

Conversion efficiency of EUV emission from the laser-produced Tin and Xenon plasmas

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Outline of talk

Summary of our results calculated by the 1-D radiation hydrodynamic simulation code for LPP.



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**A part of this work has been
conducted under the auspices
of Leading Project promoted
by MEXT**

summary

By radiation hydrodynamic code, we have investigated properties of Extreme Ultra-Violet (EUV) emission from laser-produced plasmas

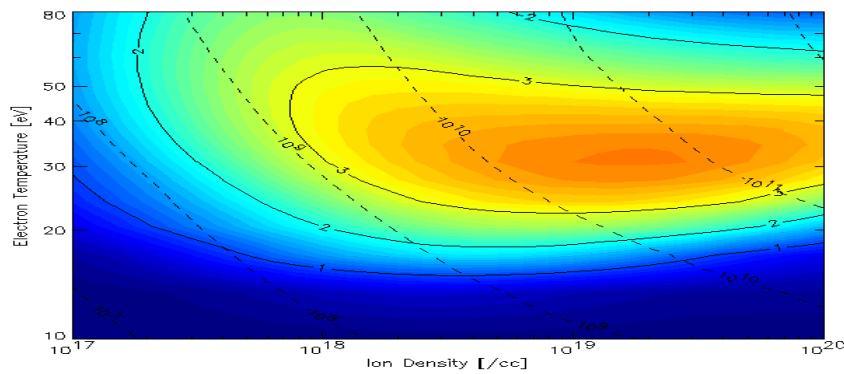
- The 1-D Lagrangian Radiation Hydrodynamic code "Star-1D" shows;
 - For Tin plasma, self-absorption of EUV must be considered due to the larger opacity.
 - With CO₂ laser, the hydro simulation gives relatively higher CE.
 - For Xe plasma, self-absorption is ineffective compared to that with Tin plasma.
 - Laser wavelength dependence (from CO₂ to 0.26μm) appears to be relatively weak compared to Tin case.
 - Comparison of the simulation results with the power balance model gives a qualitative agreement.

