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EUV Emission from Z-pinch Plasmas Driven by Ultra-short Currents

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Abstract

Discharge produced plasmas (DPP) are presently the most powerful extreme ultraviolet source for the 45nm or less rule photolithography process. For DPP based EUV sources, one of the most important issues is to reduce the heat load at the discharge chamber including electrodes and its supporting insulator surface. Driving the DPP using the ultra-short current is the method not only to reduce thermal problem but also to improve the plasma confinement.

This paper describes...

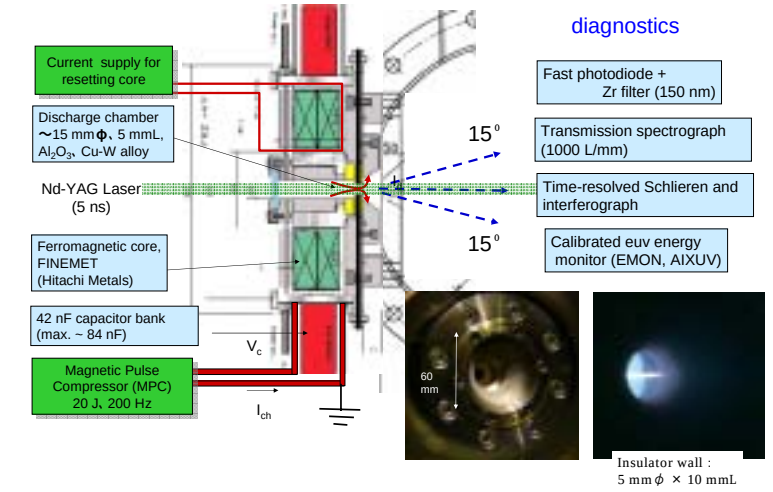
- the characteristics of EUV emission from z-pinch plasmas driven by the current with duration of 110 ns (short circuit load).
- time-resolved observation of plasma dynamics in Z-pinch scheme, using Schlieren imaging and interferogram techniques.

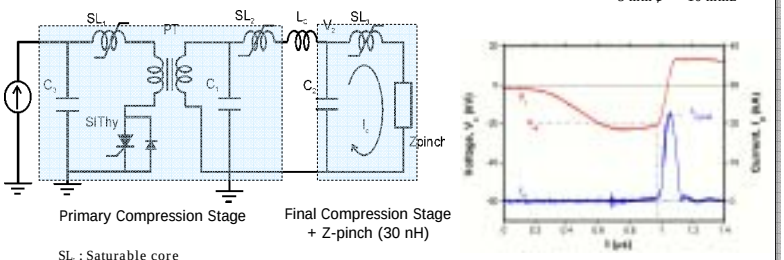
The z-pinch load is directly connected to radially arranged capacitor bank (~ 42 nF). The drive circuit with an inductance of 30 nH is turned on and off by a toroidal ferromagnetic core. The maximum repetition rate of the system is 200 Hz.

The EUV emission from z-pinch xenon plasmas is characterized with respect to the in-band light energy, spectrum, source size as well as temporal behavior of the radiation.

1. Z-pinch Device

Operation pressure : $< 10^{-3}$ torr



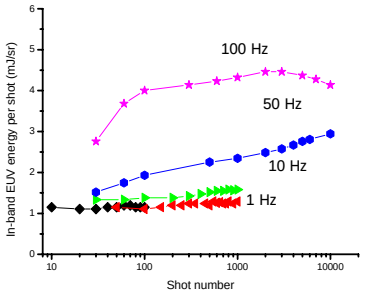


SL_1 : Saturable core (FINEMET™, FT-1H, Hitachi Metals)
PT : Pulse transformer
C_0 = 3 μF, C_1 = C_2 = 42 nF
Maximum stored energy 20 J

Capacitor voltage(C2) and current waveforms at the short load.

2. EUV Emission

2-1. In-band EUV energy dependent on pulse repetition rate (~200 Hz)



In-band EUV energy increases with increase of repetition rare of the discharges.

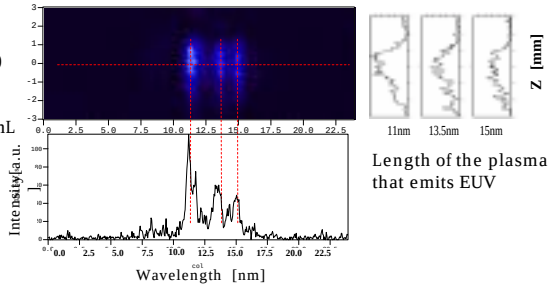
In-band EUV energy increases with the operation time for the rep rate more than 10 Hz.

- Electronic remaining? May be No.
- A temperature rise of gas?

A change of a flow (density, speed) of gas?

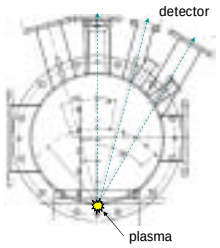
2-2. Spectrum

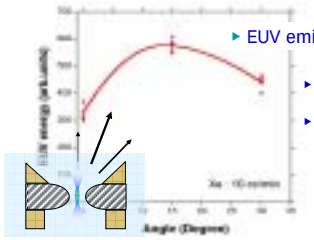
Gas : Xe (40 cc/min)
Rep.Rate : 100 Hz
Ip = 26 kA
Wall: 5mmϕx10 mmL



Length of the plasma that emits EUV

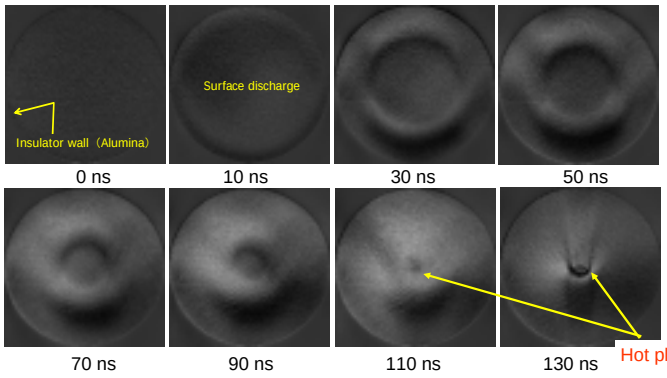
2-3. Angular distribution



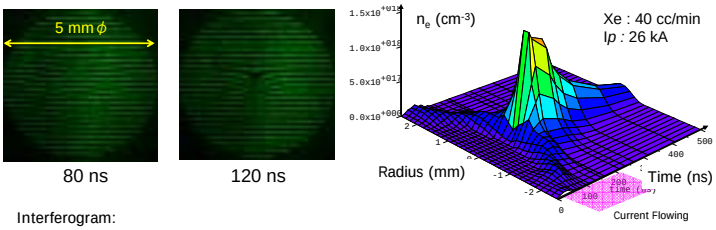


- EUV emission is not isotropic.
  - Absorption by high density gas in front of it.
  - Geometrical effect of the pinched plasma.

3. Plasma Dynamics – Time-resolved Schlieren



4. Electron Density Profile – Time-resolved Interferogram



Interferogram:

Assumption Plasma Length along Z axis : 5 mm

Summary

- EUV energy depends on pulse repetition rate.
- EUV emission is not isotropic.
- Discharge is initiated near the insulation wall.
- Diameter and length along the Z axis of the hot plasma are approximately 300 μm and 5 mm, respectively.
- As long as a current flows into plasma, electron density exceeding 10^{18} cm^{-3} is maintained. After the current ends, the plasma density fades out with a time constant of 500 ns.

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