MEADOW 2013 – Oral contributions list

Invited speakers:

Hongchang Wang - Diamond

At-wavelength metrology of hard X-ray optics

Diamond Light Source is a third generation 3GeV synchrotron radiation facility with over twenty beamlines in user operation, which will rise to thirty two in the next five years or so. The successful exploitation of the intense synchrotron light produced by Diamond depends to a significant extent on the quality and performance of the optics employed on these beamlines. As well as optical tests in the metrology lab, extensive work is being carried out at Diamond to perform at-wavelength (using X-rays) metrology. Two at-wavelength metrology methods [1-3] have been established and further developed on B16, Diamond's Test beamline [4]. One is based on the grating shearing interferometer whereas the other is based on the X-ray speckle tracking technique. Various X-ray optics, such as compound refractive lenses, Fresnel zone plate and X-ray mirrors, have been investigated by using both methods. An overview of the development of at-wavelength metrology at Diamond will be presented, including representative examples of their application.

References:

[1] H. Wang, K.J.S. Sawhney, S. Berujon, E. Ziegler, S. Rutishauser, C. David, Opt. Express 19 (17), 16550-16559 (2011).

[2] S. Berujon, H. Wang, K.J.S. Sawhney, Physical Review A 86, 063813-1-063813-9 (2012).

[3] H. Wang, S. Berujon, I. Pape, S. Rutishauser, C. David, K.J.S. Sawhney, Opt. Lett. 38, 827-829 (2013).

[4] K. J. S. Sawhney, I. P. Dolbnya, M. K. Tiwari, L. Alianelli, S. M. Scott, G. M. Preece, U. K. Pedersen and R. D. Walton, AIP Conference Proceedings – 10th Int. Conf. on Synchrotron Radiation Instrumentation, Australia, CP1234, 381 (2010)

Markus Braune - DESY

Tools for non-destructive wavelength monitoring at FLASH

Maurizio Vannoni - XFEL

The European XFEL deformable optics project

The European XFEL is a large facility under construction in Hamburg, Germany. It will provide a transversally fully coherent X-ray radiation with outstanding characteristics: high repetition rate (up to 2700 pulses with a 0.6 milliseconds long pulse train at 10Hz), short wavelength (down to 0.05 nm), fast pulse (in the femtoseconds scale) and high average brilliance (1.6·1025 photons / s / mm2 / mrad2/ 0.1% bandwidth). Due to the very short wavelength and very high pulse energy, mirrors have to present high quality surface, to be very long, and at the same time to implement an effective cooling system. A special bendable mirror system will be manufactured for this task. Here we show some details about such a project, including original specifications, prototype manufacturing and preliminary characterisation results.

Manuel Sanchez del Rio - ESRF

The current situation of optical simulation codes for X-ray beamlines

The challenging in-place ESRF Upgrade Programme foresees the reconstruction of about one third of the beamlines. The new beamlines will be very long (more than 100 m) to use routinely micro- and nano-beams. This requires a very high demagnification of the ESRF source, which makes beamline optics design a fundamental concept for the future availability of bright and small beam. In the design of these beamlines an intense use of computer tools for x-ray optics is necessary. Ray-tracing has demonstrated to be a very reliable tool for designing and optimizing synchrotron beamlines but wave-optics propagation methods are essential for studying partial coherence. I will describe the efforts invested at the modernizing the SHADOW package. Collaborative work is in place to use and further develop other codes like SRW and McXtrace. Some examples of recent simulations for Upgrade beamlines will be presented. New developments include simulations for refractive optics (CRL and transfocators), bent crystals and wave-optics methods. In parallel, we started an ambitious software development project for interfacing and integration optics codes into a new toolbox that will eventually replace XOP.

