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Potential application of DLA light source in UV region

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Outline

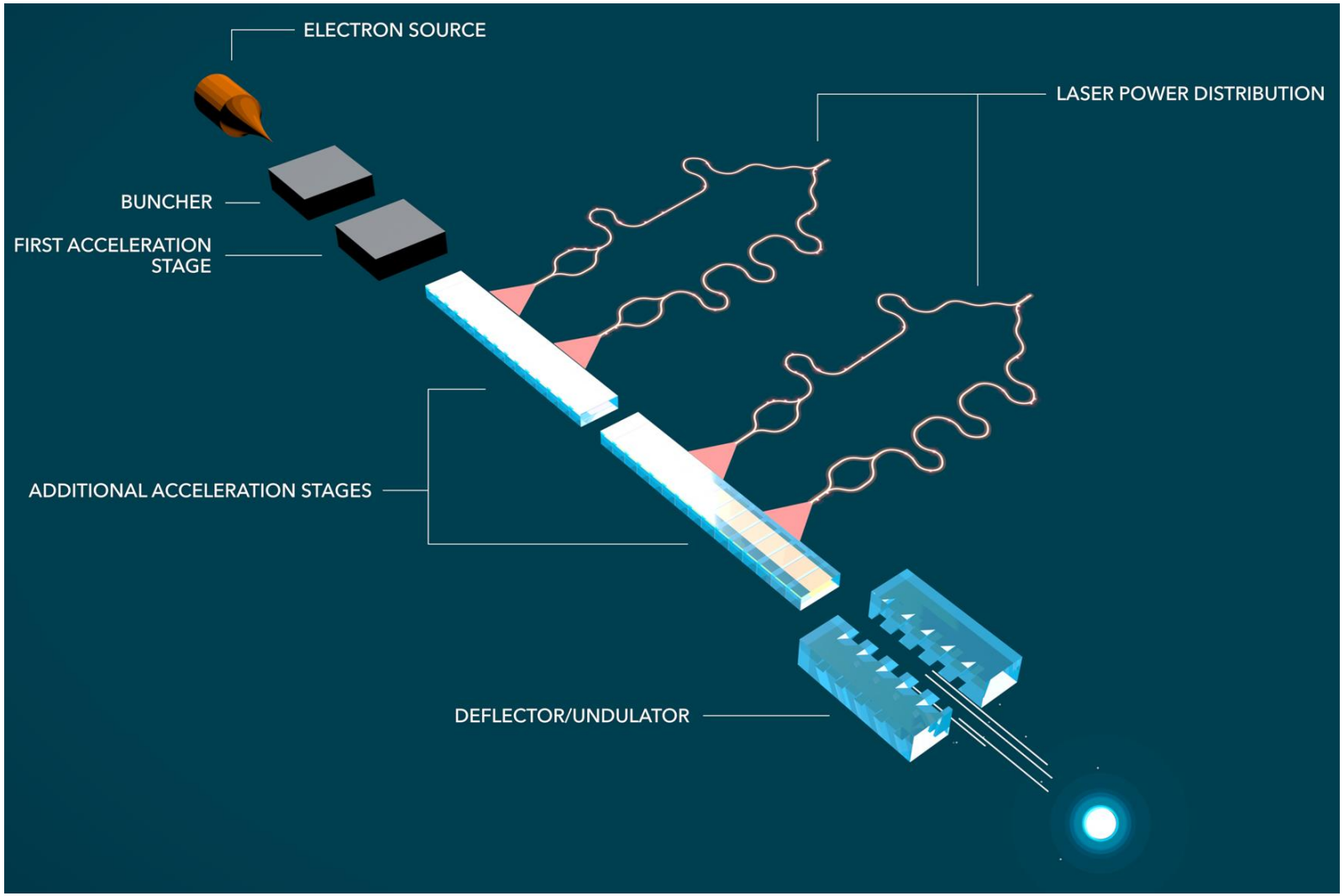
- Interest for new light source

- Why UV region?

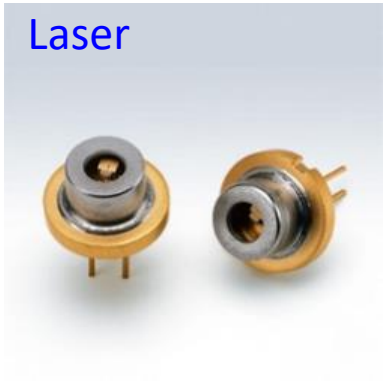
- Potential application example and current EUV technology

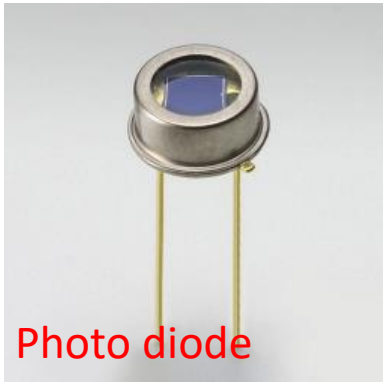
- Brief introduction of compact electrostatic lens for DLA

DLA based light source



Interest for new light source

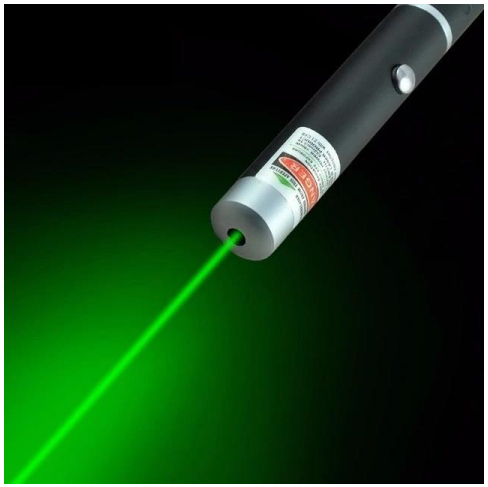




- Manufacture and develop light sources and detector
- Widely interested in new light source

Why UV region?

