INSTRUMENTATION
AND
NEW TECHNIQUES

MULTILAYER BRAGG-FRESNEL MONOCHROMATOR FOR FOCUSING SOFT X-RAYS

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A monochromator system which uses a pair of multilayer mirrors has been designed and developed for synchrotron radiation soft X-rays in the energy range of 0.4 - 4 keV. In order to intensify the X-rays in the horizontal direction, a linear Fresnel pattern which produces a phase shift of $\pi/4$ is deposited on the first multilayer mirror. The multilayer mirrors were manufactured by the helicon plasma sputtering system[1,2] and the Fresnel pattern was generated by an E-beam lithography. The dimension of the mirror is 2 inch in diameter and the incident angle to the mirror can be adjusted between 3.6 - 45 degrees. Because the focal length of the Bragg-Fresnel lens is inversely proportional to the wavelength of X-ray, the movement of the first mirror is designed so as to minimize the difference in the focal points.

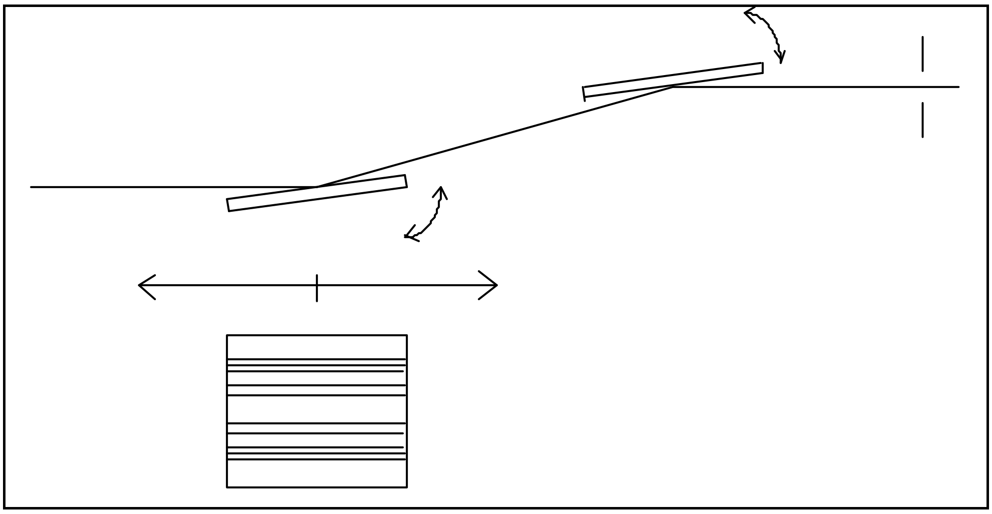

Figure 1: Schematic view of the multilayer monochromator. Fresnel pattern is deposited on the surface of the first multilayer mirror.

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SU5 : A VARIABLE POLARIZATION FACILITY IN THE VUV

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Besides its primary scientific case dealing with high resolution spectroscopy [1], the VUV SU5 beamline of Super- ACO is also devoted to the study of anisotropic systems such as laser-aligned species, molecules adsorbed on surfaces, chiral molecules or magnetic systems, via linear and circular dichroism experiments, requiring the use of "exotic polarizations", i.e. rotating linear and circular polarizations.

In order to achieve such a scientific program, we have conceived and built the first 10 period electromagnetic Onuki-type crossed undulator [2], called OPHELIE [3]. With the help of a VUV polarimeter based on 4 reflections on mirrors, we have been able to measure, for the first time in the VUV range, a complete set of polarization ellipses as produced by OPHELIE, including of course the linear (in any directions) and circular cases, by playing with the 3 undulator's main parameters K_x, K_y and ? [4].

Nevertheless, because of some mechanical defects, it was not possible to get reliable quantitative informations on the polarization rates. This led us to built, with great care on both the optical and the mechanical aspects, a new VUV polarimeter based on two elements achieving 3 reflections on prisms, according to an idea originally proposed by Koide [5]. Such a device is located in situ, i.e. just upstream of the sample, so that at any time it is possible, by inserting the prisms into the beam, to check the polarization state of the light impinging onto the sample.

We initiated a polarization analysis campaign consisting in measuring the polarization ellipses in different undulator configurations. In the linear cases, starting with the trivial $K_x = 0$ or $K_y = 0$ configurations, we found a linear polarization rate above 98 % in the vertical mode (standard) and above 90 % in the horizontal mode. In the circular case, it is less straightforward, since one has to determined the correct polarization ellipse at the undulator level providing, after modifications by the optics of the beamline, the corresponding left or right-handed polarization. The results, so far between 6 and 10 eV, are very encouraging since we obtained circular polarization rates (S3) above 93 %. At the time of the conference, a complete polarization analysis over the whole VUV range should be available.

See also : http://www.lure.u-psud.fr/Experiences/SACO/SU5/intro_SU5_eng.htm

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Optical components for polarization analysis at the vanadium L_3 edge and the carbon K edge

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A complete polarization analysis of soft x-ray radiation with primary standards can be performed using a phase retarder in transmission and an analyser in reflection [1]. Such components were realized as multilayers of Mo/Si for 97 eV [2], Cr/C for 265 eV [3] and Cr/Sc for 399 and 573 eV [1]. For practical application the phase retardation of the transmission multilayer should exceed 5 degrees and the linear reflectance ratio R_s/R_p of the reflection analyser should be as high as possible. Both features crucially depend on the selected material combination of the multilayer and on the smoothness of the interfaces, i.e. the quality of production.

At PSI, we have succeeded to produce V/Ni multilayers by sputter deposition, which give a phase retardation $\Delta = 5.7°$ at 512 eV and a reflectance ratio $R_s/R_p > 1000$ for E in the range 507-512 eV (see Figure 1), thus extending the possibility of complete polarization analysis to the vanadium L_3 edge. These measurements were carried out at the BESSY undulator beamline UE56/1-PGM using the BESSY polarimeter [1].

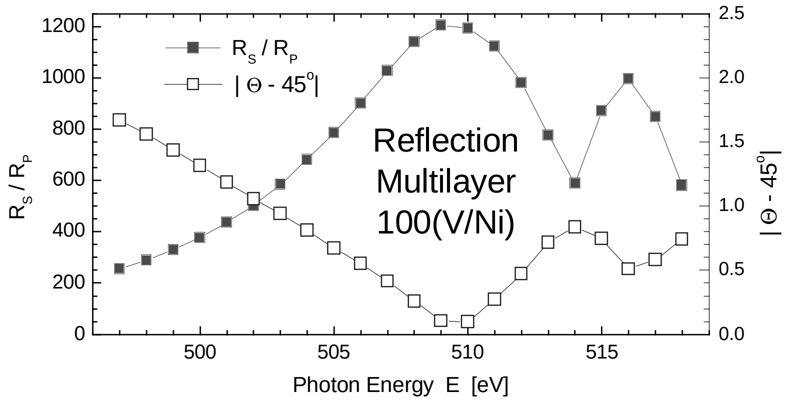

Figure 1: The reflectance ratio R_s/R_p at the first Bragg peak is strongly correlated with the deviation of the Bragg angle Θ from the Brewster angle, which is close to 45°. The energy dependence of Θ reflects the strong fluctuations of the refractive index at the L_3 edge of vanadium.

At the same time, also improved Cr/C multilayers were produced at PSI. The measurements at BESSY gave $R_s/R_p = 1400$ at 278 eV. The characterization of the phase retarder will be completed in the beginning of March 2001. First estimates can be made from the ratio t_s/t_p of its transmissions for linearly s- and p-polarised radiation, which lets us expect a phase shift much larger than 5 degrees.

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Electron and photon stimulated desorption of CO_2 condensed onto polycrystalline copper

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An experimental set-up has been developed with the aim of studying the ionic desorption of solids and surfaces induced by fast electrons and photons. It consists mainly of a vacuum chamber (base pressure: 5.0 x 10^{-9} Torr) containing a cryostat for sample cooling, an electron gun, a helium resonance lamp, a time-of-flight spectrometer and a quadrupole mass spectrometer for residual gas monitoring. In this system, a pulsed electron beam or monochromatic photons are focused on the target and as a result different fragments (ionic and neutral species) desorbed from the surface. The positive ions are analyzed through their mass/charge ratio using the time-of-flight (TOF) technique and recorded by a time to digital converter with a maximum resolution of 2.5 ns/channel. In the TOF normal operation with the electron beam, the stop signal is given by the positive ions while the start signal by the pulsed electron gun. In the case of photons, the start signal was obtained by pulsing the positive potential applied to the sample. This procedure would for instance enable the use of synchrotron radiation sources without the need for single bunch operation.

This work shows the preliminary results for CO_2 condensed onto polycrystalline copper obtained with both techniques. The results showed the presence of C^+, O^+, CO^+ and CO_2^+ as main ionic fragments, after electron bombardment as well as UV photons. The CO_2^+ ion showed however a different behavior with electron irradiation time as compared to the others fragments. In the case of photon irradiation the CO_2^+ peak intensity was much higher than the other ions. The mass calibration of the spectra was achieved through introduction of argon gas to the chamber [1].

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A new and simple mass calibration procedure for time-of-flight studies of stimulated desorption of ions from solid samples

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A technique that provides a simple mass scale calibration for a linear time-of-flight (TOF) measurement of ionic desorption from solid samples is presented. This procedure has been used in the calibration of the mass scale in experiments of electron stimulated desorption of ions from solid surfaces [1] and can be easily adapted for photon stimulated desorption experiments. The technique, which will be here exemplified with the use of electrons, is based on the admission of a small amount of a gaseous compound into the high vacuum chamber. Ions generated after electron excitation act like internal standards within the plume of desorbing ions due to the focussing capacities of the TOF-spectrometer. In the present case, a sample of either Ar or He gas, was admitted inside the ultra-high vacuum (UHV) chamber, raising the pressure from 5.0×10^{-9} to $0.1\text{-}5.0 \times 10^{-6}$ Torr. The gas was then irradiated under the same experimental conditions as the solid samples. Peaks related to the desorbed ions as well as to the atomic gases could consequently be observed in the same mass spectra, thus allowing for an accurate mass scale calibration. The solid samples were excited using a pulsed electron beam (0.18 μs, 3 kHz). The output signal of the ion detector was used to provide a stop signal to a time-to-digital converter, TDC. Start signals to the TDC were provided by the rising electron gun pulse. The TOF spectrometer employed in the present work has been developed in our laboratory and has been described in detail elsewhere [2]. Basically, it consists of an efficient electrostatic ion extraction system, a drift tube (25 cm) and a pair of microchannel plate (MCP) detectors, disposed in a chevron mode. After extraction, positive ions travel through three metallic grids (each of which with a nominal transmission of 90%), before reaching the MCP. The present calibration procedure is especially suitable in the low mass range (< 200 amu).
The authors would like to thank CNPq and FAPERJ for financial support.

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ELECTRON OPTICS WITH CYLINDRICAL DEFLECTOR FOR SPIN-RESOLVED INVERSE PHOTOEMISSION SPECTROSCOPY

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In Hiroshima University, the set up for both spin-resolved photoemission and inverse photoemission spectrometers is in progress. For spin-resolved inverse photoemission spectrometer, the most important components are the 90-degree deflector and lens optics with a high transmission for spin-polarized electrons from GaAs photocathode to the sample.

Spherical deflector has been used by many groups in the design of spin-polarized electron gun [1, 2, 3]. Since the electronic field between two cylindrical electrodes is in inverse proportion to the radius of electron orbit, which is as same as the relation for centripetal force, therefore in principle, cylindrical electrodes are more suitable for electron deflection. Besides, the fabrication of cylindrical one is simpler than that for spherical one. For these reasons, the cylindrical deflector is adopted in our system. The structure of electron optics is shown in Figure 1. The design consideration and performance test of our electron optics will be reported.

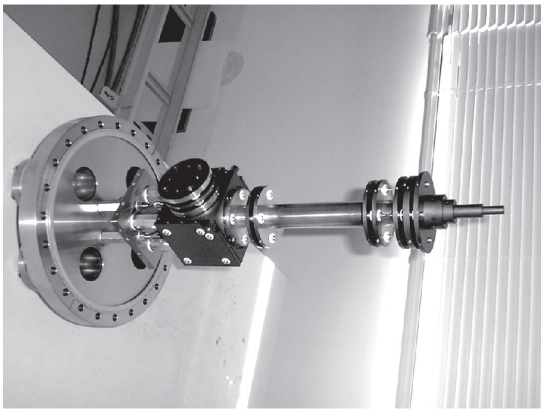

Figure 1: The photograph of the electron optics of our spin-polarized electron gun.

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Space solar patrol apparatus for the photometric measurements at photon-energy range from 8 eV to 8 keV.

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In the Vavilov State Optical Institute the special apparatus and also the methodology have been developed which enable to measure absolute fluxes from the full disk of Sun in VUV, EUV and soft X-ray spectral ranges (0.14-157 nm) [1, 2]. The apparatus have been tested in the laboratory vacuum chambers of the SOI and ESTEC [3-5]. The apparatus allows the absolute spectral measurements to be carried out due to the simultaneous operation of the radiometer and spectrometers. The radiometer is equipped with à special disk on which are fitted several filters (foils, thin films and crystalls). This enables to carry out measurements at the spectral range from 0.14 nm to 157 nm. The EUV grating spectrometer with normal incidence provides five spectral channels with channels width of 35 nm each for measurements in the spectral range under 155 nm. The spectral range from 1.8 nm to 60 nm can be covered by soft X-ray grazing grating spectrometer. All instruments are equipped with the same detectors namely with the open secondary electron multipliers (SEM) with photocathodes made of BeO which was developed at the Vavilov State Optical Institute. This photocathode has à good sensitivity in the spectral range under 150 nm and its sensitivity falls practically down to zero at the wavelengths grater than 160 nm. SEM has à great amplification (up to 10^8) and stable to atmospheric influence. The stability of SEM could be control with radiation of isotope ^{55}Fe (0.2 nm). There are plans to use this complex for mutual calibration of various synchrotron sources. The work is financial supported by the International Science and Technology Center, Moscow (projects #385, 385B and 1523).