Tobias Mey – LaserLab Goettingen

Beam characterization of FELs by measurement of wavefront and mutual coherence function

Free-Electron-Lasers deliver EUV and soft x-ray pulses with the highest brilliance available and high spatial coherence. Users of such facilities have high demands on phase and coherence properties of the beam, for instance when working with coherent diffractive imaging (CDI). Experimentally, we recover the phase distribition of FEL beams with an EUV sensitive Hartmann sensor. This allows for online adjustment of focusing optics as ellipsoidal mirrors or Kirkpatrick-Baez systems. Thus, aberrations in the focused beam are minimized resulting in smaller foci. To gain highly resolved spatial coherence information, we have performed a caustic scan at BL2 of FLASH employing the ellipsoidal beam line focusing mirror and a movable EUV sensitive CCD detector. This measurement enables to reconstruct the Wigner distribution function, being the two-dimensional Fourier transform of the mutual intensity of the beam, which describes the beam propagation completely. By a corresponding Fourier back-transform we obtain the four-dimensional mutual coherence function. Hence, we are able to provide comprehensive information about spatial coherence properties, such as coherence length and the global degree of coherence. Additionally, we derive the beam propagation parameters Rayleigh length, waist diameter and M^2.

Kai-Wing Chan – NASA (Goddard)

Fabrication and Testing of Lightweight X-ray Optics for Future Astronomical Missions

Peter Z. Takacs – BNL

Metrology of X-ray Optics: In Pursuit of Perfection

Contributed talks:

Y. Kayser - PSI

Wavefront metrology at SACLA by means of x-ray grating interferometry

Y. Kayser, S. Rutishauser, C. David, U. Flechsig Paul Scherrer Institut, 5232 Villigen-PSI, Switzerland T. Katayama, M. Yabashi RIKEN Harima Institute, Kuoto 1-1-1, Sayo, Hyogo 679-5148 Japan

The knowledge of the x-ray wavefront is of importance for many experiments at synchrotron sources and hard X-ray free-electron lasers. We will report on metrology measurements performed at the SACLA XFEL [1] by means of grating interferometry, a technique which was first used for radiography and tomography [2,3,4]. More recently grating interferometry was also used for wavefront metrology measurements at synchrotron facilities [5,6,7] as well as at the LCLS [8] to investigate for example the wavefront distortions introduced by optical elements. Indeed, grating interferometry allows for an in-situ, at wavelength characterization of the x-ray wavefront. At SACLA it was used for the study of the x-ray optics, two off-set mirror systems and a double crystal monochromator [9]. The measurements were realized in the moire mode with one-dimensional gratings. The moire mode is especially suitable for pulsed x-ray sources since it allows in contrast to the phase stepping configuration for single shot measurements while still preserving a good spatial resolution. The moire patterns were recorded at x-ray beam energies of 7 keV, respectively 12.4 keV, using a non-doped YAG screen and a lens-coupled CCD. Fourier analysis [10] on the moire pattern allowed to obtain the differential phase of single shots at the interferometer. Through integration, the phase profile with respect to a spherical wave could be obtained, the height profile of the optical element in the direction perpendicular to the grating lines being contained in the aspherical component. The two different offset mirror systems and the monochromator were found to show flat wavefront profiles. Thus, it could be concluded that the optical components do not present considerable surface roughness or curvature. Only a slight defocusing effect in the horizontal direction was found for the offset mirrors. Moreover a good shot-to-shot stability was observed during the experiment. References: [1] T. Ishikawa, H. Aoyagi, T. Asaka, et al., A compact X-ray free-electron laser emitting in the sub-angstrom region Nat. Phot. 6, 540-544 (2012). [2] C. David, B. Nöhammer, H. Solak, and E. Ziegler, Differential x-ray phase contrast imaging using a shearing interferometer, Appl. Phys. Lett. 81, 3287–3289 (2002). [3] A. Momose, S. Kawamoto, I. Koyama, et. al., Demonstration of X-ray Talbot interferometry. Jpn. J. Appl. Phys. 42, 886–868 (2003). [4] T. Weitkamp, A. Diaz. C. David, X-ray phase imaging with a grating interferometer. Opt. Express 13, 6296–6304 (2005). [5] T. Weitkamp, B. Nöhammer, A. Diaz, et al., X-ray wavefront analysis and optics characterization with a grating interferometer, Appl. Phys. Lett., 86, 054101 (2005). [6] A. Diaz, C. Mocuta, J. Stangl, et al., Coherence and wavefront characterization of S-111 monochromators using double grating interferometry, J. Synchrotron Radiat. 17, 299-307 (2010). [7] S. Rutishauser, A. Rack, T. Weitkamp, et al., Heat bump on a monochromator crystal measured with X-ray grating interferometry, J. Synchrotron Radiat., 20, 300-305 (2013). [8] S. Rutishauser, L. Smoylova, J. Krzywinski, et al., Exploring the wavefront of hard X-ray free-electron laser radiation, Nat. Comm., 3, 947 (2012) [9] H. Ohashi, M. Yabshi, K. Tono, et al., Beamline mirrors and monochromator for X-ray free electron laser of

