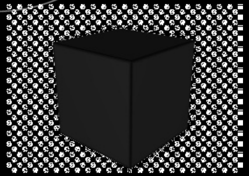
UNIVERSITY OF TWENTE.

PROXIMITY EFFECT CORRECTION FOR E-BEAM FABRICATION OF ALUMINUM OXIDE WAVEGUIDES

N. CHAHIR

Outline:

1. Introduction
2. Proximity Effect Correction
3. Results
4. Conclusion & Outlook



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Who are we..

- Integrated Optical Systems (IOS) @ University of Twente (Netherlands)

MESA+ Nanolab

Research areas:

- Electronics
- 3D nano shaping
- MEMS/NEMS
- Fluidics
- **Photonics**

n (ISO 5/ISO 7)
ized equipment
CVD),
n, etching,
XRD, annealing

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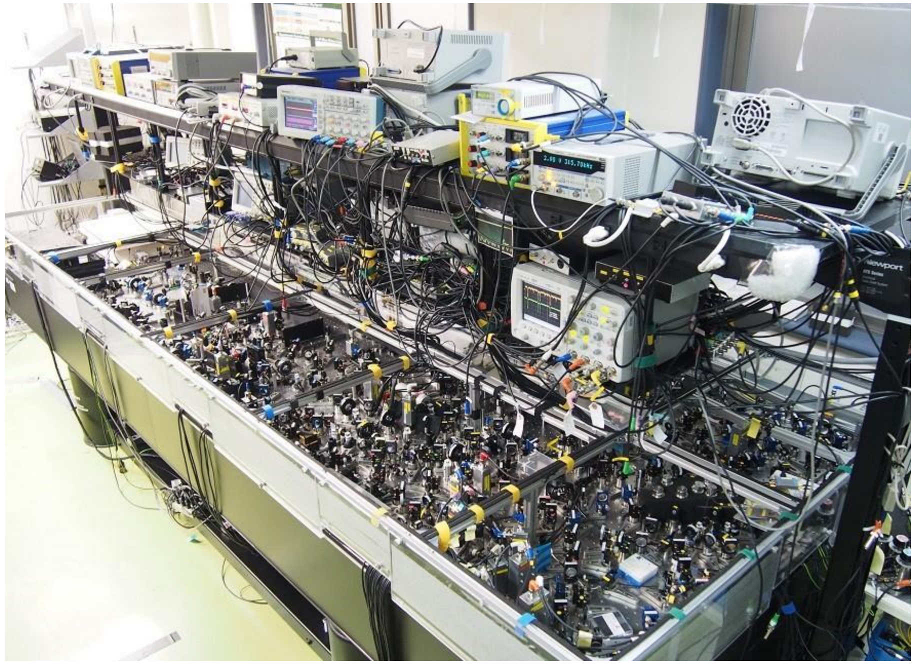
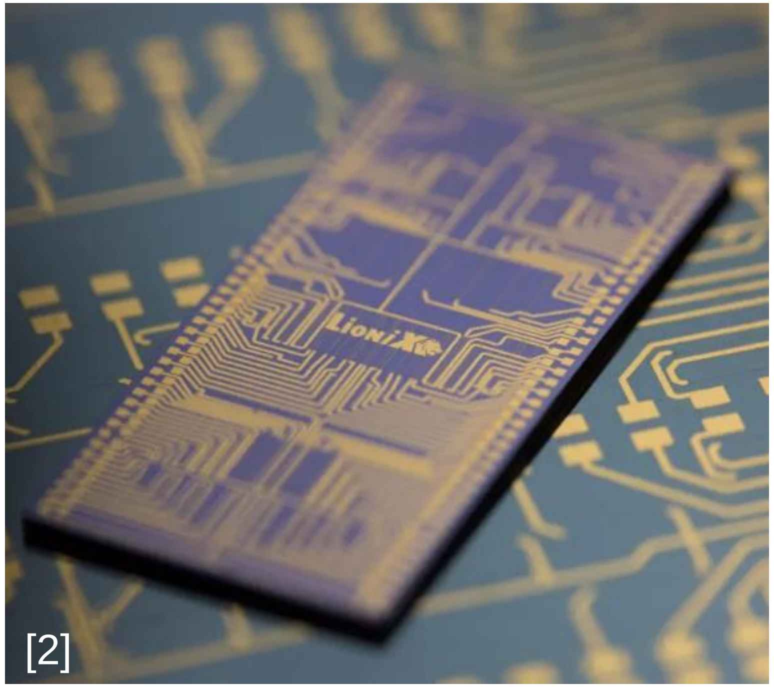
PHOTONIC INTEGRATION



Photonic Integration

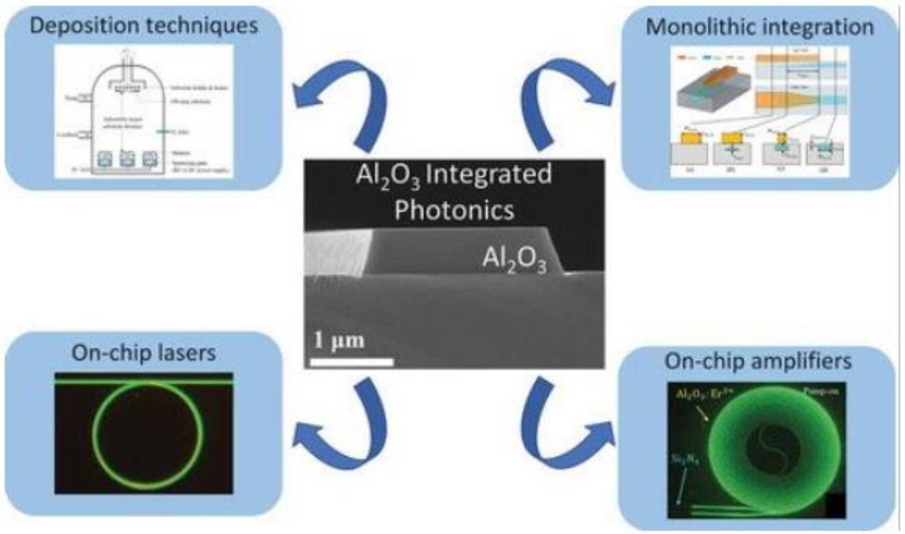
- Energy efficiency
- Increased speed
- Reduced size and cost
- Scalability
- Novel functionalities



[1] https://www.eurekalert.org/news-releases/738849
[2] https://www.lionix-international.com/photonics/photonic-integrated-circuit-development/photonic-integrated-circuit-design/

Al2O3 AS A PHOTONIC MATERIAL

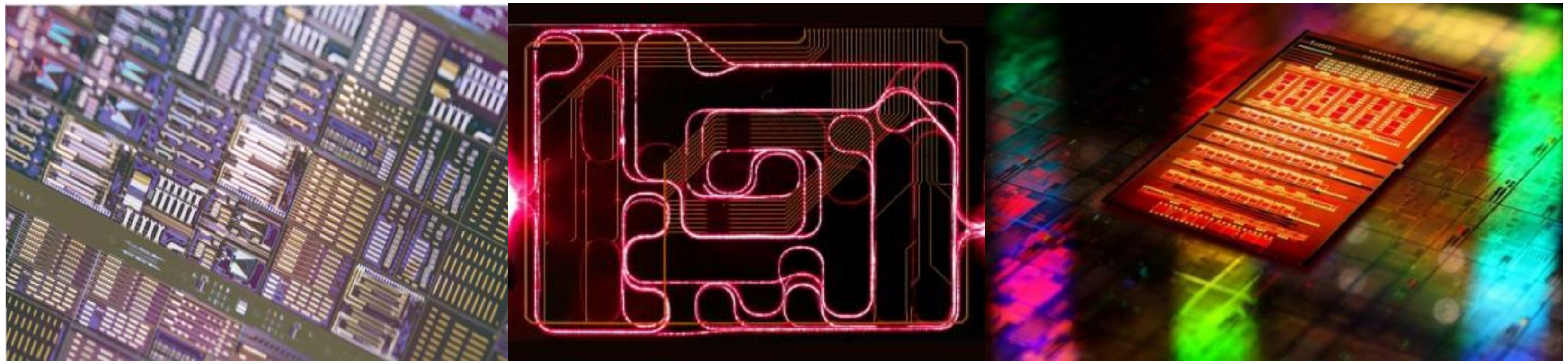
- Large transparency window: UV-mid-IR
- Low propagation losses: 5 dB/m
- Moderate refractive index: 1,72@1550 nm
- Wafer level deposition
- High rare-earth ion solubility
- In the Nanolab → RF reactive sputtering

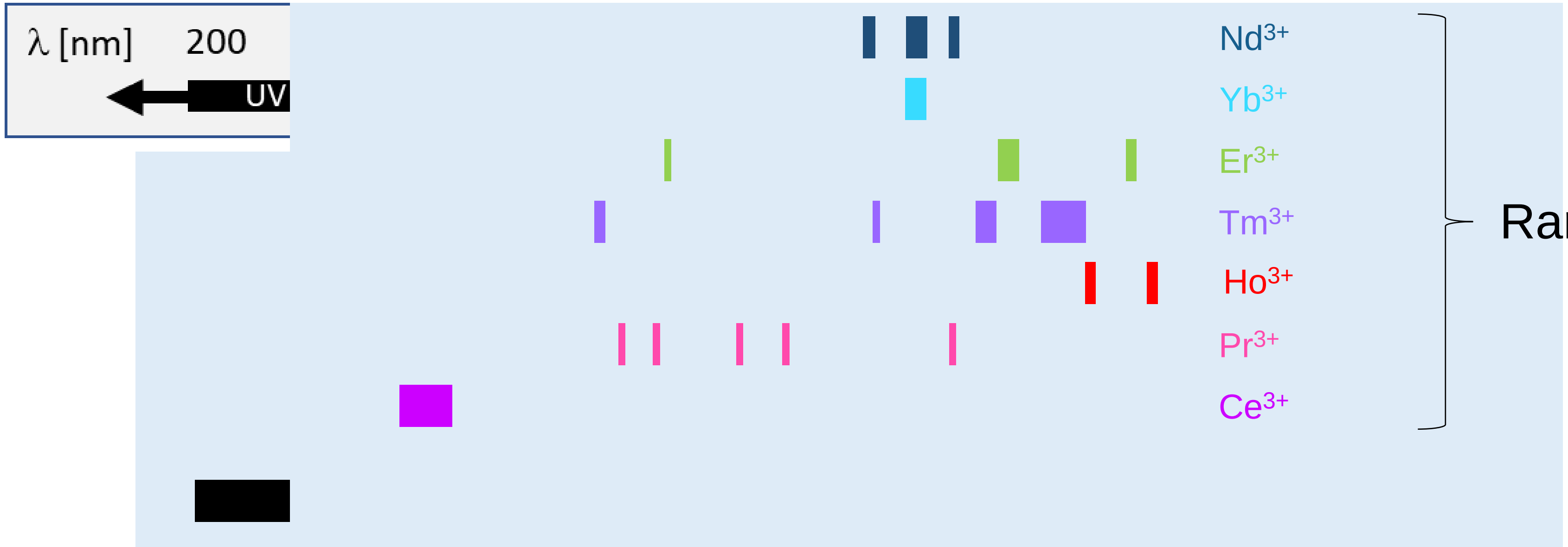


[Review: Hendriks et. al. , Advances in Physics: X, 6 (1), 1833753 (2021)