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RESOLUTION OF EMISSION ELECTRON MICROSCOPY IN THE PRESENCE OF MAGNETIC FIELDS AT THE OBJECT SURFACE

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The well-known Brüche-Recknagel formula for the resolving power of an emission electron microscope (EEM) was derived under the assumption of ideal conditions: a flat object surface and a uniform electric field accelerating the electrons [1,2]. However, it is obvious that in realistic samples various violations of these conditions will be present and may thus deteriorate the resolving power [3]. It can be a corrugation as well as the presence of local electric or magnetic fields at the object surface. In the present work, the sensitivity of an emission electron microscope for the situation of an object surface with local magnetic fields is calculated. In this case, the deterioration of the sensitivity depends on the local field magnitude not only at the given point of the object surface, but also in the neighboring regions. The estimations performed show that due to this long-range influence of magnetic microfields at a real ferromagnetic surface, the lateral resolution in an EEM can be several times worse than in the field-free case. The theoretical results are supported by an experimental study performed on ferromagnetic $Fe_{80}Ni_{20}$ (permalloy) microstructures. In these experiments magnetic domain patterns were imaged by means of EEM, exploiting magnetic circular dichroism (XMCD) at the Fe $L_{2,3}$ absorption edges as a magnetic contrast mechanism.

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Accurate figure error correction of multilayer mirrors for Cu Kα radiation

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Synthetic multilayer structures have now been used for comprising imaging mirrors at wide ranges of radiation from EUV to X-ray including Cu Kα radiation[1]. For these imaging, the mirror shape must be finished within a figure error of the wavelength, which is extremely difficult to achieve. To find a possible solution, we extended theoretical study of figure error correction by multilayer milling[2] to the Hard X-ray mirrors working at grazing incidence.

At the wavelength of 0.154nm, material combinations of Cu and/or Ni with Al, Be, C, Mg and Si, were selected for high reflectivity. For each combination, the optimum ML structure was calculated at a grazing angle of 3° by layer-by-layer designing[3] up to 800-1000 periods, where the reflectance increase was in saturation. Then the milling was applied with keeping the reference at the original surface before the milling. Figure 1 shows an example for a Cu/Al ML with an additional 30 nm top Cu layer. Milling within the Cu top layer results in a phase correction rate of -2.2 deg/nm with slight reflectivity increase due to decrease of the Cu layer absorption. For the milling more than 30 nm into the ML, the phase correction rate is -1.9 deg/nm with negligible reflectivity variation. The oscillations in the curves are due to interference. Such calculations will be summarized with brief discussion of practical applicability of this approach.

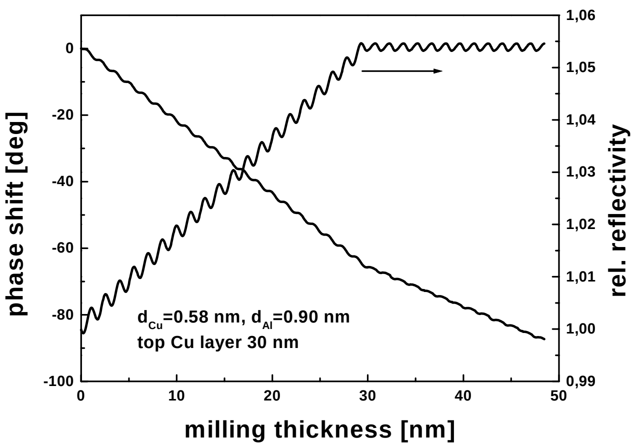

Figure 1: Phase shift and relative reflectivity as a function of milling thickness of Cu/Al multilayer with a 30 nm top layer of Cu. The addition of the Cu top layer decreased the reflectivity from 73.1 % to 69.6%. Phase shift of 20º by 10nm milling at the surface of a ML mirror corresponds to accurate 0.1nm figure correction at the substrate."

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Activity at the Spectromicroscopy End Station at the PLS 8A1 Undulator Beamline

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A scanning photoemission microscope (SPEM) at the Pohang Light Source has a spatial resolution of 0.4-0.5 µm with a focused flux of ~10^8 photons/s. The SPEM has been applied to a sensor chip passivated with an insulating layer and to Cu patterns embedded in Si substrate, in order to obtain elemental or chemical distribution on the devices. As an example Fig.1 shows SPEM images of the Cu patterns in Si substrate obtained at the C 1s, Si 2p, Cu 3d peaks and at continuum of the photoelectron spectra, indicating that Cu patterns are more contaminated with carbon.

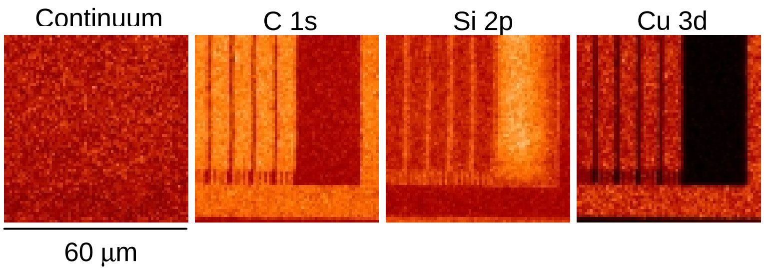

Fig.1. SPEM images of Cu patterns embedded in Si substrate

Coherence property of the beamline has been investigated using a coherent X-ray application (CXRA) setup. Fig. 2 shows Young's interference patterns from a double-pinhole at different photon energies. Lateral coherence length and coherence factor as a function of photon energy has been investigated. Interference patterns from other samples and proposed application of the CXRA setup will be presented.

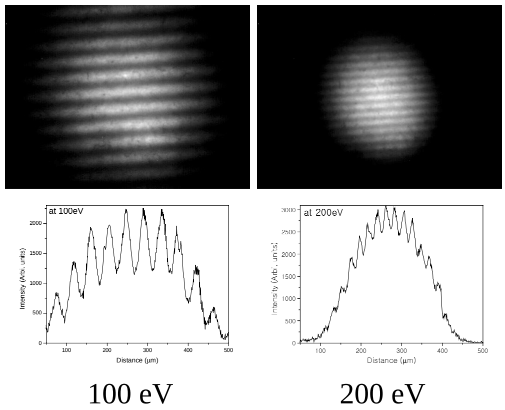

Fig. 2. Young's interference patterns from double-pinhole at different photon energies.

Near edge X-ray absorption spectroscopy (NEXAFS) in total electron yield mode with spectral resolving power of about 3,000 has been applied to investigate electronic structures of the transition metal composites such as battery materials, magnetic materials, and oxide materials. Recent results of the NEXAFS setup will be presented.

INELASTIC ULTRA VIOLET SCATTERING (IUVS) BEAMLINE

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The goal of the IUVS project at Elettra is the construction and operation of a high energy resolution spectrometer to study collective atomic dynamics in dense systems, especially disordered systems, in a time-space domain not accessible so far. This is of fundamental importance for the understanding of the elementary interactions in the investigated system, as well as for the connection between long and short wavelength dynamics, that correspond respectively to those behaviors referred to as hydrodynamic and kinetic.

The uniqueness of this instrument consists in reducing the momentum transfer gap (see Fig. 1) in the study of propagating collective excitations (*sound modes*). Indeed, using Brillouin Light Scattering (BLS) one can study excitations up to 0.07 nm^{-1}, while Inelastic X-ray Scattering (IXS) is routinely used down to 0.8 nm^{-1}. Inelastic Neutron Scattering (INS) has strong kinematic constraints which make difficult investigations of acoustic-like excitations with a speed of sound larger than 1.5 *Km/s*. The present instrument will operate up to 0.3 nm^{-1}, reducing the unexplored momentum gap from 0.07 – 0.8 nm^{-1} to 0.3 – 0.8 nm^{-1}.

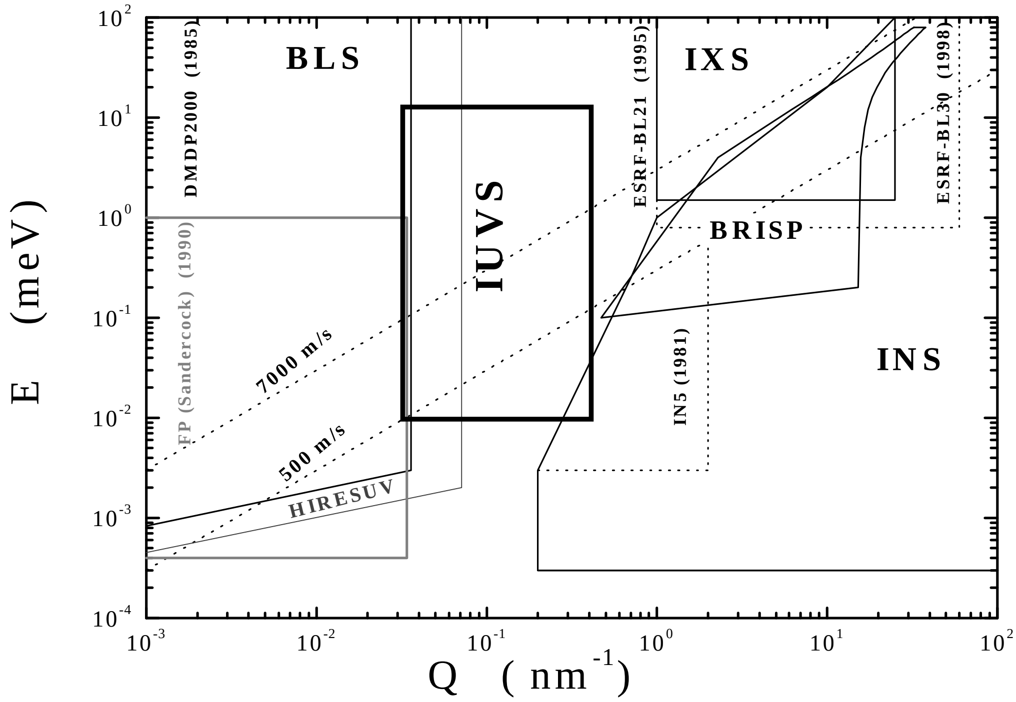

Figure 1: Kinematic regions accessible from the existent (DMDP2000, FP, IN5, BL21, BL30) and in construction (HIRESUV, BRISP, IUVS) instruments. The lines corresponding to 500 m/s and 7000 m/s represent the lower and upper limit of speed of sound measured in disordered systems.

It is worth noting that this facility would be one of its kinds in the world, and it will take full advantage of the tunability of the radiation source, and of the high brilliance of a third generation synchrotron source.

DIFFERENTIAL INTERFERENCE CONTRAST FOR X-RAYS

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X-ray microscopy suffers often from a lack of sufficient absorption to provide suited contrast, especially when low-Z matter is imaged or high photon energies are used. Different approaches were performed to use the orders of magnitudes higher real, phase shifting part of the refractive index in the recent past [1, 2, 3]. The purpose of this work is to demonstrate the feasibility of differential *interference* contrast (DIC) for X-ray microscopy using zone plates. Use of zone plates takes advantage of (i) presently highest possible spatial resolution in X-ray focusing combined with (ii) the generation of smallest shear wave front division by displacing two zone plates transversely to the optical axis and generating two focal spots in close distance. Recently achieved advances in lithography and nano-structuring allow displacing two zone plates within their optical resolution, thus also the Airy disks of the focal spots are displaced within the spatial resolution and the X-ray imaging is of differential type. The contrast increase by applying DIC was demonstrated with nearly pure phase shifting test structures and biological samples at 4 keV. This technique is not limited to any photon energy and its versatility allows applying DIC in full-field imaging *and* scanning X-ray microscopy [4, 5].

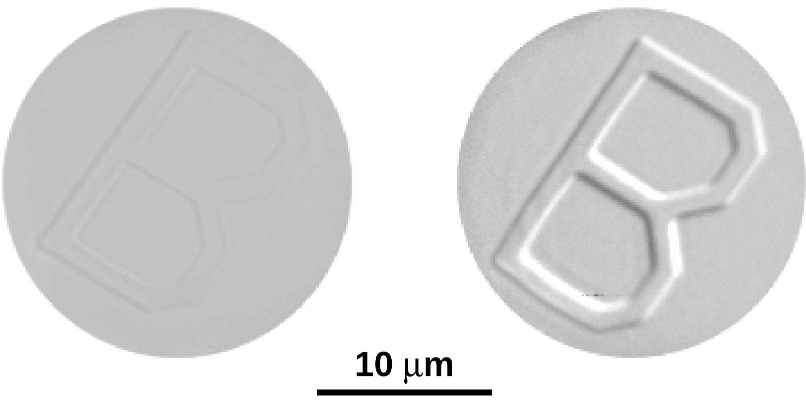

Fig. 1: X-ray images taken with a full-field imaging microscope (ESRF, ID21) at 4 keV. Left image was acquired in absorption contrast, the right image shows the tremendous increase in contrast when DIC is applied

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DESIGN OF A FLAT FIELD SPECTROMETER FOR SOFT X-RAY EMISSION SPECTROSCOPY

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Soft X-ray emission spectroscopy (SXES) is a powerful tool for studies of electronic structure of various matter including liquid and wet samples. We have designed a new spectrometer aiming to do experiments on adsorbate, liquid, and biological samples. As the soft X-ray emission intensity from adsorbate and liquid samples is low and biological samples are easily damaged by irradiation of soft X-ray, a spectrometer with high detection efficiency is required.

