PAUL SCHERRER INSTITUT

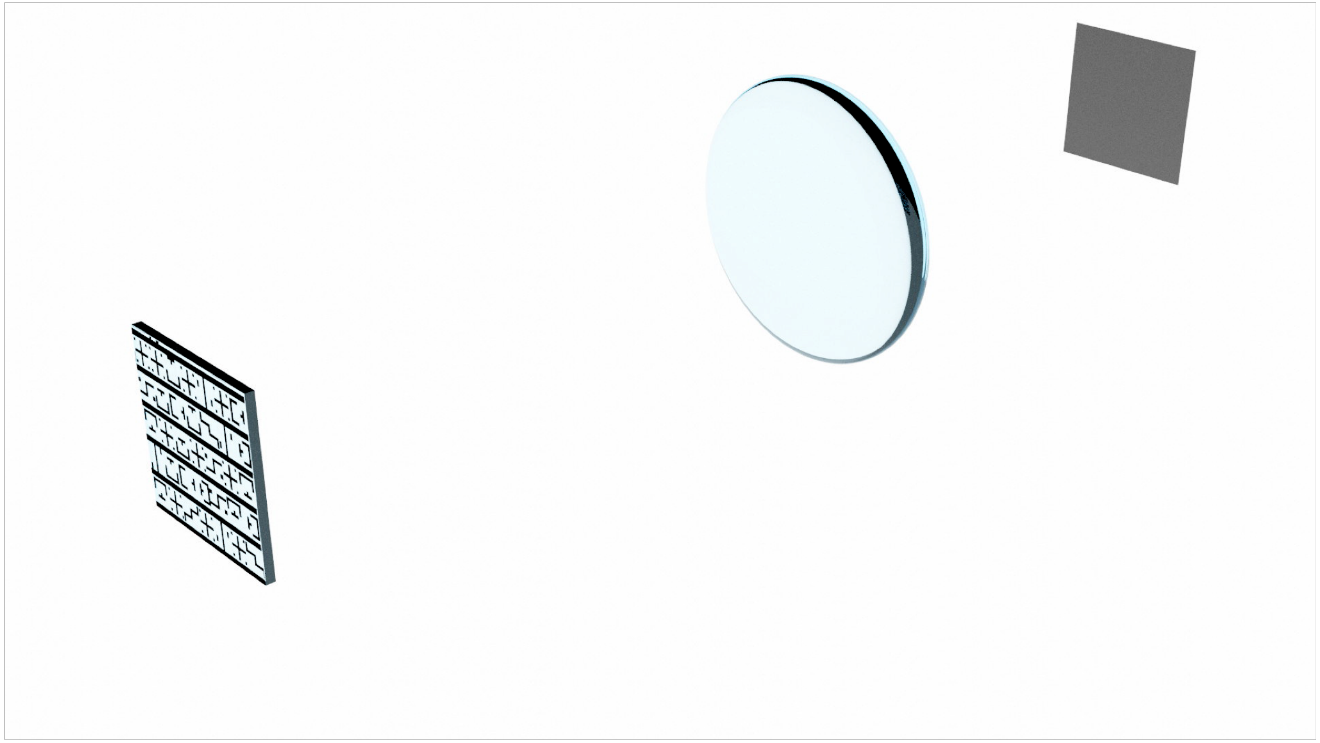

WIR SCHAFFEN WISSEN – HEUTE FÜR MORGEN

EUV metrology with a compact accelerator-based source

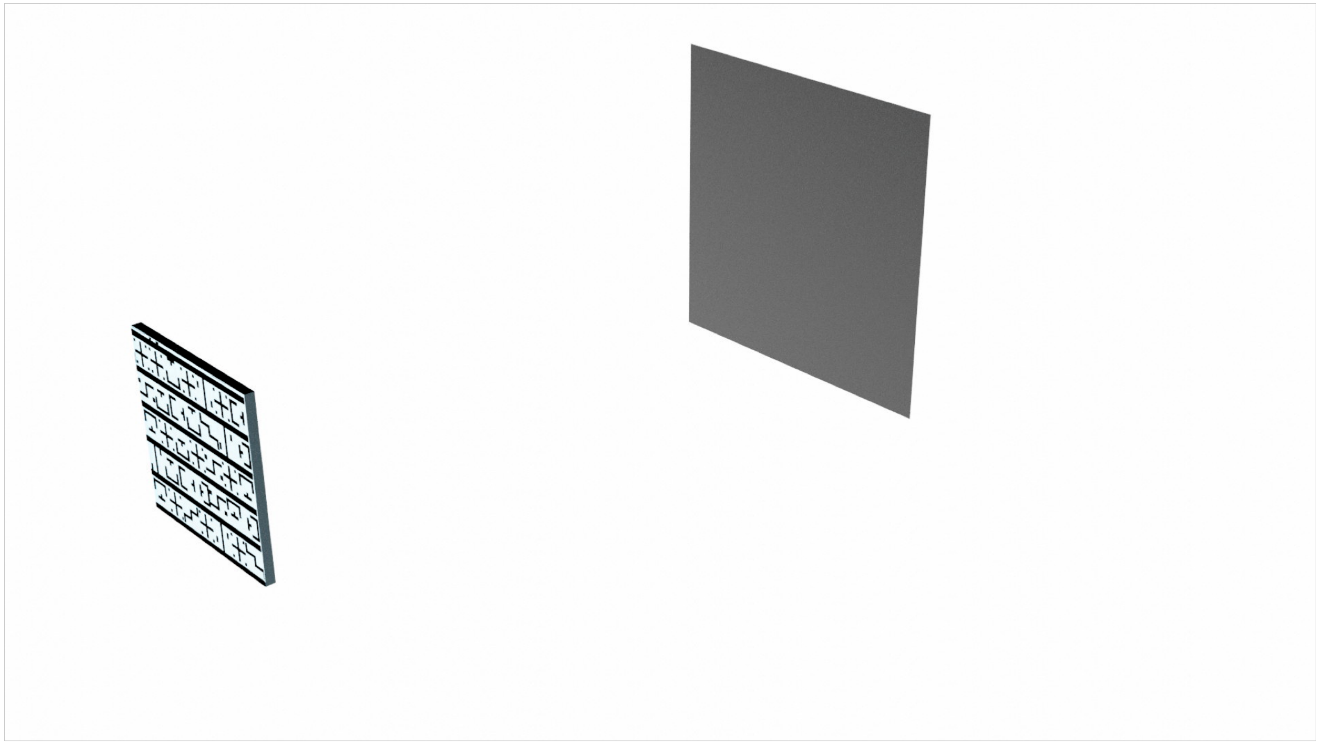
Yasin Ekinci

Paul Scherrer Institut

