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New wiggler beamlines at BSRF

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A new multipole wiggler has been installed in the ring of the Beijing Electron Positron Collider (BEPC), and two new beamlines were extracted from it for experiments, including LIGA, microprobe fluorescence analysis, high-pressure diffraction and soft X-ray research. The beam profile and photon intensity were measured and compared with the calculated values. The main parameters and characteristics of the two beamlines are illustrated. Some experimental results are presented.

Keywords: beamlines; experimental stations; upgrades.

1. Introduction

In the upgrade program of the BSRF, a new permanent-magnetic wiggler, two beamlines and related experimental stations have been installed and operated since the end of 1996. 3W1 is a permanent-magnetic wiggler installed at quadrant IV of the BEPC storage ring. The operation parameters are as follows: total length of straight section, 7.5 m; period number, 5; gap, 4.3 cm; magnetic field, 1.43 T; critical energy, 4.6 keV; deflection coefficient, 40. It can be operated in either the dedicated or parasitic mode of the BEPC. The spectral brightness of 3W1 is shown in Fig. 1.

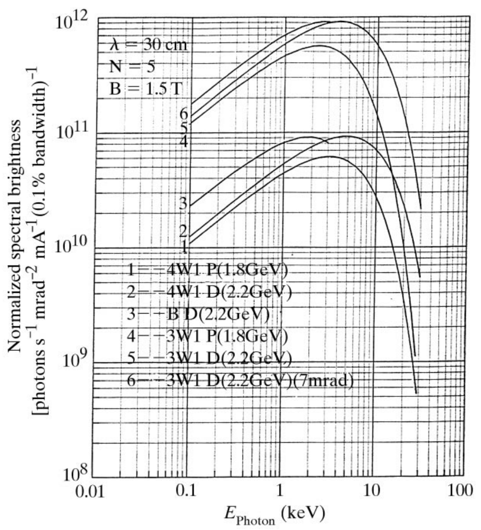

Figure 1
Brightness of the 3W1 wiggler.

2. Design

The photon beam from the front end is separated into two beamlines at an angle of 6.3 mrad. 3W1*A* is a white-radiation beamline with an acceptance of 1 mrad, and −1 mrad with respect to the wiggler axes. 3W1*B* is a monochromatic focusing soft X-ray beamline with an acceptance of 1 mrad, and +5.3 mrad with respect to the wiggler axes. Fig. 2 shows a sketch of beamlines 3W1*A* and 3W1*B*.

2.1. *Beamline 3W1A*

A beam slit, beam-position monitor, photon shutter and Be window were set up successively on beamline 3W1*A*. LIGA, microprobe analysis and high-pressure diffraction stations have been installed in series and under a time-sharing operation.

A scanning irradiation chamber has been set up at beamline 3W1*A* for deep-etching X-ray lithography. An irradiation depth of a polymethyl methacrylate (PMMA) photoresist of more than 1000 μm can be achieved in the chamber.

An Si(Li) spectrometer has been equipped in the microprobe fluorescence analysis station. Total reflection and scanning microprobe fluorescence analysis technology has been developed. The lower detectable limits for total reflection and scanning microprobe are 5 p.p.b. and 1 p.p.m., respectively.

An extra high-pressure diffraction station, with parameters of 100 GPa pressure and 273–873 K temperature, has been established.

2.2. *Beamline 3W1B*

3W1*B* is a soft X-ray double-focusing monochromated beamline with energy range 50–2000 eV and energy resolution 1×10^{-3}. A varied-space plane grating (VSPG) has been adopted as a monochromatic component for correcting the aberration of the grating. The optical path of 3W1*B* is shown in Fig. 3. The monochromator consists of an incident aperture AP1, reflection mirror PM, VSPG, exit aperture AP2 and exit slit S.

A soft X-ray reflectometer with angle precision $\leq 0.0005^\circ$ has been set up at the end of 3W1*B*. It has been designed for soft

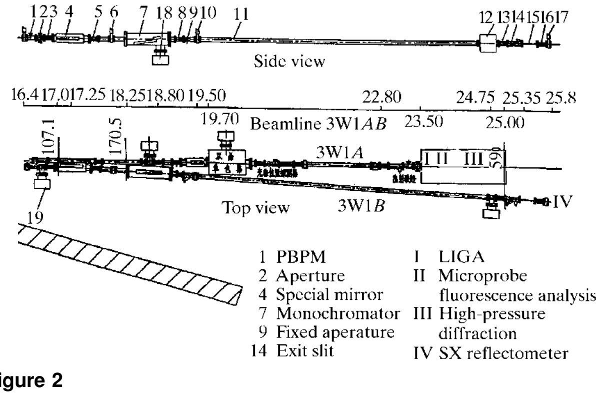

Figure 2
Layout of the new beamline from wiggler 3W1.

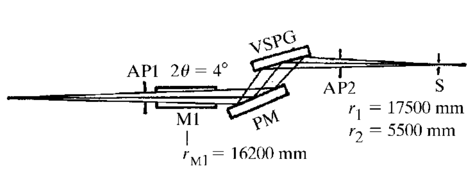

Figure 3
Optical path of 3W1*B*.

X-ray research, soft X-ray detector calibration and light-element fluorescence analysis.

