Electron impact type laboratory EUV source for metrology and imaging

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What energies are we looking for?

**XUV spectral region**

- **Soft X-ray**: 200eV – 2000eV
- **X-ray**: 2 keV – 50 keV

**EUVL wavelength**: 13.5 nm
Introduction

DPP and LPP sources for metrology and imaging

• Pulsed Energy
• Repetition rate
• Lifetime
• Lasing, coherence
• Focusibility – source size, system geometry
• Optics
• Compactness
• Cost
Laser Produced Plasma – gas puff target

- high-Z gas (xenon, krypton, argon)
- low-Z gas (helium, hydrogen)
- inner nozzle
- outer nozzle
- laser beam

- electromagnetic valve system
- X-ray backlighting images

EUV condenser - geometry

Mo/Si ellipsoidal mirror

Nd:YAG beam

EUV source

Double stream valve system

Image of the source

254

254,00

R 179,605

Dy = 80

Taken from report titled “Opracowanie projektu układu optycznego do formowania wiązki promieniowania laserowo-plazmowego źródła EUV Nr 451/WAT/2001 (SPUB-M)”

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Scheme of the EUV microscope condenser alignment

Series of images of the spatial distribution of radiation focused by the condenser in the proximity of the condenser focal plane.

The distances show displacement of the measurement plane from the optimal in-focus position at z= 0 mm

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Capillary discharge source

Introduction

Z-pinching Capillary Discharge

- Radial compression of plasma by Lorenz force
- Plasma heating
- Fast cooling of plasma due adiabatic expansion
- Preionisation for discharge stabilisation

DPP source at CTU

CAPILLARY DISCHARGE APPARATUS FOR INTENSE EUV RADIATION GENERATION

- Ceramic Capacitors (1.25 ÷ 31 nF).
- Al₂O₃ capillary, 3.2mm dia., 20cm long.
- Low inductance -> high dI/dt.
- Pulse-charged: 1x Marx + coil.
- Rogowski coil.

CTU Prague, Fac. of Nucl. Sci
DPP source and condenser metrology
(images of focused beam)

MicroSOURCE®

X-ray source – X-ray mirror combination

- The focus may be changed from spot to line electronically
- Stability of focal spot assured
- Modular design allows ease of access for tube changes
- Patents
- Focal spot size, shape and position are controlled automatically
Ellipsoidal X-ray Mirror

Y-AXIS IN THE SAME SCALE AS X-AXIS

0 mm

Y-AXIS NOT IN THE SAME SCALE AS X-AXIS

1 mm bar

X-ray Source

Ellipsoidal Mirror

Beam Stop

Direct Beam

Reflected Beam

Focal Area

a

b

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Ellipsoidal X-ray Mirror
(X-ray beam images)
Example: Ellipsoidal mirror

- Mirror surface has shape of rotational ellipsoid
- Source is placed in left focus
- Detector or sample is placed in right focus
- Radiation strikes mirror surface at grazing angles 0.5° ÷ 20°
- Mirror is focusing radiation from left focus on right focus
**Microfocus X-ray tube**
(high complexity, high cost, low power)

**Large anode X-ray tube**
(lower complexity, lower cost, higher reliability, higher power)

- **Anode**
- **e-GUN**
- **e-beam optics**
- **Small focus**
- **Large focus**
3D X-ray source & 3D X-ray mirror combination

(higher power, small X-ray focal spot, lower complexity, higher reliability)

1. e-source
2. Anode - target
3. X-ray optic
4. X-ray focus

PATENT PENDING
Grazing incidence angle distribution (disk target)

$Z_1 = 5 \text{ mm}$

$Z_1 = 250 \text{ mm}$

Computer simulation
Focal intensity distribution
(disk target, $Z_1 = 5$ mm)

Computer simulation

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Focal intensity distribution
(disk target, Z1 = 50 mm)

Computer simulation
Focal intensity distribution
(disk target, \(Z1 = 100\) mm)

Computer simulation
Computer simulation

FWHM = 1.676 mm, HEW = 0.588 mm
Computer simulation
## FWHM, HEW, Flux parameters

<table>
<thead>
<tr>
<th>Vzdálenost Z-O (mm)</th>
<th>FWHM$_x$ (mm)</th>
<th>FWHM$_y$ (mm)</th>
<th>HEW$_x$ (mm)</th>
<th>HEW$_y$ (mm)</th>
<th>Input Flux</th>
<th>Reflected Det. Flux</th>
<th>Transfer Efficiency</th>
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</thead>
<tbody>
<tr>
<td>5</td>
<td>3.4</td>
<td>3.6</td>
<td>1.6</td>
<td>1.8</td>
<td>0.3975</td>
<td>0.1733</td>
<td>44%</td>
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<tr>
<td>13.5</td>
<td>3.4</td>
<td>3.4</td>
<td>1.8</td>
<td>1.8</td>
<td>0.1742</td>
<td>0.0831</td>
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<tr>
<td>50</td>
<td>3</td>
<td>2.9</td>
<td>1.4</td>
<td>1.4</td>
<td>0.0237</td>
<td>0.0147</td>
<td>62%</td>
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<tr>
<td>100</td>
<td>2.4</td>
<td>2.4</td>
<td>1</td>
<td>1.2</td>
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<td>0.0044</td>
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<tr>
<td>150</td>
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<td>1.9</td>
<td>0.8</td>
<td>0.8</td>
<td>0.0028</td>
<td>0.0020</td>
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<tr>
<td>200</td>
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<td>1.7</td>
<td>0.6</td>
<td>0.6</td>
<td>0.0016</td>
<td>0.0012</td>
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<tr>
<td>250</td>
<td>1.5</td>
<td>1.5</td>
<td>0.6</td>
<td>0.6</td>
<td>0.0010</td>
<td>0.0008</td>
<td>76%</td>
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Computer simulation
Summary

3D X-ray source & 3D X-ray mirror combination
for metrology and imaging

• Electron tube
• Rotationally symmetric X-ray optic
• CW or pulsed operation
• mm X-ray focal spot size
• Power
• Compactness
• Stability
THANK YOU FOR ATTENTION

Prague