In Visible and Infrared region, there are so many types of light sources

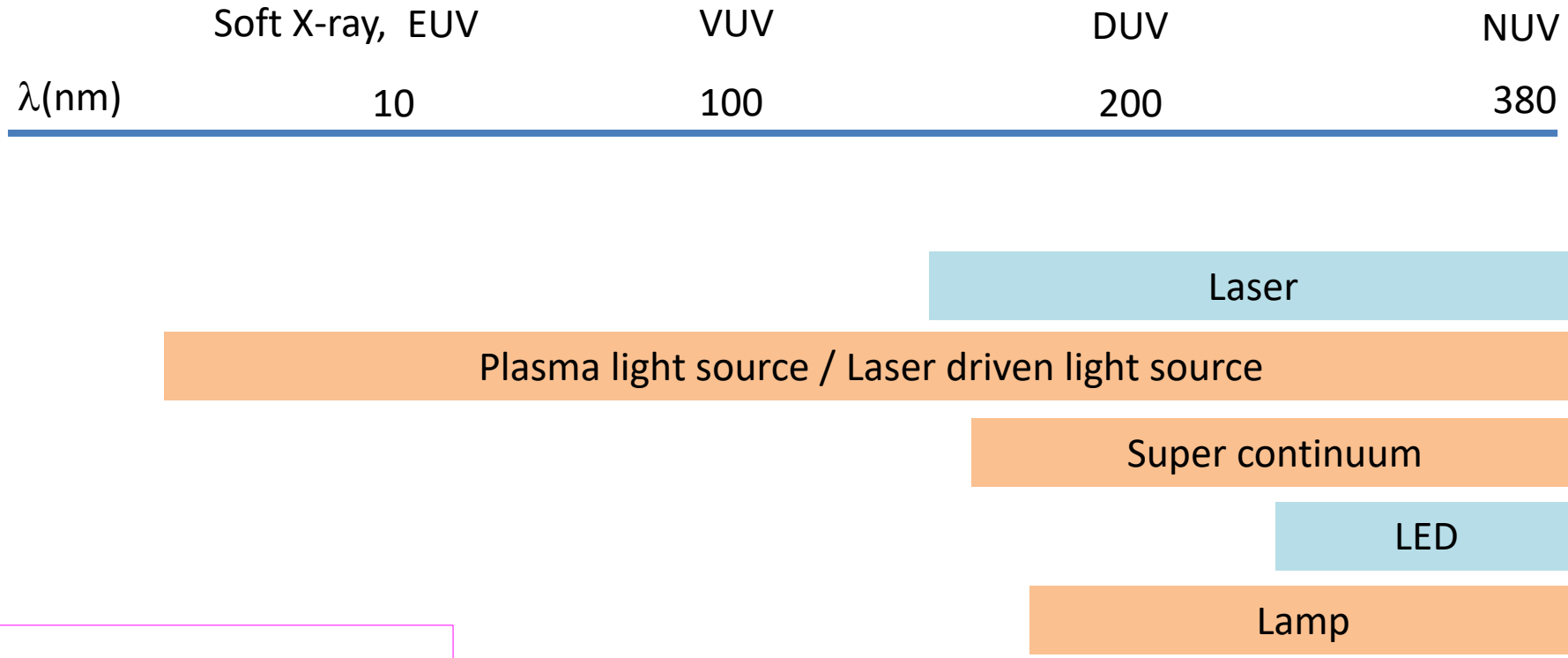


In UV,

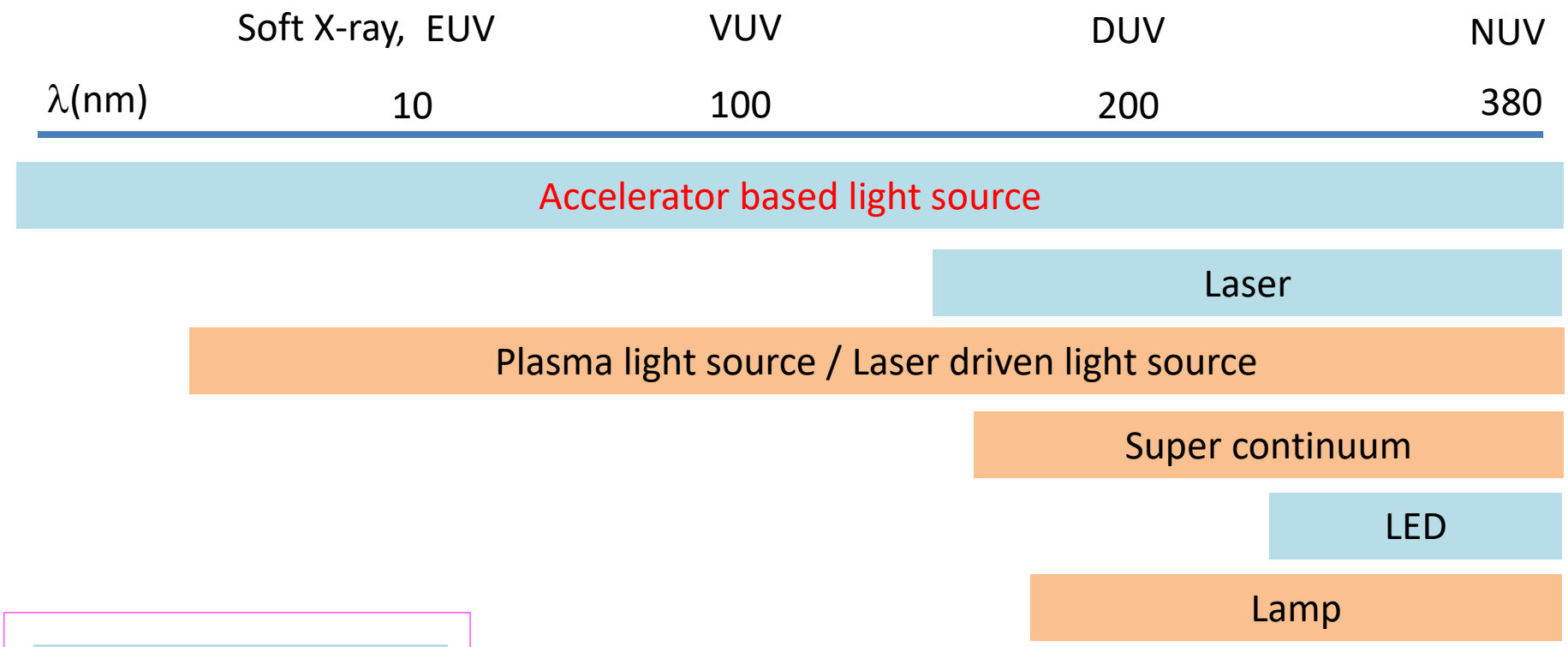
Still frontier to develop new light source especially in shorter wavelength region

