Investigation of Wavelength Dependence of Conversion Efficiency using Xenon Jet for LPP EUV Light Source

EUVA

(**E**xtreme **U**ltra**v**iolet Lithography System Development **A**ssociation)
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Introduction

- High power EUV light sources require high conversion efficiencies (CE) in order to reduce the necessary input power.

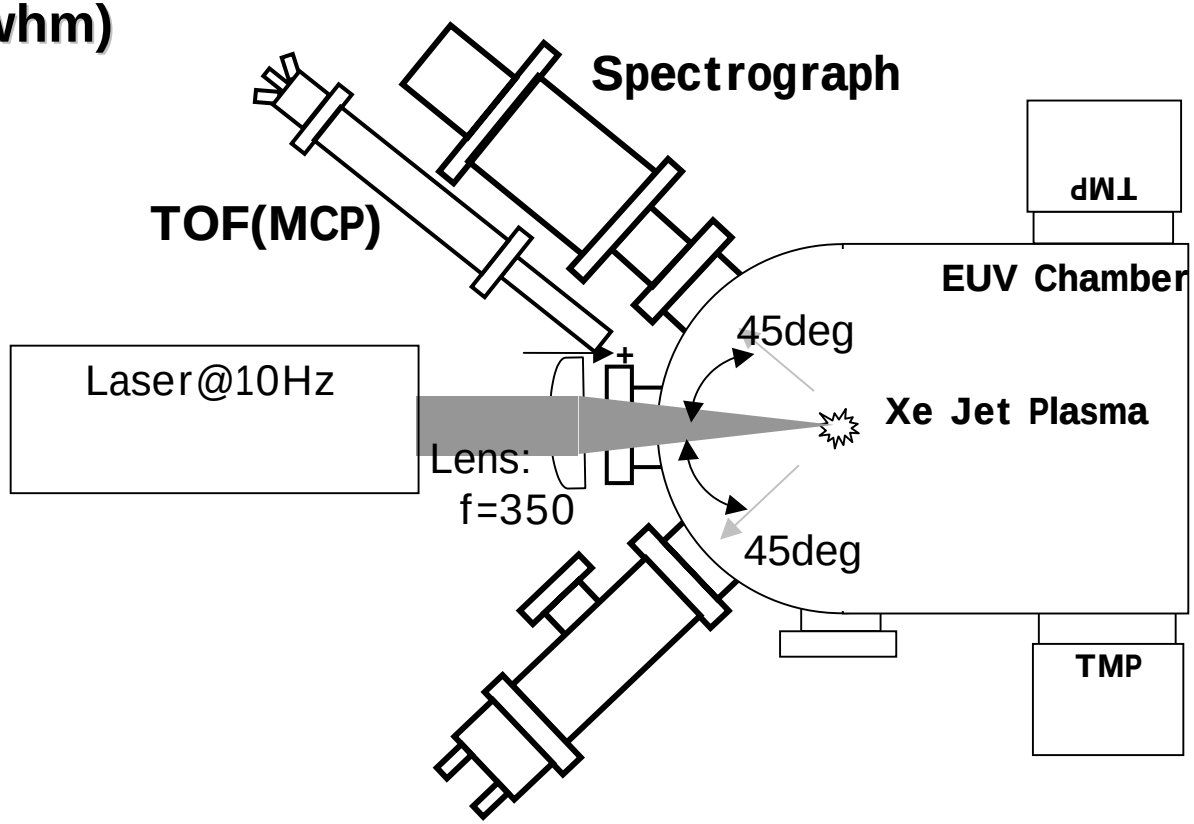
- Currently a conversion efficiency of 1.0% (2% BW, 2π sr) using a frozen xenon target and a Nd:YAG laser oscillating at 1064nm is obtained.

- Target:
  1) To obtain guidelines for higher CE development.
  2) Investigation of an optimum laser wavelength for CE.

- This poster outlines the dependence of the conversion efficiency on various parameters, e.g. laser energy, at different wavelengths (266nm, 532nm and 1064nm) for a Xenon jet target.

