Introduction

Most light sources, especially in the extreme ultraviolet (EUV), emit a full spectrum of wavelengths, however many applications in science and industry require monochromatic light. Therefore, a monochromator is needed, to select and focus certain wavelength bands from this spectrum and direct them to a sample. With regard to X-ray photoelectron spectroscopy (XPS) and photoemission electron microscopy (PEEM), monochromaticity is of crucial importance as it directly affects the width of the energy distribution of the emitted electrons and thus the maximum achievable energy resolution in the microscope. Because oxygen has emerged as a high performance emitter with separated emission lines between 10 nm and 20 nm (124 eV - 62 eV), the requirements for a monochromator are to separate the strong emission lines in this range and focus the light on a spot with 250 µm diameter which corresponds to an average field of view (FOV) of currently available PEEMs. The photon energy must be tunable over several tens of electron volts (eVs) with an energy resolution better than 200 meV which is sufficient for most experiments. However, there are applications requiring much higher spectral purity which can be addressed using the intrinsic Doppler broadened linewidth of the emission lines of about 15 meV.

Design of the Monochromator

- Requirements:
  - Separate two emission lines located at 15.01 nm of O\textsuperscript{2+} and 15.15 nm of O\textsuperscript{2+}
  - Spot size on the sample should match the field of view of the PEEM
  - High intensity at the sample
  - Wavelength selection by rotation of the grating
  - Separation slit moves with focus when the wavelength is changed
  - Toroidal mirrors with different curvatures can be used to focus light onto the sample positioned at different distances, e.g. 250 mm and 500 mm
  - Sketch shows:
    - Wavelength separation (top)
    - Throughput optimization (bottom)

Spectral Resolution

- Emission lines located at 15.01 nm of O\textsuperscript{2+} and 15.15 nm of O\textsuperscript{2+} can be selected independently

Time of Emission and Fluence at Focus

- Source operation frequency: 3 kHz
- Measurement without Kr-After
- 0th order decomposed by fitting 2 Gaussians
- 1st order (EUV radiation only) and decomposed EUV time of emission agree
- Visible light: (166.30 ± 32.21) ns
- EUV: (63.84 ± 15.48) ns

Table 1: Summarized values (position, fluence, photon energy, and wavelength)

<table>
<thead>
<tr>
<th>Position</th>
<th>Fluence</th>
<th>Photon Energy</th>
<th>Wavelength</th>
</tr>
</thead>
<tbody>
<tr>
<td>0th order</td>
<td>2422.7 ± 275.0 eV/m²·ns</td>
<td>15.01 nm</td>
<td>15.01 nm</td>
</tr>
<tr>
<td>1st order</td>
<td>2422.7 ± 275.0 eV/m²·ns</td>
<td>15.15 nm</td>
<td>15.15 nm</td>
</tr>
<tr>
<td>Visible light</td>
<td>166.30 ± 32.21 ns</td>
<td></td>
<td></td>
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</tbody>
</table>

Summary

We present raytracing simulations, design, experimental characterization and evaluation of a compact tunable imaging monochromator (a combined collector and emission line selector) for 5 to 20 nm wavelength, based on a curved grating [Medvedev, S83, 2017 Source workshop] and a toroidal mirror. The presented results were obtained using a high power EUV gas discharge source and are compared to the raytracing simulations. The irradiance near the focus is of the same order of magnitude as for our successful proof-of-concept experiment using Bragg multilayer mirrors, but with the possibility to select a desired wavelength and focus the light to 250 µm spot size diameter. An average fluence of 2422.7 eV/m²·ns at 250 nm for the 15 nm or 86.66 eV photon energy emission line was measured. Also, spectral resolution was investigated to separate the single emission lines of light elements, e.g. oxygen, to take advantage of the inherent small bandwidth of these emission lines.