- Excitation of UV require high energy process than those of visible and IR
- Material limitation for DUV, VUV, EUV

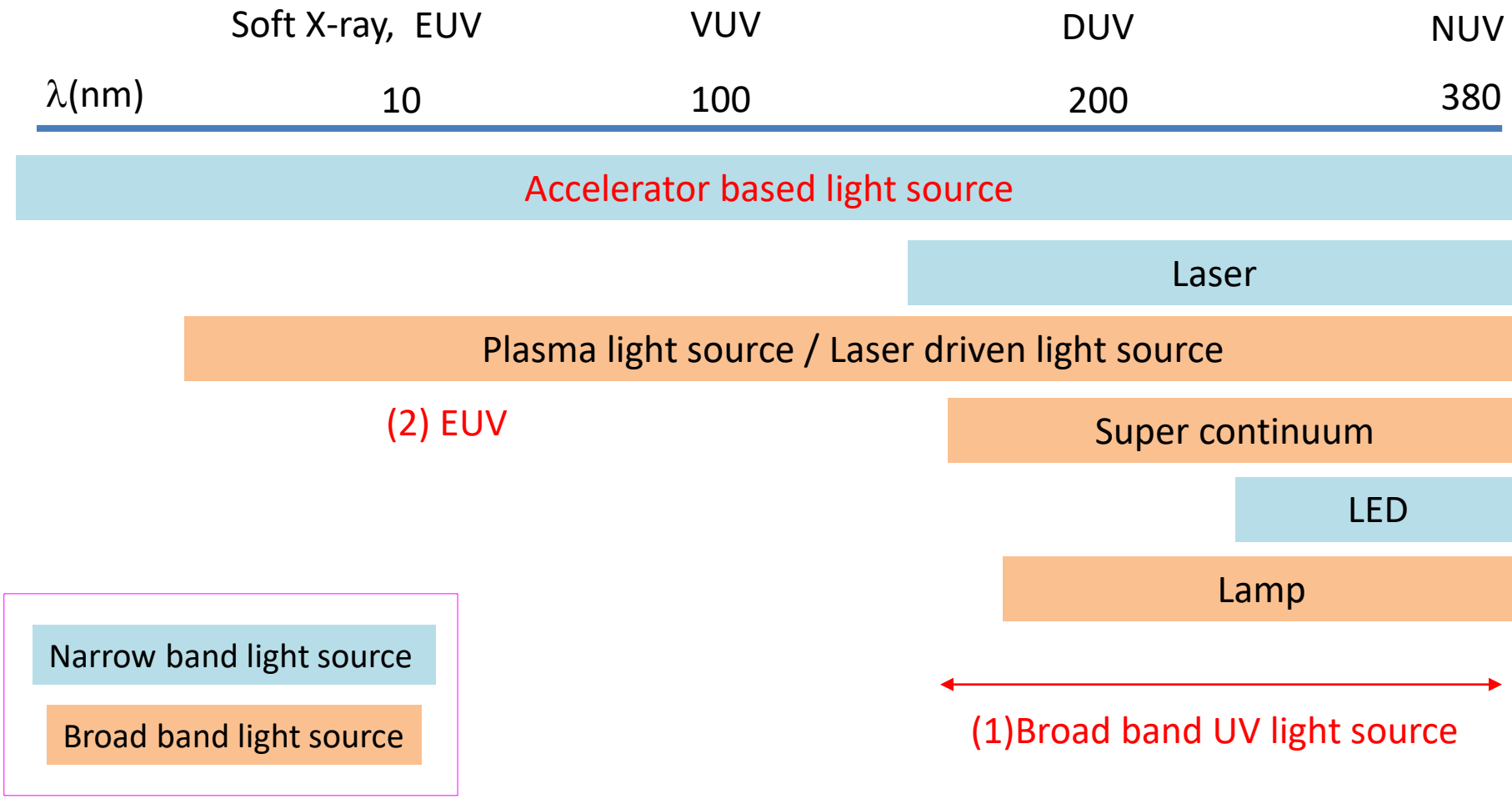
Light source overview in UV region



Light source overview in UV region

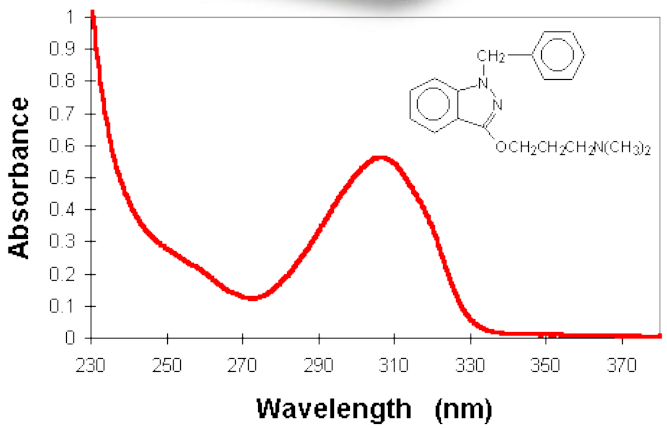


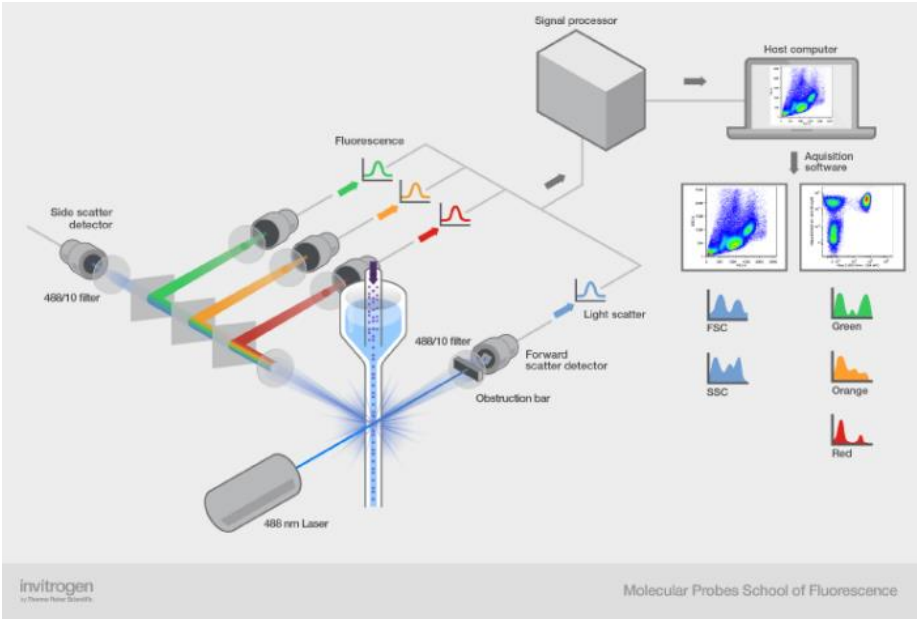
Light source overview in UV region



(1) Broadband UV light source

- Many molecular has absorption in DUV to NUV region