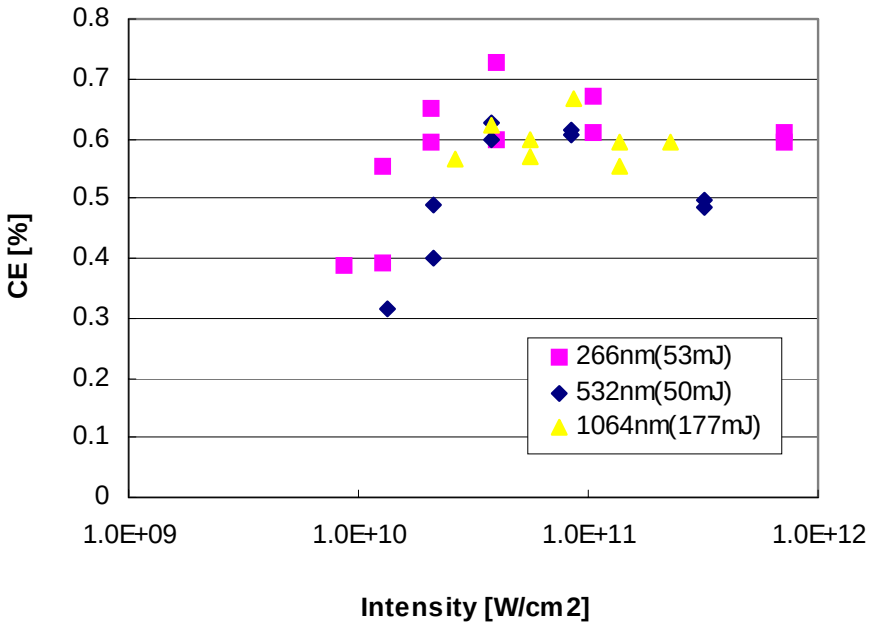
Experimental Setup

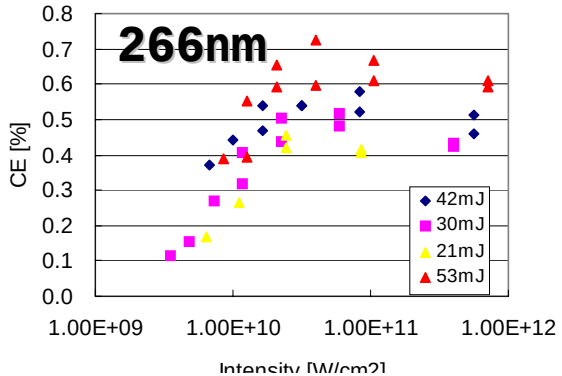
- **Laser**
  - Wavelength : 1064nm(~450mJ), 532nm(~165mJ)
    266nm(~55mJ)
  - Pulse width : ~8ns (fwhm)
  - Rep. rate : 10Hz
- **Target**
  - Xenon jet
    (350μm max)
- **Evaluations**
  - ✓ EUV energy (CE)
  - ✓ Spectrum
  - ✓ Fast ion

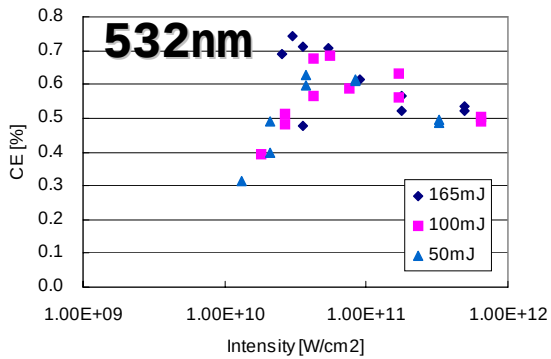


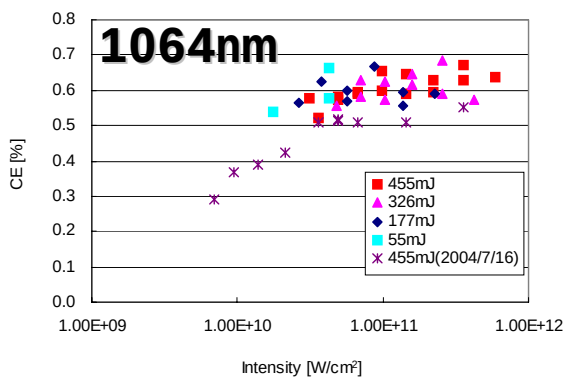
Flying Circus 2
-EUV energy

Experimental Results (CE vs. Intensity)





