

Performance improvement of laser-assisted and laser-driven EUV sources for metrology applications

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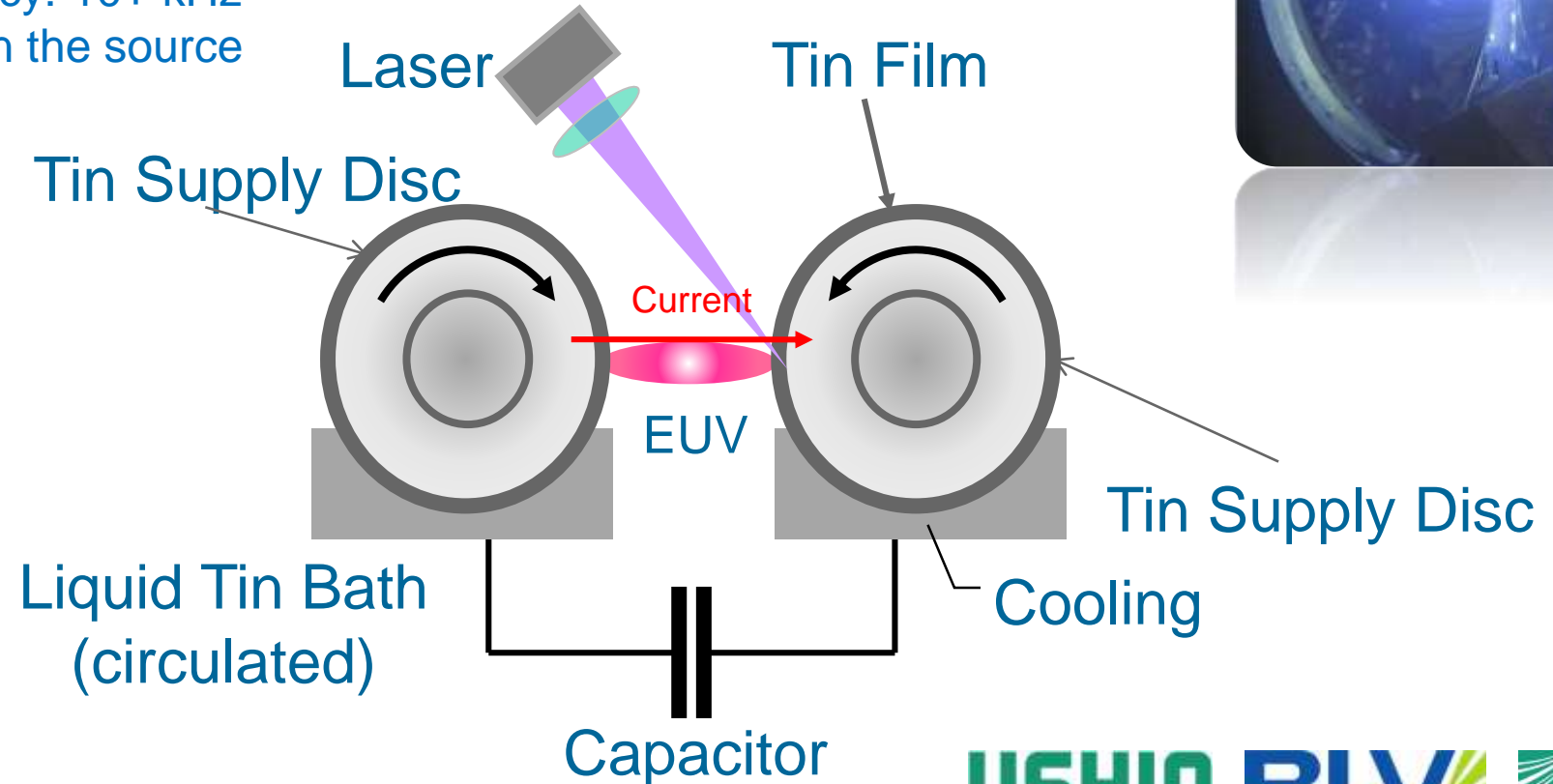
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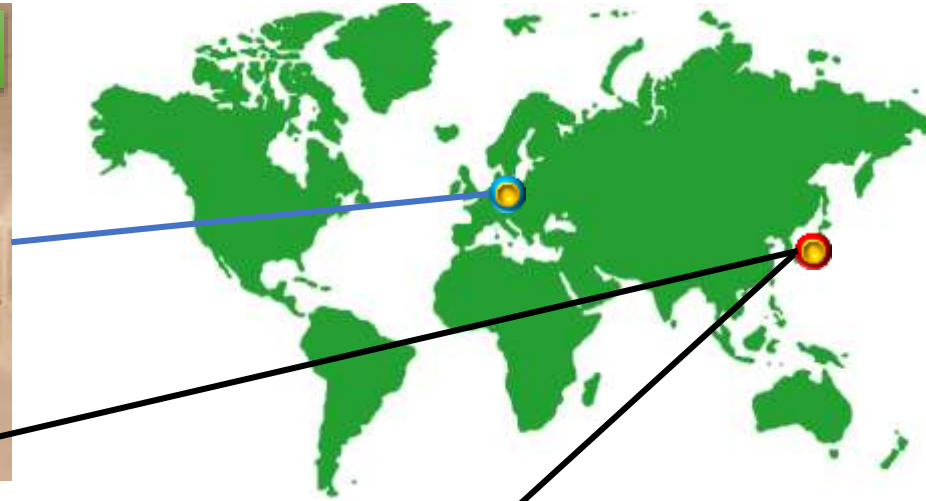
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Laser-assisted Discharge-produced Plasma

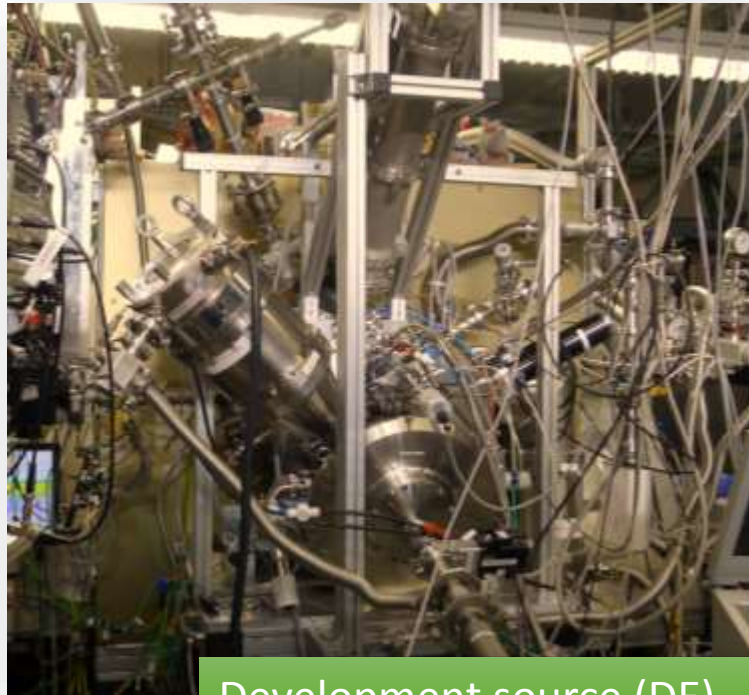
- Liquid-Sn-covered disc target
- Low-power laser for discharge ignition
- Pulsed discharge for EUV generation
- Plasma size: 200x450 um (typical)
- Large number of photons
- Maximum operating frequency: 10+ kHz
- Debris mitigation: included in the source



