Characterization of EUV Detectors and Tools at NIST

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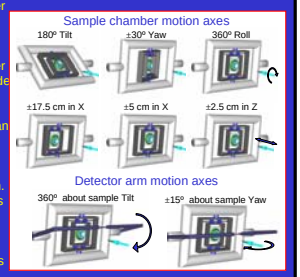
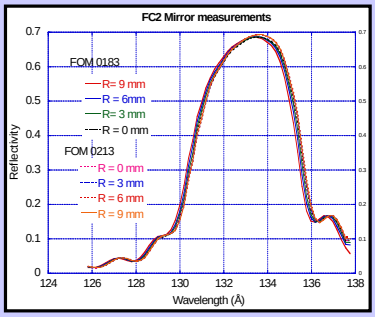
Introduction:
For decades The National Institute of Standards and Technology (NIST) has been providing metrology services in the extreme ultraviolet for industrial and scientific applications. Recently, NIST has developed the ability to measure the responsivity of assembled EUV radiometry instrumentation. In this poster we will present experimental setup and the results of these measurements

NIST/DARPA Reflectometer :
The reflectometer sample chamber was designed to measure the reflectivity of large, highly-curved optics for use in EUVL tools. To accomplish this a 2 meter diameter by 3 meter long chamber was made containing a motion system which can position and manipulate large optics in vacuum. The chamber can handle samples up to 40 cm in diameter and 40 kg mass. The beamline's monochromator has a wavelength range of 3 nm - 40 nm. The beamline incorporates 2 types of EUV-sensitive photodiode detectors optimized for different wavelength ranges. Despite its large volume the reflectometer has a short 2 hour pump-down time.

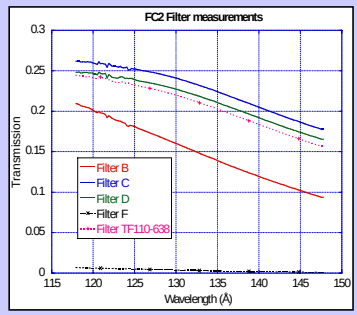




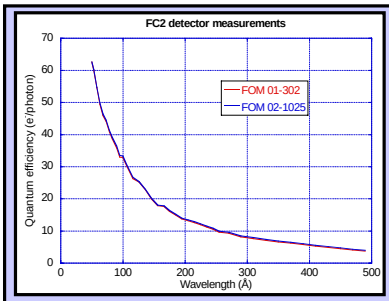
EUV mirror and filter calibration

The NIST/DARPA EUV reflectometry facility has demonstrated accuracy of ~ 0.3%* reflectivity with a wavelength uncertainty of up to 0.1 Å. Its double exit slit beam monitoring system allows for accurate normalization with uncertainty of ~0.1%. MoSi mirrors are one of the key components of filtered radiometers and accurate measurement of their reflectivity is key for the absolute calibration of an instrument. The figure to the left shows the reflectivity scan of two curved MoSi mirrors for use in the Flying Circus 2 (FC2).

The reflectometer can be configured to measure both the reflectivity of optics and the transmission of thin foils or filters. Filter materials like Zr and Be can be used to filter attenuate visible and IR light with minimal EUV transmission loss. Filter transmission measurements can made on this beamline have a 1% uncertainty. Examples of these measurements are shown in the right hand figure which contains transmission scans of several Zr filters of various thicknesses for use in the FC2.



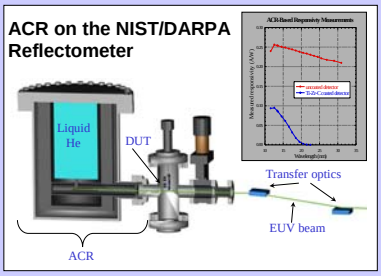
*All uncertainties are given as the combined standard uncertainty with a coverage factor k=1.



EUV Detector calibration

Transfer optics can be added to the reflectometer chamber to allow for the use of external endstations to expand the capabilities of the beamline. One of these endstations is an Absolute Cryogenic Radiometer (ACR) is pictured on the right. An ACR is an electrical substitution detector that determines the power of incident light to an uncertainty as low as 0.1%. The ACR endstation was used for the calibration of EUV transfer standards for use on the NIST EUV detector calibration beamline. This improved the uncertainty of detector calibrations in the 13 nm regime to 1%. This improvement not only reduces the uncertainty of detector calibrations (like those pictured to the left) but also the responsivity measurements of fully assembled metrology instruments since they are directly compared to the same transfer standards.