- Applications: spectroscopy, flow cytometry, industrial inspection





- Market of spectroscopy is large and still increasing.
- $17B in 2023

Broad band UV light source (DUV-NUV)

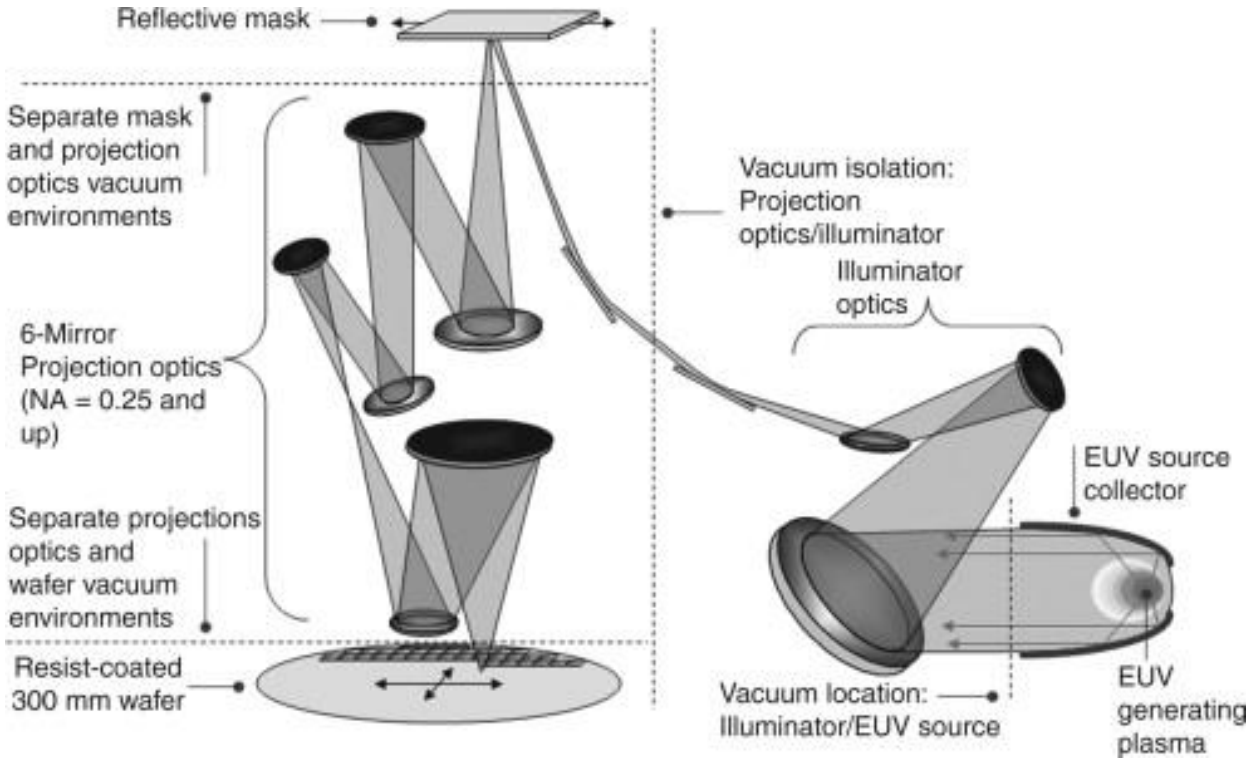
Comparisons of conventional light sources in UV region

	Super continuum light source	Laser driven light source	Xe lump
Approximate relative brilliance in UV region	1000	10	1
Source size (mm)	0.001-0.01	0.1-0.2	1-3