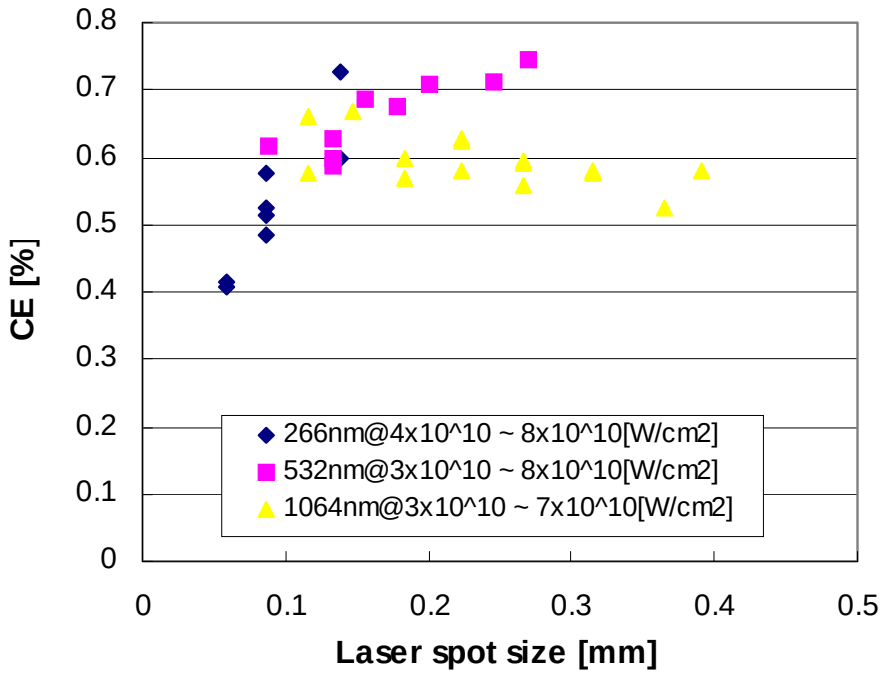


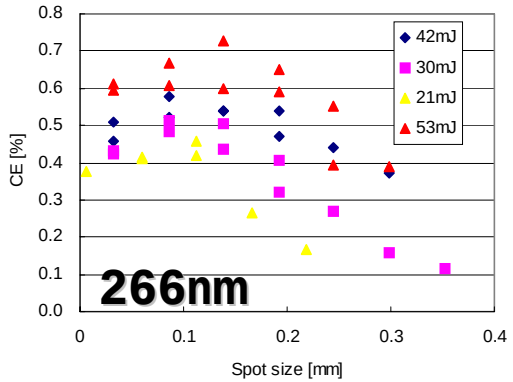


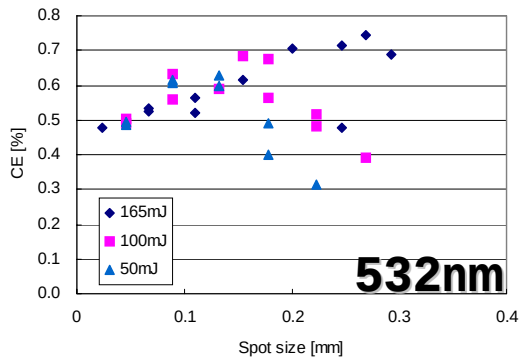
✓**Optimum Laser Intensity for CE at different wavelengths:**

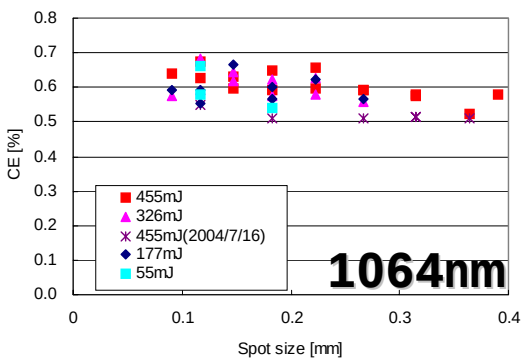
266nm: $5x10^{10}W/cm^2$
532nm: $5x10^{10}W/cm^2$
1064nm: $\sim 1x10^{11}W/cm^2$

Experimental Results (CE vs. Spot size)





