Soft/tender X-ray 2D-RIXS spectrometer design

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Abstract

New optical design inseparably hinges on the mathematical deduction of light path function with Taylor's expansion under Fermat's condition[1-3]. The deduced equations are basic to pinpoint the focal positions with coma-free state[4,5], and it is of great importance in tolerance analysis[6]. However, such deductions are sophisticated. To avoid this issue, we propose a visual and universal approach based on the ray-tracing method. Firstly, this method is capable to clarify the groove parameters of a varied-line-spacing grating to any arbitrary order in a complex optical layout. Secondly, the energy-dependent focal position calculated using the Hybrid Powell's method. This paves the way toward the analysis of engineering tolerance over a whole energy range and the associated pulse stretching due to grating. Thirdly, the performance analysis newly includes assessing the diffraction efficiency (thanks for the core program uses a freely-available code RETICOLOR from Institut d'optique[7]). Based on above codes, we designed a 2D-RIXS spectrometer. In summary, this work might be useful for incoming automated design of soft/tender X-ray optics.

Keywords: varied-line-spacing grating, automated design, soft/tender X-ray

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Tender X-ray microfocus beamline for dipole radiation at BESSY II

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Abstract

We have set up a new beamline on a dipole magnet in PTB's laboratory at BESSY II. The new beamline provides monochromatized radiation from 1.5 keV to 10 keV, which is focused typically to a 20 µm x 20 µm spot. This microfocus will simplify and improve X-ray spectrometric measurements such as micro X-ray fluorescence spectroscopy and X-ray emission spectroscopy with a von Hamos spectrometer.

The beamline combines two monochromator modules, a double crystal monochromator (DCM) with two Si 111 crystals and a plane grating monochromator (PGM) with a multilayer-coated blazed grating and plane mirror. The beamline can be operated in PGM (below 3.5 keV) or DCM mode (above 2.45 keV). All other mirrors are coated with Pt, except for the toroid (M1), which has also a stripe with a carbon coating to suppress higher order contributions above 4 keV. The toroid M1 and a cylinder (M2) behind the monochromator generate a vertical and horizontal intermediate focus at the exit slit of the monochromator, which is demagnified by a Kirkpatrick-Baez optic with two plane-elliptical mirrors.

We will present first results about the performance of the beamline from the commissioning phase and discuss the advantages and disadvantages of the beamline concept. The characterization of the photon flux (see figure 1), the spot size and the spectral purity including the higher order contributions is largely completed. The measurements for the PGM energy scale and resolving power are currently underway. If possible, we will also present preliminary results.

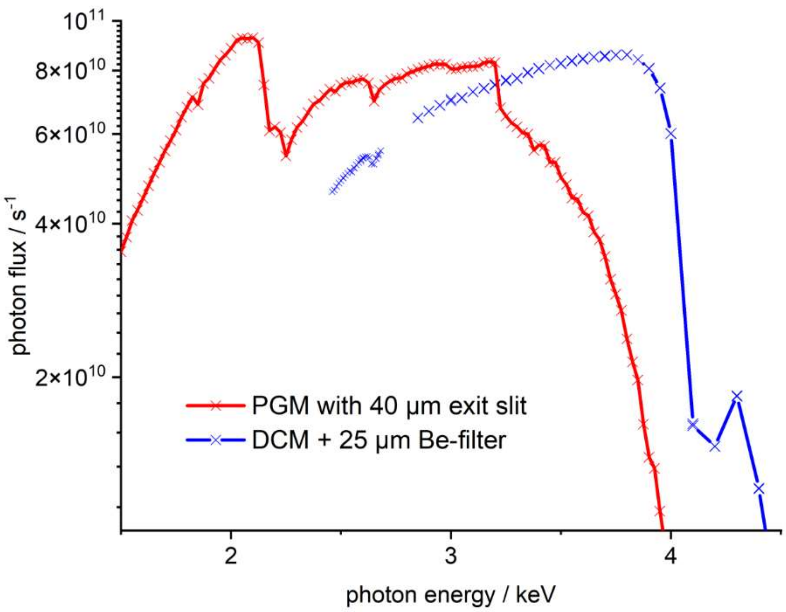

Figure 1: A comparison of the photon flux provided by the beamline in PGM and DCM mode.

Keywords: beamline performance, multilayer-coated blazed grating

X-ray Optics and instrumentation testing at P25: Enabling multifunctional developments towards PETRA IV

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Abstract

The under-construction beamline for Applied Biomedical Imaging, Powder Diffraction, and Innovation, P25 at PETRA III, with a U32 undulator, will serve as an important testbed for optical and instrumental developments for PETRA IV. It will also serve as an innovative facility for a wide range of research, including applied biomedical imaging and powder diffraction. The beamline test facility has a comprehensive setup, including a dedicated optics hutch that is compatible with both white and monochromatic beam. The monochromatic beam is generated by a state-of-the-art cryo-cooled Double Crystal Monochromator (DCM) with two crystal pairs, Si 111 and Si 311, providing access to photon energies in the range of 10-60 keV to meet a wide range of experimental requirements. A second experimental hutch houses the imaging and powder diffraction endstations.

The multi-functional design of the beamline accommodates a wide range of optical and instrumental tests, including the testing of monochromators, mirror systems, lenses, and various focusing optics, as well as beam position monitors and detectors. Moreover, the facility will incorporate wavefront characterization and sensing techniques, as well as coherence measurements.

As the planning for PETRA IV unfolds, the optics test facility at P25 is playing a key role in the development of next-generation optics, which are crucial for the success of PETRA IV.

Keywords: *Wavefront characterisation, optics testing facility, instrumentation and diagnostics*

New Out-of-the-box Synchrotron Radiation Source in RAY-UI

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RAY-UI [1] is a ray tracer that is being developed specifically for the simulation of beamlines or spectrometers at synchrotron radiation sources. In order to prepare RAY-UI for the planned synchrotron radiation source BESSY III [2], it is necessary to implement a light source for undulators that is as physically accurate and easy to use as possible. Based on the recently upgraded WAVE [3] code, we are now able to offer such a source that works out-of-the-box; only the scalar parameters of the storage ring and the undulator are needed. In this poster, we explain the underlying algorithms and the individual input parameters. Additionally, we present and discuss examples of initial simulation and benchmark results. Lastly, we provide an outlook on potential concepts for further expansion and enhancement.

RAY, RAY-UI optical simulation, beamlines, undulator, synchrotron radiation, ray tracing

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RAYX: A Next Generation Tool for Simulating and Designing Beamlines

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The escalating demand for precise and efficient optical simulations in various scientific and technological fields necessitates advancements in computational tools capable of leveraging modern hardware capabilities.

RAYX is an open-source software suite enhancing the simulation of physics-based light tracing using modern hardware. It is a successor of the RAY, RAY-UI [1], and REFLEC software packages and migrates core functions to C++ and Vulkan [2], building on their feature sets. During our development we focus on the needs of both beamline and data scientists to support and accelerate their research. Our iterative and agile development process allows us to provide robustness, precision, and broader accessibility in our software solutions.

We have implemented the simulation core of RAYX for use with both a CPU or a GPU. The GPU tracer is achieved by utilising the Vulkan framework, which is an industry leading, cross-platform graphics and computing API. Through this we can provide strong performance increases even on consumer-grade graphics cards compared to RAY-UI.

One notable feature of RAYX is the addition of RAYX-UI, a graphical application which aims to accelerate the process of designing beamlines. It enables scientists to visually interact with the beamline in 3D space and renders trace footprints along all beamline objects. Additionally, we have implemented the option of dynamic or sequential tracing as well as new light sources and optical elements. To improve usability and performance further, we have enhanced the command line control adding deterministic seeded execution and implementing ray filtering.

RAY, RAYX, optical simulation, beamlines, undulator, synchrotron radiation, ray tracing

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July 11th 2024

List of submitted abstracts for the 8th IWXM-Workshop

Poster contributions:

Mechanical Benders for Sub-100-nrad Mirrors

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Abstract

The continuous advance towards diffraction-limited synchrotrons and free-electron-laser (FEL) sources requires beamline components with ever-increasing optical and mechanical performance. For applications using focussing mirror optics appropriate benders conserving the optical quality of the mirror are key to achieve small, non-blurred foci and to maintain wave fronts.