Higher brilliance than Super continuum is interested

(2) EUV

- Most important applications are semiconductor lithography and inspection

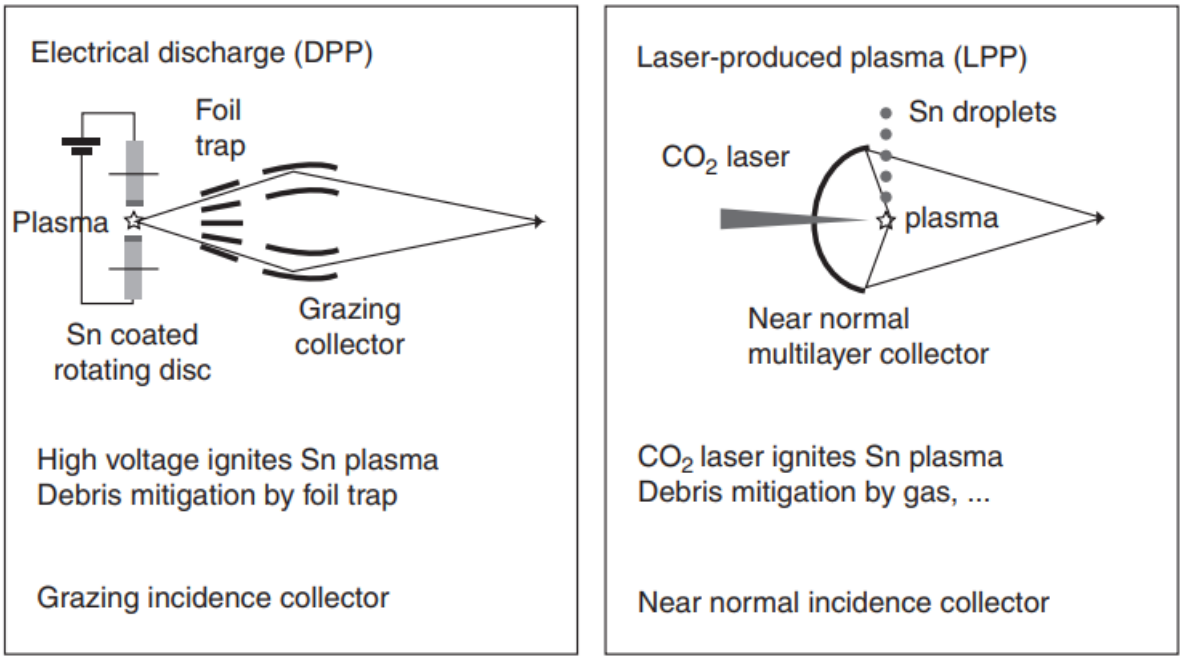


The Art of Fabricating Nanoelectronic and Nanophotonic Devices and Systems 2014, Pages 42-79

EUV (13-14 nm) light source

Current technology

- Plasma source

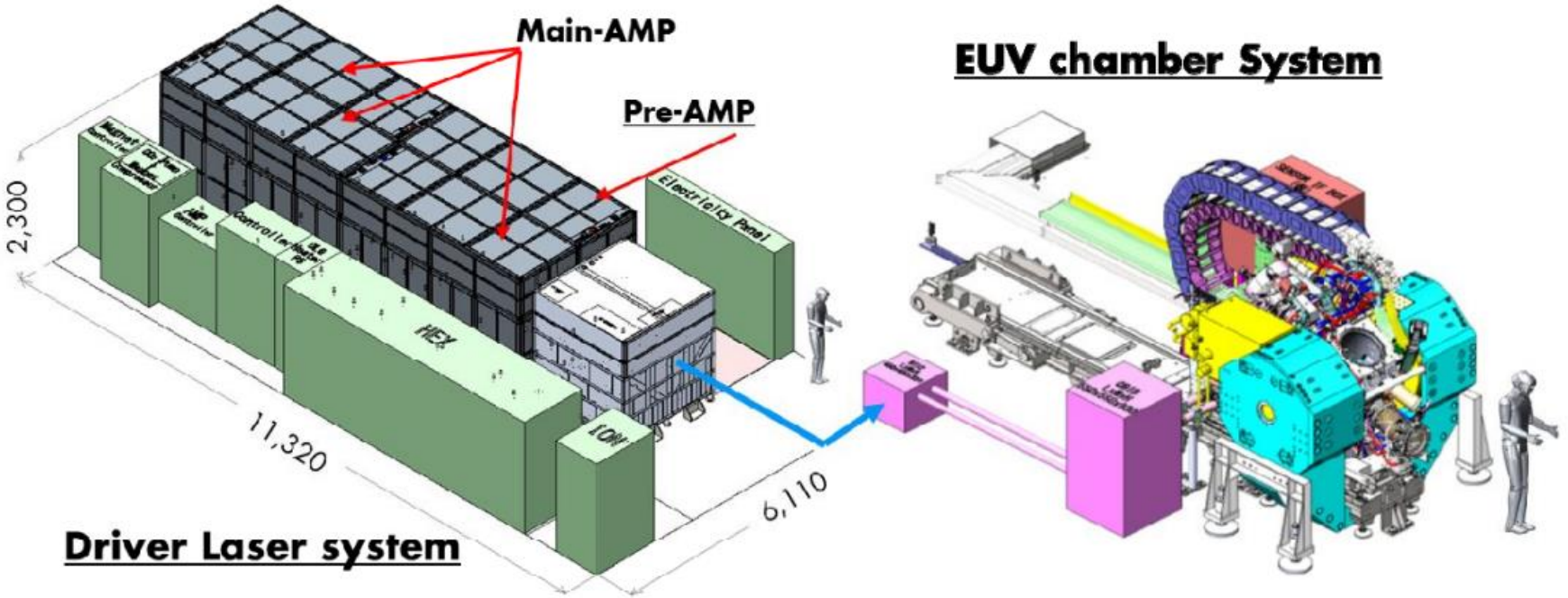


2.4 Typical configurations for LPP and DPP EUV sources. (*Source*: ASML.)

The Art of Fabricating Nanoelectronic and Nanophotonic Devices and Systems 2014, Pages 42-79

- Accelerator

Current EUV source: LPP



Yoshifumi Ueno et al, "Key components development progress updates of the 250W high-power LPP-EUV light source," Proc. SPIE 10583, Extreme Ultraviolet (EUV) Lithography IX, 1058328 (19 March 2018);

