

Measurements of EUV Radiation at the Intermediate Focus

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Introduction

Our goal is to provide a comprehensive set of intermediate focus (IF) measurements for the characterization of EUV sources. Here, we review the conditions and candidate arrangements for measurements at the IF and give estimates of the achievable measurement accuracy. In addition, we provide data in preparation of measurements carried out with our IF measurement chamber on an LPP source with 1.6 sr collector mirror.

Proposed techniques for IF measurements:

- EUV monitors using Zr or SiN filter foil and multilayer mirror with 2% bandwidth for in-band EUV detection
- ML mirror combinations with 2% bandwidth for imaging of IF region
- Power meter (thermal) for average total power measurements
- Filters for out-of-band measurements (CaF₂ and others)
- Angular distribution device with fluorescence converter and visible imaging
- EUV spectrometer with fat-faded plane and CCD camera detection
- IF measurements carried out under argon backing pressure
- Debris analysis behind IF by RGA and witness plates

Parameters, Methods and Accuracy of IF Measurements

- EUV measurements to be carried out in a chamber behind the IF
- Only radiation reflected by the collection optics and some scattered light passes through the IF aperture
- Not all tools can be mounted simultaneously together
- EUV monitors and mirrors have to be inserted into the beam path
- A gas barrier can be used to provide contamination isolation

Source parameter	Method	Accuracy of Measurement
In-band EUV Power	Calibrated EUV Monitor	±10%
Energy Stability, p-p	Relative EUV Monitor	±0.1%, 3σ over 100 pulses
Integrated Dose Stab.	Relative EUV Monitor	± 0.01%
Uniformity/Ang. Distrib.	Moving Relative EUV Mon. Image Converter + vis. CCD	±2%
Position, Size of Int. Focus	EUV Imaging + CCD camera	100 μm resolution
Out-of-band Spectral Data	Filter and Photodiode Mon.	coarse, dependent on filter
Wavelength	EUV FT-Spectrometer	±0.05 nm wavelength scale

In-band EUV Monitors

In-band EUV detectors with thin Zr foils and multilayer mirrors at near-normal or 45 degree incidence, AXUV photodiode detectors. Used at lower photon flux with Zr foils on support structures.

Use of Thermal Power Meter at High Rep. Rates

Calorimeter-based detection scheme for high EUV average power measurements

Metal filter mesh can serve as neutral density attenuator.
 CaF₂ plates can be inserted to determine DUUV/DIR contributions by subtraction.
 Detector (water-) cooling is required to avoid thermal drift of detector.

Measurements of Contamination Behind IF

- A residual gas analyzer (RGA) with differential pumping connected to the IF chamber via an orifice is used to monitor contaminants.
- MLM/Si-witness plates can be mounted behind the IF aperture to record particle debris. After exposure for a given number of pulses the witness plates will be examined by surface analysis techniques.

Spectral Analysis of EUV Emission

- Spectrometers mounted at chamber behind IF
- Fat-field grazing-incidence spectrometers with EUV-sensitive CCD detectors can record the entire emission spectrum in one measurement

EUV spectrometer: 6 nm – 22 nm
 VUV spectrometer: 10 nm – 80 nm
 resolving power: λ/Δλ – 200-400

Filter-based Measurements for Out-of-Band Regions

Two rotating filter wheels in sequence, each with 8 positions for filters, allowing measurements with a photodiode detector, also for combinations of two filters.

Examples of filters:

Filter type	Major spectral range
Zr foil	6 nm – 17 nm
Nb foil	6 nm – 15 nm
Si foil	12 nm – 35 nm
Al foil	17 nm – 75 nm
CaF ₂	130 nm – IR
UV filter	250 nm – 400 nm
UV long pass filter	390 nm – IR

View of one filter wheel:

IF Measurement Chamber Allows Rotation for Angular Distribution Measurements

View of adjustable IF chamber design with gas barrier capabilities

Test data for suppression of Xe gas by argon gas barrier

In-band Imaging of Intermediate Focus Spot

Using multilayer-coated mirrors at near normal-incidence, the in-band radiation at the IF can be imaged onto an EUV-sensitive CCD camera. Suppression of non-EUV light and attenuation of EUV light is accomplished by a Zr foil on support structure.

Angular Distribution Measurements

- Fluorescence converter-based device with Si/Cr for conversion of EUV to visible-light

Concept of Measurements with Insertion Devices

ML Mirrors with Combined 2% Bandwidth for EUV Filtering

Detection chamber with mounts for Z-type in-band imaging mirrors and holder for insertible CaF₂ window in front of EUV detector

Use of ML mirrors with combined 2% bandwidth at 13.5 nm for EUV imaging and filtering

Conclusions

- IF measurement techniques are developed and presented for EUV light collected from an LPP source
- A set of IF measurements is proposed
- Chambers and contamination reduction techniques were installed
- Tools and measurement parameters are discussed

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