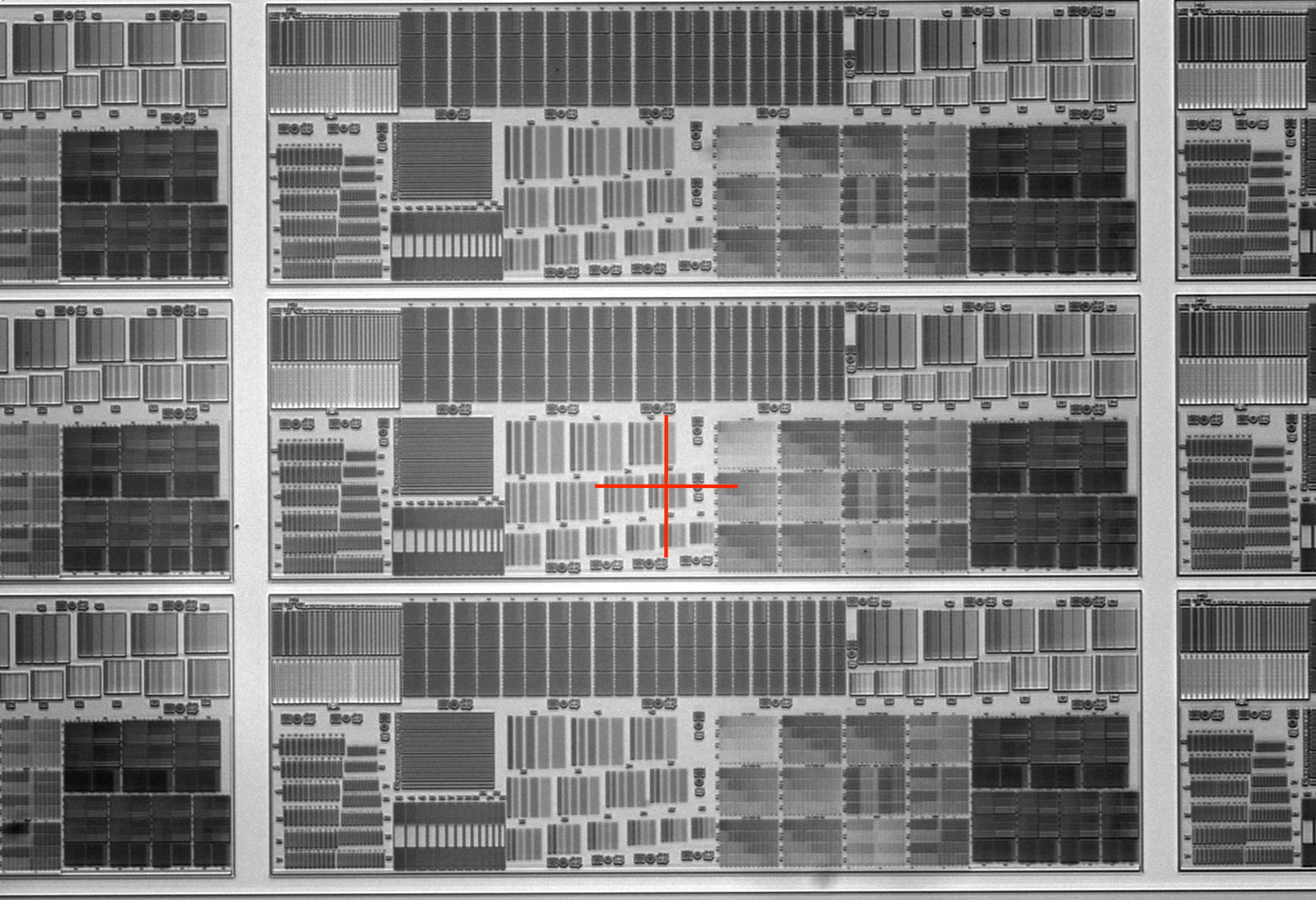
brightfield & darkfield
illumination

34-mm working distance





SHARP's *in-situ* visible-light microscope



SHARP’s *in-situ* visible-light microscope

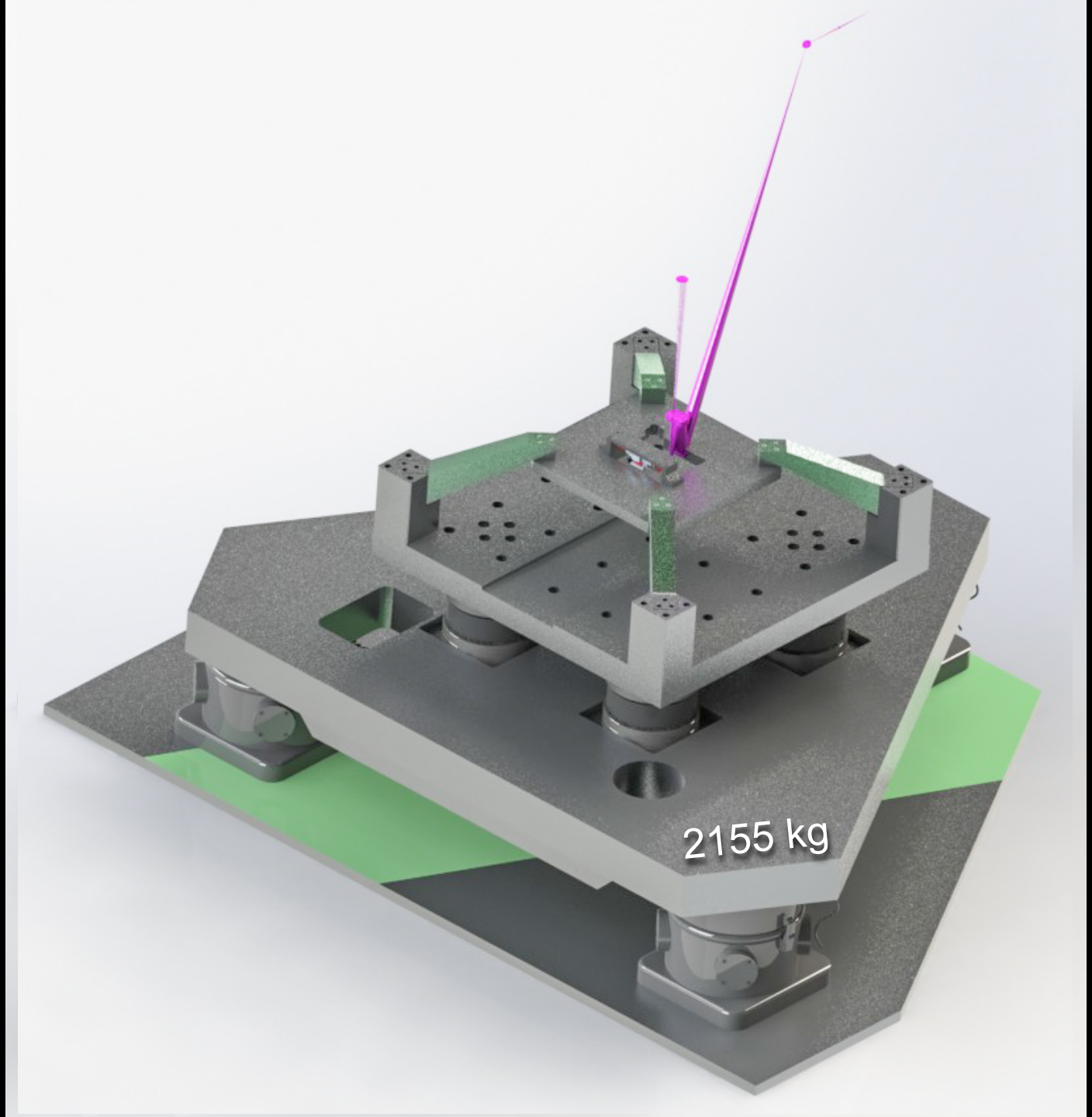
STABILITY

