

High power EUV source with kW Solid state lasers and tin-doped droplet target

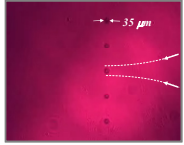
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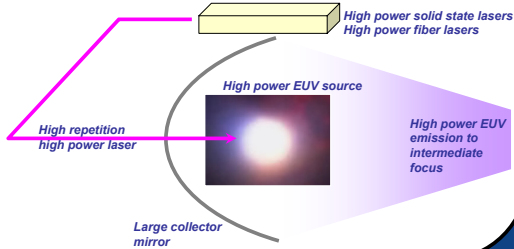


Approach of High Power EUVL sources

High Conversion Efficiency (CE) EUVL source

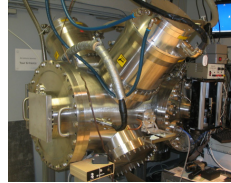


High efficiency radiator, tin, doped
 Mass of tin within droplet limited to approximately 10^{13} atoms per droplet. Droplet technology minimizes target debris,
 High frequency droplets matched to high repetition rate laser



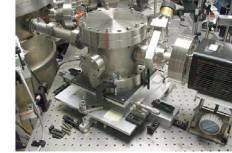
High power EUV source facilities

High power EUVL source chamber

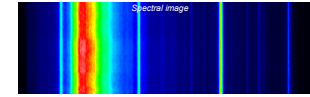


Chamber pressure: $<10^{-4}$ Torr
 Turbo pump speed: >3000 lps
 Spectrograph: FFS
 EUV energy meter: FC calibrated
 Target imaging system
 Labview controlled

Flat-field Spectrographs (FFS)



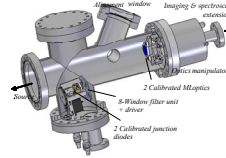
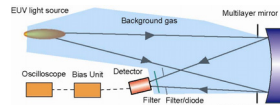
Flat-field Spectrograph Parameters:
 > Gold plated Harada grating
 > ROC = 5.649 m
 > Line spacing = 1200 lines/mm (nominal)
 > Angle of incidence: $\alpha = 87^\circ$
 > slit width = 100 μ m
 > at ~ 10 nm, $\Delta\lambda = 0.06$ nm, R ~ 250



Spectrograph is cross-calibrated against Flying Circus

EUV energy meters

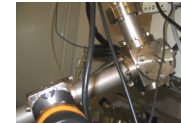
Calibrated absolute EUV energy meter – Flying Circus



The "Flying Circus" diagnostic measures absolute EUV energy

- a Mo/Si multilayer mirror, narrow band reflectivity peaks at 13.5nm, to collect light
- a Zr metal filter to select wavelength: 6.5 – 16.8 nm (FWHM).
- a Si-PIN x-ray photodiode from IRD to detect EUV

Calibrated absolute EUV energy meter



- 45 μ m Mo/Si multilayer mirror reflectivity is calibrated at NIST
- a Zr metal filter transmission is calibrated at NIST
- a Si-PIN x-ray photodiode from IRD to detect EUV
- Signal is cross-calibrated against FC

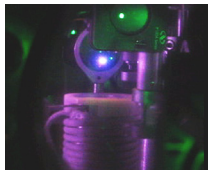
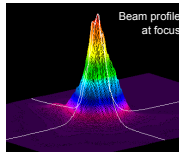
High Power (~kW) Solid state laser

Powerlase Starlase laser



Installed in LPL's laser bay, the next laboratory to the target chamber

Industrial proved high power solid state laser
 Long term operation

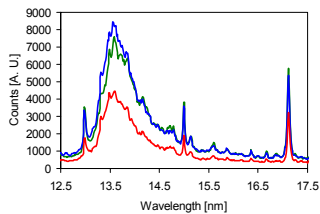


Visible image of the plasma taken from a view port on the target chamber

Tin-doped droplet target and the laser pulse are synchronized

Stable high repetition rate (3-5kHz) laser plasmas are created in the target chamber

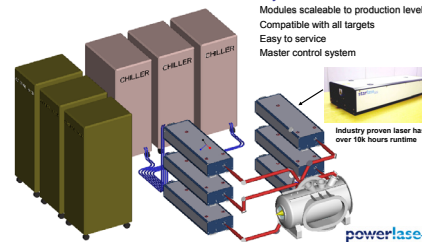
The vacuum in the chamber remains under 10^{-4} Torr during the operation



Tin UTA changes as laser intensity changes, corresponding to the plasma temperature. Optimum intensity for highest CE $\sim 1.7 \times 10^{11}$ W/cm²

Future extension of High Power EUVL source facility

Multiplexed laser system



Advanced target positioning system

30 kHz stable laser irradiation demonstrated

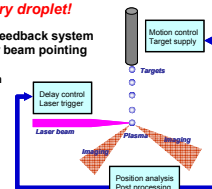
Laser shoots every droplet!

Intelligent 3-D imaging feedback system controls target and laser beam pointing

3-D droplet stability of 3 μ m

24 hour operation at 30 kHz

Single term operation for several days already demonstrated



Large collector mirror

Small source size ($\sim 100\mu$ m diameter) provides large collection angle

Nearly isotropic EUV emission provides collection in backside laser illumination

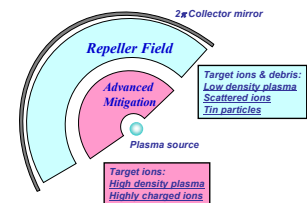
$> 2\pi$ collection reduces the source power required and input laser power with the same CE ($> 2\%$)

Overall transmission from source to IF of >0.5 is possible

Laser power of 10 kW will provide >115 W at IF

Long lifetime will be achieved with use of high transmission mitigation schemes

High transmission mitigation schemes



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.

Conclusion

Mass-limited tin-doped droplet target is coupled with kW class solid state laser

CE of 1.8 % achieved at 3 kHz, at 500 W laser power

EUV power at source is 9 W (2 π , 2%BW)

EUV power at IF (50% transmission) is 4.5 W
 7.2 W at full laser power (800 W)

FUNDING

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