

# Coherent EUV source based on High-order Harmonic Generation for Actinic Inspection Tool

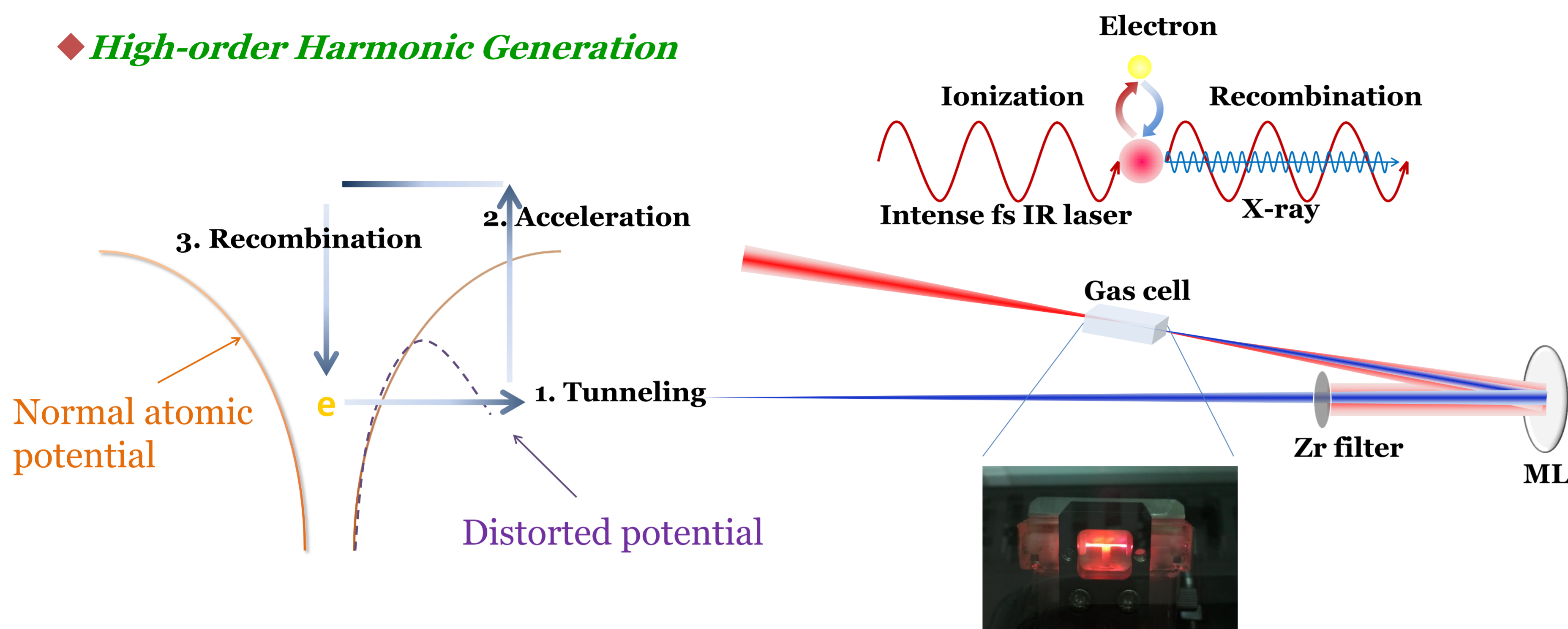
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## Introduction