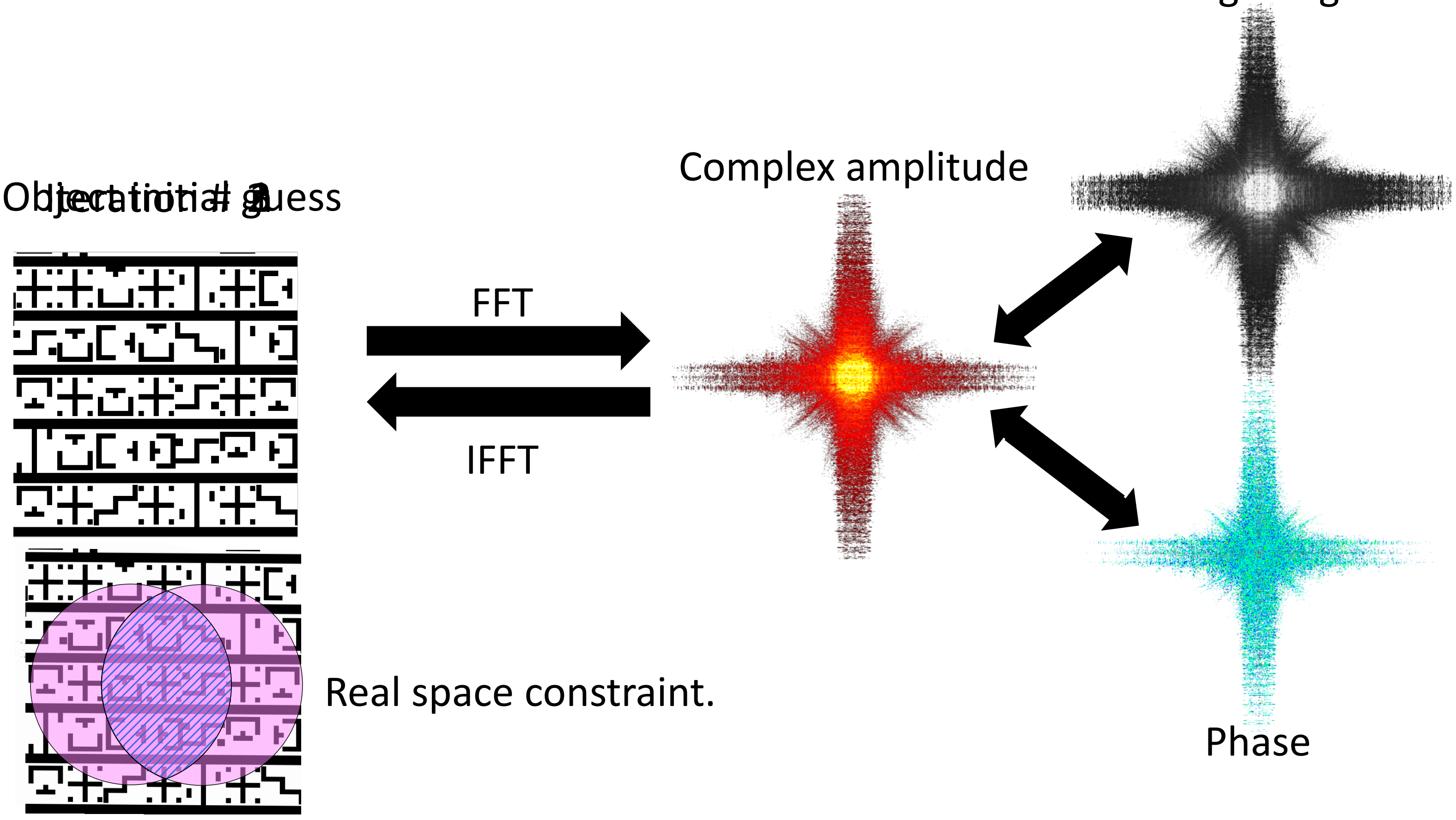
Imaging system with lens



Lensless imaging (Coherent diffraction imaging)



Iterative phase retrieval algorithms: Ptychography



Object initial guess

Iteration # 3

FFT

IFFT

Real space constraint.