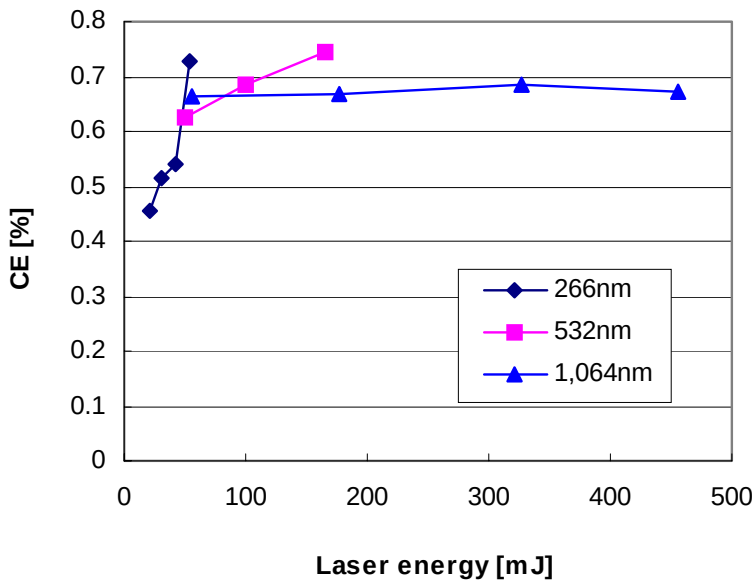


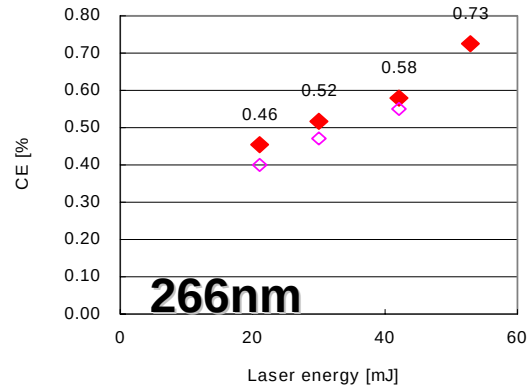


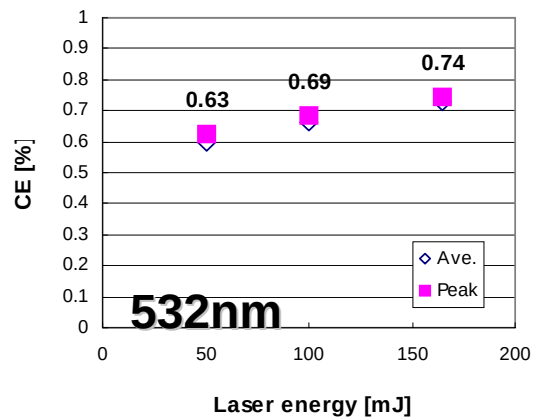
✓**Best Laser Spot size for CE at different wavelengths:**

266nm:	**0.14 mm**
532nm:	**0.28 mm**
1064nm:	**0.15 mm**

Experimental Results (CE vs. Laser energy)