### High-order Harmonic Generation



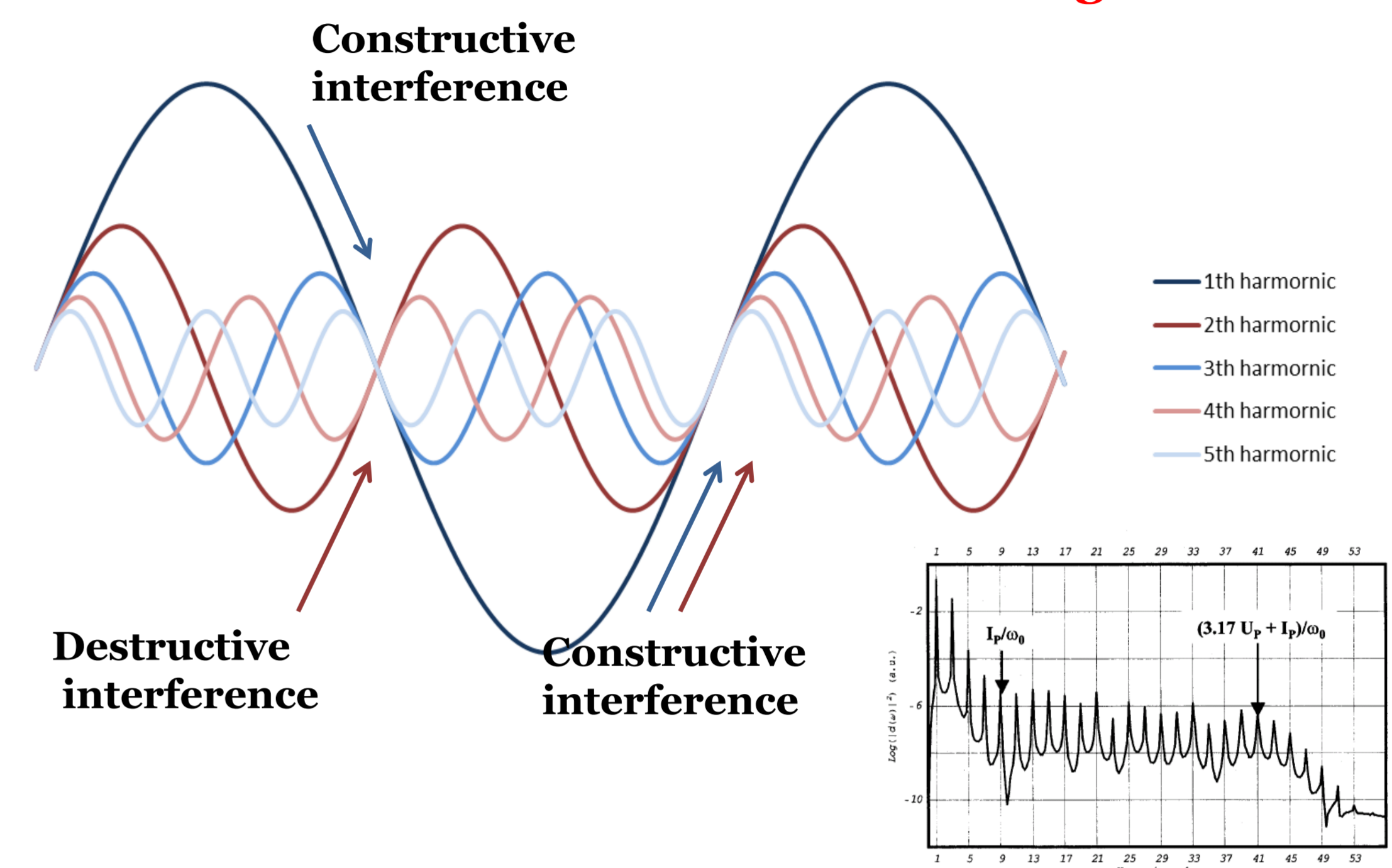
- (1) Laser field induced tunneling ionization
- (2) Acceleration in the laser field
- (3) Recombination & EUV generation

- The high-order harmonics are emitted in a coherent laser-like beam.
- Femto-second pulse width is good for probing ultrafast dynamics.
- Fully spatially coherent 13.5-nm harmonic beam (59th of 800-nm pump laser beam) is best EUV source for EUV mask metrology.

- HHG covers wide spectral range from UV to Soft X-rays.
- HHG shows peaks of odd numbered harmonics

Harmonic order	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>rd</sup>	.....	58 <sup>th</sup>	59 <sup>th</sup>	60 <sup>th</sup>
Wavelength(nm)	800	400	266.6	.....	13.79	13.56	13.33