- High power (250 W) for EUV lithography
- Large foot print

Accelerator EUV source

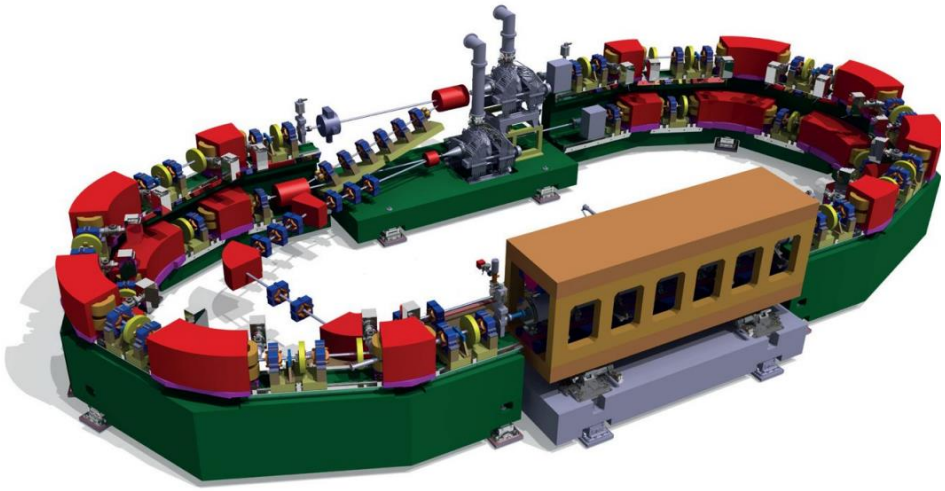


Figure 1. 3D mechanical integration of COSAMI (COmpact Source for Actinic Mask Inspection).

Table 1. Basic parameters of the source.

Wavelength	13.5 nm
Flux	~100 mW
Brilliance	~ 10^9 W/(mm^2·sr)
Bandwidth	0.5%
Beam energy/beam current	430 MeV/150 mA
Pulse structure	~50 ps every 2 ns
Beam stability	0.1%
Availability	>95%
Reliability	<1% downtime
Footprint	5m × 12m

Yasin Ekinci et al, "A high-brightness accelerator-based EUV source for metrology applications," Proc. SPIE 10810, Photomask Technology 2018, 108100W (8 October 2018);

- 100mW for EUV metrology
- Large foot print

Key point

- High efficient and compact source

“Compact” means....

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"Compact" means....

Like this.

EUV output

- Inspection of EUV photo mask (least requirement)
  > 10^10 photons/s,
  In general inspection,
  - Data acquisition rate > 100 MHz
  - Photon in one pulse is approx. 100
    for sufficient S/N on detector

My optimistic estimation:
- Single DLA has only small current but it is very compact
- Multi channel DLA or stacking DLA unit will output larger power for industrial application

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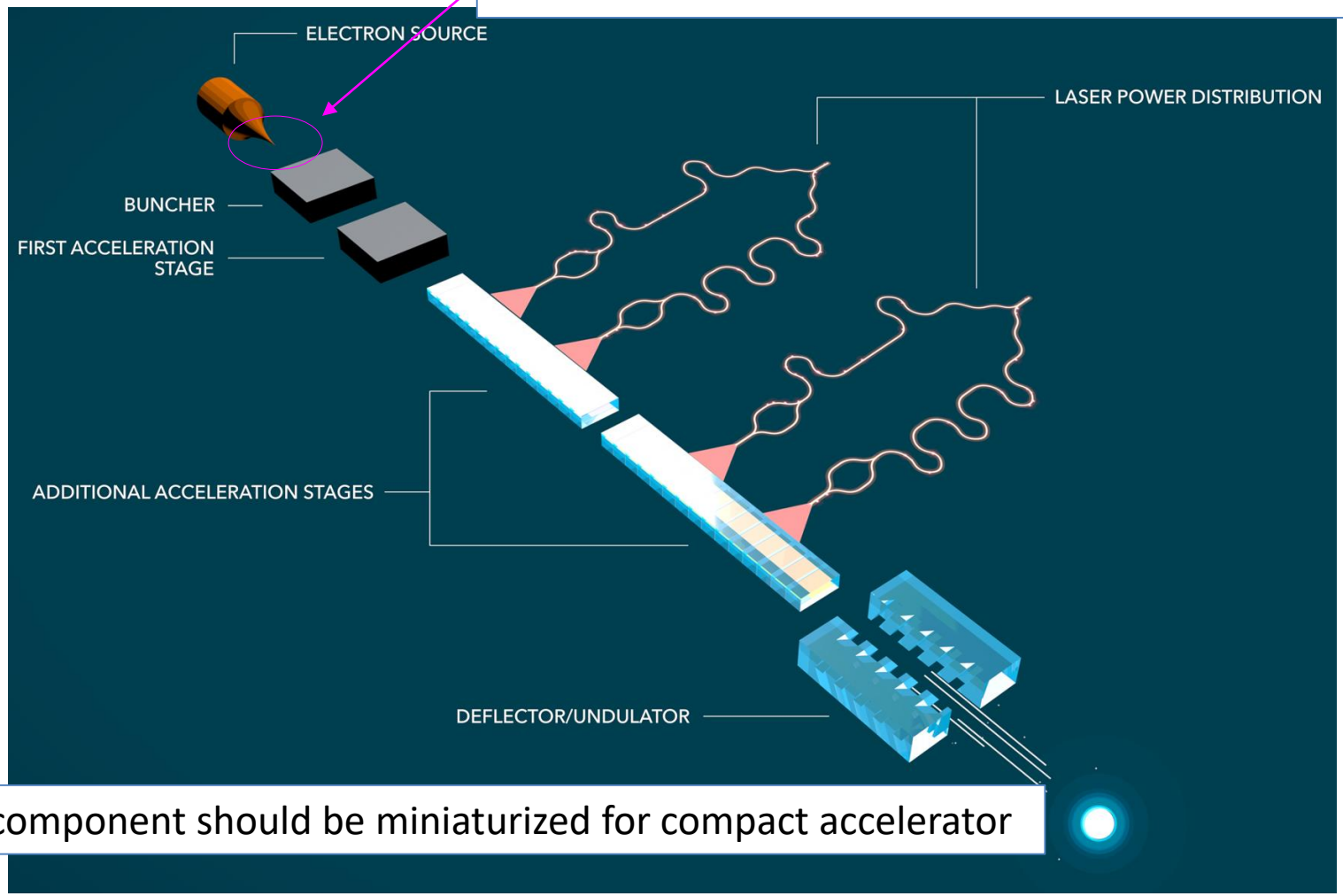
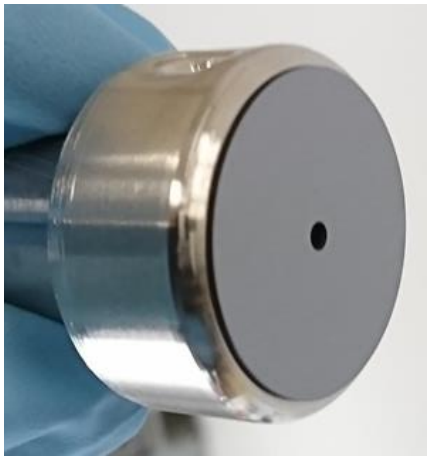
DLA based light source