We have developed a mechanical bender allowing to elliptically shape mirror optics. The design is flexible and generic being easily adaptable to different mirror sizes, orientations and shapes and different ranges of bending radii. The design allows to bend from concave to convex offering minimisation of required bending torque with regards to focus distances. We provide an overview of the bender design as well as metrology results of the mechanics with an integrated state-of-the-art mirror optics achieving < 100 nrad rms slope error with minimal contribution from the bender mechanics itself.

Figure 1: Left: in-vacuum mechanics for a KB system for GMCA/CAT, APS; right: mirror bender including optics at NOM metrology

Keywords: sub-nrad, x-ray, mirror, bender, two-momentum, elliptical, metrology, bi-directional

References:

Poster No. #006

SXP bendable mirrors substrates characterisation

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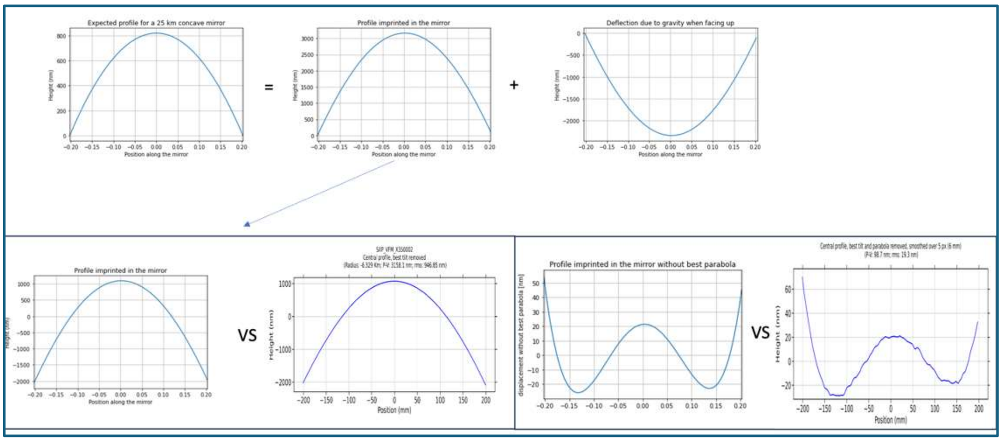
Abstract



The European XFEL is a large-scale user facility for very intense X-ray radiation located in the Hamburg metropolitan area. It operates a 3.4 km-long X-ray laser, which produces X-rays of unique quality for studies in physics, chemistry, life sciences, materials research, and other disciplines.

The SASE3 undulators provide soft X-rays from 250 eV to 3000 eV since 2018 for two scientific instruments: the Small Quantum Systems (SQS) instrument [1] and the Spectroscopy and Coherent Scattering (SCS) instrument [2]. In June 2020, the implementation of a third instrument, the Soft X-Ray Port (SXP) started. The instrument is in operation since 2023. The SXP instrument embraces several ultrafast X-ray science fields, and their applications aim for pump–probe spectroscopic experiments on timescales below 100 femtoseconds. The instrument is conceived as an Open Port, where users provided experimental stations can be integrated, providing techniques not available at the SCS and SQS baseline instruments. The first implemented technique is femtosecond time-resolved photoelectron spectroscopy on solids.

The variety of techniques to be implemented requires a versatile focusing system using bendable mirrors. The station was equipped with provisional, fixed focus mirrors, that were already available and gave the opportunity to go quickly into operation. A variable focus, based on benders, was designed and procured and it will be installed this year as an important upgrade. It will allow a variable size of the focus spot, using through focus configuration, without the need to change the direction of the reflected xray beam and therefore making operations much easier and less time consuming.

We will share the basic setup of the mirrors and the interferometric measurements that were done on the flat substrates, unmounted. Some considerations about gravity sag and mount induced errors will be discussed.

Keywords: Xray Optics, Metrology, KB System

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Modelling the temporal effects of multilayer structures in Python using the transfer matrix method

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Abstract

Modelling multilayer structures is commonplace in x-ray optics simulation codes, however simulating the temporal effects of the structure on ultra-short pulses is often omitted. With future XFELs promising access to near transform-limited, fsec-duration pulses at x-ray wavelengths, the ability to assess the temporal impact is becoming increasingly important in XFEL beamline design. By combining the Fourier decomposition of an input pulse in time into the frequency domain and an open-source transfer-matrix method optics package[1], we can perform these simulations. Here we present the subtleties of this implementation and the benchmarking against literature that has been conducted so far. We aim to make temporal simulations more accessible to the community.

Keywords:
Ultra-short pulses, optical design, optical simulation, multilayer mirrors, XFEL

References:

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Poster No. #008

PyLOSt – a software package for sub-aperture stitching and data analysis of metrology data of reflective X-ray optics

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Abstract

The apertures of X-ray mirrors are often larger than the measurement apertures of common optical metrology instruments. To overcome this limitation, sub-aperture stitching is an increasingly used technique for X-ray mirror surface metrology. In this approach, the full surface is measured in a series of highly overlapped sub-apertures which are subsequently recombined numerically to recover the overall surface topography. The fidelity of the stitched data to the measured surface can be strongly influenced by the stitching algorithms which are employed. Although some commercial software is available to perform the numerical reconstruction of such surfaces, the algorithms employed are rarely documented and are inflexible for the implementation of new calculation strategies. PyLOSt (Python Large-Optic Stitching) is an open-source software tool designed to perform stitching and data analysis of surface metrology data. The standard software release includes several algorithms for stitching. It also incorporates routine data analysis such as arithmetical operations, 1D profile / 2D surface fitting, visualization and extraction of statistical parameters which will be of use for a wide range of surface metrology data. The latest software version focusses on speed and memory use efficiency as well as automation possibilities for large dataset input. PyLOSt uses the Orange data analysis suite which provides an intuitive graphical interface, and silx as the main data visualization tool. PyLOSt supports the common surface datafile formats as well as the latest HDF5/Nexus based data exchange format developed within the LEAPS-INNOV Superflat project. The code framework is also designed to allow the straightforward integration of customized tools for data import/export, surface reconstruction and analysis. In this presentation we will showcase the current code features including global optimisation algorithms permitting the reduction of stitching errors.

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under Grant Agreements No.101004728.

Improving Fizeau stitching measurements with a fan

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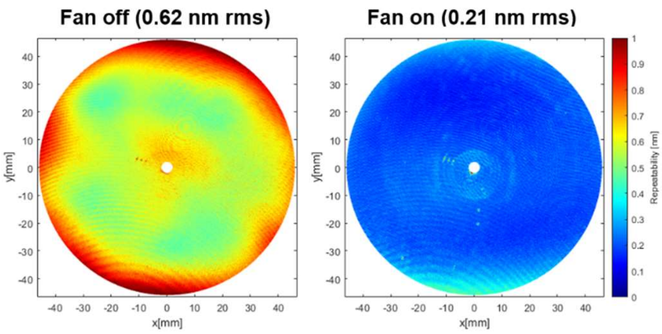
Abstract



Stitching systems with a Fizeau interferometer are well-established methods for analyzing the 2D surface topography of X-ray mirrors. On the one hand, these systems are robust to displacement errors and reference manufacture errors. On the other hand, they are sensitive to environmental noise. Luckily, the impact of the environmental noise in the metrology can be reduced through measurement averaging. However, averaging involves more measuring time, resulting in a compromise between time and measurement uncertainty.

In this work, we explore the use of a fan to reduce the impact of environmental noise, like Vivo et al. [1], since the original perspective of isolating the measuring area with a plastic tube [2] showed a counterproductive variability in the measurement uncertainties. We analyze the contribution of the fan in the Fizeau measurement repeatability. Then, the phenomenon is studied through high-frequency interferometric acquisition experiments and computational fluid dynamics simulations. Finally, we replicated the stitching measurement scenario standard at ALBA, with a 550mm section of an X-ray mirror, to assess the benefits of using a fan in terms of measurement repeatability.