### EUV generation

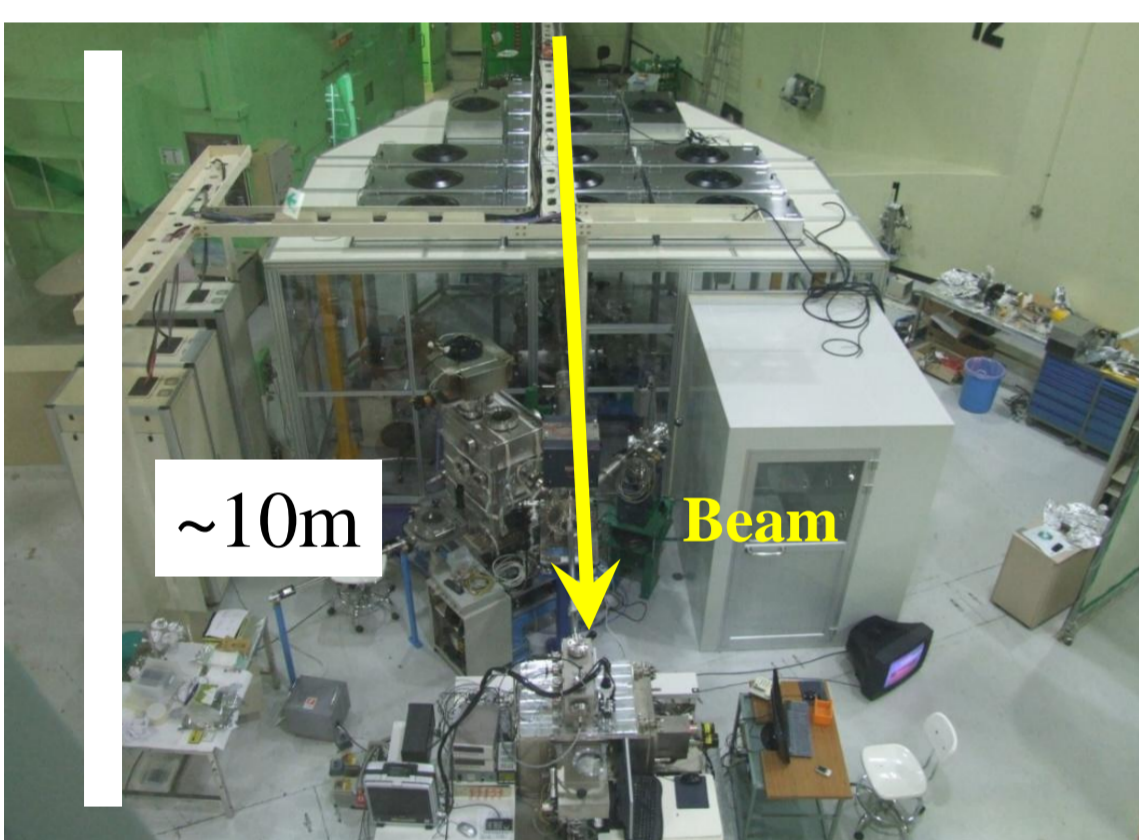


## Facility

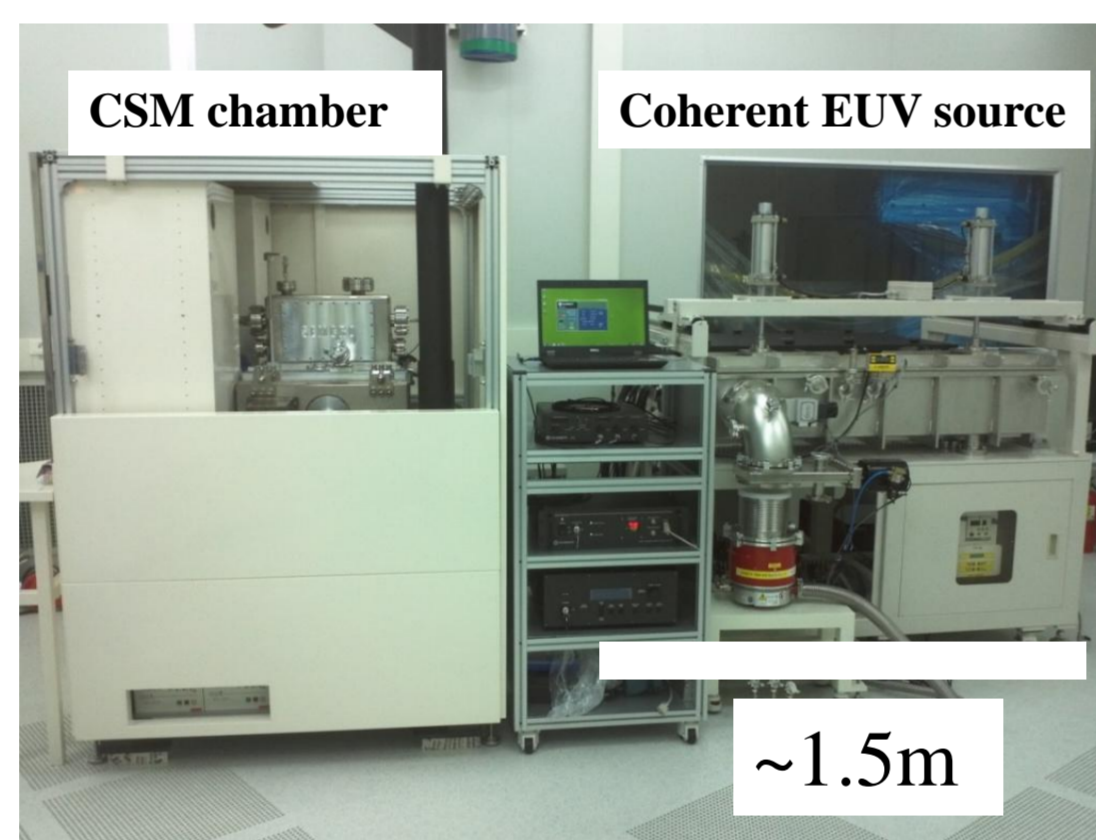
## Source properties

### Stand-alone EUV CSM