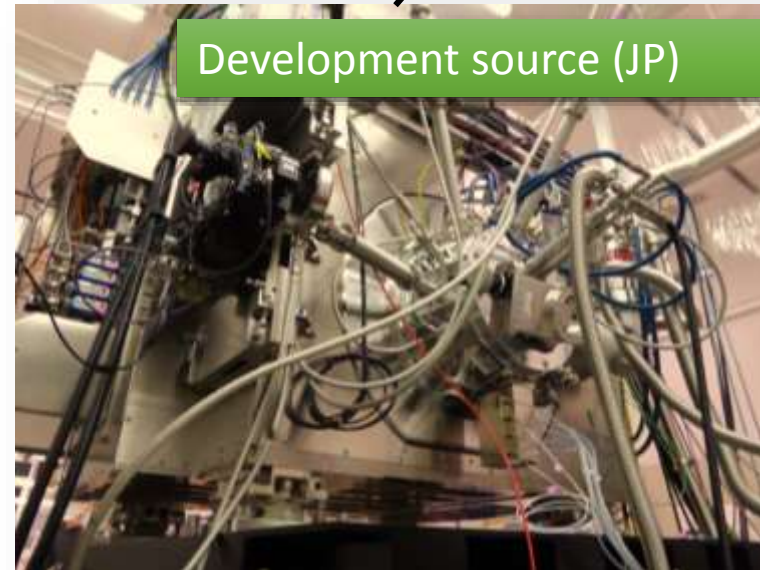
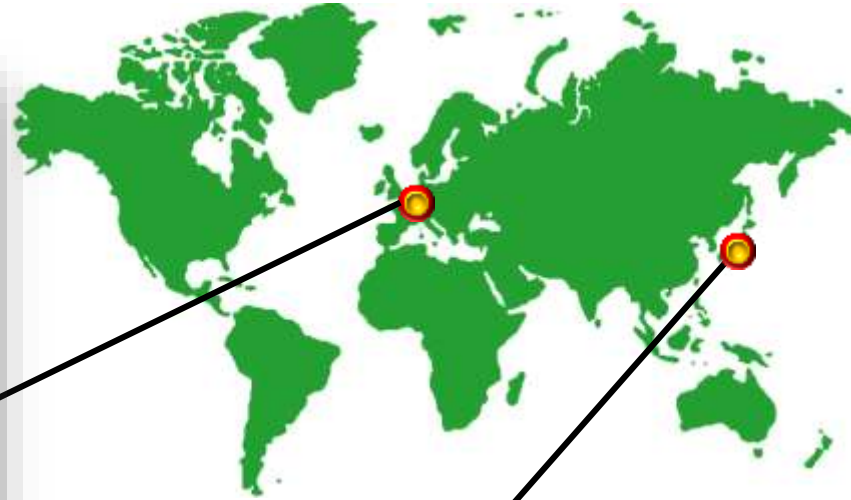
LDP sources in operation



LDP sources in operation

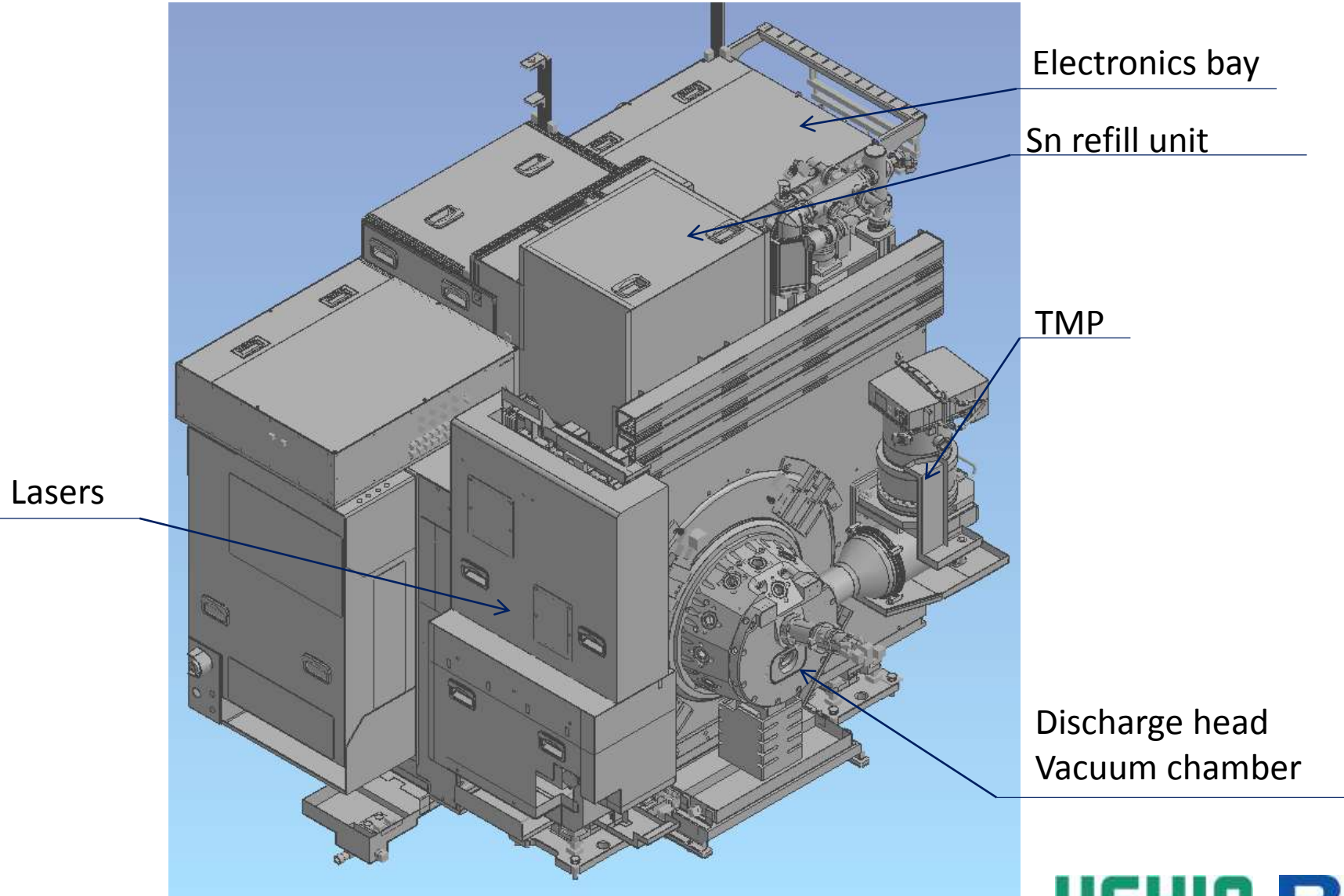


Development source (DE)



