Spatial characterization of a discharge based radiation source in the extreme ultraviolet

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Application Note

Introduction

A variety of new metrology applications in the spectral range of extreme ultraviolet lithography require intensive sources where the brilliance is the figure of merit rather than the total photon flux. The main request is based on ongoing activities in the environment of extreme ultraviolet lithography operating at a wavelength of 13.5 nm. This technology is considered as most probable for future chip production with ever smaller features. As example, future inspection tools for photo masks have to be equipped with a light source with several 10 W/(mm^{2}sr) into a spectral bandwidth of 2% at the central wavelength of 13.5 nm [1,2]. Plasma based sources are principle candidates, where a target is heated up to several 100.000 °K in a short pulse to emit characteristic radiation in the extreme ultraviolet. Either a pulsed laser or a pulsed electrical discharge current is used for heating up the target or the working gas. In the Institute for Laser Technology a special kind of discharge based EUV source has been developed in the past [3,4]. This source creates a dense and hot Xenon plasma of typically few 100 µm in diameter and few millimeter in length. Current investigations are aiming at a better understanding of the brilliance scaling around a wavelength of 13.5 nm [5].

Set-up

A photograph of the experimental set-up is shown in Fig. 1. The plasma light source is mounted to the chamber, where vacuum pump (top) and diagnostic is attached. The base pressure of the vacuum system is <1E-6 mbar. During source operation the Xenon pressure is around 1E-3 mbar. At this pressure the self-absorption for the 13.5 nm radiation in the neutral Xenon environment is less than 10% from the source to the detectors. The brilliance is determined by simultaneous measuring of the total photon flux of the plasma in a spectral bandwidth of 2% and taking a radial profile in axial direction using a pinhole camera. The calibrated energy monitor consists of a spectral filter including two multilayer mirrors and a coated photo diode. The pinhole camera with a magnification around ~1 consist of a 40 µm pinhole and a Zirconium coated silicon nitride window for suppression of visible light from the discharge plasma. As detector a back-illuminated CCD camera (iKon-M DO934P-BN) from Andor Technology is used. The absolute peak brilliance in the center of the emission profile is calculated from the measured spatial profile and the absolute photon flux.

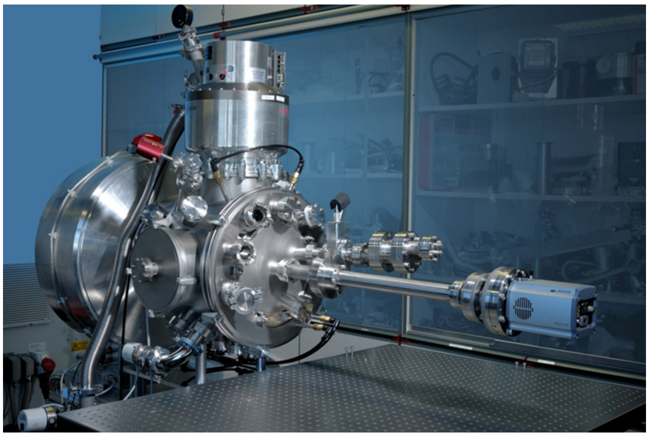

Fig. 1: Photograph of the experimental setup shown EUV source and diagnostics

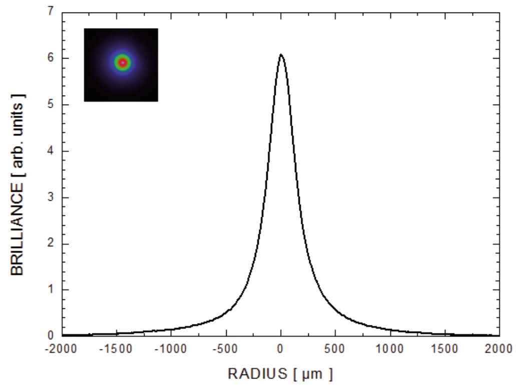

Fig. 2: Typical pinhole image and line scan across the center of the measured intensity distribution.

Results

A typical pinhole image and a line scan across the center of the profile are shown in Fig. 2. In the axial direction the spatial emission profile has a radius of 220 µm (FWHM). At a typical exposure time of 50 ms about 75 pulses contribute to the pinhole image.
The two-dimensional distribution of the brilliance can be written as $L(x,y) = L_{peak}\, f(x,y)$ introducing the normalized function $f(x=0,y=0) = 1$, which is taken from the pinhole image.

The peak brilliance L_{peak} can be calculated from the measured total photon flux per steradian, $P_{13.5nm}$, using the relation $P_{13.5nm} = L_{peak} * \iint dx\, dy\, f(x,y)$. A typical peak brilliance of the plasma source is of around 8 $W/(mm^2 sr)$ at a repetition rate of 1500 Hz.
In long term experiments with thousands of automatically acquired images it was possible to show, that spatial jitter of the center of gravity of the EUV emitting plasma is less than a few micrometer.

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