Keywords: Optics, Metrology, Stitching, Interferometry, Environmental Noise

References:

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Poster No. #010

Long Trace Profiler downwards and sideways facing measurement simulations

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Abstract

At synchrotron facilities, the precision and quality of X-ray beams are critically dependent on the perfection of the optical elements used. For X-ray mirrors, ensuring the highest standards in optical shape and surface quality optimises X-ray beam characteristics, thereby improving the performance and reliability of synchrotron-based experiments. However, optics may be used in many different configurations, such as those found in the Kirkpatrick-Baez (KB) arrangement, in which the mirrors are supported in optomechanics in specific orientations. Thus, assessing a mirror solely facing upwards may not adequately capture its shape error under operational conditions. In this work we simulate measurements of sideways or downward-facing configurations using optical simulations alongside conducting tolerancing analyses. The considered optical configurations are based upon the ESRF Long Trace Profiler; nonetheless, the results could offer insights applicable to various profilometer models.

An initial concept involves adding an extension to the movable head to enable beam redirection along a selected axis. However, designing this extension poses a challenge to ensure minimal sensitivity to Pitch, Yaw, and Roll during head translation. This approach was introduced on the ESRF LTP in 20051 for downwards facing mirrors facing, and we aim here to develop the theoretical aspects of this measurement approach, and to quantify the consequences of component misalignment during assembly. The combination of a roof prism and a folding mirror is analogous to a cube corner setup, restoring the profilometer's initial pitch, yaw, and roll attributes. Potential solutions for sideways facing measurements were also investigated through the simulation of different beam folding optics, employing Zemax in conjunction with a Python routine. In all configurations tested, motion errors directly impacted the measurements without compensation by the instrument or the arm. A 90° rotation of the movable head was therefore simulated, and the

Keywords: Metrology, X-ray mirrors, Long Trace Profiler, Simulation, Optic Studio Zemax.

Reference:

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Poster No. #011

Fast mirror metrology with the ALBA-NOM

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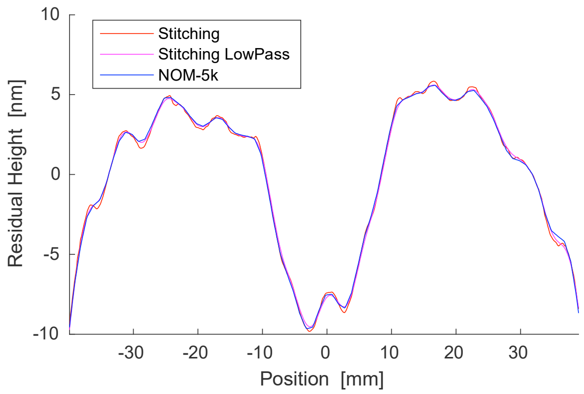
Abstract



At the Optics Laboratory of ALBA, the NOM is the main instrument used for the characterization of x-ray mirrors and mirror benders. The system is in operation since 2010, without any significant hardware modification, aside from a few changes required for measuring mirrors facing side or facing down. The control software of the system, however, has been modified significantly, in order to allow the implementation of LEEP (linear error elimination procedure), and the operation in continuous scan, which is the standard mode since 2016. Obtaining high quality surface profiles, even if 1D, at fast speed, is actually one of the main features of the instrument, and is tremendously useful for the characterization of mechanical benders and adaptive optics systems.

The ALBA-NOM has been recently upgraded by integrating a new autocollimator: a Moeller-Wedel Elcomat 5000/10. This autocollimator is designed to operate with narrow beam apertures, as its predecessor was (Elcomat 3000/8). The new device offers, in addition, three main features: It allows for fast data acquisition, up to 250 fps, It has a lower noise level, and it allows electronic triggering of the acquisition.

The system has been integrated to the ALBA-NOM, and has been extensively tested during commissioning. The main goal of the tests was to demonstrate that the system can be reliably used for metrology of x-ray mirrors. unlike, for instance, the standard Elcomat 5000, which generates unsolvable artifacts when operated with a narrow aperture.

In this work, we report the main results of the commissioning tests. These include a study of the noise level achieved by the system, and a study of the dependence of the calibration curves, for instance on the aperture of the iris. We report also direct comparison of its measurements with measurements obtained by other instruments. In particular, the figure above shows a comparison of the measurements of a 100 mm long sphere with radius 178 m obtained with the NOM and with the stitching interferometry system. The agreement between measurements is better than 0.145 nm.

Keywords: X-Rays,Optics, Metrology, Deflectometry,

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TITAN: plug and play stitching topography at nanoscale

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Abstract

New developments in the field of mirror polishing and growing demands for cutting edge synchrotron optics have been pushing for an increase in metrology validation. Nanometer scale surface topography and slope measurements in the range of the hundreds of nano-radians are becoming new standards in the field. New synchrotron sources prompt more focus on transverse surface analysis versus the line profiling methods, hence the uptake in 2D measurement interest.

In this context the *Tracking Interferometer for Topography At Nanoscale* (TITAN) project was imagined at SOLEIL, to allow interferometric measurements of synchrotron mirrors of up to 1m in length facing either up or sideward. Based on a commercial large field of view interferometer (by ZYGO), the system combines it with high precision motion control in the form of a hexapod (by Symetrie) for fine alignment and a 2 meter range translation (by QSys) for tiling.

The system is now operational and providing high resolution topography maps. The follow up development of a user environment for tiling acquisition, stitching and data analysis has been very fruitful combining many tools from the community. The PyMoDAQ[1] acquisition platform interface has allowed us to develop our own plug-ins for hardware control and provide a sturdy framework for handling acquisition sequences. These include the interferometer data, the stages and motion control but also crucially temperature probes tracking and recording and data consolidation in a single file. The surface is acquired in a series of 100 mm apertures and then stitched and analyzed using the PyLost[2] software package. The PyMoDAQ platform allows for convenient sharing of the plugins and an easy installation on similar setups to reproduce our results.

A large measurement campaign on a bending mirror for the SWING[3] beamline has allowed us to fine tune acquisition sequences, reduce vibration sensitivity, and streamline the analysis pipeline. The goal to extract calibration parameters from the driving motors to the focusing distance of the mirror. It has also allowed us to model a substantial dependance of the mirror shape to the local temperature and detrend it to provide a reduced uncertainty on the calibration tables. The complete surface topography data are also saved and exported, ready to be used in optical calculations.

Keywords: X-ray; metrology; topography; coherence; synchrotron; modelling; simulation; interferometry

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Development of super-resolution interference microscopy metrology of x-ray VLS diffraction gratings

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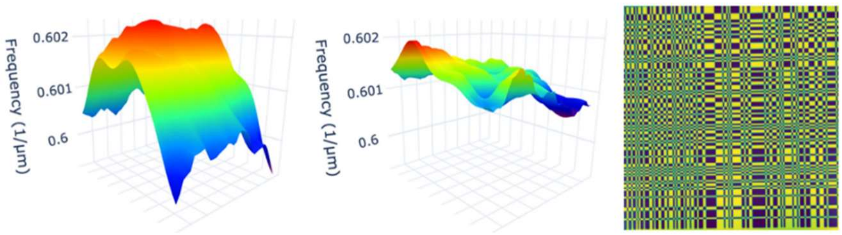
Abstract

We report on efforts to improve interference-microscopy-based metrology of variable-line-spacing (VLS) x-ray gratings. The technique [1], first suggested and demonstrated at the Advanced Light Source X-Ray Optics Laboratory [2], estimates groove density values from the power spectral distribution peaks of optical microscope measurements of grating surface sub-areas. We are working to advance the technique with higher accuracy and dynamic range of groove density variation through a combination of image reconstruction to correct for blurring and distortion by the measurement instrument, multi-image super-resolution to increase resolution beyond the single-image limit, and image stitching to increase the measurement area. The global aim of this work is to allow improved VLS grating manufacture and beamline performance.

In particular, we have found that lens distortion causes significant systematics in grating frequency estimation. Using test standards patterned with a two-dimensional uniformly redundant array (URA) binary pseudo-random array (BPRA), we have characterized and corrected for lens distortion, as well as calibrated the effective image pixel size.



Apparent spatial frequency as a function of position estimated from an interferometric microscope measurement of a constant-line-spacing grating before (left) and after (center) distortion calibration with a URA BPRA target (right).