Conversion Efficiency

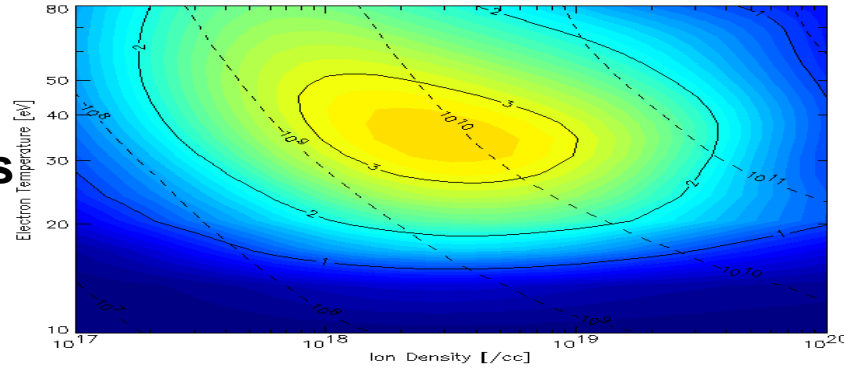
no absorption

pulse duration

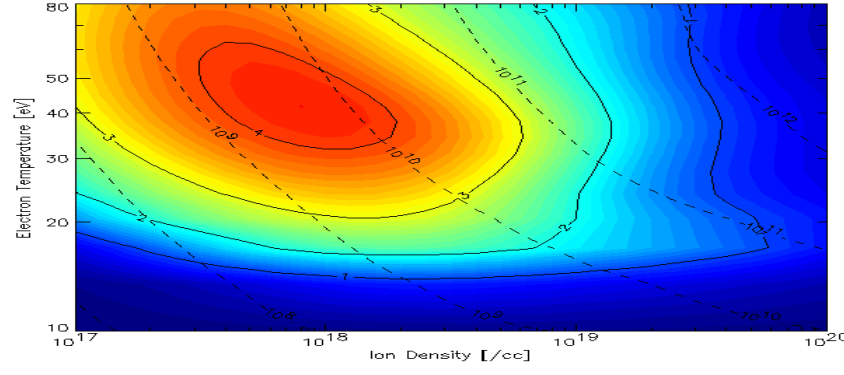
with absorption



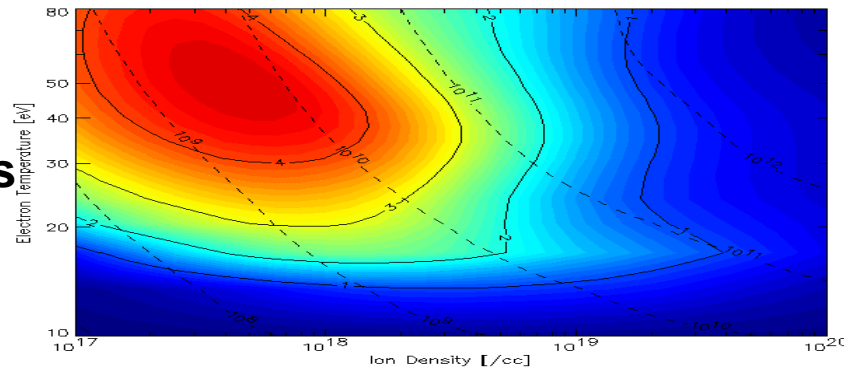
1.2ns



5ns



10ns

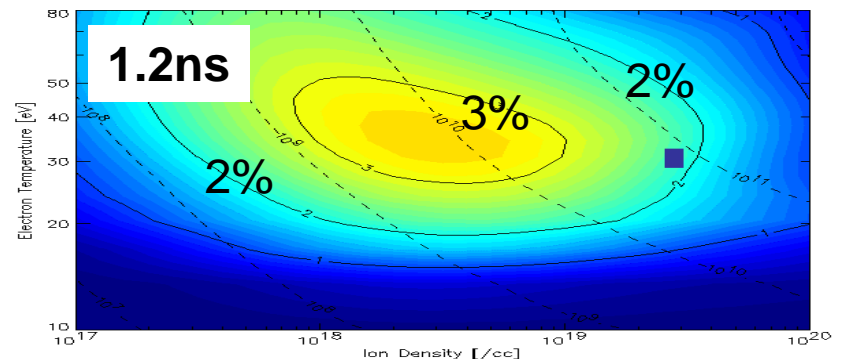
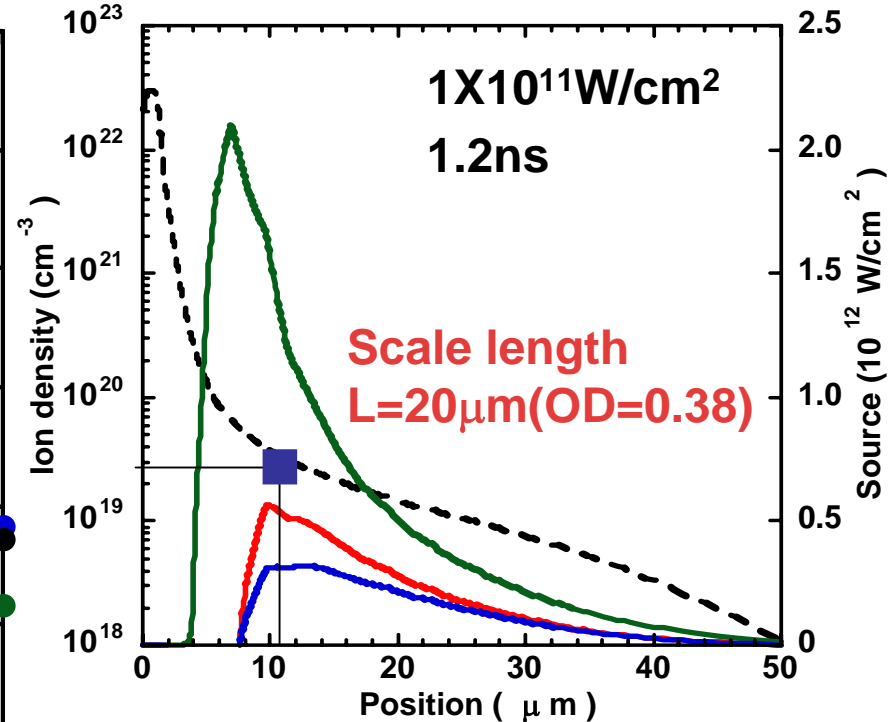
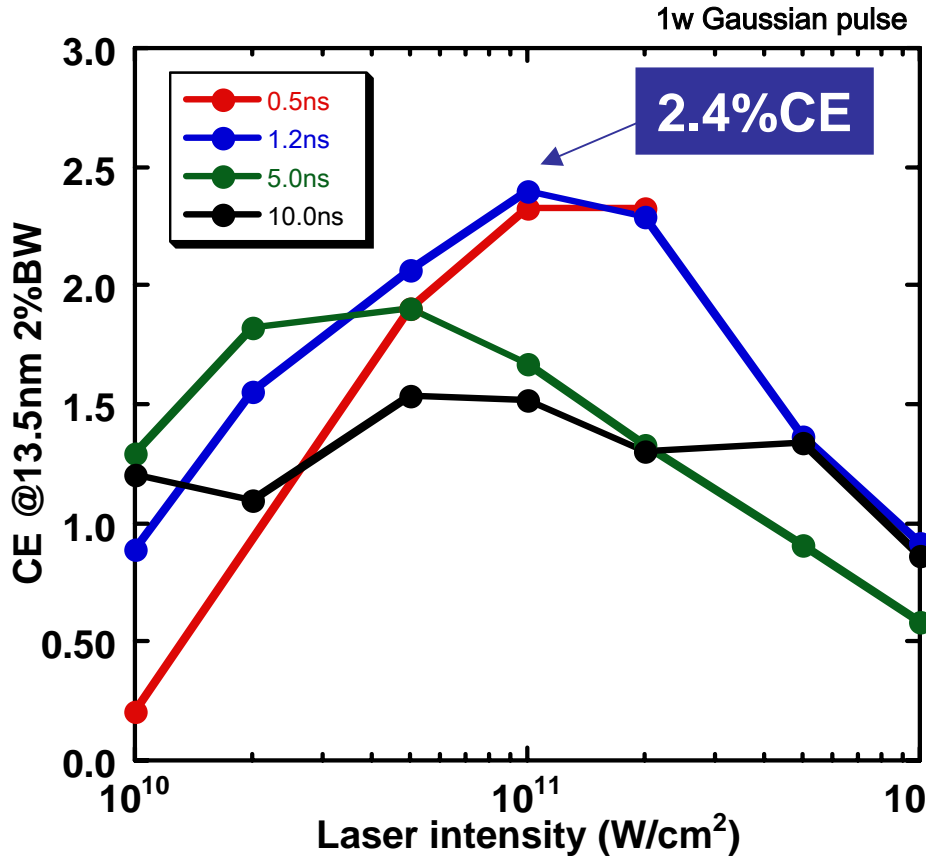


