PAUL SCHERRER INSTITUT

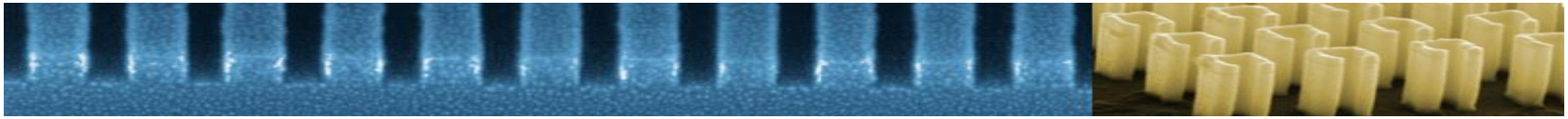
PSI

Iacopo Mochi - Paul Scherrer Institute

EUV interference lithography and metrology at PSI

2021 EUVL Supplier Showcase

Laboratory of Micro and Nanotechnology



- X-ray Optics and Applications
- Polymer Nanotechnology
- Molecular Nanoscience
- Quantum Technologies
- **Advanced Lithography and Metrology**
  - Extreme Ultraviolet Interference Lithography
  - EUV Lensless Imaging
- **Nanotechnology**
  - Operating the ISO4/ISO6 hybrid cleanroom
  - Technological and technical support of users
  - Developing micro/nanofabrication processes

Laboratories

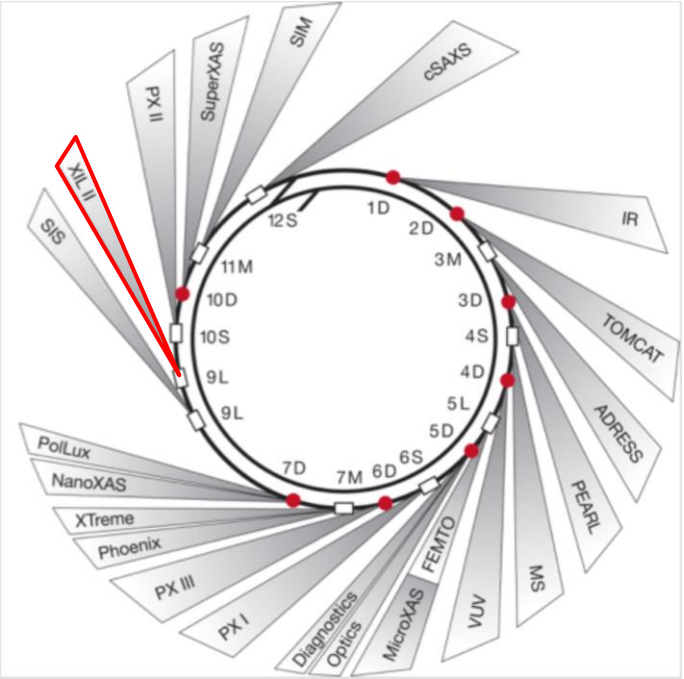
- Cleanroom
- Microscopy
- Beamline

Facilities

- Electron Beam Lithography
- **XIL – EUV interference lithography**
- **RESCAN – Lensless EUV microscopy**

XIL-II

Energy range: 70 – 500 eV. Optimized for 92 eV (13.5 nm)