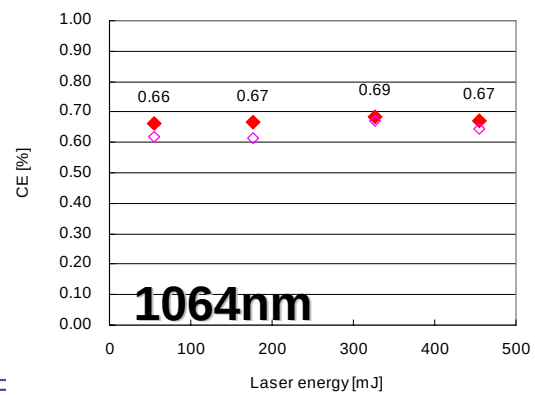




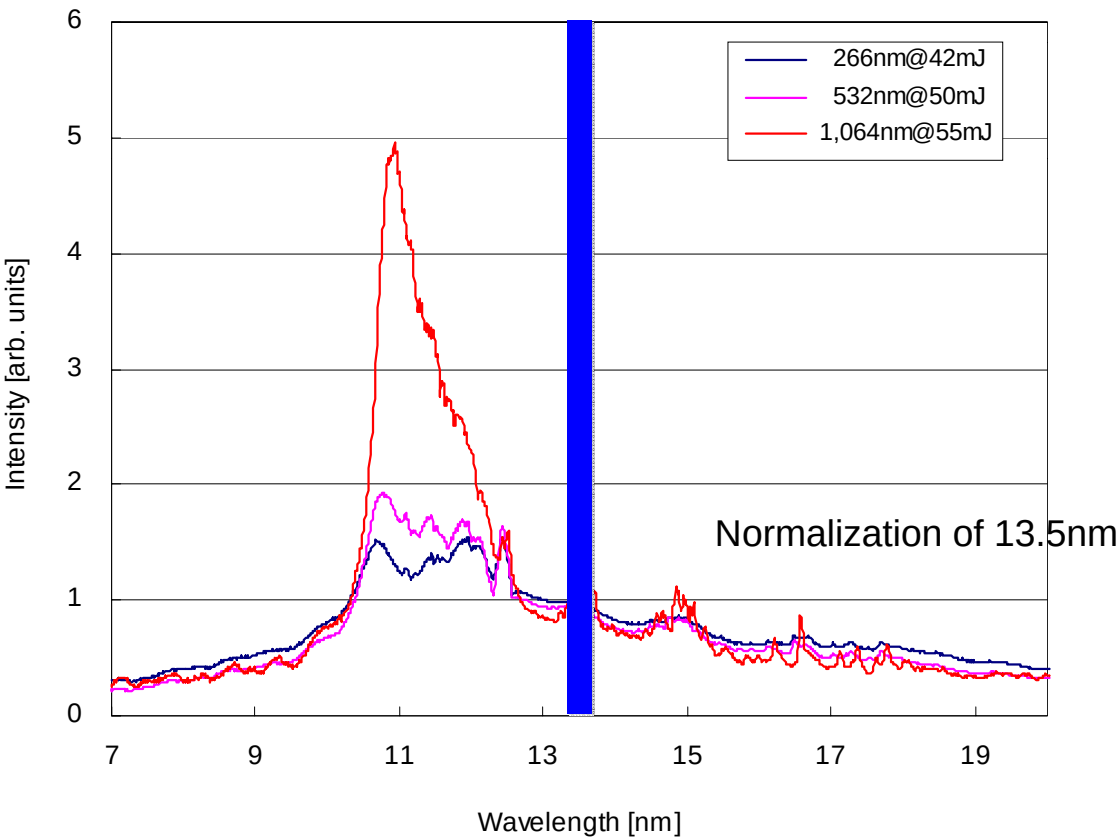


Maximum CE at different wavelengths:

266nm : 0.73% @ 55mJ
532nm : 0.74% @ 165mJ
1064nm : 0.69% @460mJ



Experimental Results (Spectra)



Spectrograph (Shinseiki)

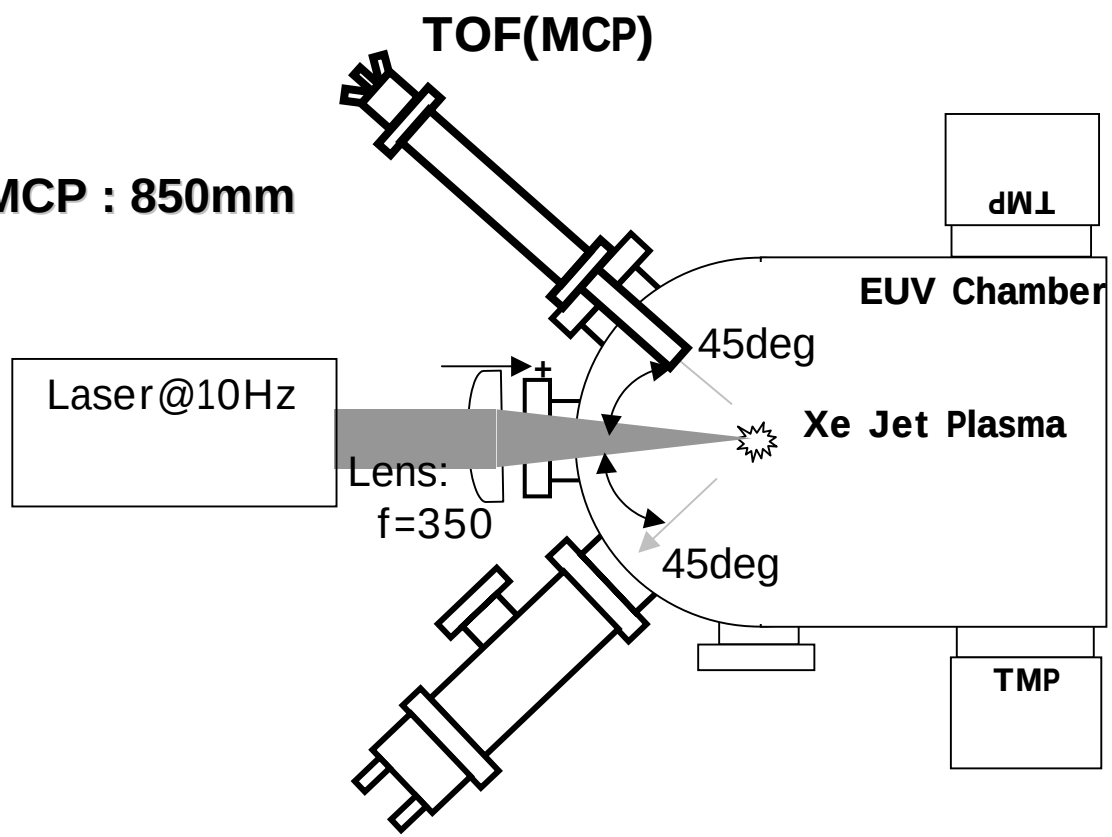
- **Grazing Incidence Spectrograph**
- **Grating：1200 l/mm**
- **Slit ： 25 μm**
- **Back illuminated CCD**

✓ **Lower plasma emission at 11nm for 266nm wavelength laser compared to 1064nm laser.**

Experimental Setup (TOF)