Spectrometers for SXES are usually Rowland mount type equipped with a constant line spacing spherical grating, which forms a circular focal curve. In that case, a detector must be mounted at grazing incidence to fit the focal curve. On the other hand, the focal curve of a spherical VLS (Varied Line Spacing) grating is nearly straight (flat field) and the incidence angle to the detector surface can be enlarged. Owing to these characteristics, flat field spectrometers using a spherical VLS grating can achieve a wide energy range and high detection efficiency[1,2].

The spectrometer (see Figure 1) consists of two VLS spherical gratings and a CCD (Charge Coupled Device) detector. A CCD detector was chosen to get further detection efficiency instead of MCP (Micro Channel Plate). There is no entrance slit, because the vertical size of the soft X-ray beam at the focus point is less than 30 μm at SPring-8 BL27SU. In order to find optimal line spacing function making nearly straight focal curve and larger incidence angle to the detector [3], a simulation program was developed. Optical performance was tested with a ray-tracing program.

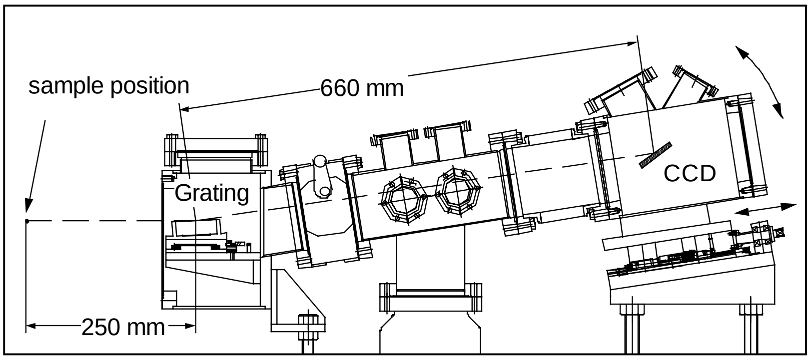

Figure 1: A schematic diagram of the flat field spectrometer.

The spectrometer covers 250-900 eV by two gratings, a 1500 lines/mm grating for the low-energy region (250-450 eV), and a 2400 lines/mm grating for the high-energy region (400-900 eV). Estimated energy resolution of this spectrometer is about 1000 (E/ΔE) for beam size of 10μm.

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Characterization of mirror coatings for X-ray Free Electron Lasers

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Worldwide, there are strong activities to develop free electron lasers with unprecedented peak and average power for the VUV and X-ray region up to $\sim 10^4$ eV photon energy. The VUV FEL at the TESLA Test Facility at DESY has recently demonstrated gain between 7 and 15 eV photon energy and will provide photons up to 200 eV in the next development stage. For these new sources, mirrors of very high radiation stability are required.

DESY and GKSS have therefore started a joint program to produce and characterize optical coatings optimized for FEL applications in the VUV and X-ray spectral region. In order to minimize radiation damage and thermal deformation, coatings with lowest possible absorption and highest possible reflectivity have been selected. Ideal candidates are low-Z elements and compounds below their K absorption edges, such as Be, B, C, and B_4C, and Si below the 2p threshold at ~ 100 eV. The best choice for the mirror substrates is Si because it has superior thermal properties and can be machined and polished to very high standards.

Plane, well polished Si mirrors were coated with C and B_4C at GKSS using magnetron sputtering [1]. The coatings with thicknesses of ~ 35 nm were prepared under different sputtering conditions. The optical characterization of the mirrors was done at HASYLAB/DESY using the reflectometer beamline G1. The reflectivity measurements were carried out at energies below the C-K edge, at grazing incidence angles between 0° and 5°. Energy dependent reflectivity spectra of different selected C coatings will be presented. The C-K edge is clearly visible, and reflectivity is typically 95 - 93 % in the energy range of 40 - 230 eV. In addition to this the Ar-$L_{2,3}$ edge is quite pronounced in the spectrum of one sample and the reflectivity is reduced. Obviously a significant amount of Ar has been incorporated in this sample deposited under non-optimal sputtering conditions.

For fixed photon energies between 40 eV and 300 eV reflectivities were measured as a function of incidence angles (0° - 50°). The optical constants, surface roughnesses, and layer thicknesses were determined for all samples by fitting these curves using modified Fresnel coefficients [2]. The optical constants determined for each energy agree very well with those of amorphous carbon given by Henke et al. [3]. Surface roughness before and after coating was also measured directly using atomic force microscopy.

The project also includes studies on chemical and physical stability under extreme radiation and thermal conditions. First annealing experiments, which have been carried out between RT and 1200°C, using Cu-K_α radiation, will also be presented.

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IMAGING OF DICHROISM IN PHOTOEMISSION ELECTRON MICROSCOPY AT NON-MAGNETIC MATERIALS USING CIRCULARLY POLARIZED LIGHT

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A new approach for investigations of circular dichroism in the angular distribution of photoelectrons (CDAD) is presented. The image contrast using a photoemission line of a certain material is combined with imaging of the angular distribution pattern using a photoemission electron microscope (PEEM). CDAD can be used to investigate pure scattering information by means of the same instrument in microscopically selected regions on a surface. This so-called CDAD-holography method [1] delivers structural information about the local environment of the emitter atoms in an indirect but simple and reliable way.

There are two exciting aspects to use this novel approach. The first concerns the angle resolved XPS-imaging, the second an indirect mapping of the local environment of atoms by means of CDAD-holography. In a conventional photoelectron diffraction or photoelectron holography experiment, it is necessary to move the sample and/or the detector, e.g. a rotatable electron analyser is used to map a full angular pattern.

In the present approach, we map the diffraction plane for a certain kinetic energy of electrons in the backfocal plane. Direct photoemission from the W-4f core levels was observed at the fixed photon energy $h\nu = 148eV$ and at different polarisations. A high-pass energy filter has been used in combination with PEEM based on a retarding field analyzer (RFA) [2] implemented at the end of the imaging column. In addition, a transfer lens was implemented which allows to image the backfocal plane of the objective lens.In the experiment, we measured two diffraction patterns of the W-4f emission line using light of opposite helicity. We adjusted the contrast aperture slightly in an off-centre position in order to obtain the maximum difference. The agreement of calculations with the experimental result is satisfactory. This constitutes a very encouraging starting point for the further use of the CDAD-holography together with the PEEM providing mesoscopic and atomic as well as chemical resolution in micro-selected areas on solid surfaces. From previos measurements at the same system, we have proven an inversion of the measured CDAD-hologram that clearly shows the positions of the neighboring atoms in the layer 1.937Å above the plane of the emitting atoms. The accuracy of the measurement is better than 0.2Å. It should be stressed that this was already possible with a measured set of CDAD-data taken at only one photon energy.

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A TIME OF FLIGHT DETECTOR FOR VISUALIZATION OF PHOTOEMISSION IMAGES AND MOMENTUM DISTRIBUTIONS

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We present new methods for space-, momentum- and time- selective imaging by means of a TOF (time of flight) technique. Two new instruments employ a time- and space-resolving delayline detector (see ref. [1]) in combination with different electrostatic lens systems. For use as a spatial imaging instrument, the electrostatic lens is a modified photoemission electron microscope (PEEM). In the case of the momentum-imaging device, a parabolic electrostatic field and a drift tube is used.

Photoemission electron microscopy offers access to many aspects in surface chemistry, physics and thin film magnetism on a mesoscopic length scale. The fast parallel image acquisition with wide zoom range establishes a growing interest in this method. The additional opportunity to add a spectroscopic filter makes it valuable for chemical microanalysis or spectromicroscopy. The conventional solution is an imaging dispersive energy filter being integrated into the electron-optical column (for example see [2]). In this work we present a new and very simple approach to this technique. It is based on the photoelectrons' time-of-flight by making use of the pulsed time structure of synchrotron radiation. The new spectroscopic PEEM-detector has the technical advantage of retaining a linear column. We will show that it works as a detector with very low noise and high efficiency. It will be compared to conventional methods like the combination of a fluorescence screen together with a CCD-camera.

The TOF-spectrometer for complete momentum analysis is used to raise the efficiency of energy and angular resolved experiments. The main difference to conventional photoemission experiments, using a rotatable spectrometer, is the simultaneous detection of all emitted photoelectrons regardless of energy and emission angle. The angular distribution becomes directly visible, without mechanical movement. In future it will serve to study dynamics at surfaces by angular resolved photoemission in a fast way. The present time resolution is 500 ps with the potential of 100 ps in an advanced design.

First results obtained with the single-bunch mode at BESSY I are presented.
(This project was funded by the German government via BMBF - 05 SL8 UM10)

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A UHV APPRATUS FOR SOFT X-RAY SPECTROSCOPIC STUDIES OF SURFACES UNDER TOTAL REFLECTION CONDITION

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We have constructed a new UHV apparatus for soft x-ray spectroscopic studies of surface systems such as molecular adsorbates on metal or semiconductor crystals and metal/semiconductor interfaces. A high performance electron energy analyzer, SES2002 (SCIENTA), is equipped for resonant photoemission spectroscopy with high energy resolution. An originally designed flat field spectrometer with a CCD (Charge Coupled Device) detector is under construction for resonant soft X-ray emission spectroscopy and will achieve the energy resolution of 1000 ($E/\Delta E$) with high detection efficiency [1].

For these soft X-ray spectroscopies, polarization dependent measurements are very essential in order to resolve the symmetry both of core-excited (intermediate) and final electronic states. To do such experiments, a measurement chamber equipped with an electron energy analyzer and a spectrometer is usually rotated around the incident beam axis, making the apparatus complicated. On the other hand, at the beamline BL27SU [2] of SPring-8, where our new apparatus is placed, can supply horizontally and vertically polarized soft X-rays so that the electron analyzer and the soft X-ray spectrometer can be fixed on the vertical and horizontal direction, respectively, in the plane vertical to the incident beam. This arrangement enabled us to measure the resonant photoemission and soft X-ray emission spectra simultaneously for the same irradiated area on the sample surface. This is valuable to do the experiments efficiently and also to check the surface condition.

One of the characteristics of the apparatus is soft X-ray spectroscopic measurements under the total reflection condition without loss of the incident beam owing to the small spot size shaped by a post-focusing mirror system. Furthermore, glazing emission of soft X-rays and photoelectrons can be detected. These experimental geometry should strongly enhance the surface sensitivity and enabled us to investigate electronic states of not only surface adsorbates but also a very thin surface layer such as metal/semiconductor.

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FEASIBILITY STUDIES OF THE 3-DIMENSIONAL DETECTOR FOR THE SOFT X-RAY EMISSION SPECTROSCOPY

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Soft x-ray emission spectroscopy (SXES) is a powerful tool to study the electronic structure of matter and the relaxation process of the core-excited states with a localized core-hole [1,2]. The SXES also allows us to separate the angular momentum components of the valence states because of a clear selection rule due to the dipole nature of the x-ray transitions. Furthermore, since the mean free path of the soft x rays is much longer than that of the electron, the SXES provides us bulk sensitivity giving rise to an opportunity to study the electronic structure of bulk of the materials as well as the buried structure such as multi-quantum well.

Recently, we have adopted a time-resolving two-dimensional position sensitive detector [3], *i.e.* 3-dimensional detector, to the SXES in order to study the relaxation dynamics of the core-hole states and to pioneer new applications in spectroscopic studies. In this paper, we briefly describe the recent feasibility studies in which SR-bunch gated SXES, coincidence measurements as well as the SXES with simultaneous irradiation of SR and laser were carried out. Figure 1 shows the typical example of the SR-bunch gated SXES showing the improvement in the S/N ratio. Details will be discussed at the conference.

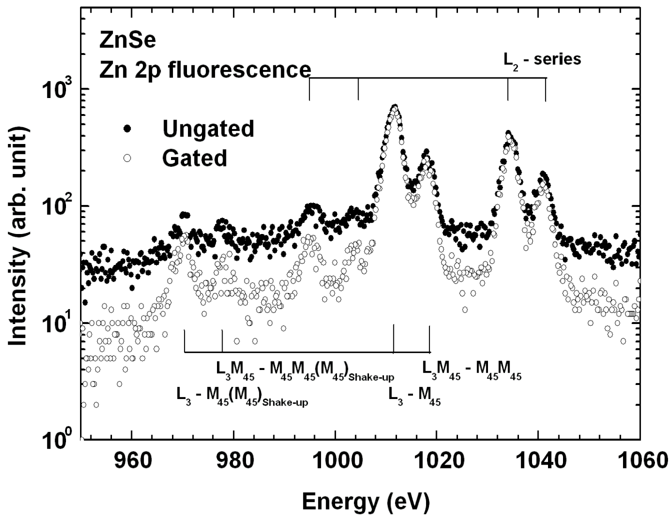

Figure 1: SXE spectra emitted from 2p-excited Zn of ZnSe target. Open circles show SR-bunch gated SXE spectrum and closed circles represent ungated spectrum. In the spectrum, characteristic diagram lines of Zn and some satellite lines emitted in the multielectron processes are clearly resolved.