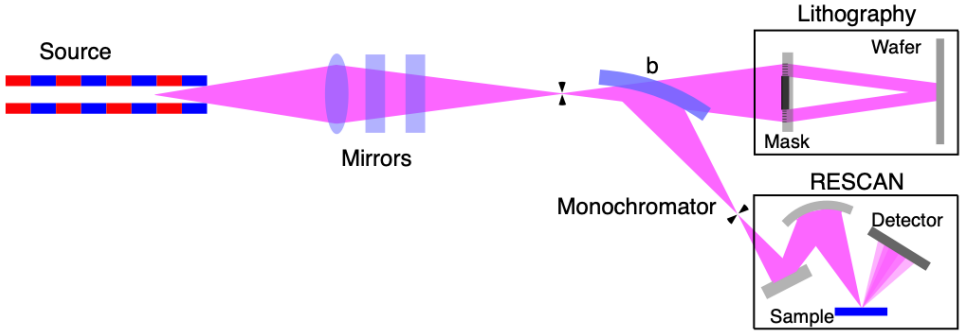


EUV Interference Lithography

Advanced resist testing and nanofabrication

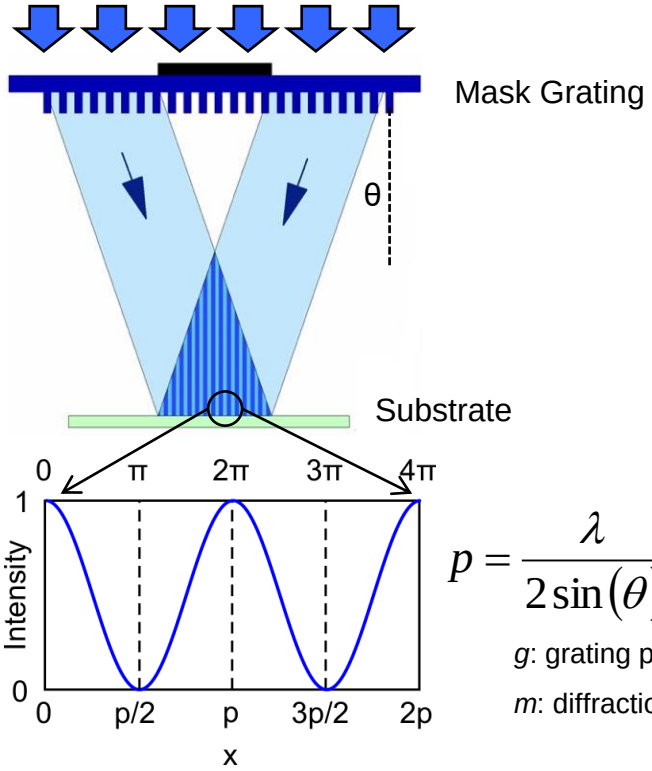
EUV Metrology

Mask and pellicle inspection



Extreme Ultraviolet Interference Lithography

- No depth of focus: Mask-to-wafer = 0.2-10 mm
- High resolution:
  - Theoretical limit: half-pitch= 3.5 nm
  - Lab record: half-pitch 6 nm
  - Routine: half pitch 11 nm
- Large area:
  - Typical 0.5x0.5 mm^2, up to 5x5 mm^2 stitching free
  - Step and repeat: up to 80x80 mm^2
- High throughput: typically 10 s: 10000x e-beam
- Quality, reproducibility: enabling industrial operation



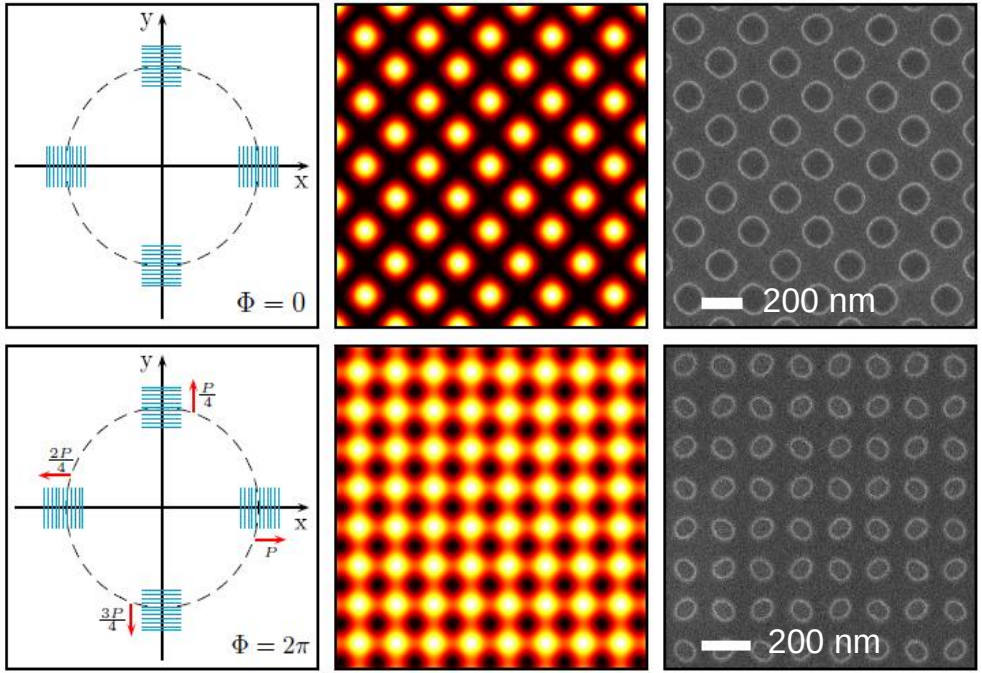
$$p = \frac{\lambda}{2\sin(\theta)} = \frac{g}{2m}$$

g: grating period

m: diffraction order

Phase-controlled EUV-IL (4 beams)