Development source (JP)

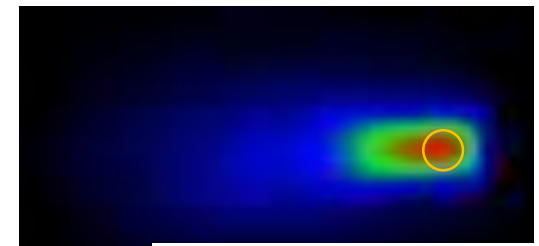
LDP source cabinet



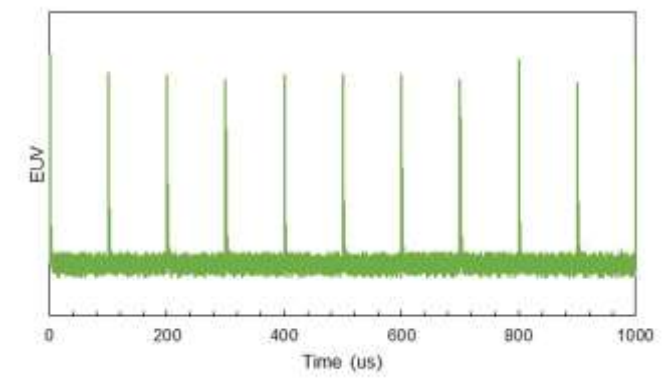
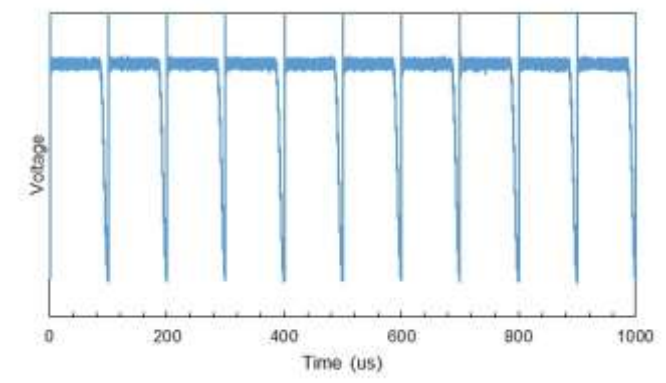
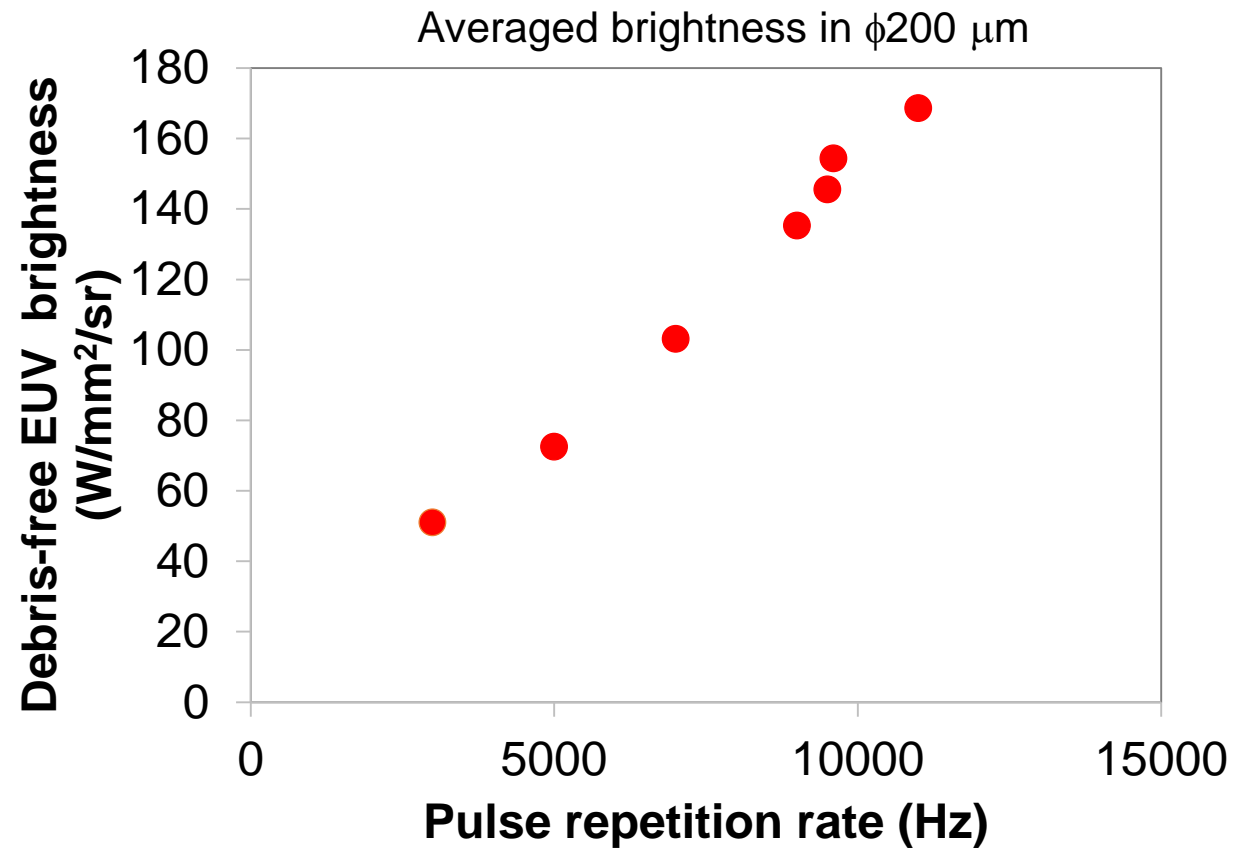
Brightness scaling up to 170 W/mm²/sr at 11 kHz

Measured after debris shield as debris-free EUV photon

- ❑ Area-averaged brightness: up to 170 W/mm²/sr
- ❑ Long-term tests underway at around 10 kHz