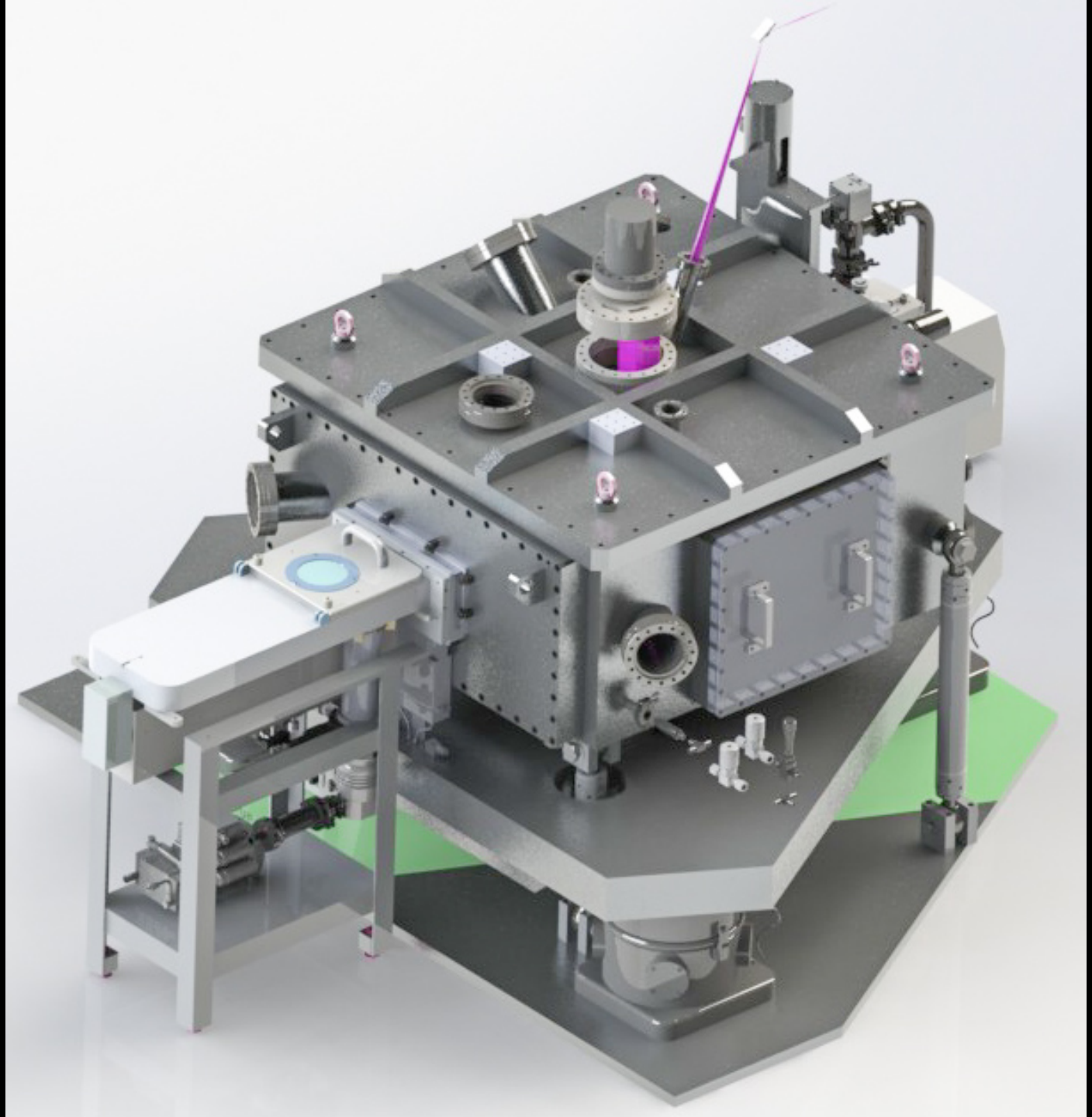
Arnaud Allezy, Seno Rekawa

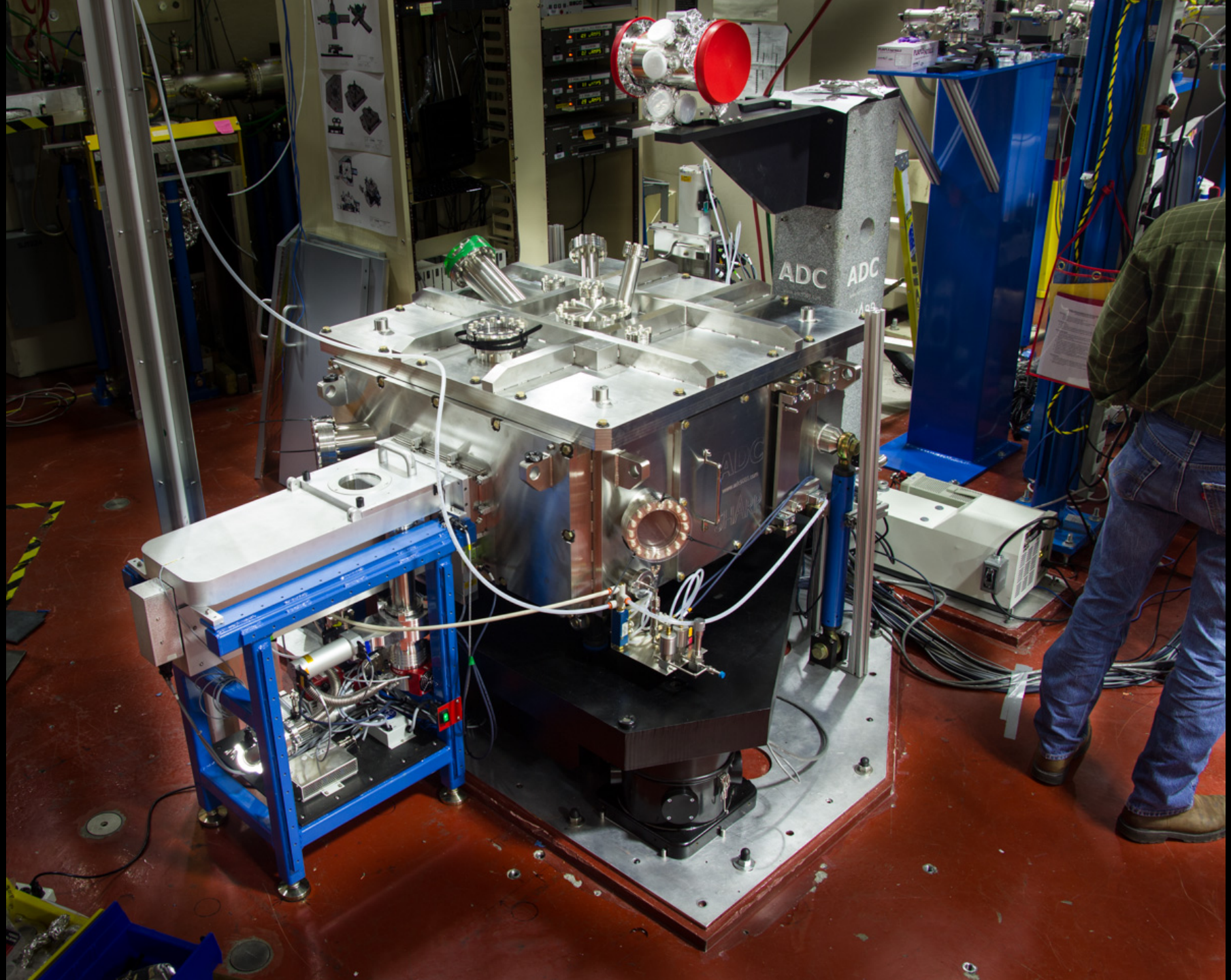
CXRO, LBNL

Eric Acome, Eric Van Every

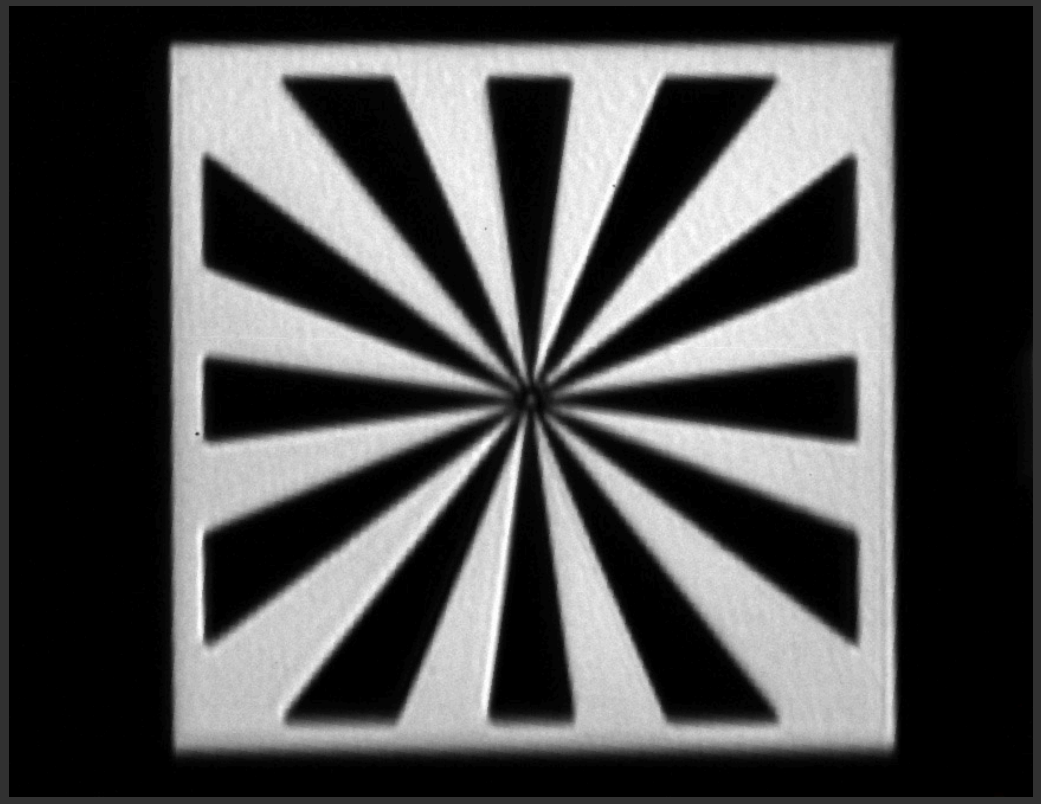
ADC, USA


2155 kg




ADC
ADC

RESULTS

