



# MPL new research projects

BEAMeeting Munich 2025

Katrin Ludwig



# MPL

## Max Planck Institute for the Science of Light – Erlangen (Germany)



**CELL PHYSICS**  
JOCHEN GUCK



**THEORY**  
FLORIAN MARQUARDT



**NANO-OPTICS**  
VAHID SANDOGHDAR



**EMERITUS AND ASSOCIATED GROUPS**  
LEUCHS | RUSSELL | HARTMANN | HOMMELHOFF | SCHMAUSS | FRANZE |  
LADOUX | ZABURDAEV



**INDEPENDENT RESEARCH GROUPS**  
CHEKHOVA | DEL'HAYE | FATTAHI | GENES | JOLY | KAYSER | KRENN | KUNST |  
C.MARQUARDT | MÖCKL | STILLER | TANI | WANJURA | WEHNER | ZIESKE



**MAX-PLANCK-ZENTRUM FÜR PHYSIK UND MEDIZIN**

# Technology Development and Service Units (TDSU)

- MPL Cleanroom

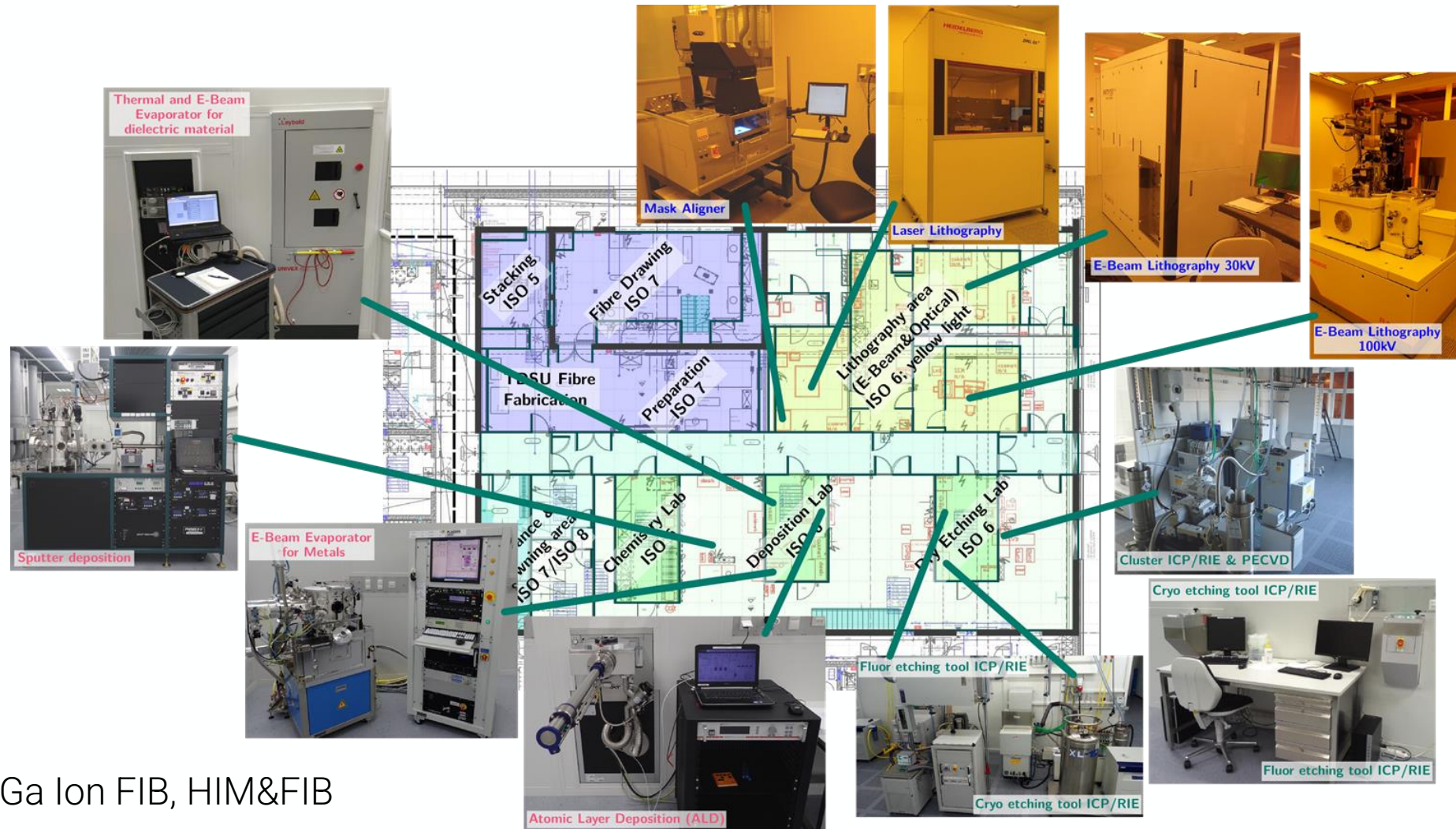


- Shared facility of TDSU Micro- and Nanostructuring and TDSU Fiber Fabrication & Glass Studio
- 350 m<sup>2</sup> white area (ISO 5/6/7)
  - 111 m<sup>2</sup> yellow light
- 280 m<sup>2</sup> grey area



# TDSU Micro- and Nanostructuring

- Multi user facilities



+ SEM, Ga Ion FIB, HIM&FIB

# GenISys Software applications at MPL

## Laser lithography

- BEAMER
- **Heidelberg Instruments DWL 66+**: Data preparation and layout generation, flexible data import, LIC export



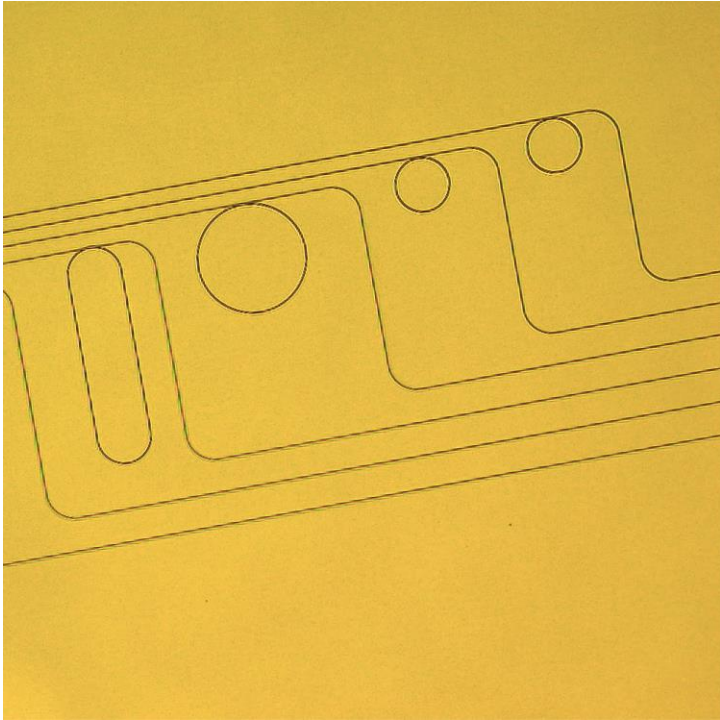
## Electron beam (E-beam) lithography

- BEAMER + Tracer
- **Raith 150two**: Large area PEC & pre-fracturing, multiple data import, structure debugging
- **Raith EBPG 5200**: Data preparation, fracturing, GPF export, flexible data import, PEC



# Microphotonics

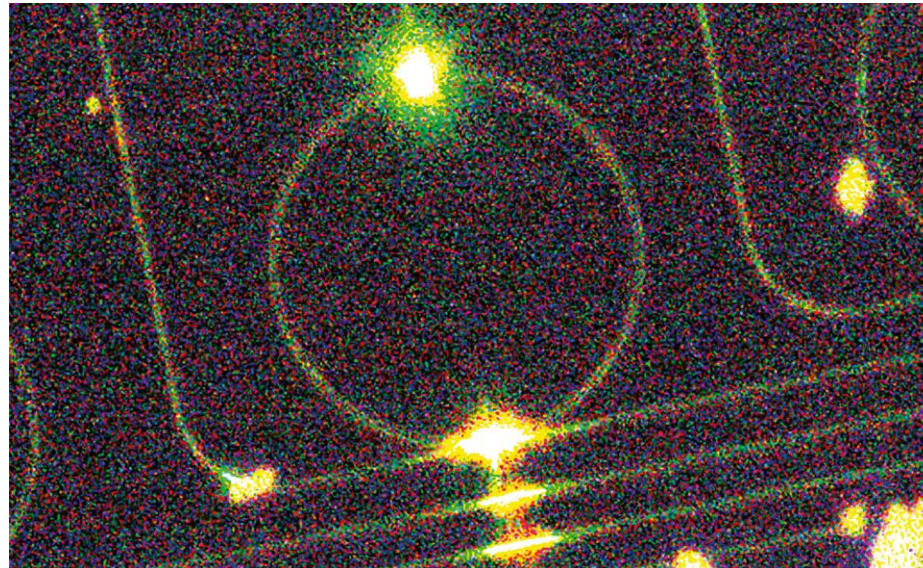
- Research group Pascal Del'Haye



Challenges for fabrication:

- High quality factor → data preparation
- Precise distance resonator-waveguide → PEC

- Integrated microphotonic devices and nonlinear optics in microresonators
- Silicon nitride ( $\text{Si}_3\text{N}_4$ ) based photonic components



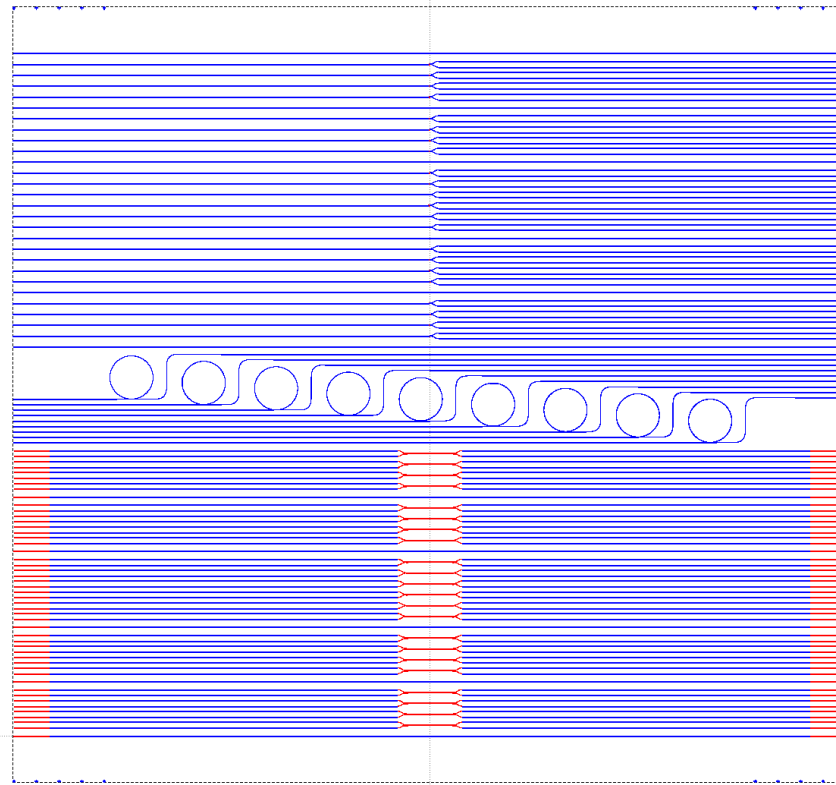
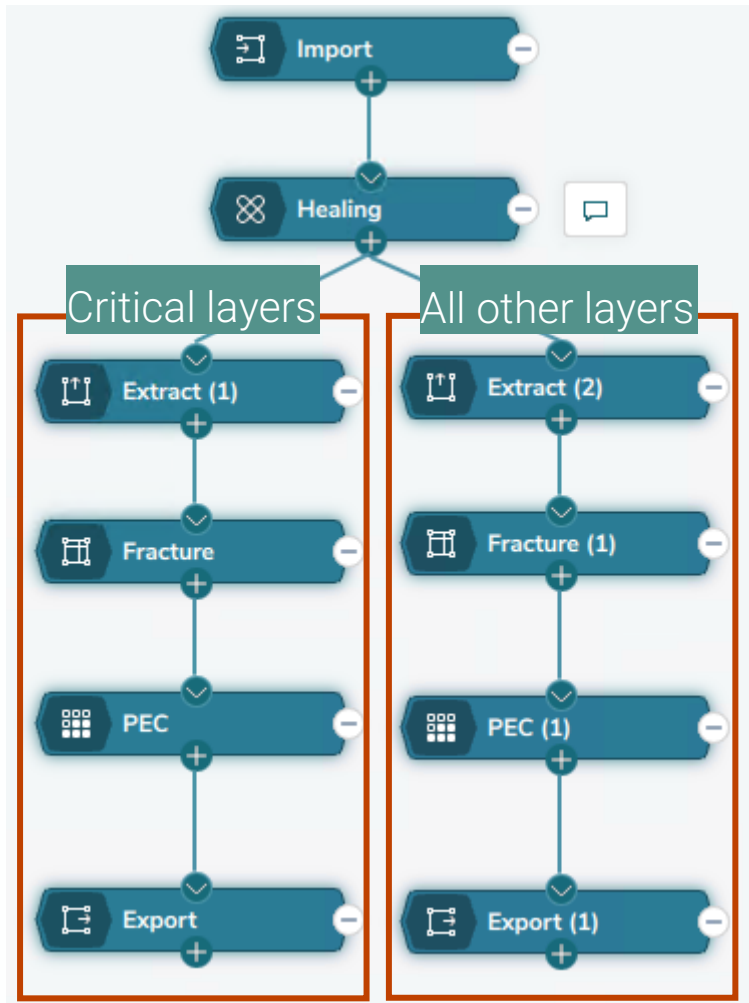
$\text{Si}_3\text{N}_4$  (250-800 nm)

$\text{SiO}_2$  (3  $\mu\text{m}$ )

Si

# E-Beam Lithography – EBPG 5200

- Waveguides in BEAMER



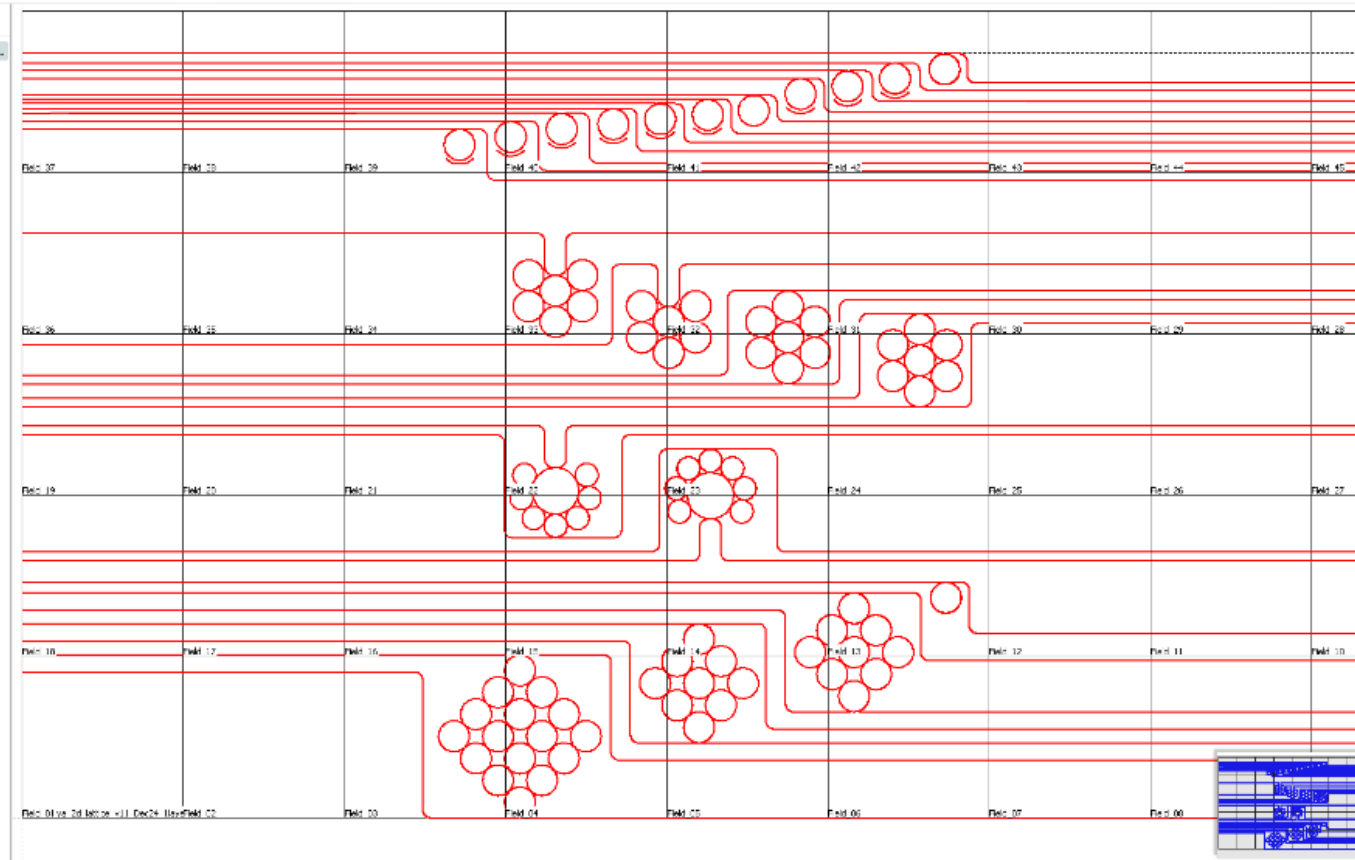
Layer 1  
Critical data

Layer 2  
Non-critical data

- Critical data and non-critical data separated in different layers
- For critical data define critical sections into own writing field
- Use lower dose and current for critical data