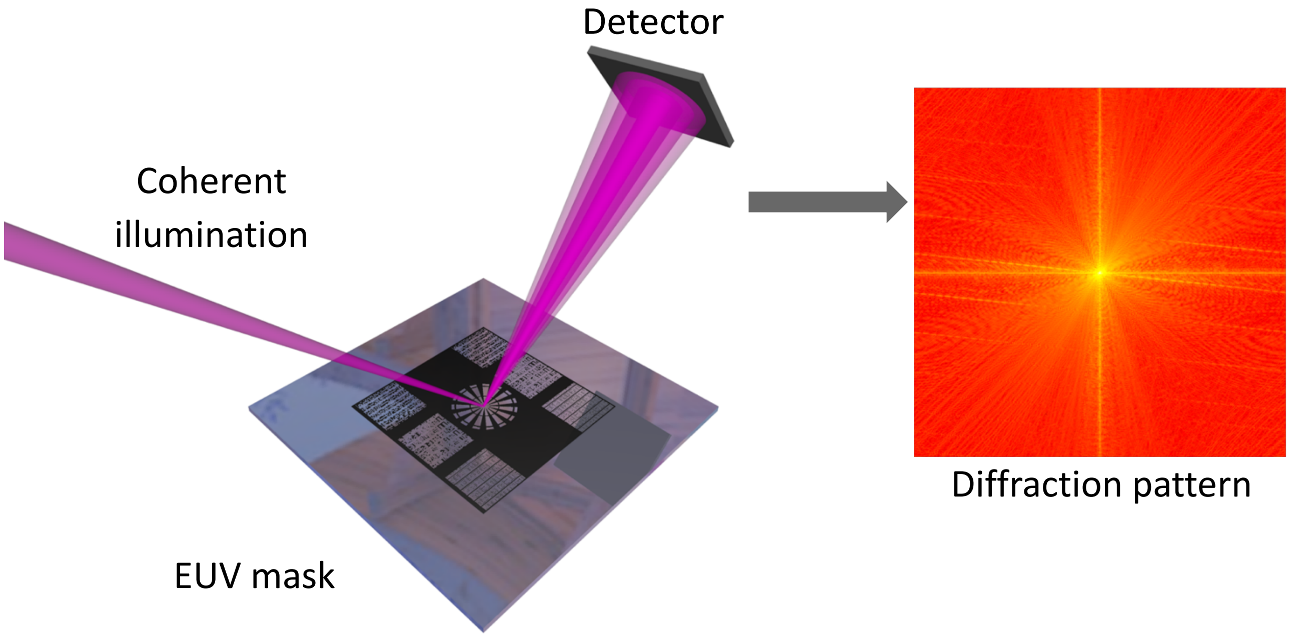
Complex amplitude

Measured Magnitude

Phase

Fourier domain constraint

How does RESCAN work?



Detector

Coherent illumination

EUV mask

Diffraction pattern

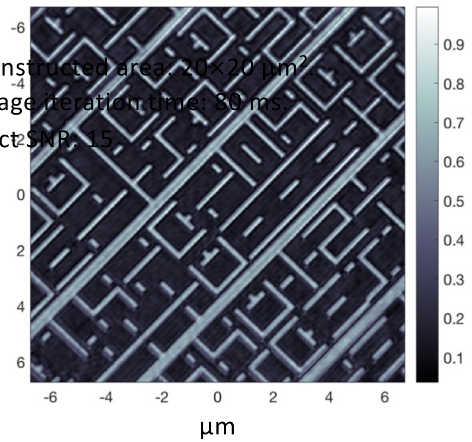
Actinic = EUV (13.5 nm), reflective, incidence angle = 6°

Resolution = 35 nm

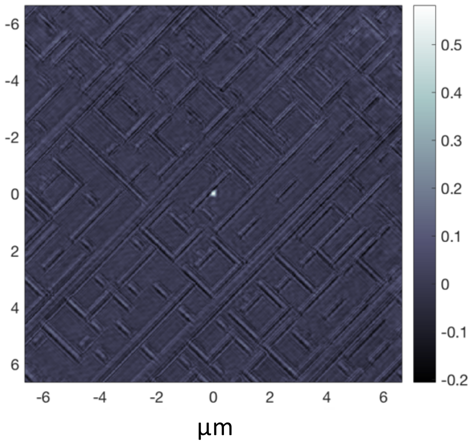
Pattern comparison for accurate defect localization

Die to die defect inspection: comparing a defect free area of the sample to a defective one.

- Reconstructed area: 20×20 µm².
- Average iteration time: 80 ms.
- Defect SNR: 15


Reference

µm


200-nm extrusion

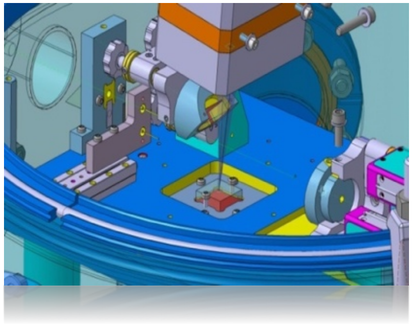
µm


Defect map

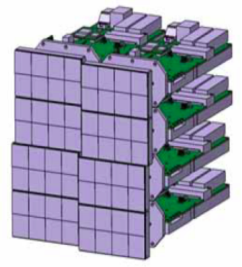
Roadmap for RESCAN

Target:

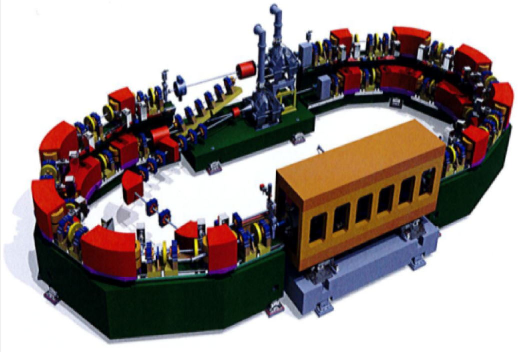
- S/N > 8.5 for all printable defects (~10 nm)
- scan time < 7 hours for 10x10 cm^2 mask



RESCAN: Lensless Microscope
Continuous scanning
20 μm steps @ 2kHz = 3.5 hours)



Jungfrau: High Performance Detector
2 kHz frame rate
High dynamic range: 10^5



Cosami: Mini synchrotron for EUV
Hight brightness
Small footprint: 5x12 m^2

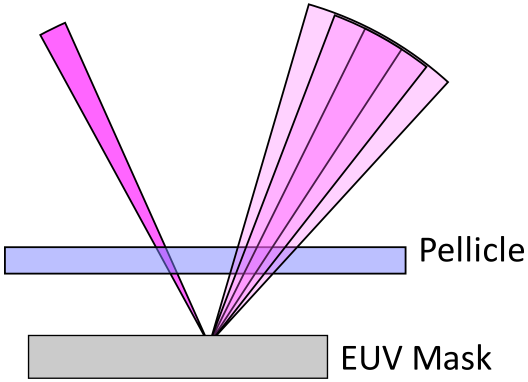
- RESCAN is a viable approach for a commercial mask inspection tool