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Microscopic Ultraviolet Photoelectron Spectrometer using He-I and He-II Resonance Lines

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Microscopic ultraviolet photoelectron spectrometers (micro-UPS) have been required to investigate the electronic structures of condensed matters of small size and those consisting of grains in laboratories. With excitations by He-I and He-II resonance lines the partial density of states of valence bands with different symmetries can be obtained, but the micro-UPS developed so far utilizes only the He-I resonance line, because its normal incident ellipsoidal mirror was coated with the platinum monolayer, so that it could not reflect efficiently the He-II resonance line [1]. Recently, *two-color* reflection multilayers were developed, which reflect efficiently both the He-I and He-II resonance lines [2]. In this study, a micro-UPS is developed using a Schwarzschild objective coated with *two-color* multilayer, a He lamp and an electron energy analyzer [3] as shown in Fig.1. The spot size by the use of a pinhole of 300 μm-diameter is 4 μm, which was measured using the visible light from a Xe lamp. In the present micro-UPS, a pinhole of 2 mm-diameter is used to gain the sufficient photon intensity, so that the spot size is 25 μm. In Fig. 2 the valence band spectrum of a $NiWO_4$ single crystal (2×0.5×0.5 mm^3) measured by the present micro-UPS is presented, which has not been obtained because the crystal of sufficient size cannot be fabricated. The valence band of $NiWO_4$ is found to consist of O 2p and Ni 3d orbitals.

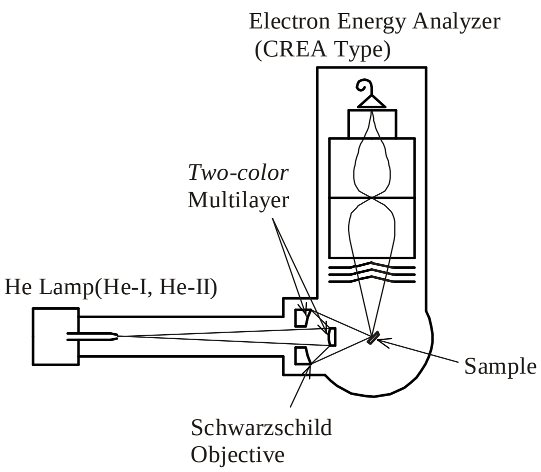

Figure 1: Schematic of microscopic ultraviolet photoelectron spectrometer.

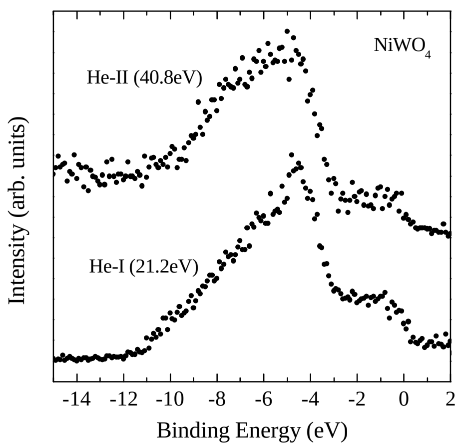

Figure 2: Valence band spectrum of $NiWO_4$ obtained by the micro-UPS. The sample size is 2×0.5×0.5 mm^3.

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HIGH-RESOLUTION LOW-TEMPERATURE PHOTOEMISSION SPECTROSCOPY AT HiSOR LINEAR UNDULATOR BEAMLINE

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We report a high-resolution low-temperature photoemission spectroscopy (HRPES) measurement system installed on the linear undulator beamline (BL-1) of a compact 700 MeV electron-storage ring (HiSOR) at Hiroshima University [1-3]. A spherical grating monochromator on the beamline covers the photon energy range of hν = 26 - 300 eV. According to the gas phase experiments, the maximum photon energy resolving power (E/ΔE) of the monochromator is estimated to be >16,000 at hν ~ 48 eV (ΔE ~ 3 meV) with the photon flux $>10^{10}$ photons/sec/200mA [4]. We have connected a high-resolution electron energy analyzer (GAMMADATA-SCIENTA, ESCA200) to the beamline. To estimate the energy resolution, we measured the Fermi edge of evaporated Au cooled at 8 K. If we set the entrance and exit slit openings at 50 μm and 100 μm, respectively, the total energy resolution was 25 meV at hν ~ 47 eV in good agreement with the expected value. Now the beamline is ready for HRPES experiments. We will examine the electronic states of strongly correlated electron systems with intense undulator radiation, collaborating with groups for development of new materials.

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The VUV Spectrometer for the Investigation of Optical Properties of Solid State.

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The optical spectrometer for the VUV region is presented. This instrument was recently commissioned to work with the synchrotron radiation of Siberea-1 storage ring at Kurchatov Synchrotron Radiation Source.

The spectrometer was designed for the work in the wide energy region with high efficiency, so the original "coupled" optical scheme was proposed to satisfy this criterion. The originality consists in the use of two different optical schemes for the VUV and soft X-ray region. Namely the Seya-Namioka normal incidence scheme is used for the region 4-40 eV(30-300 nm), while the grazing incidence scheme works in the region 30-200 eV.

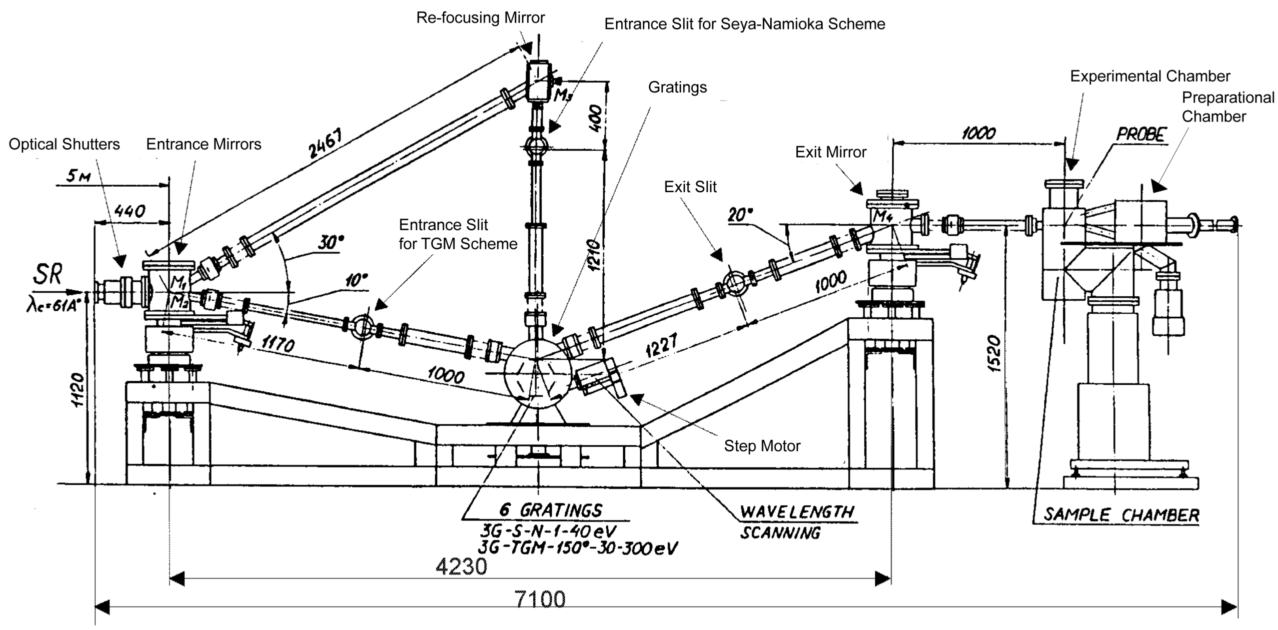

Figure 1. Overview of the spectrometer.

The station is devoted to the optical investigations in the VUV and is accomplished with the UHV sample chamber, UHV chamber for sample preparation, fast entry lock, windows transparent in visible region, helium cryostat, equipment for the luminescence and absorption measurements. The installation of VUV reflectometer is supposed in the future.

SR beam was passed trough the monochromator in the February, 2001. The first test measurements with sodium salicilate luminophore were performed to compare theoretical and experimental brightness in the region 4-40 eV.

HIGH-RESOLUTION LOW-TEMPERATURE PHOTOEMISSION SPECTROSCOPY AT HiSOR HELICAL UNDULATOR BEAMLINE

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We report a high-resolution low-temperature photoemission spectroscopy (HRPES) measurement system installed on the helical undulator beamline (BL-9) of a compact 700 MeV electron-storage ring (HiSOR) at Hiroshima University [1-3]. 3m Off-plane Eagle normal incidence monochromator on the beamline covers the photon energy range of $h\nu$ = 4 - 40 eV. The maximum photon flux with 100 μm slit at the BL-9 end station was 1.4 x 10^{12} photons/sec for the 1200 lines/mm grating at $h\nu$ = 30 eV for the 200 mA storage current. According to the gas phase experiments, the photon energy resolving power (E/ΔE) of the monochromator is estimated to be 12000 - 30000 at $h\nu$ = 6 - 30 eV (ΔE ~ 2.3 meV at $h\nu$ ~ 30 eV)[4]. We have connected a high-resolution electron energy analyzer (GAMMADATA-SCIENTA, SES2002) to the beamline. To estimate the energy resolution, we measured the Fermi edge of evaporated Au cooled at 6.4 K. If we set the entrance and exit slit openings at 20 μm and 20 μm, respectively, the total energy resolution was 7.5 meV at $h\nu$ ~ 23 eV. Now the beamline is ready for HRPES experiments (Figure 1). We will examine the electronic states of strongly correlated electron systems with intense undulator radiation, collaborating with groups for development of new materials.

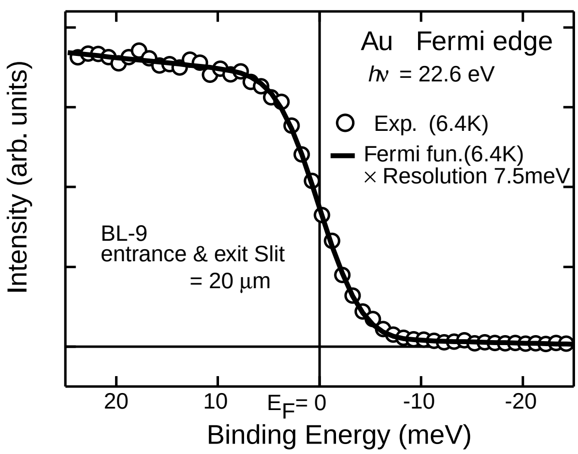

Figure 1: Photoemission spectrum of Au Fermi edge at BL-9.
The total energy resolution was estimated to be 7.5 meV.

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TWO-PHOTON PHOTOELECTRON EMISSION MICROSCOPY OF MAGNETIC COPT NANOSTRUCTURES

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The increasing miniaturization in non-volatile data-storage devices demands substantial shortening of read-write cycles. In order to study the underlying physical phenomena and fundamental limits it is necessary to probe the spin-dynamics in nanostructures on a fsec time-scale. We present a novel approach where this can be achieved together with the required nm spatial resolution. The method is based on the combination of fsec pump-probe laser-techniques and photoelectron emission microscopy. Magnetic sensitivity is obtained by analyzing the spin-polarization of the emitted photoelectrons. The spatial and angular distribution of photoelectrons excited by multiphoton absorption events was investigated for magnetic CoPt nanostructures grown on a lithographically patterned Si substrate. We show that for magnetic dots of 200 nm x 200 nm size there is a pronounced dependence of the emission characteristics on the light polarization. The results are interpreted in terms of plasmon-assisted multiphoton photoemission in nanoparticles. Investigations of the fsec electron and spin dynamics in the nanoparticles demonstrate that significant changes in the sample magnetization occur already during the duration of the laser pulses.

A novel apparatus for laser excited *time resolved* photoemission spectroscopy

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In recent years a new area has been opened to photoemission spectroscopy thanks to the developments of sub picosecond laser source in the UV regime. This is the investigation of electron dynamics by time resolved photoemission measurements [1].

We will present here a novel apparatus devoted to pump and probe and non linear photoemission experiments composed by a Ti:Sappire laser source, a UHV experimental chamber and a Time of Flight electron energy analyser. The laser source is characterised by a pulse duration of 150 fs at a wavelength of 790 nm (1.57 eV) and operates at a repetition rate of 1 kHz. The experimental chamber is equipped by standard tools for surface analysis and it has been realised completely on μ-metal steel to reduce the internal magnetic field down to 10 mG. The sample, mounted on a 5 degrees manipulator, can be heated to1000 K and cooled to150 K.

A new Time of Flight (TOF) electron energy analyser has been developed for this apparatus. The key part of the TOF spectrometer are the drift region and the acquisition system. The drift tube is a cylindrical weak lens that allows two different angular resolution modes selected by chancing electrodes polarisation. In the High angular resolution mode ($\Delta\alpha=\pm 2.7^0$) the energy range from 0.1 eV up to 5 eV can be analysed with an energy resolution better than 30 meV. In the Low angular resolution mode ($\Delta\alpha=\pm 5.6^0$) the luminosity is increased at the expenses of the energy range and energy resolution. The spectrometer characteristics, in the second operational mode, have been optimised by electrons trajectories simulations and we have estimated an energy resolution of 60 meV for 4 eV electrons. The acquisition system consist of an home made MCP detector assembly characterised by a rise time below 800 ps and a Multiscaler Card (Fast 7886) directly mounted on the PC bus which perform the time measurement with an intrinsic resolution of 500 ps.

The first direct photoemission spectra from the Ag(110) clean surface have been recorded at room temperature using the 4th harmonic emission line (λ=200nm and hν=6.2 eV). The Fermi edge behavior convoluted with a gaussian-like profile for the energy transmission function of the TOF spectrometer has demonstrated an energy resolution of the order of 25 meV (FWHM) for 2 eV electron energy.

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THE XMOSS OPTICAL AND PHOTOEMISSION SPECTROSCOPY PROJECT AT ELETTRA

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We present a new near UV/soft X-ray facility currently under installation at Elettra. The X-ray magneto optics and surface science (XMOSS) project, which includes light transportation and monochromatisation plus spectroscopy and preparation end stations, exploits the potential offered by the interaction of a polarised photon beam with matter. The aim is to study the interplay between the electronic (magnetic included) and structural properties of systems with reduced dimensionality, such as free surfaces, adsorbates, metal-metal and metal semiconductor interfaces and multilayers.