# E-Beam Lithography – EBPG 5200

- Waveguides in BEAMER



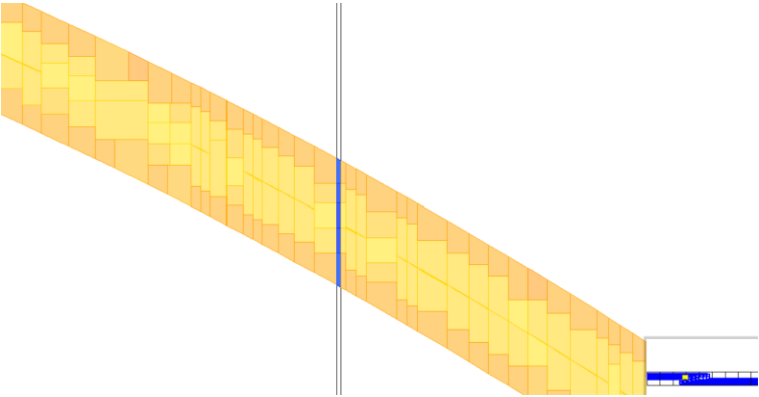
- Waveguide patterns large designs with many writing fields
- Avoid stitching error → field overlap

# E-Beam Lithography – EBPG 5200

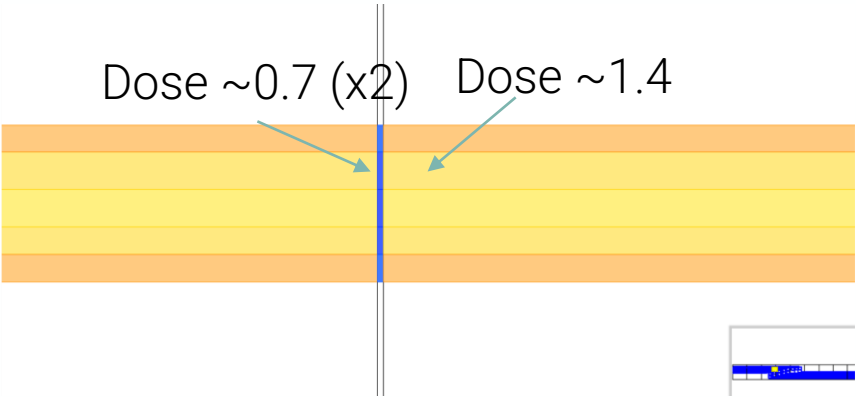
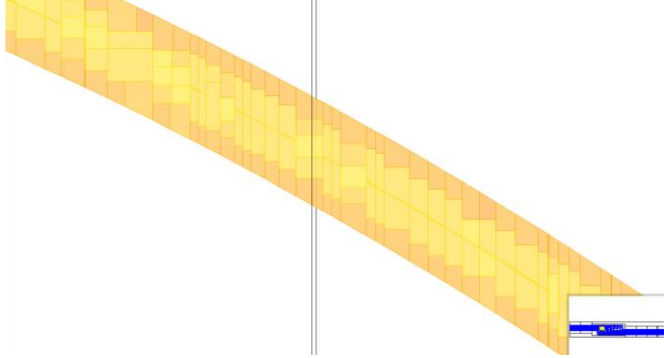
- Mitigating field stitching by overlapping fields

Split Dose between fields, Overlap 50 nm, fixed fields

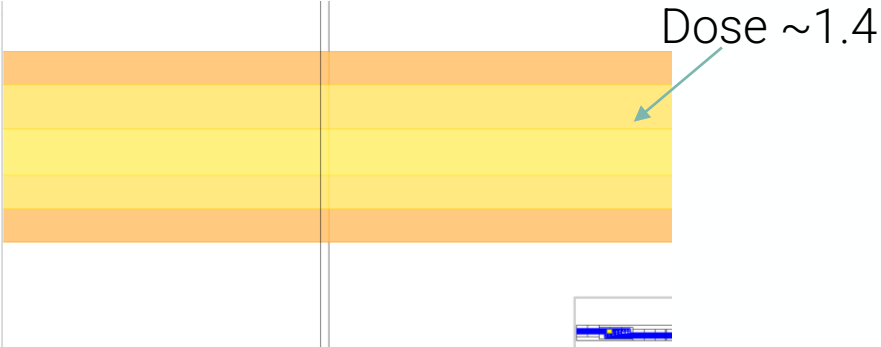
Split Dose between fields, Overlap 50 nm, floating fields  
→ No dose splitting