SACLA, Nucl. Instrum. Meth. A, 710,139-142 (2013). [10] M. Takeda, H. Ina, and S. Kobayashi, Fourier-transform method of fringe-pattern analysis for computer-based tomography and interferometry, J. Op. Soc. Am., 72, 156-160 (1982).

R. Reininger – APS/ANL

The short pulse x-ray beamlines at APS

The SPX Facility consists of three independent beamlines: SPXSS (SPX spectroscopy and scattering); SPXIM (SPX imaging and microscopy); and the SPSXS (SPX soft x-ray spectroscopy). These three beamlines were assumed to be located between two rf deflection cavities which provide chirped electron pulses, where a correlation is imposed between the longitudinal position of a particle in the bunch and the vertical momentum. The x-ray radiation emitted during traversal through an undulator or bending magnet preserves the correlation and a short pulse can be selected out simply with a pair of slits.

Y. Emi – Osaka Univ.

Development of a full-field hard X-ray imaging microscope based on Advanced Kirkpatrick-Baez mirror optics

To realize an achromatic full-field hard X-ray microscope with a high resolution, we have developed Advanced Kirkpatrick-Baez (AKB) mirror optics which consist of two sets of elliptic mirrors and hyperbolic mirrors aligned perpendicular to each other. So far, we have fabricated each mirror with accuracy higher than 2 nm peak to valley, and constructed a mirror manipulation system. To demonstrate the performance of the AKB mirror optics, we performed a magnification imaging experiment with the AKB mirror optics at BL29XUL in SPring-8. A test pattern made of tantalum was irradiated with 10-keV X-rays, and a transmission image with a 50 nm resolution was obtained.

K. Yamauchi – Osaka Univ.

Adaptive focusing optics of hard X-rays with piezoelectric deformable KB mirrors

An X-ray focusing system, in which beam size can be adaptively changed from 50nm to 1ƒÝm under the diffraction-limited condition, is proposed and discussed. To realize such optical system, a piezoelectric deformable was designed and tested. An on-line wavefront measurement and correction methods based on a pencil beam method was also developed with the slope measurement accuracy of 0.1urad. Smallest spot size obtained was 65nm x 100nm with a 15keV X-ray.

X. Shi - Argonne

Optics Modeling and Simulation at APS

Simulations of geometrical and physical optics have proven to be essential in the optics development and design of beamlines for Synchrotron Radiation (SR) sources. In this presentation, wave propagation methods based on different approximations (e.g., Fourier optics and stationary phase approximation, SPA) are reviewed with example calculations. A simulation package using the stationary phase approximation is under development at APS. Example simulations of grazing-incidence optics with different surface figures and figure errors are shown and compared with other programs. A hybrid ray-tracing-wave-propagation method is introduced for diffraction-limited beamline design. The ray-tracing results are convolved with the wave propagation results containing the diffraction effects from finite apertures and mirror figure errors. The In Situ Nanoprobe beamline at APS is shown as an example.

