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Status update of EUV light source development for inspection tools

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Lasertec Corporation

Agenda

1. APMI with High-Brightness EUV Light Source
2. Light Source Requirements for Patterned Mask Inspection
3. Beam Scanning System for Large Field of View
4. Summary

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Actinic Patterned Mask Inspection Roadmap

2020 2025 2030

ACTIS A100
First actinic patterned mask inspection tool

ACTIS A300
Higher sensitivity & higher throughput model for High-NA EUVL

ACTIS higher throughput model

ACTIS Next generation for Hyper-NA EUVL

ACTIS Large mask support

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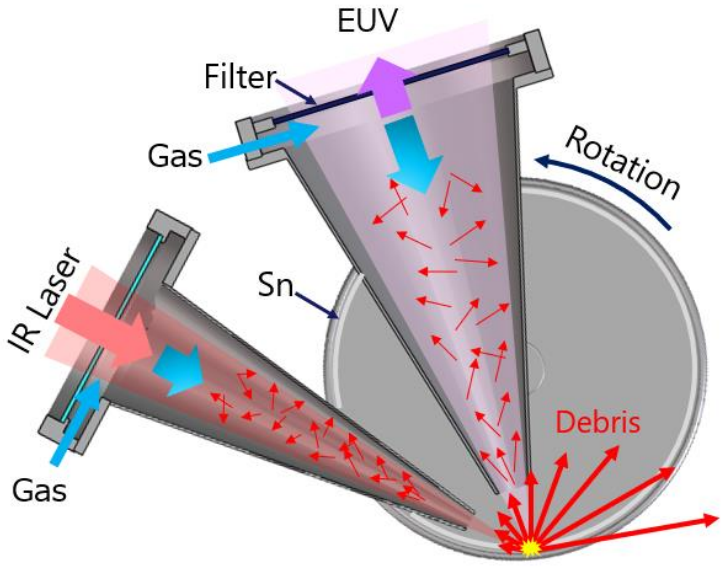
Lasertec's In-house EUV light source: URASHIMA

The high-brightness, small-etendue EUV light source enhances inspection performance for EUV mask patterns.

Improvements Over the Last Year

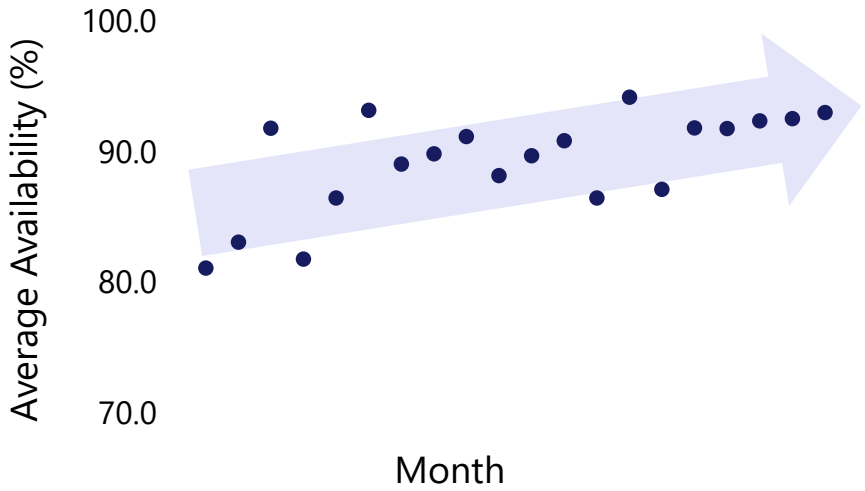
- Improved plasma control extends continuous operation
- Average availability reaches over 90%

Sn-based LPP Light Source



Principle from ISTEQ

Average Availability of All Units



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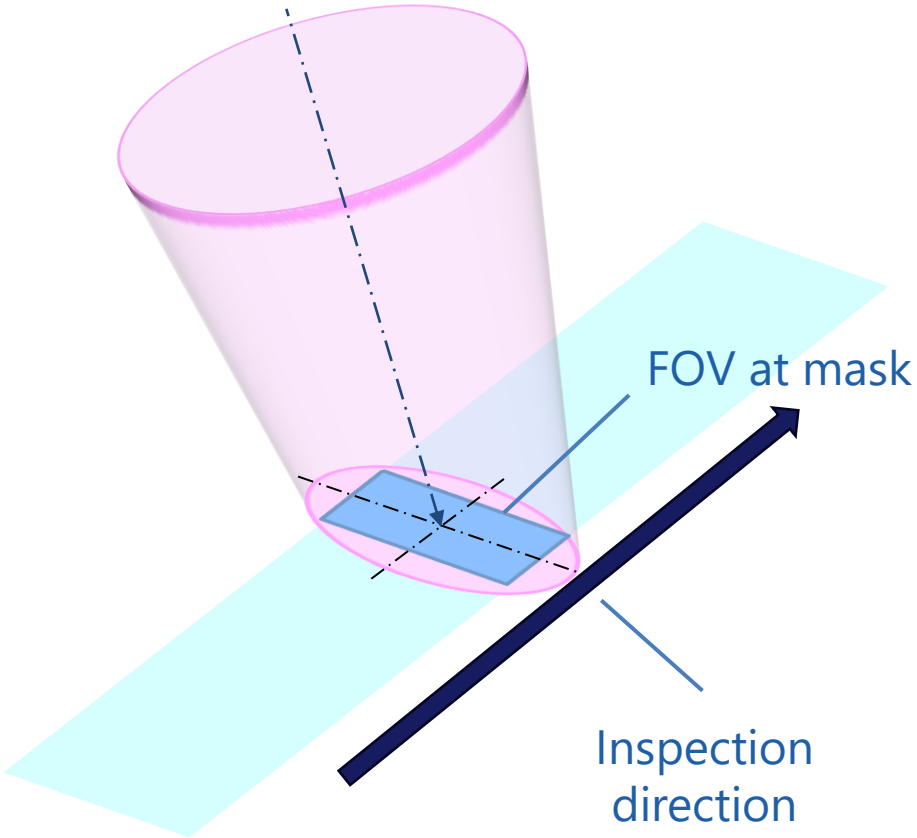
Light Source Requirements for Patterned Mask Inspection



Requirement for APMI

- **Higher sensitivity** for further smaller pitch
- **Large inspection area** for high-speed inspection

Requirement for light source

- **Higher brightness** for high sensitivity
- **Large Illumination** to cover large FOV

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Trade-off Between Uniformity and Efficiency

The balance between uniformity and efficiency is important for large FOV.