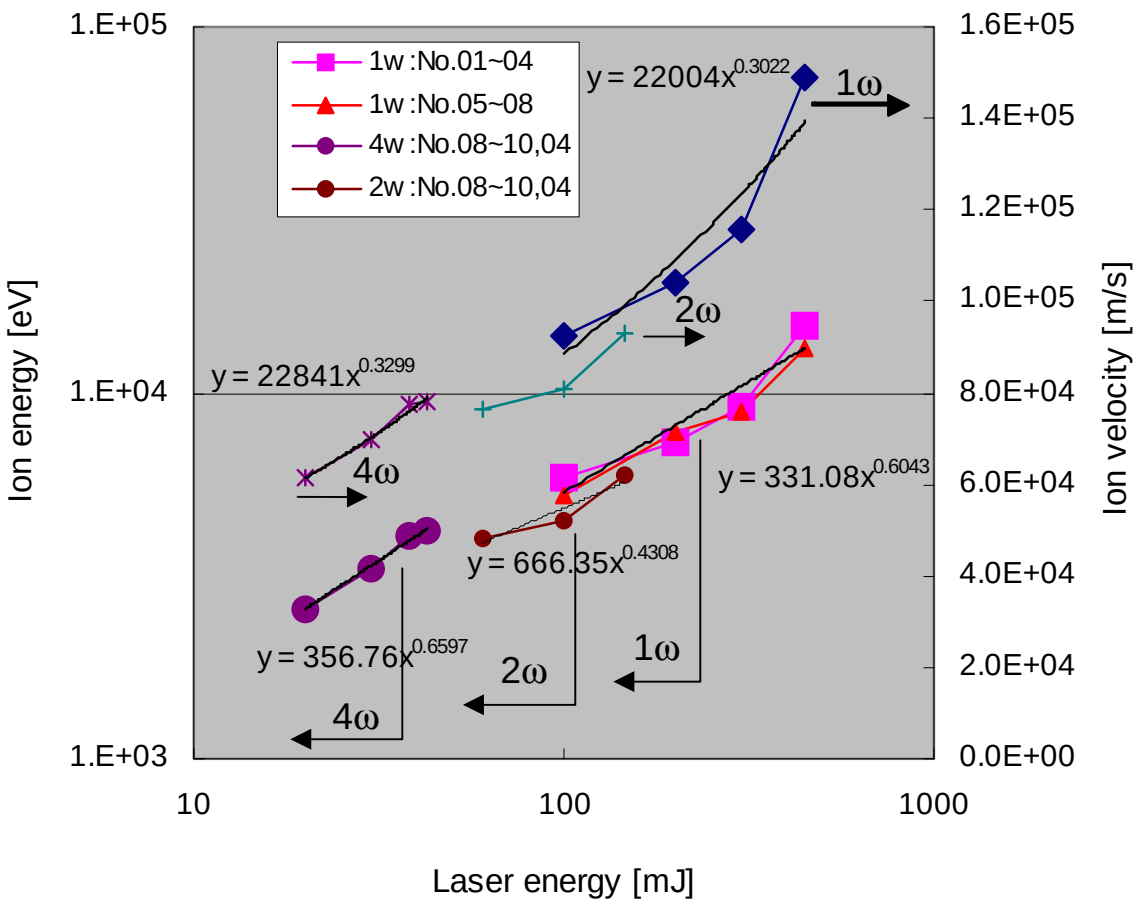
- **MCP**
  Maker : Hamamatsu Photonics K.K.
  Type: F4655-13
  Bias voltage: 1.4kV

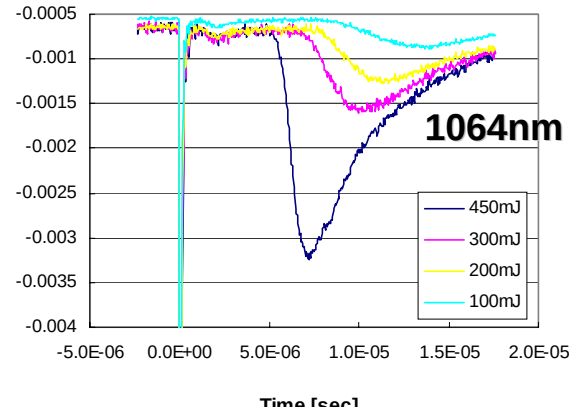
- **Distance from Plasma to MCP : 850mm**