T_e

80
50
30
20
10

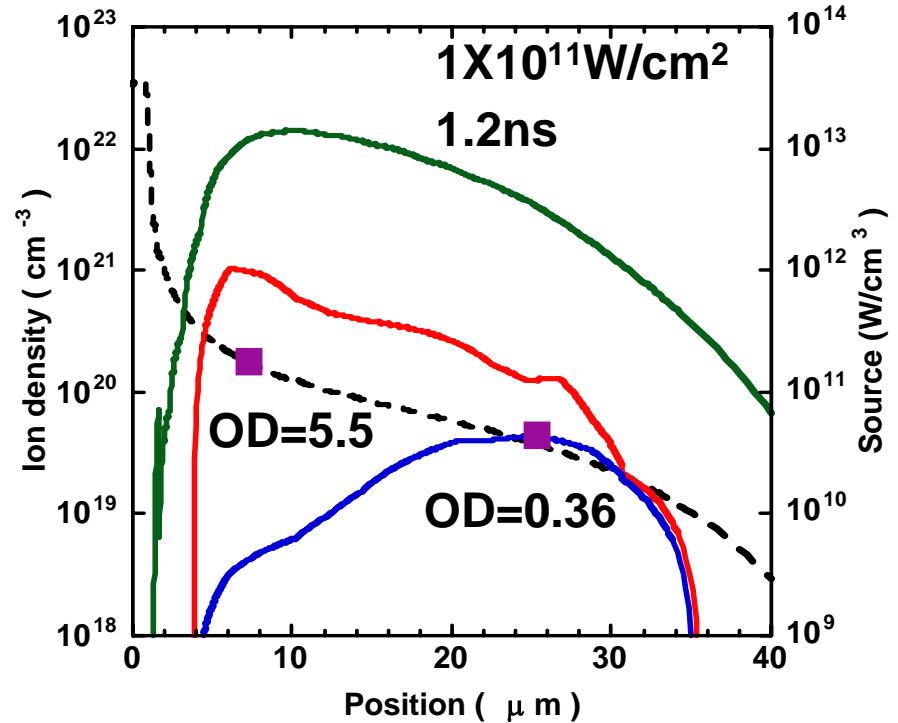
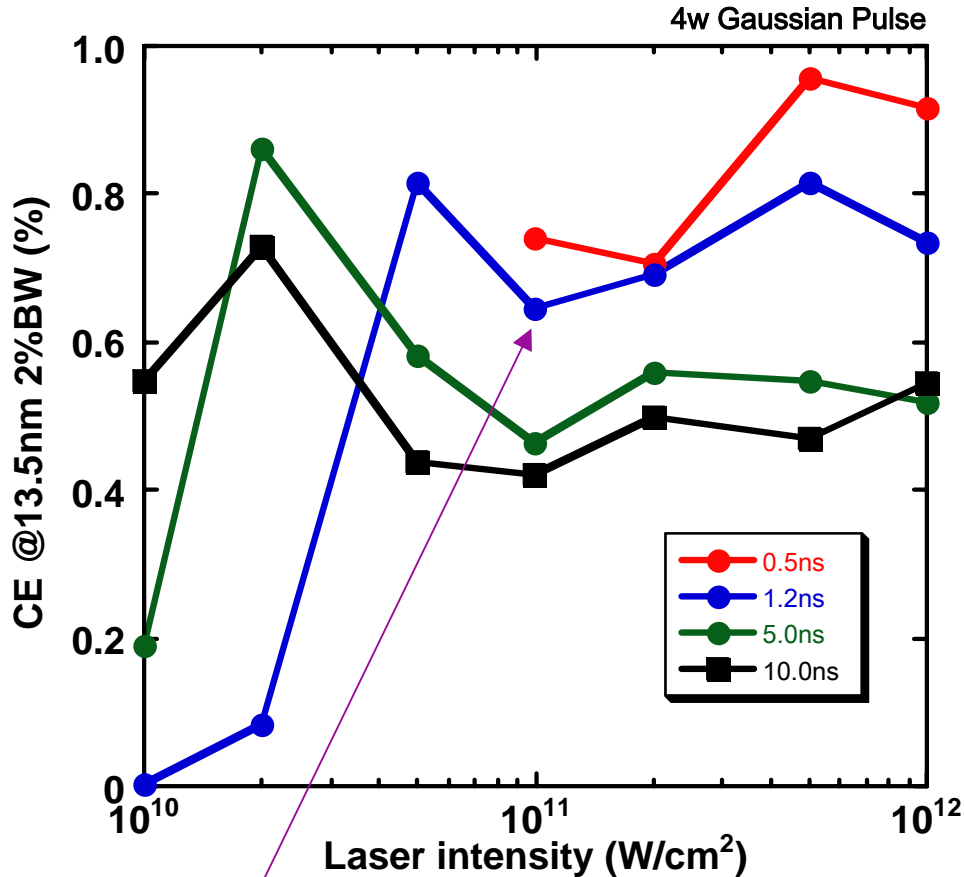
10^{17} 10^{18} 10^{19} 10^{20} n_0

With 1.06 μm laser the optimized pulse duration is estimated to be located at 1-5ns. CE of 2.4% is obtained for 1.2ns 1X10¹¹W/cm².

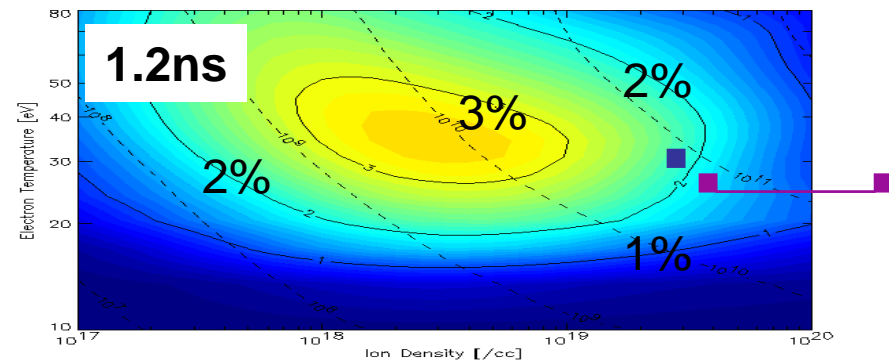


With longer duration pulse (> 5ns), the optical depth(OD) can become Larger than OD=1.