Definition

$$\text{Uniformity Index (\%)} = \frac{E_{max} - E_{min}}{E_{max} + E_{min}}$$

E_{max} : Maximum brightness in FoV
E_{min} : Minimum brightness in FoV

Uniformity index indicates the degree of variation in brightness uniformity.
When it is 0, the brightness is perfectly uniform.

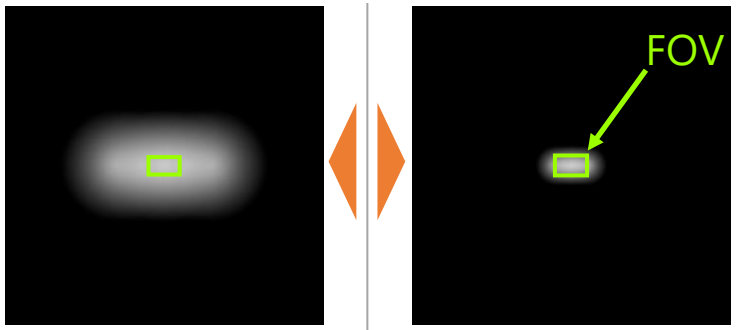
A low figure of uniformity index is required to achieve equal sensitivity in the FOV.

$$\text{Efficiency (\%)} = \frac{\mathrm{P}_{FoV}}{\mathrm{P}_{Total}}$$

P_{FoV} : EUV power in FOV
P_{Total} : Total EUV power on mask

High efficiency is important to minimize the heat load on pellicles.