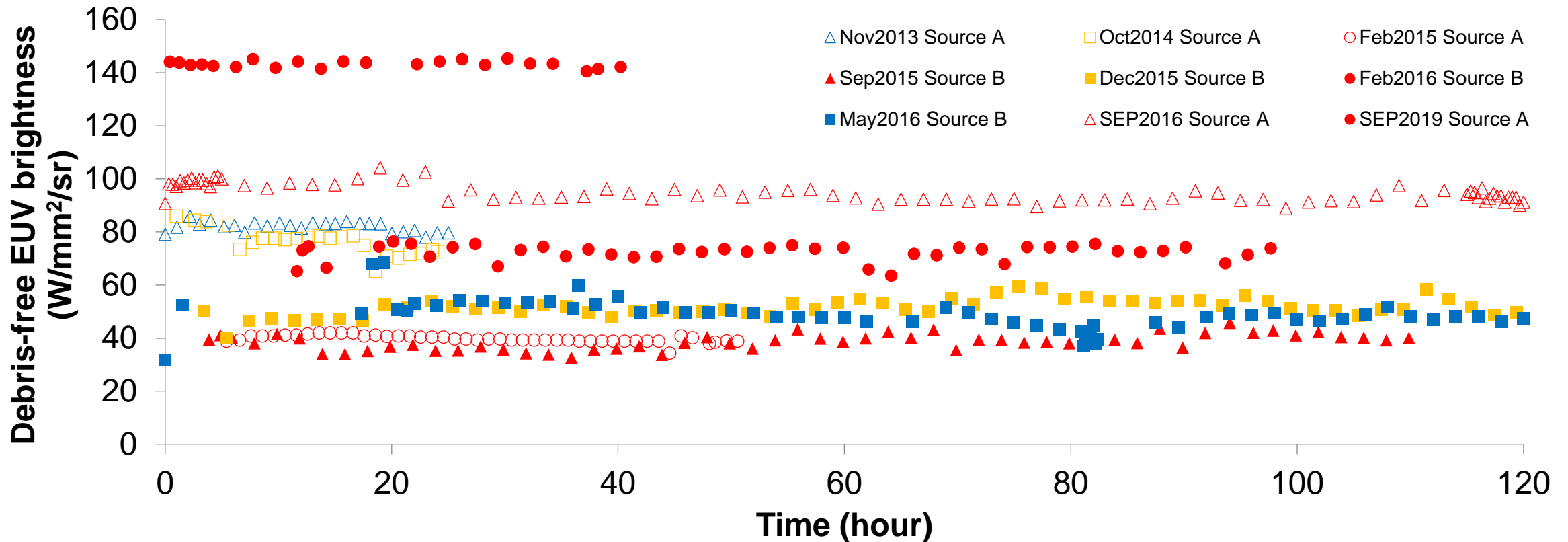


In-band EUV image
λ=13.5 nm, 2 % BW



Long-term brightness stability

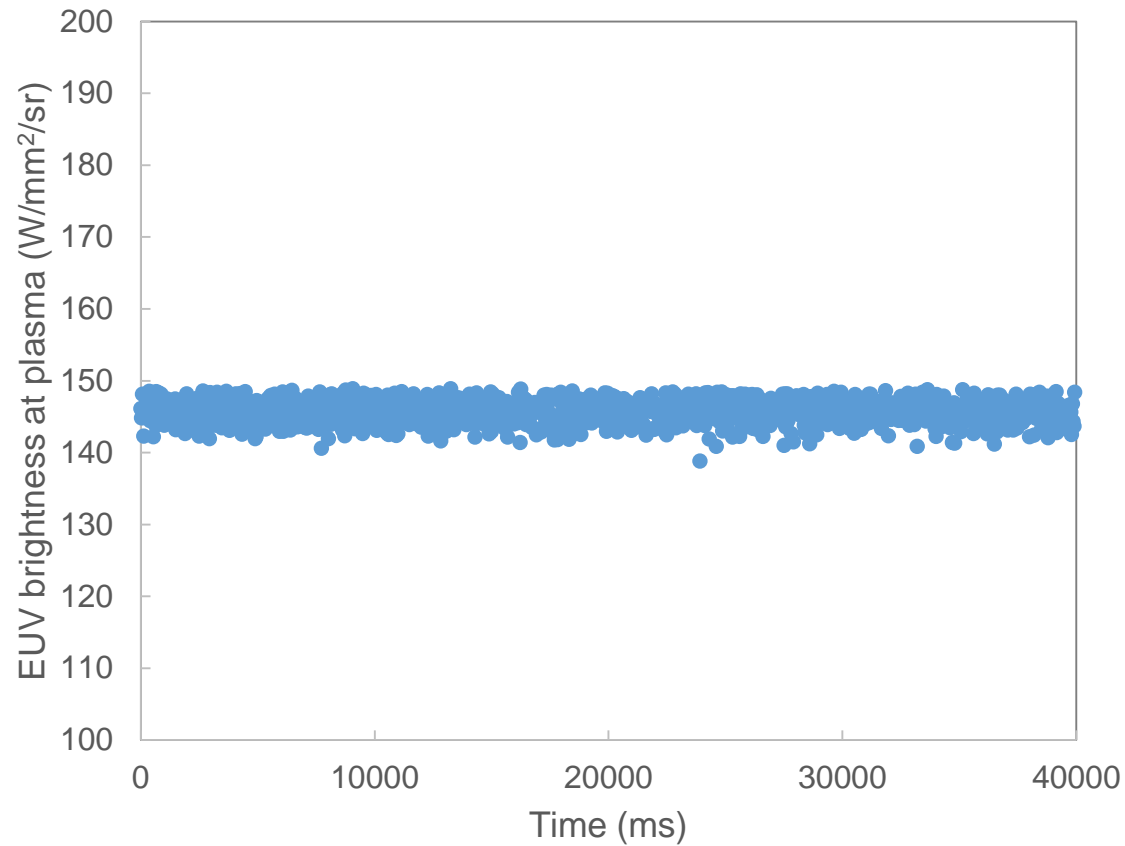
- ❑ Stability, reliability, robustness are the main focus of the current development.
- ❑ Mid- and long-term tests are being carried out.
 - ✓ 100 W/mm²/sr for >5 days
 - 140 W/mm²/sr for 40 hours