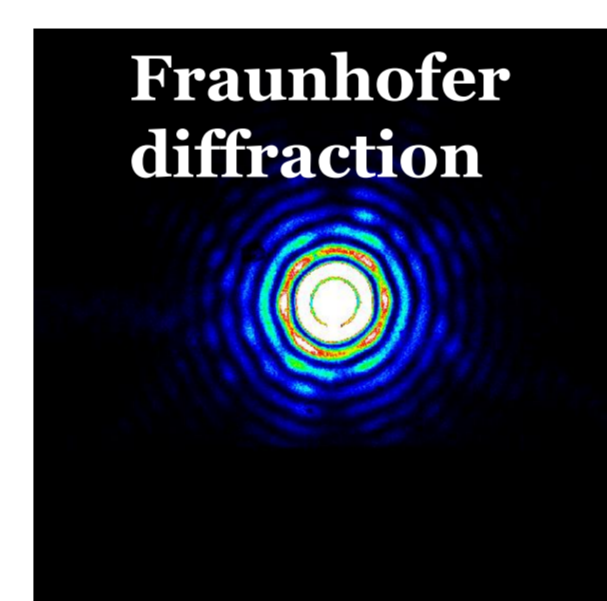
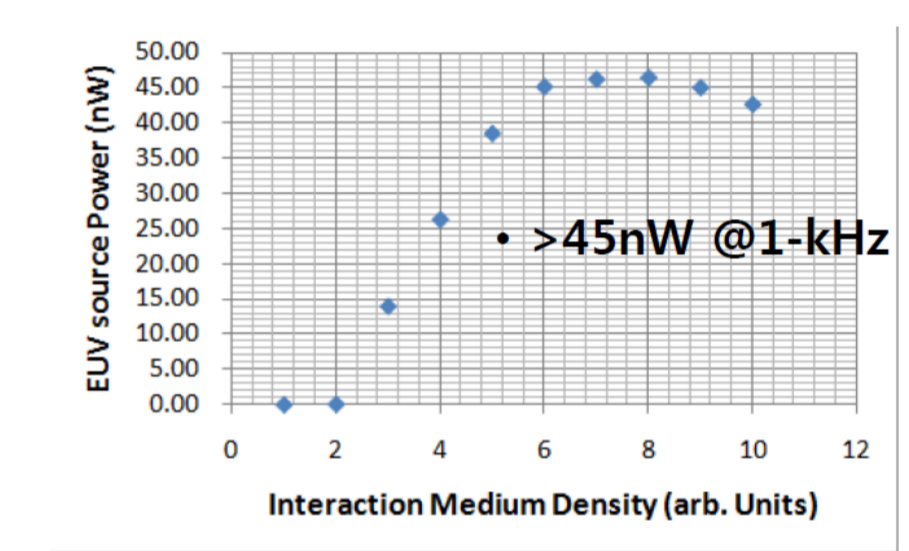
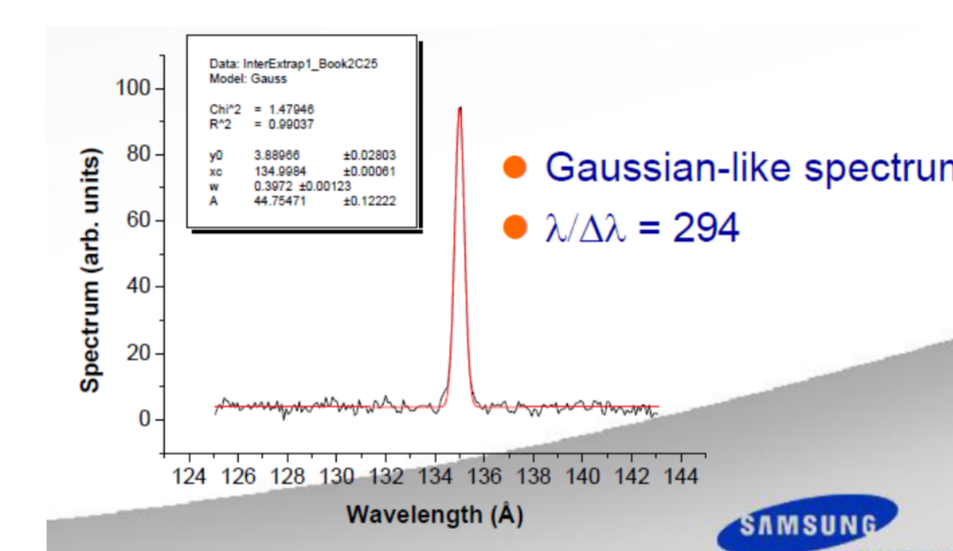
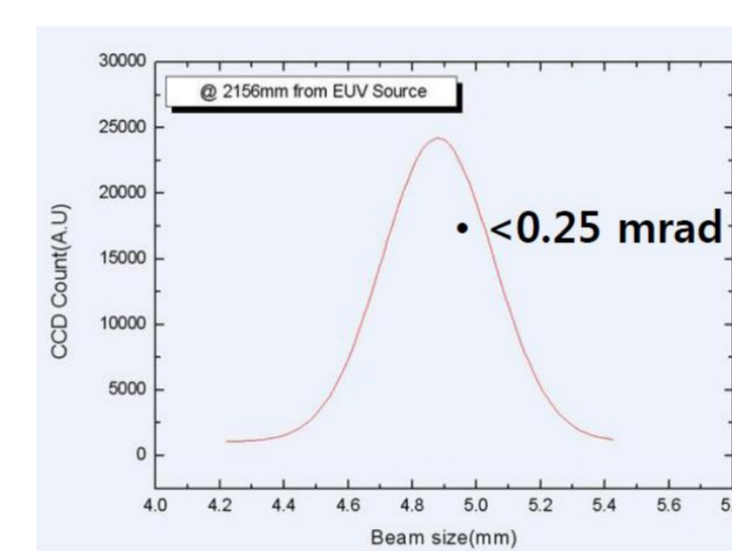
#### 11B EUVL