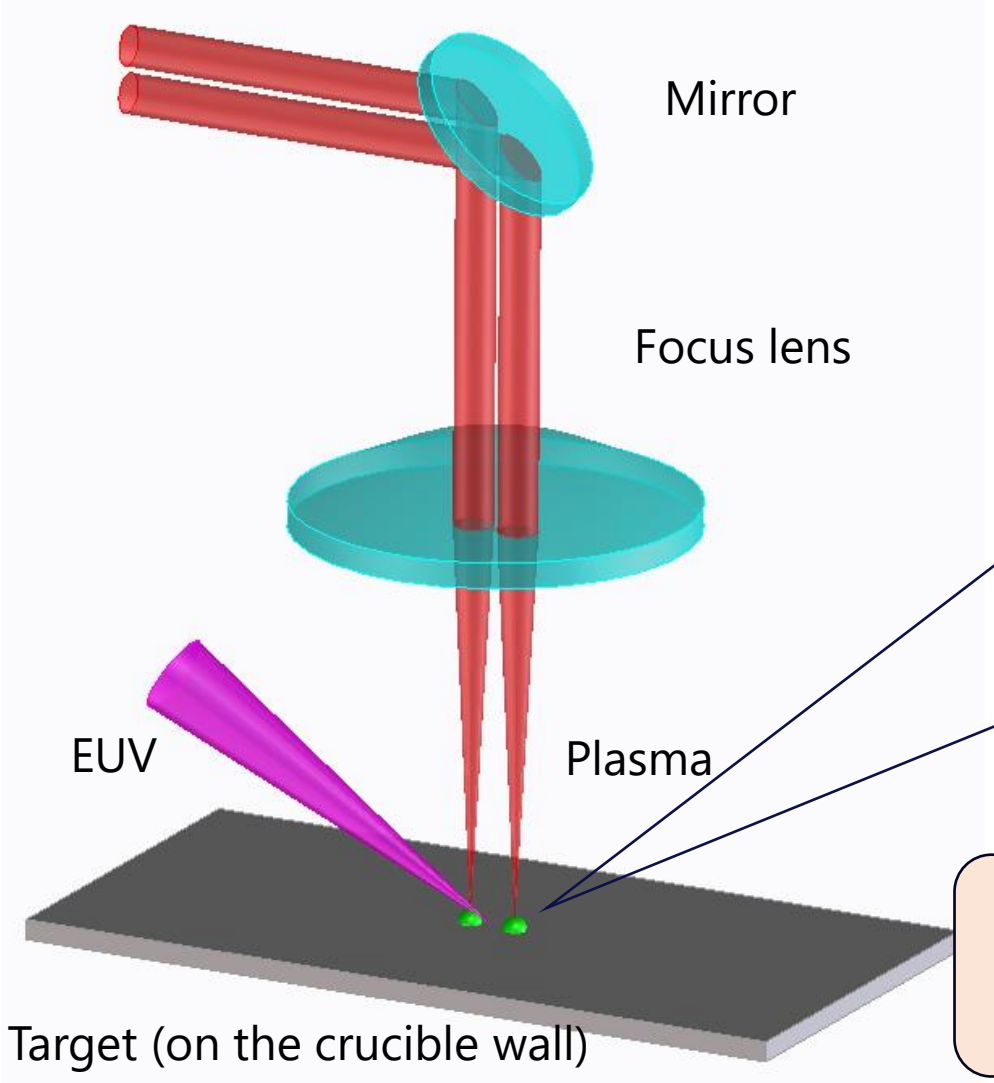
Trade-off between the two factors

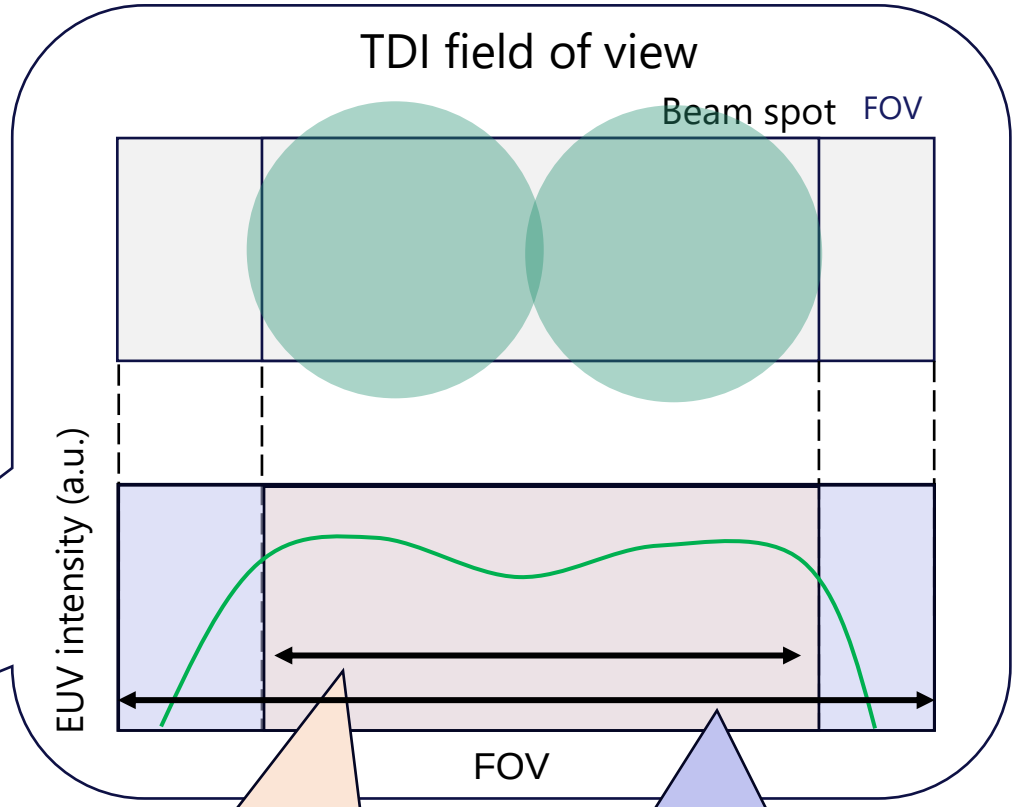
	Large size plasma source	Small size plasma source
Plasma shape at mask	Same power in FOV 	
Uniformity	✓ Easy to achieve low uniformity index	× Needs to be optimized
Efficiency	× Difficult to get high efficiency	✓ Easy to achieve high efficiency

Challenge of a Large FOV

The current model has a configuration that efficiently illuminates the FOV with two beams.

With the current optical design, the uniformity will deteriorate if the FOV is expanded.