J. Sutter - Diamond

Structure in out-of-focus beams of X-ray focusing mirrors: causes and possible solutions

Grazing incidence mirrors are now a standard optic for focusing X-ray beams. Bimorph mirrors have become especially widespread at Diamond Light Source because they permit a wide choice of focal lengths. They can also be deliberately set out of focus to enlarge the X-ray beam, and indeed many beamline teams now wish to generate uniform beam spots of variable size. However, progress in this direction has been slowed by the appearance of fine structure in these defocused beams. Measurements showing the relationship between the medium-frequency polishing error and this structure over a variety of beam sizes will be presented. A theoretical model for the simulation of general bimorph mirrors will then be developed. The model predicts that the usual periodic arrangement of electrodes will give rise to an oscillating residual figure error that will also affect the beam structure. Not only the figure error and its first derivative the slope error, but also the second derivative, the curvature error, must be considered. In conclusion, possible ways to reduce the defocused beam structure, such as making the electrode positions non-periodic, will be discussed.

M. Idir – BNL-NSLS II

A new 2 D high accuracy slope measuring system based on a Stitching Shack Hartmann Optical Head

We present a new 2D Slope measuring System based on a Stitching Shack Hartmann Optical Head (SSH-OH) aiming to perform high accuracy optical metrology for X-ray mirrors. This system was developed to perform high-accuracy automated metrology for extremely high quality optical components needed for synchrotrons or Free electrons Lasers, EUV lithography and x-ray astronomy with the objective of speeding up manufacturing at the meter scale level and with slope error accuracy better than 60 nrad rms.

B. Menz – MPI Garching

Characterising X-ray optics with a collimated X-ray beam: The zone plate approach

An open question in the measurement of X-ray optics for telescopes in space is what the point spread function (PSF) looks like in orbit and what is the focal length for an infinite source distance. In order to measure such a PSF, a parallel X-ray beam with a diameter of several centimeters to meters is needed. For this purpose it is studied of how to collimate the X-rays using a zone plate. Furthermore, a configuration study is presented to characterize X-ray optics with such a collimated beam at the PANTER X-ray test facility. In particular, estimations for segmented optics for future X-ray missions such as ATHENA+ with a focal length of 10 to 20 are presented.

F. Frassetto – IFN-CNR Padova

Deformable diffraction gratings for a time delay compensated monochromator in the EUV spectral region

Time-delay-compensated grating monochromators (TDCM) are becoming more and more demanded for the use in extreme-ultraviolet ultra-short pulses beamlines using high-order laser harmonics. The TDCM is asked to select a single harmonic within the broad-band plateau and to preserve the ultra-short pulse duration by correcting the pulse-front tilt after the grating diffraction. Two basic optical layouts have been proposed, the former uses two plane gratings in the off-plane diffraction geometry, the latter two toroidal gratings in classical diffraction. Both designs have their own strength and weakness: throughput and tunability in the first case, and optical simplicity in the second case.

Here we present an alternate configuration, using two spherical deformable gratings and a toroidal mirror. The grating's curvature radius is varied applying a variable tension to a piezo-ceramic actuator. The two gratings are used in a compensated configuration to select, and compensate temporally the radiation. The toroidal mirror is finally used to provide the output focus. The configuration is simple and flexible, since the possibility of varying the curvature radius of the two gratings permits to maintain on focus the radiation for a large choice of incidence angle and entrance and exit arms.

We present the grating realization and characterization in the XUV, in terms of surface quality, diffraction efficiency and focusing capabilities.

A TDCM prototype has been realized and tested with Ti:Sa ultrashort pulses at 800 nm, in particular the pulse front-tilt compensation has been measured and demonstrated.

W. Jark – Elettra

On the transmission of X-rays through Kirkpatrick-Baez mirrors: What to do with grazing incidence X-ray dioptrics

Today everybody working in the field of X-ray instrumentation knows the name of Paul Kirkpatrick and associates it with the KB mirror pairs [1], which are most commonly used for the focusing of X-rays. Instead hardly anybody refers to another work of him, which was published about one year later [2] with the title "X-Ray Images by Refractive Focusing". Here an attentive reader would have found the encouraging statement "In spite of a long-standing impression to the contrary, *refractive* x-ray focusing is also a possibility." Less encouraging comments by him in [1] had contributed and seem to have contributed even later to the "long-standing impression".

