Available online at www.sciencedirect.com
ScienceDirect
C. R. Physique 9 (2008) 477–478
COMPTES RENDUS PHYSIQUE
http://france.elsevier.com/direct/COMREN/

Synchrotron x-rays and condensed matter/Rayonnement X synchrotron et matière condensée

Foreword

The following review deals with the application of synchrotron X-rays to condensed matter physics, and is mainly science-oriented. By X-rays, we mean both soft and hard X-rays, spanning the wavelength range from 10 nm to 0.05 nm or so (i.e. an energy range from 100 eV to 20 keV).

Although a majority of the articles do fall in the "small review" scope, some emphasize more new features. The first 3 articles serve as introductory to X-ray interaction formalism, to synchrotron sources (including future ones) and to advanced optics. Then the main body of articles reviews scientific highlights, based on advanced techniques that benefit from today's source potential, such as adjustable polarization or partial coherence.

The basic interaction between X-rays and an isolated atom is well documented in the article by J. Als-Nielsen, providing the necessary background to the following parts of the review.

Then M.-E. Couprie and J.-M. Filhol present the accelerator physics for charged particles (electrons in this case) and the characteristics of the radiation emitted up to X-rays. Circular machines, as used today, deliver 100 ps pulses with MHz repetition rates, whereas the new generation, linear machines, have ultrashort pulses (100 fs) at lower repetition rates and laser-like emitted photons (free electron laser). "Hybrid" accelerators (linear + recirculation) will show intermediate situations. The worldwide situation of existing and future machines is also given.

Although the best optics to configure the photon beam is ... no optics, in many cases it is a necessary ingredient to fit to a given application. A. Snigirev and I. Snigireva describe fairly exhaustively new focusing device types, taking advantage of the tremendous quality of the source (nm.radian occupancy in phase space), to obtain micro-nano beams.

A very powerful technique for determining electronic structure is photoemission spectroscopy. The limits of soft X-rays to determine the band structure of a model surface is addressed by F. Venturini and N.B. Brookes. Then Panaccione et al. present the long-awaited application of getting true bulk data using the hard X-ray regime; in this way, electron screening effects are shown to be different between bulk and surface in strongly correlated materials.

Also in the soft X-ray range, the electronic structure, from band mapping to inter-orbital excitations, can now also be studied by resonant X-ray inelastic scattering, as demonstrated by J. Lüning and C.F. Hague. Since it provides bulk sensitivity and is element specific, electron excitations of complex materials can be studied. The basics of this method are described in some detail. This still emerging technique is developing rapidly thanks to the very high flux available.

The next 3 articles are devoted to magnetism. Unexpected for a long time, the X-ray potential is now established to be very unique and subtle in many respects. The article by L. Paolasini and F. de Bergevin is a masterpiece on the general theory of magnetic and resonant scattering, and also provides applications of hard X-rays, again to strongly correlated systems, but now under extreme conditions. G. van der Laan deals with magnetic nano-objects using the resonant soft X-ray technique, which is an element-, site- and valence-specific probe. Some theoretical complements are given for the determination of vector magnetization profiles. Its application is unique to magnetic domain nano-morphology and its dynamics, especially when the coherence properties of the pinholed beam are used. Finally, Y. Acremann describes a specific brand new application in the spintronics field, which demonstrates that in spin injection devices, magnetization switching involves the motion of a magnetic vortex.

In the article by R. Rüffer, the nuclear scattering formalism is recalled and applied to a wide variety of domains in solid state physics, from nano-scale materials through disordered system dynamics to extreme environments. This field, which emerged after long decades of pioneering work, is now exhibiting a very large potential thanks to third generation synchrotron sources.

1631-0705/$ – see front matter
doi:10.1016/j.crhy.2008.04.004

The following article, by G. Monaco, is also devoted to disordered systems, in the newly developing field of inelastic X-ray scattering, which complements the more traditional inelastic neutron scattering. Technical performance allied to high brilliance beams have allowed high momentum and energy (in the meV range) resolution. The present status is exemplified on the study of high-frequency atomic dynamics.

The advances in hard X-ray imaging and microanalysis are presented by J. Baruchel et al. This exploding field is shown in a very exhaustive way, from novel achievements in classical techniques to brand new ones. Technically driven through the full use of beam properties (including coherence) and progress in the detector/acquisition systems, various fields of application are now opened. 2D (and increasingly 3D) mapping in density, chemical composition, structure and crystallographic imperfection are produced, with the future prospect of reaching the nanoscale range.

A very challenging, and very recently pioneered field, well known from long in the visible range, is the X-ray optical activity. A. Rogalev, J. Goulon and F. Wilhelm deal with the detection of natural OA, a time-reversal even effect, as well as the non-reciprocal odd one.

The last 2 articles are devoted to the X-ray correlation spectroscopy method. In the first one, M. Sutton reviews the present status and results of this rather new and very promising technique, whereas the final text, by G. Grübel, shows its huge perspective in the framework of the next laser-like sources, here the 0.1 nm European project XFEL under construction.

To conclude, we should emphasize that due to its large scope, the present review is by no means exhaustive. Among the aspects most lacking, we cite the advances in surface crystallography and the developing use of coupled techniques, such as pump-probe for ultrafast dynamics, or X-ray-near-field methods for complementary characterization. A new review, some years from now, would clearly be most welcome.

Acknowledgements

It is a pleasure to thank François de Bergevin for his interest and kind help during the whole process of this review.

Michel Belakhovsky
Former CEA-Grenoble & ESRF physicist
E-mail address: michel.belakhovsky@numericable.fr

Available online 20 May 2008