We are also investigating whether techniques that increase the effective resolution of an interferometric measurement can increase the accuracy and/or precision of grating frequency estimation. High-frequency detail can be recovered by deconvolution of the instrument transfer function, which we measure using a recently developed technique that employs highly randomized BPRA test standards for their white-noise spectral characteristics. So-called super-resolution can be achieved by combining, after correction, multiple measurements taken under sub-pixel displacement by a nano-motion stage.

This work was supported by the U.S. Department of Energy under contract number DE-AC02-05CH11231 and award number DE-SC0022412.

Keywords: variable line spacing grating, instrument transfer function, binary pseudo-random, super-resolution, power spectral density, interferometric microscope

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Superflat – an initiative for improved flat mirror quality

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Abstract

Mirrors and diffraction gratings are among the most commonly used optics at X-ray/EUV beamlines where they act in various roles including beam deflection, harmonic rejection, monochromatisation and beam focusing.
The performance of such devices is intimately dependent upon the shape fidelity and roughness of their optical surfaces. Even today, despite considerable improvements in manufacturing, the quality of these optical components remains a fundamental limit to the quality of the photon beams delivered by accelerator based light sources.
Superflat [1] aims to improve technologies for the production of very high-quality X-ray mirror and grating substrates which are key to achieving the ultimate performance of our user facilities. Superflat is a workpackage of the broader EU-funded LEAPS-INNOV innovation pilot project[2].
The Superflat consortium involves 10 European accelerator light sources who are combining their expertise across 3 principal activities:

1. A Pre-Commercial Procurement (PCP) action to develop pilot processes for the industrial production of moderate length flat X-ray mirrors with sub-1 nanometre figure errors and sub-50 nanoradian slope errors with surface roughness below 1 Ångström
2. The exploration of basic limits of figure correction technologies for X-ray mirrors in view of more complex optical figures
3. The development of new metrology methods and protocols suitable for implementation in industrial environments applicable to complex (freeform) optical figures.

We present an update of the project status including: i) results of interlaboratory round-robin tests of 2D surface measurements performed on two different flat artefact mirrors, ii) the development of a metrology data format intended to facilitate data-exchange and cross-comparisons iii) results of figure correction methods being explored within the consortium.

Keywords:
X-ray mirrors, grating substrates, PCP, figure-correction, optical metrology

References:

[1] Superflat: https://www.leaps-superflat.eu
[2] LEAPS-INNOV: https://www.leaps-innov.eu

Poster No. #015

Optical Metrology of the High Energy Photon Source

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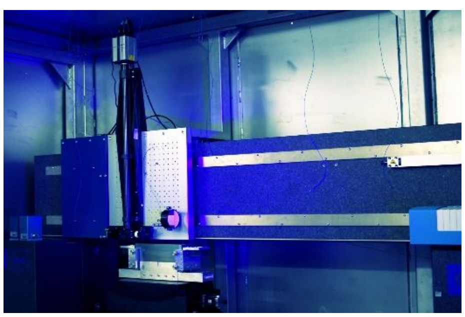
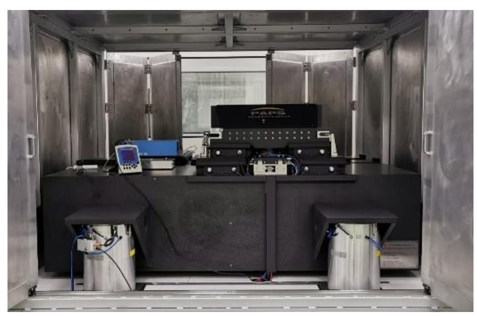
Abstract

The High Energy Photon Source (HEPS) demands stringent specifications for the X-ray mirror surface, requiring a slope accuracy of 50 nrad (rms) and a height accuracy of merely 0.4nm (rms). Meeting these exacting standards presents a significant metrological challenge. In response, the optical group of the Institute of High Energy Physics (IHEP) has pioneered a novel long trace profiler, known as the Flag-type Surface Profiler (FSP), tailored to deliver precise surface measurements for HEPS X-ray mirrors. To date, 35 X-ray mirrors of HEPS with high accuracy have been successfully characterized using FSP, whose measurement accuracy has been endorsed by JTEC. For now, FSP has achieved an accuracy of 0.05 nm (rms) of the strongly curved advanced KB mirror. In addition to developing high-accuracy one-dimensional metrology, we have also developed two-dimensional metrology. Concurrently, a novel stitching interferometer has been proposed and developed independently, knows as the Frequency-decomposed Stitching Interferometer (FSI). This method combines the FSP with a commercial Fizeau interferometer. By using sub-aperture stitching, globally optimized data processing, and frequency-domain fusion, this method supplements the high-frequency surface profile information and surface profile information in sagittal direction, achieving large field of view, full-frequency, and ultra-high-accuracy metrology of strongly curved surfaces from one-dimensional to two-dimensional. FSI achieves a comparison accuracy of 0.13nm with FSP of strongly curved elliptical diffraction-limited nano focusing mirrors.



Flag-type Surface Profiler (FSP)



Frequency-decomposed Stitching Interferometer (FSI)

Keywords: High-accuracy optical metrology, Flag-type Surface Profiler, Frequency-decomposed Stitching Interferometer, High Energy Photon Source

Poster No. #016

Newly Developed Wavefront Metrology Techniques and Application of HEPS

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Abstract

In this work, a novel edge scan wavefront metrology technique, named double edges scan (DES) method has been developed at Beijing Synchrotron Radiation Facility (BSRF). This technique employs a double-edge tracking method, making diffraction-limited level wavefront measurement a reality. In a comparative measurement of a mirror using both the DES method and long trace profiler, the quantitative agreement for the height error and similar prominent features for the slope error profiles providing robust support for the DES method. Achieving diffraction-limited performance in fourth-generation synchrotron radiation sources demands monochromator crystals that can preserve wavefront across an unprecedented extensive range. As the DES method minimally affects measurement accuracy in image blurring caused by crystal extinction effect[1] and can deliver high spatial resolution, it has obvious advantages in crystal absolute diffraction wavefront measurement. The results demonstrate an equivalent diffraction surface slope error below 70 nrad (corresponding to a wavefront phase error of 4.57 % λ) RMS within a nearly 6 mm range for a flat crystal in the crystal surface coordinate. The double-edge structure contributes to exceptional measurement reproducibility, achieving levels below 15 nrad even at a first-generation synchrotron radiation source. Currently, the measurement known as Double-Edge Scan (DES) has already been regarded as a critical feedback mechanism in the processing of next-generation crystals. Besides, the near-field speckle wavefront metrology technique was also developed with the help of SSRF and was used to measure massive commercial CRLs.

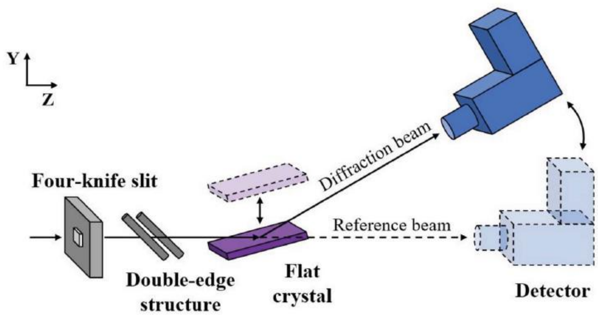

Figure 1. Diagram of double edges scan (DES) method

Keywords: wavefront metrology; crystal diffraction; double-edge; diffraction-limited; wavefront error.

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New wavefront sensor for renewed differential pumping unit at FLASH2 beamlines

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Abstract

In the past years, DESY in collaboration with the Institut für Nanophotonik Göttingen e.V. (formerly Laser-Laboratorium Göttingen e.V.) has developed several Hartmann wavefront sensors for FEL focus characterization and optics alignment in the soft x-ray spectral range, approx. 5 - 40 nm [1-3]. In principle, a Hartmann wavefront sensor (WFS) is used in the direct beam at a suitable position behind the focusing system to be characterized. In practice, at FLASH, this straight direction is often blocked by an experimental setup, thus preventing fast focal spot characterization and in-situ adjustment during the experiments. For this reason, and as a first improvement, the FEL beam at beamline FL24 could be deflected by 90° shortly before the experiment and directed to a WFS located at a distance of about 3 m behind the focusing position.