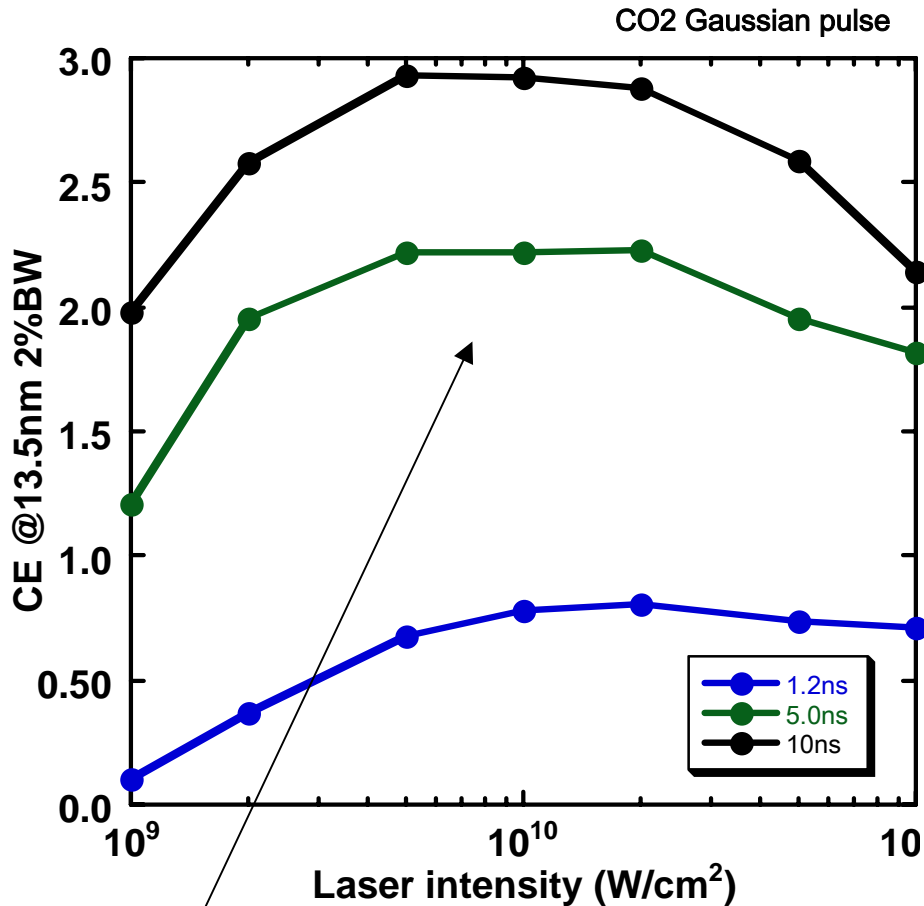
The short wavelength laser condition of $0.26\mu\text{m}$ shows the displacement between heated region and EUV emission region.



With $0.26\mu\text{m}$, 1.2ns pulse, the intensity of $1 \times 10^{11} \text{ W/cm}^2$ gives OD >1 in the heated region.

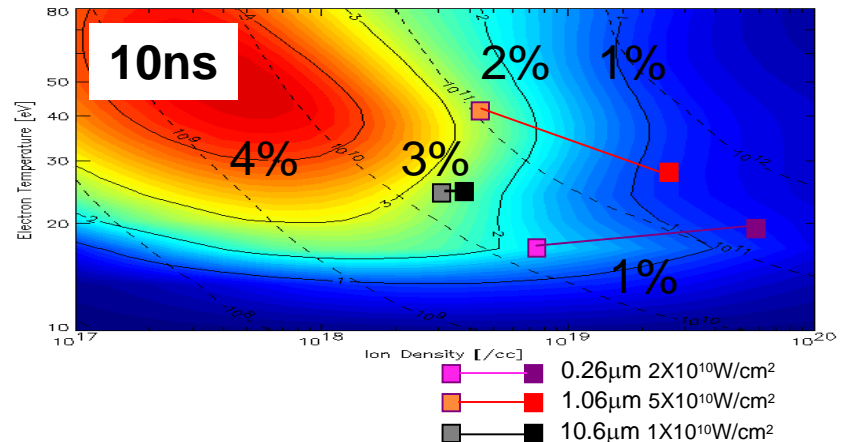
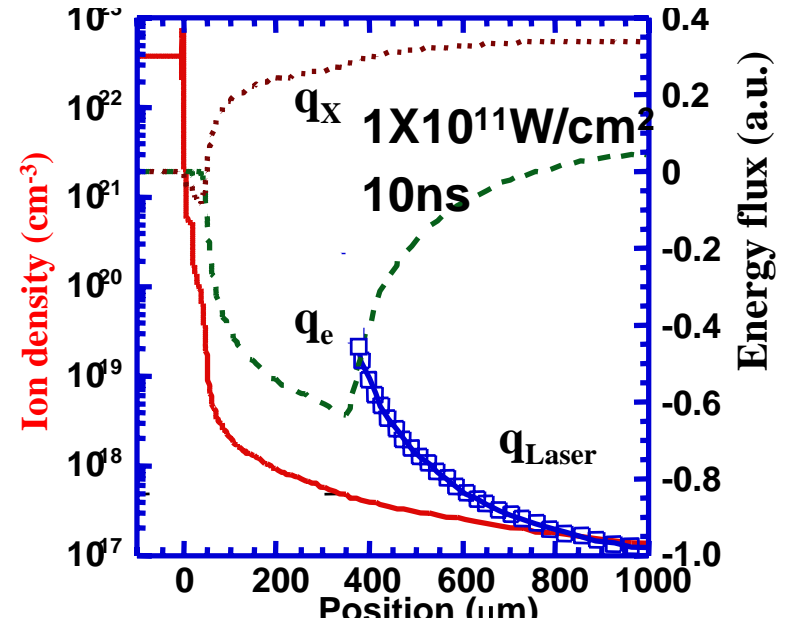


With the long wavelength laser condition of $10.6\mu\text{m}$, the longer pulse duration ($>10\text{ns}$) is needed to obtain $\text{OD}=1$.



