

Modification of Z-pinch Plasmas with an External Longitudinal Magnetic Field

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Abstract

For the discharge produced plasma (DPP) EUV sources, it is huge task to improve the conversion efficiency (CE) from electrical energy to in-band EUV emission. To reduce the heat load in the discharge chamber including electrodes and its supporting insulator, the plasma should be driven by the current with large amplitude (> 20 kA) and short duration (~ 100 ns). In this situation, however, the plasma behaves so dynamically that the optimum plasma condition for the EUV emission might not last so long.

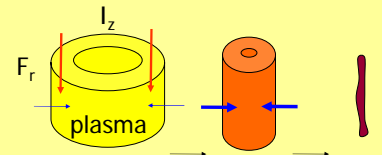
An external longitudinal magnetic field applied to the z-pinch plasma makes the plasma implosion softly, so that the plasma density and temperature, which are strongly associated with the EUV spectrum, might be reduced. Therefore, the rolled by adjusting the magnetic field strength, in addition to lengthening the EUV emission. Besides, the soft implosion helps preventing plasma instabilities and possibly changing the property of high energy ions generated in the implosion process.

This paper describes the experimental study of the z-pinch discharge plasma with an external longitudinal magnetic field and the EUV emission from the plasma. The z-pinch device is driven by a current with 30 kA in 110 ns duration. The longitudinal magnetic field, of which the strength is varied up to 1000 gauss, is produced by a solenoid coil placed beside the anode.

1. Concept; Role of an External Magnetic Field, B_z

Concept

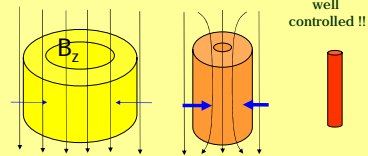
- External magnetic field suppresses the hard implosion so that energy density (TxN) of the plasma should be changed.



Normal Z-pinch

Advantages

- Controlling an energy density of plasmas, spectra
- stable emission and spatial distribution
- Sustaining high energy density status
- Effective plasma heating due to spiral movement of electrons

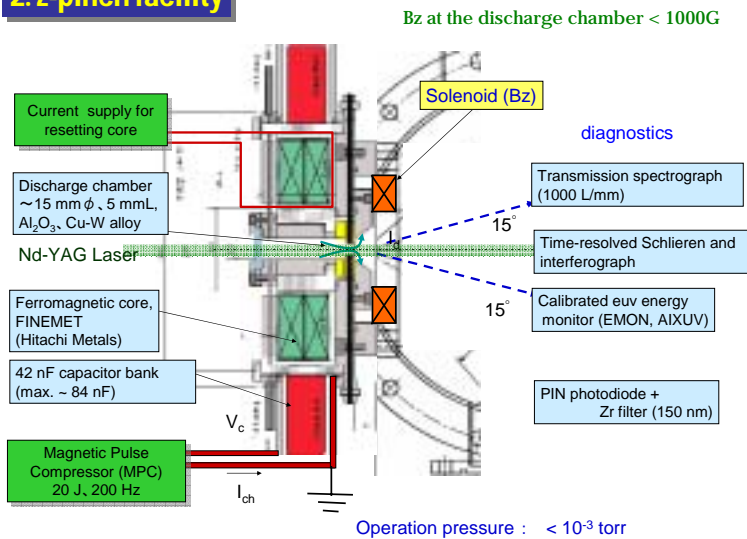


Z-pinch with B_z

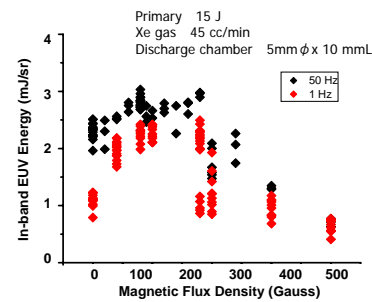
Possible disadvantages

- Enlargement of source size

2. Z-pinch facility



4. In-Band EUV Energy as a Function of B_z



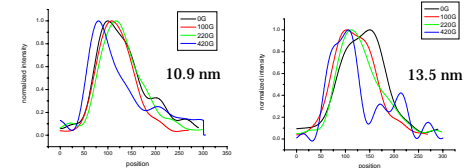
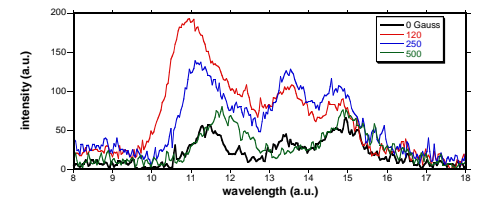
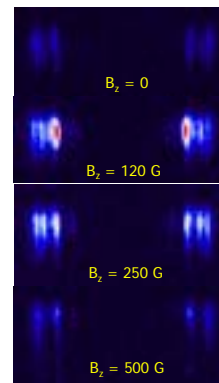
In-band EUV energy varies with changing the magnetic field strength B_z .

- Change in plasma temperature / density?
- Change in a plasma volume?

Sensitivity for the external magnetic field is strong low rep rate operation.

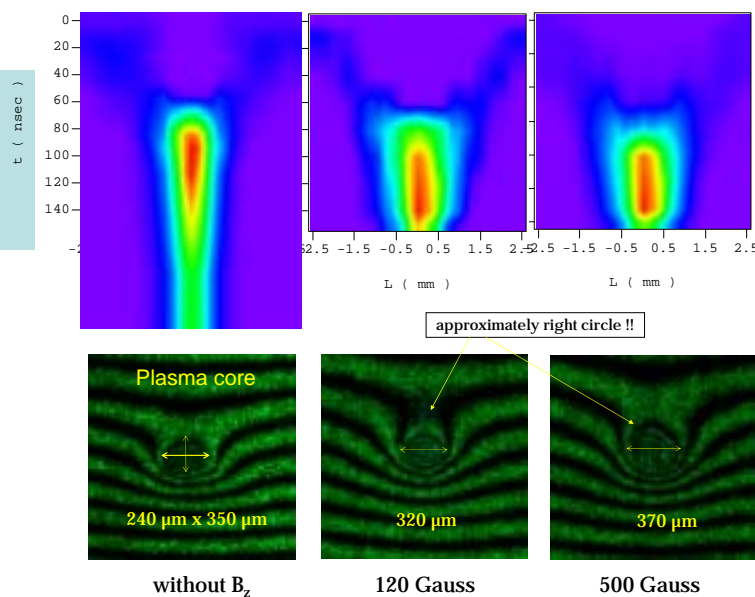
How about in kHz operations?

5. EUV Spectra and Source Size (view angle (at 15°))



Spatial Distribution along Z axis ($\times 2$ mm)

3. Plasma Dynamics - Time-resolved Interferogram (5 ns)



Summary

By applying an external magnetic fields to the plasma,

- spatial stability of hot plasma was improved.
- emission time becomes longer.
- the emission spectrum shifts to the long wavelength side with increasing the magnetic field strength.
- in-band EUV energy (150) was increased.
- both plasma diameter and length were slightly increased.

Above-mentioned experimental facts indicate the energy density of the hot plasma should have been changed by the external magnetic fields.

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