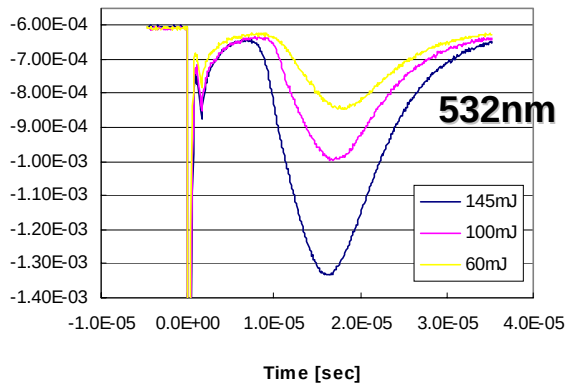


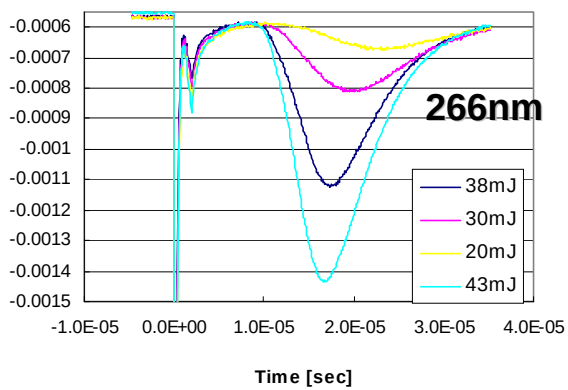
Flying Circus 2
-EUV energy

Experimental Results (Fast ion energy)



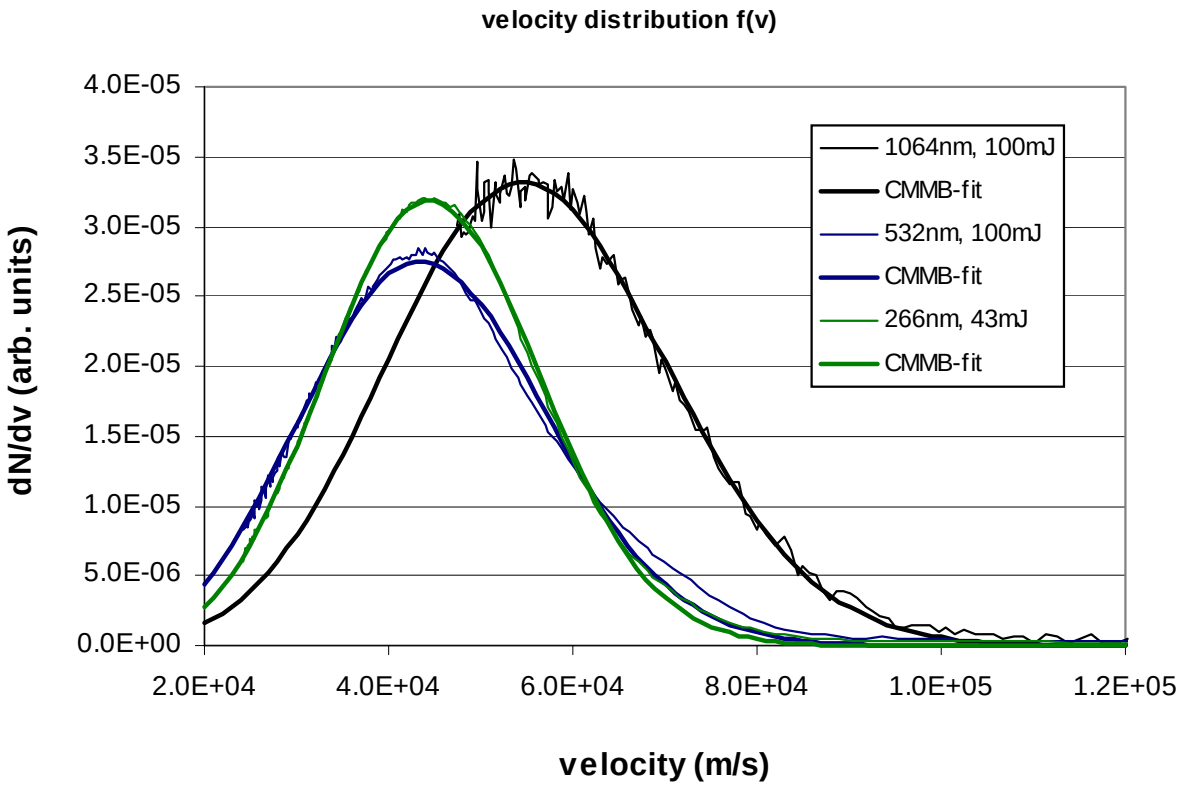






✓ **Fast ion energy depends on laser energy and not the laser wavelength.**

Experimental Results (Ion velocity distribution)