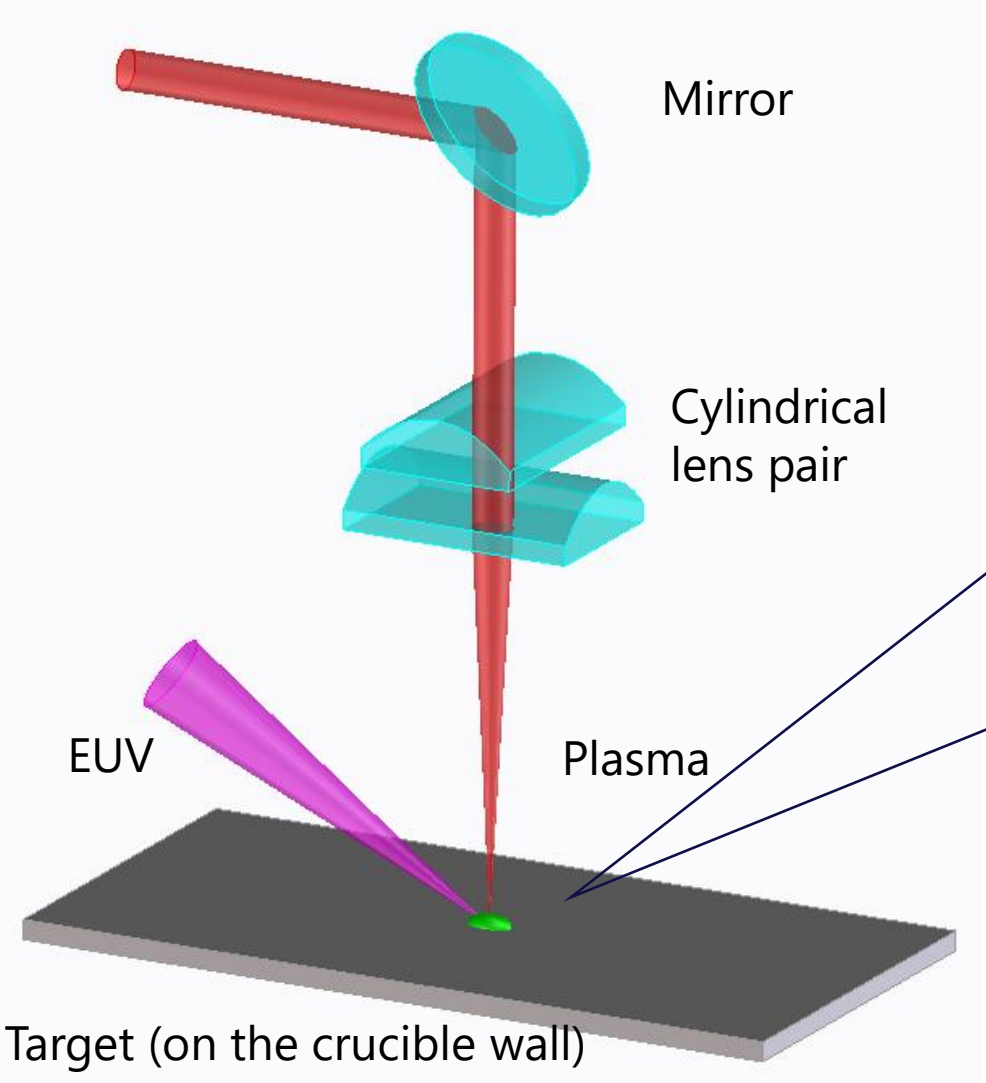


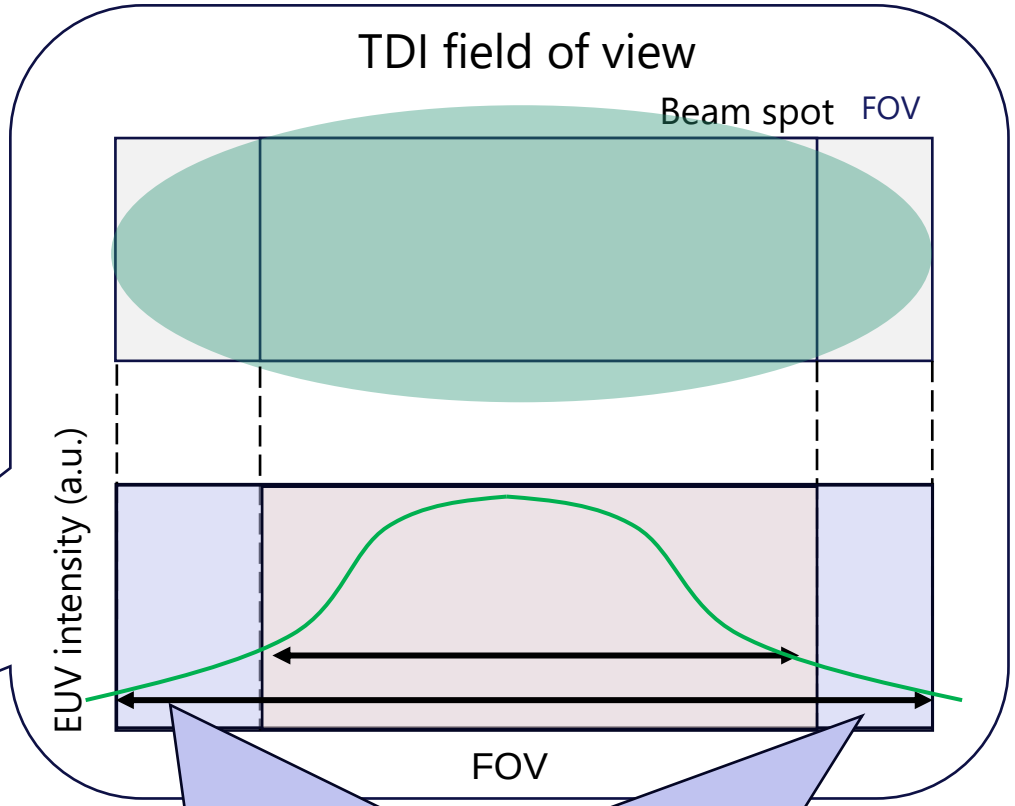
FOV for current model
-> Uniformity ~ 5%

Expanded FOV
-> Uniformity ~ >10%

How to Efficiently Illuminate a Large FOV?

It is important to have a steep gradient at the plasma edge. If you enlarge the plasma using a cylindrical lens, it will make the edges blurry and reduce efficiency.





The gradient of the plasma intensity becomes less steep and the illuminated area outside the FOV increases.