The optical performance of the facility takes advantage of the flexibility offered by bending magnet radiation, such as smooth photon flux over a wide range and polarisation selection. The end station equipment includes detectors of energy and *k*-resolved photoemitted electrons and of absorbed and reflected photons. With this combination of excitation source and detectors it is possible to perform angle resolved photoemission on a wide range of kinetic and photon energies and optical absorption and reflection spectroscopy.

To take full advantage of the vectorial properties of the light-matter interaction, the end station is designed to grant maximum flexibility in the experimental geometry. In particular the chamber allows to vary the angle between the impinging photon and the momentum vector of the scattered/emitted particle (photon or electron) and between these and any other vector relevant to the experiment such as surface normal, magnetisation, direct or reciprocal vectors.

The optical lay-out of XMOSS [1] includes five elements: a parabolic mirror (to defocus the divergent beam at the source into a parallel beam), a plane mirror-plane grating monochromator stage, a second parabolic mirror (to refocus the beam on the monochromator exit slit) and finally an elliptical mirror (to refocus the beam at the experiment). The use of parallel light enhances the performances of the beamline by suppressing the effect of aberrations due to the angular distribution of the photon beam. The theoretical performance of the beamline is as follows: range- 4 to 1400 eV, flux- in the range 10^{11} to 10^{12} photons/sec, resolution 3000/5000, spot size- 100x20 μm. Polarisation selection (photon helicity selection) is achieved by means of apertures that allow the collection of in plane (linear) or out of plane (right or left circularly polarised) light emission.

The end station is supported by a preparation chamber intended for UHV preparation of surfaces, interfaces and multilayers and in situ characterisation.

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CLEANING OF OPTICAL ELEMENTS USED IN BEAMLINE BY SYNCHROTRON RADIATION EXCITED ETCHING

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Hydrocarbons are gradually deposited on the surface of optical elements (mirrors and gratings), which used in a beamline even if the chamber is kept in an ultrahigh vacuum. It cases a decrease of reflectivity around carbon K absorption edge at 284eV[1]. Because the loss of photon flux is one of the most serious problems, some techniques have been developed in several synchrotron radiation facilities. Cleaning by ozone asher [2] or by oxygen-discharge [3-4] were applied to mirrors or gratings used in vacuum ultra violet (VUV) region. Some excited sources such as UV light, dc- or rf-discharges were used in order to produce oxygen atoms or ions efficiently.

On the other hand some materials containing carbon such as diamond and silicon carbide were etched by irradiating "white" synchrotron radiation (SR) at room temperature and at the low-pressure atmosphere [5-6]. SR excited etching provides us with unique features owing to many advantages (1) cleanliness, (2) soft process without accelerated ions, (3) lowering of the process temperatures, and (4) materials selectivity. These features are useful to cleaning of optical elements.

In this report SR excited etching was applied to cleaning of VUV optical components. The test pieces of silicon were used in beamlines of SPring-8 during a few years. Interference fringes were observed as footprints of SR beam on the samples. The cleaning by SR excited etching was tried in BL27SU [7] at SPring-8. A light source is an undulator, which produces linearly polarized soft X-rays between 0.1 and 5keV. When the samples at low-pressure atmosphere of oxygen were irradiated by the 1st photon energy of 1.1keV, the removal of contamination was measured by surface stylus meter. Other conditions and results will be discussed.

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MULTILAYER THICKNESS CONTROL OF ION BEAM SPUTTERING ON A SPHERICAL MIRROR SUBSTRATE

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We are developing an ion beam sputtering apparatus with a programmable shutter to fabricate multilayers with the thickness distribution controlled. In our system a deposition shutter moves at a programmed speed in front of a rotating substrate as shown in Fig. 1.

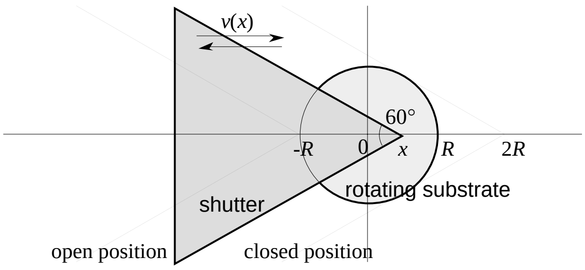

Figure 1: Schematic illustration of a deposition shutter.

The deposition rate on a curved substrate has a different spatial distribution from that on a plane substrate due to the variation of the slope and the sputtering distance. Figure 2 shows the Mo/Si multilayer period distribution of 100 mm in diameter fabricated on a plane substrate and a spherical substrate of a radius of curvature of 300 mm without shutter control. We applied the system to control the thickness distribution uniform on the spherical substrate, successfully. The required shutter speed function and full exposure time are shown in Fig. 3.

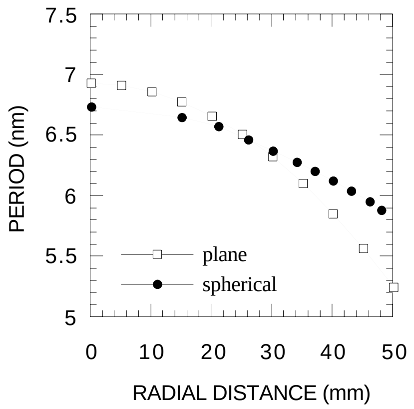

Figure 2: Period distribution of Mo/Si multilayers on plane and spherical (r = 300 mm) substrates.

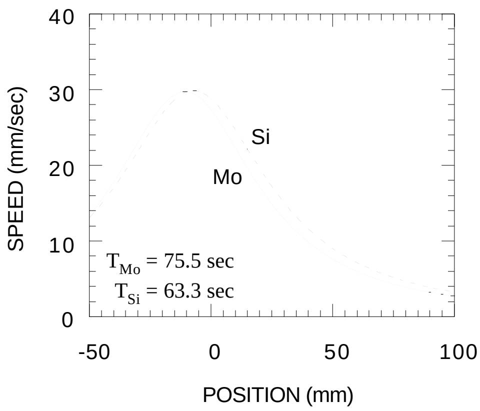

Figure 3: Shutter speed program designed for a Mo/Si multilayer of uniform thickness on a spherical substrate.

THE CIRCULAR POLARIZATION BEAMLINE AT ELETTRA: RECENT PROGRESS

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In this paper we report the present stage of the commissioning of the Circular Polarization beamline at ELETTRA synchrotron radiation facility. The beamline uses the circularly polarized radiation produced by an Elliptical Electromagnetic Wiggler/Undulator. Photon energies between 5 eV and 1200 eV are provided by means of two spherical grating monochromators, one operating at normal incidence (NIM) for the low energy range (5-30 eV) and the second working at grazing incidence in Padmore configuration. The best available resolving power at grazing incidence depends on photon energy and ranges from 3900 to 10000. The photon flux, at the sample position, varies from $2.0*10^7$(phot/s/0.1%bw/mA) to $1.0*10^{10}$(phot/s/0.1%bw/mA), while the degree of circular polarization has values from 1 to 0.65 according to the selected photon energy and the mode of operation of the insertion device. The NIM performances will be discussed in more details in terms of resolution and photon flux and several absorption spectra of He and Ne will be reported.

The polarization characteristics of the beamline make it particularly suitable for the dichroic spectroscopies such as Magnetic Circular Dichroism (MDC) and Natural Circular Dichroism (NDC) which need to make comparison between absorption spectra taken with right- and left-handed radiation. The MDC and NDC signals are often very small and located at the onset of the inner absorption edges. For these reasons special attention has been devoted to the reproducibility and stability of the photon beam in the right- and left-handed polarization, to the normalization of the signal to the incident intensitiy and to the signal to noise ratio. In order to improve these features we developped a low frequency modulation of the polarization of the source which allows to measure almost sinchronously the signals from the sample in each one of the two polarization condition. Experimental results obtained at L2,3 edges of transition metals (600-900 eV) and at Carbon K-edge on organic molecules will be presented.

A SOFT X-RAY UNDULATOR BEAMLINE AT THE ADVANCED LIGHT SOURCE WITH CIRCULAR AND VARIABLE LINEAR POLARIZATION FOR THE SPECTROSCOPY AND MICROSCOPY OF MAGNETIC MATERIALS

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The use of polarized x-rays to study the chemical and physical properties of materials has become an experimental technique of great utility. In particular, linearly and circularly polarized radiation has been used to study the magnetic properties of ferro- and antiferro-magnetic materials. The Advanced Light Source at Lawrence Berkeley Laboratory has completed a new beamline, Beamline 4.0.2, which has been optimized for performing high resolution spectroscopy using circularly and linearly polarized x-rays. This new beamline has as its photon source an elliptically polarizing undulator (EPU). This insertion device directly produces high flux, high brightness beams of x-rays of variable polarization, from linear horizontal to circular to linear vertical. A novel feature of this undulator is the ability to generate linearly polarized x-rays at arbitrary polarization angles. The output from the EPU is directed to a beamline with two branches. The first branchline is optimized to produce high spectral resolution x-rays from 50 eV to beyond 1600 eV. The second branchline is equipped with a photoemission electron microscope for the full field imaging of magnetic materials.

This paper will present the operating characteristics and key performance parameters of the new beamline, including measurements using the variable linear polarization. Recent experimental results illustrating the utility of circularly and linearly polarized x-rays to studies of advanced materials will also be presented, including examples of the spectroscopy of transition metal and rare earth compunds and alloys.

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The beam position monitor for the XMOSS beamline at ELETTRA

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Aim of this contribution is to present the design and performance of the beam position monitor (BPM) installed as first element of the XMOSS (X-ray magneto optics and surface science) beamline.

The XMOSS beamline, currently under installation at the ELETTRA in Trieste, collects 4x2 mρ horizontal x mρ vertical of the radiation emitted from a bending magnet (the critical energy of a bending magnet at ELETTRA is about 3200 eV at 2 GeV storage ring energy). The beamline optics is based on parabolic mirrors and on the Naletto-Tondello monochromator [1]. The absence of an entrance slit and the presence of a parabolic mirror as firs optical element require an accurate monitoring of the relative orientation between the beam direction and the optical axis of the first mirror. To this end a BPM based on four photo-emitting Mo plates was constructed and installed upstream the first parabolic mirror at a distance of 11150 mm from the bending magnet source. Each plate has a horizontal x vertical size of 11 mm x 10 mm. The four ground-isolated Mo plates are mounted onto a water cooled copper frame and are arranged in two sets of vertically adjacent plates. Each set is placed at the horizontal edges of the beam intercepted by the first mirror. The vertical distance between the centers of the two plates within each set is of 13 mm. This assembly can be moved in the x-y plane orthogonal to the beam direction. Both movements are accomplished by step motors and are computer controlled. Home made high stability and low noise floatable transimpedance amplifiers were used to detect the drain current. A small negative bias (≈ 25 V) was applied to the input to reject spurious negative currents. The measured photoemission yield of each Mo plates was of the order of 1 μA per ELETTRA mA. A simulation of the photoemission yield due to the white beam of ELETTRA was carried out. The comparison with the experimental results shows that the dominating contribution comes from photons with an energy falling in the 500 – 1000 eV range, in agreement with the absorption coefficient of molybdenum. The beam position monitoring is achieved through two different and complementary modes. In the first mode, through a vertical scan of a single plate across the beam. In this case the absolute position of the beam in the laboratory frame of the is achieved. An overall accuracy not worse than 0.1 mm was obtained in this mode. In the second mode the drain currents from two vertically adjacent plates are simultaneously and continuously recorded. The unbalance signal allows to get the upward or downward displacement of the beam with an accuracy not worse than 10^{-3} mm. Time response will be also discussed. Comparison with the performance and response of the BPMs operating at ELETTRA will be made.

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SPACE-RESOLVING VUV AND SOFT X-RAY SPECTROSCOPY IN THE TANDEM MIRROR GAMMA 10 PLASMA

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Vacuum ultraviolet (VUV) and soft X-ray (SX) spectroscopic measurements are important means to diagnose radiation power loss, impurity ion densities, impurity transport and Z_{eff} in magnetically confined plasmas such as fusion plasmas. Recently, we have constructed space- and time-resolving flat-field VUV (150-1050 Å) and SX (20-350 Å) spectrographs by using aberration-corrected concave gratings with varied spacing grooves which give us a wide simultaneous spectral coverage on a micro channel plate intensified detector. Absolute calibration experiments have been conducted at the beamline 11C and 12A at the Photon Factory in High Energy Accelerator Research Organization. Absolute sensitivities of the VUV and SX spectrographs have been taken for two (S and P) polarization geometries (Fig. 1). Thus, we can measure absolute intensities of emission spectra from impurity ions together with their radial distributions in plasmas. Carbon and oxygen ions are main impurity ions observed in the tandem mirror GAMMA 10 plasma. The total emissivities of various ions including line spectra and continuum spectrum in the wavelength range from VUV to SX was integrated over plasma cross section and axial length, then over plasma volume. The total radiation power obtained from the above procedure was determined to be less than 6 kW in the plasma operation with 70 kW input power. The radiation power loss during the period of the plug potential formation by ECRH at the plug cells was higher than that in the period without plug potentials. Density profiles of impurity ions were reduced by using absolute emissivities of impurity lines and a collisional-radiative model. The radial profiles of impurity ion densities in the central cell also increased at the core of the plasma during the formation of plug potential. This could be explained from the effect of the axial confinement of the plasma during ECRH phase. Moreover, we obtained the value of Z_{eff}. It is less than 1.01 in the GAMMA 10 central cell.