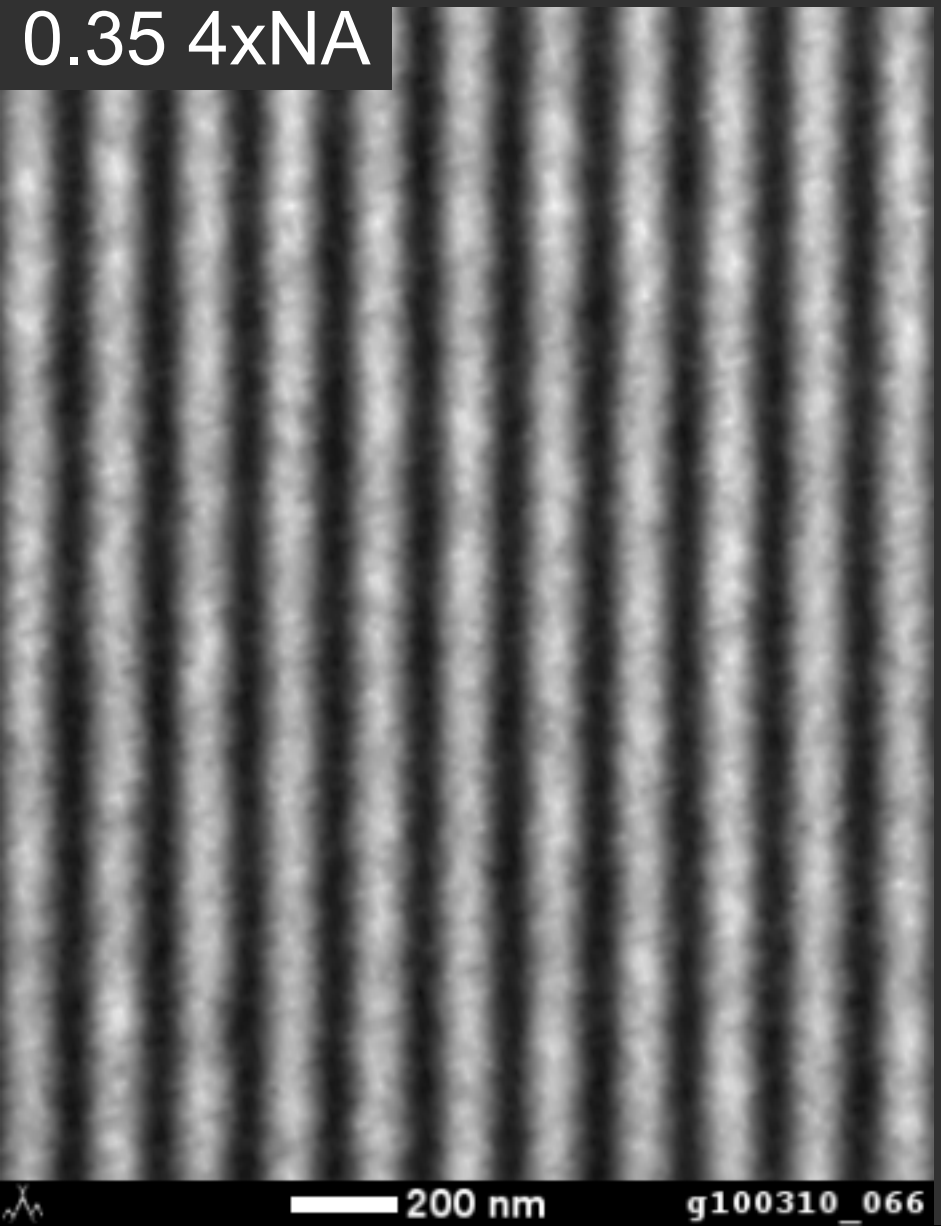


EUV Power

85-nm hp (21.25)

AIT

0.35 4xNA



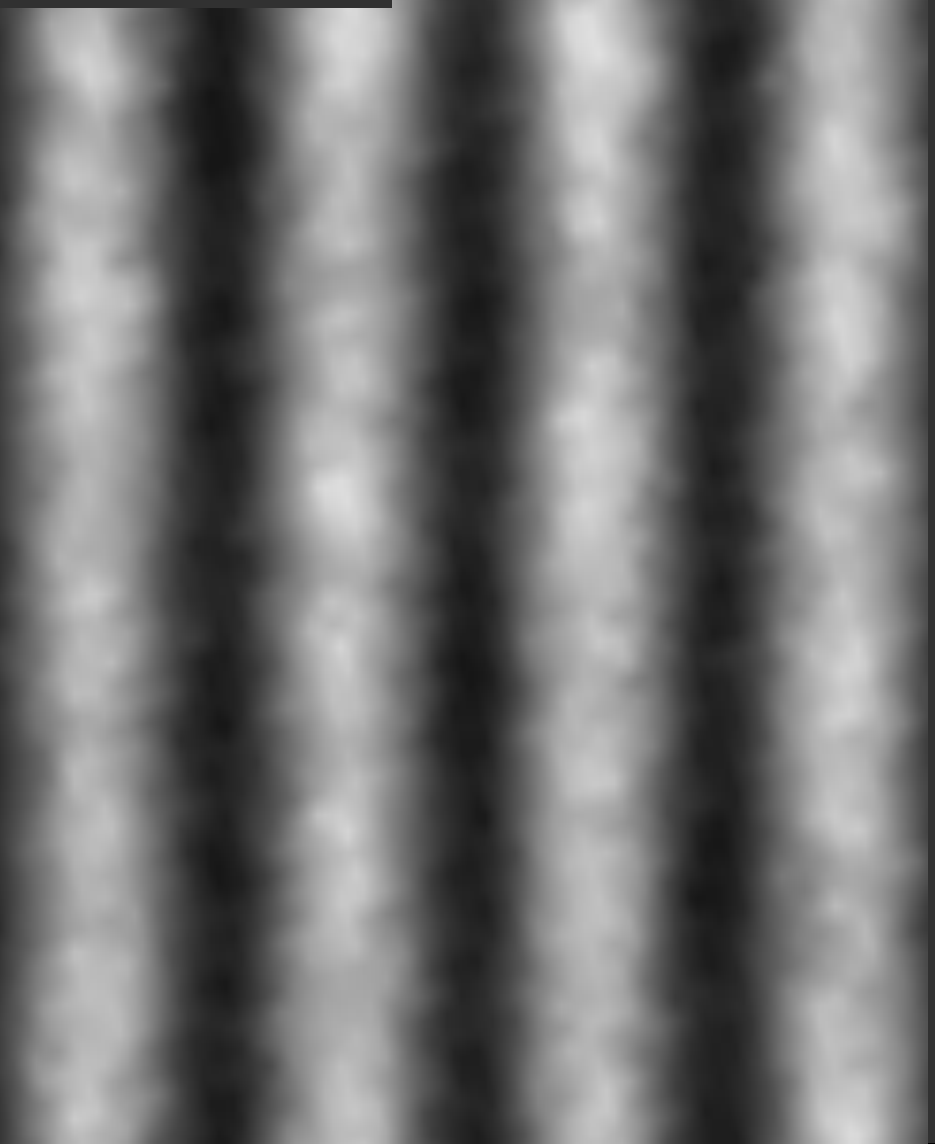
SHARP

0.35 4xNA

85-nm hp (21.25)

AIT

0.35 4xNA



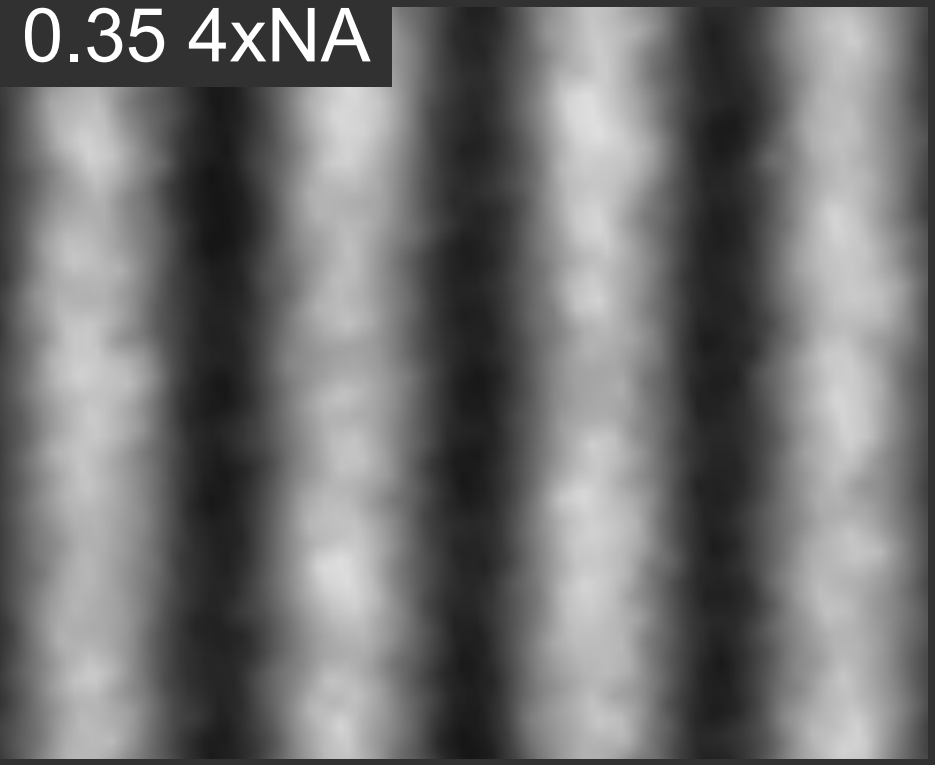
SHARP

0.35 4xNA

85-nm hp (21.25)