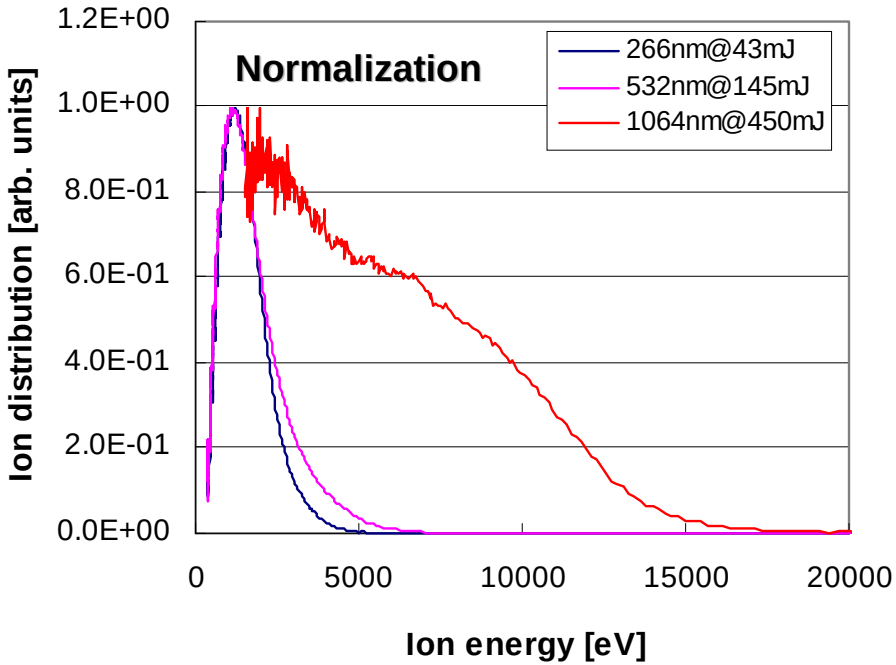
Fitting parameter

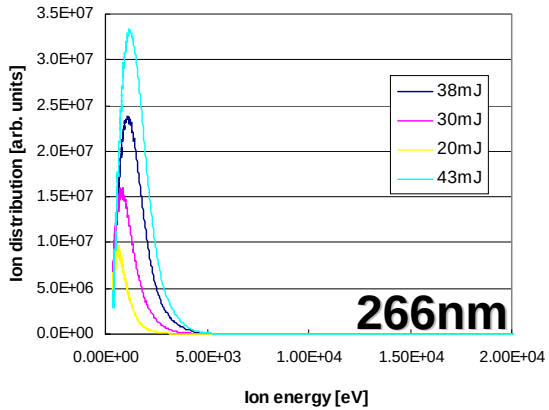
	T (eV)	v_CM (m/s)	v_max (m/s)
266nm	239	32583	45013
532nm	335	26438	43947
1064nm	416	37769	53525

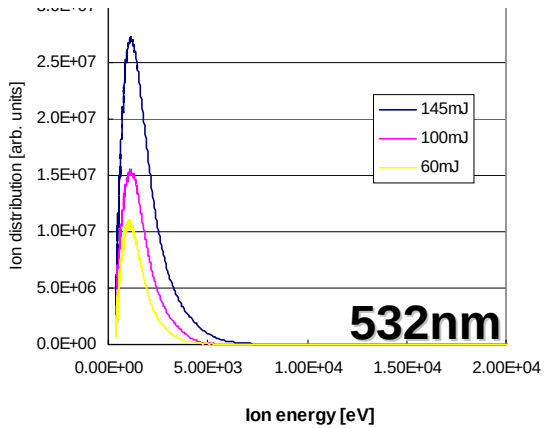
f(v) ~ v^3 Exp[-1/2 m (v-v_CM)^2 / (k_b T)]

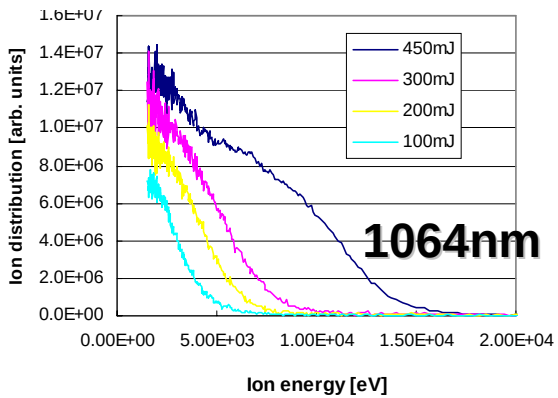
✓ **Plasma close to thermal equilibrium – most ion distributions well described by a shifted center-of-mass Maxwell-Boltzmann distribution.**

Experimental Results (Ion energy distribution)









- ✓ **The ion distribution shows two peaks for 450mJ at 1064nm.**

Summary

- ✓ **Maximum CE obtained is approximately 0.7%.**
- ✓ **At 266nm the CE shows strong dependence of laser energy.**
- ✓ **Max. CE limited by available laser energy for 266nm and 532nm.**
- ✓ **Reduced plasma emission at 11nm for 266nm laser wavelength compared to 1064nm.**
- ✓ **Fast ion energy depends on laser energy not laser wavelength.**

Acknowledgements

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