#### Coherent EUV source

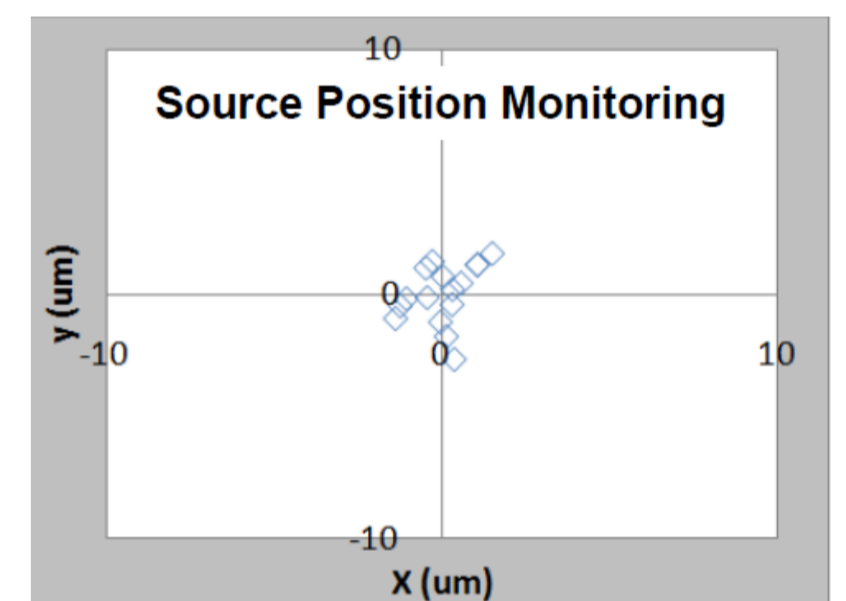
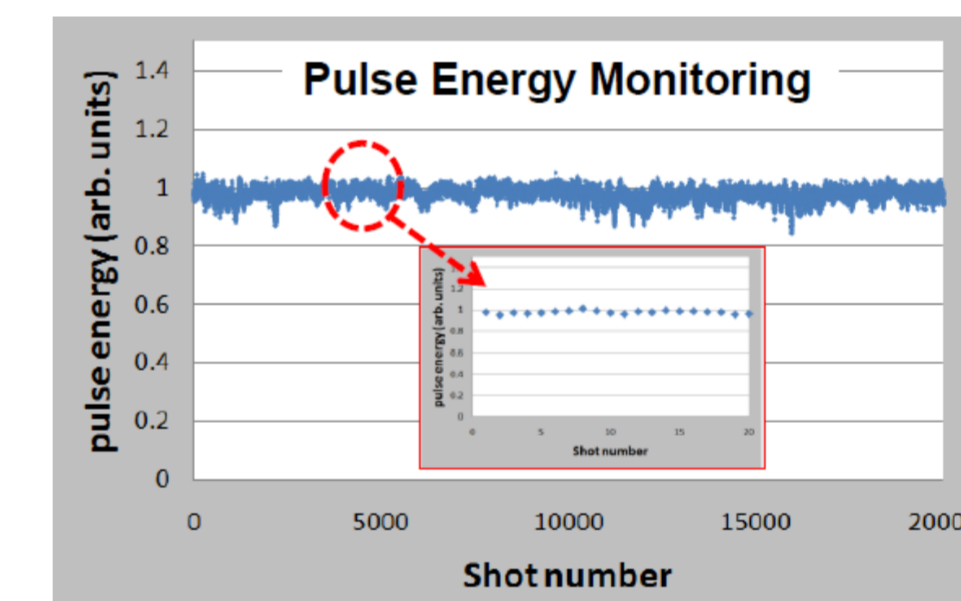


### Source coherence and energy stability



Synchrotron beam

HHG EUV source



- The CSM using the coherent EUV source has built at Hanyang university
- The coherent EUV source has a smaller footprint than synchrotron, so can be easily installed in a fab line