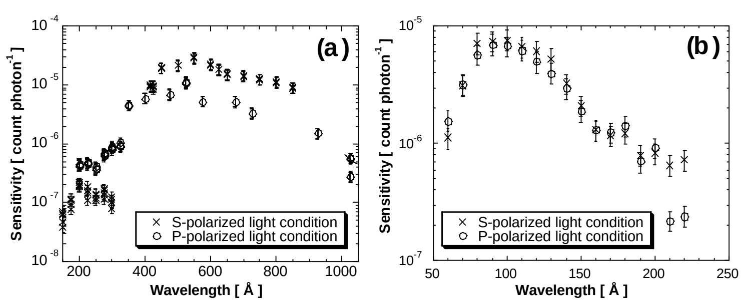

Figure 1: Absolute sensitivity of VUV (a) and SX (b) spectrographs under S and P polarized light conditions.

DEVELOPMENT OF SUPERCONDUCTING TUNNEL JUNCTIONS FOR EUV DETECTORS

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Superconducting tunnel junctions (STJs) have the potential for good photon detectors which can have energy resolution and a high photon counting rate. The basic physical principle underlying the STJs is that an absorbed photon produces quasiparticles that are then recorded as a charge pulse. STJs have good performance for soft X-ray and extreme ultraviolet (EUV) [1], because materials of STJs have high absorptance below 1 keV. We are developing an energy-dispersive detector for EUV radiation using STJs with Al trapping layers[2]. We have evaluated the performance of the detector for EUV photons using the Synchrotron Facility at KEK-PF in Tsukuba,Japan. We have achieved the energy resolution of FWHM=18 eV (including the external noise of 17 eV) for 55 eV EUV photons with a 100 x 100 um^2 STJ. In this presentation, we will present and discuss the details of the junction design, our experiments and the results.

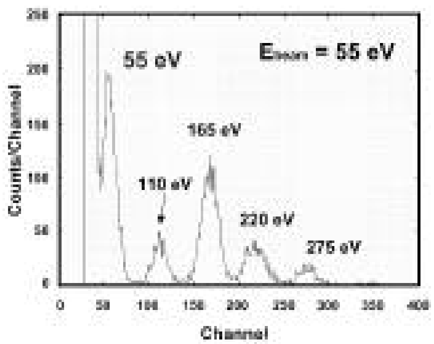

Figure 1: We have achieved the energy resolution of FWHM=18 eV for 55 eV EUV photons with a 100 x 100 um^2 STJ.

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Interaction of a pulsed aluminum vapor plasma with the low density polyethylene wall

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An experimental method is proposed to investigate the radiation emitted from the boundary layer which is formed near the insulator wall. It consists of a fast pulsed exploding aluminum wire set near the Low-Density PolyEthylene (LDPE) flat wall. The observed visible light detected by a high speed camera in streak mode shows the effect of the wall on the expansion of the aluminum vapor plasma. Two phases have been observed in the intensity shape of the carbon atoms line showing an enhancement during the collisionless interaction regime. The photoablation of the LDPE surface was occurred during the plateau as observed in the temporal behavior of the intensity of the carbon atom line, which agree with the observed peak value in the Ultra Violet (UV) radiation emission.

PHOTON ENERGY DEPENDENCE OF PHASE-CONTRAST SYNCHROTRON-LIGHT IMAGING

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We studied the edge enhancements due to the phase effect which are produced in images taken with synchrotron light. We demonstrated that even unmonochromatized photons can produce strong edge enhancement due to refraction and/or diffraction effects. This result is consistent with theoretical predictions that only limited time coherence is required for edge-enhancement. We then explored different geometries, being able to change the relative weight of diffraction and refraction effects. The results are quite important in view of practical applications, which require either one of the two mechanisms. Using monochromatic photons, we detected changes in the edge enhancement as a function of the photon energy in proximity of absorption edges. These affects are interpreted in terms of the rapid modification of both the real and the imaginary part of the complex refractive index. This opens up interesting opportunities for chemical analysis based on images taken at different absorption edges.

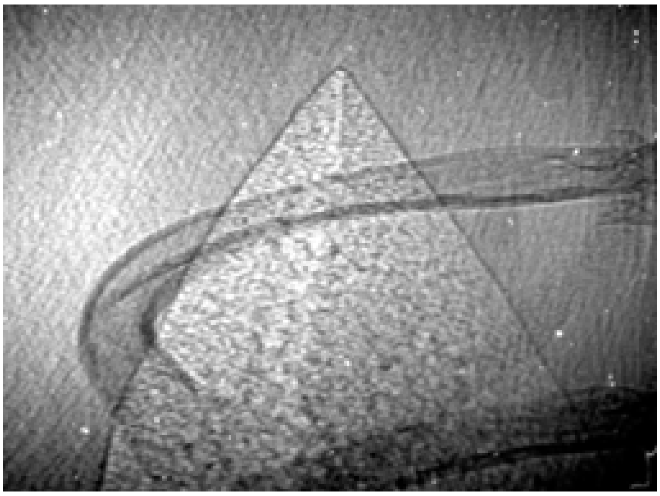

Figure1: An example of edge-enhanced synchrotron-light image taken with unmonochromatized synchrotron light.

FEASIBILITY OF MICROSCOPY WITH LOW ENERGY X-RAYS BY USE OF THIN-FILM WAVEGUIDES

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Thin film X-ray waveguides were introduced very recently as a novel and unconventional means for the production of microbeams in the hard x-ray regime [1,2]. They permit to obtain reliably x-ray beams with one dimension as small as 10 nm [3]. Indeed applications in some new microscope schemes, where spatial resolutions of the order of 100 nm have been achieved, were already successfully tested [4,5]. By the use of waveguides, this resolution is an intrinsic limit of the experimental set-up and is not depending on the source parameters. A single object can provide an intensity gain compared to the incident intensity over a rather large photon energy range limited, however, to the x-ray regime. For the operation at lower x-ray energies the most promising material is Be with favorable absorption characteristics. Actually a waveguide with a Be guiding layer of 74 nm thickness provided until now the highest intensity gain at 13 keV photon energy [6]. The measured value in excess of 100 is very competitive with the gain possible with other microscope objectives. The observed performance is about 30% of the expectation for ideal waveguides. On this basis and with a starting value of gain 40 for the same waveguide for 8 keV photon energy the feasibility of thin-film waveguides for lower x-ray energies will be discussed.

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Design and fabrication of multilayer mirrors for He-II radiation

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In this work, our process of multilayer mirror development will be described by taking the wavelength of 30.4nm He-II radiation as an example. The process starts by optical selection of materials in referring to their Fresnel amplitude reflectances as shown in Fig.1. Based on optical criteria[1], Mg, Al, Si, Cr, and C were selected as small absorption materials to be paired. Figure 2 shows theoretical best reflectance as the function of the number of layers, each with the best thickness structure obtained by layer-by-layer designing. The curves above the reflectance level of 0.3 are with Mg as an element. In referring to previous works, Mo/Si[2] and Sc[3] were also added in the selection process.

Multilayers of Al, Au, C, Sc, paired with Mg, C/Si, Al/C, and Mo/Si were then fabricated by ion-beam sputtering. Best candidates will be discussed with XRD data, and reflectance spectra measured around 30.4nm including a 30-layer Mg/Sc showing reflectance of 27%.

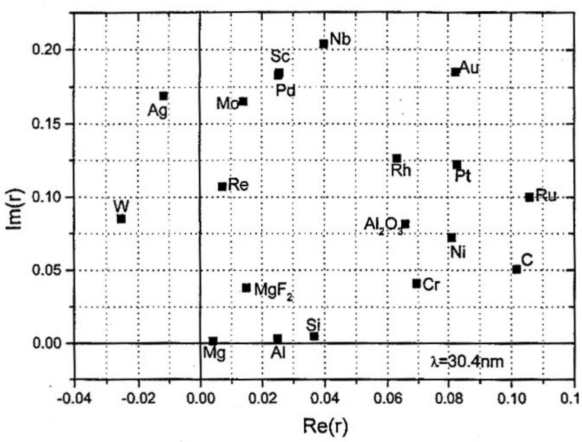

Fig.1 Fresnel amplitude reflectance of material at a wavelength of 30.4nm for selection of the pair for high reflectance multilayer mirror

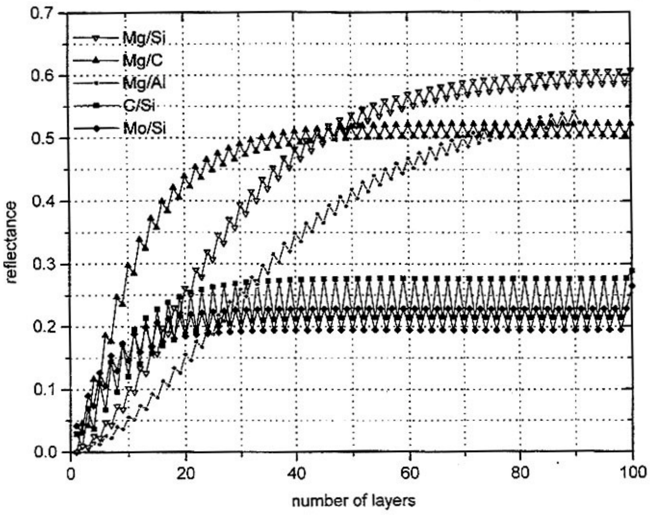

Fig.2 Theoretical reflectance *vs.* number of layers calculated by layer-by-layer method showing the ideal possible gain of each multilayer combination.

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REAL-TIME IMAGING OF THE NEAR-SURFACE CRYSTAL STRUCTURE BY BACKSCATTERED ELECTRONS

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Scanned-angle photoelectron diffraction is one of the most powerful tools for study of surface structures. Forward-scattering peaks occurring in spatial distributions of fast photoelectrons are also the dominant features of medium-energy diffraction patterns, which can be applied for analysis of surface structure as well. In this paper we present the original technique suitable for real-time imaging of the near-surface atomic structure. It is based on two-dimensional recording of spatial distributions of backscattered electrons with the energy of 2 keV [1]. The instrument consists of a grazing-incidence electron gun, a retarding field energy analyzer equipped with a microchannel plate, and CCD video camera. A few recent case studies related to ultra-thin silicide films epitaxially grown on silicon wafers and in situ intercalation of transition metal dichalcogenides with alkali metal will illustrate the promise of the technique. The data obtained for K_xTiS_2 intercalation compound are shown in Figs. 1 and 2. They illustrate a typical diffraction pattern taken within ±60° cone and transformation of the image due to intercalation. Model simulations of the observed patterns have demonstrated that spontaneous intercalation of TiS_2 starts from the surface and develops deep into the crystal, accompanied by lateral shifts of adjacent sandwiches of the host material. The process leads to transition from the 1T polytype of the crystal to the 3R(I) polytype of the intercalation compound. The dramatic expansion of inter sandwich distances is found out as well. Final example of the technique application is imaging of the reverse process of de-intercalation stimulated by adsorption of oxygen onto the K_xTiS_2 surface.

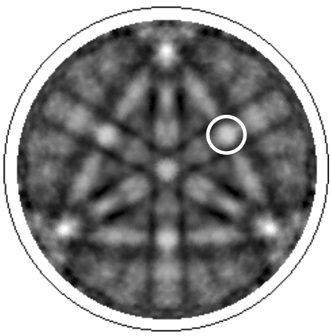

Figure 1: Diffraction pattern taken from K_xTiS_2 intercalation compound. The data are shown in stereographic projection and a linear-gray scale.

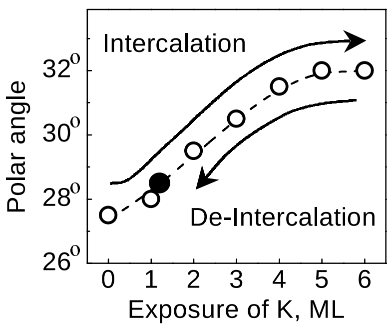

Figure 2. The angular shift of forward-scattering peak 'A' (see Fig.1) during K deposition, which indicates reconstruction of the nanometer subsurface layer.

The work is supported by the Russian Foundation for Basic Research (Projects N 99-02-18267) and the Russian State Program «Surface Atomic Structures» (Project N 5.10.99).