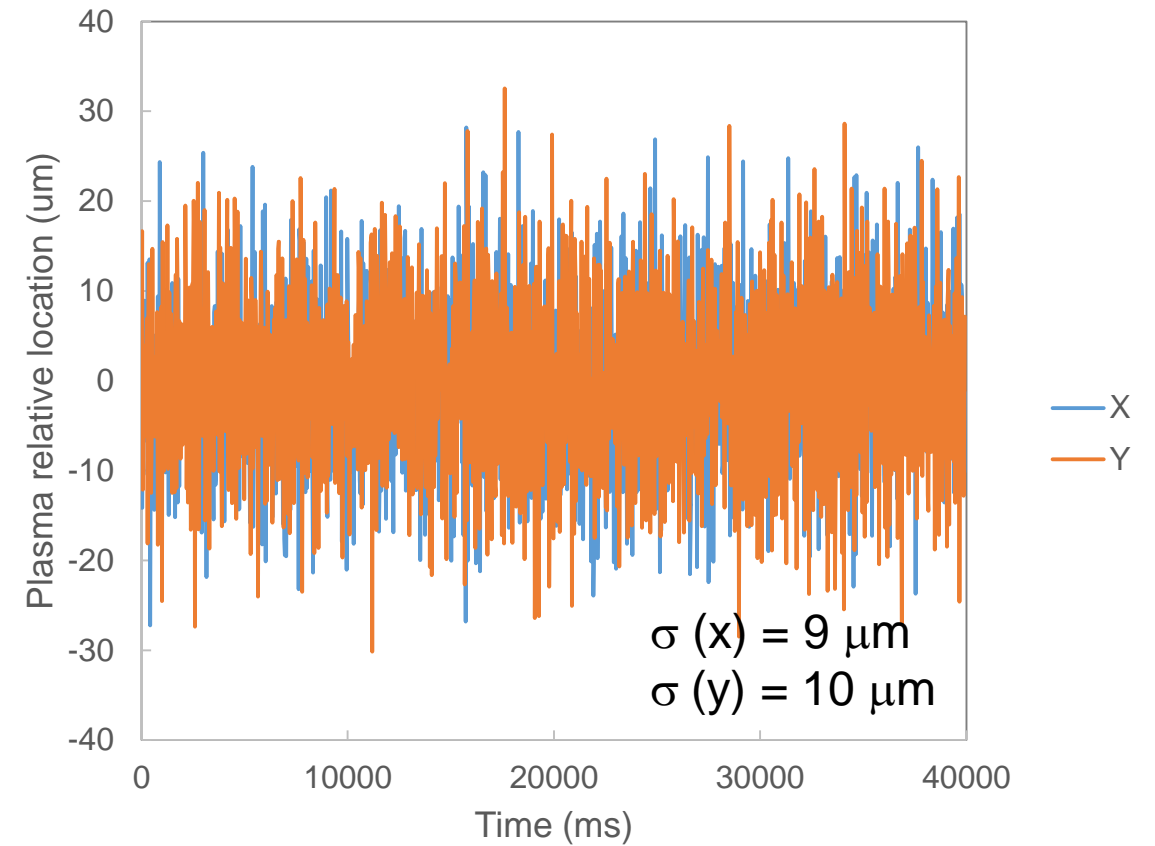
Brightness stability at 9.6 kHz

Data of side-on in-band EUV camera
Exposure time 9 ms

Brightness

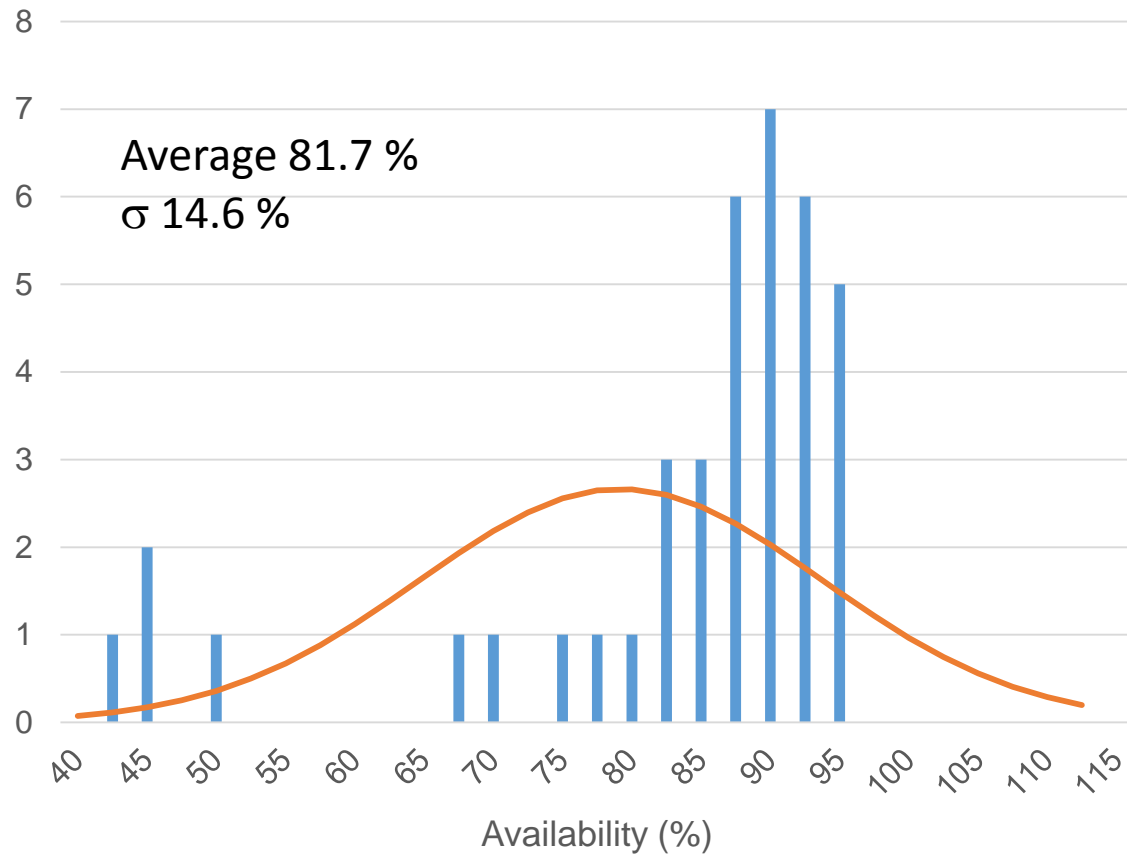


Position



Source availability

4-week moving average availability



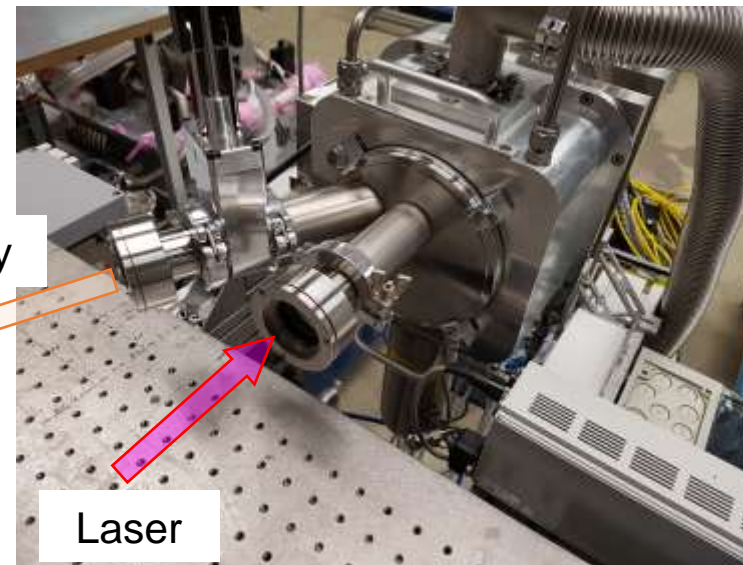
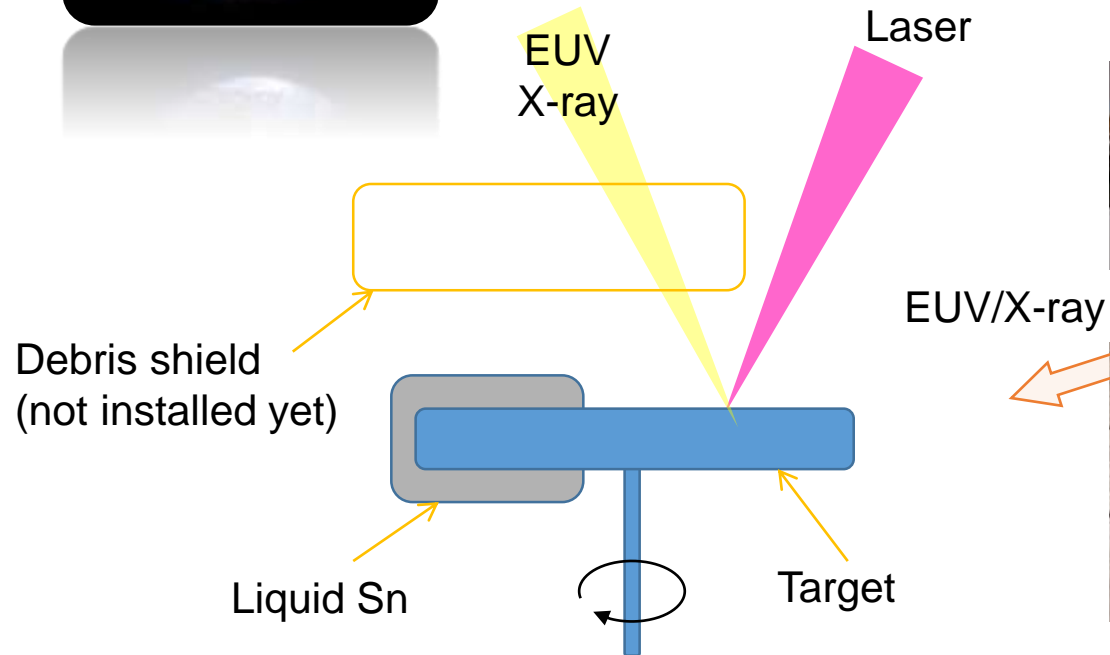
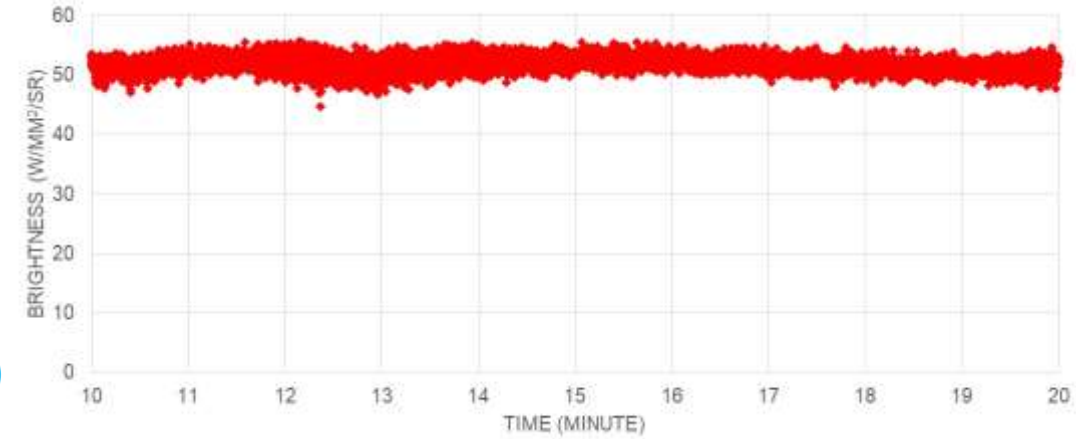
- Average availability was 81.7 %.