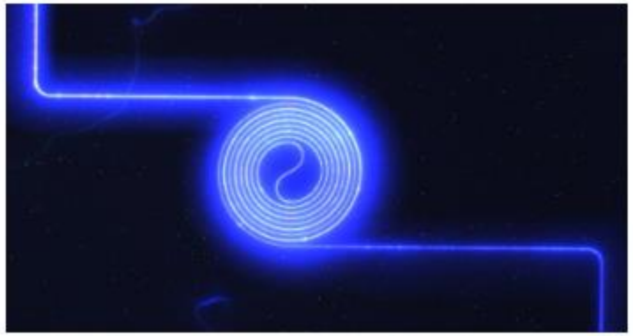
INTEGRATED PHOTONIC PLATFORM

InP SiN Si

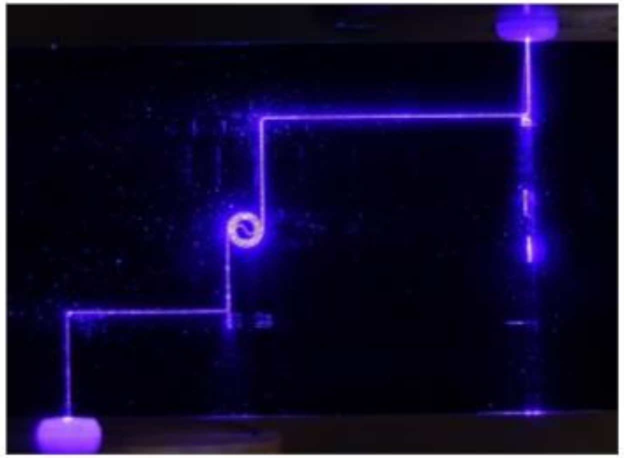


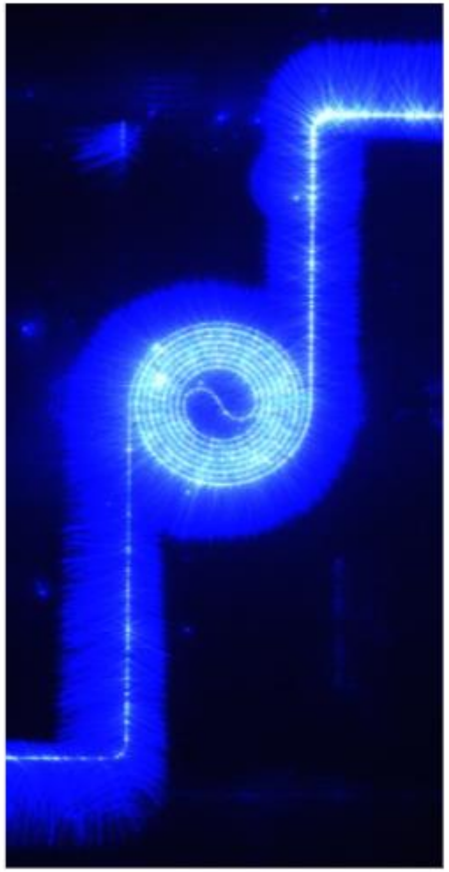


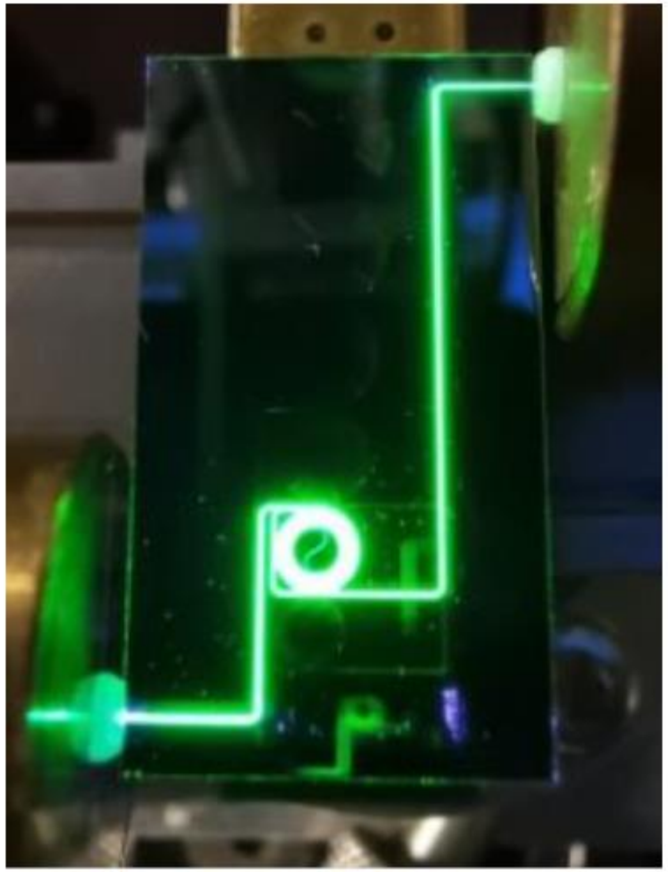
BROADBAND OPERATION

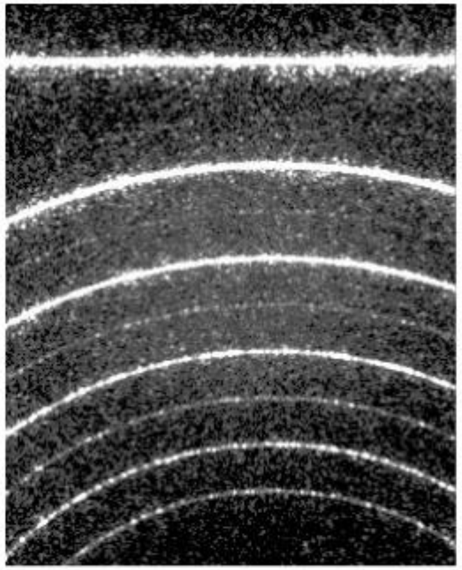


405 nm transmission

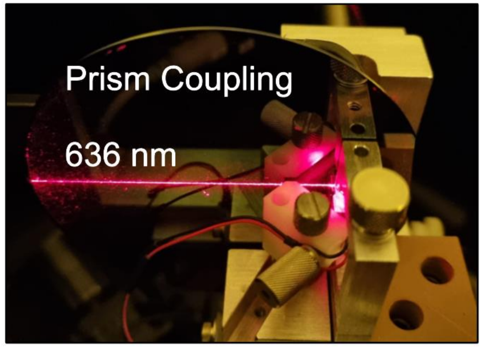


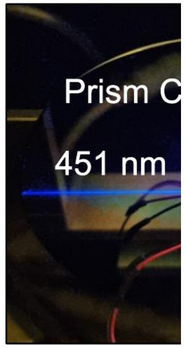






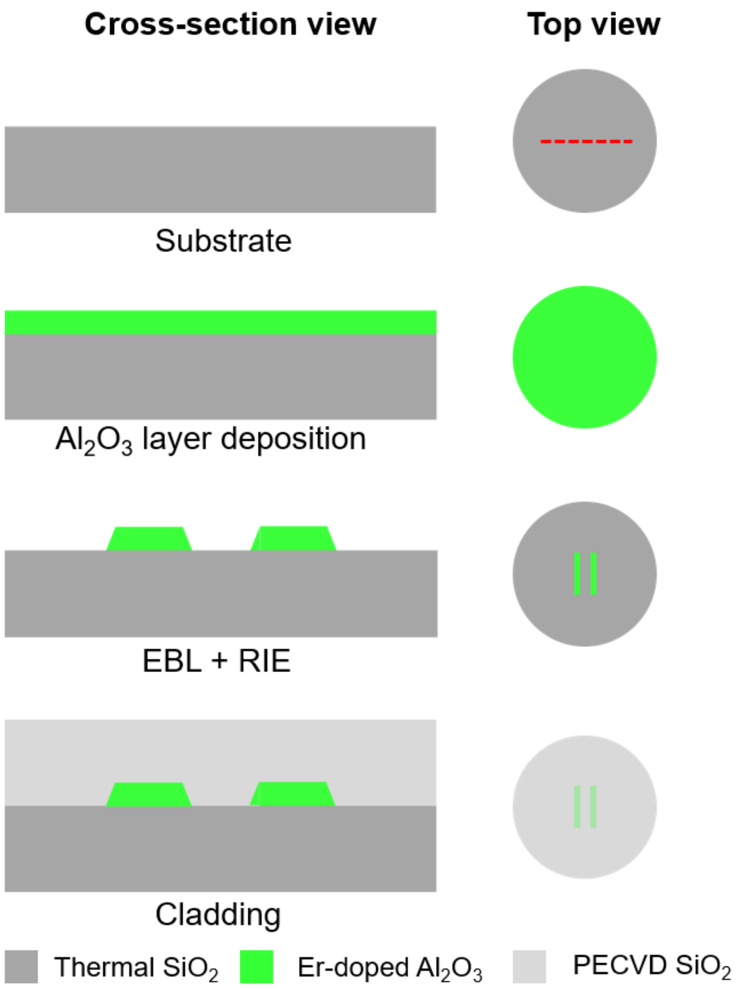
Fabrication





AJA ATC 1500:

- AR-PC 5091.02 (60 nm)
- Negative electron beam sensitive resist AR-N 7520.18 (350 nm)
- Layer of 100 nm thick of Al_2O_3
- 8 um thermal oxide on silicon
- Electron beam Raith EBPG515 system
- Electron beam (100 keV, 12 nA, aperture 300 µm)

