PHOTOEMISSION BEAMLINE FOR CESLAB

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Abstract

This paper describes shortly a project of a beamline that focuses and monochromatises the synchrotron radiation from an undulator source at the proposed Central European Synchrotron Laboratory (CESLAB) in the range from 20 to 1000 eV with spectral resolving power better than 4000.

Introduction

Synchrotron radiation (SR) has become a very important tool in many branches of science. Current SR sources generate radiation continuously tuneable across a wide region of the electromagnetic spectrum. The SR is also highly polarized and collimated in a very narrow forward cone. With these features, SR is currently applied in surface physics, materials science, chemical, biological and medicine research.

The recent development in low-emittance storage rings and magnetic insertion devices allows their broad use in many experimental and technological methods. Being a research tool of broad range and high power it enables users to become world leaders in many rapidly moving scientific and technological fields. The fundamental basis that the economic prosperity of modern society originates from is the development and exploitation of new materials. Information technology has been made possible by the availability of suitable electronic materials for device fabrication and magnetic materials for data storage. High Tc superconductors are supposed to provide improved performance and cost savings in a range of applications from chips to power transmission in the coming decades. Ceramics are applied in a rapidly expanding market of structural materials and sensors. All these materials, as well as others like catalysers and polymers, need to be characterized in order to be understood. SR in combination with variety of spectroscopic techniques is the most sophisticated tool for the physical and chemical examination of materials.

A new storage ring in Brno will be the first dedicated SR source in Middle and Eastern Europe optimised to generate VUV and XUV radiation using magnetic insertion devices and low emittance bending magnets. Although the project is a Czech one, its importance is international and the participation of scientists from other countries is intended and actively promoted. This policy opens activities for the whole scientific community and it also enables transfer of know-how into the industry.

The Photoemission beamline proposed for CESLAB

The technical specifications of the Photoemission beamline (PB) have resulted from the experiments that we have carried out at the Materials Science Beamline, the Czech beamline at synchrotron ELETTRA in Trieste, Italy.

The photon energy range is 20–2000 eV and will be covered with four gratings. The spectral resolution shall reach 10^5 for the small and 10^4 high energies. Higher harmonic content should be less than 20 % for any harmonic. The beamline should be easy to align, operate and maintain, thus to be user friendly. There will be provisions for in-situ calibration of photon beam parameters such as energy, resolution, spot size and polarisation.

The choice of the monochromator is the most critical step. In addition an operation with a large tuning range from UV to soft X-rays using only one or two gratings and keeping the exit slit position fixed is required in a materials characterisation (structure, electronic structure, chemical state) with methods such as photoemission, ESCA, EXAFS, NEXAFS or photoelectron diffraction.

The current development in soft X-ray beamlines shows that the plane grating monochromators working with the collimated synchrotron radiation beam are the most versatile instruments that cover most of the needs of users.

The proper choice of the source for the beamline is essential as well. The undulator source properties must be matched to the beamline design. An Elliptically polarized undulator (EPU) of the Apple II type seems to be the appropriate source for PB.

Experimental station

Since the aim of this beamline is to provide maximum versatility and flexibility, the measurement station should be designed accordingly. It will be combined from two substantial parts. The first will be a set of technological chambers with attached growth control devices and the second will be an analyzing chamber equipped with the photoemission facility operating in different modes as a main experimental tool. These two parts will be connected with a preparation chamber designed for the sample treatment and characterisation using standard surface physics methods.

Preparation chamber

Most of the proposed experiments require different kinds of sample treatment under UHV conditions and also related surface control methods. To include all these methods into one measurement chamber, time for realisation of an experiment will increase by a factor 2 and also will increase the hazard of beamline contamination. There will also be the possibility of damage of some important parts of a spectrometer by evaporation, sputtering or by other effects resulting from sample treatment. Therefore the measurement station will be equipped with a preparation chamber which will fit all measurement chambers. The chamber will include LEED or RHEED and AES facilities, a sputter ion gun, cleaving facility, an evaporator, a thickness monitor, heating and cooling facility. A gas handling system and a residual gas analyzer will be available. Sapphire and/or quartz windows will be attached to the chamber allowing the laser processing of the samples and the substrates. A turbomolecular pump in combination with a titanium sublimation pump will be used to keep the base pressure $<1\times10^{-10}$ mbar. The joint preparation and measurement chambers will be fixed to a support which allows an independent movement in three perpendicular directions for the final alignment. A fast entry lock will allow rapid sample exchange and there will be a mechanism to move the sample between preparation and measurement chamber.

In the next stage, a scanning tunnelling microscope will constitute a valuable additional tool for the sample investigation and characterization.

Technological chambers

This part of the measurement station will be equipped with different methods for sample growth and preparation. In the final stage, MBE, plasma, remote plasma, hot wire and laser depositions will be available. The requirements and the conditions of the growth are so different that at least two working chambers will be needed. All the above mentioned technological methods will have to be handled by well experienced and well trained operators. A close cooperation with specialized technological laboratories and sponsoring industry is considered.

In the first stage, a simple glow discharge reactor will be built up. There should be windows for the laser beam transmission into the chamber which could be used for stimulation during the growth process.