Curved waveguide



Straight waveguide

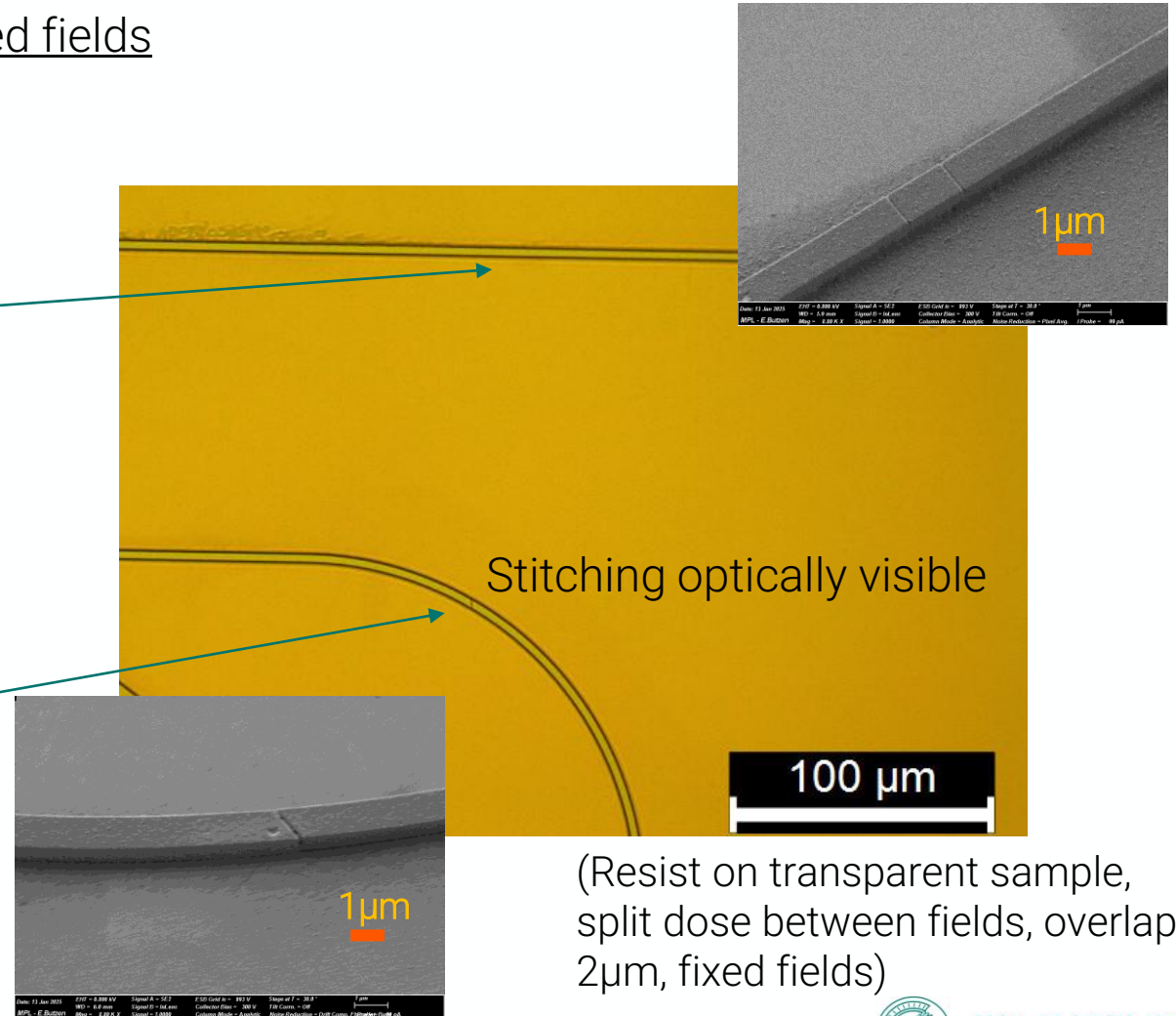
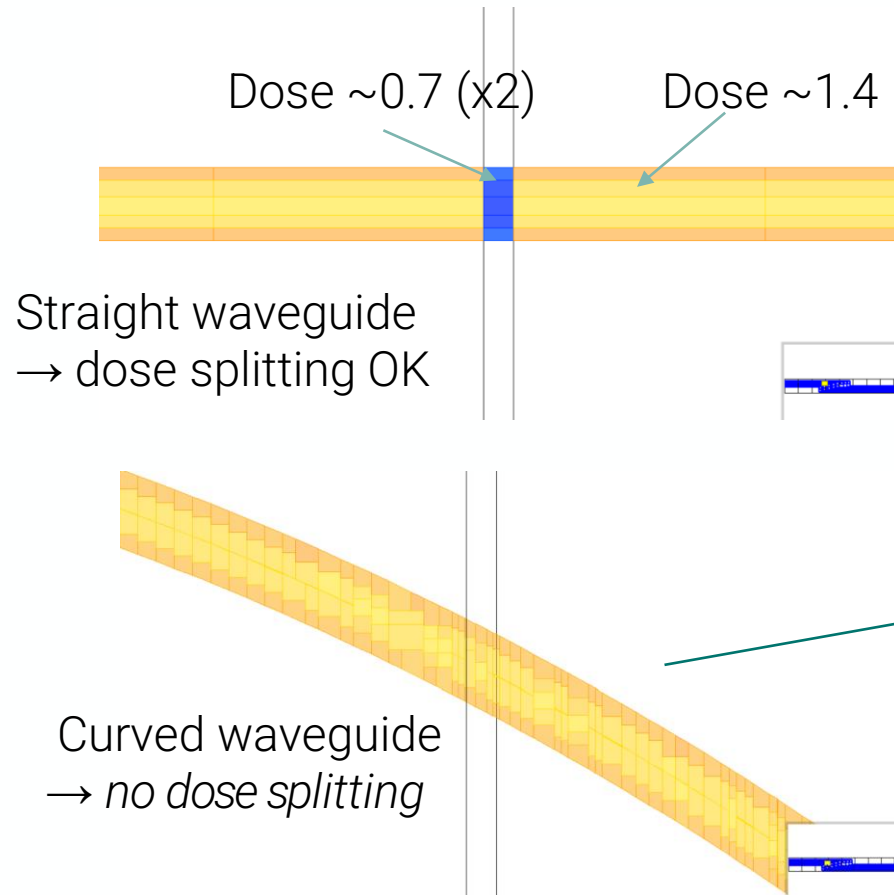


Adjusted dose range settings to [0.64, 1.549]

# E-Beam Lithography – EBPG 5200

- Mitigating field stitching by overlapping fields

Split Dose between fields, Overlap  $\geq 500$  nm, fixed fields

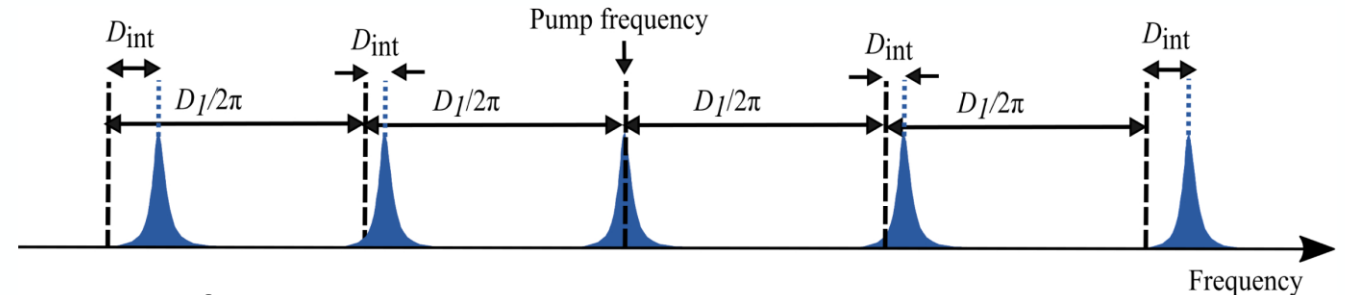
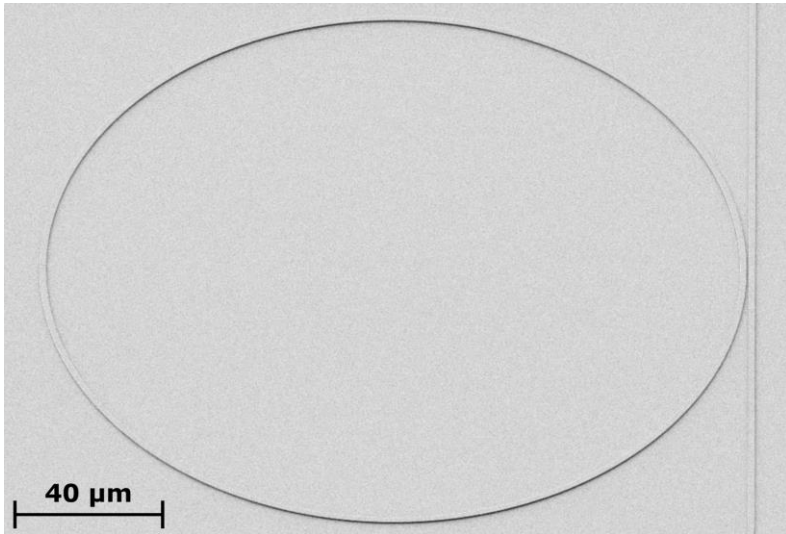


(Resist on transparent sample, split dose between fields, overlap  $2\mu\text{m}$ , fixed fields)

# E-Beam Lithography – EBPG 5200

- On-chip microresonator dispersion engineering

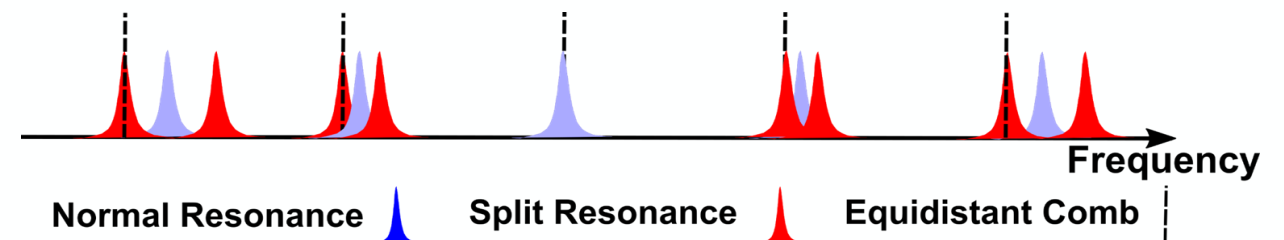
In cooperation with Microphotonics research group – project of Masoud Kheyri



Optical frequency comb generation in microring resonators (via Kerr effect,  $\text{Si}_3\text{N}_4$  on  $\text{SiO}_2$  platform, shift  $D_{\text{int}}$  due to resonator dispersion)

Changing resonator dispersion by changing the ring geometry

Example: frequency splitting by local geometry modulation



M.Kheyri et al., [10.1364/PRJ.530537](https://doi.org/10.1364/PRJ.530537), *Photon. Res.* **13**, 367-372 (2025)