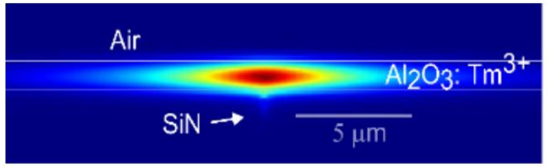


Recent Demonstration

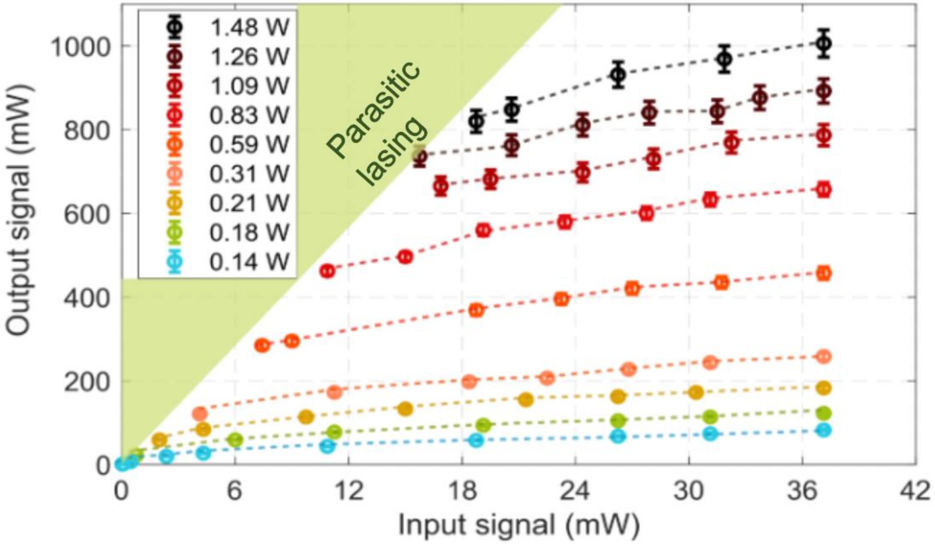
Erbium doped Al_2O_3 for LIDAR

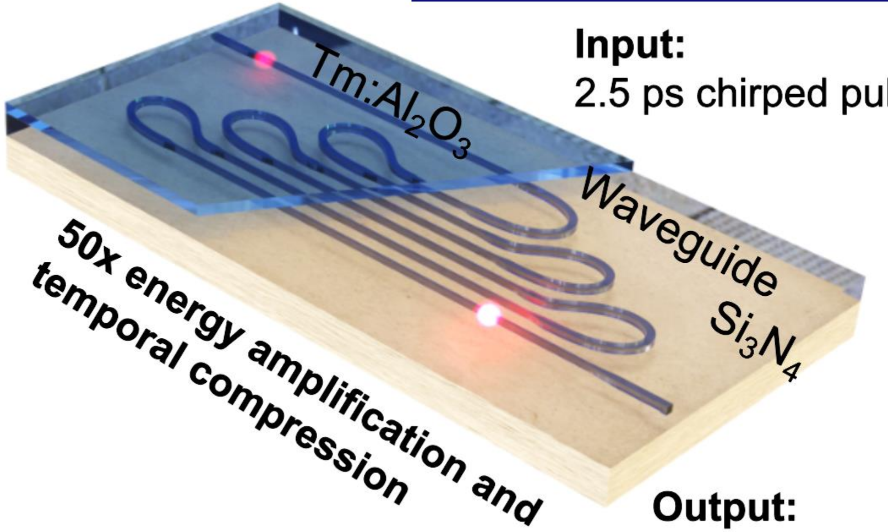
Recent record results of ~34 dB internal

Thulium doped Al_2O_3 for Q-switched lasers



Recent result (small signal)





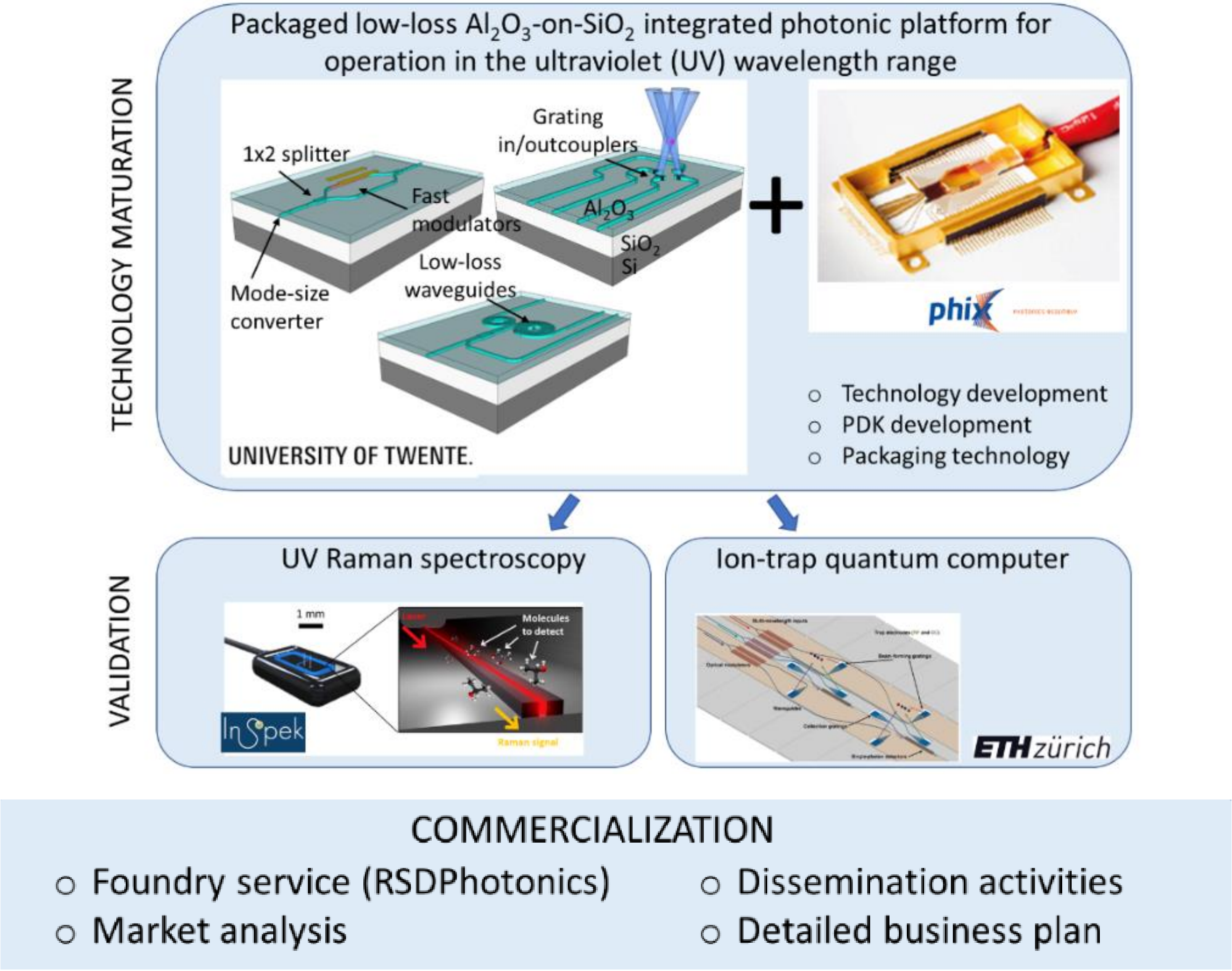
Input:
2.5 ps chirped pulse

Output:
116 ps chirped pulse
800 W peak power

ALUVIA PROJECT

- Technology maturation of low-loss Al2O3 waveguides for UV wavelengths

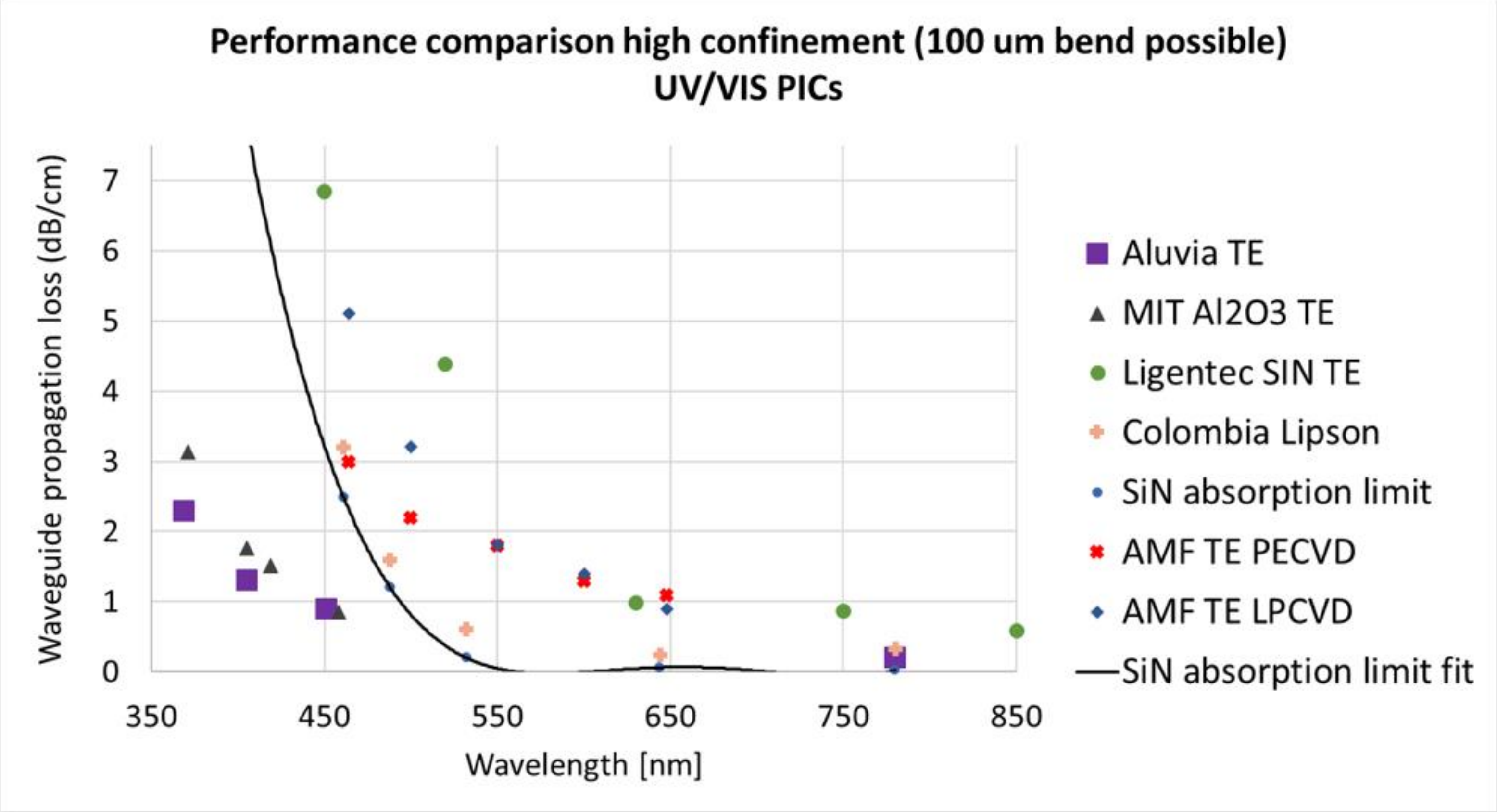
- Validation in UV waveguide-enhanced Raman spectroscopy (**WERS**) and surface **ion traps** for qubit generation