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MULTILAYER OPTICS FOR THE EXTREME ULTRA-VIOLET, SOFT X-RAY AND X-RAY SPECTRAL DOMAINS

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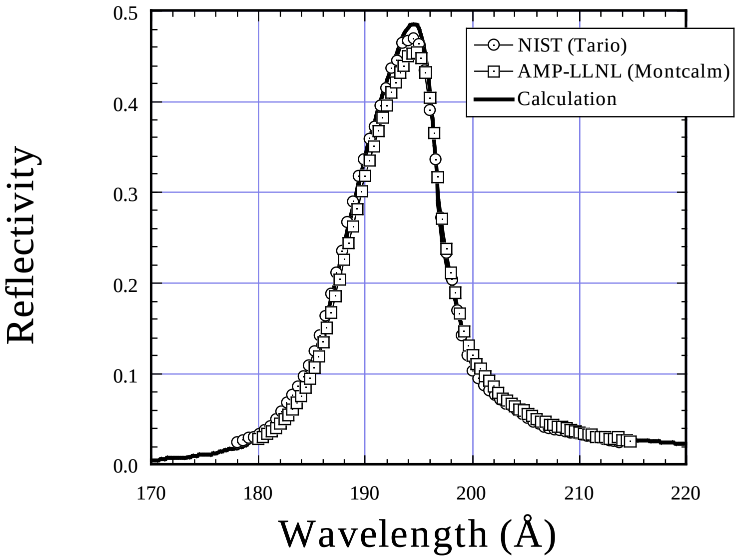
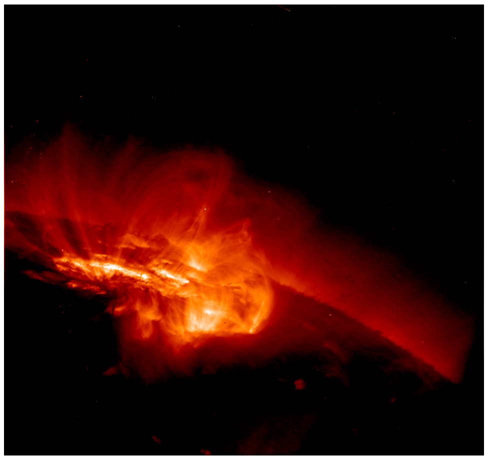
Extreme ultraviolet (EUV), soft x-ray (SXR) and x-ray (XR) multilayer optics are successfully applied in spectrally resolving experiments. Thus, EUV, SXR and higher photon energy x-ray (XR) multilayers, multilayer optics and multilayer optic systems have demonstrated the ability to enable new science and technologies. Multilayers are nano-engineered synthetic thin film layered materials of sufficient quality to be applied as reflecting/diffracting dispersion elements and optics in such instrumentation. Their importance to space science observations is that they enable instrumentation to be designed for previously inaccessible spectral ranges important to the understanding of the physics of both solar and astrophysical phenomena. Hence, new





understanding of these phenomena is gained from the new data gained by use of multilayer optical systems. The figure on the left presents the measured reflectivity [1] for a witness multilayer fabricated at the same time as the multilayer applied in the TRACE [2] EUV telescope used to obtain the image of the Solar Corona at 19.5 nm (FeXII) on the right. In this paper the emphasis will be on multilayer structures and optics, their current capabilities and expected advances in performance. Both normal incidence and grazing incidence multilayer optic structures will be considered. Needed advances in multilayer technology are outlined and efforts in this area described. The paper will be concluded with an assessment of current capabilities and the potential for new optic structures and enhanced performance.

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[2] Transition Region and Coronal Explorer (TRACE) : http://vestige.lmsal.com/TRACE/

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Design of a Complete Photoemission Experiment

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A new photoelectron spectrometer is being set-up featuring a full three-dimensional spin polarimeter, which makes it complete in the sense that all properties of the photoelectrons in the frame of reference of the sample crystal lattice can be measured. The spectrometer is devoted to spin-resolved Fermi surface mapping using angle resolved ultraviolet photoelectron spectroscopy. Studies on thin film and surface magnetism require full information on in plane and out of plane spin components. The rotation of the sample for different emission angles makes it necessary to record all three components of the spin-polarization to retrieve the true spin polarization in the sample.

VUV photoelectrons are energy and angle selected by a hemispherical analyzer (EA125 from Omicron Vakuumphysik GmbH). The photoelectron beam is switched at ~1 Hz between two orthogonally mounted Mott detectors, which span the 3D polarization space, because in an electrostatic transport, the spin orientation is preserved from the sample to the detector. A two-axis sample goniometer covers the full range of emission angles above the sample surface. After successful commissioning at Zürich university, the instrument can be operated at the new Swiss Light Source (PSI, Villigen, Switzerland) and/or at ELETTRA (Trieste, Italy).

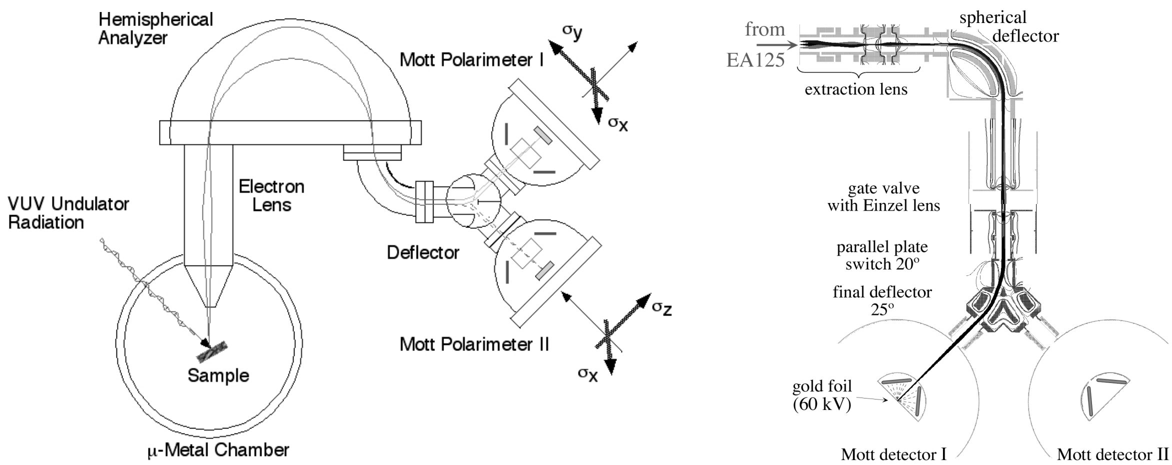

Figure 1) Left: Schematic view of COPHEE, the *co*mplete *ph*oto*e*mission *e*xperiment. Electrons photoemitted from a sample by UV radiation are energy- and angle-selected by an electrostatic analyzer and detected in two orthogonal Mott polarimeters. Right: Details of the beam transport system that takes the electrons from the analyzer into the two Mott detectors (ray tracing and graphics made using SIMION [2], Mott assembly rotated 90° with respect to the analyzer for graphical clarity).

[1] V.N. Petrov, M. Landolt, M.S. Galaktionov, B.V. Yushenkov, Rev. Sci. Instr. **68**, 4385 (1997).

[2] "SIMION 3D Version 6.0" by David A. Dahl 43rd ASMS Conference on Mass Spectrometry and Allied Topics, May 21-26 1995, Atlanta, Georgia, pg 717, http://www.srv.net/~klack/simion.html

Wide bandgap EUV and VUV detectors for solar observations

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The BOLD (Blind to the Optical Light Detectors) [1, 2] is an international investigation dedicated to the development of novel imaging detectors for the X-UV to Near UV wavelength ranges. It relies on the diamond and nitrides materials that have lately undergone key advances. Several detector designs are being evaluated. The potential applications in science and industry are numerous, but the current initiative is carried out towards future Solar Physics missions such as the planned Solar Orbiter of ESA [3] to be launched around 2010. These developments occur in the particularly propitious context of a mission, which will operate close to the Sun, where the expected properties of the new sensors -visible blindness and radiation hardness- are highly beneficial. We report on the latest progresses achieved in the course of this objective.

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A NEW XUV BEAMLINE ON A MULTIPOLE WIGGLER IN THE SRS

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An XUV beamline has been constructed on the SRS synchrotron radiation source exploiting the output from a 2T Multi-pole Wiggler (MPW). The beamline is based on an SGM design and produces photons in the energy range 40 eV to 350 eV. By taking a 7.5 mrad fan, a high flux can be delivered of between 1 x 10^{13} and 1 x 10^{14} photons/sec/300mA ring current with a resolving power of around 1000. A Kirkpatrick-Baez mirror pair focuses the light onto the entrance slit of the monochromator. Using 10 micron entrance and exit slits, a resolving power of up to 10,000 can be achieved, with a flux of 0.5 – 2 x 10^{11} photons/sec/300mA.

The calculated and measured performance will be presented, with emphasis on the challenges associated with utilising the XUV output of a high field MPW source.

Development of a conical energy analyzer for angle-resolved photoelectron spectroscopy

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A new angle-resolved electron energy analyzer incorporating a position sensitive detector (PSD) has been constructed to measure the angular distribution of photoelectron from rare gas atoms excited by linearly polarized synchrotron radiation. This analyzer has the advantages of high angular resolution and wide angular acceptance simultaneously. These characteristics are required to measure complicated angular distributions of photoelectrons caused by the atomic alignment with relatively short accumulation time of signals.

The conical analyzer consists of a set of an inner and outer conical electrode, cylindrical lenses, a gas cell and a PSD unit as shown in Figure 1. Photoelectrons emitted in the gas cell are accelerated between the cell and an extractor electrode, then focused on an entrance slit by the cylindrical lenses. The electron trajectories between the inner and the outer conical electrodes are similar to those expected for a conventional parallel-plate analyzer [1]. Energy selected electrons exiting out of the conical deflector electrodes are detected with the PSD of an effective diameter 40mm mounted behind the analyzer. The azimuth angular resolution is determined from the diameter of the sample volume (ϕ1mm) and the position sensitivity of PSD, and we expect the angular resolution of 1.5 degree.

The apparatus has been tested by carrying out gas phase ultraviolet photoelectron spectroscopy with a helium discharge lamp. Since the light produced in the discharge lamp is unpolarized and the photoelectron distribution is expected to be isotropic, we made a calibration cone electrode on which the entrance slit is a series of circular holes as test objects. Details of apparatus and a performance test will be presented at the conference.

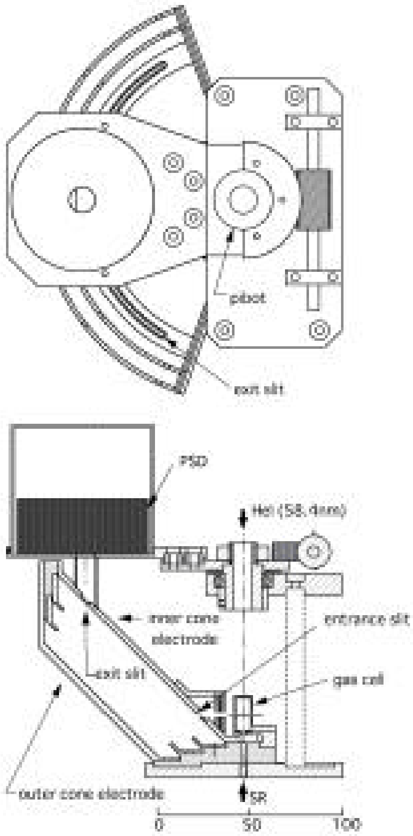

Fig.1. Schematic of the conical analyzer.

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THE SURFACE AND INTERFACE: SPECTROSCOPY BEAMLINE AT SWISS LIGHT SOURCE

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We report here on the Surface and Interface: Spectroscopy (SIS) beamline which is under construction at the Swiss Light Source. This beamline is dedicated for electronic and atomic structure study on surface and interface using high resolution photoemission, angle-resolved ultra-violet photoelectron spectroscopy (ARUPS), photoelectron diffraction, Fermi surface mapping, X-ray absorption spectroscopy and X-ray emission spectroscopy. The energy range of this beamline is 10 to 800 eV with an overall resolving power $E/\Delta E > 10000$. The beamline will used twin electromagnetic undulators providing variable photon polarization (linear and circular) at high switching rate (approx. 1msec). In order to provide high resolving power and harmonic rejection also at low photon energies we used quasi-periodic scheme for the two undulators and an opical scheme combining normal (NIM) and grasing (PGM) incidance monochromators.The end station is equipped with a high resolution hemispherical photoelectron spectrometer with an energy resolution of 1.5meV and an angular resolved < 0.2 deg. A high precision manipulator equipped with a 1K Helium flow cryostat is used for the low temperature measurment. The normal operation of the beamline is schedule for 2002.

MULTILAYER POLARIZERS FOR USE OF He-I AND He-II RESONANCE LINES

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The multilayer polarizers for the use of He resonance lines have been developed. Mg/Si and Mg/SiC multilayers were designed with the parameters listed in Table 1 and fabricated by magnetron sputtering for the He-I (584 Å) and He-II (304 Å) resonance lines, respectively.

Table 1: Design parameters of multilayer polarizers for He-I and He-II resonance lines.

	Wavelength	Material(Thickness)	Number of Periods	Angle of Incidence	*s*-Reflectance	Polarizance
He-I Polarizer	584 Å	Mg(235 Å)/Si(287 Å)	10	31.5°	45%	0.93
He-II Polarizer	304 Å	Mg(131.8 Å)/SiC(79.5 Å)	20	40°	44%	0.99

The performance was checked at BL5B of UVSOR Facility. The multilayer was mounted at the center of a goniometer. The Stokes parameters, S_0 and S_1 of the incident and reflected lights were measured by a rotating analyzer unit mounted with the same multilayer, which gives the complete information about the *s*-reflectance and the polarizance. The experimental results for the He-II resonance line are shown in Fig.1. The measured *s*-reflectance and polarizance at the angle of incidence of 40° were 41% and 0.98, respectively. The measured polarizance of the He-I polarizer was 0.96.

Both polarizers will be used to measure the degree of polarization of the He resonance lines passing through a grating monochromator for the angular distribution measurements of photoelectrons from isolated molecules.

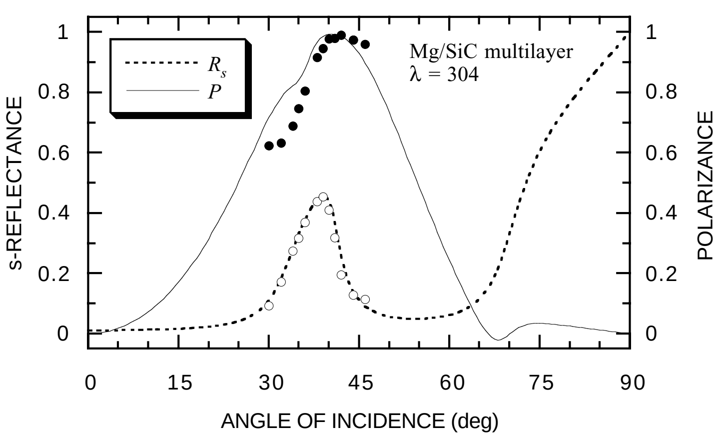

Figure 1: *s*-reflectance and polarizance of Mg/SiC multilayer for He-II resonance line. Open and closed circles are experimental results and solid and dotted curves, designed ones.