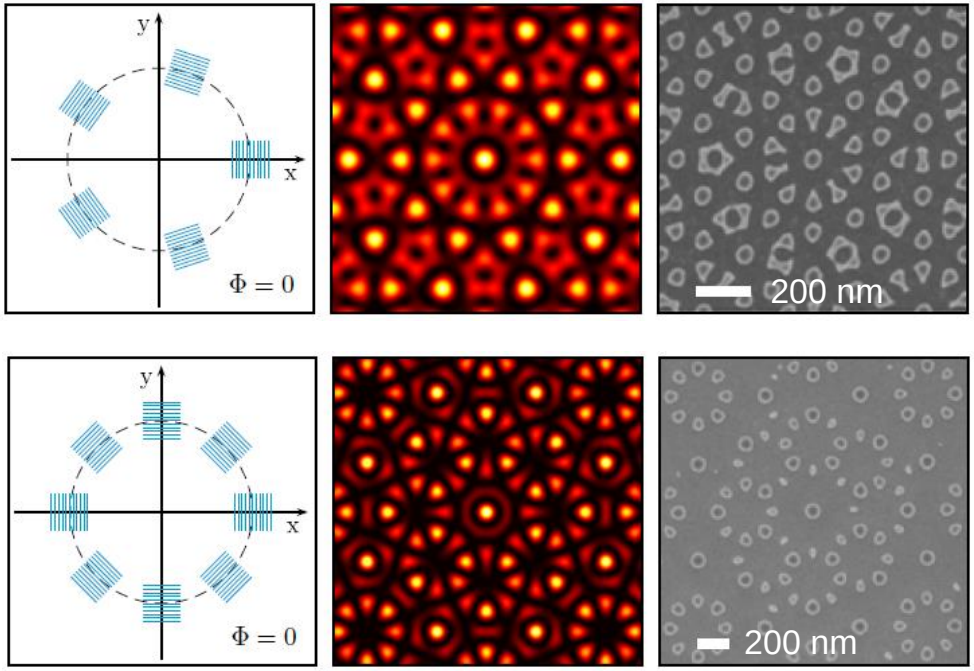
Grating configuration | simulation | SEM image



pitch=grating pitch/√2

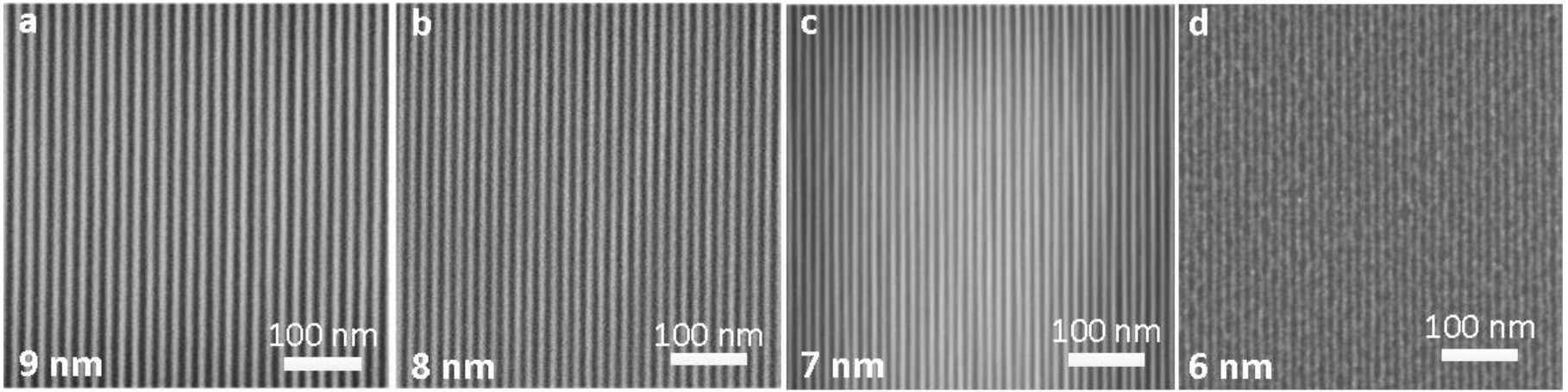
pitch=grating pitch/2

Quasicrystals (Penrose tilings)