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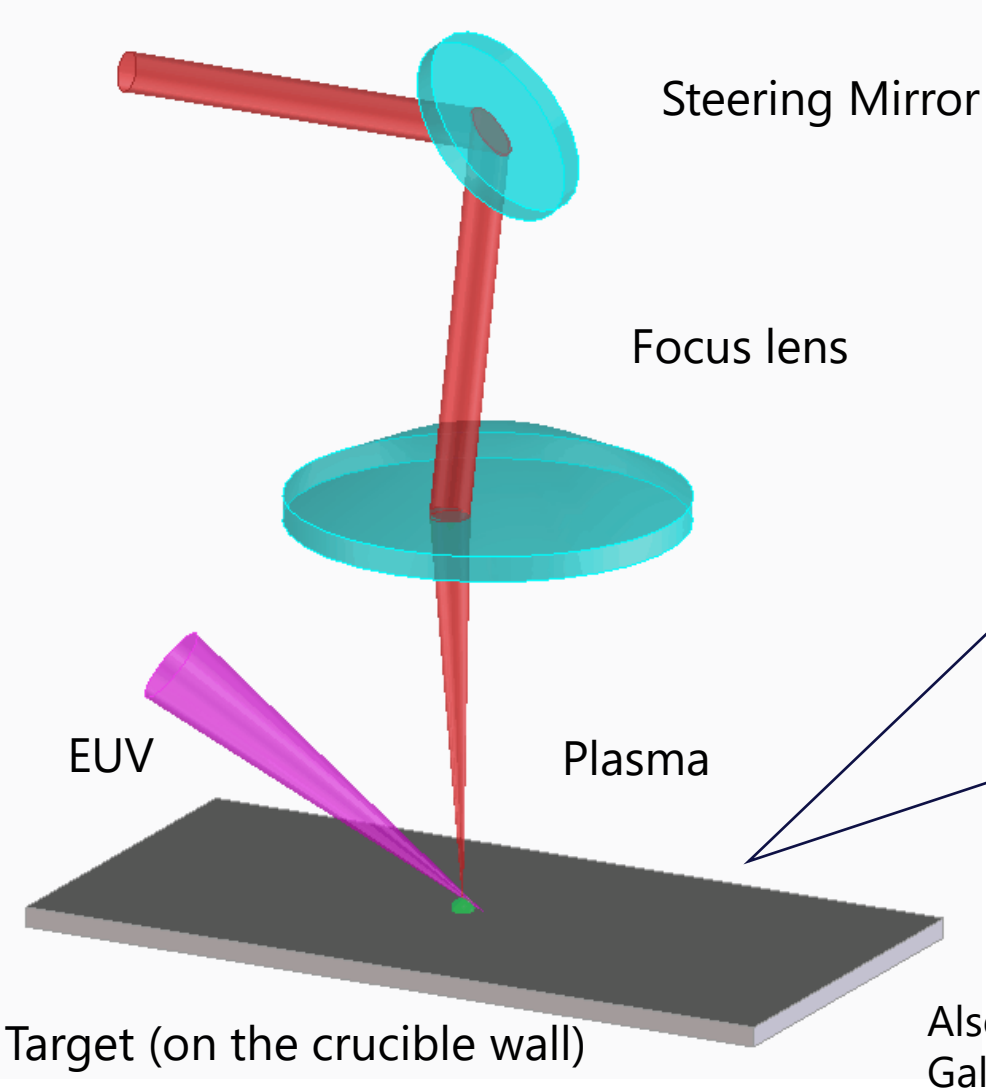
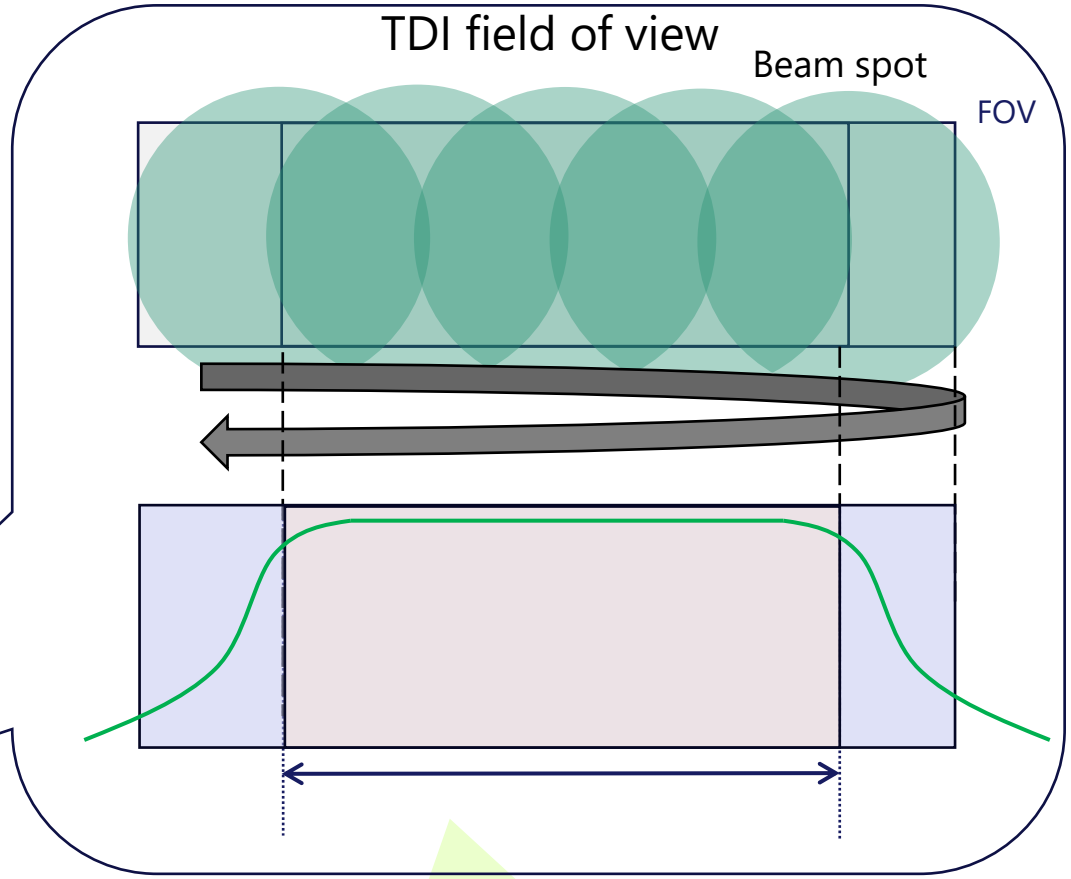
Plasma Shaping by Beam Scanning

The target is on the crucible wall and the plasma shape can be manipulated by simply scanning the beam.