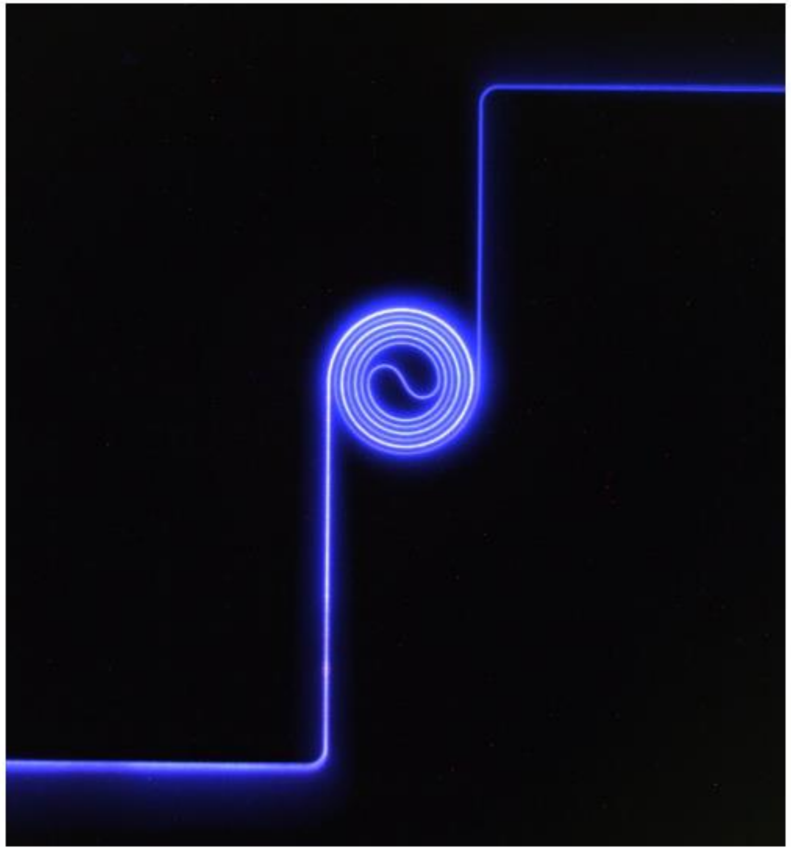


FILM STATUS & LOSS COMPARISON

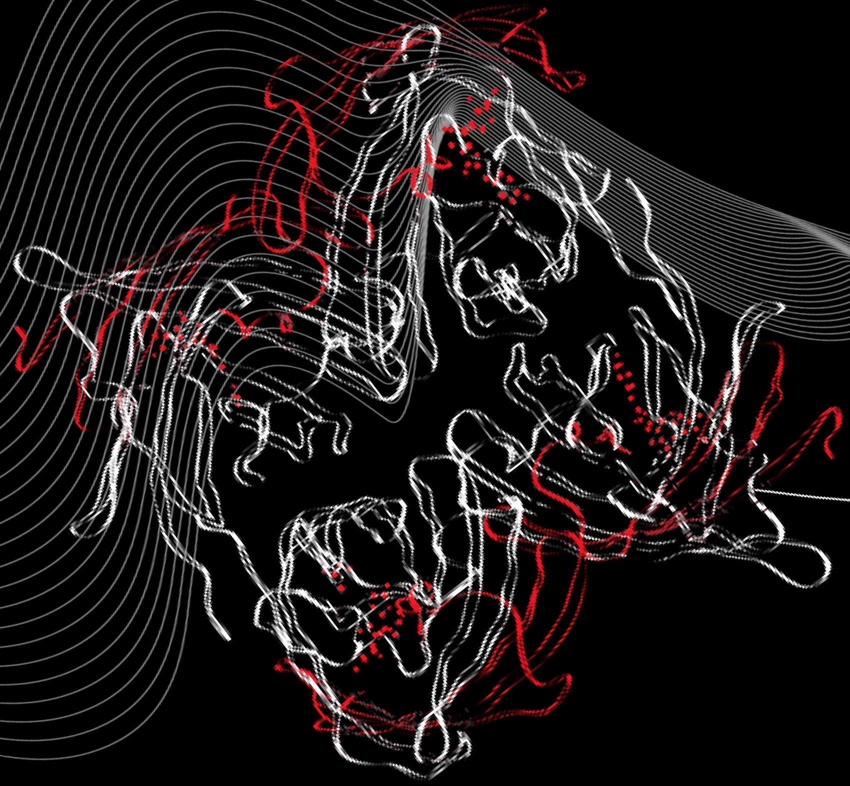
- Layer uniformity 1-4%
- Refractive index uniformity <1%

- Slab losses of 0.4 dB/cm @ 377nm
- Lowest loss of 1.3 dB/cm for TM @ 369nm & 1.1 @ 405nm





1. Proximity Effect

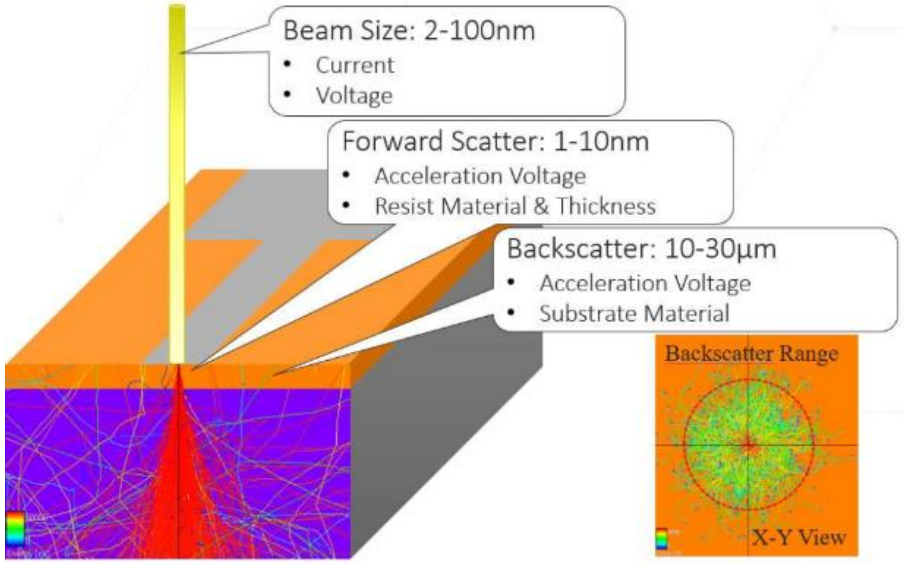


Why a PEC?

- Different CDs in the same layout
  - tapers
  - waveguides
  - coupled lines and gaps
  - gratings

- Correction of all CDs in one exposure

- Dose depends on lines dimension and pattern density

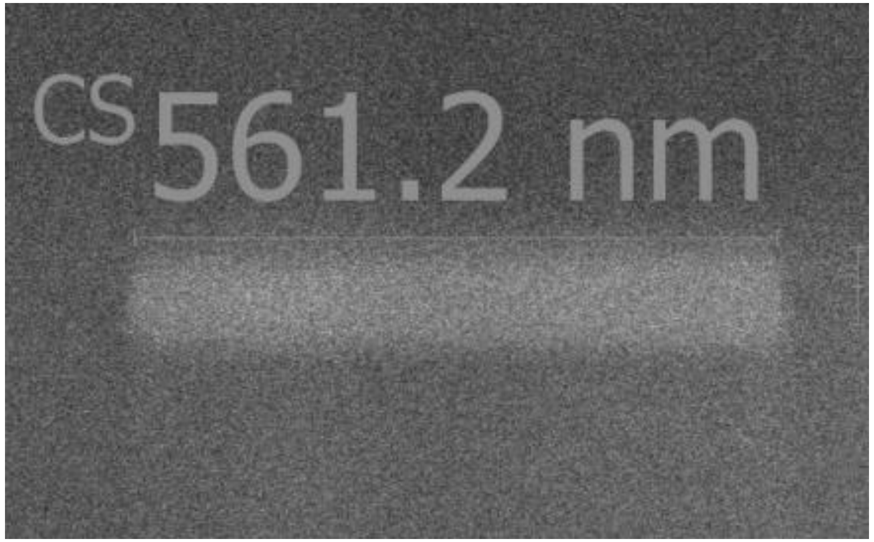


https://www.genisys-gmbh.com

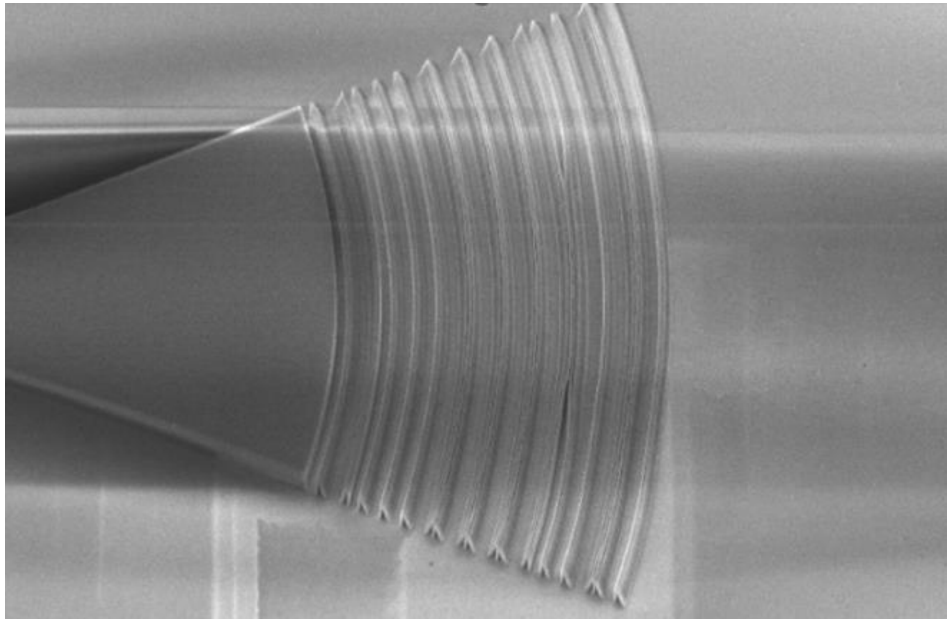
- Exposure → Scattering → Absorbed energy → Feature