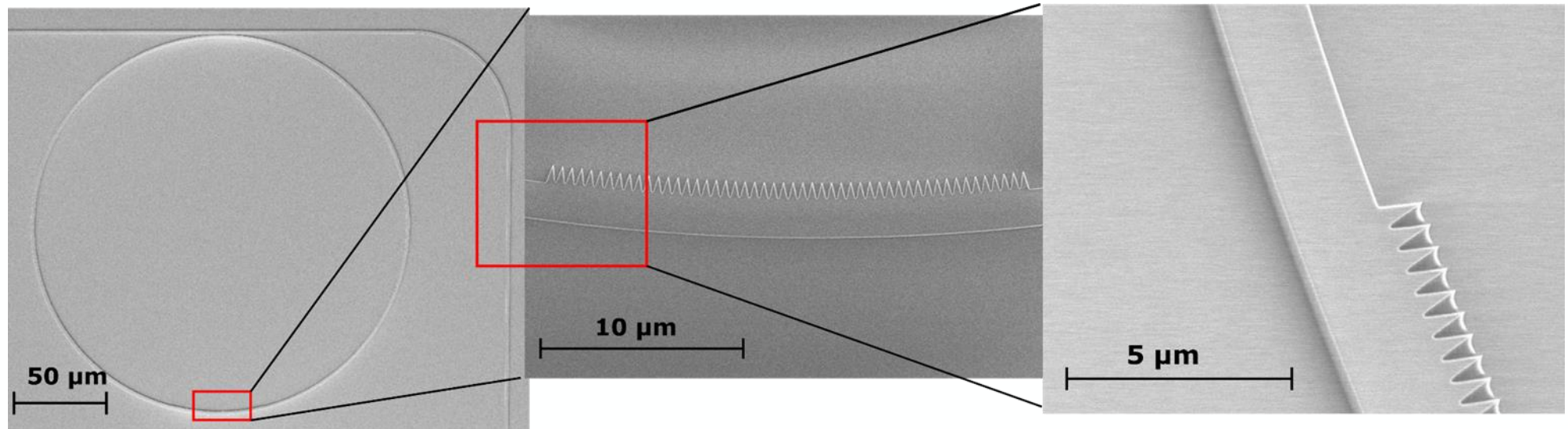
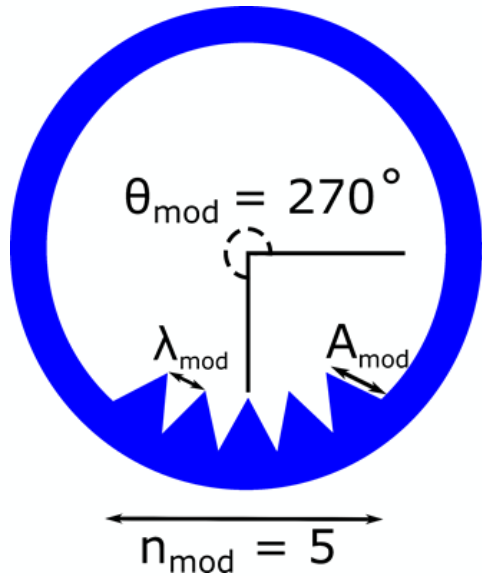
S.Zhang et al., [10.1002/lpor.202300642](https://doi.org/10.1002/lpor.202300642), *Laser Photonics Rev* 2024, **18**, 2300642

Y.Zhang et al., [10.1364/OE.503637](https://doi.org/10.1364/OE.503637), *Opt. Express* **31**, 41420-41427 (2023)

# E-Beam Lithography – EBPG 5200

- On-chip microresonator dispersion engineering

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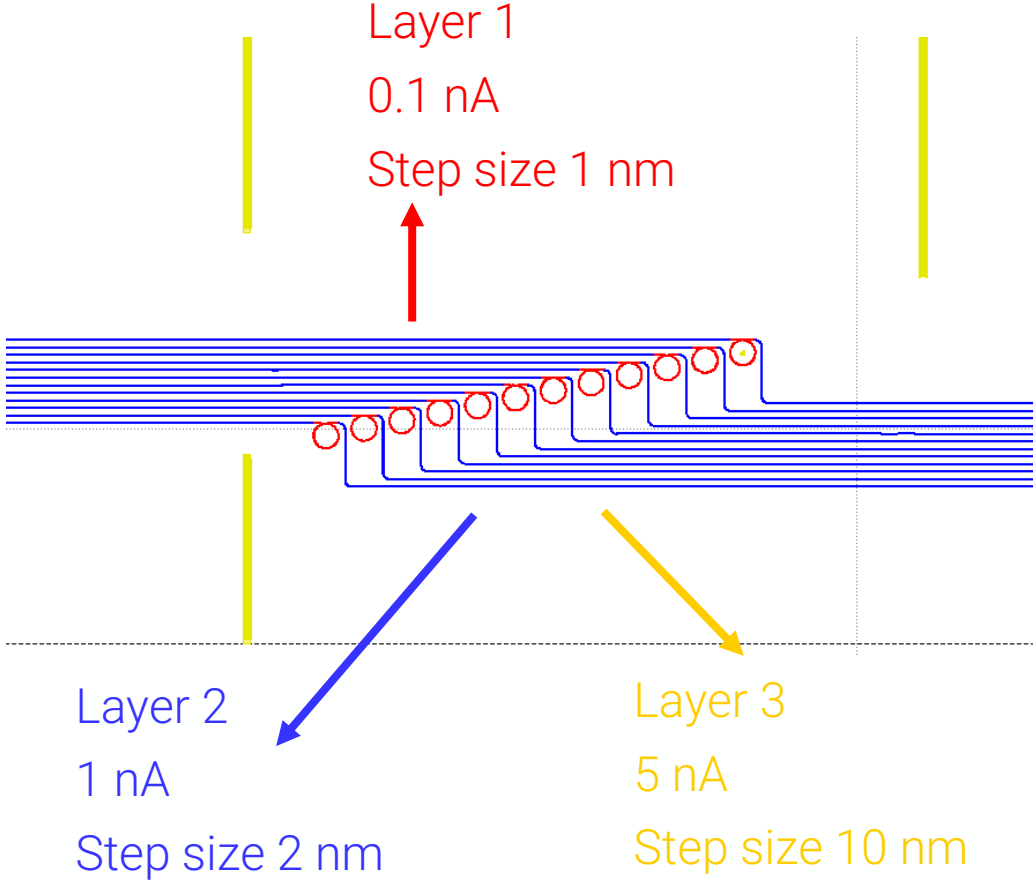
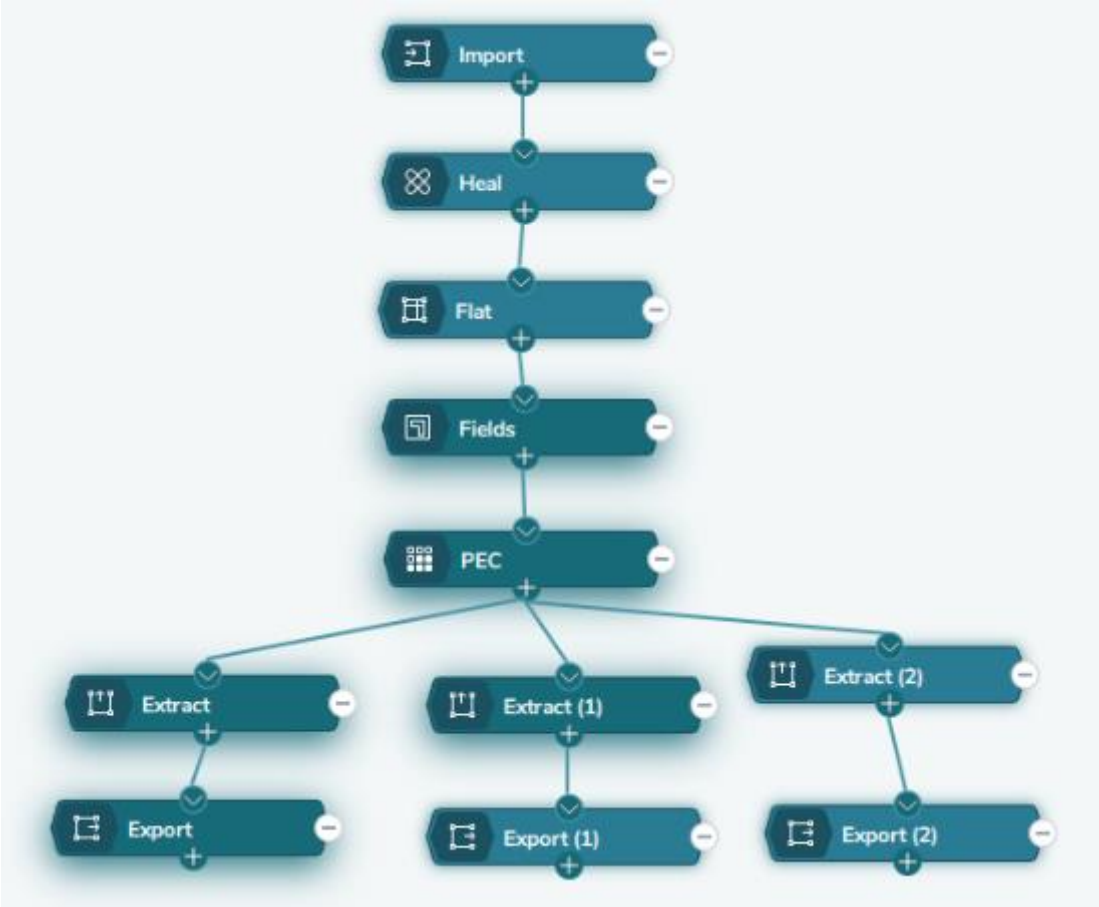


