Multi 10 kW short pulse CO_2 laser development for HVM-EUVL

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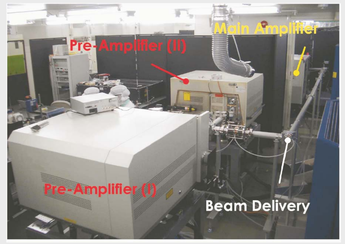
Abstract
The solution for HVM EUV lithography is a laser produced plasma light source with a cost effective CO2 drive laser and a Sn target. To demonstrate this we developed a RF-excited CO2 laser MOPA system with an output power of 8 kW at a pulse length of 20 ns at 100 kHz repetition rate. The laser has a very good beam quality and wave front aberration is therefore no limitation at all contrary to solid state laser.

High-Power Short-Pulse RF-excited CO_2 Laser for EUV Lithography



High Power and short pulse RF-excited MOPA CO_2 laser for LPP EUV light source

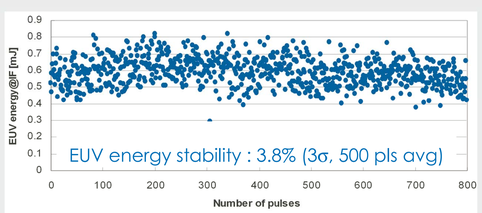
Block Diagram of MOPA CO_2 laser system

Oscillator
Wavelength: 10.6 um
Rep. rate: 100 kHz
Pulse width: 20ns (fwhm)

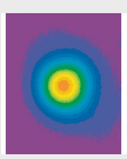
60W → Pre-Amplifier RF-excited CO2 laser → 3kW → Main-Amplifier RF-excited CO2 laser → **8kW**

EUV generation from high power CO_2 laser produced Sn plasma

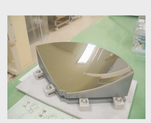
EUV pulse energy (in-band) at intermediate focus



IF image (in-band EUV)



size :
3.6 mm (H),
3.3 mm (V) at 1/e^2

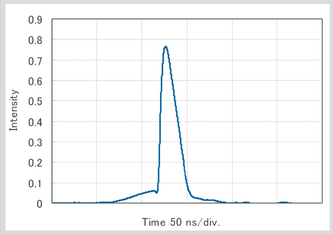


1/3 pi sr collector (120 deg)

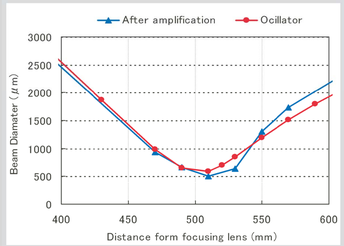
Target : Rotating Sn plate, Laser irradiation power: 6.5 kW (100 kHz, 20 ns)

In-band EUV at IF: **60 W** (4 sr collector), 16 W measured (1/3 pi sr mirror)

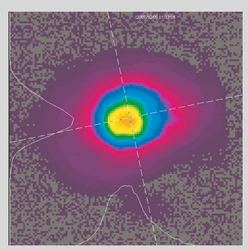
Output laser beam characteristics of the CO_2 MOPA system



Temporal pulse shape of the amplified output pulse. Pulse duration is 20 ns(FWHM). Pedestal component is below 10%.

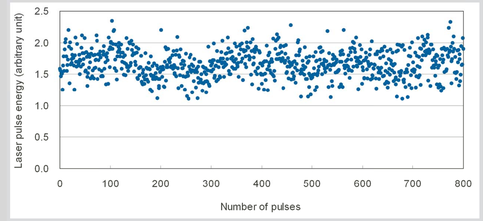


Dependence of focused beam diameter on the distance from the focusing lens. There is no significant change after amplification.



Beam profile of the laser output. M2 was 1.1

CO2 laser pulse stability



Output laser pulse energy stability : 2% (3sigma, 500 pulse)

Development of 20 kW short-pulse RF-excited MOPA CO_2 laser system

OSC → Amp 1 (50 kW pump power) → Amp 2 (120 kW pump power) → Amp 3 (120 kW pump power) → **20kW** 200mJ at 100kHz

Multi-line Oscillator
Rep. rate: 100 kHz
Pulse width: 20ns (fwhm)

Conclusion

- High-power and short-pulse RF-excited CO_2 laser MOPA system has been developed.
  - ✓ Output Power: **8 kW**
  - ✓ Pulse Width: 20 ns
  - ✓ Repetition Rate: 100 kHz
  - ✓ Beam propagation factor M2 : 1.1
- Short-Pulse Amplification Performance
  - ✓ Amplification performance of the MOPA system has been evaluated.
  - ✓ There is no significant wavefront distortion by amplification.
- EUV generation from high power CO_2 laser produced Sn plasma
  - ✓ IF EUV power **60 W** (4 sr, calculated), 16 W (measured by π sr, 1/3 angle collector)
- Next Step
  - ✓ For 20 kW output power
    - *Increase the filling factor for effective amplification.*
    - *Evaluate the laser damage threshold of the optics.*

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