What did Kirkpatrick show in [2]? He proved, that X-rays can also be brought to a focus, when they are refracted at grazing incidence at a concave interface. Consequently in addition to filing a patent application for the use of concave total reflection mirror pairs as X-ray catoptrics for the purpose of microscopy [3], he also filed a patent application for a similar mirror pair to be used in transmission as an X-ray dioptrics [4] for two-dimensional focusing.

He recognised already that the high absorption for X-rays in matter will make the dioptrics to have a rather small geometrical aperture. On the one hand this will lead to a rather large diffraction limited beam size; on the other hand it will make an x-ray dioptrics of this type to be rather short. The focal length in this case can also be short.

This contribution will discuss with experimental examples the possible applications of refraction at grazing incidence in X-ray dioptrics as monitoring systems for different properties of X-ray sources. Such devices can be used as spectrographs or spectrometers for the registration of emission spectra from continuous or polychromatic sources. It is particularly interesting that these spectra will not suffer from any higher order or other false light content. It will also be shown, that the devise can be used for the determination of the source size. As the dioptrics is rather small, it can also be fabricated in beryllium or in diamond, the most resistant materials for high power X-rays sources. Infact the present experimental results were obtained with a small diamond sample, as were similar results by Tur'yanskii et al [5].

[1] Kirkpatrick, P. & Baez, A., "*Formation of Optical Images by X-Rays*," J. Opt. Soc. Am. **38**, 766-774 (1948).
[2] Kirkpatrick, P., "*X-Ray Images by Refractive Focusing*," J. Opt. Soc. Am. **39**, 796-796 (1949).
[3] Kirkpatrick, P., "*Short-wave electromagnetic radiation catoptrics*," US patent 2,557,662 (1951).
[4] Kirkpatrick, P., "*Formation of X-ray images by refractive focusing*," US patent 2,559,972 (1951).
[5] A. G. Tur'yanskii, I. V. Pirshin, R. A. Khmel'nitskii and A. A. Gippius, "*X-ray Spectrum Determination from the Angular Dispersion of Radiation in a Diamond Prism*," JETP Letters **73,** 457–460 (2001).

A. Vivo – ESRF

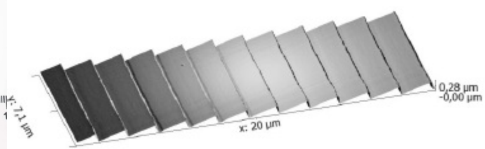
Current status of micro-stitching at ESRF

The ESRF upgrade, which started 4 years ago, has led to a considerable number of new X-ray mirrors being ordered for the different beamlines in construction. Specifications of these mirrors are extremely challenging in terms of metrology thanks to the polishing improvements made by manufacturers. Many of them have already been delivered and tested at the ESRF metrology laboratory prior to their commissioning on the beamline. We will first give a short overview of the mirror quality that can be currently achieved. Among these mirrors we will discuss a fixed-figure KB system designed for nano-focusing applications. The specifications of these deeply aspheric X-ray mirrors, requires shape errors in the nanometer range. Both metrology as well as fabrication are extremely challenging. Their strong curvature preventing LTP measurements even by applying methods such as LTP stitching or linearity error elimination procedure, we investigated methods of micro-stitching interferometry. Recently delivered to ESRF for intermediate metrology during their fabrication, we will present some of the results obtained. Finally will discuss some limitations of the micro-stitching procedure applied to flat mirrors.