- Change modulation of microresonator by variation of the ring form  $\rightarrow$  frequency splitting

# E-Beam Lithography – EBPG 5200

- On-chip microresonator dispersion engineering

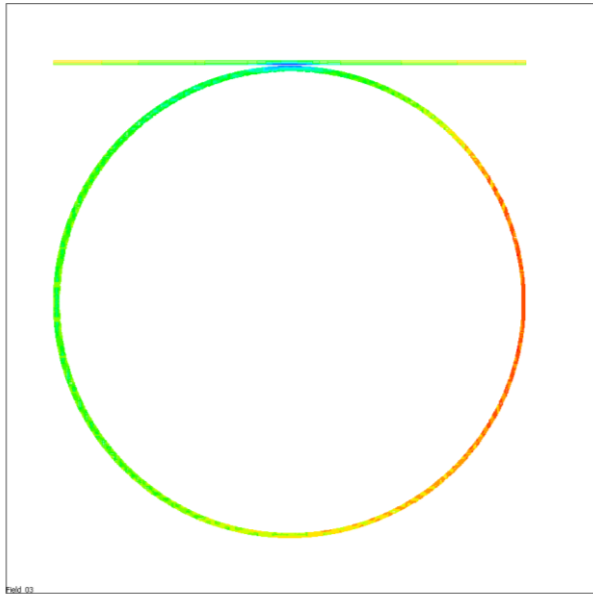
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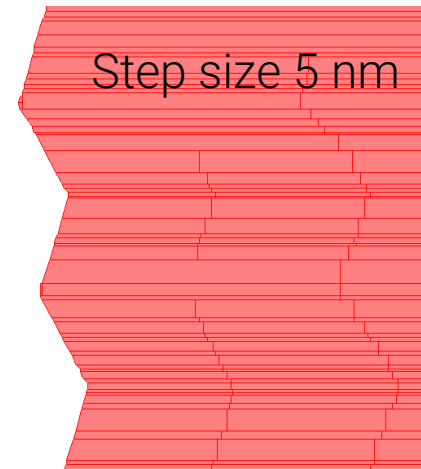
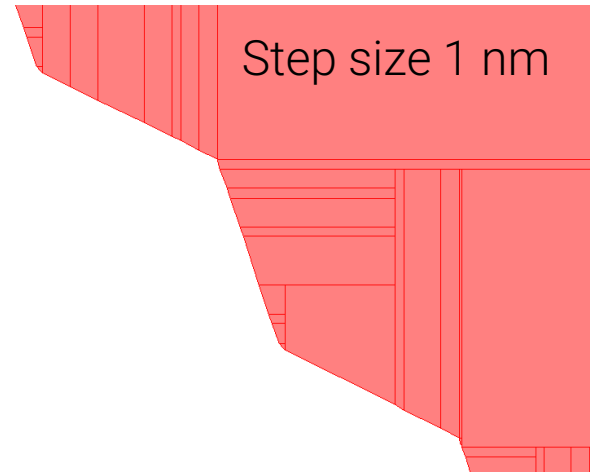
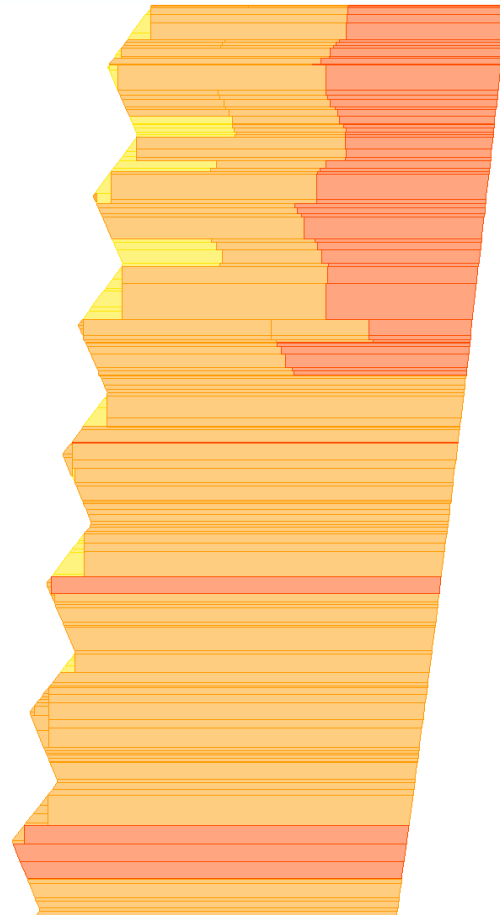
# E-Beam Lithography – EBPG 5200

- On-chip microresonator dispersion engineering

In cooperation with Microphotonics research group – project of Masoud Kheyri



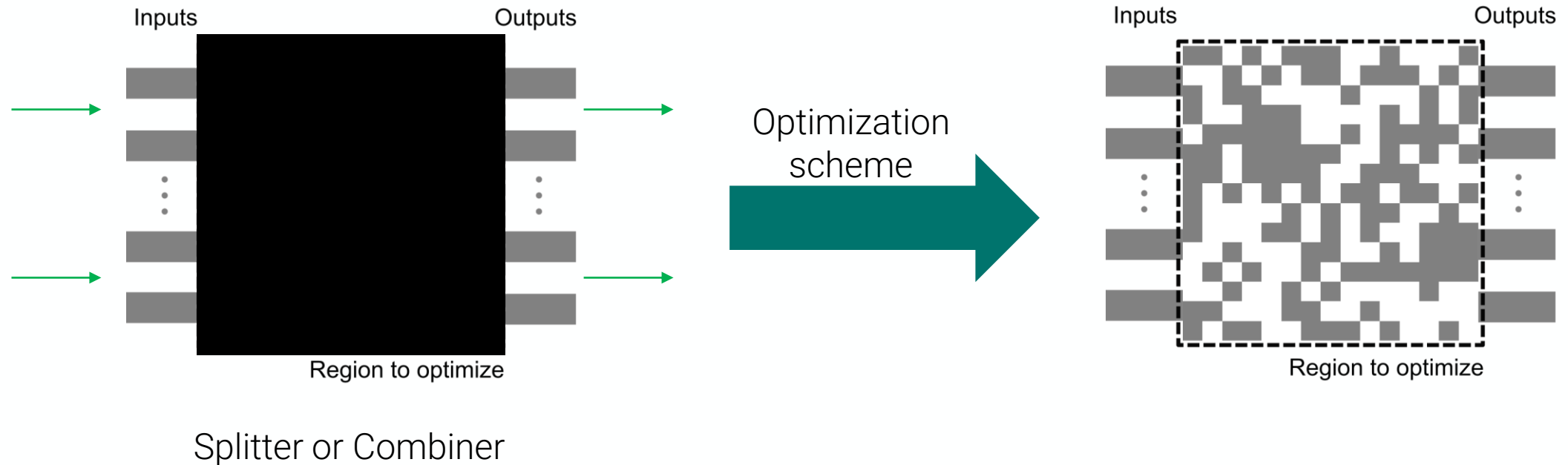
Saw-tooth-profile  
in microresonator  
ring critical  
structure