Using the advantages of lensless methods

Lensless imaging is flexible:

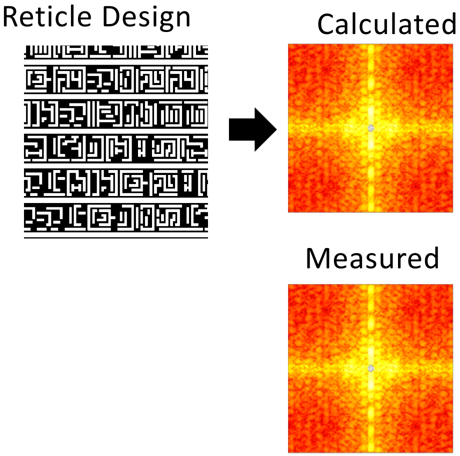
- Flexibility with the geometry and angles and wavelengths
- Flexibility: Change in algorithm instead of hardware for customized solution to a problem

Through pellicle inspection



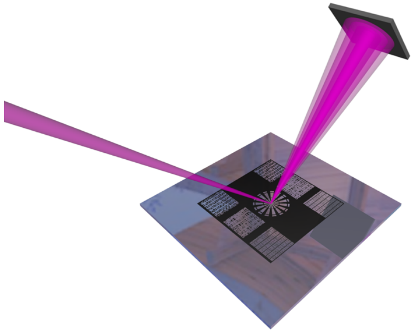
RESCAN is already future ready

A priori information



Faster experiment or reconstruction

EUV wafer metrology

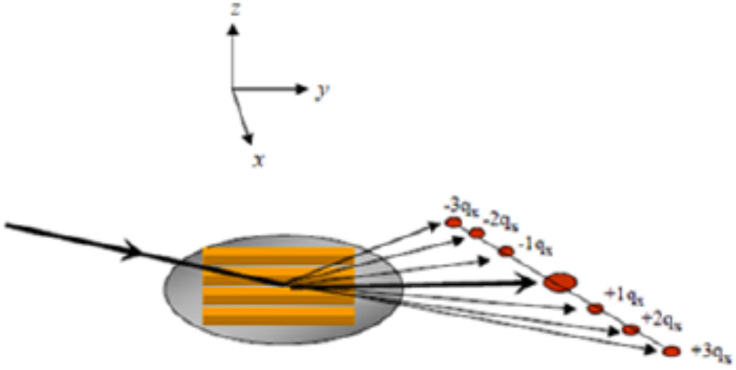


Better resolution than optical metrology

Optical metrology at short wavelengths

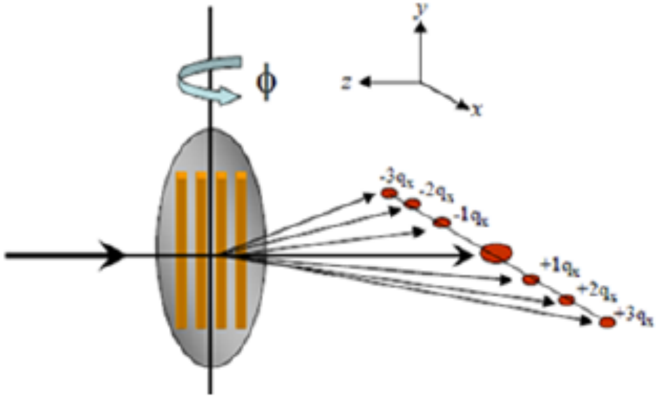
CD-SAXS

Grazing angle reflection
(~ 8 keV)



Large spot on the wafer
Lack of bright source

Transmission
(> 13 keV)



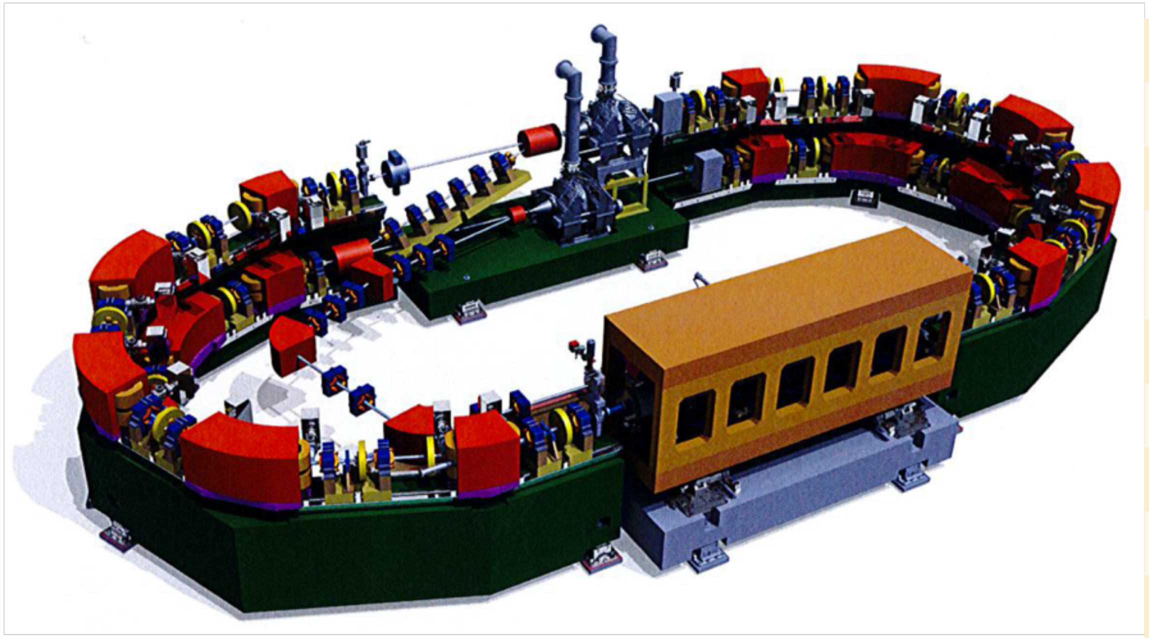
Wafer thinning
Lack of bright source

EUV Metrology sources

- **EUV metrology sources for**
  - Actinic blank inspection (ABI)
  - Actinic patterned mask inspection (APMI)
  - Actinic mask review
  - Actinic pellicle inspection
  - Wafer metrology
  - Wafer inspection
  - Mask substrate inspection

