Available online at www.sciencedirect.com
SCIENCE DIRECT
Nuclear Instruments and Methods in Physics Research A 556 (2006) 371–378
NUCLEAR INSTRUMENTS & METHODS IN PHYSICS RESEARCH Section A
www.elsevier.com/locate/nima

Design of a high-flux low-energy synchrotron radiation monochromator

Giampiero Naletto[a,b,*], Giuseppe Tondello[a,b], Roberto Cimino[c]

[a] Dipartimento di Ingegneria dell'Informazione, Università di Padova, Via Gradenigo 6/B, I-35131 Padova PD, Italy
[b] CNR/INFM Unity of Padova, Italy
[c] I.N.F.N. Laboratori Nazionali di Frascati, Via E. Fermi, 40, I-00044 Frascati (Rome), Italy

Received 23 September 2005; accepted 10 October 2005
Available online 8 November 2005

Abstract

The characteristics and the performance of a new design low-energy high-flux synchrotron radiation beamline are here presented. This instrument, initially conceived for being applied to DAΦNE at the Frascati electron-positron collider, has been developed for a possible application to a fully dedicated synchrotron radiation third generation bending magnet. The beamline has a very innovative point in locating the first optics within the accelerator tunnel to collect as much flux as possible; the light is then focused on the entrance slit of a double normal and grazing incidence monochromator, to cover the 5–200 eV energy range; finally, a refocusing system collects the light from the monochromator exit slit and focuses it on the sample under study. The goal of this beamline is to deliver an high flux of photons in the energy range 5–200 eV with a resolution $\mathscr{R}$ larger than 10 000 for energy range 5–20 eV, and larger than 3000 for the range 30–200 eV. With this performance, the flux delivered is comparable to the one obtained by existing undulator beamlines: this shows that placing the first optical element as close as possible to the ring guarantees the required performance without the need of a straight section and an undulator.

PACS: 07.85.Qe; 41.85.Si; 42.15.Eq; 87.50.Hj

Keywords: Synchrotron radiation; Monochromator; Optical design

1. Introduction

In this paper, we present the detailed optical study of a high-flux low-energy beamline which uses the bending magnet (BM) radiation of existing and/or planned synchrotron radiation (SR) sources. Many are the scientific issues guiding the technical solutions adopted for this beamline, but the main one is to produce an intense and highly energy resolved photon beam in the low vacuum ultraviolet (VUV) energy range (from 5 to 35 eV) without the need of occupying one of the few straight sections available in the ring plus an ad hoc designed low gap undulator. Moreover, the very low energy range is not optimally covered by undulator beamlines on existing facilities, because the undulator gap must be extremely small to obtain a very low energy first harmonics; even *in vacuum* undulators have been designed and constructed to reach the required small gaps. Also, on an undulator beamline, photon energy tuning requires changing the undulator gap itself: this process is certainly time consuming and could sometimes cause unwanted effects on the beam stability.

The low energy VUV photons produced by the proposed beamline will be useful not only for a number of scientifically important experiments, as for example band mapping Angle Resolved Ultraviolet Photoelectron Spectroscopy (ARUPS) [1] on solids and gas phase studies, etc., but also to attract some more technologically oriented experiments, such as VUV detector studies. Rather than searching maximum intensity and resolution, in which case an undulator beamline would have been anyway preferred, we consider as a key feature of this beamline easy photon energy tunability, which is intrinsically available from a BM source. This feature will allow us to exploit all the SR

*Corresponding author. Dipartimento di Ingegneria dell'Informazione, Università di Padova, Via Gradenigo 6/B, I-35131 Padova PD, Italy.
E-mail address: giampiero.naletto@unipd.it (G. Naletto).

0168-9002/$ - see front matter
doi:10.1016/j.nima.2005.10.012

techniques based on smooth intensity variations photon energy scans, like Constant Initial State (CIS) spectroscopy, Constant Final State (CFS) spectroscopy and energy dependent ARUPS without requiring complex tuning between monochromator position and undulator energy gap changes.