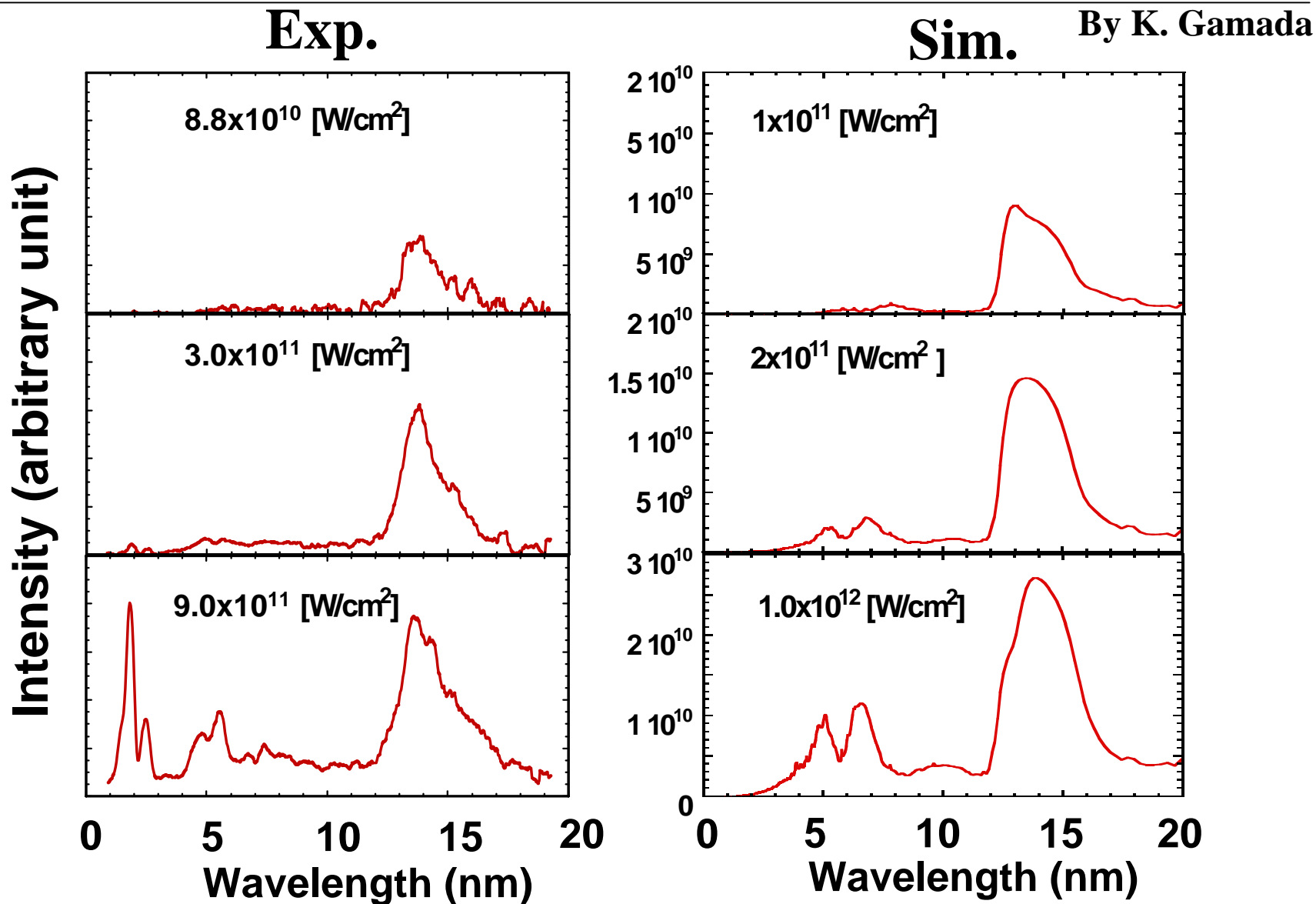
The $10.6\mu\text{m}$ laser wavelength gives higher CE in the wide range of laser intensity.

The electron transport can take the absorbed laser energy into the dense region.



Comparison with experimental results

Calculated X-ray emission spectra using Hullac and AA model are in good agreement with the experimental observations.

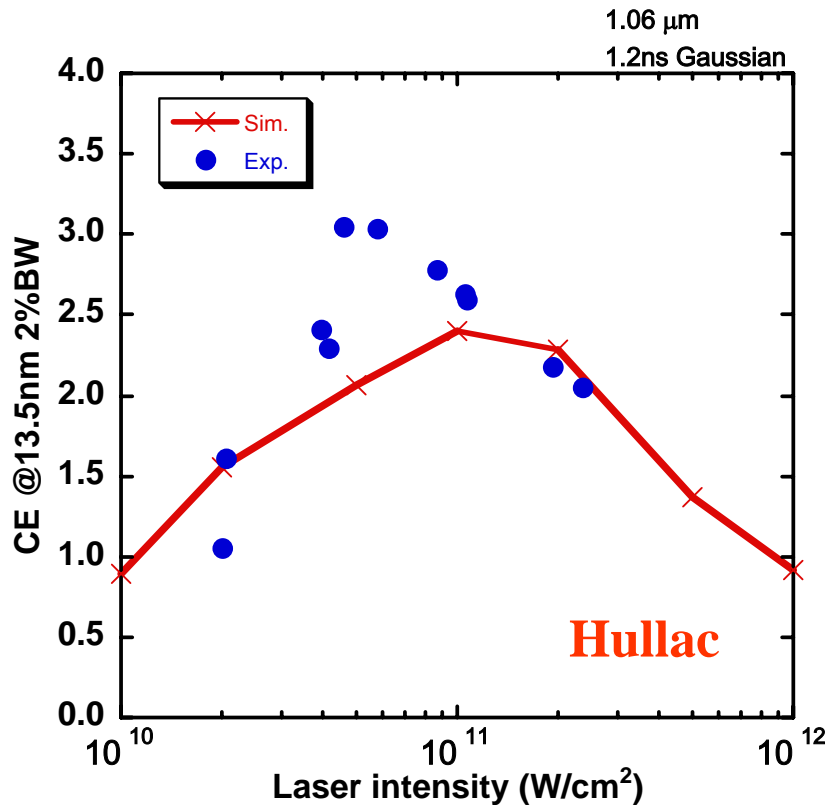


Comparison of CE with Experimental results

Difference exists between simulation and experimental data

GXII exp.