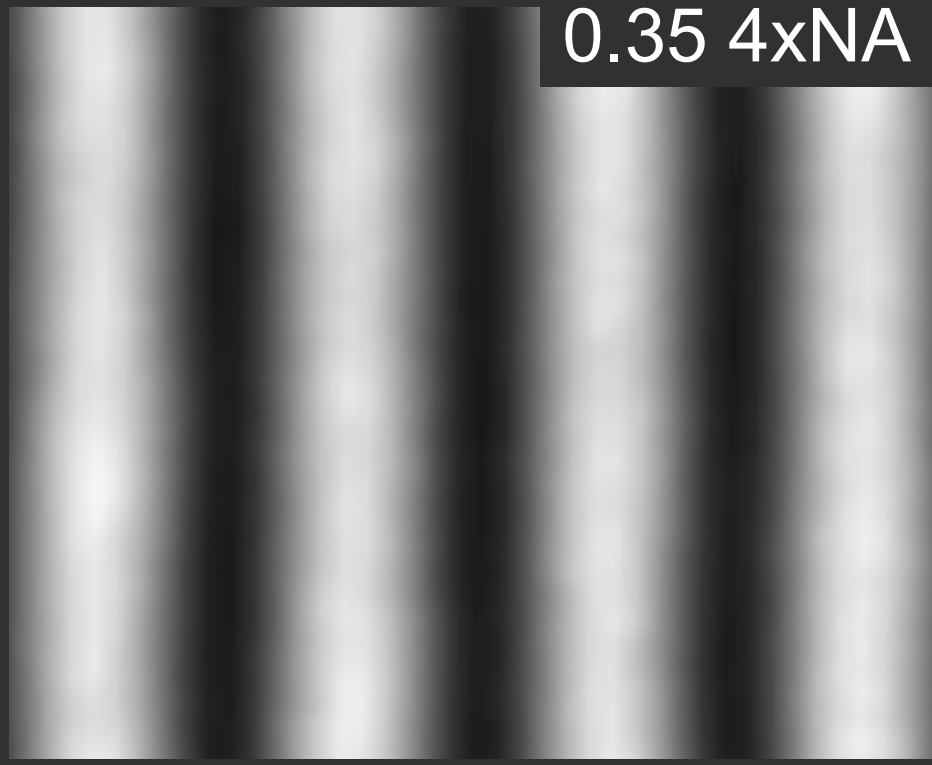
AIT

0.35 4xNA



SHARP

0.35 4xNA



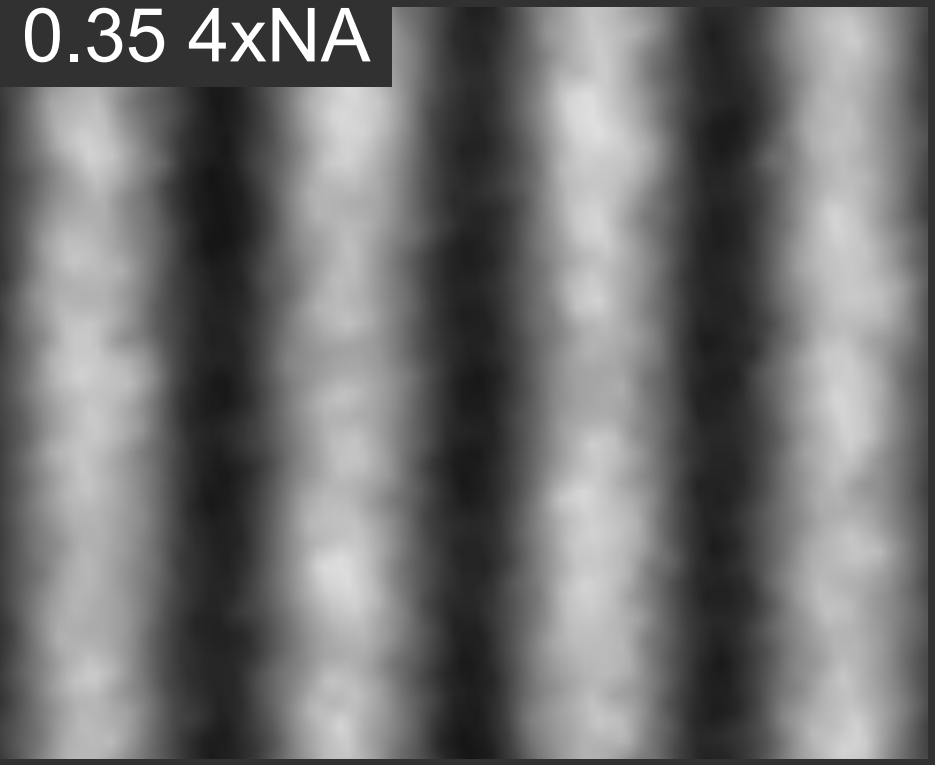
measured

contrast:	70%	77%
flux:	→	**153× higher**

85-nm hp (21.25)