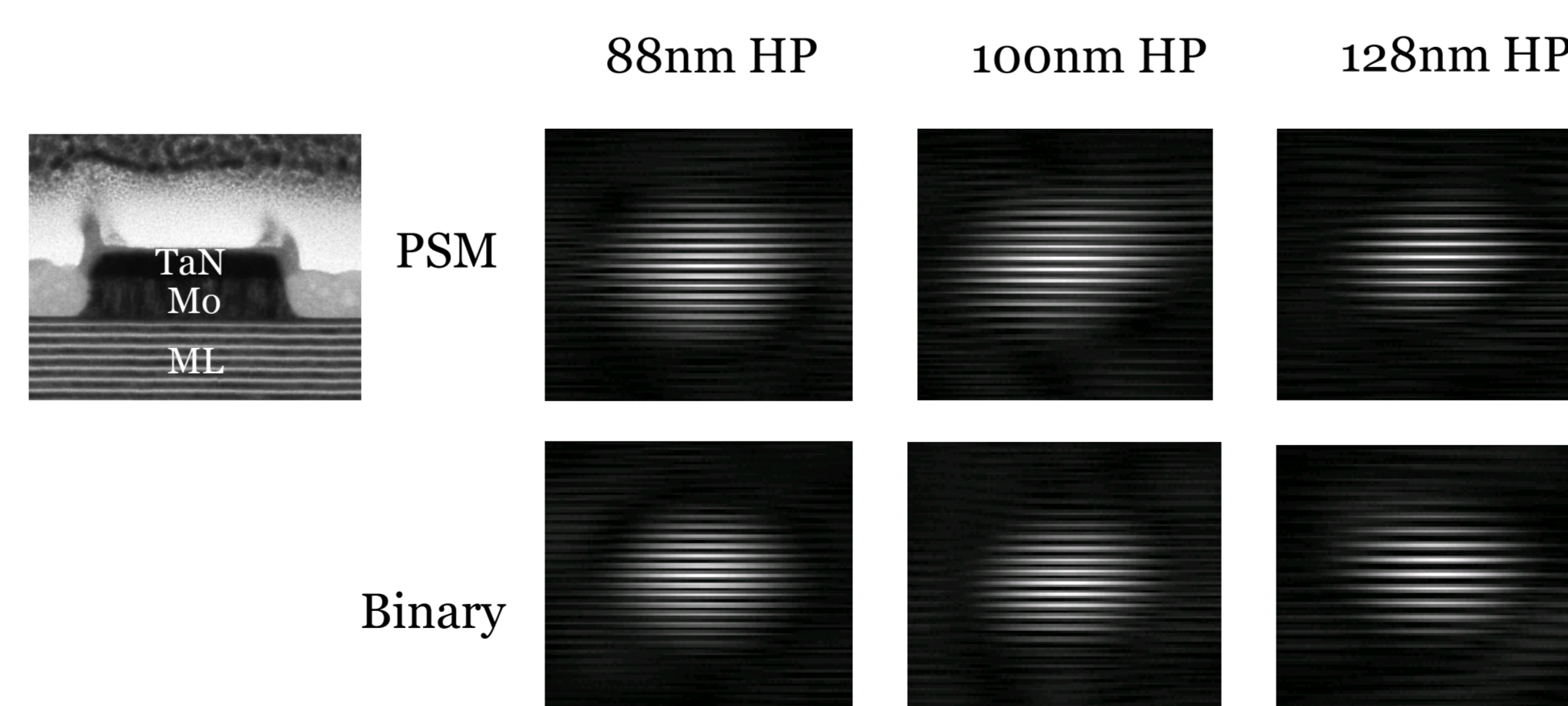
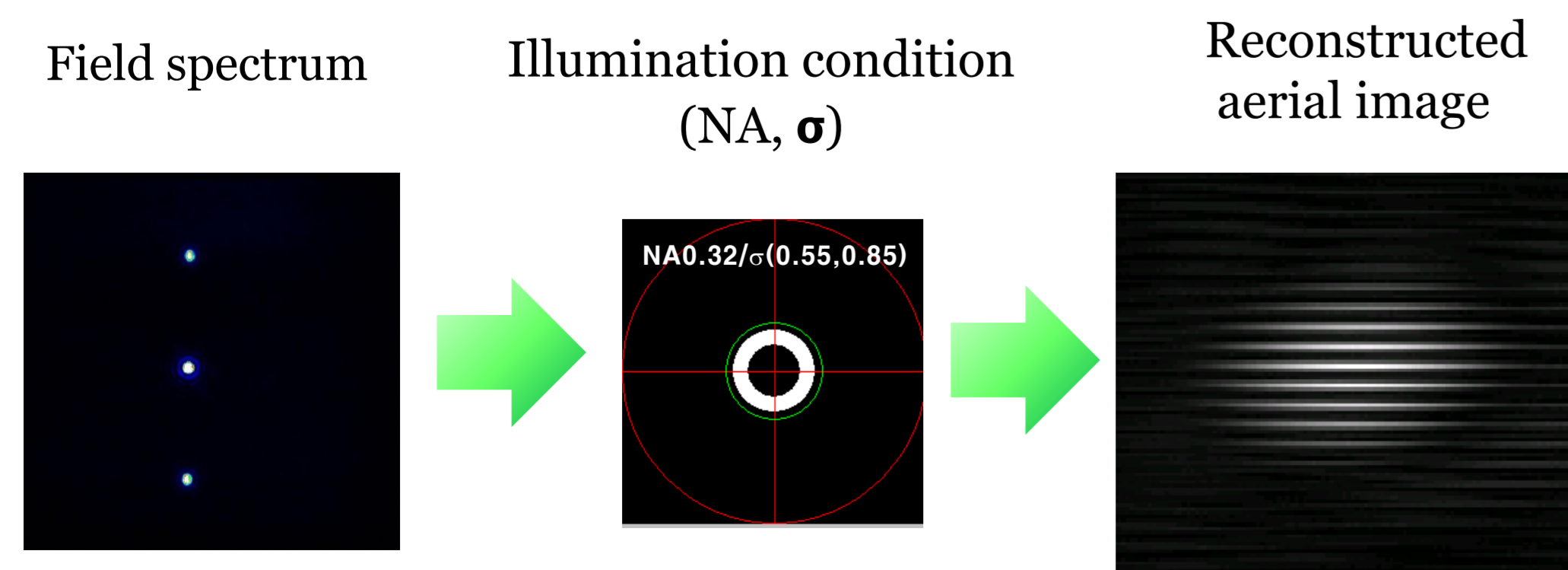
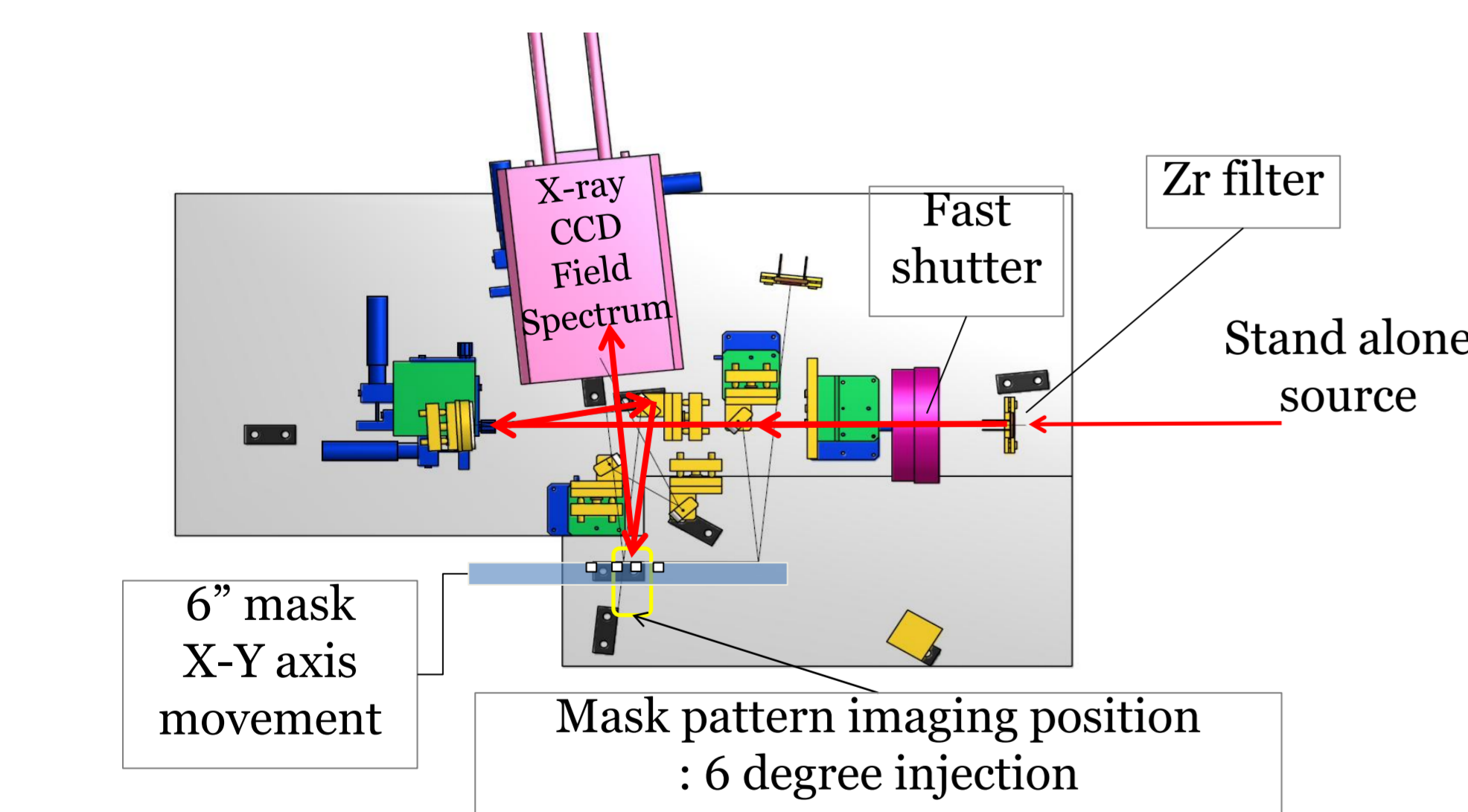
- To achieve spatial coherence, synchrotron used pinhole.
- HHG shows good coherence without pinhole
- Lowest EUV divergence at far-field