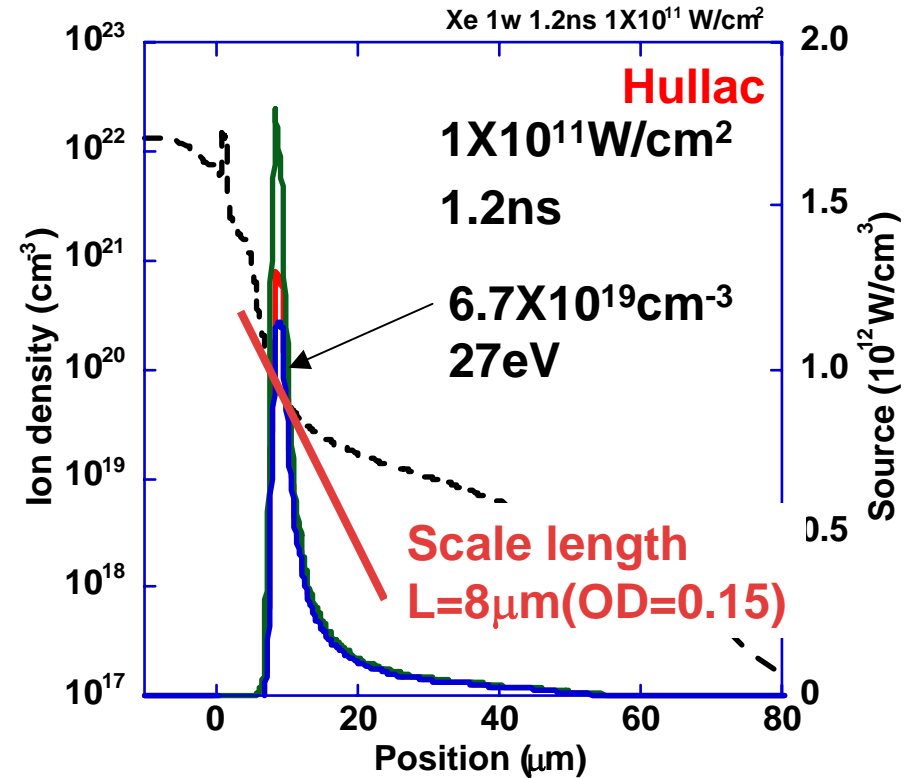
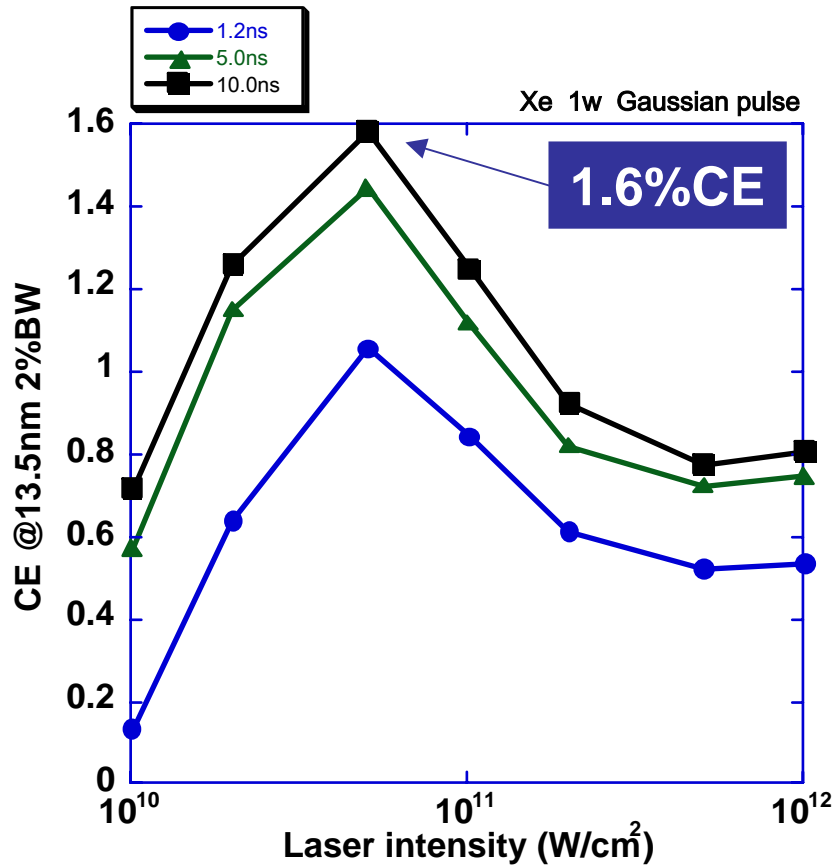
1.06 μ m 1.2ns Gaussian



Need to examine all the processes included in the simulation.