- **Requirements:**
  - High brightness
  - High stability (intensity and beam position)
  - Compact (As compact as possible, But without increasing the machine complexity)
  - Reliability: minimal down time, use proven technology, robust design
  - Minimize R&D costs, risks and lead time: Choose only proven concepts and technologies

COSAMI: Compact Source for Actinic Mask Inspection



Wavelength	13.5 nm
Flux	~100 mW
Brilliance	~ 10^9 W/(mm^2·strd)
Beam energy/beam current	430 MeV/150 mA
Pulse structure	~50 ps every 2 ns
Injection system	Top-up mode
Beam stability	0.1%
Availability	>95%
Reliability	<1% down time
Footprint	5m × 12m

Innovative solutions:

→ adopt technology of Diffraction Limited Storage Rings

→Co-centric design: vertical stacking of booster and ring → small footprint

→ multi-bend magnet lattice

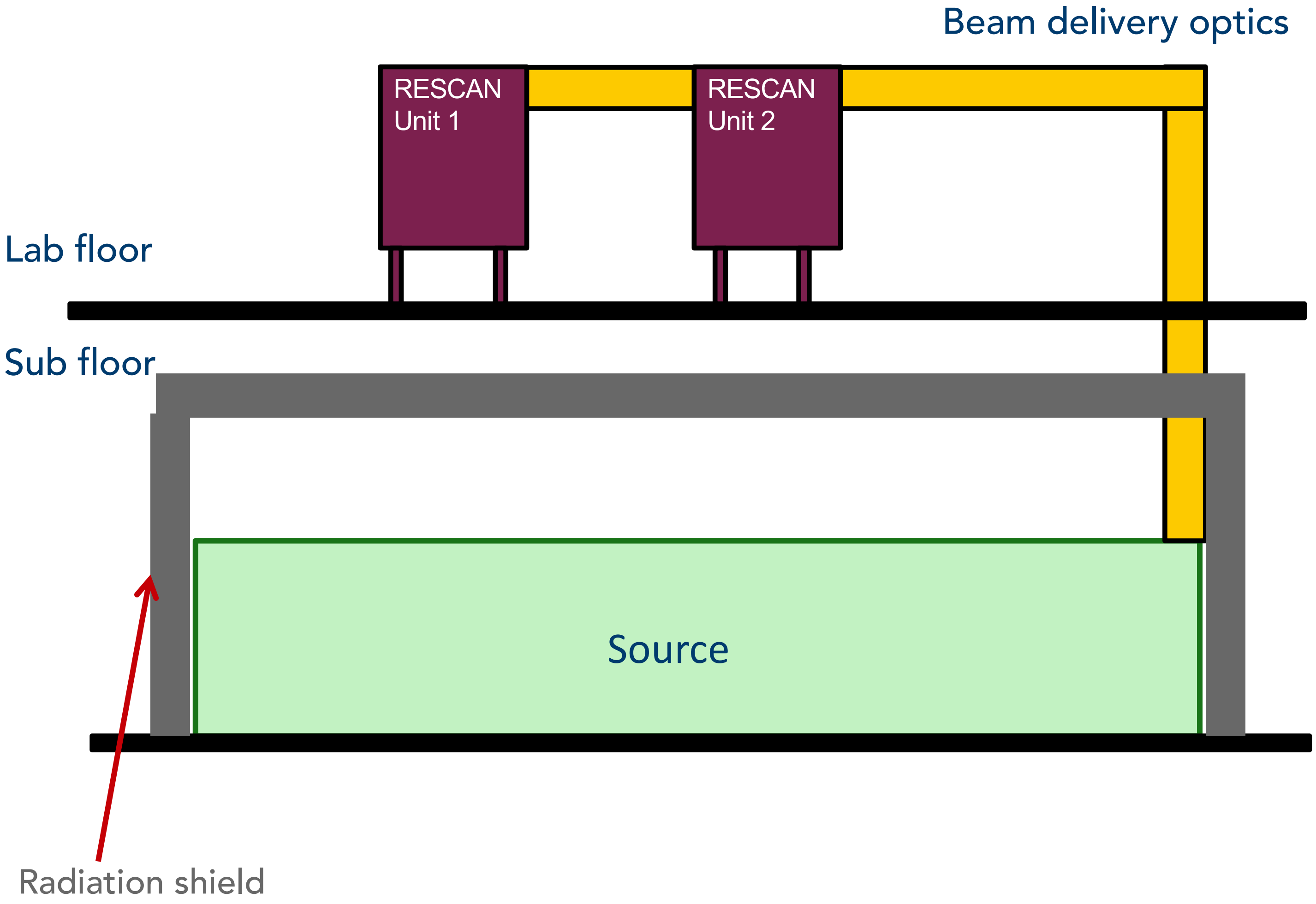
→ implementation of undulator

→ combined function magnets

→ small vacuum chambers with NEG coating

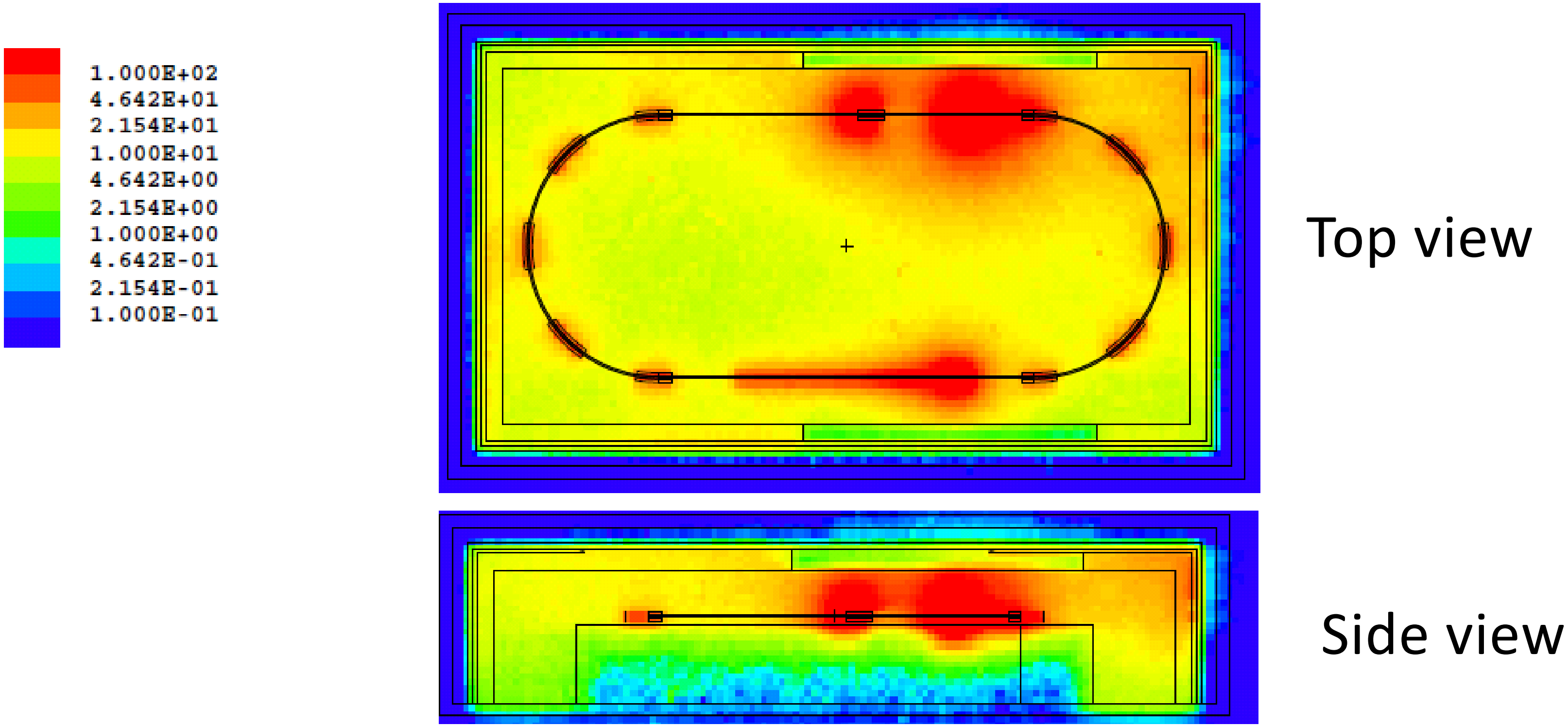
→Photo injector

Does it fit into a fab?



Radiation shielding

Performed using codes MCNPX 2.7.0 (local) / MCNP 6.1 (outer wall)
Loss rates ~ 1.2x10^8 electrons/s at 430 MeV → ICRP data used to convert flux to dose rates. Losses dominated by storage ring.