- Effective blur → CD variation
  - Beam size
  - Scattering
  - Process

Exposure with wrong dose



600 nm lines



unstable grating lines

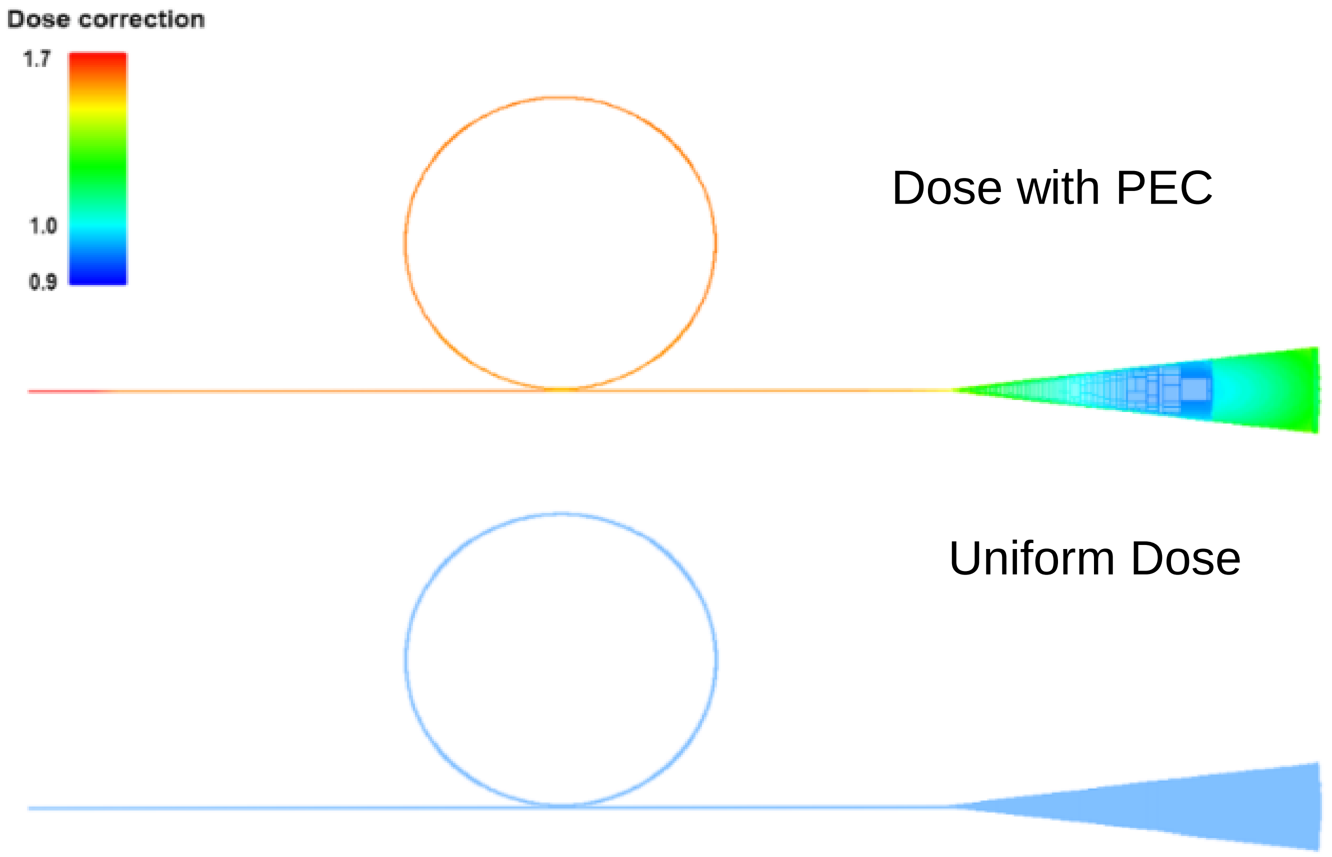
Calibration Process

- PSF simulation (Monte Carlo Simulation)
- Data-prep (test pattern, resist contrast)
- Exposure
- Resist development
- Pattern transfer
  - RIE etching
- Inspection
  - SEM → find base dose

Dose correction

- Base dose

- Dose factor



2.1st PEC-Results

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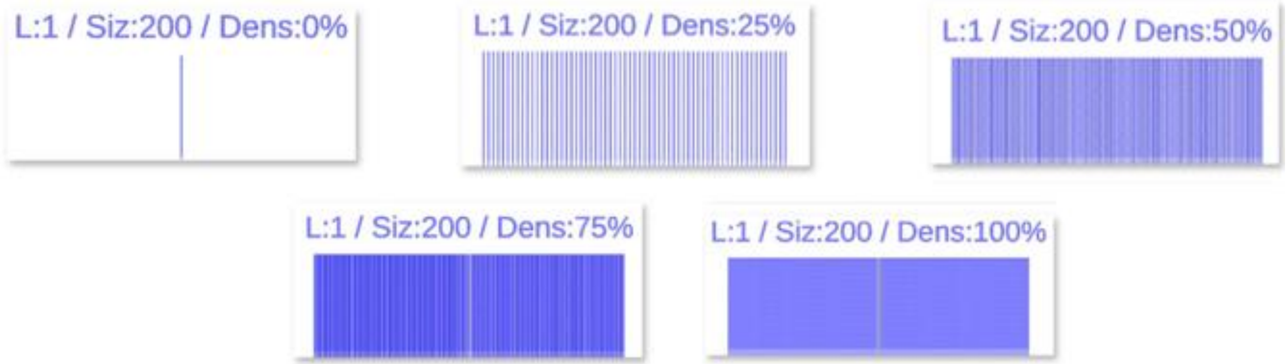
Test pattern + Exposure

Local pattern density variation from isolated to fully dense

- Filling factors:

  0%, 25%, 50%, 75%, 100%



- Dose range: 250 -1150 $\mu C/cm$^2

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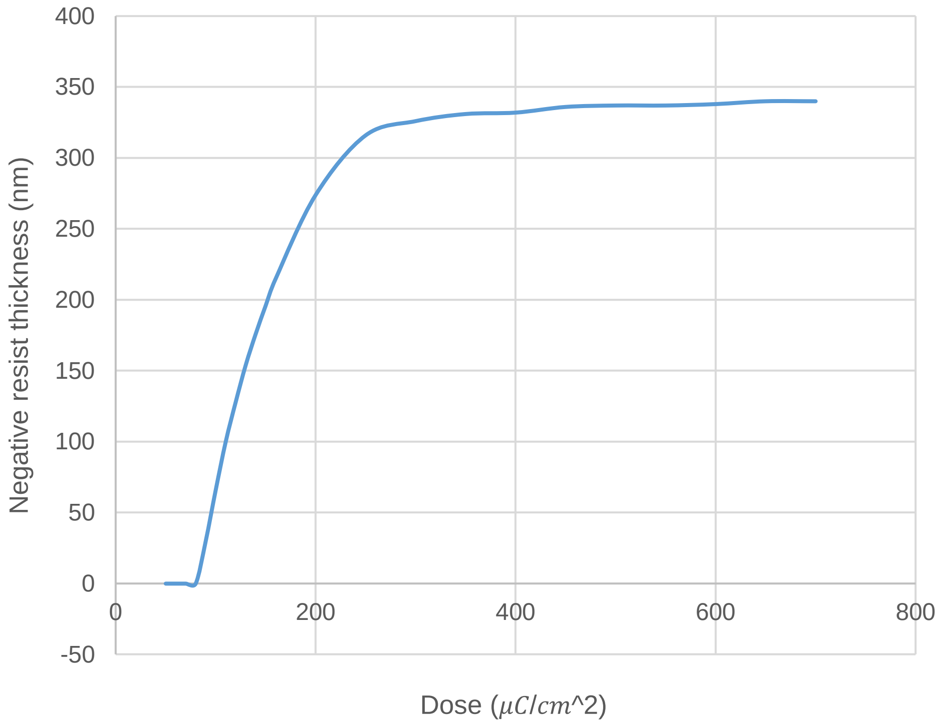
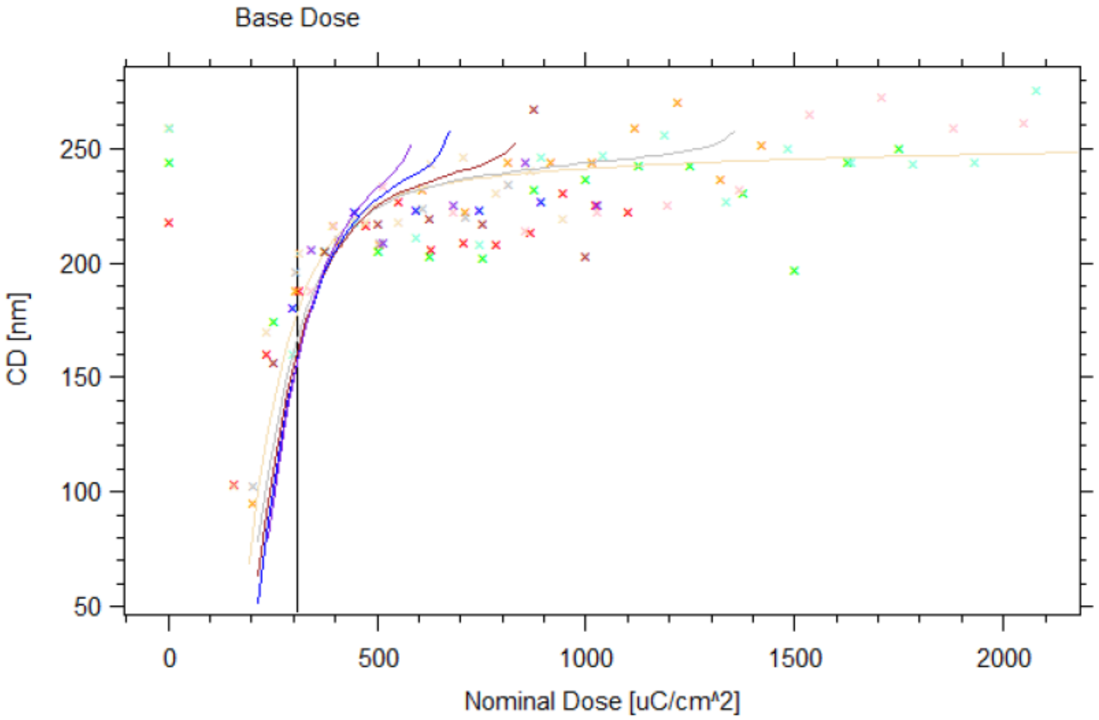
Measurements