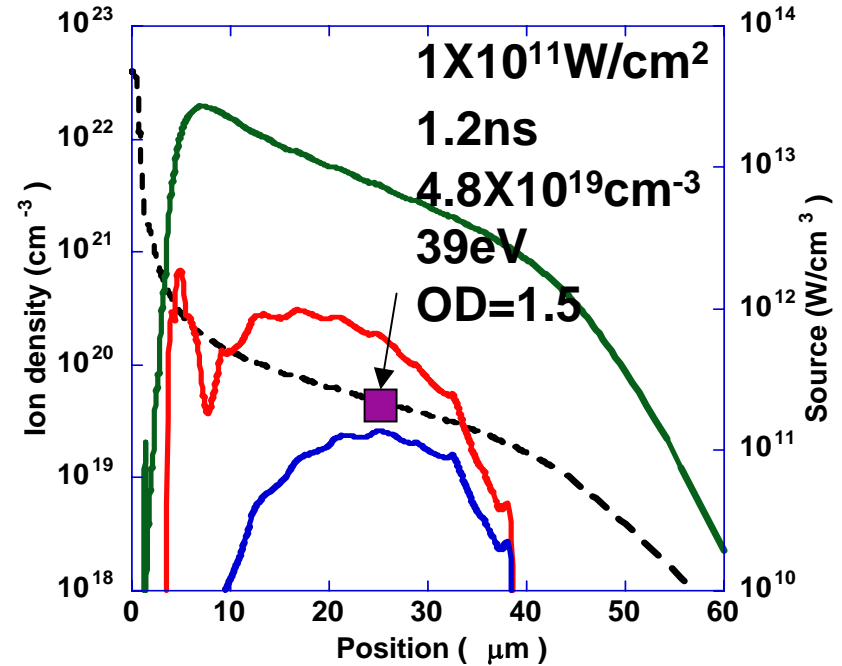
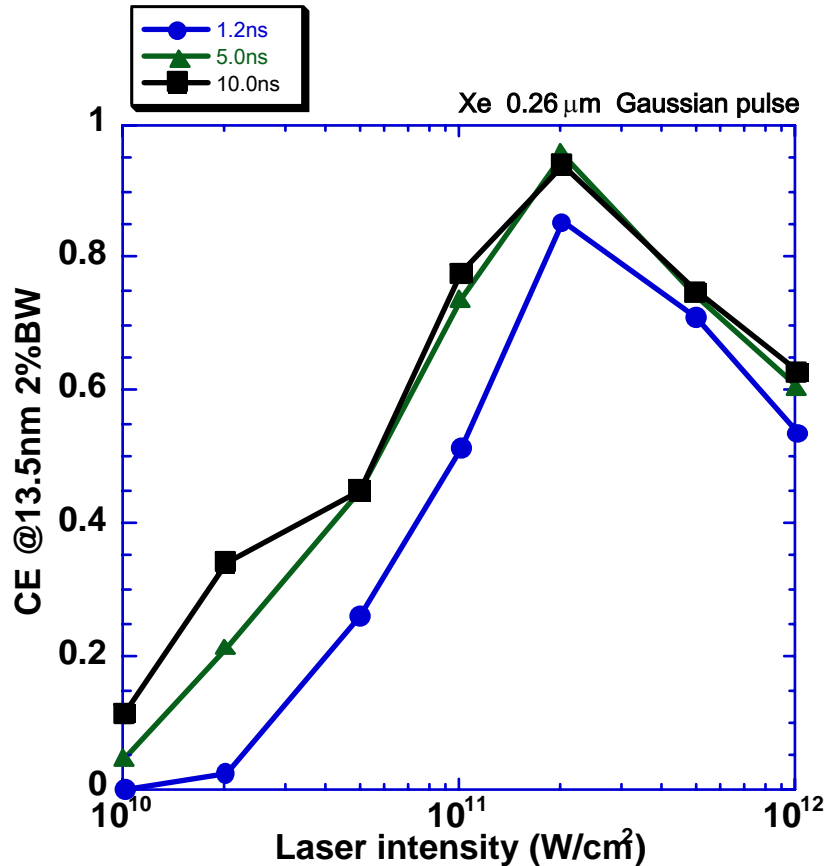
Improving of the atomic data table is required.

LPP Xe plasma give CE up to 1.6% with $1.06\mu\text{m}$, $5 \times 10^{10} \text{W/cm}^2$ laser.



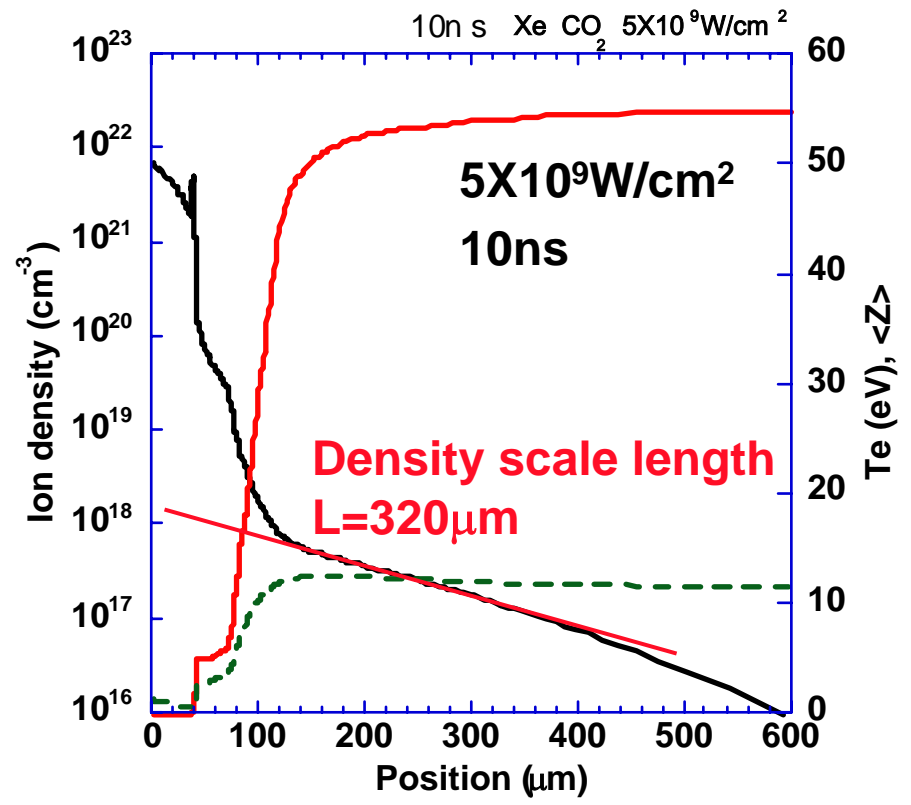
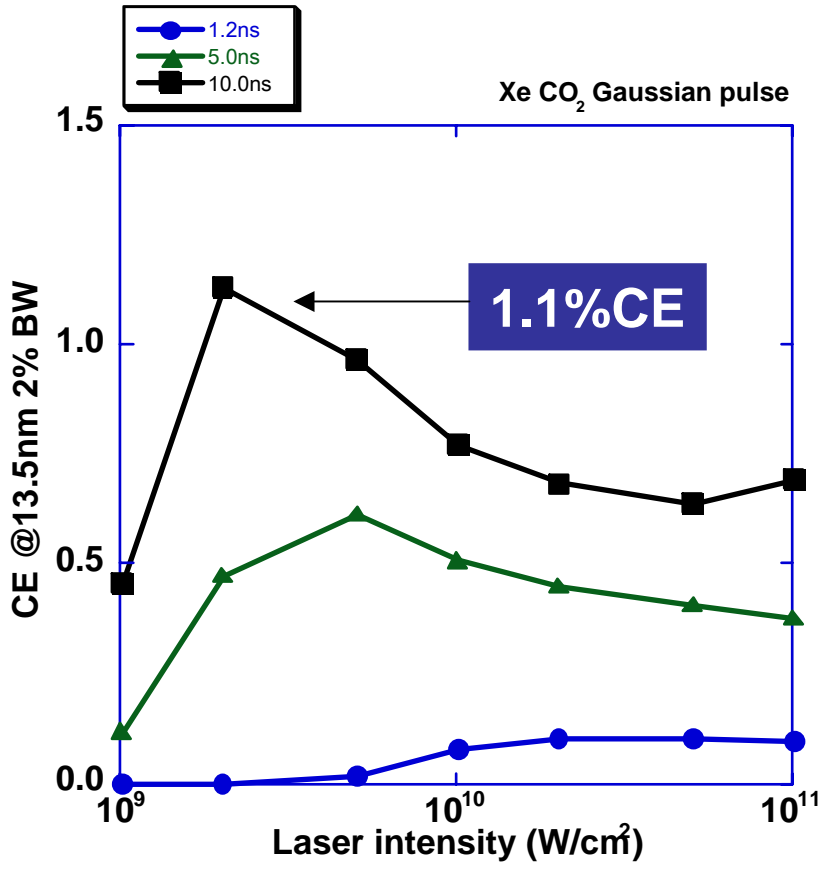
The self-absorption effect of EUV is not effective for Xe plasma due to smaller opacity compared to that with Tin plasma.