- Temporal coherence :  $\lambda / \Delta \lambda = 194$
- EUV power : >45nW at 1kHz
- Shot-to-shot energy stability :  $\sigma = 2.3\%$  (pulse width < 50 fs)
- Shot-to-shot source position stability :  $\sigma_{x,y} < 1.2$  mm, Range < 4.3 um

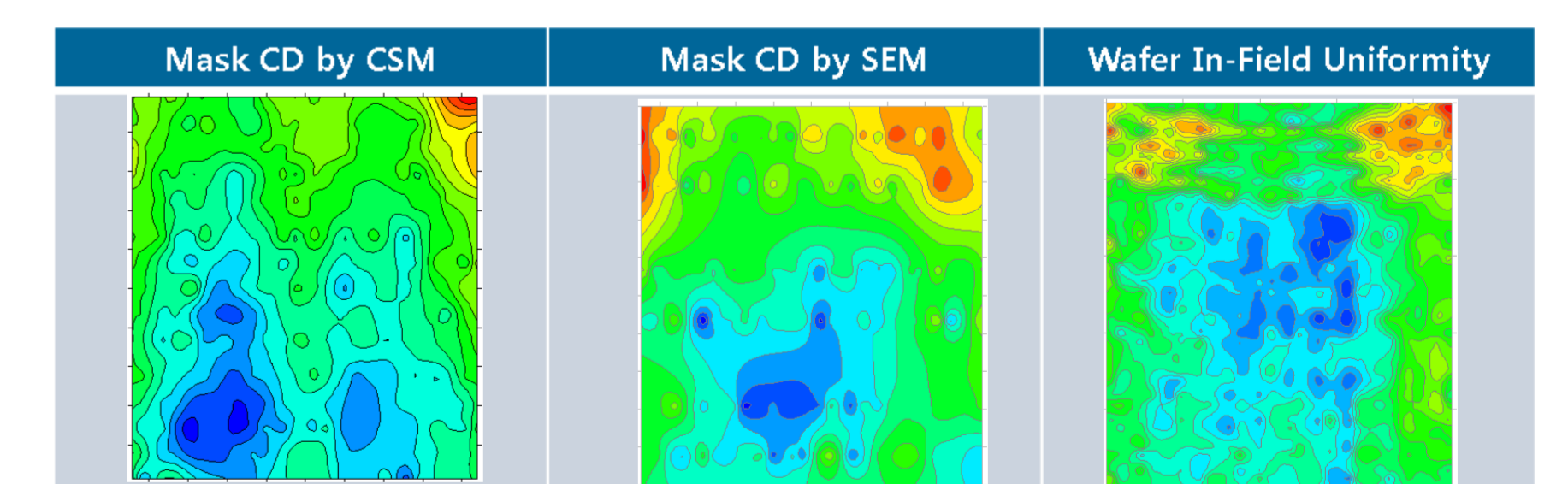
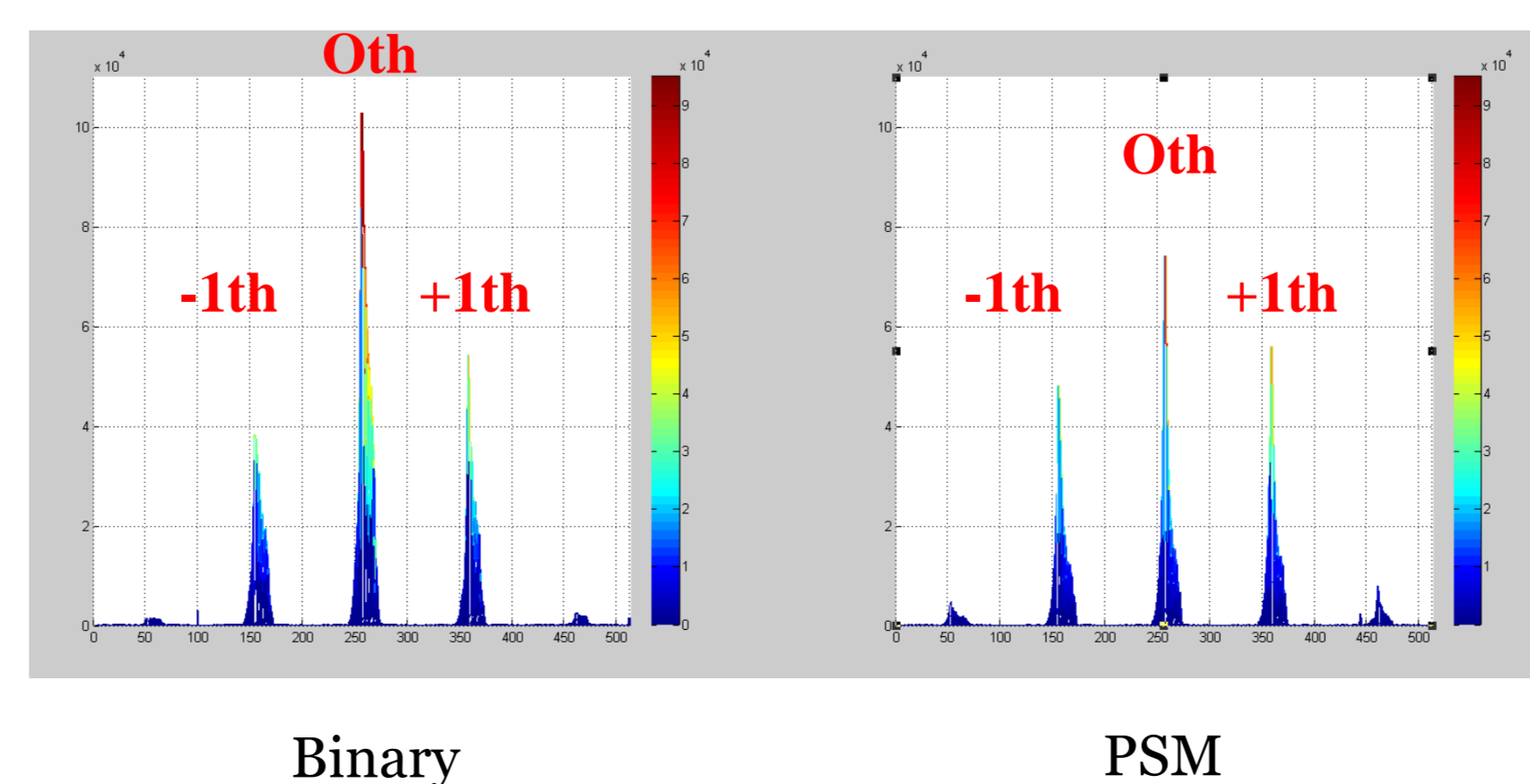
## CSM using HHG

## Actinic CD metrology

### PSM, BIM Aerial images



### Field spectrum Analysis



- CSM result shows good correlation with mask CD SEM and Wafer CD

### Conclusion and future work

- Shot-to-shot source position stability will be improved by quad-photodiode and automatic mirror stages.
- 13.5nm wavelength with good coherence was obtained through HHG with fs laser.
- This small coherent EUV source using HHG is suitable to use for actinic inspection tool in laboratory.
- Actinic inspection results by CSM show good correlation with CD-SEM and wafer CD
- The programmed defect (especially buried defects) will be inspected using CSM.