Towards Single-Digit Half Pitch

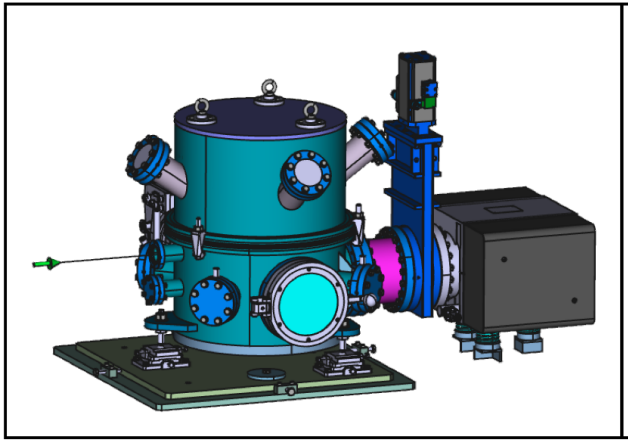
SEM (L/S) images HP = 9-6 nm on hydrogen silsesquioxane (HSQ)

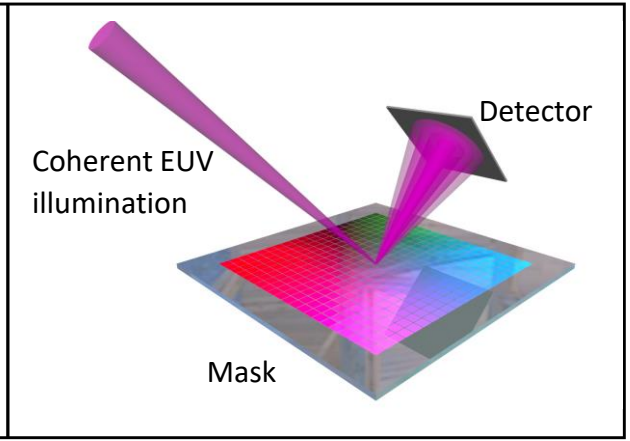


SnO_x (YA)	SnO_x (YA)	HfO_x (XE15IB)	Iridium-ALD

Mask grating material used

Actinic mask imaging through coherent diffraction imaging





- Synchrotron-based
- Tunable wavelength
- $\lambda/\Delta\lambda \approx 1500$
- Resolution limit: 42 nm

- Max sample size: 2×2 cm^2
- Inspection area: 200×200 μm^2
- Customizable environment (Vacuum or low pressure H_2)

Imaging process

Lens

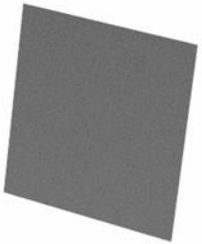
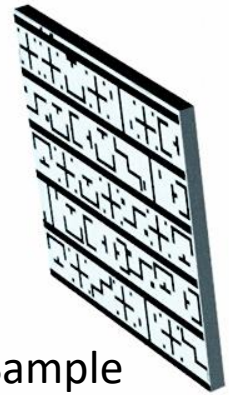
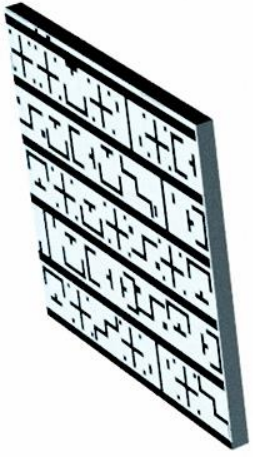


