Table-top laser-based EUV source for metrology

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Introduction:

The successful implementation of EUV lithography systems strongly relies both on the efficiency of the employed optical components and the precise control of the relevant source parameters. Metrology tools for comprehensive characterization of EUV radiation and related optical components and sensoric devices are developed at Laser-Laboratorium Göttingen, utilizing a table-top laser-based source for the generation of 13nm radiation. The spatial emission characteristics of this source was monitored by the help of various diagnostic tools, including pin-hole cameras, a spectrometer and a Hartmann-Shack wavefront sensor sensibilized for 13nm radiation. Rayleigh scattering was used to visualize the target gas jet [1].

Experimental:

The experimental arrangement is shown in Fig. 1. The EUV plasma is produced with the help of a Nd:YAG laser (1064nm, 500mJ, 6ns), which is focused into a pulsed gas jet. The alternate use of xenon or oxygen as target gas accomplishes either an intense broad-band or a less intense narrow-band line emission at 13nm, respectively (cf. Fig. 7).

Different types of nozzles and laser parameters were tested in order to optimize the emitted radiation with respect to maximum EUV intensities, small source dimensions, pulse-to-pulse fluctuations and positional stabilities. The investigation of these crucial source parameters was performed with a specially designed EUV pinhole camera (cf. Fig. 3), utilizing evaluation algorithms developed for standardized laser beam characterization. In addition, a rotatable pinhole camera was developed which allows both spatially and angular resolved monitoring of the soft X-ray emission characteristics.

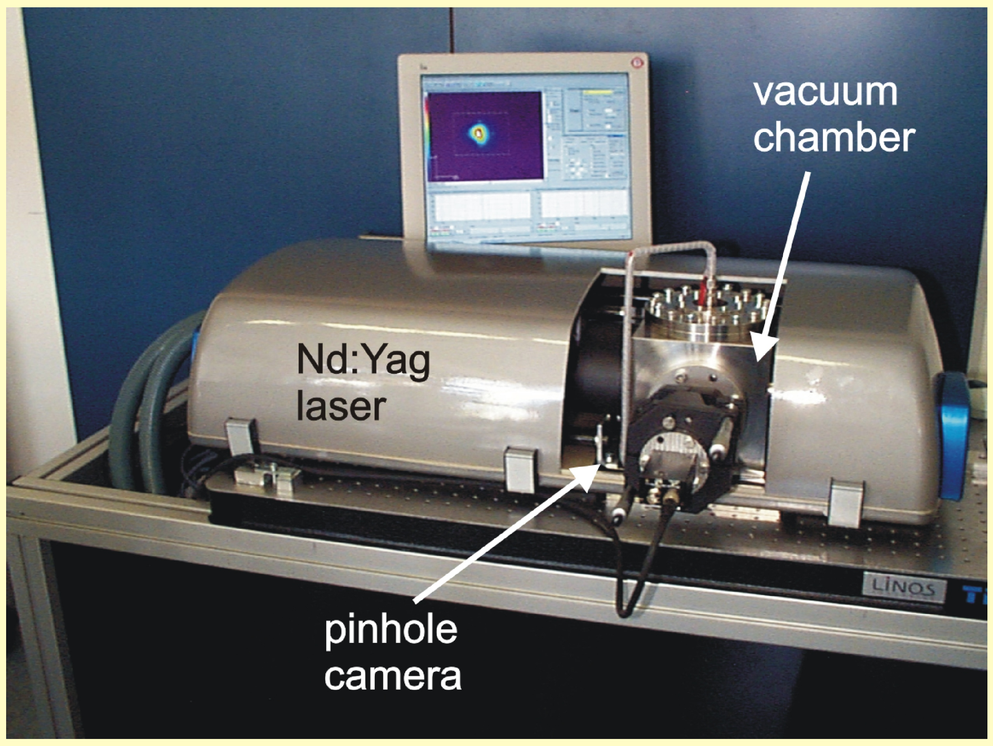

Fig. 1: Table-top EUV source for metrology, consisting of a Nd:YAG laser with integrated target chamber and a pinhole camera. The EUV plasma is generated by focusing the laser (1064nm, 6ns) into a pulsed Xe gas jet. The diagnostics equipment comprises pinhole cameras, an EUV spectrometer and a Hartmann-Shack wavefront sensor for 13nm radiation.