- Low availability was caused by unscheduled maintenance, module failure, longer service time.
- Improved modules are being deployed to increase availability.

Laser-driven compact EUV/X-ray source

Proof-of-concept experimental setup

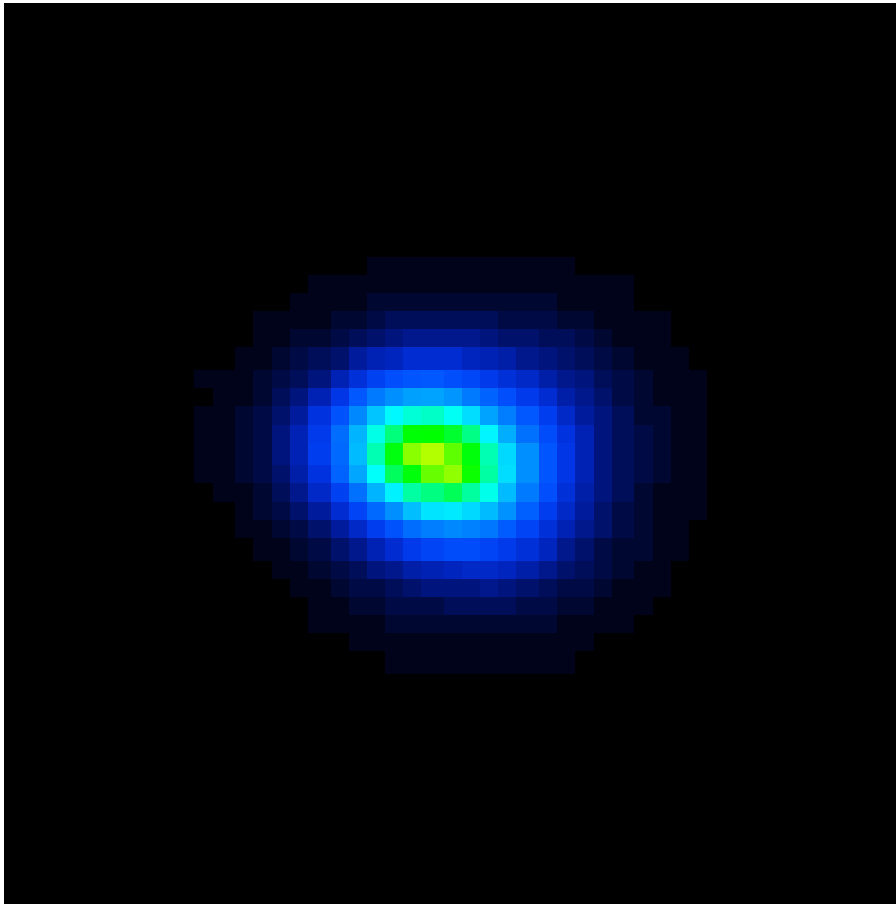


- Laser-driven source
- Low output power
- High output brightness
- Table-top size
- Currently liquid Sn target ($\lambda=13.5$ nm)