Image plane

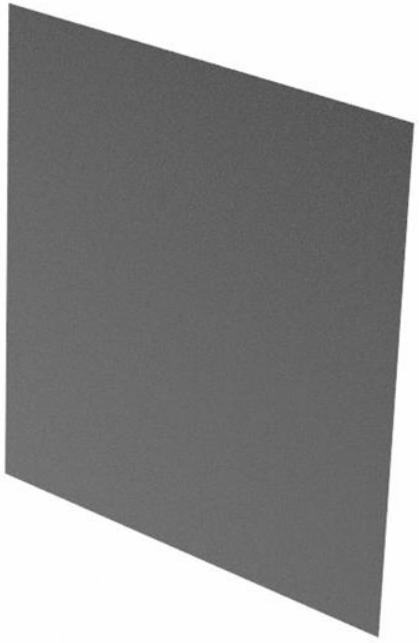


Sample

Coherent diffraction imaging



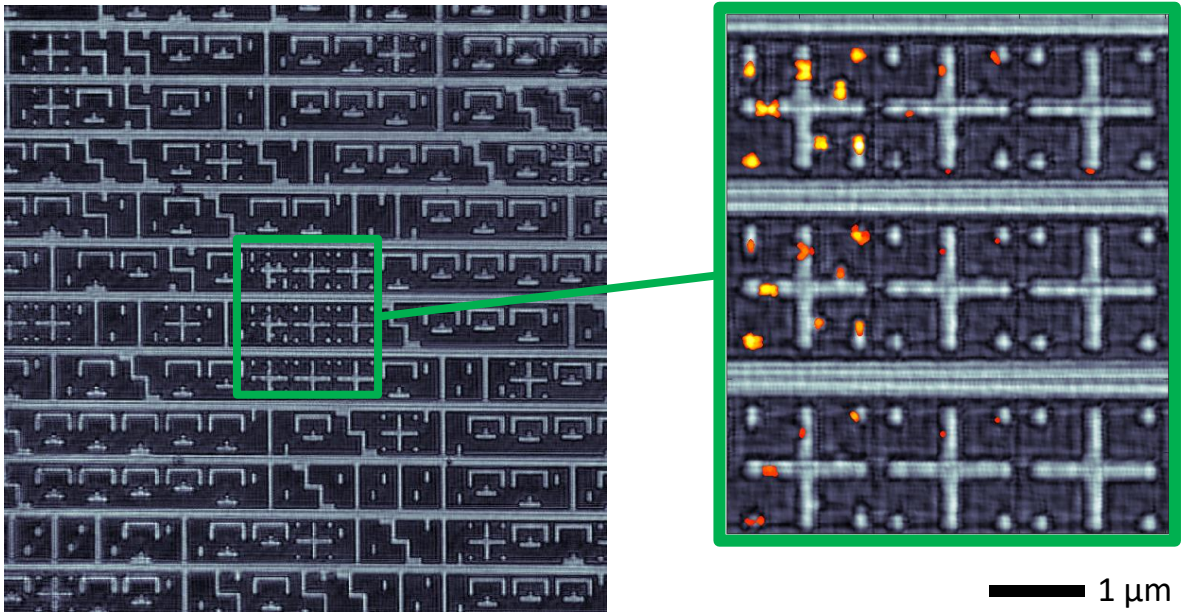
Sample



Detector

Actinic Patterned Mask Inspection

Absorber defects detection



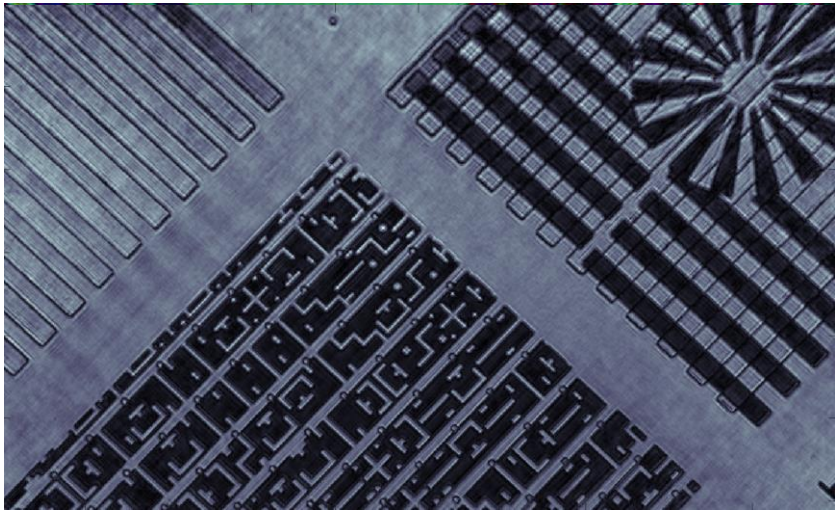
Smallest defect resolved: 50×50 nm^2

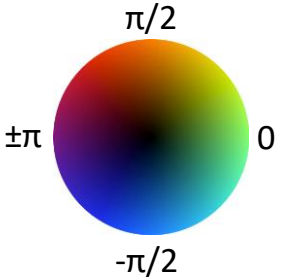
Smallest defect detected: 30×30 nm^2

Phase defects sensitivity in RESCAN

Phase defect detection

3.5 nm carbon structures (200 nm pillars)