ACR on the NIST/DARPA Reflectometer



Measurements of assembled EUV instrumentation

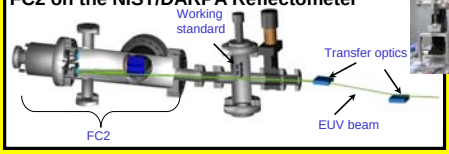
Recently NIST conducted the measurements on assembled EUV radiometer packages the FC2 by Scientec and FOM and the Emon by Jenoptik.** This was done by utilizing in-vacuum transfer optics to relay EUV radiation from the reflectometer sample chamber into an external endstation. Beyond the sample chamber the endstation housed a removable calibrated transfer standard followed by the filtered radiometer. Measurements were conducted by placing the working standard in to the incident beam and transferring its calibration to the double slit beam monitor of the reflectometer by scanning the wavelength of the monochromator and recording the ration of the two detectors. The working standard was then removed from the beam path and light was transmitted into the radiometer where it was directed onto its detector. The calibration of the beam monitor was then transferred to the output of the radiometer. This cycle was repeated for various configurations to fully measure the instruments' performance. Both instruments were measured in similar fashion however improvements in NIST apparatus and technique allowed the reduction in measurement uncertainty.

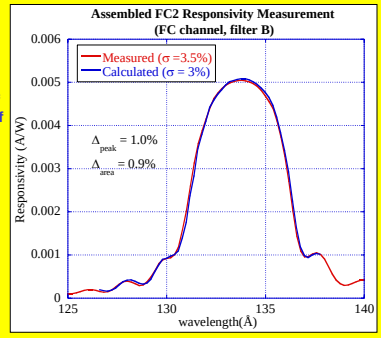
** Certain commercial equipment, instruments, or materials are identified in this paper to foster understanding. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

Assembled FC2 Calibrations at NIST

The graph on the right shows a comparison of the measured responsivity of the assembled FC2 and calculations based on the measurements of the performance of components internal to the FC2 including its filters, mirror and detector. The example shows agreement well within the combined uncertainty: the relative difference in the peak responsivity (Δ_{peak}) is 1% and relative difference in integrated responsivity (Δ_{area}) is 0.9%. The measurements of the fully assembled instrument have an uncertainty of 3.5% and the combined uncertainty of the individual component measurements is 3%. Several measurements and calculations of the FC2's responsivity were made using a variety of filter and mirror combinations. All of the measurements agreed to within the uncertainties of the measurements and were typically on the order of 2.5% and never exceeded 4.2%.

FC2 on the NIST/DARPA Reflectometer



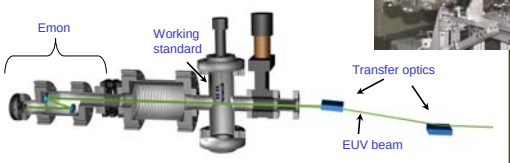


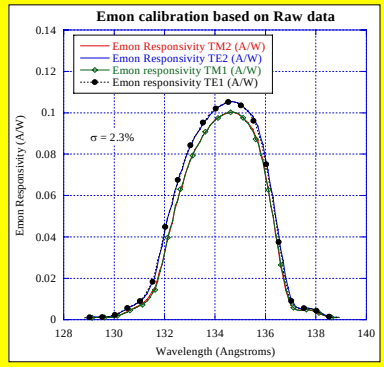
Note: The measured peak is shifted due to the high angle of incidence necessary for the NIST measurement, under normal use the FC2's responsivity is nominally at 135Å.

Assembled Emon Calibrations at NIST

The graph on the right shows the results of measurements of the responsivity of and Assembled Emon. The two curves represent performance under TE and TM input polarization. The Emon is a two mirror system whose response is affected by the polarization of the input light due to the twin 10° reflections. Further modeling was also done to determine monochromator effects on the measurement to provide a more accurate calibration.

Emon on the NIST/DARPA Reflectometer





Future plans:

- Reflectometer monochromator upgrade.
- Laser-produced Plasma-based responsivity measurements of an assembled FC2.
- Development of Al_2O_3-based detectors for pulsed source monitoring.
- Characterization of EUV detector performance under pulsed irradiation.
- Development of characterization techniques for EUV CCD and spectrographs.

Summary::
The National Institute of Standards and Technology has expanded and improved its EUV metrology program to aid in the development of EUV sources to fit the needs of EUVL. This includes the development of calibration facilities and techniques for assembled EUV radiometers for source development purposes.