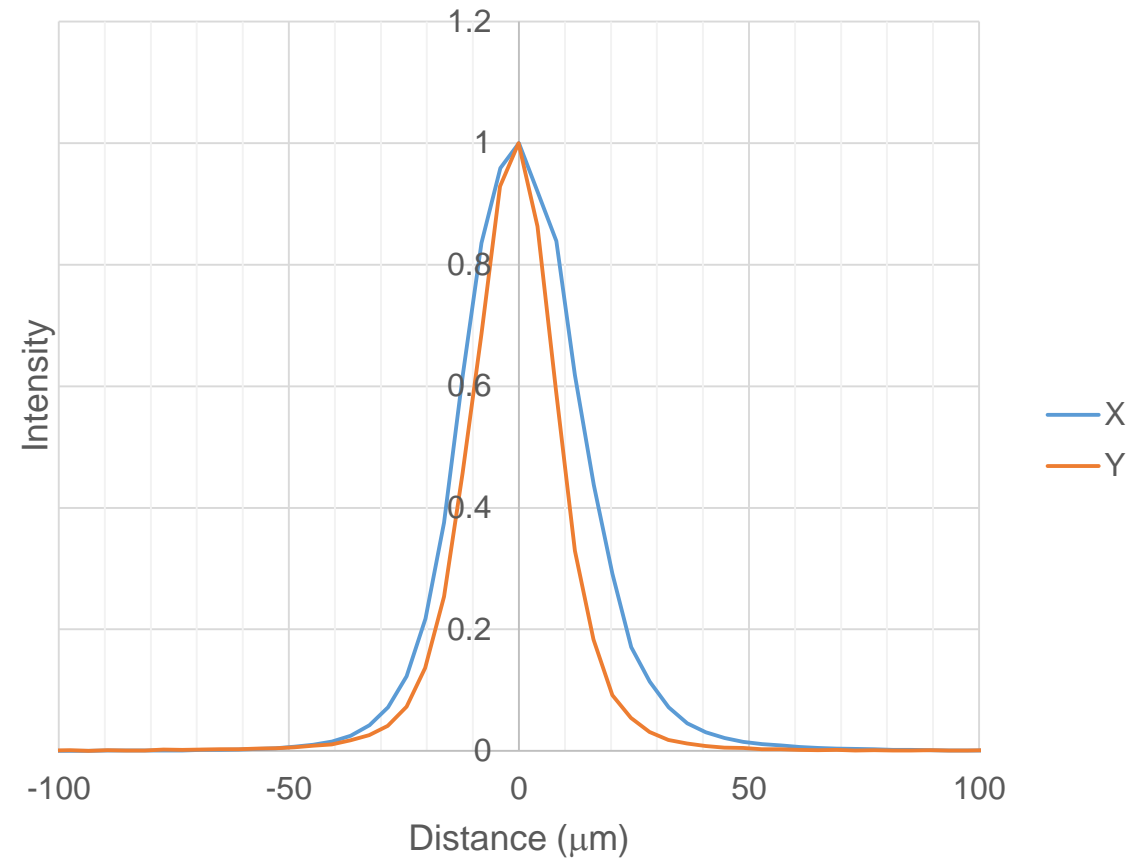


Laser-driven compact EUV/X-ray source

In-band EUV emission image taken at 28 kHz

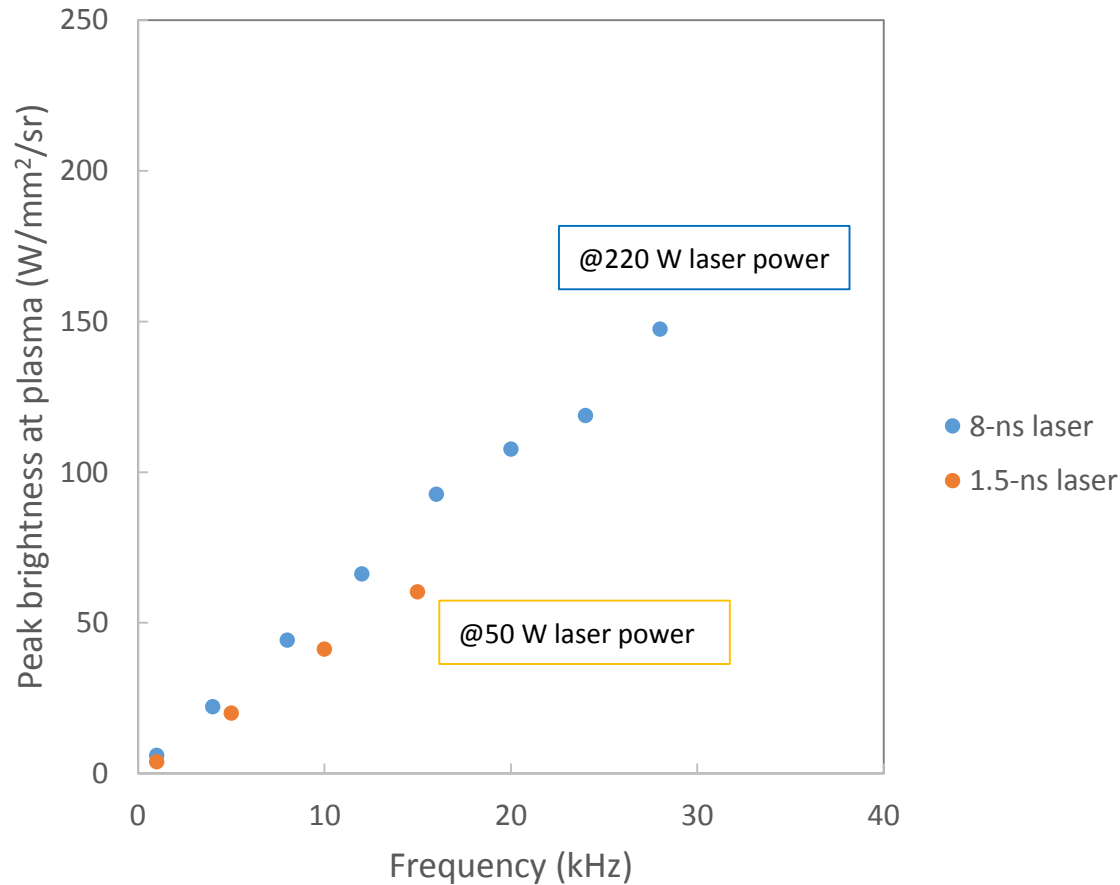


In-band EUV emission size: approx. 60 μm in diameter (FWHM)