# E-Beam Lithography – EBPG 5200

- Inverse-designed photonics

In cooperation with Microphotonics research group – project of Toby Bi

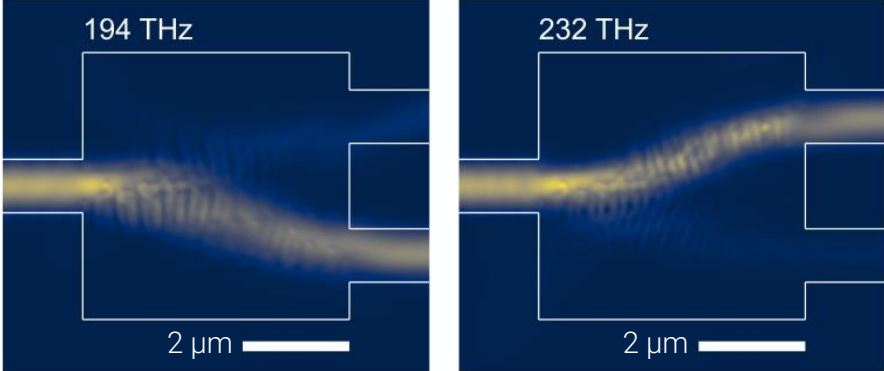
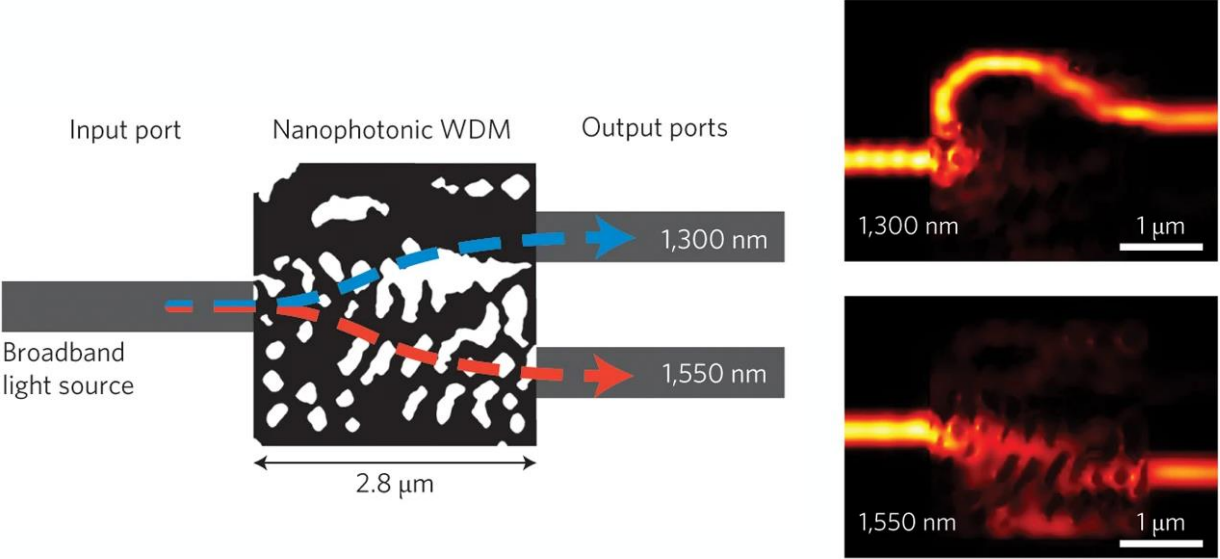


- Reduction of device footprint from  $\text{mm}^2$  to  $\mu\text{m}^2$
- Define structure by input and output → inverse-designed device

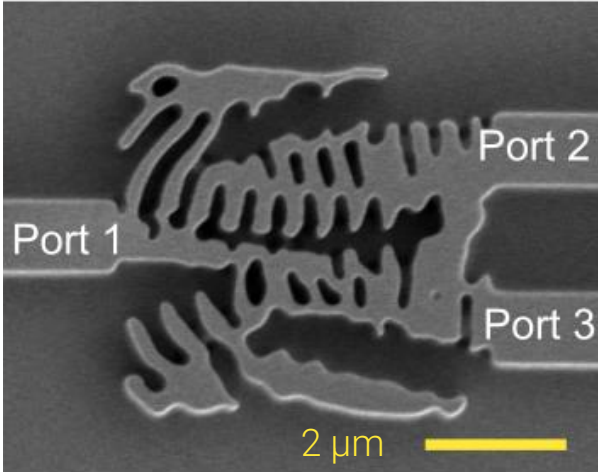
# E-Beam Lithography – EBPG 5200

- Wavelength-division multiplexer

In cooperation with Microphotonics research group – project of Toby Bi



3D FDTD simulations

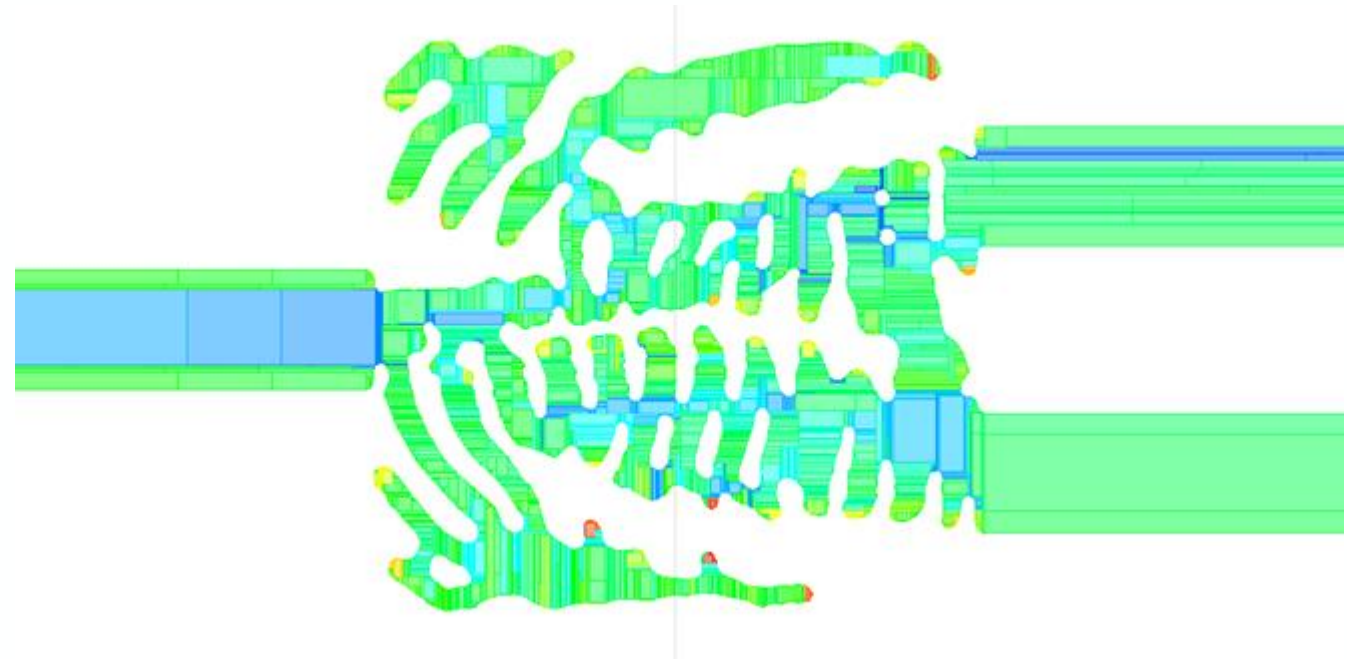
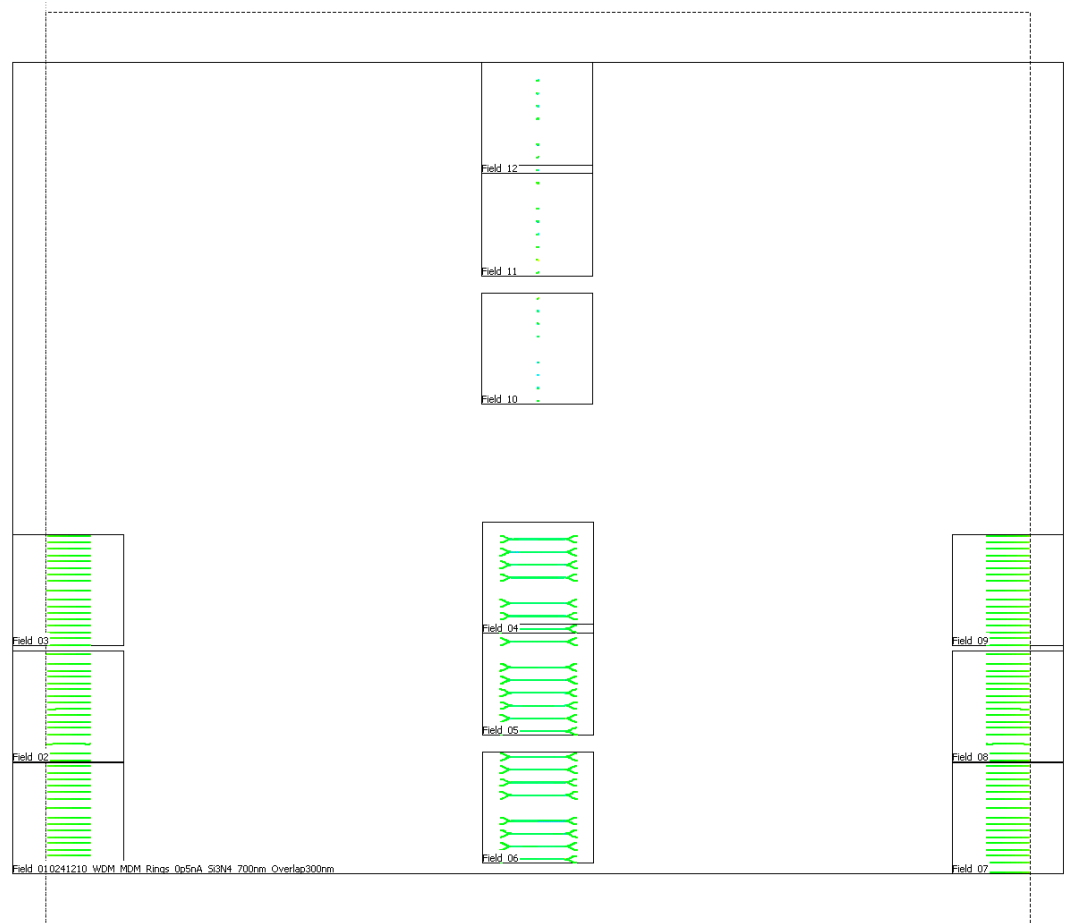