AIT

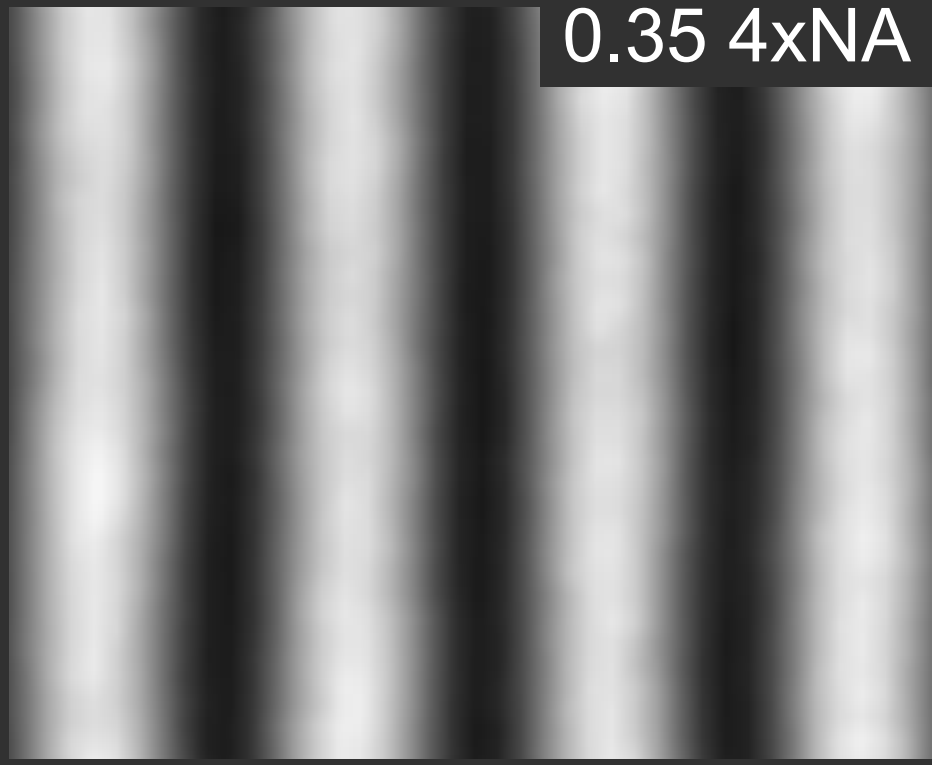
0.35 4xNA



45 second exposure

SHARP

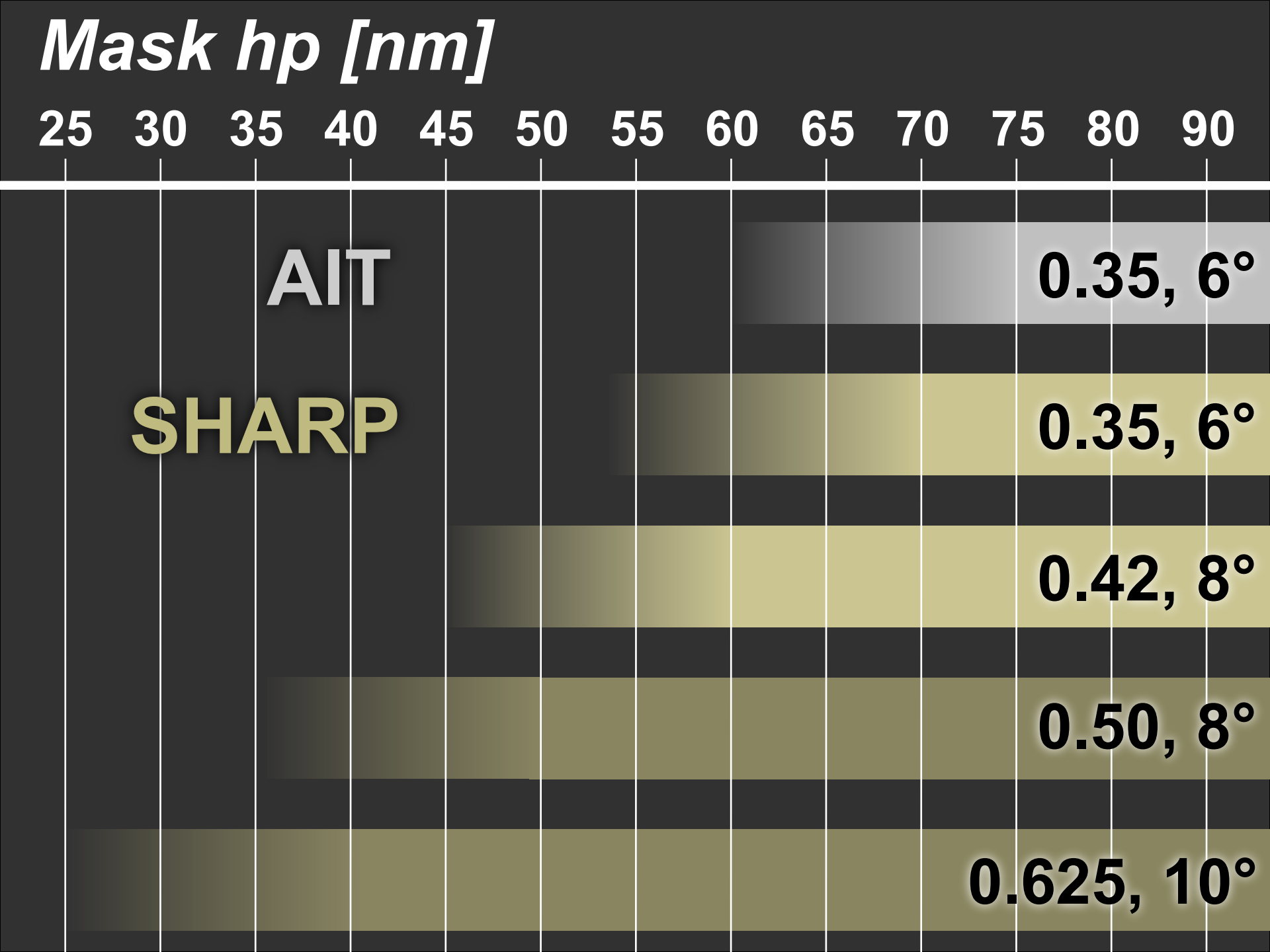
0.35 4xNA



2 seconds

AND 7x more light

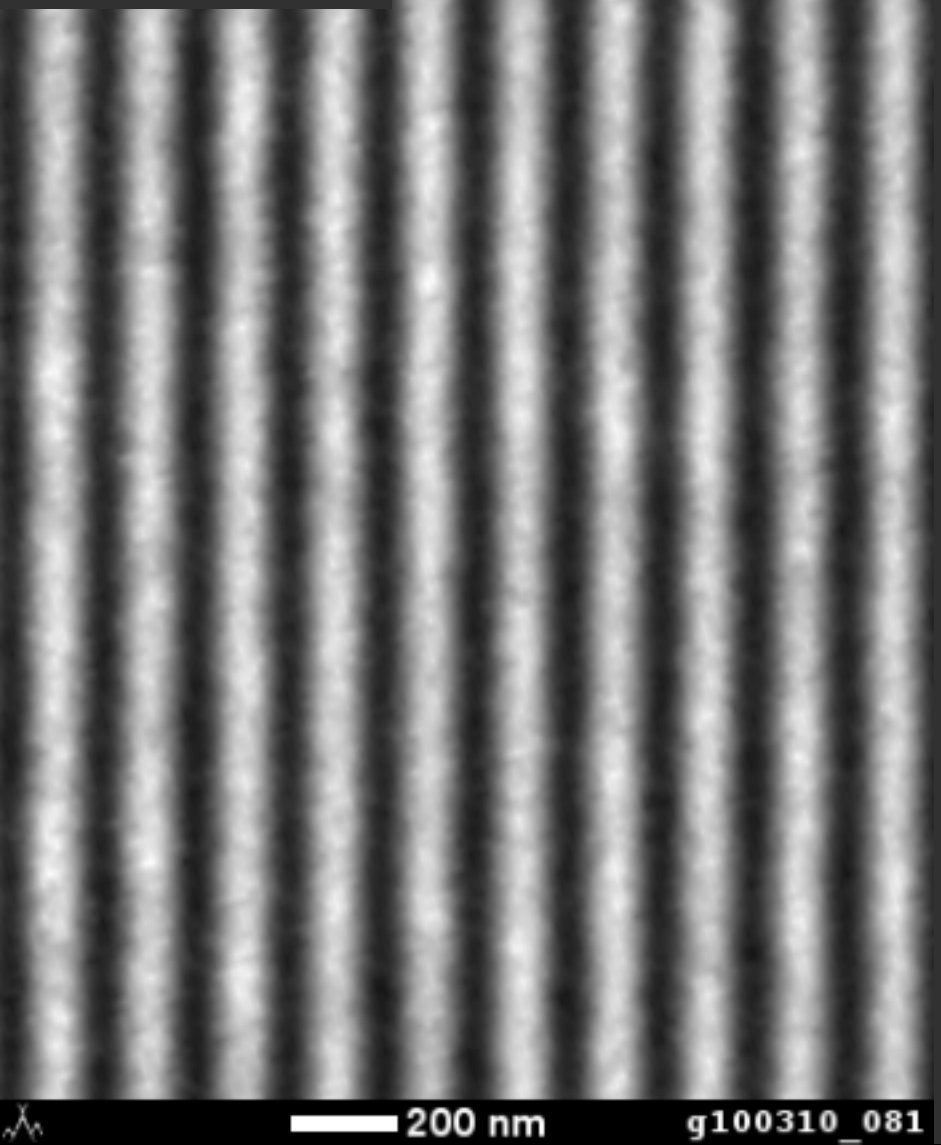
EUV Resolution


Mask hp [nm]
25 30 35 40 45 50 55 60 65 70 75 80 90
AIT
0.35, 6°
SHARP
0.35, 6°
0.42, 8°
0.50, 8°
0.625, 10°

90-nm hp (22.50)

AIT

0.35 4xNA



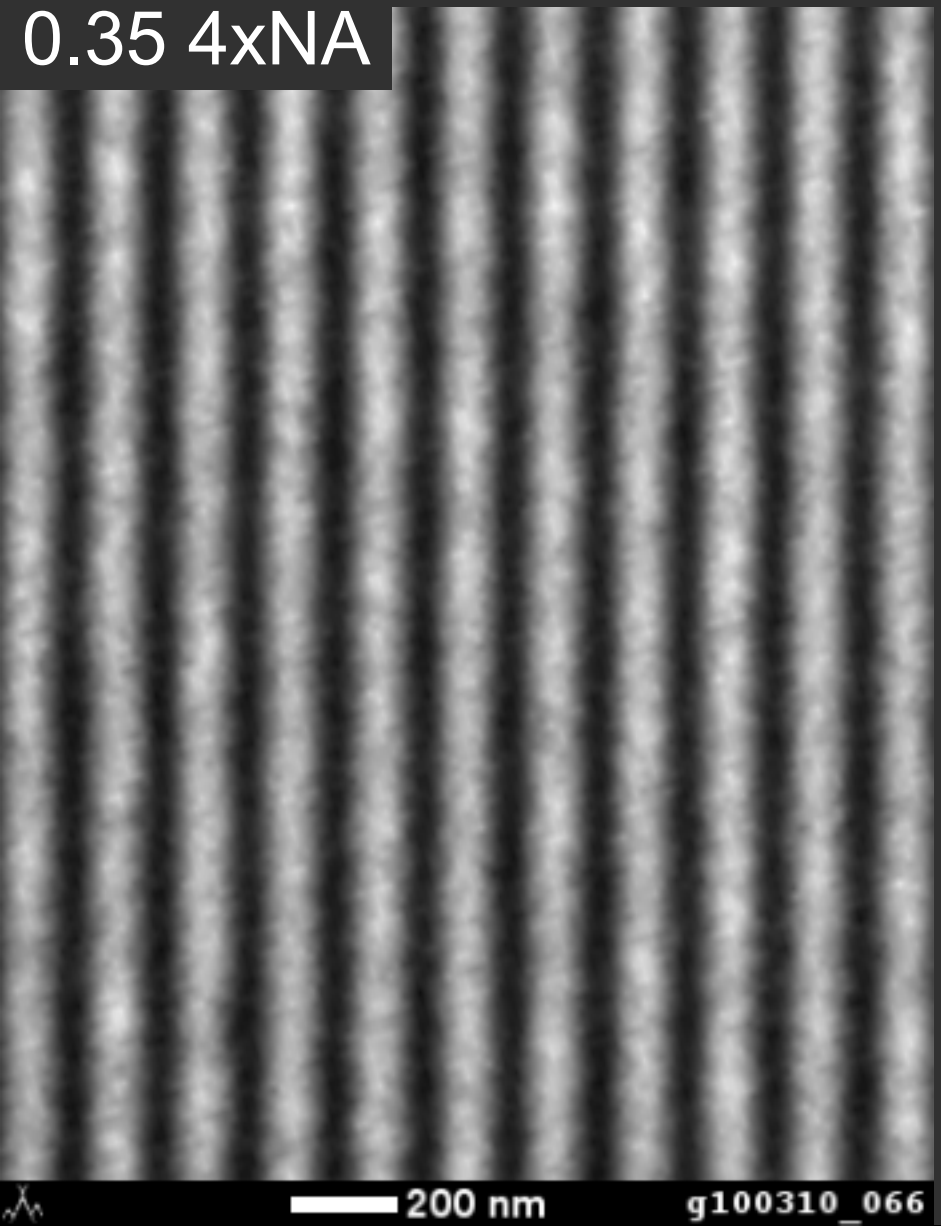
SHARP

0.35 4xNA

85-nm hp (21.25)

AIT

0.35 4xNA



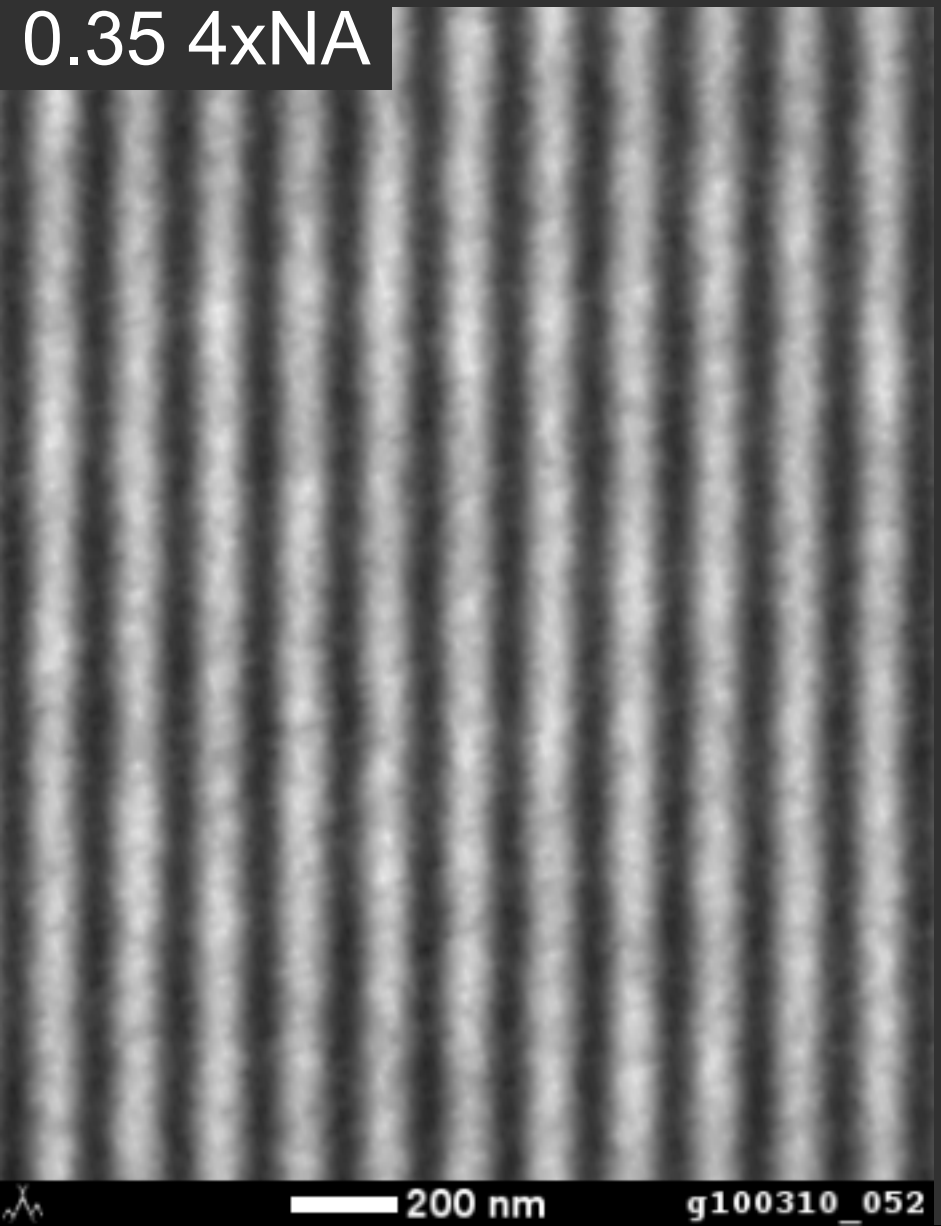
SHARP

0.35 4xNA

80-nm hp (21.25)