Since this concept is very space-consuming, a new differential pumping unit with a permanently integrated WFS has been developed, which is located directly after the K-B focusing optics system. This newly designed WFS is located in front of the nominal focus position of the beamline at an angle of 45° to the beam. The beam is directed to the WFS by a Ni mirror that is adjustable in 6 degrees of freedom. This deflection mirror can be moved in very quickly to align the optics and optimize the focus. Although not in-situ, this allows efficient preparation of the beamline focus for user experiments. This fast and space-saving method will be presented and first results of the comparison of wavefront measurements with the straight beam direction will be shown. In addition, another new and compact WFS under development will be presented.

Keywords: Hartmann wavefront sensor, wavefront, free-electron laser, soft x-ray

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Near-field probing potentials using Ronchi method and Hard X-ray FEL pulses

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Abstract

Ultra-high intensity, ultrahshort (femto-second) duration, and high degree of spatial coherences are the typical characteristics of the X-ray pulses produced at X-ray Free-Electron Laser facilities (XFELs). Such features offer unique advantages, as much as they are essential, to the experiments reliant on the knowledge and control of them. Various components inevitably contributes to the modulation of such parameteres along the optical path – notably reflecting, diffracting, collimating, and focusing X-ray optics [1-6]. Therefore the capability, and sensitivity, to diagnose these modulations from the original pulse characteristics determines the achievable data quality and, subsequently, impact the ovrall experiment outcome.

Here we present the results from the recently performed experiments at the European XFEL, at 9 keV energy and using Ronchi double-grating shearing interferometry [6]. With just SASE bandwidth XFEL pulses, online and pulse-based retrieval results of µm (or less) spatial coherence and sub-µm X-ray focus reconstructions are presented. We further demonstrate the method sensitivity to the phase modulation that is easily visulaised as shearing distortion in phase-correction plate for Compound Refractive Lens (CRL) systems, and notably its sensitivity to the near-field distortion caused by a low-Z material.

Keywords: Hard X-ray Grating Interferometry, Ronchi Interferometry, X-ray Characterisaion, X-ray Free Electron Laser

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Experimental correction of wavefront distortion recorded by Talbot interferometer with mismatched gratings

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Abstract

X-ray beam quality is degraded by deformations of optical elements, which include thermal deformations caused by insufficient cooling against high power density synchrotron radiation. Such deformations not only reduce the beam intensity, but also cause a loss of homogeneity in the phase distribution of the reflected beam. In a focusing optics, a slight deformation of a crystal or mirror may change the focusing position and make it impossible to achieve the desired performance. In order to quantify the deformation of the crystal or mirror, it is necessary to measure the wavefront with high accuracy.

The beam wavefront can be measured with a wavefront sensor such as a Talbot interferometer [1,2]. To measure the deformation of the beam irradiated area of the crystal or mirror, it is necessary to detect low-order wavefront structures of a few mm to several tens of mm in the reflected beam. Talbot interferometer using two gratings is suitable for such measurements because a moire fringes are formed by overlaying an absorbing grating on a self-image formed by a phase grating, thus increasing the fringe spacing, enabling measurement over a wide field of view of several mm to several tens of mm without the need to directly observe a self-image with several μm periods.

In order to measure low-order deformations (mainly 2nd-order component) of optical elements, high precision measurement of the wavefront radius of curvature (ROC) is necessary. To estimate the error of the measurement system, we examined the measurement error caused by the adjustment errors of the Talbot distance and grating angles, and the period error of the gratings, and we found that the error that significantly affects the measurement of the wavefront ROC is the period ratio difference between the two gratings. The period ratio difference between the two gratings is given by (p2/p1)-1 where p1 is the period of the phase grating and p2 is the period of the absorption grating. Assuming this is $\pm 10^{-4}$, a wavefront ROC of 30 m corresponds to a change of ±1 m. Converting to the shape change of the optical element surface, the shape (sag value) changes by about ±20 nm for an 80-mm length and 4-mrad grazing angle. This would have a significant impact on the accurate measurement of surface shape.

The following experiment was performed to evaluate the period ratio difference between the two gratings. A secondary light source is generated by the slit, and the spherical wave from this source is measured at two Talbot distances. With p1 set to 4.8 μm and p2 as a variable, the period ratio difference between the two gratings was calculated so that the wavefront ROCs match at the two Talbot distances. This experiment was performed with different grating combinations and grating irradiation positions to evaluate the variation. As a result, for a virtual source distance of 45.47 m, for a given grating combination, the variation of the period ratio difference was $\pm 1.1 \times 10^{-5}$, and the measured wavefront ROC was 45.42 ± 0.12 m, indicating that the measurement was made with high accuracy.

Using the parameters obtained above, the shape of the total reflection mirror with different heat loads was measured by wavefront measurement and compared with the simultaneously measured Fizeau interferometer shape and the finite element method simulation shape, and it was confirmed that they were almost consistent. This confirmed that highly reliable measurements could be performed.

In this presentation, these details will be reported.

Keywords: Talbot interferometer, grating interferometer, wavefront measurement

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Poster No. #020

Development of stitching CGH interferometry for manufacturing 2-dimensionally curved X-ray mirrors

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Abstract

Since the mid-2000s, JTEC has produced high-precision flat, spherical and aspherical (elliptical, hyperbolic, parabolic, etc.) X-ray mirrors named "Osaka Mirror" using RADSI (relative angle determination interferometry), MSI (microstitching interferometry) and EEM (elastic emission machining) [1-3]. Currently, 2-dimensionally curved focusing mirrors, especially Wolter mirrors, ellipsoidal mirrors and toroidal mirrors, are attracting attention due to advantages such as reduced number of mirrors and easier alignment. However, RADSI and MSI using plane-wave interferometry have difficulty in measuring mirror shapes that are steeply curved shape in the sagittal direction.

Therefore, we have developed a stitching interferometer using a cylindrical CGH (computer generated hologram) that generates steeply curved spheric wavefronts and can be applied to rotational mirrors with a small radius of 10 mm or less [4]. As a demonstration, we have fabricated a monolithic Wolter-I mirror of 700 mm length with a sagittal radius of curvature of 17-22 mm. The mirror was designed to achieve a focus size of 1 μm in hard X-ray. Residual errors were removed by EEM. Focusing tests of the fabricated mirror were performed at BL29XU of SPring-8 with 10 keV X-rays and confirmed that a focus size of 1 μm x 0.9 μm in the tangential and sagittal direction, respectively.

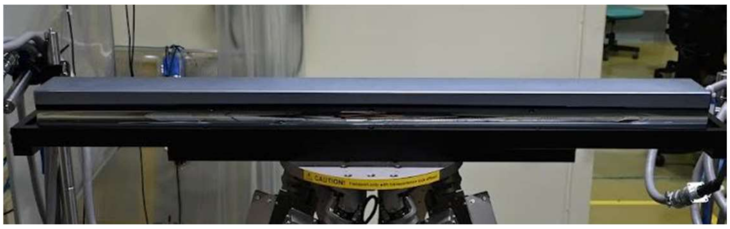

Fig. 1 Photograph of developed 700 mm-long monolithic Wolter mirror.

Keywords: 2D curved mirror, CGH interferometry

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An ultra-stable, 3-axis goniometer for precise angular positioning for optical metrology of X-ray mirrors

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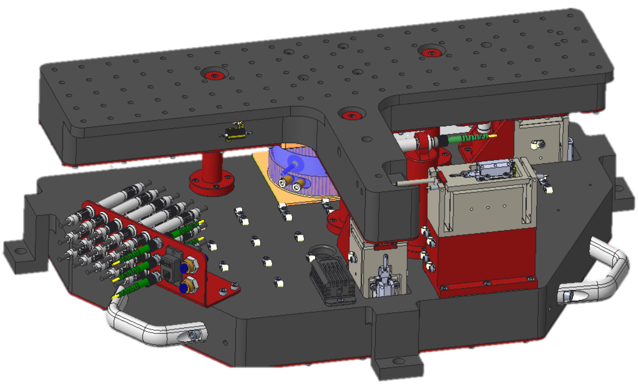
Abstract

For the forthcoming Diamond-II facility upgrade, many beamlines require X-ray optics with enhanced surface quality to achieve diffraction-limited performance. Deterministic polishing requires metrology technologies and acquisition strategies which are capable of accurately measuring state-of-the-art X-ray mirrors with slope errors < 50 nrad rms. Optical metrology requires high-quality motion stages to precisely orient and stabilise the surface under test relative to the measurement instrument. Controllable alignment also enables sophisticated algorithms to extract systematic errors from the metrology data, thereby improving accuracy [1].