Another focal point comes from the widely accepted concept that the limited energy range available at an optimized low energy beamline greatly limits its powerfulness. In fact, since optimized low energy beamlines generally use near-normal reflection optics, which are very inefficient above 30–35 eV, this puts an upper limit to the available photon energy range. However, in many issues it is considered very important not only to have high quality low energy photons, but also to have easy access to higher energy photons to observe lower binding energies features. For this purpose, we have coupled a grazing incidence monochromator to the one using close to normal incidence optics, allowing us to reach photon energies higher than 150 eV.

One of the innovative part of our proposal is to place the first optics as close as possible to the source, hence within the accelerator tunnel. This is certainly an inconvenience due to the need of installing the chamber within the accelerator tunnel and the need of having secure remote control of the complete system; but it is still conceivable due to the confidence with which nowadays it is possible to construct and remotely control optical elements. The clear advantage is represented by the saving of a straight section in the ring and of the undulator itself. As shown in the next sections, this would allow to get very high fluxes (close to those obtained by an undulator) with high resolution. This makes the proposed solution extremely interesting not only for third generation accelerator facilities like ELETTRA (Trieste, Italy) for which a detailed calculation is here reported, but also for lower energy rings like DAΦNE. The latter is the Frascati electron-positron collider with 1.02 GeV center of mass energy (Φ-factory) [2] for which this project has been initially conceived.

2. Optical design

The beamline here described has been designed thinking to a possible application to a BM source on a third generation SR facility. As example of an actual source, we have considered the BM of BEAR [3,4] at ELETTRA, whose characteristics are summarized in Table 1. The goal of this instrument is to cover the energy range 5–200 eV with a resolution $\mathcal{R}$ larger than 10 000 for energy range 5–20 eV, and larger than 3000 for the range 30–200 eV. It can be remarked here that in the case of the application to DAΦNE, which was the subject of our initial study, the source was much larger than the one described in Table 1: in fact, for the same energy range, the DAΦNE instantaneous source rms size (horizontal × vertical) is 2.2×0.27 mm, and its rms divergence is 1.9×0.6–2.8 mrad. Even if, obviously, the required performance in that case was much more relaxed, this shows that the optical design of this beamline is very versatile, and can be successfully applied to different types of source.

The proposed instrument can be divided in four portions: the *collecting* optics, the pre-focusing optics, the monochromator, and the re-focusing system (see Fig. 1).

As already mentioned in Section 1, the first optics M1 (the *collecting* optics) is located as close as possible to the BM source, to be able to collect a large "horizontal" portion of the beam. For this application we have designed the system to collect 15 mrad of horizontal beam: to this end, M1 has been located at 3 m distance from the BM source and its length is of only 350 mm (to be compared, for example, with the 1 m long first optics of BEAR which collects more than four times less flux). Owing to the very short distance between the BM source and M1, this mirror has to be located inside the accelerator tunnel.

Table 1
Characteristics of the source used for the simulations. Here the *instantaneous* rms size and divergence of the source are summarized: the actual horizontal size and divergence of the source seen by the beamline are obtained by considering the portion of the beam effectively collected by the first optics

Energy (eV)	σ_h (mm)	σ_v (mm)	σ'_h (mrad)	σ'_v (mrad)	Flux (Ph/s/mrad/0.1%BW)
5.0	0.14	0.097	0.263	2.25	2.43E + 12
7.8	0.14	0.082	0.263	1.86	2.80E + 12
12.2	0.14	0.069	0.263	1.54	3.23E + 12
19.2	0.14	0.059	0.263	1.27	3.73E + 12
30.0	0.14	0.052	0.263	1.05	4.29E + 12
38.3	0.14	0.048	0.263	0.95	4.62E + 12
49.0	0.14	0.045	0.263	0.85	4.98E + 12
62.6	0.14	0.042	0.263	0.77	5.35E + 12
80.0	0.14	0.040	0.263	0.69	5.74E + 12
100.6	0.14	0.038	0.263	0.63	6.12E + 12
126.5	0.14	0.037	0.263	0.57	6.49E + 12
159.0	0.14	0.035	0.263	0.52	6.89E + 12
200.0	0.14	0.034	0.263	0.47	7.28E + 12