AIT

0.35 4xNA



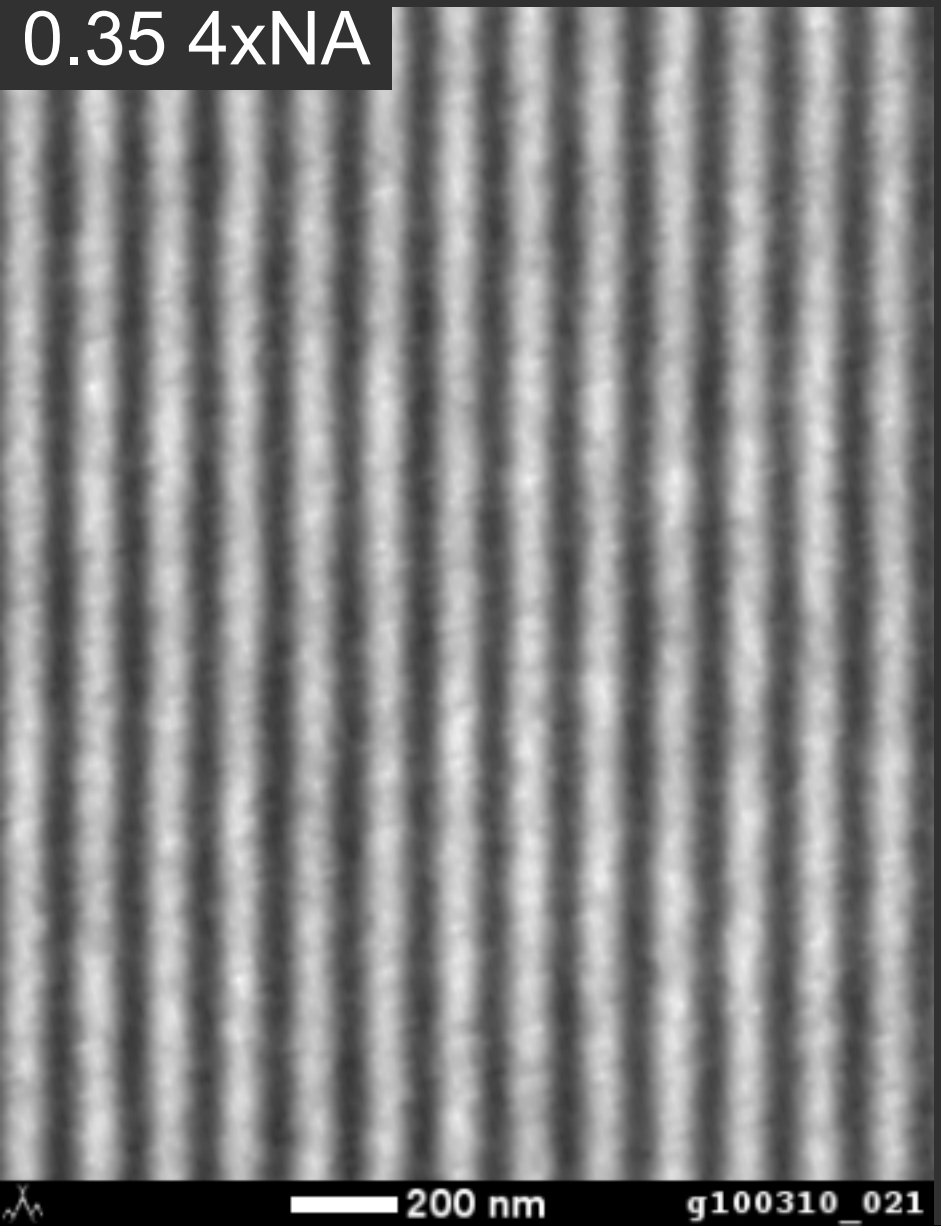
SHARP

0.35 4xNA

70-nm hp (17.50)

AIT

0.35 4xNA



SHARP

0.35 4xNA

65-nm hp (16.25)

AIT

0.35 4xNA

SHARP

0.35 4xNA

65-nm hp (16.25)

AIT

0.35 4xNA

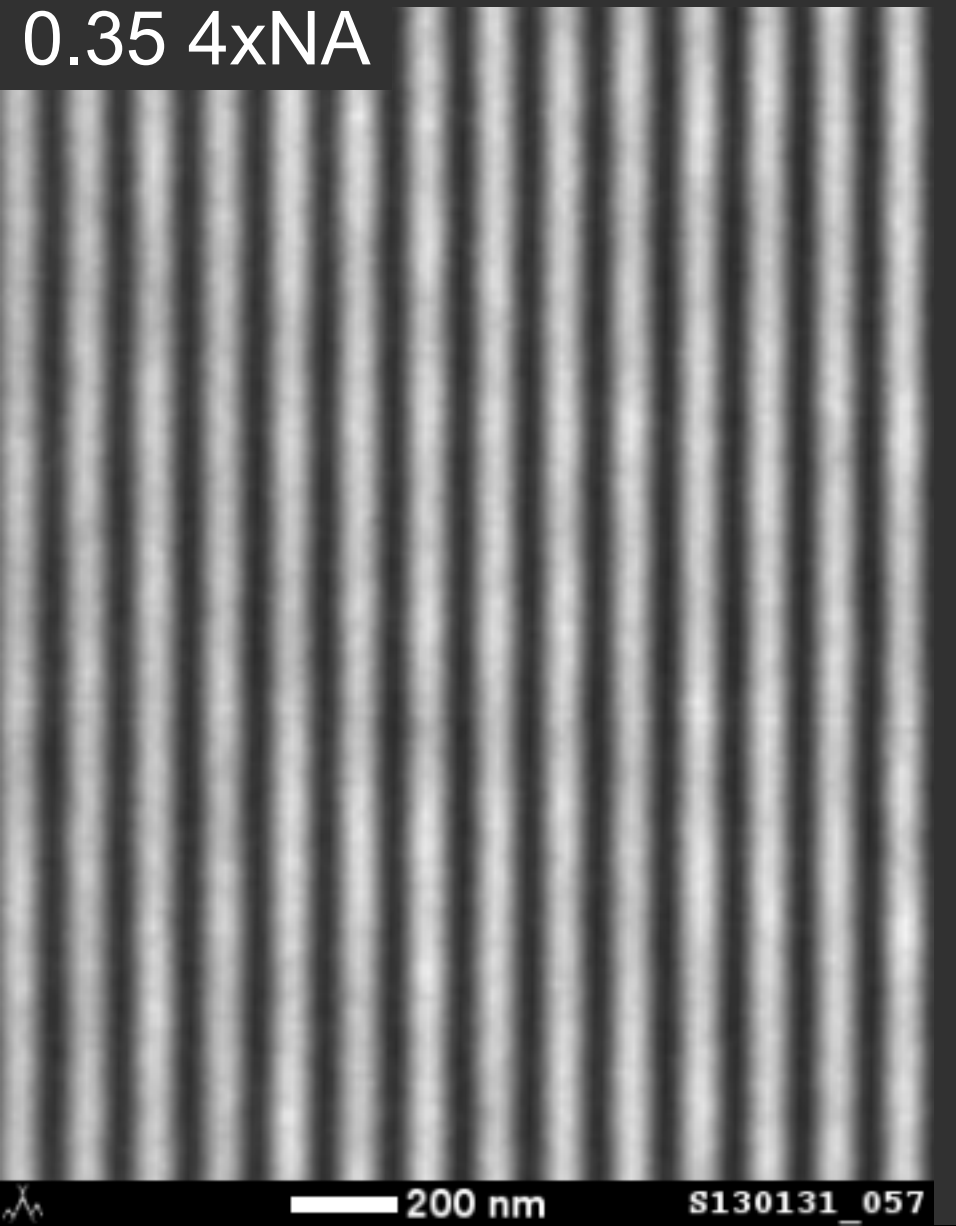
SHARP

0.35 4xNA

65-nm hp (16.25)

SHARP

0.35 4xNA



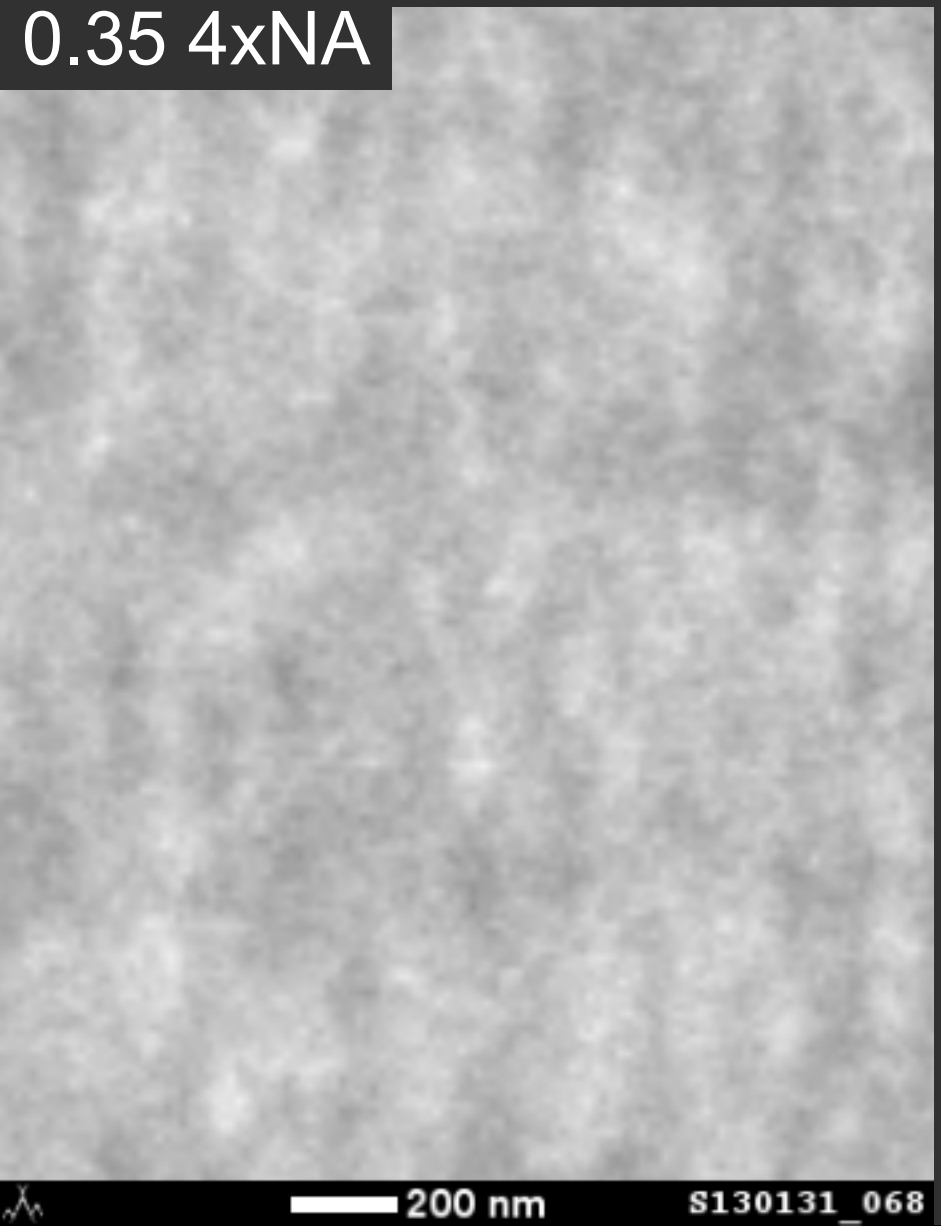
SHARP

0.42 4xNA

60-nm hp (15.00)