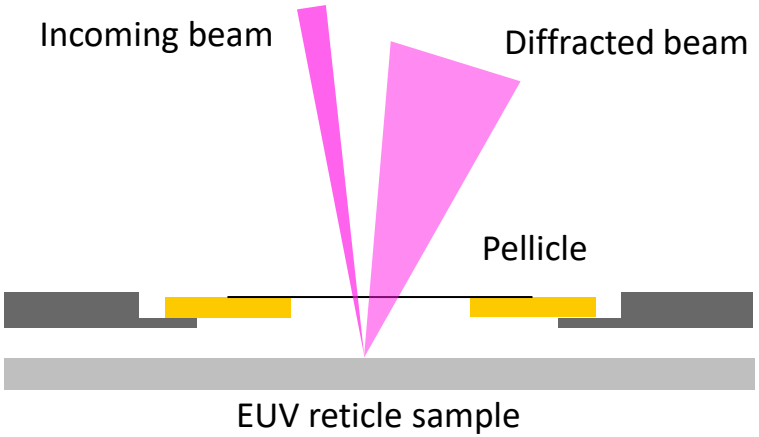
$$\Delta\phi = (0.95 \pm 0.02)\pi \quad \text{(Measured)}$$

$$\Delta\phi = 0.96\pi \quad \text{(Predicted)}$$

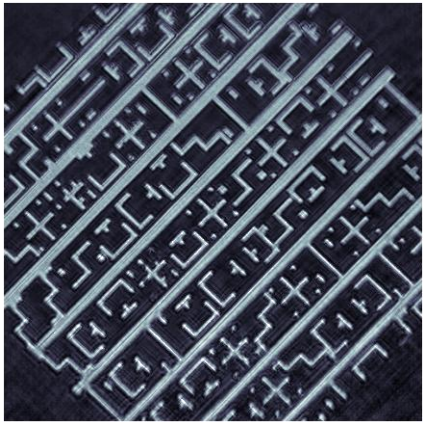
I. Mochi, et al. "Quantitative characterization of absorber and phase defects on EUV reticles using coherent diffraction imaging," J. Micro/Nanolith. MEMS MOEMS 19(1) 014002 (30 January 2020) **https://doi.org/10.1117/1.JMM.19.1.014002**

EUV Pellicle

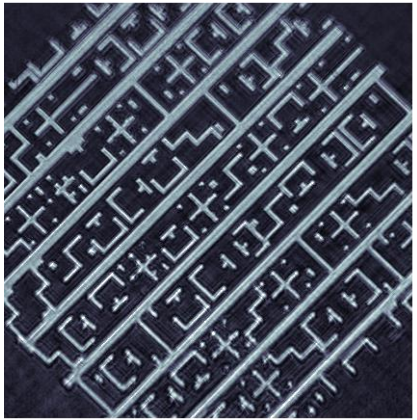
Through pellicle imaging and characterization



No pellicle



Metal-coated SW-CNT pellicle



I. Mochi, et al. "Experimental evaluation of the impact of carbon nanotube EUV pellicles on reticle imaging," J. Micro/Nanolith. MEMS MOEMS (2019) **https://doi.org/10.1117/1.JMM.18.1.014002**

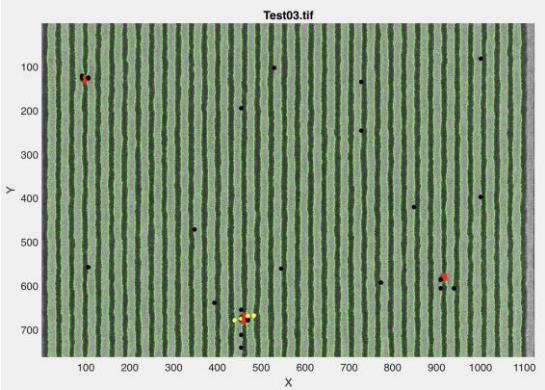
SEM image metrology with SMILE

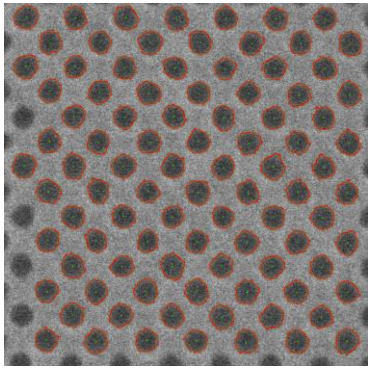
SMILE SEM-Measured Image Lines Estimator

- SEM L/S and contact metrology
- XIL resist screening program support
- Free and open source software

