

The LPL tin-doped micro-droplet laser-plasma EUV source

Mass-limited target regime – mass of tin within droplet limited to the number of atomic radiators heated by the laser – typically $\sim 10^3$ atoms per droplet.

Droplet technology minimizes target debris

High frequency source matched to high rep rate laser

35 μm diameter droplets
20 m/s

35 μm

Debris, ion emission degrade mirror reflectivity

Intermediate focus

IF-target axis

Plasma

Collector mirror

High NA collection is possible

Nearly isotropic plasma expansion

Emission characteristics in a quadric plane represent the emission in 2π

Axis symmetry

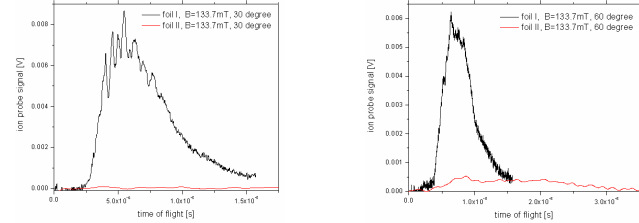
Objective: Characterize debris emission & mitigation effectiveness in a plane

Electron density profile

Sub nano-second interferometry

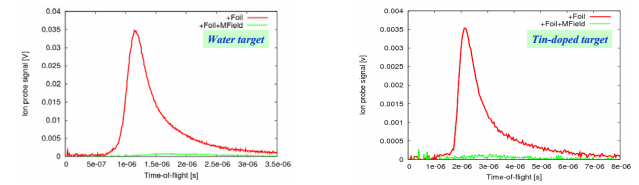
Effect of Magnetic Foil Trap mitigation

Angular dependency of the effect



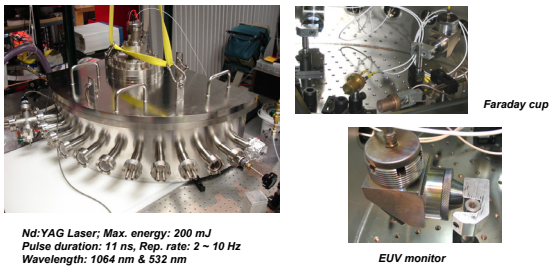
The magnetic Foil Trap reduces the ion signals at two different angles. Assuming the axis symmetry, mitigation effect of up to π sr is confirmed. $> 2\pi$ sr solid angle can be covered by the magnetic field.

Droplet target

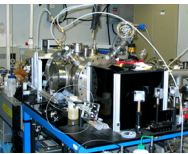


The magnetic Foil Trap suppresses the ion flux from both water droplet plasmas and tin-doped droplet plasmas. Small levels of scattered ions are observed. They will be mitigated by other mitigation schemes such as Repeller Field.

Laboratory Facility

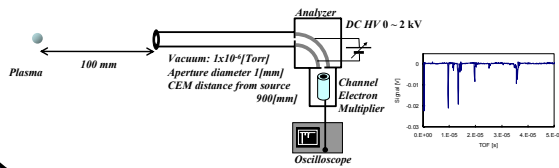


Nd:YAG Laser; Max. energy: 200 mJ
 Pulse duration: 11 ns, Rep. rate: 2 – 10 Hz
 Wavelength: 1064 nm & 532 nm



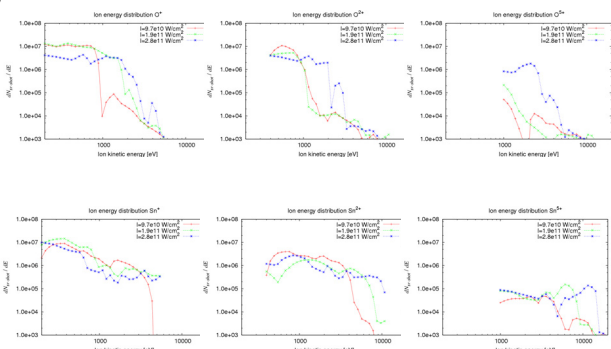
Vacuum: 4×10^{-6} Torr
 1064 [nm], 100 [Hz], Max. 300 [mJ], 10 [ns]
 Focal length: 50, 100 [mm]
 Droplet target Diameter: 30–50 [μm]
 Ion probes: 50 – 150 [mm]
 Max. Ion energy: 5.0 [keV] for Z=1

Ion spectrometer (Electro Static Ion Energy Analyzer ESIE-A)



Ion spectrometer measurement

Ion Energy distribution

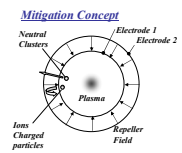


There are no fast ions generated at the laser intensity for the optimum CE ($\sim 10^{11}$ W/cm²). High charge state ions with high kinetic energy observed at too high intensity ($\sim 3 \times 10^{11}$ W/cm²). Controlling the laser intensity is important to achieve the required mirror lifetime.

Combination of debris mitigation schemes

Repeller Field Mitigation

Mitigation Concept

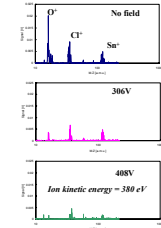


Repeller field captures anything charged

Advantages:
 Simple structure
 High EUV transmission

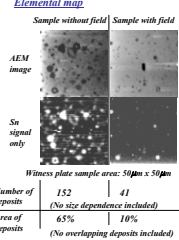
Effect on ion flux

Ion spectrometer measurement

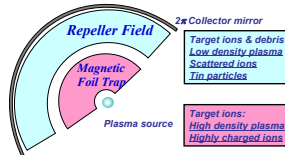


Effect on tin-particles

Auger Electron Spectroscopy (Elemental map)



Combination of mitigation schemes integrated with 2π collector mirror



Both mitigation schemes are designed for high EUV transmission, low erosion of the materials, and large solid angle. Both schemes of the schemes can be integrated without losing their advantages.

Complete reduction of ion flux except small portion of high energy ions. Possible to optimize with higher magnetic field.

Conclusion

- First experimental data proves the effectiveness of the scheme as high transmission/large solid angle debris mitigation apparatus
- The applied principles are independent from each other and therefore superimpose its effects =>Magnetic Foil Trap mitigation combined with Repeller field – Satisfy lifetime requirement
- Cost effective mitigation of ions at long mitigation scheme lifetime

Outlook

- Optimization of geometry
- Integration of the different schemes
- Angular debris and EUV measurements with high power/high repetition rate tin-doped droplet target source

FUNDING

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