Resist contrast curve

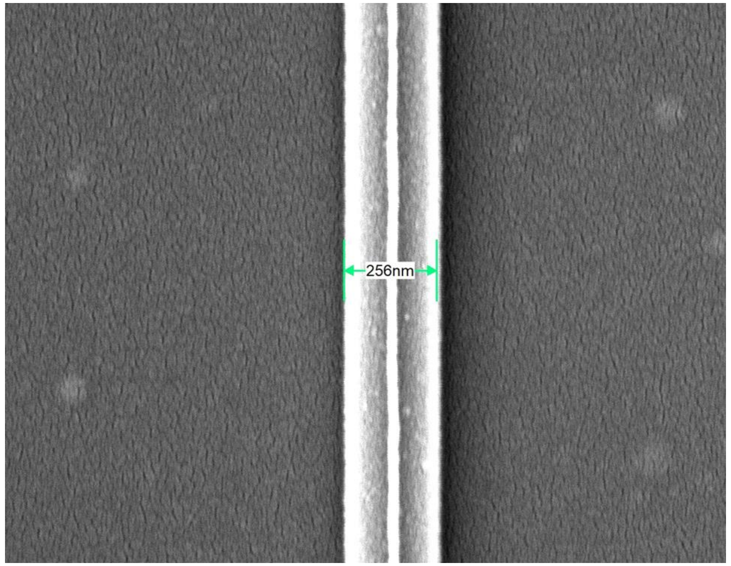


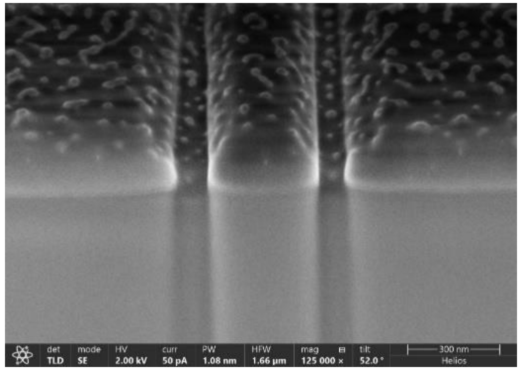
Linewidths

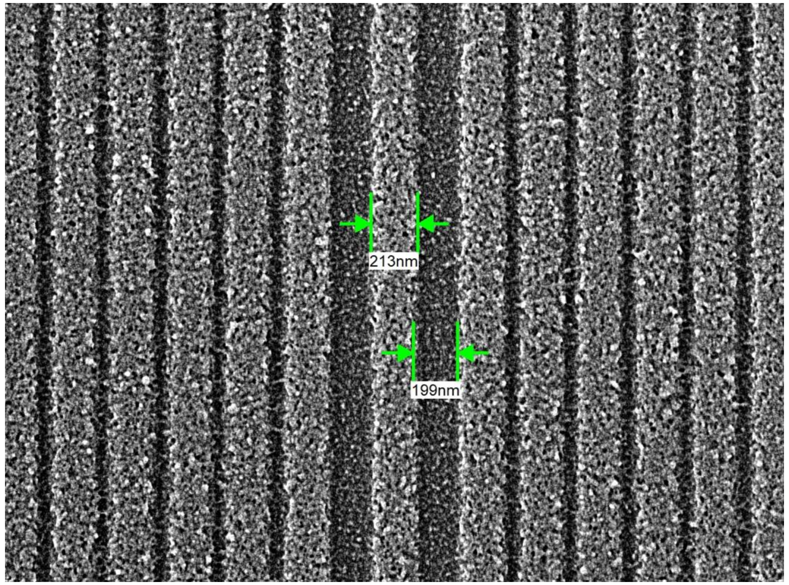


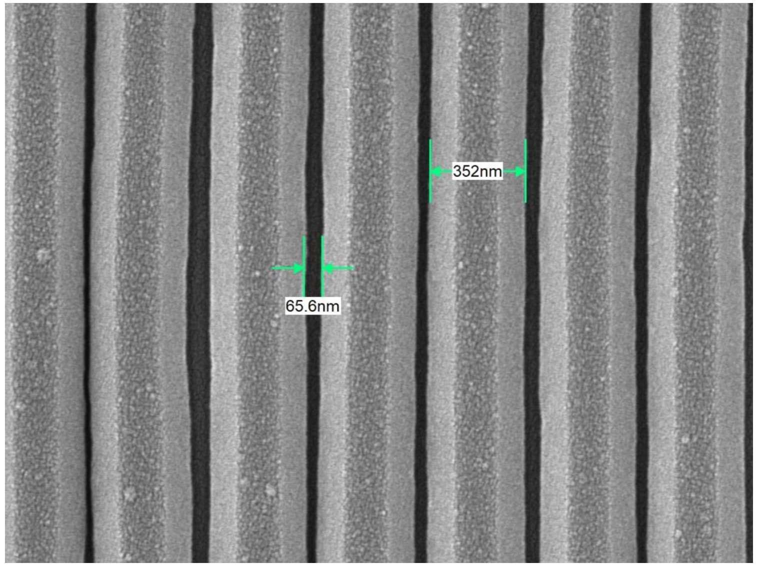
Base dose of 250 $\mu C/cm$^2

Results









200 nm lines

What's wrong?

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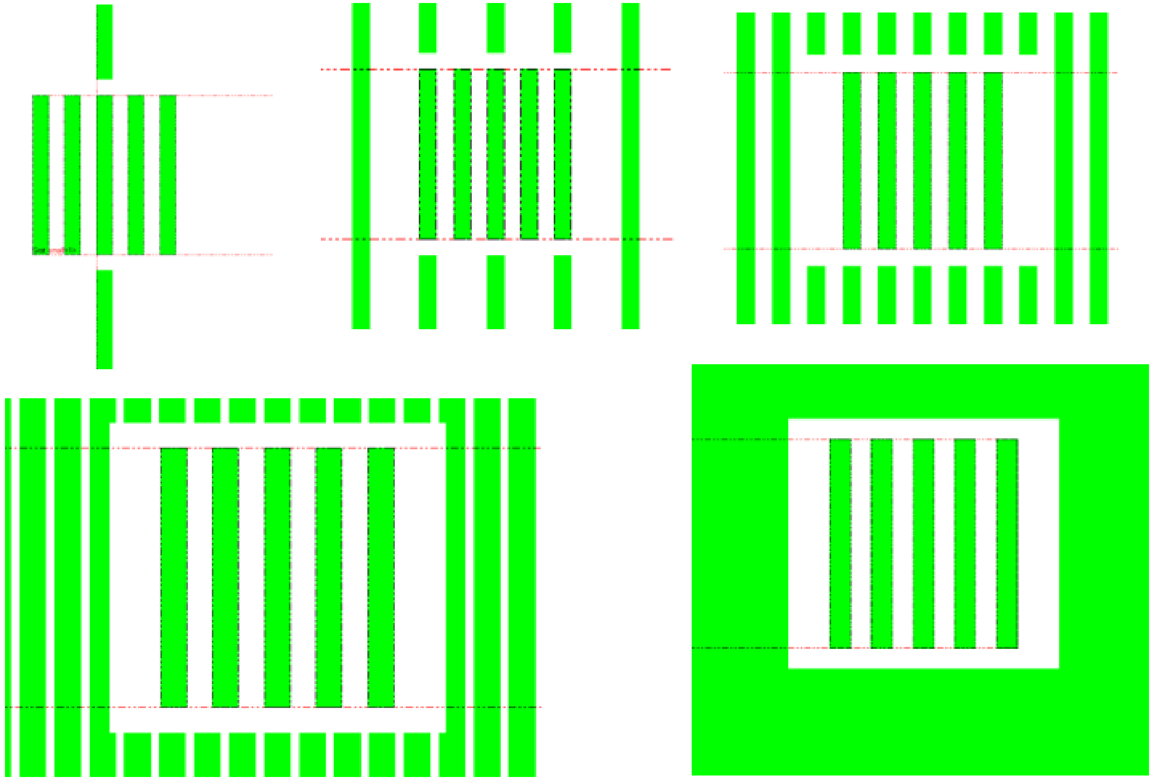
3. 2nd PEC-Results

Test pattern + Exposure

- Filling factors:

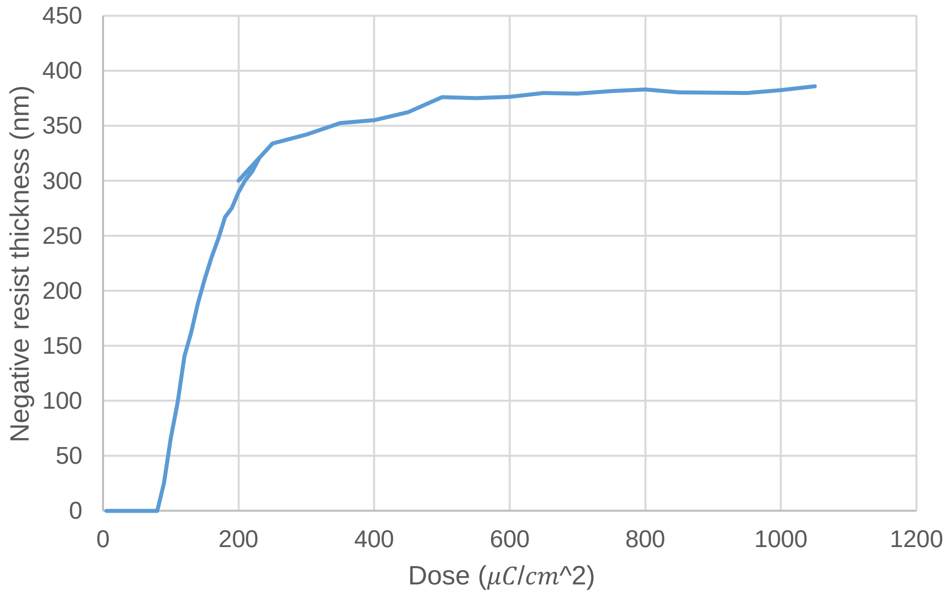
  0%, 25%, 50%, 75%, 100%

- Dose range: 60 – 400 $\mu C/cm$^2

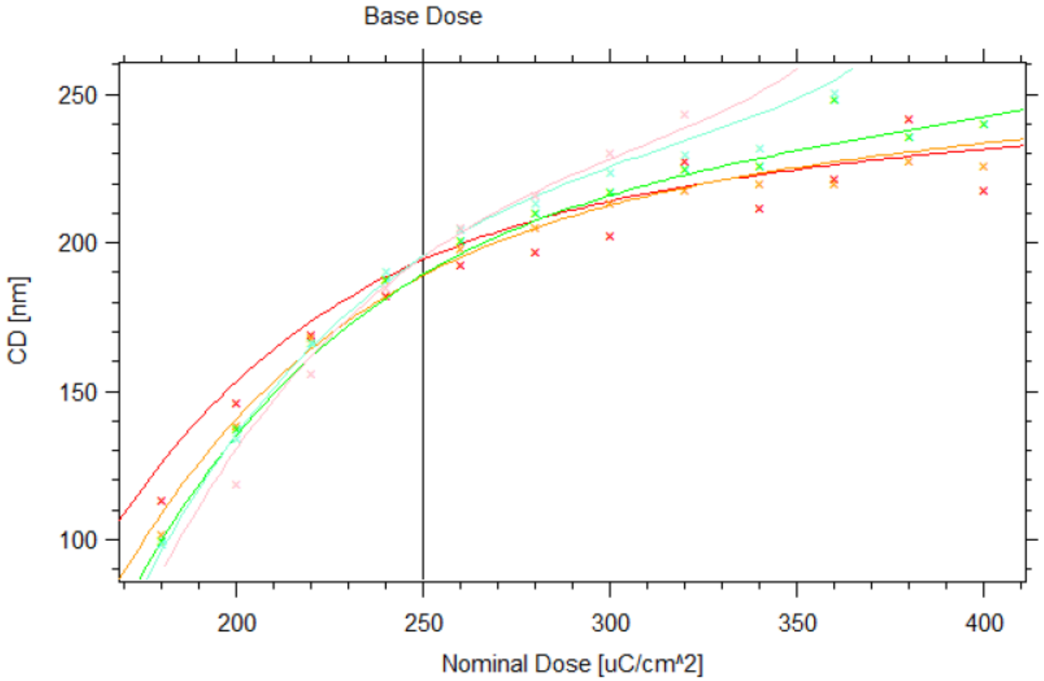


Measurements

Resist contrast curve

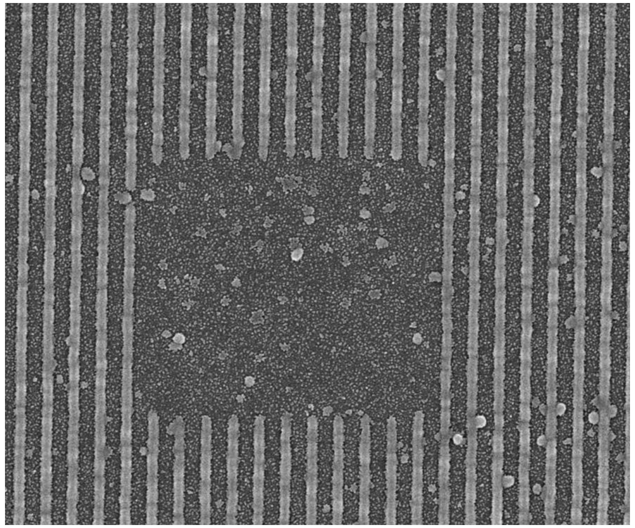


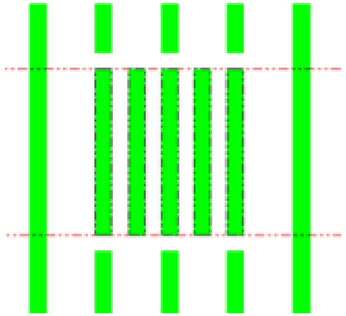
Linewidths



Results

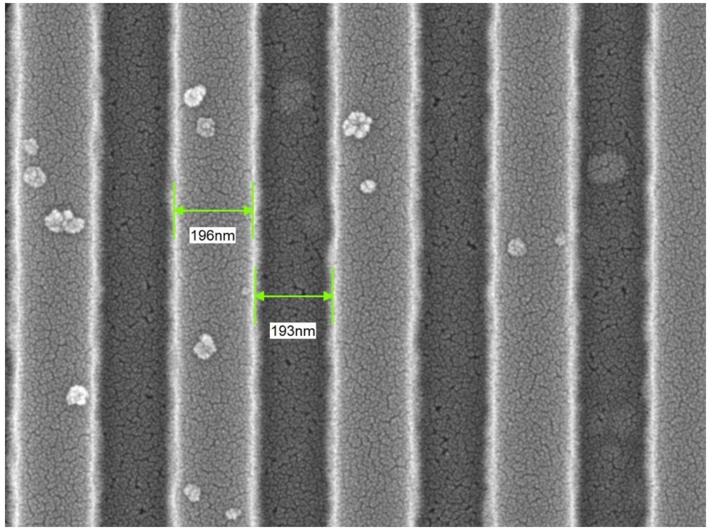
under dose

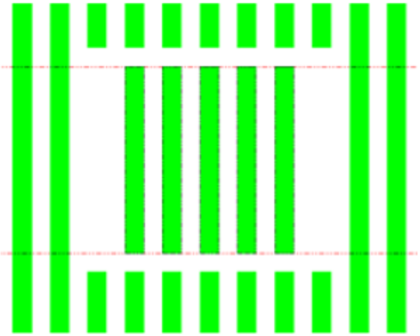




25% FF

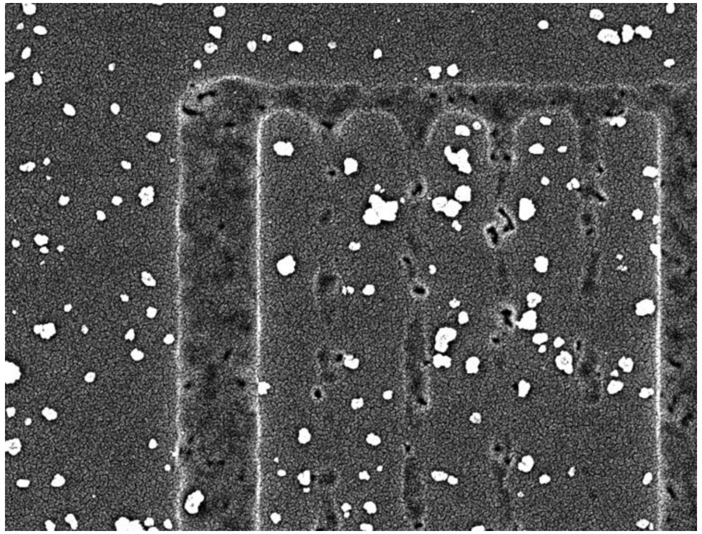
on dose

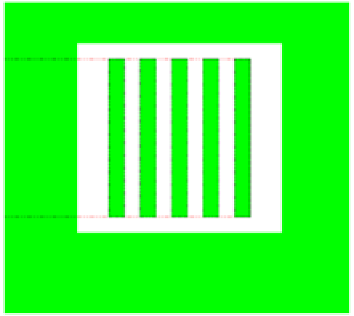




75% FF

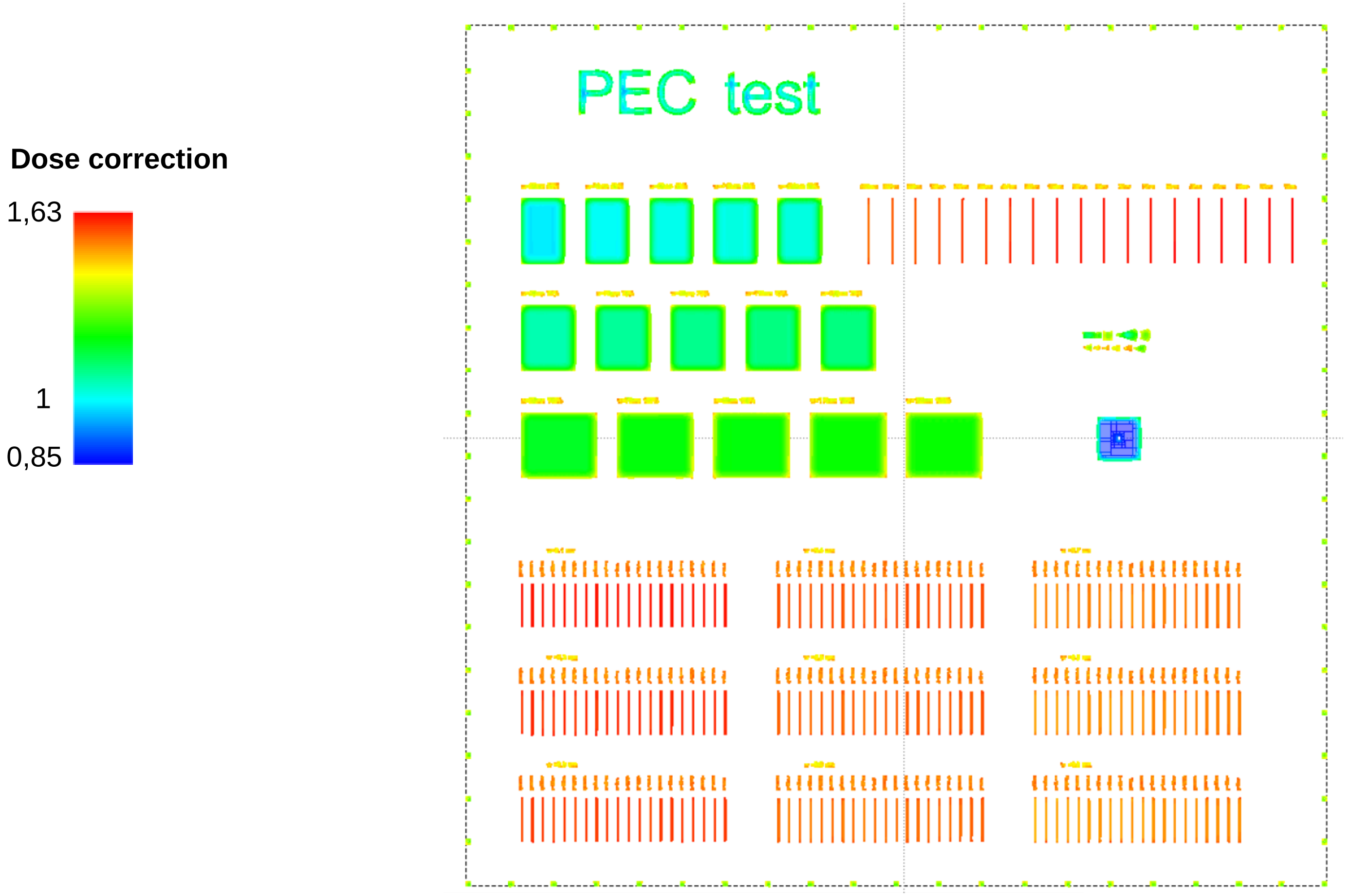
over dose



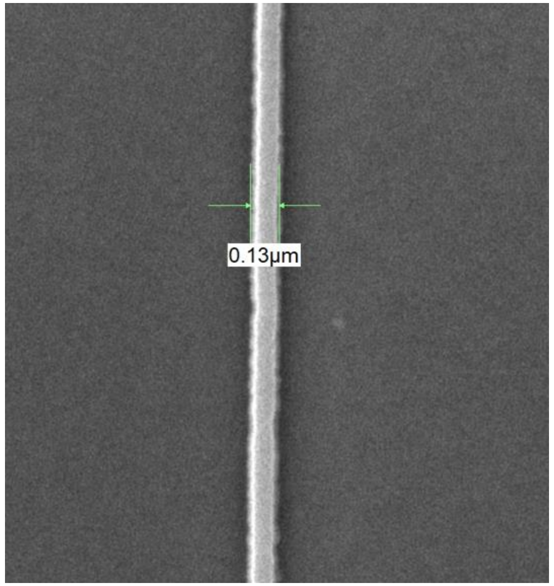


100% FF

Dose correction

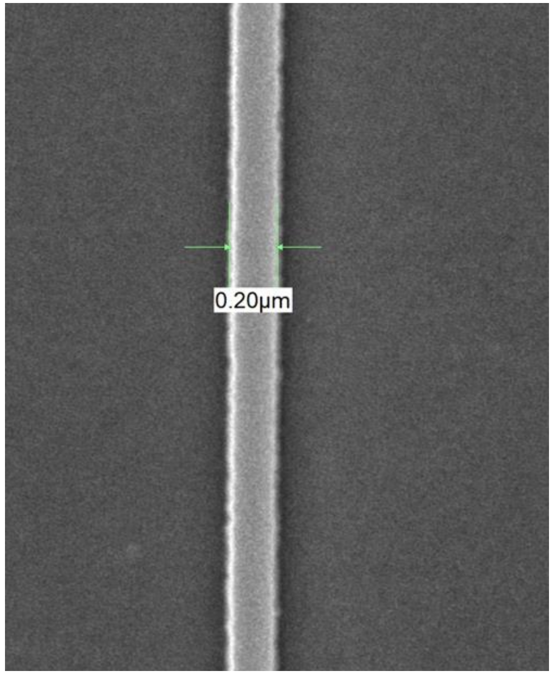


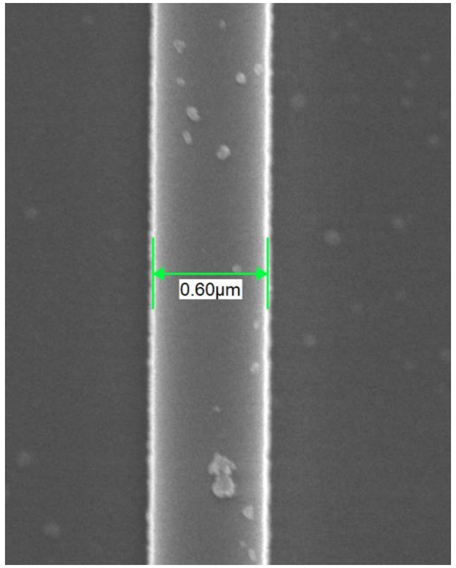
PEC validation



130 nm line