F. Siewert – HZB

Status of the grating production facility at the Helmholtz Zentrum Berlin

F. Siewert1*, B. Löchel1, F. Senf1, T. Zeschke1, C. Waberski1, T. Seliger1, I. Rudolph1, G. Gwalt1, O. Kutz1, J. Wolf1, S. Lemke1, F. Schäfers1, A. Sokolov1, F. Eggenstein1, B. Nelles2 A. Erko1 1Helmholtz Zentrum Berlin / BESSY-II, Institut für Nanometer Optik und Technologie, Albert-Einstein-Str. 15, 12489 Berlin, Germany 2DIOS-GmbH, Schmittstr. 41, 53902 Bad Münstereifel, Germany. *Tel.: +49(0)30 – 8062 – 14846 e-mail: frank.siewert@helmholtz-berlin.de



For the manufacture of blazed and laminar gratings, we are currently establishing a new technological laboratory at the Helmholtz Zentrum Berlin (HZB), including instrumentation from the former grating laboratory at Carl Zeiss. Recently the first blazed gratings for synchrotron application have been produced and characterized. A blazed plane-grating of 120mm length (600l/mm; blaze angle 2.0°, see Fig. 1) for the new Optics-beamline at the BESSY-II storage ring as well as e.g. two toroidal, blazed gratings (1123 l/mm, blaze angle: 1.4°) for seeding application at LCLS. Besides using the former Zeiss technology, we are developing an advanced technology line, including a new ultra-precise ruling machine, ion etching technology, as well as laser interference lithography [1]. The final at wave-length characterization of gratings will be performed by use of a new reflectometer [2] at the Optics beamline. This presentation will report on recent achievements on the production of gratings. In addition we will describe future plans to establish a laboratory for the production and ex-situ inspection of gratings located in a new building.

References:

1 B. Löchel et al., , Journal of Physics Conference Series, Vol. 425, Issue 21 (2013) 212012

2 F. Eggenstein et al., A reflectometer for at-wavelength characterization of gratings, NIMA 710 (2013) 166-171

M. Thomasset - SOLEIL

Latest results in Phase-Shifting interferometry at SOLEIL

M. Thomasset, F. Polack SOLEIL Synchrotron, l'Orme des Merisiers, 91192 Gif-sur-Yvette, FRANCE

With new surface finishing techniques, EEM, IBF, differential coating, becoming more widely available, X-ray mirrors with diffraction limited imaging property can be specified and ordered. These mirrors which are often used to produce nanometer wide x-ray beams have usually a limited active area 100- 200 mm long and some mm wide, but their surface shape should be machined and controlled, over this area, with a height precision better than 1nm and an in-plane lateral resolution better than 0.1 mm. SOLEIL is not directly concerned by manufacturing issues but need to control the delivered mirrors. The Long Trace Profiler (LTP), which was till now its reference instrument, is not suited for 2D measurements, doesn't have the desired spatial resolution. For these high performance mirrors, we are now moving to stitching phase-shift interferometry with a goal of: ±0.1 nm height accuracy, a field of view up to 16 mm and a pixel size of about 20 µm. The new instrument was designed around a “custom-made” telecentric objective, in order to render the measured shape (namely the mean curvature) almost insensitive to the actual focus position [1]. Results have been improved lately by damping the vibrations coming from the laboratory floor. Careful calibration of the phase-shifter and correction of image distortion are critical, especially when measuring large optics areas requiring that stitching procedures are used [2]. Latest results will be showed.

M. Richter - PTB

The impact of FEL photon metrology on multiphoton ionization experiments

In close cooperation with Deutsches Elektronen-Synchrotron (DESY) in Hamburg, the Physikalisch-Technische Bundesanstalt (PTB), Germany’s national metrology institute, has developed and applied various methods and tools to measure pulse energy, pulse duration, and beam diameters of soft and hard X-ray free-electron lasers (FELs) in absolute terms. Because these methods are based on atomic photoionization, also the mechanisms of multiphoton ionization have been studied in this context. In the present contribution, the impact of FEL photon metrology on multiphoton ionization experiments will be discussed with emphasis on the distinction between sequential and non-sequential multiphoton processes and strong-field effects by experiments at different pulse duration.