In the second stage, the laser deposition chambers should be made ready for the connection to the preparation chamber. A careful design of the gas handling system has to be realized because inflammable and toxic species are often used in these technological processes. In addition, a simulator of corrosion processes in steam generators used in conventional or nuclear power stations will be installed.

A chamber for catalytic studies will be designed. The main goal is to prepare and characterize the nanosize metal particles to study their electron structure in relation with catalytic properties in different gas mixtures and at elevated temperatures.

Analyzing chamber

Our philosophy will be to purchase a commercial spectrometer and then to upgrade it to achieve the required performance. Provision will be made for angle-integrated and angle-resolved photoemission and partial yield photoabsorption spectroscopies. Sophisticated software operating the monochromator together with a spectrometer will be developed to enable other methods like photoelectron diffraction, CIS and CFS operation modes EXAFS and NEXAFS. The energy resolution 10 meV below 50 eV and resolving power of 4000 above this value would be sufficient in most of the experiments. In the angle-integrated mode, the acceptance of the analyzer should be better than 30ş full angle. A hemispherical analyzer with advanced lens system will be suitable for this purpose. There will be a second analyzer mounted on a precise two-axis goniometer for angle-resolved measurements. The angular resolution of the analyzer should be adjustable up to very high parallel momentum resolution of about 0.05 inverse Angstroms.

In the analyzing chamber, a facility for in-situ calibration of the spectrometer must be attached, for example by means of a noble gas discharge lamp EELS monochromator. A general method of calibrating the energy resolution is the measurement of the Fermi edge width. This works best at lower photon energies where the photoionisation cross-section is reasonably large. At sufficiently high flux, it could be used for higher photon energies, too. This method determines the resolution of the entire photoemission experiment including the monochromator resolution.

The thermal width of the Fermi edge is about $4kT$, i.e. 100 meV at room temperature. To measure the resolution of 10 meV, it is necessary to achieve the temperature ~20 K at which the Fermi edge is about the same width. Thus, the analyzing chamber should have a facility for attaching of a liquid He cryostat.

Specifications of beamline Source

The Apple II type elliptically polarized helical undulator has a pure permanent magnet structure composed of four arrays. The arrangement of blocks is such that there are four blocks per period. By moving two opposing magnet arrays with respect to the other two longitudinally (a phase shift), the strengths of the vertical and horizontal magnetic field components can be varied, and hence different polarizations (linear horizontal, vertical and circular) of the radiation are produced.

Beamline optics

The PB optics will be based on a concept of collimated plane grating monochromator (cPGM). All the reflecting optical elements of PG, except for the plane mirror and plane grating, will be horizontally deflecting.

The first mirror will have a toroidal or paraboloidal figure and will collimate the radiation coming from the undulator. The collimated beam is vertically deflected by the plane pre–mirror to one of the four plane gratings. The dispersed radiation is sagitally focused to the exit slit with a toroidal or paraboloidal mirror. The exit slit selects the chosen wavelength. The selected radiation is refocused with a sagitally focusing toroid to the sample in the experimental chamber.

The plane grating monochromator contains two independent rotational axes on which the plane mirror and the plane grating rotate. Using a certain combination of the angles, one can tune the monochromator for certain energy. Due to the fact that the incidence and the diffraction angles are not identical, the plane grating produces an optical magnification on the beam. The magnification of the plane grating is influenced by the value of C_{ff}, historically used to be called a fixed focus constant.

Since the cPGM works with a collimated beam, one can choose variable C_{ff} for different purposes in a certain range. Decrease of C_{ff} at lower energies can lead to better suppression of higher orders while the increase can enhance the resolving power. The C_{ff} value usually ranges from 1.2 to 6.

With all the possible combinations of different plane gratings with different groove profiles (blazed/laminar) one can trade off between the flux and resolution. The flux on the sample shall be bigger than 5.10^{12} phot/(s 0.1%BW) @400 eV and 500 mA of the ring current. The focus spot at the sample should be smaller than 50 m^2.

Summary

We have shown main features of the proposed PB for an elliptically polarized undulator of the third generation dedicated storage ring. The great advantage of PB will be the possibility to scan rapidly a great range of photon energies with high resolution. This is very suitable for many experimental techniques such as EXAFS or NEXAFS.

STRUKTURA 2008 Kolokvium Krystalografické společnosti

16. - 19. 6. 2008
Valtice, Hotel Hubertus a Národní vinařské centrum

The colloquium is devoted to synchrotron radiation and its application in different scientific fileds. Tutorials of Czech scientists will present physical and technological principles of synchrotron, origin and monochromatization of radiation in the range from infrared to hard X-rays and applications for diffraction, absorption, spectroscopic and imaging methods in materials science, physics, chemistry and biology. The colloquium is motivated by the Czech participation at existing synchrotrons (mainly ESRF and ELETTRA), preparation of the project CESLAB (Central European Synchrotron Laboratory) for construction of synchrotron radiation in the Czech Republic, and by the effort to spread the knowledge on the synchrotron and its application in a broad scientific commmunity in a form of a short school. The colloquium is low-cost. In particular, the participation of students is welcome. The main languages are Czech and Slovak. English contributions are accepted as well.

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