Ultrasoft X-Ray Spectra of Magnesium Diboride

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At ultrasoft X-ray spectrometer with high resolution the following spectra of MgB_2 were studied: emission K-spectrum of boron, quantum yield spectrum in the range of K-edge of absorption of boron and emission $L_{2,3}$-band of Mg . These spectra are compared with the corresponding spectra of pure boron and metal magnesium.

EUV Transmission Interferometer for Direct Index of Refraction Measurements

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Abstract

We have directly measured the real and imaginary part of the index of refraction of Aluminum in the vicinity of its L-edge. The experiment is done with an amplitude-division, transmission interferometer designed and used at extreme ultraviolet (EUV) wavelengths extending from 19.1 nm to 8.9 nm (65 eV to 140 eV). The real (dispersive) part of the optical constant is directly determined by the amount of phase shift of the interferogram. The imaginery (absorptive) part is determined by changes in fringe visibility. This experiments are performed using undulator radiation at Beamline 12 of the Advanced Light Source (ALS)[1]. Fine structure within the Aluminum L-edge, i.e. L_2 and L_3, is resolved in both real and imaginery parts. Other materials are in the process of being studied.

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TOROIDAL ENERGY- AND ANGLE-RESOLVED ELECTRON SPECTROMETER

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The Toroidal Energy- and Angle-Resolved Electron Spectrometer (TEARES) is a state-of-the-art high-resolution electron detector that is being designed, built and developed at Daresbury Laboratory. One of the aims of the project is to provide a toroidal electron analyser based system with simultaneous readout of energy and angle. Experiments which would benefit from such a system include photoelectron diffraction from solid surfaces, magnetic dichroism from solid surfaces, atomic and molecular physics experiments, 'spin-polarised' studies of surfaces, and electron spectroscopy based experiments where the cross-section is low.

A toroidal energy analyser allows both the energy and angle of ejection of an electron to be measured simultaneously. In the TEARES system, electrons that are ejected within ±1° of the plane perpendicular to the main axis of the spectrometer will be transported and focussed by a double-focussing cylindrical slit lens onto the entrance of a toroidal electrostatic analyser. The entrance lens is designed to transport and focus an interaction region of approximately $1mm^3$ to the entrance of the analyser. The toroidal deflector analyser is comprised of an inner and an outer toroidal sector. Electrons are deflected by the electric field between the two toroids in such a way that only those electrons having energies near the pass energy of the analyser will arrive at the exit cone of the analyser. The toroidal analyser disperses and focuses the electrons according to their energy in the radial dimension whilst preserving their initial angular direction. The single-focussing conical slit exit lens transports, demagnifies, and focuses the electrons from the exit of the analyser onto the detector.

The TEARES toroidal analyser is defined by a spherical radius of 125 mm, a cylindrical radius of 120 mm and a sector angle of 142°; these dimensions have been chosen to insure optimum focussing properties. The working distance is defined by a 40 mm radius. The resolution of the toroidal analyser is determined by the spherical radius, and slit heights of the entrance lens window and pupil; a resolution of 4 meV should be possible using 1 mm entrance slits together with a pass energy of 0.5 eV. The TEARES system is designed to operate over the kinetic energy range of $<0.5 \leq KE \leq 1000$ eV. The energy spread that is passed to the detector is ±10% of the pass energy and the useful angular range is 230°.

Further details of the TEARES system and progress to date will be given.

THE DEVELOPMENT OF A FAST IMAGING ELECTRON DETECTOR BASED ON THE CODADON CONCEPT

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3 Department of Chemistry, University of Manchester, Manchester, U.K.

A fast imaging electron detector is being developed at Leicester University as part of the Toroidal Energy- and Angle-Resolved Electron Spectrometer (TEARES) project. TEARES is a state-of-the-art high-resolution electron spectrometer that is being developed at Daresbury Laboratory. The analysed solid angle of the TEARES system is about 600 times greater than in a conventional hemispherical analyser of similar radius and entrance slit sizes. It has been estimated that the TEARES system on a third generation synchrotron source with a 'typical' solid sample utilising the full potential of the analyser, would pass countrates in excess of 1 GHz ($>1x10^9$)! However, at the present time, commercial imaging electron detectors are capable of achieving countrates up to only 1MHz ($1x10^6$). There is a large discrepancy between the commercially available imaging detectors and the optimum requirements for the TEARES system. Therefore, one of the aims of the TEARES project is to start the development of a fast 2D readout system for electron analyser systems that is capable of high dynamic range and matched to TEARES. This part of the project is driven by the great need for faster electron detectors.

The system being developed is an extension of the 1-dimensional CODACON encoder [1] developed for UV astronomy. In the 1-dimensional case, N conductor pairs encode 2^N resolution elements, so that an eight-element CODACON would provide 256 azimuthal bins. The encoder directly generates a binary address for each event from the minimum number of signal channels. In our adaptation, we are using two coupled 1-dimensional encoder tracks to obtain the required 2-dimensional data; five electrode pairs are used to obtain the energy and seven electrode pairs are used to determine the initial ejection angle of the electron. This will generate a 12-bit binary word that uniquely identifies the position (energy and angle) of the electron. It is important to note that all the electronics are outside the vacuum and no pulse shaping is required. The first version of this detector will comprise commercially available electronic components and low resistance microchannel plates with an aim of achieving a modest 2 MHz counting rate. Higher versions of the detector are envisioned whereby the advantages of this system may be fully realised. The main advantages include (1) the deliberate utilisation of all-conducting electrodes so the anode can be directly bonded to the microchannel plate, which makes possible the utilisation of ultra-low resistance conductively cooled microchannel plates, and (2) designing faster electronic components to match the speed of the detector system. It is important to note that such a detector can be easily modified to suit any output geometry by re-designing the position of the tracks on the anode.

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Fabrication of VUV blazed grating for synchrotron radiation

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A spherical holographic ion-etched blazed grating of 1200ℓ/mm with blazed angle 4.5° has successfully fabricated for a Seya-Namioka monochromator at the photochemistry experiment station of National Synchrotron Radiation Laboratory, as Fig.1.

The reason of grating line defects forming was analyzed. To eliminate these defects, the photoresist-ashing process [1] was applied to holographic-ion beam etching technique. We present the results of surface measurements made on the bare grating substrate using an scanning probe microscope (DI3100). The efficiency of the grating after coating aluminum was measured using synchrotron radiation source. The experimental result shows that holographic- ion beam etching in combination with photoresist-ashing technique is useful and effective for achieving large and good quality grating.

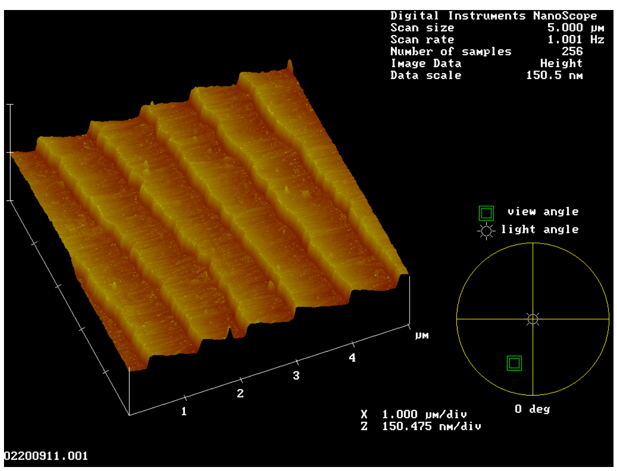

Figure 1: SPM image of a 1200ℓ/mm blazed grating

Reference

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Laser Plasma Sourced VUV Photoabsorption Imaging System

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We have recently completed the design phase of a system intended to produce a wavelength tuned and collimated Vacuum−UV beam (30 − 100 nm). The system is based on a 1m normal incidence vacuum monochromator with corrected (toroidal) optics on both the entrance and exit arms. The light source is a laser produced rare earth plasma, well known to be a virtually 'line free' continuum emitter [1]. The primary function of this system will be the measurement of time resolved 'images' or spatial distributions of Vacuum−UV photoabsorption in expanding laser plasma plumes.

We have already shown the potential of the photoabsorption technique in a proof of principle experiment which utilised a diverging beam interrogated by a back−thinned CCD array [2]. In particular we were able to (i) track and extract column density distributions in the expanding plasma plume and (ii) measure the plume front velocity which compared well with a simple model based on adiabatic plume expansion. The time resolution depends on the laser plasma continuum duration which can be as low as 100 psec [3]. Our new system design is significantly improved over that used in [2] in a number of ways:

1. The collimated beam simplifies the interpretation of the photoabsorption images and the extraction of physical information
2. The spectral resolution is improved to 0.05 nm compared to 1 nm in [2]
3. Both high VUV flux (20 nsec) and short pulse (150 psec) rare earth light sources are available offering the time resolutions indicated in brackets
4. The spatial resolution is better than 100 microns

We will present the results of ray tracing calculations for various options, e.g., collimated beam and projection imaging of the sample plasma. We will also present first measurements from the commissioning phase of the project: e.g., (i) detected flux per CCD pixel, (ii) beam footprint, (iii) beam collimation, (iv) spectral resolution, (v) spatial resolution and (vi) time resolution.

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SOFT X-RAY REFLECTIVITY AND THERMAL STABILITY OF CoCr/C MULTILAYER X-RAY MIRRORS

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4 Lawrence Berkeley National Laboratory, Berkeley, CA 94720, USA

The development of highly-reflective multilayer mirrors for use in the 6 nm region is desired for x-ray photoemission spectroscopy for inner-shell excitation using a Schwarzchild objective. For this applications, reflectivity is the most critical parameters determining the performance of multilayer mirrors, because the reflectivities of multilayers in the 6-nm region are generally very low.

We have designed CoCr/C multilayer mirrors with a comparatively high reflectivity at around normal incidence and have fabricated them by magnetron sputtering. We evaluated the structures and reflectivity of these multilayers using a soft x-ray reflectometer.

Figure 1 shows the measured reflectivities of the fabricated CoCr/C multilayer. The measured peak reflectivity is about 16 % at a wavelength of around 6 nm and an incident angle of 88 degree. This peak reflectivity is sufficient for our Shwartzshild x-ray optics. Figure 2 shows this reflectivity and reported multilayer reflectivities. The reflectivities are almost constant by annealing at 300C in an Ar atmosphere for 4 hours.

This study was performed through Special Coordination Funds of the Science and Technology Agency of the Japanese Government.

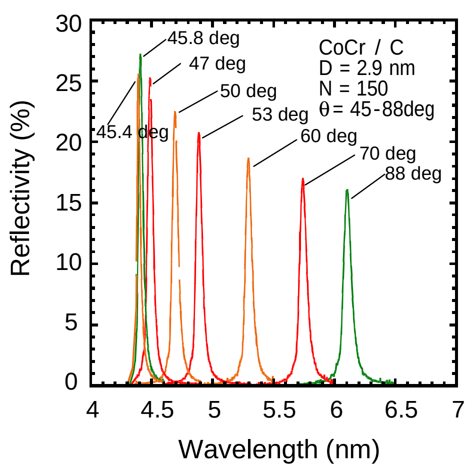

Figure 1. Measured reflectivities of the fabricated CoCr/C multilayer.

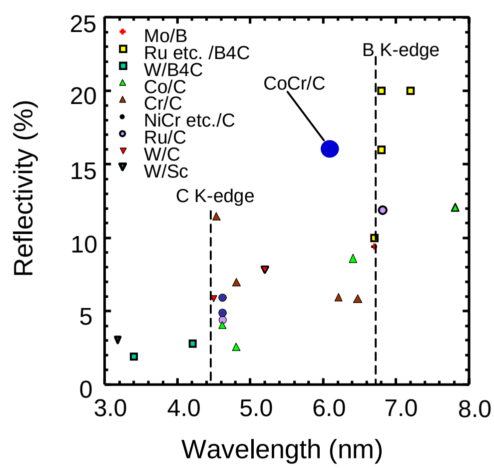

Figure 2. Reported reflectivites at incident angles more than 80 degrees[1] and CoCr/C's reflectivity at 88 degree.

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Preliminary results on the realization of multilayer EUV reflective coatings

Valentino Rigato[1], Alessandro Patelli[2], Gianluigi Maggioni[1], Piergiorgio Nicolosi[2], Maria-Guglielmina Pelizzo[2], Luca Poletto[2], Paolo Mazzoldi[3] and Giuseppe Tondello[2]

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Recently a new program for the development of coatings with enhanced EUV normal incidence reflectivity has started at the University of Padova. Here we would like to present some preliminary results obtained in the deposition of multilayer coatings. Since the properties and performance of the EUV mirrors are mainly affected by the surface roughness of each layer and by thickness uniformity initial effort has been devoted to the characterization of the growth of very thin (down to about 3 nm) layers. Mo and Si have been chosen since they are widely used for EUV reflective coatings. The adopted deposition technique has been radio frequency magnetron sputtering. The layers have been deposited on quartz and silicon substrates at different temperatures. The impurity concentration and the dependence of the deposition rate on the growth temperature have been studied using Rutherford Backscattering. The characterisation of the surface morphology has been performed by SEM and AFM. This study has been carried out in order to optimize the deposition parameters in view of the final multi-layer deposition.
The final Multilayer coatings have been characterized by X-ray diffraction and TEM and the EUV reflectivity has been measured by a dedicated apparatus.
The results of multilayer depositions optimized for 13-14 nm and for the 20-30 nm range will be presented.