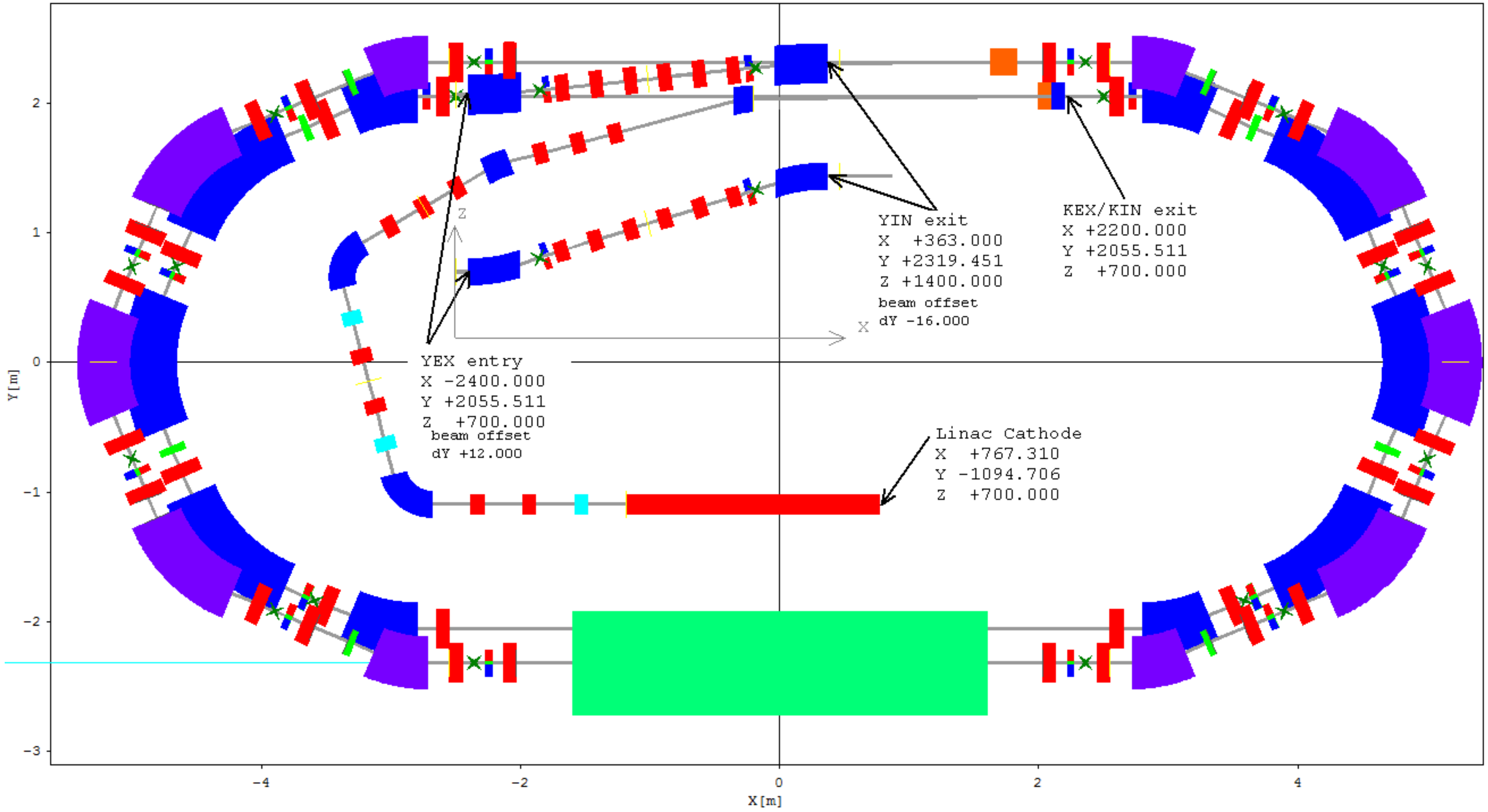


Blocks of concrete and polyethelyne required for adequate shielding.
Optimization and local shielding will reduce the thickness.
The requirements of regulatory agencies can be easily met.

Optics design

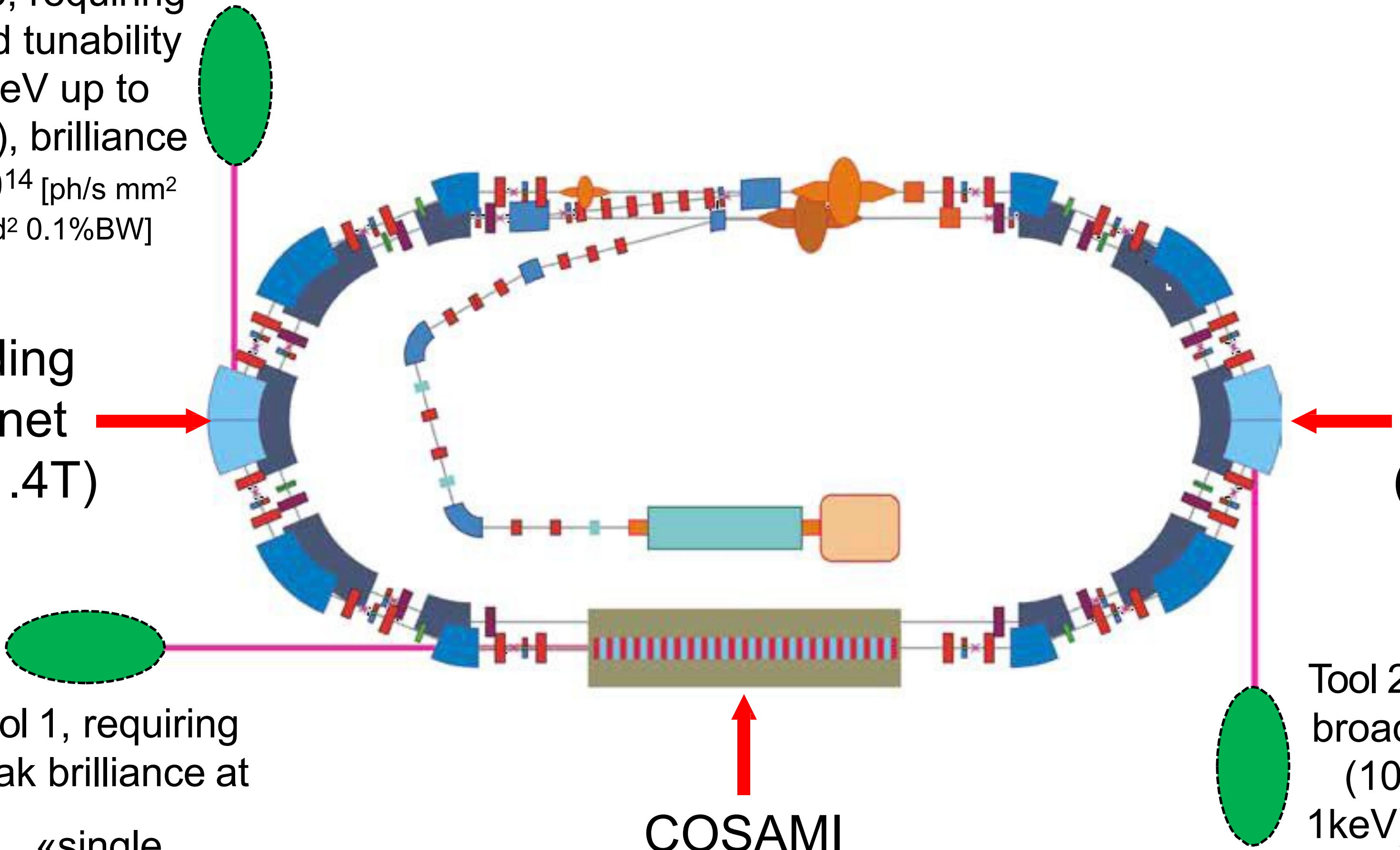
Race-track geometry: Two 5-bend achromat arcs and two straights. One straight for the undulator and one for injection and RF.