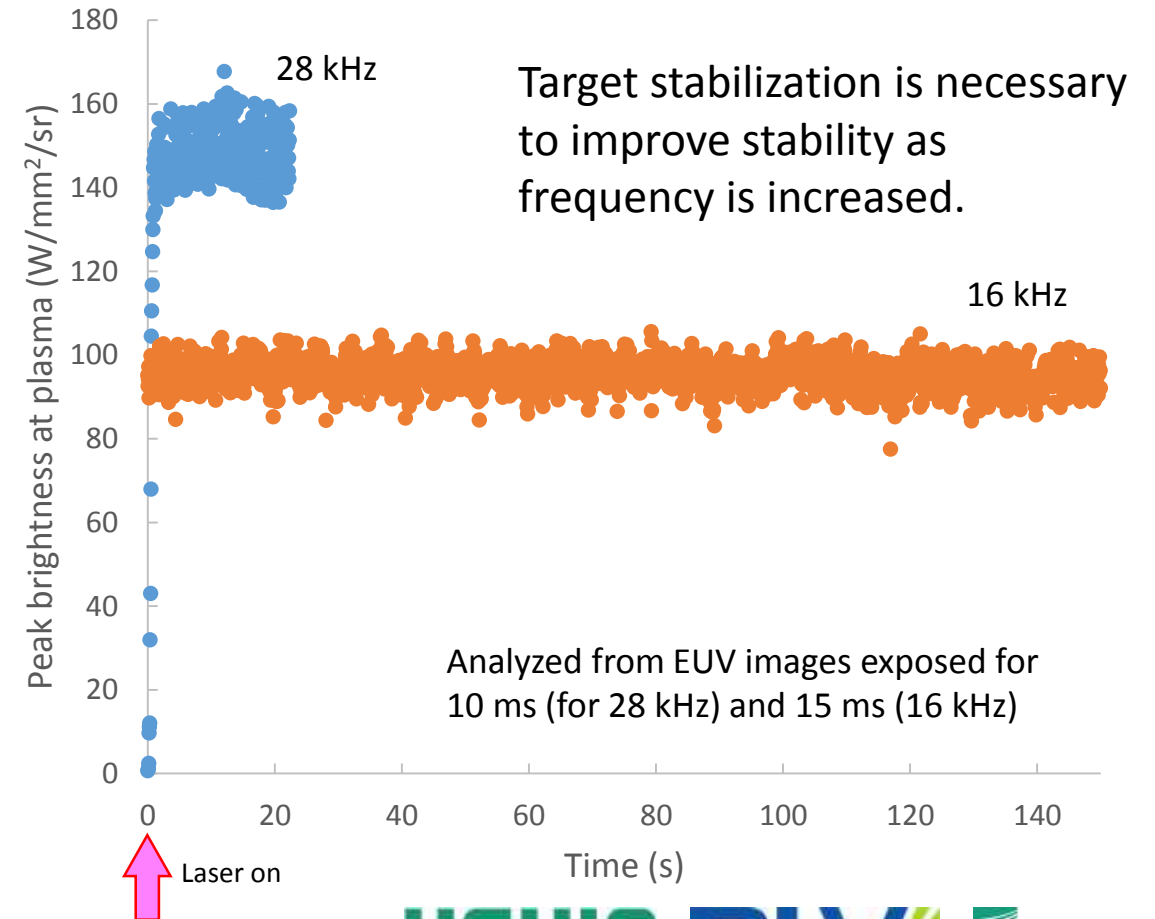


Frequency scaling up to 28 kHz

150W/mm²/sr at 28 kHz

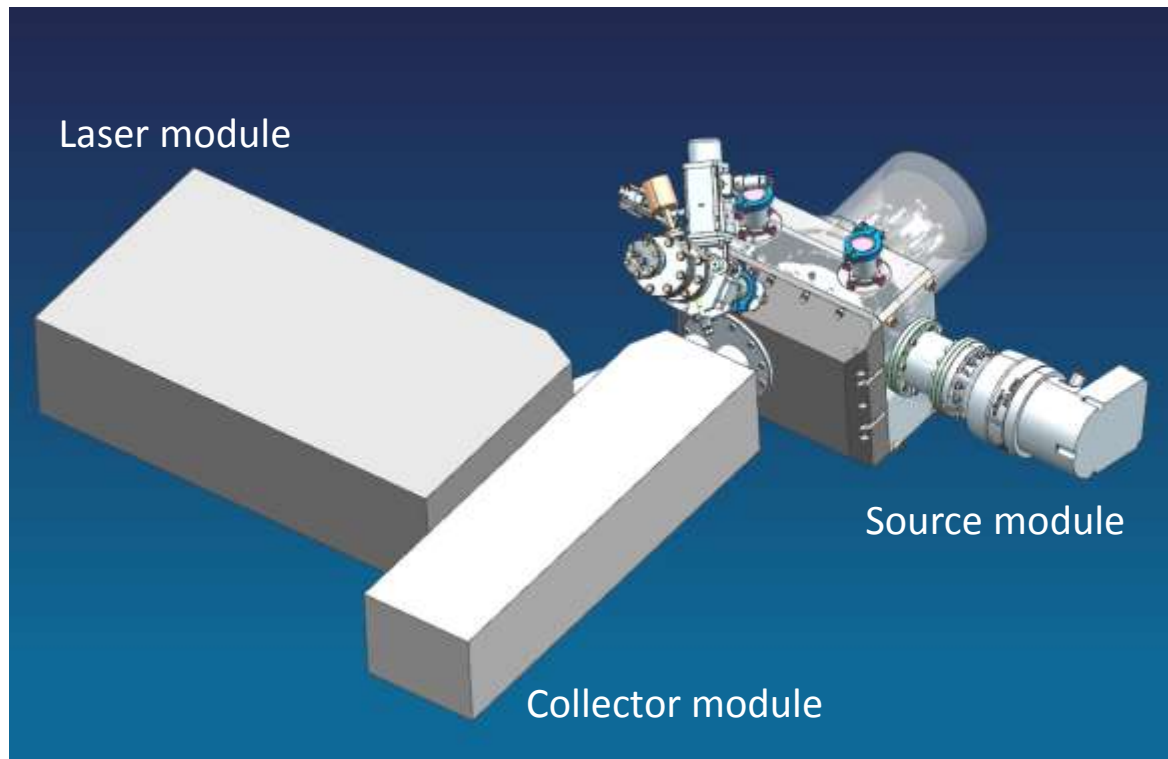


Ramp-up characteristic

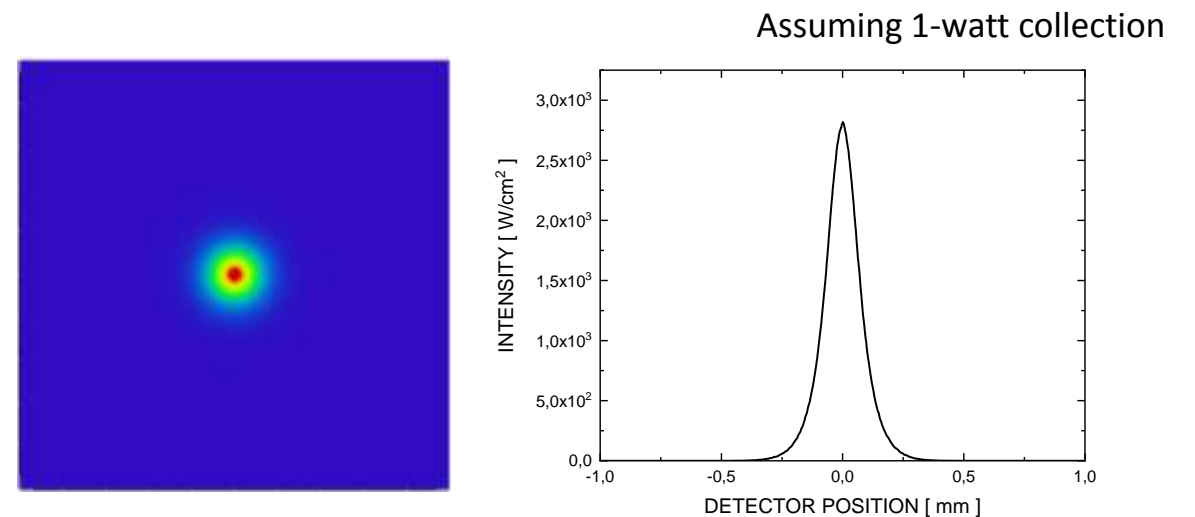


Concept of next experimental source platform

Conceptual sketch of next experimental platform



An example of IF image and intensity



Laser-assisted source

- ❑ Brightness of Sn-LDP source is sufficiently high for enabling EUV actinic mask inspections (ABI, API and AIMS).
- ❑ Current development is focusing on stability, reliability and robustness through multiple long-term tests.
- ❑ Availability is >80 %.

Laser-driven source

- ❑ Compact LPP source is being studied as EUV and X-ray sources.
- ❑ Highest brightness of approx. $150 \text{ W/mm}^2/\text{sr}$ was obtained at 28 kHz (laser power 220 W).

Thank you