As part of the developmental program to improve the performance of the Diamond-NOM slope profiler in the new Optical Metrology Lab at Diamond Light Source, we have developed an ultra-stable, 3-axis rotation stage to support the X-ray mirror under test on the Diamond-NOM [2]. The goniometer employs a spherical air-bearing, which is actuated by three piezo-walkers via flexure struts. This combination offers high stiffness, zero friction, and minimal parasitic rotations or translations. Linear interferometers provide positional feedback to the piezo actuators for fast, closed-loop stabilisation and control of 3D rotations. Closed-loop temperature controllers and forced air thermal stabilisation help minimise thermally-induced drifts. Mechanical and thermal finite element analysis and dynamic modelling was used to optimise the design of all hardware and electronic components via mechatronic principles. The goniometer can accommodate X-ray mirrors up to 500 mm in length and 10 kg in weight. It has an angular range of ± 10 mrad in 3 orthogonal directions, a minimal incremental angle step of < 100 nrad, and thermal drift of ~ 100 nrad over 30 minutes. Localised shielding of heat sources reduces air turbulence for probing autocollimators or laser beams. All axes and interferometer outputs are controllable via EPICS, which enables the goniometer to be dynamically synchronised with other motion stages or detector acquisition.



Keywords: 3-axis goniometer, optical metrology, X-ray mirrors

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Poster No. #022

MINERVA positioning system with Bayesian orientation control for assembling the NewATHENA mission mirror modules

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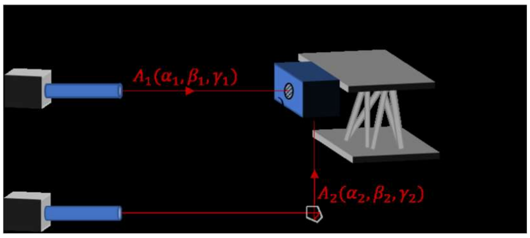
Abstract

MINERVA [1] is a new metrology X-ray facility in operation at the ALBA Synchrotron specifically designed to support the development of the NewATHENA mission (Advanced Telescope for High Energy Astrophysics). Its main goal is to assemble Silicon Pore Optics stacks manufactured by cosine [2] into mirror modules (MM) which are the building blocks of the NewATHENA optics. The MM assembling process follows the one already established at the X-ray parallel beam facility XPBF 2.0 at the Physikalisch-Technische Bundesanstalt (PTB) at BESSY II [3]. To validate the MM optical performances, its entrance pupil is scanned in front of the collimated X-ray beam produced by the synchrotron while monitoring the Point Spread Function measured on a 2D array detector at the focal position. Good performances are achieved only if the incidence angle is kept below 1.0 arcsec for the full scan. In this work, we present how we measure and actively correct the MM orientation when deviations are detected. The method is based on two autocollimators that track the orientation of the MM and a hexapod that corrects any miss-orientation detected. Sub-arc accuracy has been achieved by calibrating the geometric configuration of the autocollimators using a Bayesian approach [4]. Preliminary results of this correction loop will be shown and discussed.



Keywords: X-ray, Silicon Pore Optics, Metrology, Bayesian inference, Astronomy

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Poster No. #023

Optical metrology for differential deposition at ESRF

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Abstract

To preserve the quality of the X-ray beam produced by new generation of X-ray light sources, mirrors increasingly require figure errors below 1 nm PV. Differential deposition is one approach being explored as a deterministic correction method. The technique has been applied at the ESRF on four 300 mm long super-polished silicon mirrors by deposition of variable thickness of WSi_2, based on figure error profiles measured by Fizeau stitching and Long Trace Profiler. The surface metrology demonstrated several interesting aspects which could potentially limit the accuracy of the correction process:

- accurate fiducialization of the mirror position between metrology and deposition process is critical
- measurement errors due to partial transparency of thin layers
- impact of the crystal orientation of the silicon upon gravity corrections
- parasitic deformations due to mirror support geometry during measurements.

The paper illustrates these effects and presents some of the techniques used to mitigate and correct the metrology errors. Applying these methods, the figure errors over 280 mm of the four mirrors were reduced below 1 nm PV and 0.2 nm rms. Moreover, micro-roughness evaluated over each step of the process did not show significant degradation.

Keywords: Differential deposition, LTP, Fizeau stitching

Poster No. #024

Metrology measurements of mounted mirrors for EuXFEL HED Split and Delay Unit

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The SASE2 HED Split and Delay Unit (SDU) contains eight plane mirrors with different sets of reflective multilayer coatings. A special mounting plate is used to hold the mirrors in their position facing down or up. This holder was suspected to introduce a surface shape deformation of the mounted mirror.
Therefore, tests were done at the EuXFEL metrology lab in 2022, to investigate if the implemented mounting technique is suitable to hold the plane X-ray mirrors in place. In particular, it was tested if the adjustment and respective torque of the clamp screws is inducing a bending of the mirror and, as a result, causing a shape deformation of the mirror surface. Measurements were done using the European XFEL's 12" Large Aperture Fizeau Interferometer (ZYGO DYNAFIZ) in a normal incidence setup.
Different holder designs and mounting procedures have been tested to eliminate or reduce the shape deformation. It was seen that the present holder design was not suitable. As a consequence, the holder design was adjusted and measurements were repeated in 2024 at the European XFEL metrology lab. The measurements done with the new holder design indicate that the new design has less influence on the mirror shape compared to the first design. Remounting or shifting the mirror on its holder has less influence on the radius of curvature.
Since the Split and Delay Unit at FLASH (DESY) is a twin system of the SDU at EuXFEL, similar issues have appeared during the first operation of the SDU at the FLASH2 beamline FL24. Therefore, measurements of the FLASH SDU mirrors are planned at the EuXFEL metrology lab in close collaboration with DESY.

Keywords: Split and Delay Unit, plane mirrors, metrology, Fizeau interferometry.

At-Wavelength Metrology facility for EUV and XUV optics, modern data processing and simulations

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An accurate characterization of the real performance of sophisticated reflective or diffractive optics including cases such as XUV reflective zone plates (RZP) or multilayer coated gratings is experimentally an extremely demanding task. An At-Wavelength metrology facility for EUV and XUV optics has successfully operated for many years at the BESSY-II storage ring. The main instrument is a versatile 11-axis UHV-Reflectometer which is permanently connected to a dedicated optics beamline. The setup is suitable for measurements on both small test samples and real size optics up to a size of 360 x 60 x 60 mm3. 6-degrees of freedom for alignment and surface mapping of optical elements are possible due to a flexible sample stage support system based on a UHV-tripod. It is possible to carry out measurements with beam incident angles from 0 to 88.9 degrees and scan outgoing radiation in an almost complete in-plane circle. The entire system can be continuously rotated to achive s- and/or p- polarization. A beam of high spectral purity in the energy range from 13.5 eV to 1800 eV is provided by a 4-mirror High-Order Suppressor System. A precise calibration of the monochromator energy scale is achieved by employing more than 50 structural features visible in the flux from 12 different material transmission foils, which are inserted into the beam by FSU devices in front of the Reflectometer.

In our contribution, we present updated simulations of the beamline performance along with experimental data. To accurately replicate the real performance, ray-tracing simulations which incorporate the contamination of all optical elements which are based on experimental results were performed. Additionally we demonstrate modern Python routines for fast processing of experimental data.

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Light element analysis with the parallel wavelength-dispersive spectrometer “WDSX-300”

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Abstract

Low-Z elements, such as ^{3}Li, ^{4}Be and ^{5}B, are of high relevance in science and technology. The good transmission of Be makes it favorable for windows in X-ray optics, B is used to form glasses and dope semiconductors. Li-ion or Li-polymer batteries are prominent examples energy storage devices. Low-Z compounds become more and more important, too: in B_4C, cubic BN and BCN properties like hardness and high melting point are associated with the B atoms.