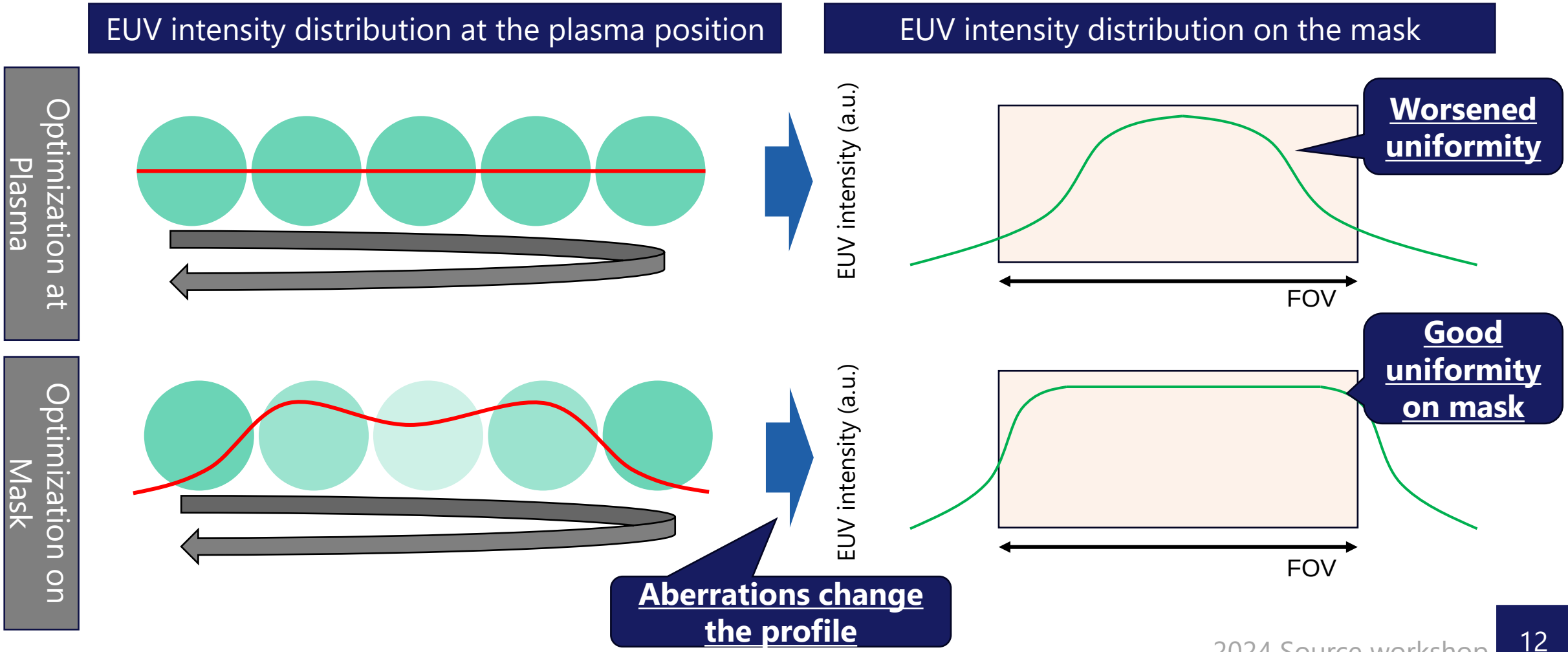
Efficient flat illumination

Also possible with AOM, Galvano mirror

Scan Waveform Optimization

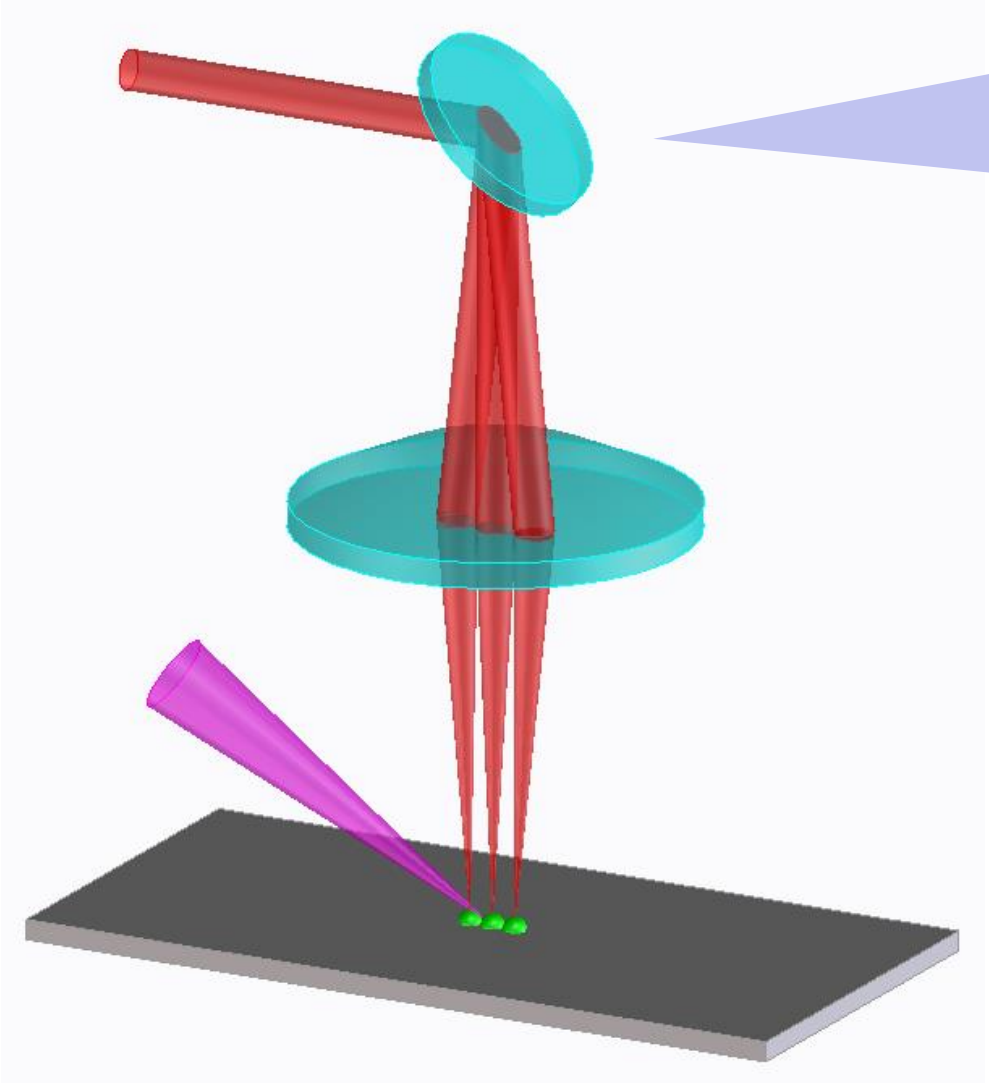
The plasma shape can be optimized by the actuator drive waveform.

Scan waveform optimization can cancel aberrations in the EUV optics.

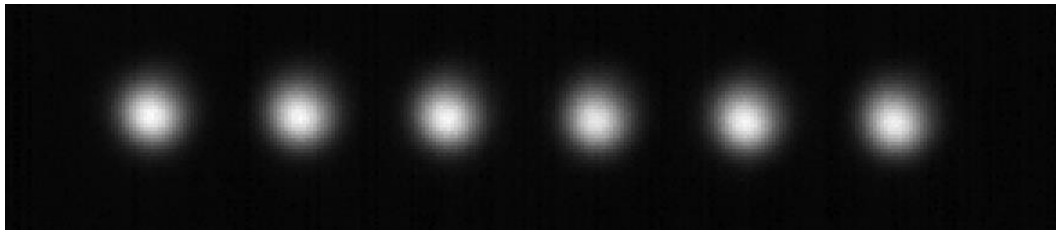


Mirror Scanning System Development

An actuator capable of high-speed scanning using an actuator and its control system have been developed.