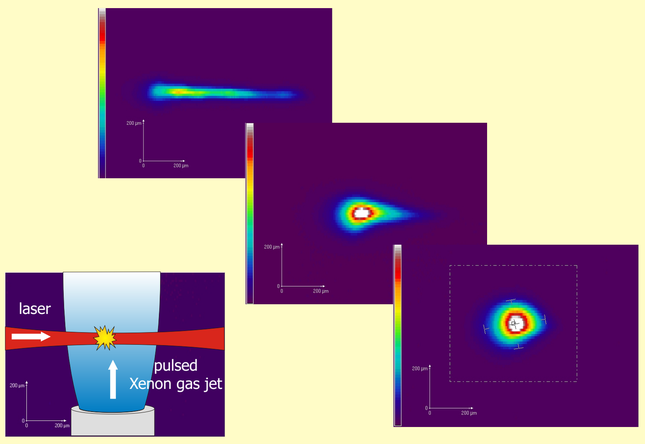

Fig. 2: EUV plasma monitored with pinhole camera for different positions of the laser focus

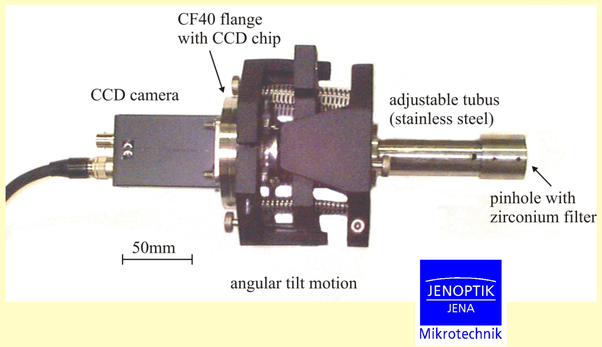

Fig. 3: Photograph of EUV pinhole camera, consisting of a 30µm pinhole, a Zr filter and a CCD chip with EUV-Vis quantum converter. The EUV camera system has been developed for JENOPTIK Mikrotechnik..

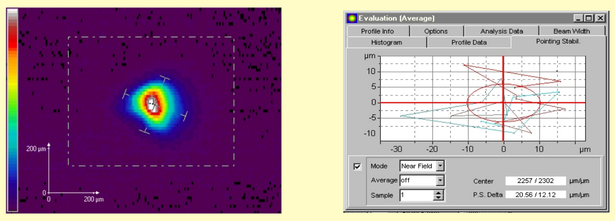

Fig. 4: Recording of pulse-to-pulse fluctuations and determination of positional stability (P.S. Delta) for laser-generated EUV plasma with pinhole camera @13nm, accomplishing single-pulse resolution up to repetition rates of several kHz.

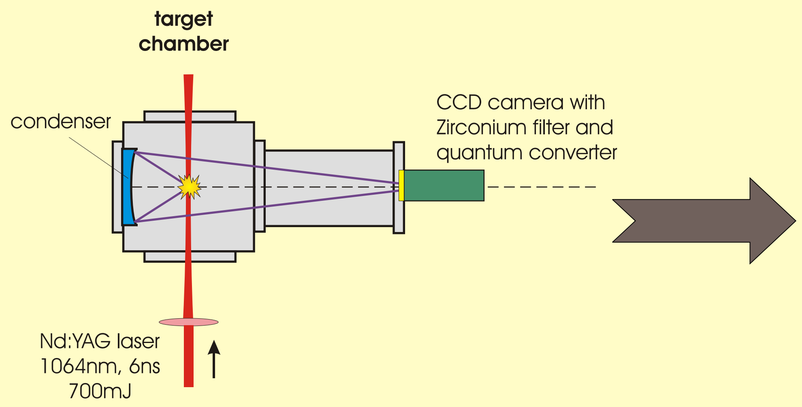

Fig. 5: Sketch of EUV target chamber with integrated spherical condensor (Mo/Si multilayer mirror coated by Fraunhofer Institut IOF / Jena)

Profile @ 13nm:

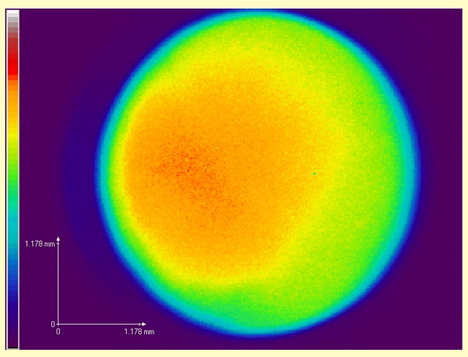

Fig. 6: EUV radiation monitored in focal plane of spherical condensor mirror, using CCD camera sensibilized for 13nm radiation by quantum converter

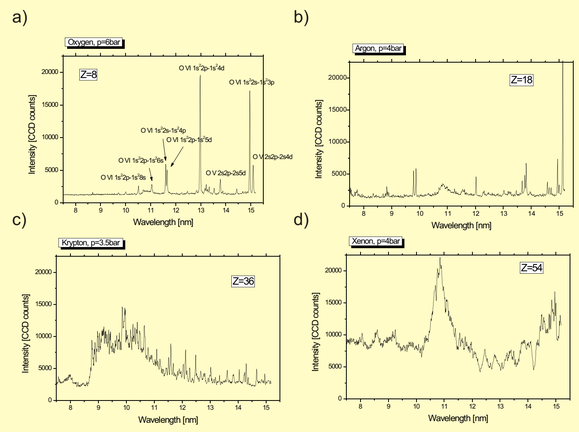

Fig. 7: Laser-induced EUV spectra of various target gases recorded under identical conditions; a) Oxygen, b) Argon, c) Krypton, d) Xenon