In our contribution, we present results obtained with a novel parallel wavelength-dispersive X-ray spectrometer, developed at NOB Nano Optics Berlin GmbH in cooperation with the Institute of Applied Photonics e. V.. The instrument is designed for the analysis of fine structures in the energy states of the bonding electrons in compounds of ultra-light elements.
The system is based on the off-axis, “hybrid” reflection zone plate (RZP) [1] on a spherical substrate [2], featuring an enlarged aperture. In addition, the energy range around the design energy which is well focused is not restricted any more to ± 2% as for an RZP on a flat substrate but shows values of ± 50%!
With only one optical element, that combines dispersion, reflection and focusing [3], the detection efficiency is optimized. From a practical point of view, the inexpensive concept enables a compact setup with an overall optical path length of 0.3 m and a simplified alignment.
The spectrometer “WDSX-300” has an energy resolution of 0.3 eV at the Al L-edge with an overall efficiency of the optics up to 30 % in the energy range of (40 – 350) eV. Optionally, the spectrometer can be equipped with RZP optics for the energy range up to 1200 eV.

† We mourn the loss of our recently deceased colleague Prof. Dr. Alexei Erko and honour him for his important contributions to the development of reflection zone plates.

This research was partially funded by the Federal Ministry for Economic Affairs and Energy within the project “WDSX” under the grant numbers ZF 4302304 SY9 for IAP e. V. and ZF 4303904 SY9 for NOB GmbH.

Keywords: wavelength-dispersive spectroscopy, reflection zone plates, low-z elements

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A reflection zone plate for parallelized high-resolution X-ray spectroscopy at the Fe L3-edge

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Abstract

We present an advanced reflective-diffractive optical element (DOE) for high-resolution, parallelized soft X-ray absorption or resonant inelastic X-ray scattering (RIXS) spectroscopy of transition metals [1], in our case designed for the Fe L3-edge around 706.8 eV. Based on a “hybrid” reflection zone plate [2] on a spherical substrate [3], which maintains aberration-corrected focusing under wide angular acceptance of 8.5 msr, slightly slanted grating grooves transpose the wavelength dispersion in (−1)st diffraction order from the vertical (z) partially into the horizontal (y) direction, and the signal is read out from a pixelated (50µm) line detector behind an exit slit (Fig. 1). In advantage to a conventional varied-line-space grating of equal aperture, a constant resolution is achieved across the full range from 695 eV to 715 eV. Transmission efficiency P_{trm} as well as energy resolution ΔE scale in proportion to the adjustable slit width Δh, e.g., for a µm-sized source and Δh = 5 µm, we expect P_{trm} ≈ 0.3 % and ΔE ≈ 0.24 eV – with a large potential for their product P_{trm} x ΔE to be “tuned” [1]. The substrate curvature of 4.5 m and line densities ≤ 7.19 x 10^2 mm−1 are compatible with fabrication by laser lithography, whereas state-of-the-art metrology is used to evaluate the quality [3] of the wavefront-corrected and Ni-coated RZP. In-vacuum operation is supported by the optical path length of 490 mm [2]. We derive the vector field of the DOE [1,2], simulate its optical function (Optica™), and characterize the performance for a variable source size. Conceptual extensions for large-scale facilities [1,2] and in the lab [2,3] will be discussed.
Keywords: diffractive optical elements, “hybrid” reflection zone plates, parallel XUV / soft X-ray spectroscopy.

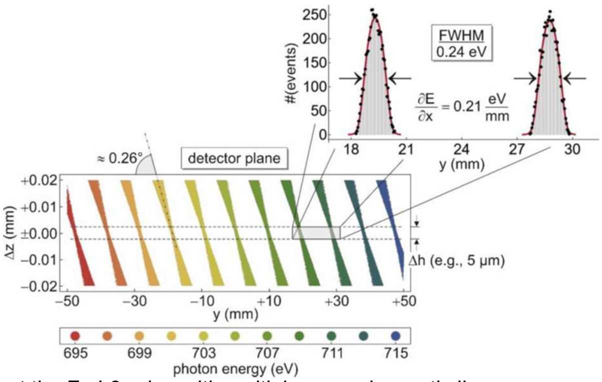

Figure 1: Simulated spectrum at the Fe L3-edge with multiple monochromatic lines within (695 – 715) eV. From a slit (width □h) in the detector plane, the signal is read out along the y-axis. The intensity profiles for two photon energies are zoomed out.

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Poster No. #028

Reflection zone plate optics for ultrafast soft X-ray absorption spectroscopy in the laboratory

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Abstract

For transient (tr) Near Edge X-ray absorption Fine Structure (NEXAFS) studies in the ps and fs range on thin film systems in transmission, optical density (OD) changes in the range of 10^{-3} and below must be detected. Using laboratory based ultrafast x-ray sources such as laser produced plasmas (LPP) or High Harmonics Generation (HHG) efficient optical elements and detectors together with advanced data acquisition techniques are required. Off-axis reflective zone plates (RZP) combine two-dimensional focusing and wavelength dispersion in a single diffractive optical element. Recently, we have demonstrated the performance of RZPs on a planar substrate in tr-NEXAFS experiments in the sub ns-range using a LPP source [1]. RZPs on planar substrates only focus particular photon energies across a few-eV bandwidth spatially and spectrally onto a detector for a given RZP structure and RZP-to-detector distance. Consequently, a large spectral range, covering more than 200 eV, requires a time-demanding scan of different RZP alignments, which needs to be stitched together. In addition, in the RZP focal region of a given design energy, spatial imaging over a wide spectral range is not retained, which excludes spectral-spatial imaging. In order to overcome this, our novel approach for high-resolution NEXAFS spectroscopy relies on a hybrid reflection zone plate array (H-RZPA) on a spherical substrate [2]. The H-RZPA provides consistently high spectral resolution E/ΔE > 500 in the photon energy region from 100 eV to 1500 eV [3]. Each RZP structure thereby spans a large spectral interval with a high efficiency which is comparable to planar RZP optics, while maintaining a spatial dimension for imaging.

In this work, we report on a novel spectrometer design based on H-RZPAs. We will present two experimental setups based on a LPP and a HHG source and H-RZPA optics for time-resolved NEXAFS spectroscopy.

Keywords: NEXAFS, Laser produced plasma, High Harmonics Generation, L-edges, transition metals

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Poster No. #029

Standard design and evaluation of monolithic Wolter mirror for hard X-ray focusing at SPring-8

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Abstract

Wolter optics [1], which consists of an ellipsoidal mirror and a hyperbolic or parabolic mirror, is known for its achromatism and relatively large aperture. Additionally, it has low comatic aberration due to its approximate compliance with Abbe's sine law, it is widely used as imaging optical elements. We have proposed a monolithic Wolter mirror [2] as two-dimensional focusing optics, which incorporates a partial ellipsoidal mirror and a partial hyperbolic mirror on a single substrate. The monolithic Wolter mirrors have been utilized at SPring-8 as a universal micro-focusing system, requires few adjustment axes, is easy to adjust, and has high stability. The elliptical and hyperbolic shape parameters of the monolithic Wolter mirror are determined using five parameters: the central incident angles on both surfaces, the incident length of the elliptical mirror, the exit length of the hyperbolic mirror, and the total length of the monolithic mirror. The incident angles are derived from the usable energy range by considering reflectivity. The incident length depends on the position of the mirror in the beamline, while the exit length depends on the magnification or working distance. The total length is dictated by the required opening size and incident angle, but is also constrained by measurement and processing equipment capabilities. Typically, a grazing incidence two-dimensional focusing mirror features a steep shape with a small radius of curvature in the sagittal direction. Optical parameters were selected to ensure the minimum radius of curvature feasible for measurement and fabrication. The focusing performance and influence of errors were evaluated using ray tracing. Due to the monolithic structure, there is no mechanism to adjust the position between the two surfaces, necessitating strict fabrication tolerances for positioning errors on the order of microradians and micrometers. However, the advantage of small comatic aberration results in easy mirror alignment and stable focusing condition, with tolerances of a few milliradians and a few millimeters. It was also observed that a 10% change in incident length move the focusing position along the optical axis without significant effect on the focusing size. The impact of astigmatic focusing conditions caused by low-order shape errors in upstream elements induced by heat loads was also evaluated. This presentation will detail the optical design methodology, fabrication and alignment tolerances, effects of other beamline elements, and the results of the mirror's installation on the beamline.