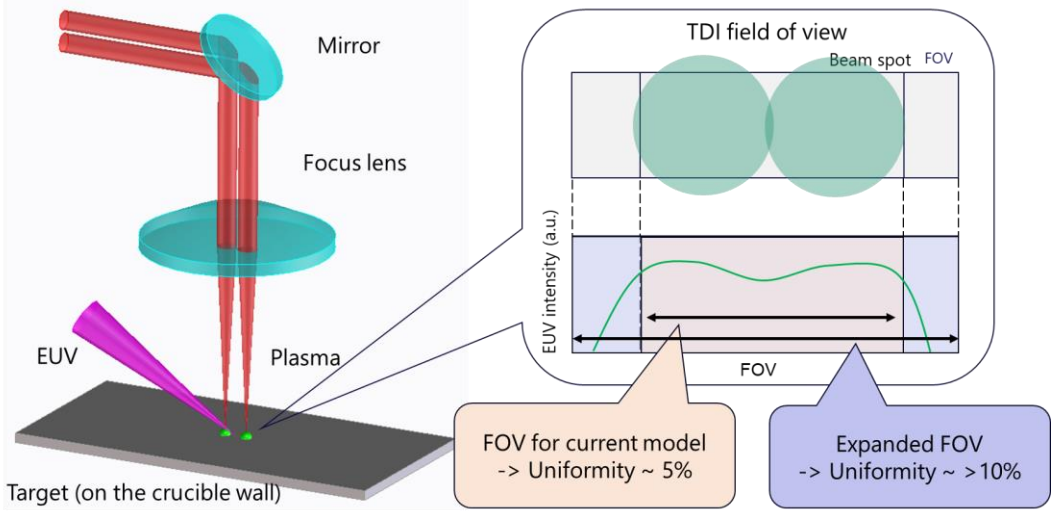
IR Focus spot position change with different stage angle



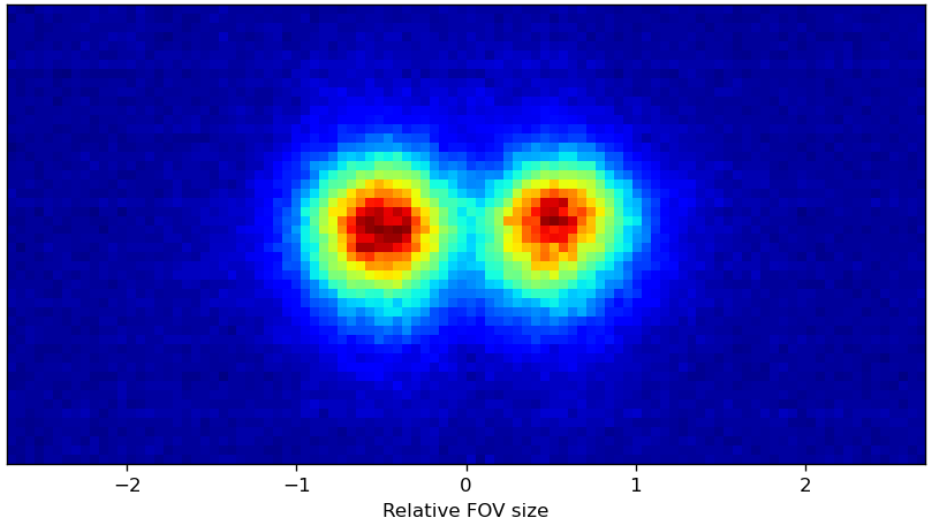
Comparison of Conventional and Scanning Beam Methods

The scanning beam method has achieved a flat plasma shape.