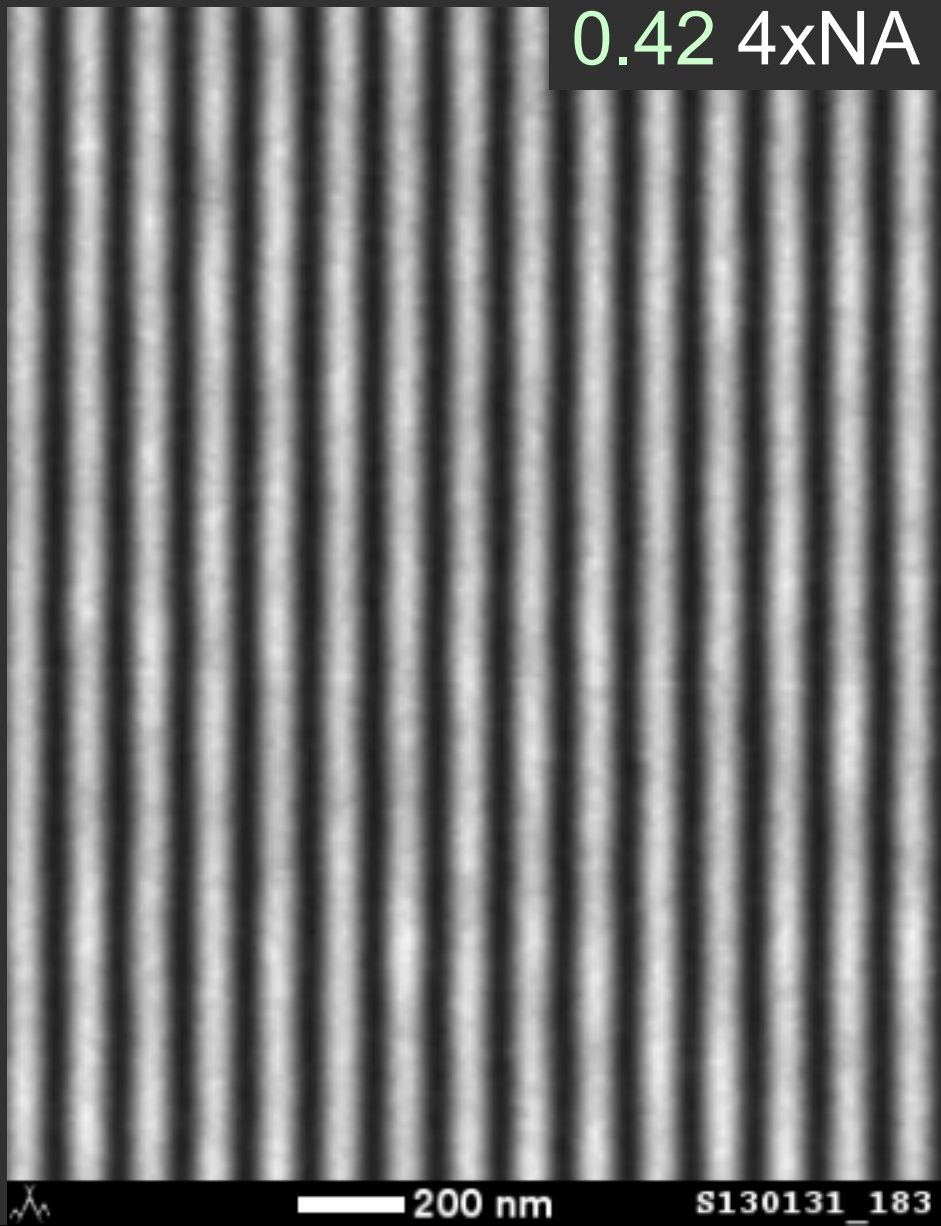
SHARP

0.35 4xNA



SHARP

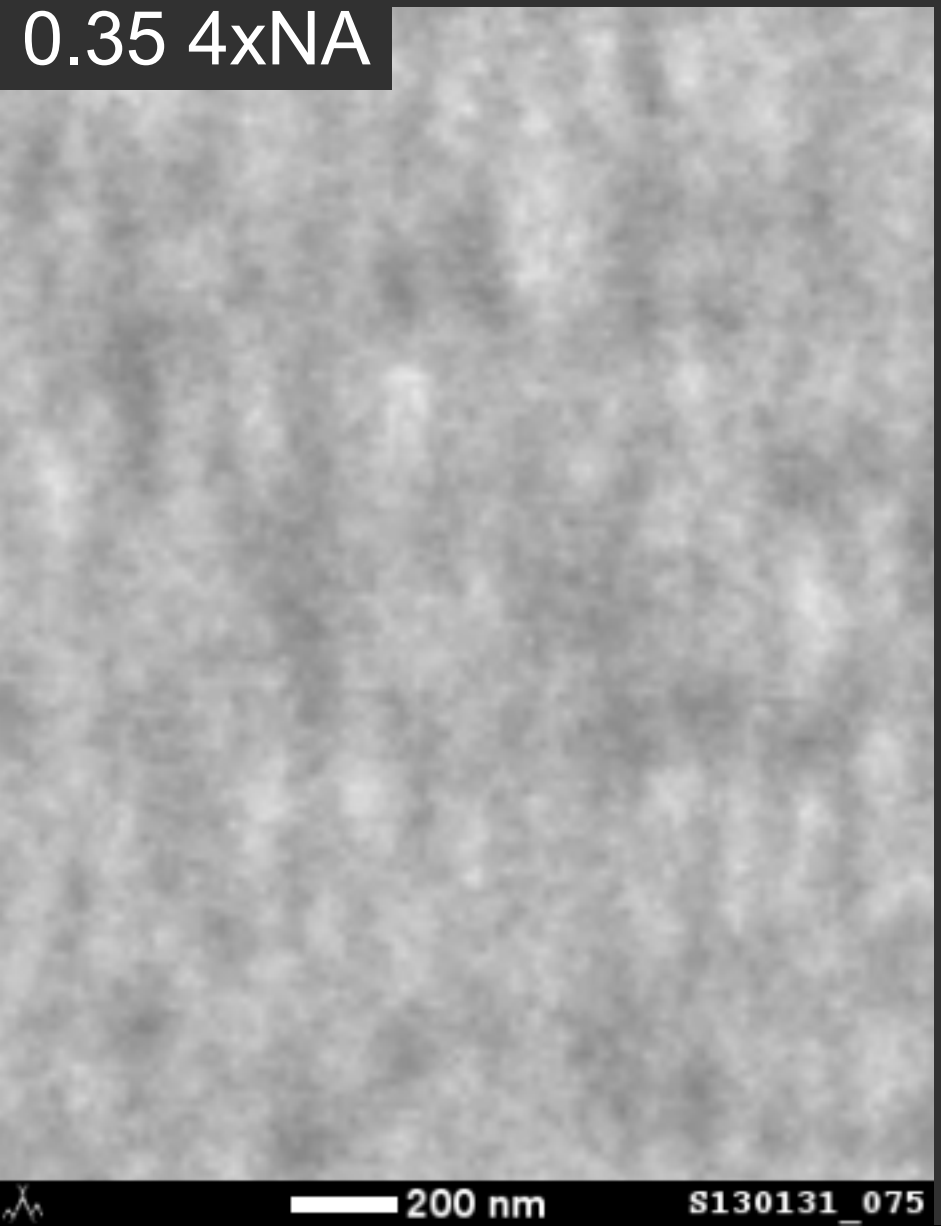
0.42 4xNA



55-nm hp (13.75)