With 0.26 μm laser-produced Xe plasma, 1.2ns duration pulse gives optical thick condition of OD=1.5 at the EUV emission peak.



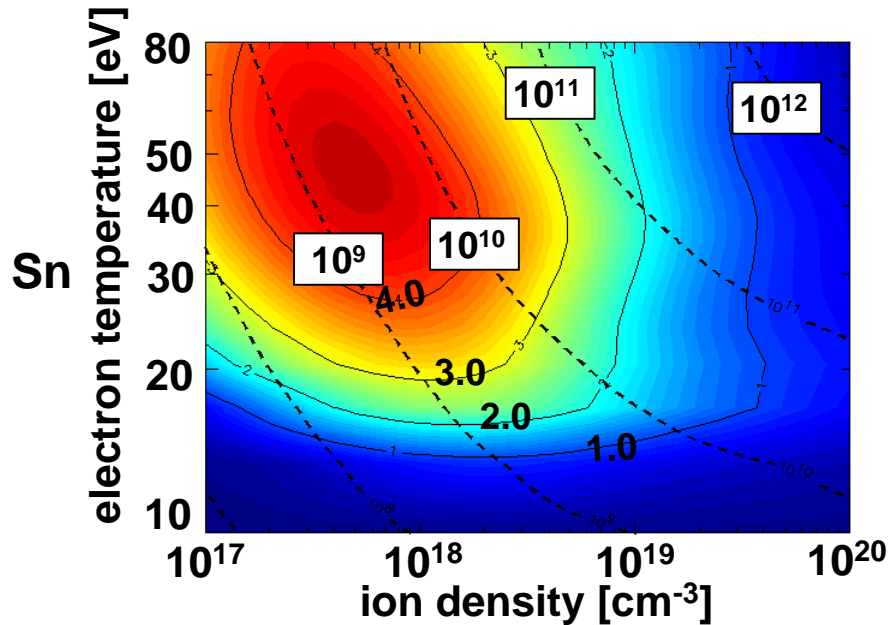
With 0.26 μm laser, dependence of pulse duration on CE is weak at the optimum laser intensity.

With CO₂ laser, the long duration pulse is required for the larger CE, where Etandue may limit the maximum pulse duration.

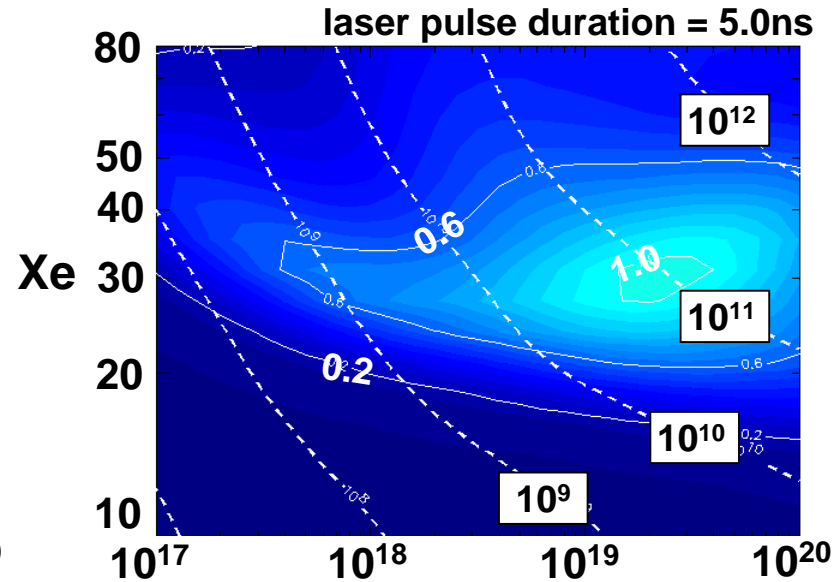


The optimum laser intensity is about an order of magnitude lower than that with 1.06μm condition, where the longer duration pulse is also required for obtaining similar EUV power per shot.

Comparison of the simulation results with the power balance model gives a qualitative agreement.



Low density ($\sim n_i=10^{18}\text{cm}^{-3}$) gives higher CE ($\sim 4\%$)



Relatively high density ($\sim n_i=10^{19}\text{cm}^{-3}$) gives higher CE ($\sim 1\%$).

Simulation present results (*not completely optimized)

CO ₂	CE= 2.9% with 10ns	1.1% with 10ns
1.06	2.4% with 1.2ns	1.6% with 10ns
0.26	0.95% with 0.5ns	0.95% with 5ns and 10ns
	The laser pulse duration should be properly chosen to avoid the self-absorption of EUV.	The wavelength dependence on CE is weak.

Summary /Conclusion

By radiation hydrodynamic code, we have investigated properties of Extreme Ultra-Violet (EUV) emission from laser-produced plasmas

■ The 1-D Lagrangian Radiation Hydrodynamic code” Star-1D” shows;

- For Tin plasma, self-absorption of EUV should be considered because of the larger opacity.
 - With CO₂ laser, the hydro simulation gives relatively higher CE.
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■ The further verification of our simulation results will be done.

Acknowledgements



Co-Researchers

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