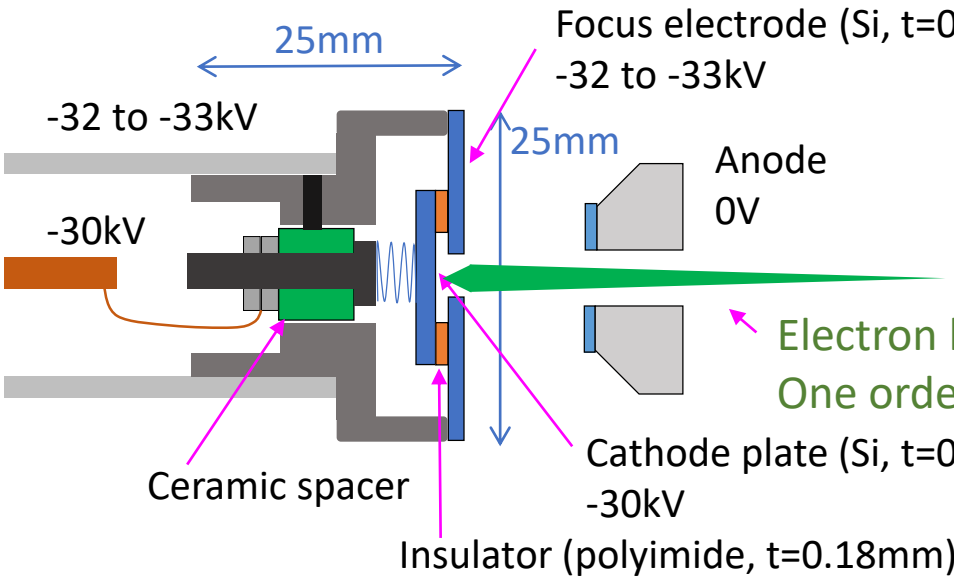
Miniaturization of Interface between cathode and anode

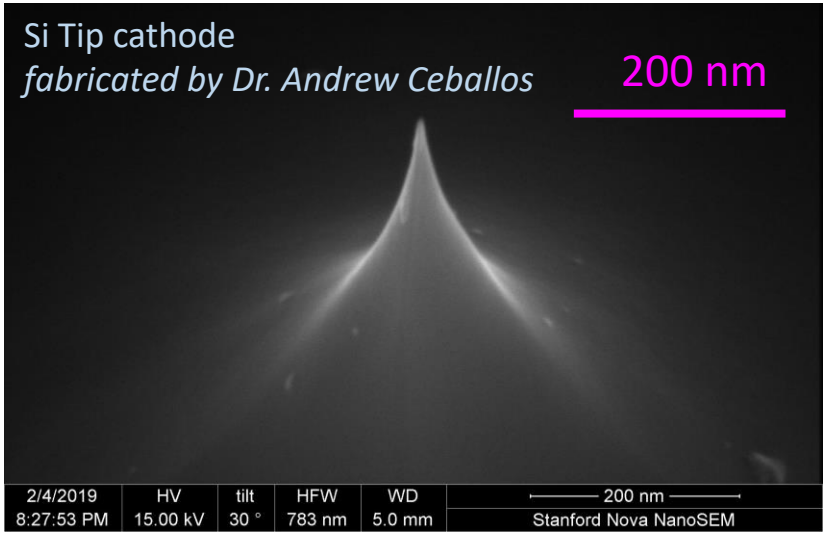


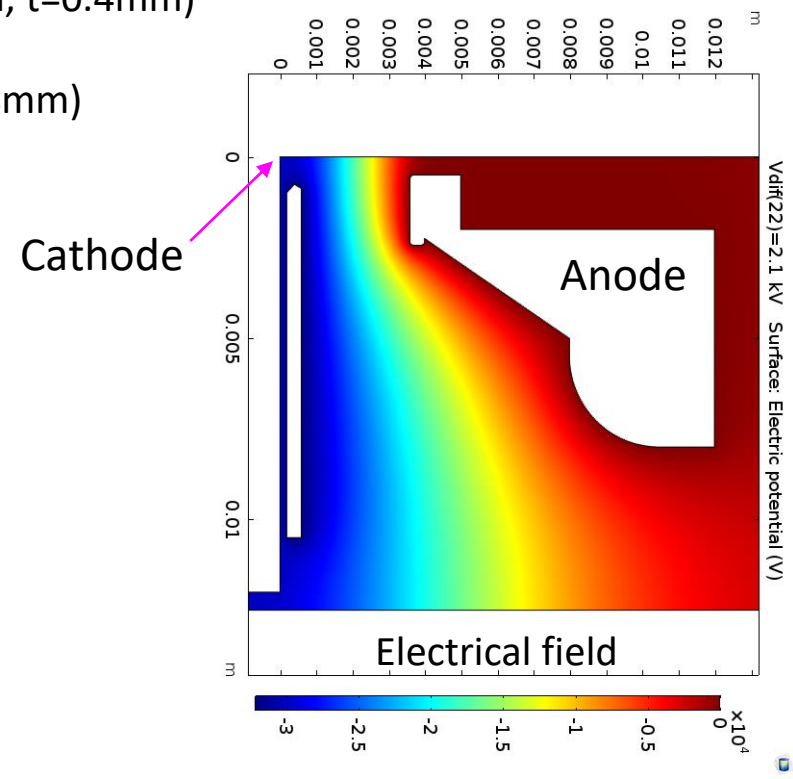
Each component should be miniaturized for compact accelerator