- Ring: 430 MeV, 25.8 m
- Booster: 43 → 430 MeV, 24.0 m
- BR transfer line -18.6° inclination
- LB transfer line
- Gun/Linac: 43 MeV, 2.1 m



Lattice design is an iterative process to minimize the electron position, dispersion, and spread

COSAMI for broadband



Tool 3, requiring broad tunability (10eV up to 1keV), brilliance of 10^{14} [ph/s mm^2 mrad^2 0.1%BW]

Bending Magnet (e.g. 1.4T)

Bending Magnet (e.g. 1.4T)

Tool 1, requiring peak brilliance at

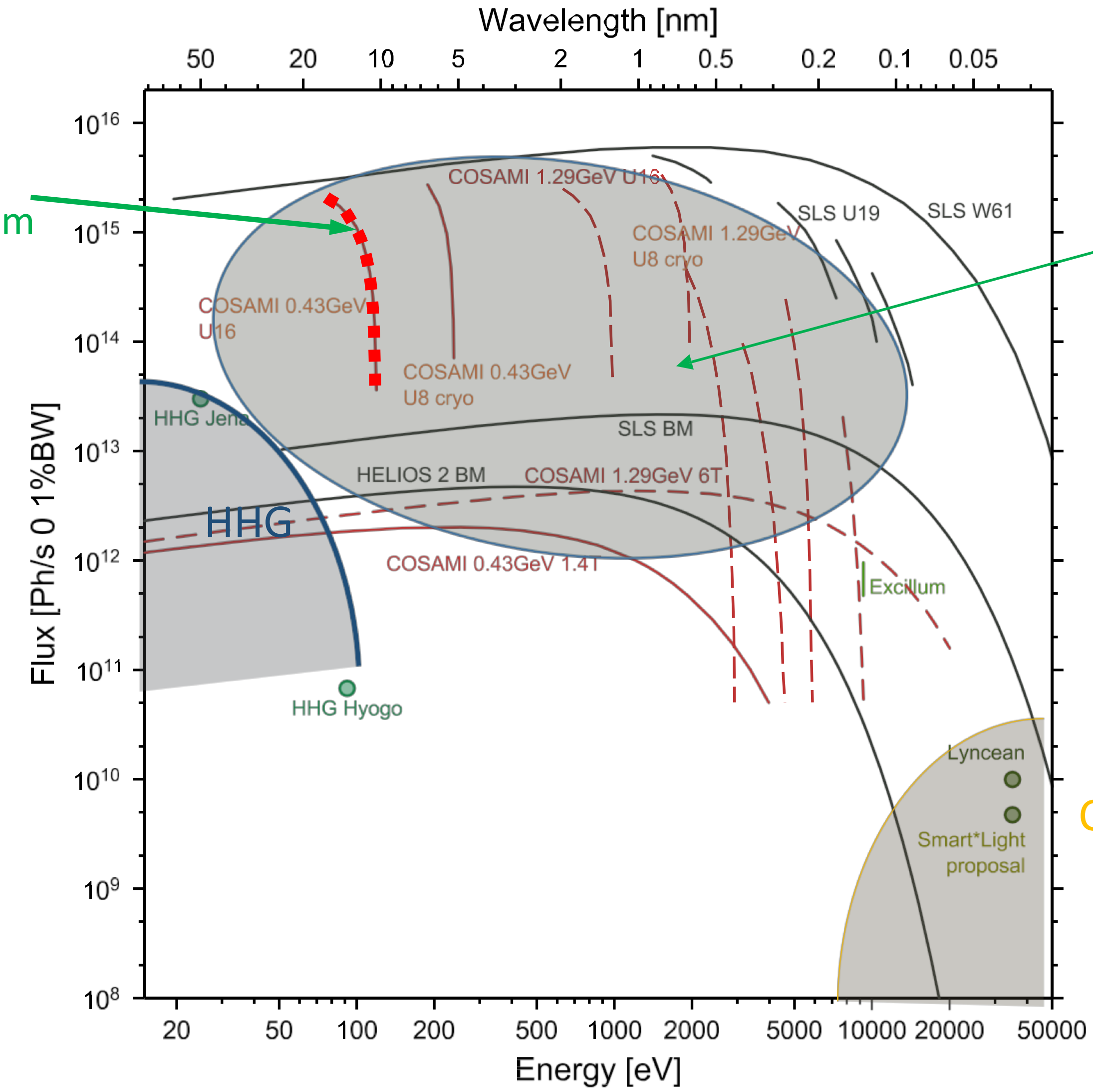
«single wavelength» (13.5nm)

COSAMI

undulator

Tool 2, requiring broad tunability (10eV up to 1keV), brilliance of 10^{14} [ph/s mm^2 mrad^2 0.1%BW]

Flux vs E of various sources



COSAMI with undulator @13.5nm

COSAMI - type Compact Sources based on PSI Technology

Compton Sources

Summary

- EUV metrology has many advantages:
  - Actnitic
  - Short wavelength
  - High material contrast
  - Easier source
  - Stay in reflection
  - Penetration depth: 10-100 nm

- COSAMI design philosophy:
  - Go for proven concepts and well established technologies
  - Minimum delivery time by avoiding R&D and prototyping
  - Compact design without compromising performance
  - High-reliability as a production tool
  - Ensuring radiation safety standards in production environment

- COSAMI Design specifications
  - Clean EUV power: >100 mW
  - Tunable EUV wavelength
  - High brightness: > 1GW/mm^2.std
  - High intensity stability: 0.1%
  - High reliability: up time > 99%
  - Minimum maintenance: <5%

Acknowledgements

PSI: M. Aiba. R.M. Bergmann, T. Bieri, P. Craievich, M. Ehrlichman, C. Gough, P. Lerch, A. Mueller, M. Negrazus, C. Rosenberg, L. Schulz, L. Stingelin, V. Vrankovic, A. Zandonella Gallagher, R. Zennaro.

Advanced Accelerator Technologies

This work has received the finacial support of the Swiss Commission for Technology and Innovation under grant # 19193.1PFNM-NM

Thank you for your attention.