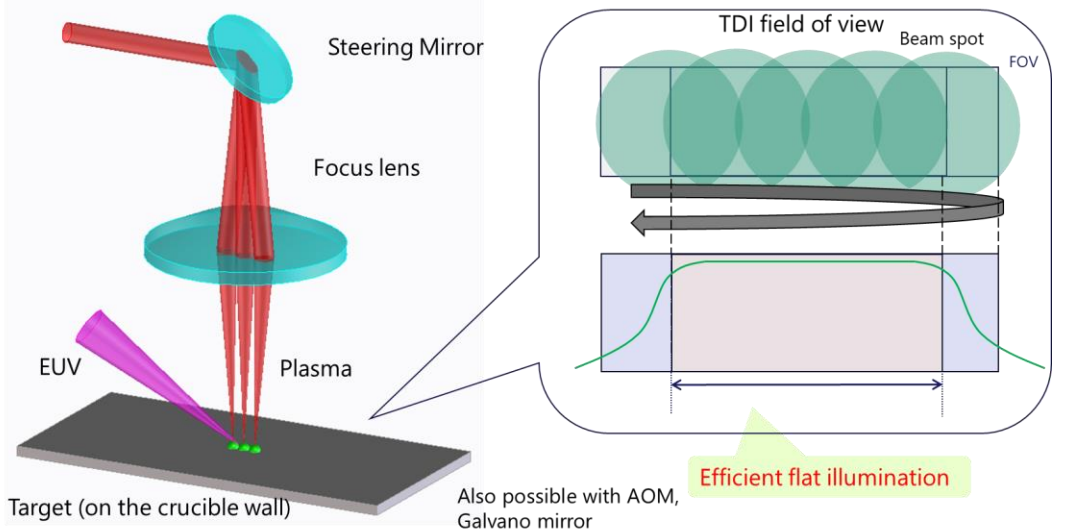
2 beam configuration



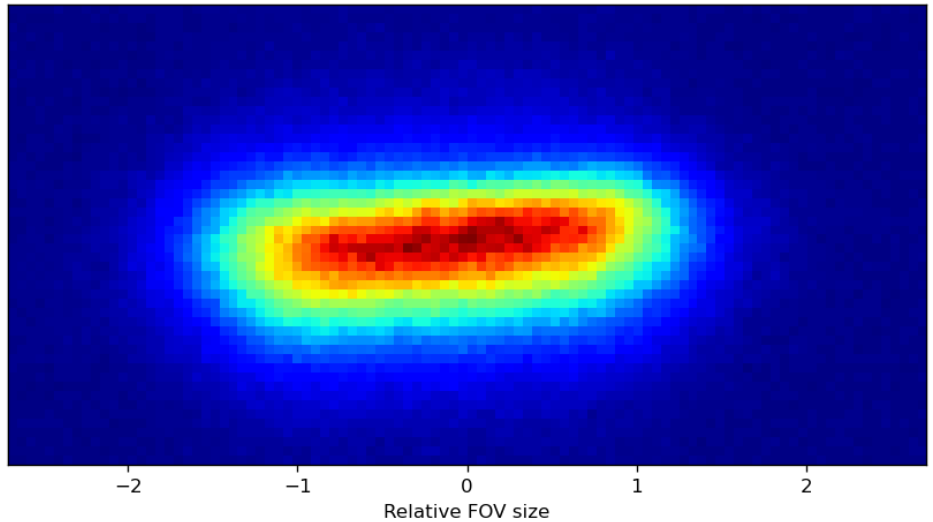
Plasma profile - Two beam



Scan beam configuration



Plasma profile - Scan Beam



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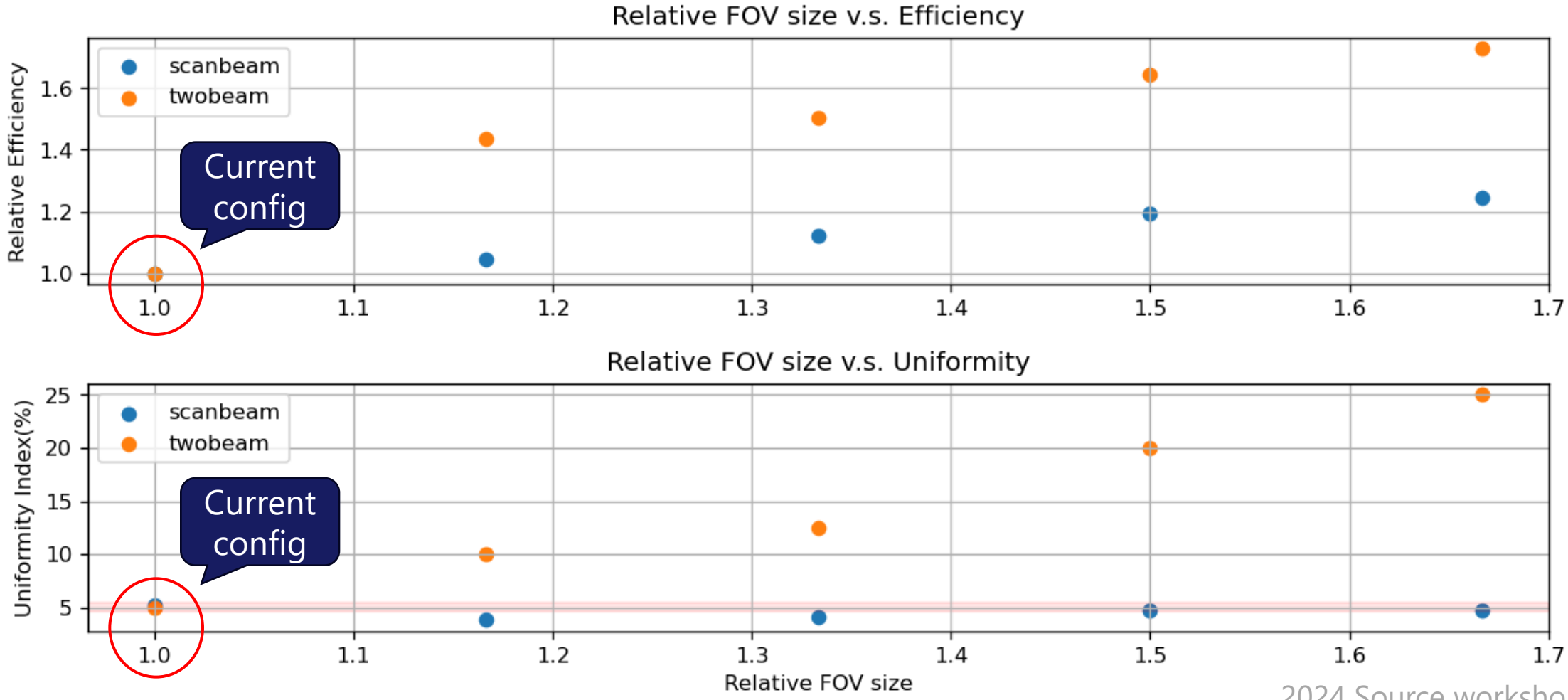
Efficiency and Uniformity of the Expanded FOV

When the field of view is expanded, the efficiency with two beams improves, but the uniformity deteriorates rapidly. With the scanning beam method, both good uniformity and high efficiency can be maintained.

Efficiency (top) and Uniformity (bottom) for Different FOV



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Summary

- **Lasertec is continuing to develop EUV light sources that is suitable for high-NA and high-throughput inspection tools.**
- **Lasertec has developed a beam scanning technology to expand the FOV for future throughput improvements.**
- **We have achieved highly efficient illumination with a high level of brightness uniformity by optimizing the scan waveform of plasma. This light source makes it easy to expand the FOV while keeping the heat load to a minimum.**

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Acknowledgements

- The principle of this light source is licensed by ISTEQ.
- Special thanks to Intel, TSMC, and Samsung for supporting us in developing this light source.

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