SEM

# E-Beam Lithography – EBPG 5200

- Wavelength-division multiplexer

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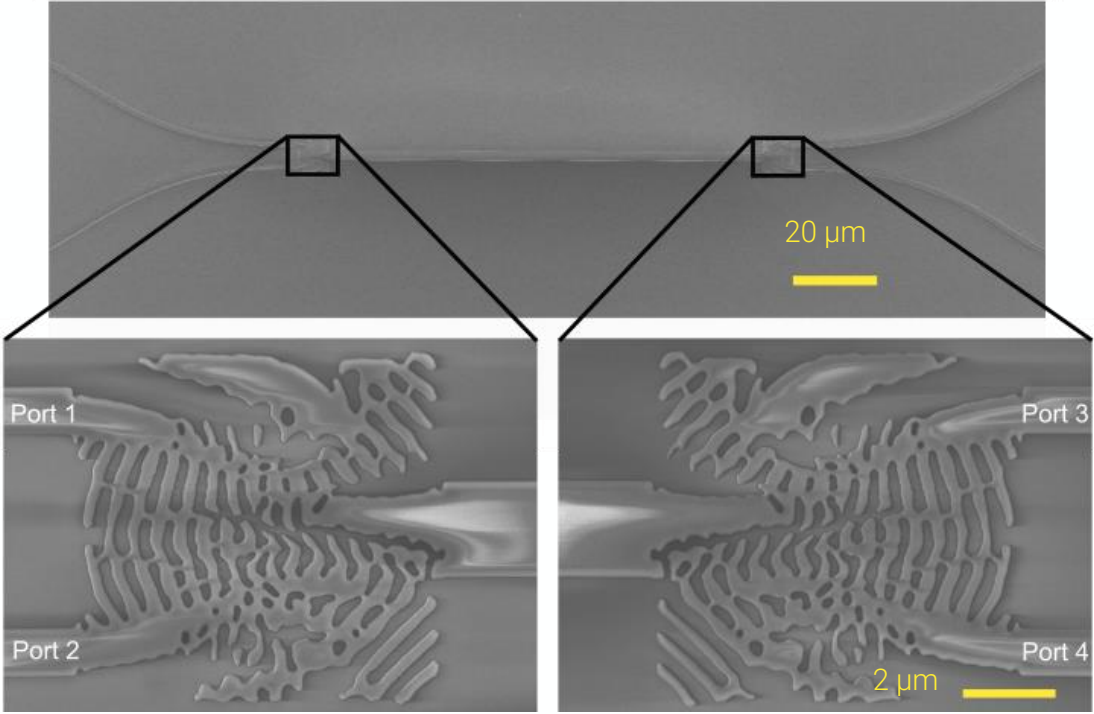
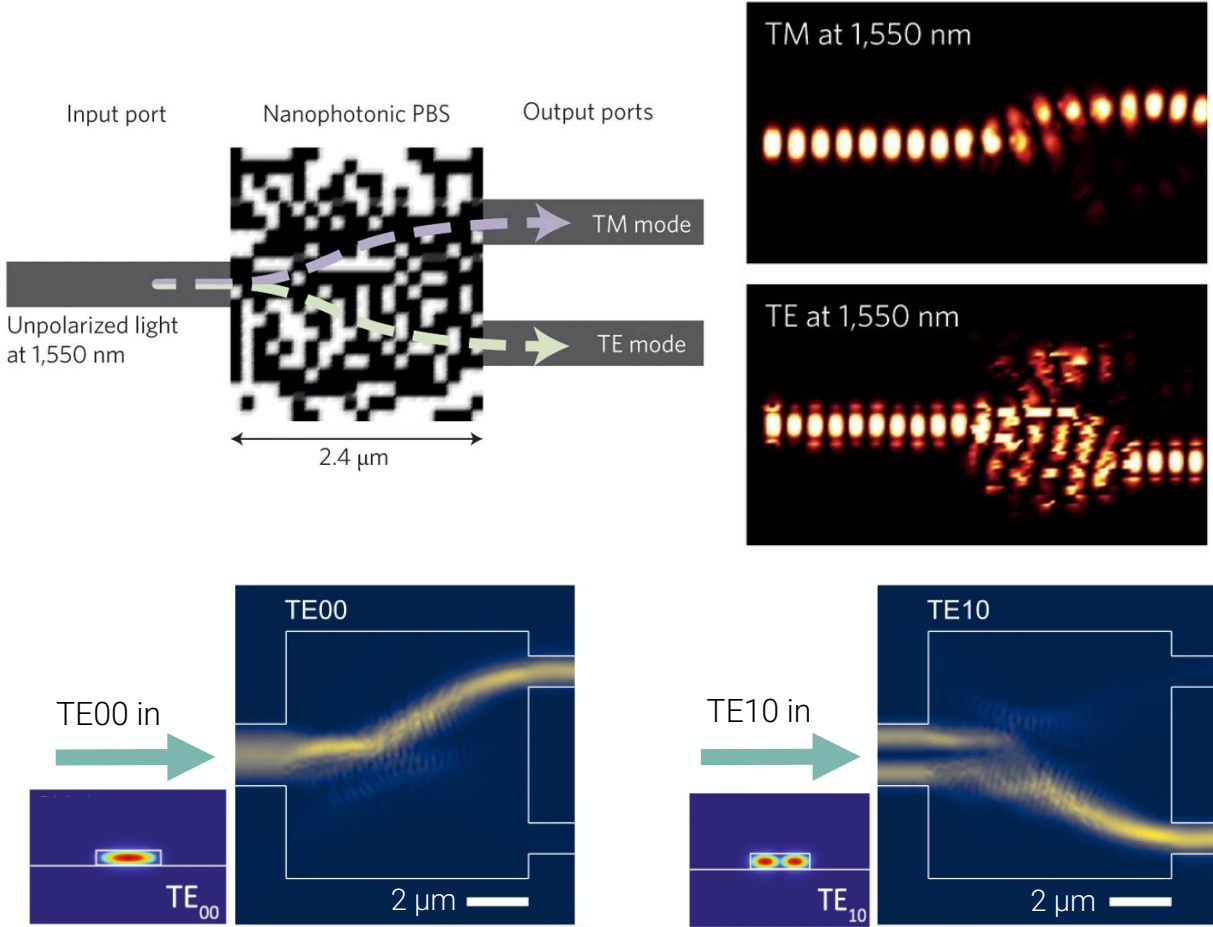


- Proximity effect correction (PEC)

# E-Beam Lithography – EBPG 5200

- Mode-division multiplexer

In cooperation with Microphotronics research group – project of Toby Bi





# Thank you for your attention!