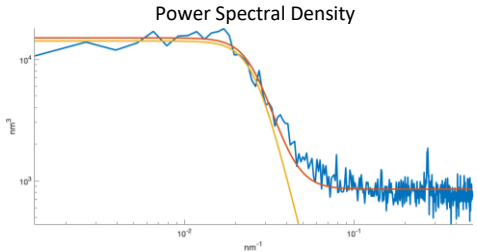
SMILE features

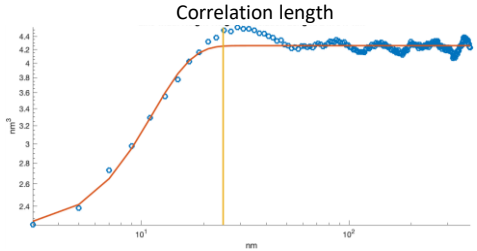
Line/Spaces and Contact detection





Profile analysis





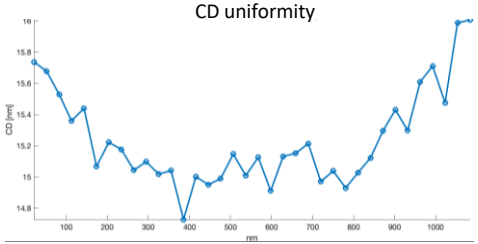


Image metrics calculation

- Average CD
- LCDU
- Unbiased LWR
- Unbiased LER
- Correlation length
- Defect detection
- **Contact CD**
- **Contact LCDU**
- **Contact placement error**
- **Contact ellipticity**
- …

New in SMILE 2.0

SMILE is available as:

- Matlab source code
- Windows-10 installer

Contact:

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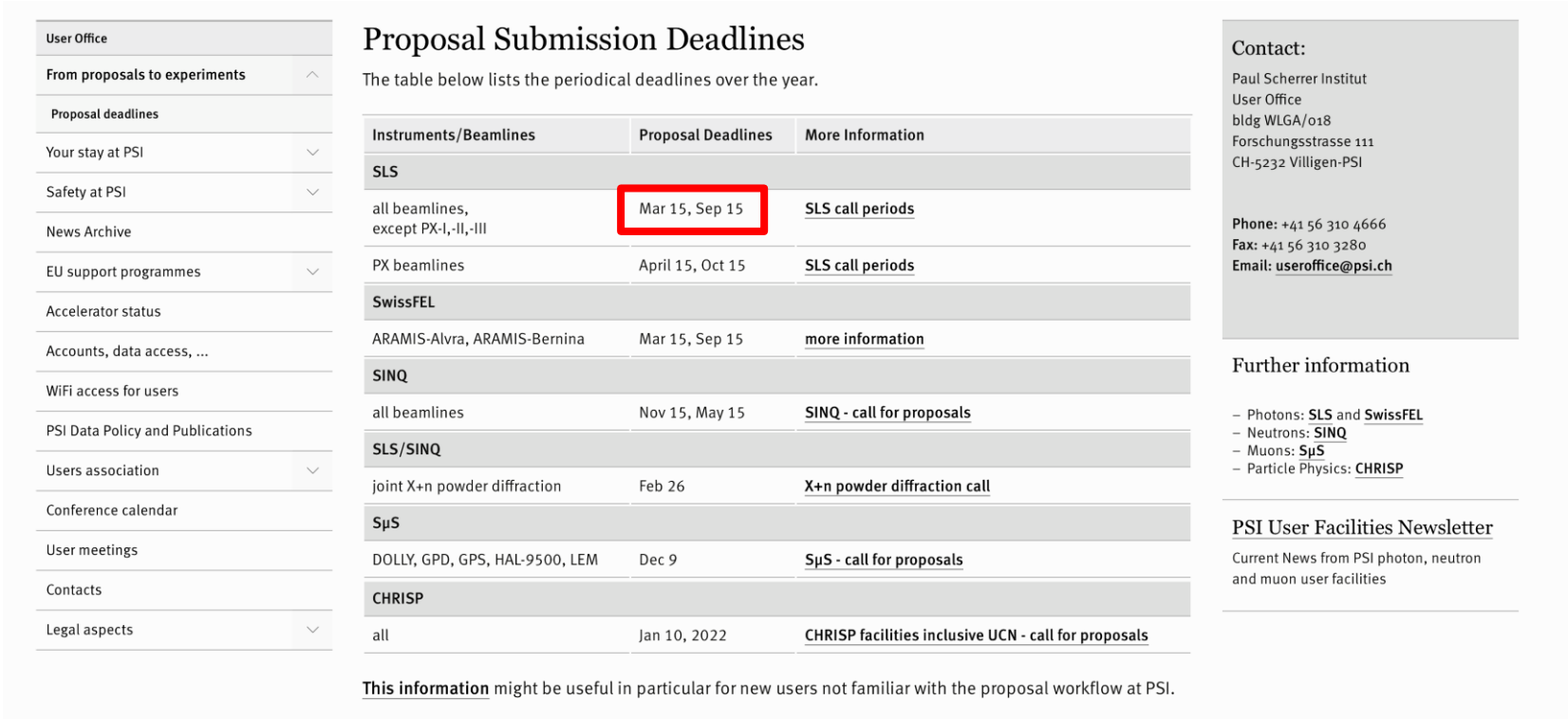
How to get access to PSI services