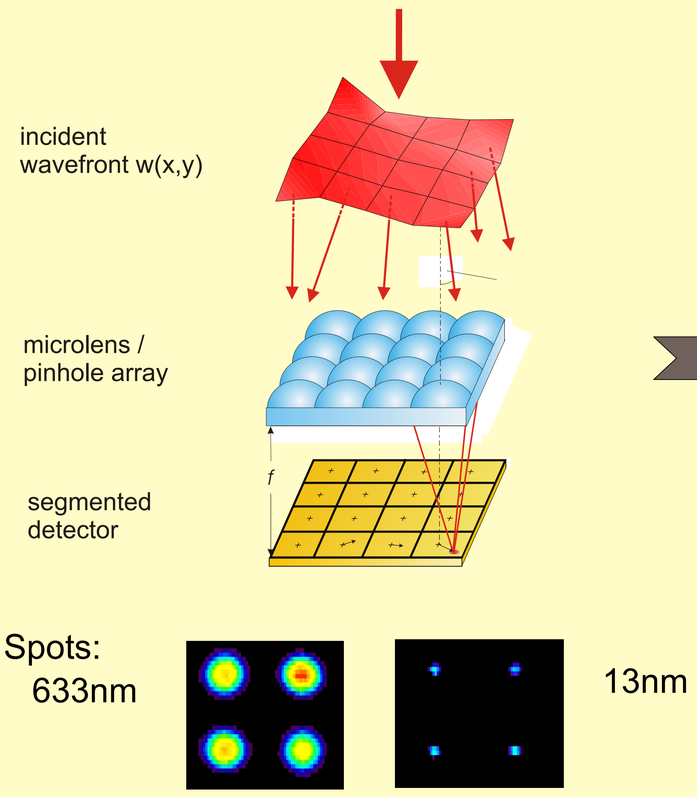

Fig. 8: Hartmann-Shack wavefront measurement @13nm;
above: Principle of Hartmann-Shack wavefront sensor
below: Spot distributions produced by Hartmann pin-hole plate,
left: He-Ne laser (633nm) used as plane wave for calibration,
right: 13nm spots

Wavefront @ 13nm:

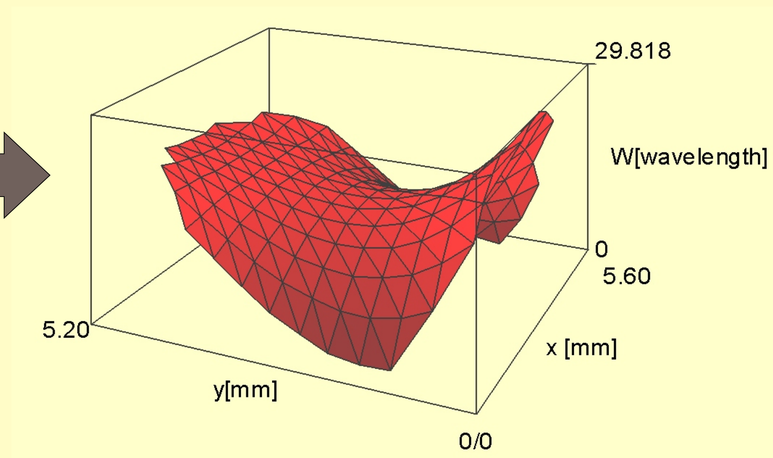

Fig. 9: EUV wavefront monitored after reflection from Mo/Si multilayer mirror, indicating strong astigmatism of mirror.

Spezifications of laser-based EUV source:

- wavelength (Xe target):	7 - 20 nm
- pulse length:	6ns
- plasma shape:	spherical, (1/e²) 200µm 10%
- pulse-to-pulse-stability:	10%
- positional stability:	10%
- repetition rate:	10Hz
- conversion eff. (Xe):	0.2- 0.5% (4)

Summary:

A table-top EUV source for metrology was developed. For spatially and angular resolved monitoring of the soft X-ray emission characteristics different pinhole cameras were utilized. With the help of these cameras a strong angular dependence of the emitted EUV intensity was found, indicating reabsorption of the EUV radiation in the surrounding target gas (Xe).

Moreover, the directional distribution of the EUV radiation before and after reflection from multi-layer mirrors can be monitored with the help of a Hartmann wavefront analyzer sensibilized for 13nm radiation.

[1] S. Kranzusch, C. Peth, K. Mann: *Spatial characterization of EUV-plasmas generated by laser excitation of a xenon gas target,* Rev. Sci. Instr. 74 (2) 969 (2003)