Keywords: focusing optics, Wolter mirror, monolithic

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The Research on the Fabrication of X-ray Optical Elements

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Abstract

To achieve the perfect wavefront maintenance in the full beam range, the optical elements with ultra-high quality are needed. The study on the fabrication of optical elements has been conducted in HEPS. In this paper, the research progresses of silicon crystals, multilayer films and X-ray lenses are introduced.

1. Silicon crystal

Flat silicon crystal, with a new self-developed flexible chemical-mechanical polishing method, the ultra-high-accuracy wavefront maintenance within the full diameter range of centimeters has been achieved. The fabricated flat silicon crystals possessed sub-nanometer surface roughness, X-ray topography with uniform contrast and 50 ~ 100 nrad RMS surface wavefront accuracy (the testing method is 'Double-edge wavefront detection method[1]' , the same below). For the Channel-cut silicon crystal, a magnetic-controlled CMP processing method named MC-CMP has been proposed to solve the fabrication problem in a narrow semi-enclosed space [2]. After processed, the inner surface reached 0.6 nm RMS roughness. The peak reflectivity was 85.1%, close to the theoretical limit of 88.3%. The X-ray morphology contrast was uniform. The wavefront error of the two diffracts was up to 133 nrad at 8 mm. The flat crystals and CC crystals meet the technical requirements of HEPS beamlines, and both of them have been successfully implemented in engineering construction.

2. Multilayers component

By dynamical diffraction theory, DC magnetron sputtering technology and micro-nano processing, Laue-type multilayer monochromator(LMM) and multilayer Laue lens(MLL) are studied. For LMM, a WSi_2/Si multilayer with 47 μm aperture and 20000 layers is designed and fabricated, and the thickness error is 0.28% (RMS). The 1st order peak angle is 5.05 mrad and the efficiency is 75.0%. And the energy resolution (ΔE/E) is 3.3% at 26 keV. For MLL, two multilayers with 63(v)×43(h) μm^2 aperture and focal spot size of 8.1(v)×8.1(h)nm^2 are provided to the hard X-ray nano-probe beamline of HEPS. The smallest accumulated layer position error is below ±5 nm in the whole area and the RMS error is about 2.91 nm by SEM and image processing. The full width at half maximum (FWHM) of focus spot is 8.4×8.2 nm^2 at 10keV, which is close to the theoretical result.

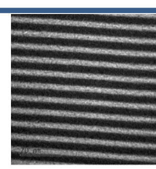
3. X-ray lenses

Nickle prism-array Lenses. A novel prism lens with phase matching is designed. Two lenses with focal length 0.979 m and 0.864 m for 80 keV are fabricated by LIGA technology. Their apertures are 614.6 μm and 546.5 μm separately. And the depth of these two lenses is about 1 mm. The two lenses can provide a focal with of 6.4 μm (H) and 4.8 μm (V) at an X-ray energy of 80 keV. And these lenses will be used in Engineering Materials Beamline of HEPS.

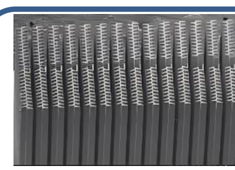
SU8 lenses. It consists of 79 parabolic lenses with radius of curvature 200 μm. And its aperture is about 700 μm and length is about 5 cm. The depth is about 666 μm. This lens was tested for one-dimensional focusing at 11.4 keV with the focal length 0.62 m at BL09B in SSRF and a focal size 3.2 μm (FWHM) was obtained.

Single-crystal Diamond Lenses. The fabrication of bi-concave 2D and 1D focusing diamond x-ray lenses by using ultraviolet femtosecond laser 3D etching technology is investigated, and the lenses are measured with XSVT method.

Channel-cut silicon crystal



TEM image of multilayer laue lens



SEM image of Nickle prism-array Lenses

Keywords: wavefront maintenance, silicon crystal, multilayers, X-ray lenses

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Poster No. #

Reflectance measurements on silicon pore optics for the NewAthena observatory

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Abstract

NewAthena will be the largest X-ray observatory ever flown. To achieve an effective area of 1 m² at 1 keV, a total polished mirror surface of 300 m² is required due to the grazing incidence. Based on silicon pore optics (SPO), a large X-ray lens with a diameter of 2.5 m will be installed at 12 m distance from the two detectors in the focal plane. It is composed of about 500 mirror modules (MM). Each MM consist of four stacks of about 40 silicon wafers with ribs at the backside. To optimize the reflectance in the photon energy range from 0.2 up to 10 keV, the mirror surfaces will be coated with e. g. iridium and carbon layers.

Two dedicated beamlines for SPO characterization in the PTB laboratory at BESSY II provide monochromatic radiation at 1 keV and a low divergence well below 2 arcsec: the X-ray Pencil Beam Facility (XPBF 1) [1], and the X-ray Parallel Beam Facility (XPBF 2.0) where beam sizes up to 8 mm x 8 mm are available while maintaining the low beam divergence [2].

Two different beamlines in the PTB laboratory, an undulator beamline with plane grating monochromator and a dipole beamline with a four-crystal monochromator, were used to measure the reflectance in several pores of differently coated MMs in double reflection over the entire photon energy range, revealing the effects due to the absorption edges and the layer thickness of the involved materials [3].

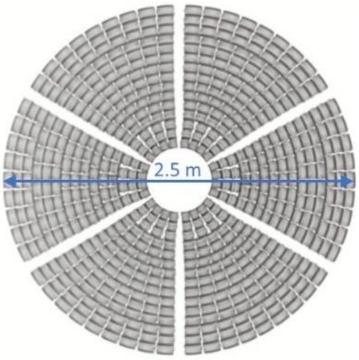

Fig. 1: X-ray lens, composed of MMs

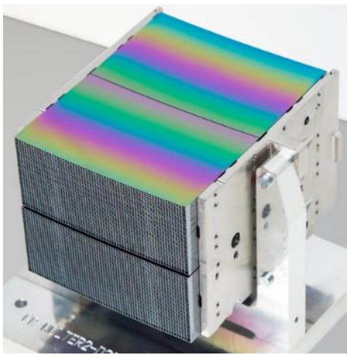

Fig. 2: MM, consisting of ribbed silicon wafers

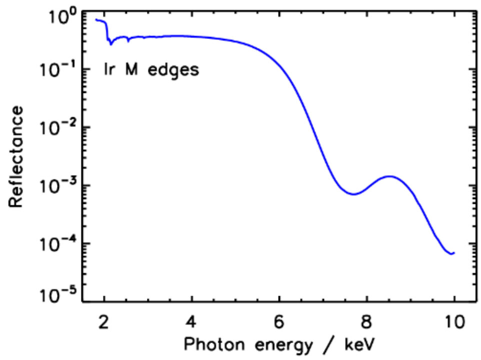

Fig. 3: Reflectance of an Ir coated MM at higher photon energies

Keywords: NewAthena, silicon pore optics (SPO), X-ray astrophysics, X-ray metrology

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Poster No. #031

Gravity compensation analysis and correction of bended mirror

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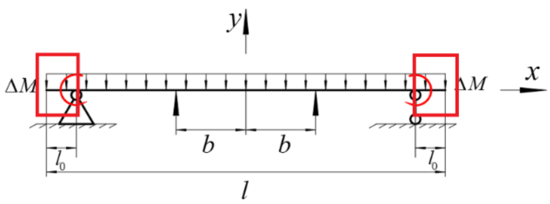
Abstract



To diminish the effect of gravity on the surface shape of a bendable mirror, additional support mechanism can be used to introduce gravity compensation in order to better approach the desired surface shape. Four-point roller contact bending mechanism is a typical design for mirror bender. It inevitably introduces two effective torques generated from the gravity of both ends of the mirror. In calculations, the impact of the consumed length of the mirror is often ignored. As a result, the optimization for gravity compensator (on both positions and applied forces) suffers from a deviation between theoretical calculations and actual engineering. Based on the conventional beam model, we introduce a comparative theoretical analysis of the mirror shape errors while considering the gravity effect of both ends of the mirror. The results show that there is an order of magnitude difference in the evaluation of the shape error caused by gravity when varying the length of the consumed part of the mirror. With such consideration, the corrected calculation is expected to be relatively more rigorous.