PSI user proposal submission page:



User Office
From proposals to experiments
Proposal deadlines
Your stay at PSI
Safety at PSI
News Archive
EU support programmes
Accelerator status
Accounts, data access, ...
WiFi access for users
PSI Data Policy and Publications
Users association
Conference calendar
User meetings
Contacts
Legal aspects

Proposal Submission Deadlines

The table below lists the periodical deadlines over the year.

Instruments/Beamlines	Proposal Deadlines	More Information
SLS		
all beamlines, except PX-I,-II,-III	Mar 15, Sep 15	SLS call periods
PX beamlines	April 15, Oct 15	SLS call periods
SwissFEL		
ARAMIS-Alvra, ARAMIS-Bernina	Mar 15, Sep 15	more information
SINQ		
all beamlines	Nov 15, May 15	SINQ - call for proposals
SLS/SINQ		
joint X+n powder diffraction	Feb 26	X+n powder diffraction call
SμS		
DOLLY, GPD, GPS, HAL-9500, LEM	Dec 9	SμS - call for proposals
CHRISP		
all	Jan 10, 2022	CHRISP facilities inclusive UCN - call for proposals

This information might be useful in particular for new users not familiar with the proposal workflow at PSI.

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Further information

- Photons: SLS and SwissFEL
- Neutrons: SINQ
- Muons: SμS
- Particle Physics: CHRISP

PSI User Facilities Newsletter

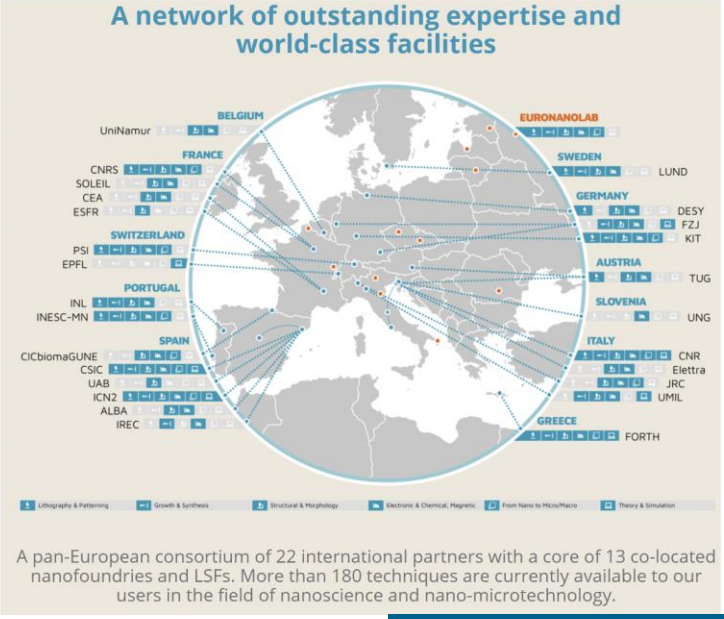
Current News from PSI photon, neutron and muon user facilities

https://www.psi.ch/en/useroffice/proposal-deadlines

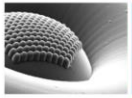
How to get access to PSI services

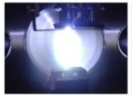
NFFA Transnational Access

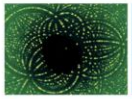
Free-of-charge access for academia and industry thanks to the Horizon 2020 pilot project

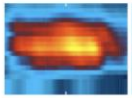


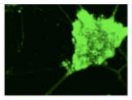
A pan-European consortium of 22 international partners with a core of 13 co-located nanofoundries and LSFs. More than 180 techniques are currently available to our users in the field of nanoscience and nano-microtechnology.


Lithography & Patterning


Growth & Synthesis


Structural & Morphology Characterization


Electronic & Chemical & Magnetic Characterization


Nano to Micro/Macro


Theory & Simulation

First call for proposals is open

DEADLINE: September 1, 2021 at 17:00 (CEST)

TA TECHNICAL ENQUIRIES

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GENERAL ENQUIRIES

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PSI SPECIFIC ENQUIRIES

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Wir schaffen Wissen – heute für morgen

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XIL – beamline:
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- José Gabadinho

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