I. Nistea - Diamond

Investigation of a Next Generation, Piezo Bimorph Mirror

Piezo bimorph mirrors are used at numerous synchrotron facilities to satisfy a range of beamline requirements, including a user defined size and shape of X-ray spot, and fine correction of aberrations from the X-ray source or other optical elements. At Diamond Light Source, we have undertaken a systematic investigation of active optics, including bimorph mirrors, to diagnose problems and find viable solutions. Old type bimorph mirrors, with piezo ceramics glued to the underside of the optical substrate, were shown to suffer from the “junction effect”: sharp defects located directly above the glued interface between piezo ceramic blocks [1]. These defects introduce unwanted structures into the reflected X-ray beam and substantially broaden the focal spot [2]. To prevent this situation, a next-generation piezo bimorph mirror was developed with piezo ceramics glued to the side faces of the optical substrate [3]. We present a study of this versatile optic, manufactured by Thales-SESO, designed to operate facing upwards, downwards, or sideways to suit various beamline geometries. Ex-situ, slope profilometry using the Diamond-NOM showed that the 640 mm long mirror had a slope error of <500nrad rms across a wide dynamic range of bending (flat to <2km concave). Piezo response functions revealed that the low spatial frequency errors of the mirror’s surface can be reliably controlled with nanometre resolution. However the curvature of the mirror was observed to drift by several percent over ~24 hours, but it is strongly suspected that friction within the kinematic mounts used to clamp the mirror into its frame is to blame. An alternative design for the opto-mechanics is under consideration to solve this issue. After beamline installation, the elliptical figure of the mirror created a smooth, Gaussian X-ray beam profile, with a spot size close to the theoretical value dictated by the beamline geometry. It is hoped that next generation bimorph mirrors can fulfil their potential and help beamlines to achieve wavefront control and micro- and nano-focussing.

R. Barrett - ESRF

Reflective optics developments for ESRF Upgrade Beamlines

R. Barrett, R. Baker, B. Lantelme, C. Morawe, A. Muth, A. Vivo, L. Zhang
X-ray optics Group, ESRF, BP 220, 38043 Grenoble Cedex 09, France barrett@esrf.fr

The ESRF is currently in the implementation phase of an extensive upgrade programme which includes the construction of 9 new beamlines and 4 major beamline refurbishments. The general trends and scope of the optical design and opto-mechanical implementation of these beamline projects will be discussed. The presentation will highlight some of the particular challenges and technologies being developed for reflective optical systems both for high-heat load beam-conditioning optics and nanofocusing applications.

G. Vacanti – COSINE

In-focus performance from intra-focal measurements for large X-ray mirrors

The next observatory-class X-ray astronomical mission will be characterized by optics with a long focal length (>10m) and large aperture (>2m). Full-aperture in-focus measurements for such large systems is impossible due to limitations of the existing X-ray facilities, and this is not expected to change in the future. Alternatives must be found to characterize the performance of the whole system based on the performance of individual sub-components. Here we report on how we characterize the performance of a large modular X-ray mirror system based on intra-focal pencil beam measurements, and how the individual measurements are combined and extrapolated to predict the in-focus performance of the complete mirror.

V. Burwitz – MPI Garching

The PANTER X-ray test facility, past, present and future

The PANTER X-ray test facility of the Max-Planck-Institute for extraterrestrial physics has a long history in developing and calibrating mirrors for X-ray satellite missions such as ROSAT, BeppoSAX and XMM-Newton. Presently the developement of the eROSITA mirrors is complete, currently the eROSITA mirrors are beeing characterised, environmentally tested and calibrated. In paralell to this very large effort PANTER is involved in the development and X-ray testing of light weight mirrors for future X-ray missions such as ATHENA+.

B. Salmaso – INAF/Brera Observatory

Direct hot slumping of thin glass foils for future generation X-ray telescopes

The large effective area requirement for future X-ray telescopes demands the production of thousands of segments made of a light material, shaped and integrated into the final optics. At INAF/Osservatorio Astronomico di Brera we developed a direct hot slumping technique assisted by pressure, to replicate the shape of a mold onto the optical surface of a glass mirror segment. The state of the art of this technology is presented together with the future perspectives.