30kV compact electrostatic lens

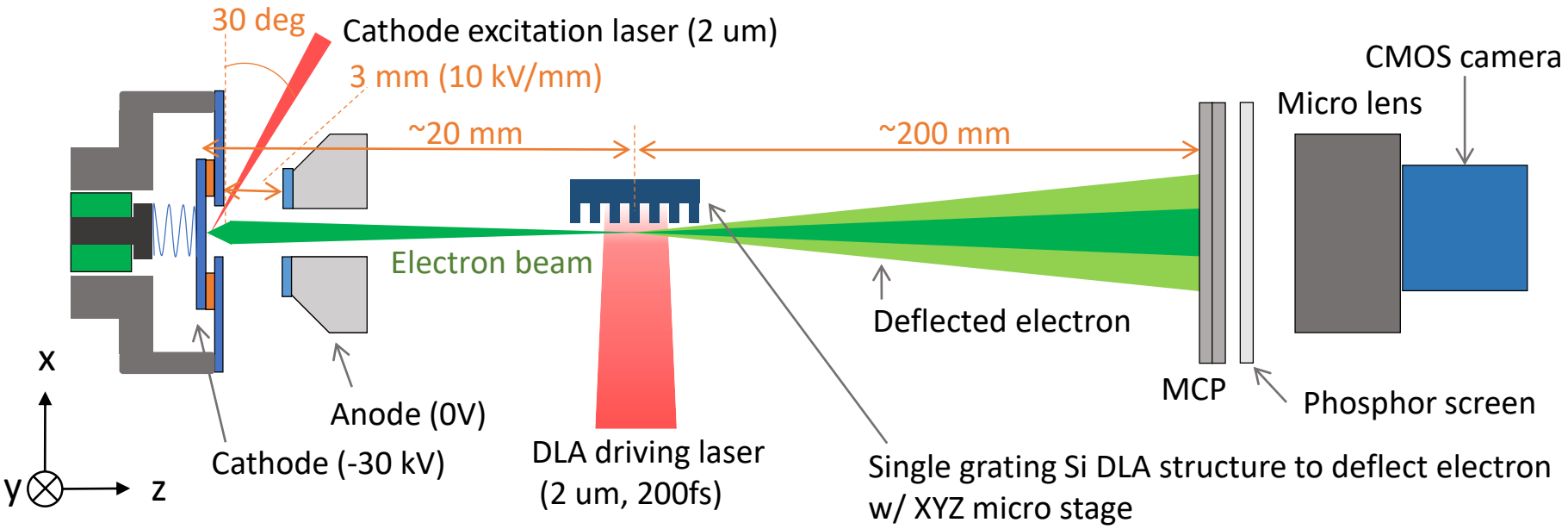


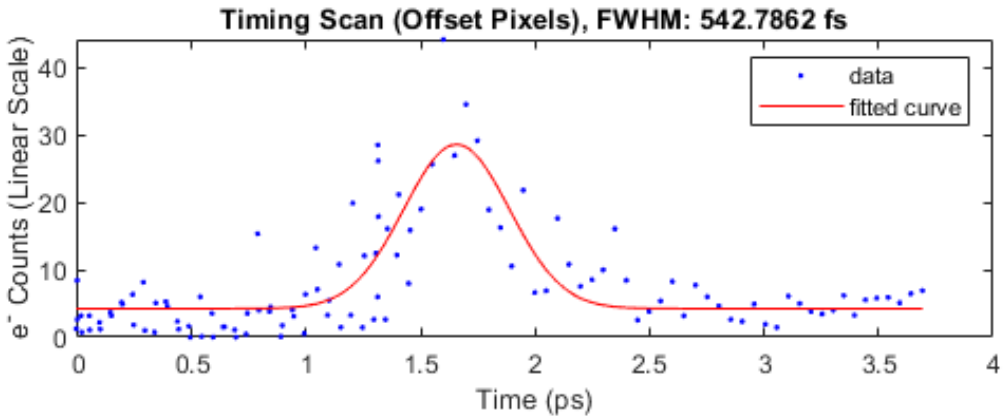






Experiment setup for beam evaluation





Cross-correlation measurement: 540fs FHWM
>> 440 fs electron bunch length

- Current results
Beam diameter: 1-2um
Incident angle: 1-2mrad

- Target value (less than)
Beam diameter: 0.2 um
Incident angle: 10mrad

Possible Focusing Issues

- Focus size seems limited by something other than tip geometry
  - Two very different tips produced similar foci with different divergences
- Instrumentation Noise:
  - Occasionally the focus size is <1um for a few seconds at a time
  - Cause is unclear
- Off-Axis Aberrations:
  - Cathode, focusing electrode, and anode need to be within 50um of beam axis or focus grows from <200nm to > 2um
  - Experimentally, the anode position does not seem to have a large effect on spot size
- Tip Pyramid Angle may strongly effect spherical aberrations
- Possible off-axis kick from photocathode laser
  - Observe different beam spots from different laser alignments from same tip
  - Needs to be investigated further

By courtesy of Dr. Kenneth J. Leedle

Summary

- UV region is still frontier in term of high power light source

- Broad band DUV-visible broad band source

- EUV light source would have potential for semiconductor inspection

- Multi-channel DLA or stacking DLA unit may produce sufficient output for industrial applications

- Compact electrostatic lens is under investigation to miniaturize entire accelerator system size

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