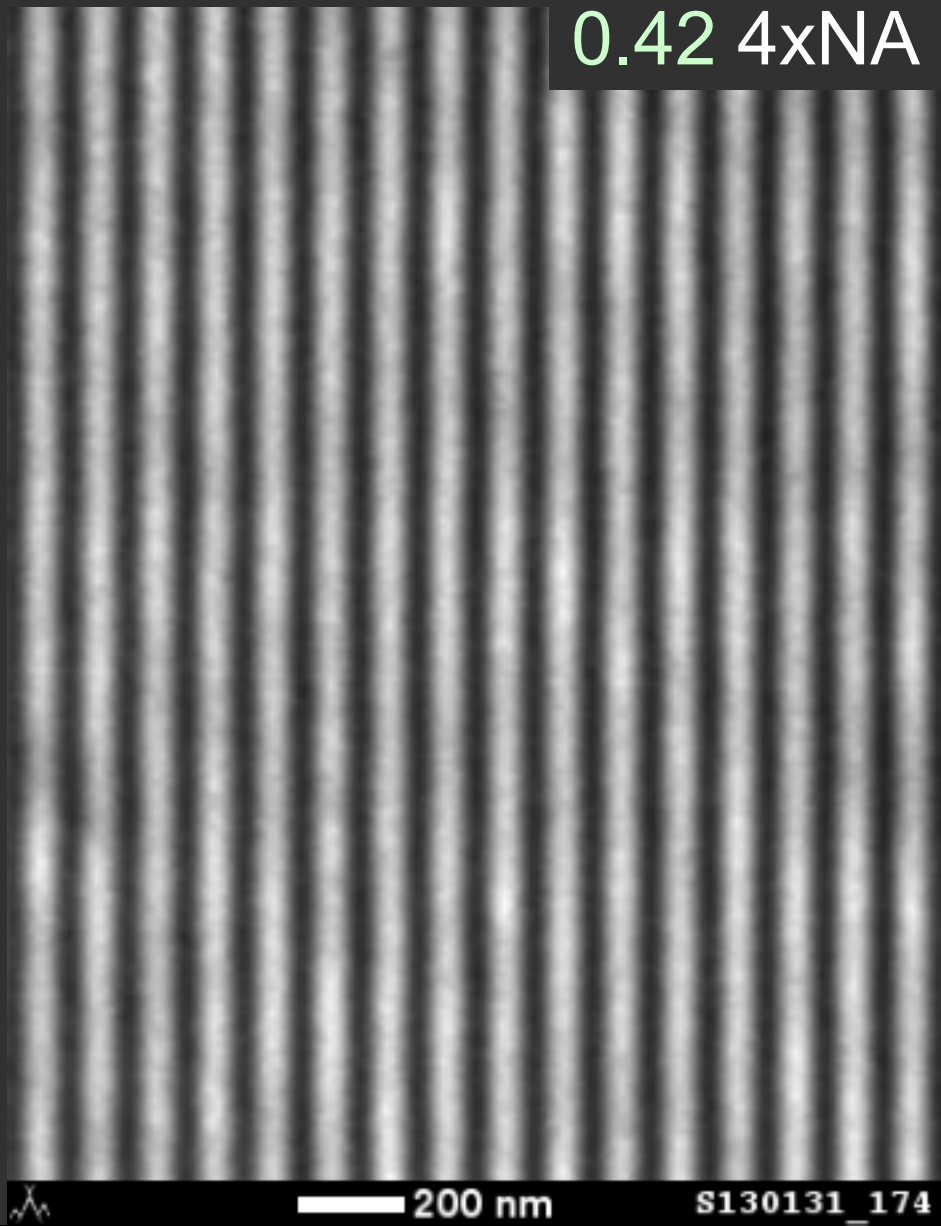
SHARP

0.35 4xNA



SHARP

0.42 4xNA



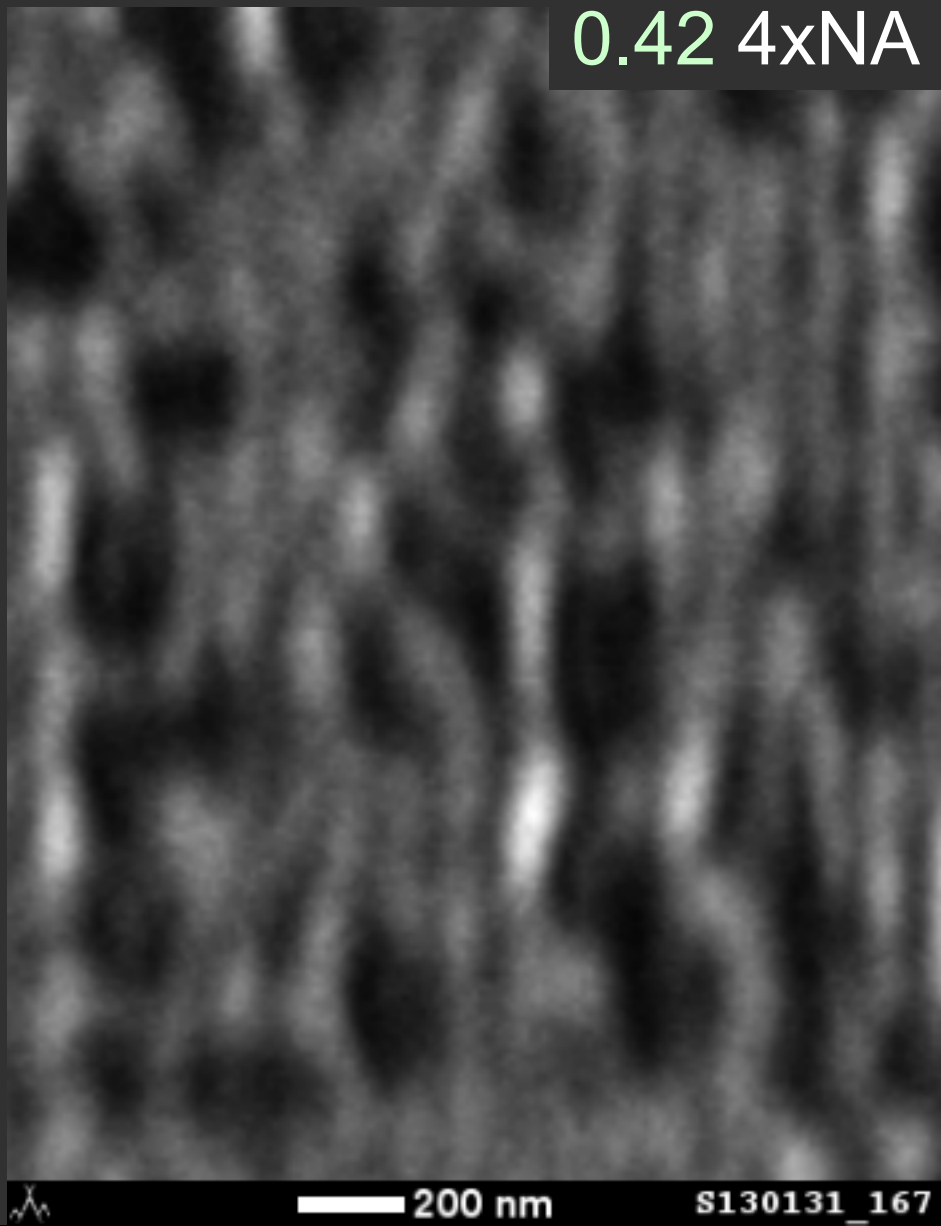
50-nm hp (12.50)

SHARP

0.35 4xNA

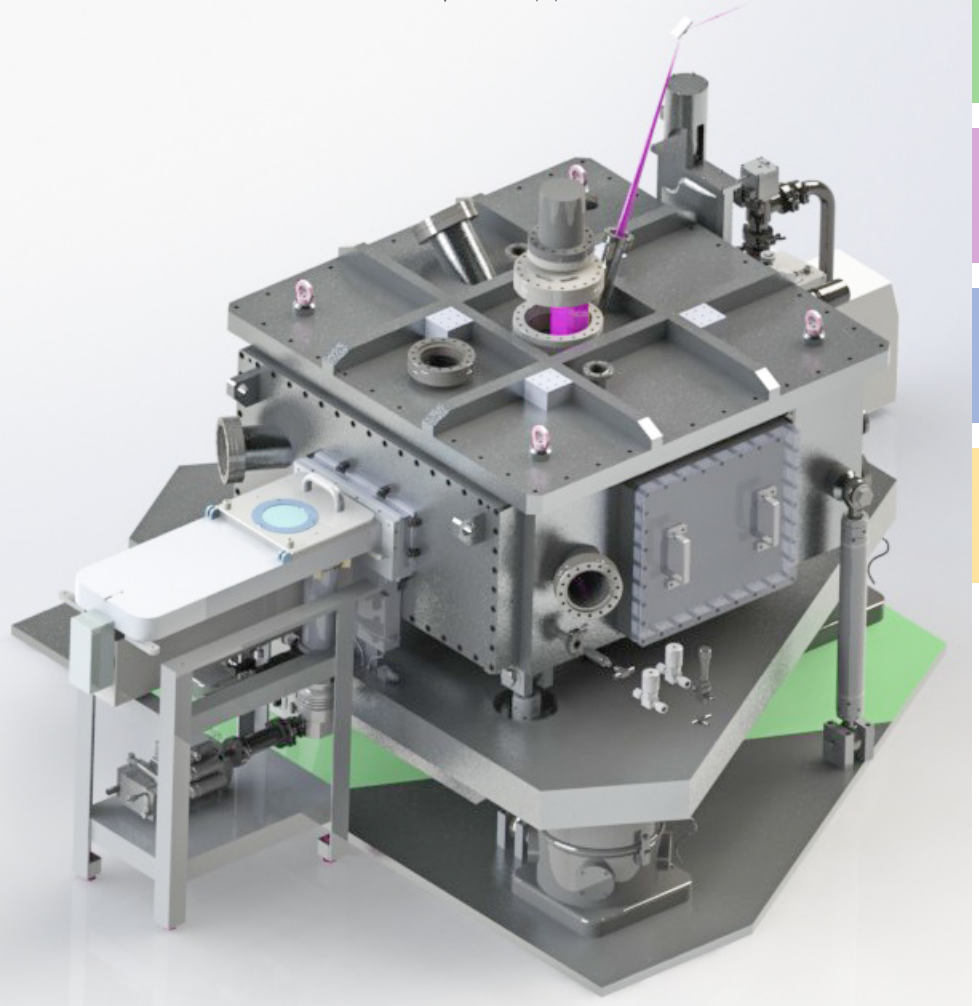
SHARP

0.42 4xNA



SHARP

SEMATECH HIGH-NA ACTINIC RETICLE REVIEW PROJECT



CONCLUSION

Commissioning

Bright

Fast

High Resolution

Coherence Control

> 100x brighter than AIT

Goldberg
Mochi
Benk
Macdougall
Rekawa
Allezy
Dickinson
Zehm
Jones
Cork
DePonte
Salmassi
Huang
Anderson
Chao
Gullikson
Gamsby
Naulleau

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Mirrorcle Technologies	**Vejlko Milanovic, Roger Hu**
L-3 Tinsley	**Adam Magruder**
PI / MICOS / MICRONIX	**Nate Evans, Manfred Schneider**

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