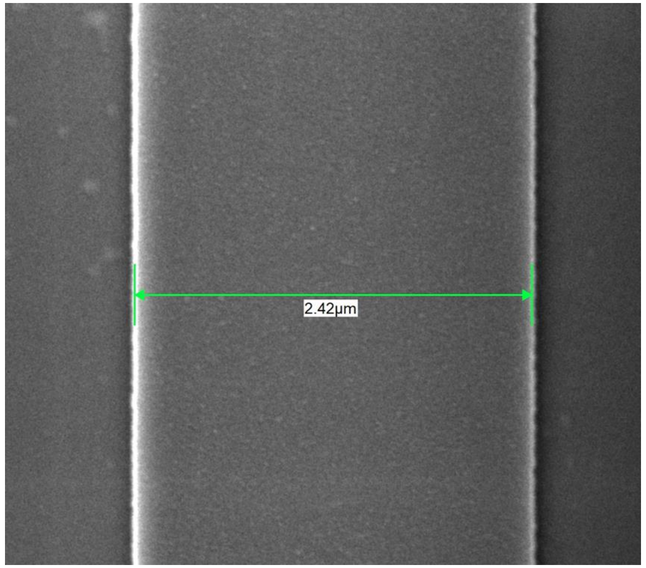
200 nm line





600 nm line

2400 nm line



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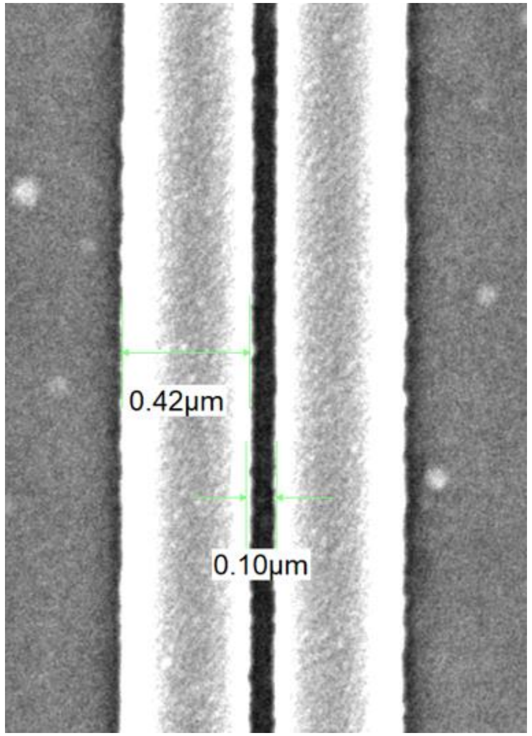
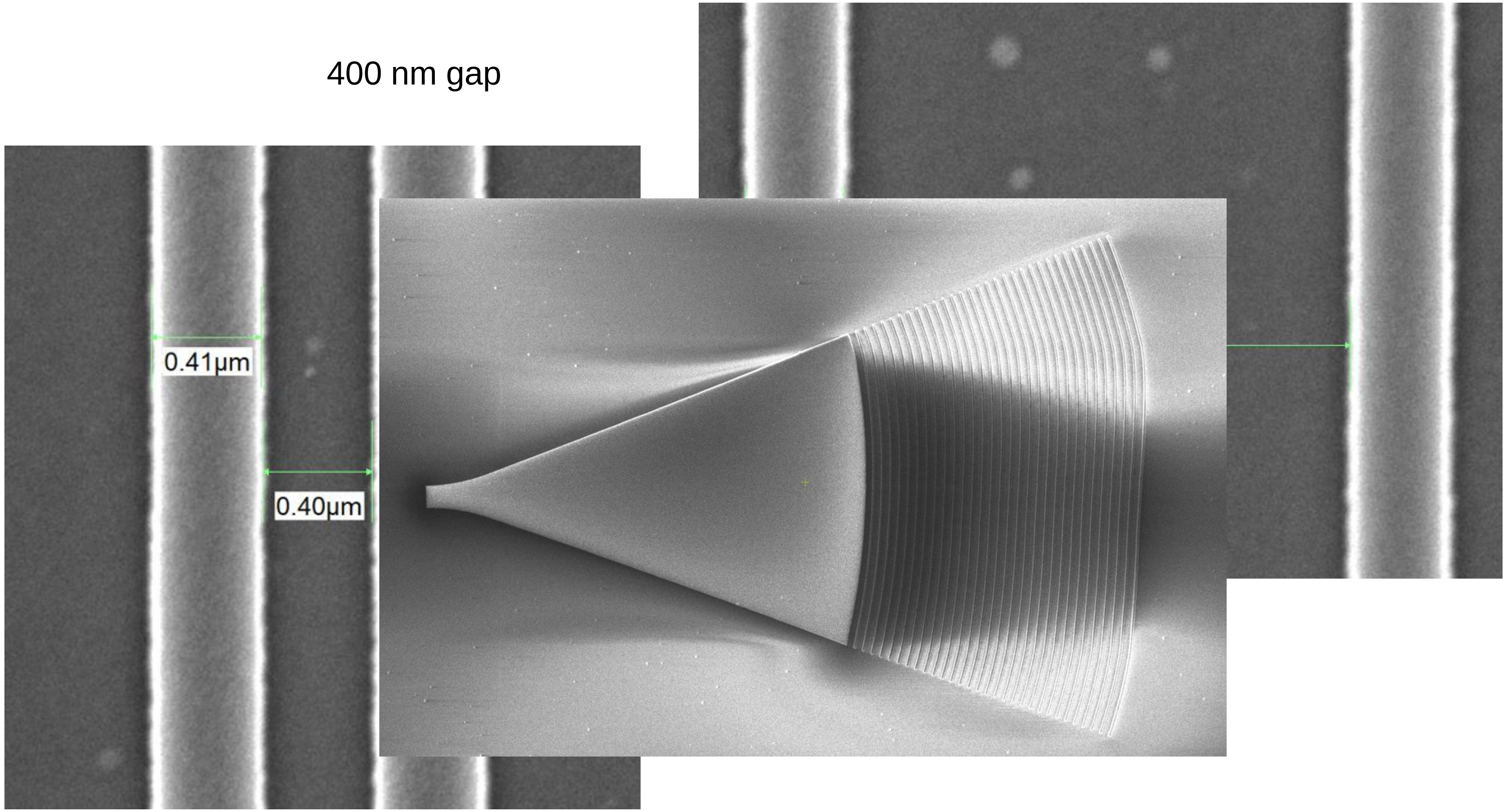


100 nm gap

400 nm gap



4. CONCLUSION & OUTLOOK

OUTLOOK

- Substantial feature fidelity improvement of the patterned features
- CD of 100nm single line

FUTURE WORK:

- High contrast resist/Hard mask
- Smaller CD (~ 10nm)
- Shape PEC
- ODUS technique
- Multi-Pass feature

ACKNOWLEDGEMENTS

UNIVERSITY OF TWENTE.

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INTEGRATED OPTICAL SYSTEMS

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THANK YOU!

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