3. Performances of the beamlines

3.1. *Beam profile in the front end*

A photon-emission beam-position monitor (PBPM) has been installed at the front end. Fig. 4 shows the vertical beam profile taken by the PBPM. The two peaks of the lower curve in Fig. 4 arise from the dipole magnet of the upstream 3B4 and downstream 3B5, respectively, without wiggler radiation (in the case when the gap of 3W1*A* was opened). When the gap of 3W1*A* was closed, a single intensity peak in the middle appeared, arising from the 3W1*A* wiggler.

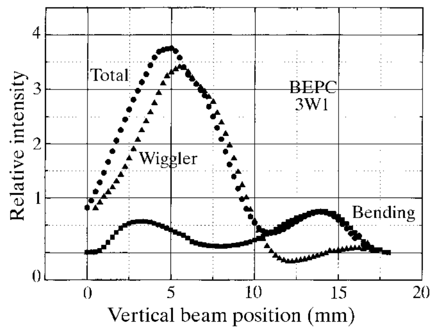

Figure 4
Vertical beam intensity.

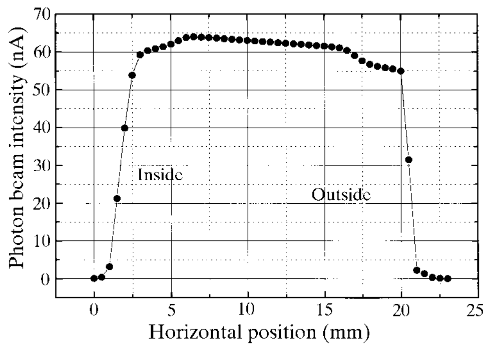

Figure 5
Horizontal beam intensity.

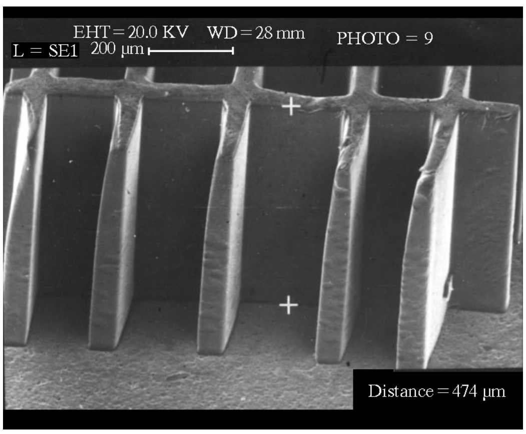

Figure 6
PMMA structure of 700 μm depth.

3.2. *Beam intensity and photon flux*

The beam intensity in the experimental station was measured using the ion chamber. Fig. 5 shows the horizontal intensity distribution. The measured results have been compared with the calculated values, showing a deviation of 1.7%, which means that the designed brightness value of the wiggler of 3W1*A* has been reached.

4. Preliminary scientific results

Since the beam intensity of 3W1*A* is an order of magnitude higher than that of the original beamlines at the BSRF, opportunities have arisen to perform experiments which previously could not be carried out.

4.1. *Deep-etching lithography*

Before completing the new beamline, deep lithography exposure was performed in beamline 3B1, dedicated to submicrometre lithography. Since the energy of 3B1 is in the soft X-ray range

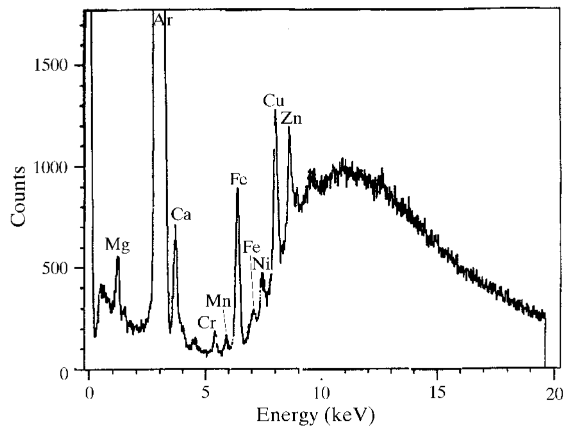

Figure 7
Fluorescence spectrum of a metal foil.

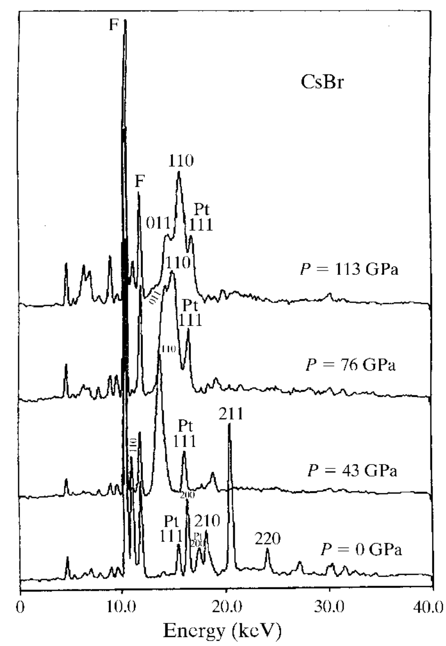

Figure 8
Diffraction of CsBr.

and the intensity is low, it is limited to deep lithography development. As an example, it may take about 8 h for a deep exposure of PMMA of 40 μm thickness; even in such a case it is difficult for the bottom to be fully melted. In contrast, for 3W1*A*, at 20 mA operation of BEPC, it takes only 30 min to etch to a depth of 700 μm of PMMA (see Fig. 6). Therefore, 3W1*A* not only provides an increase in efficiency, but also benefits the technological development of deep lithography.

4.2. *Microprobe fluorescence analysis*

Many experiments had already been performed in the microprobe fluorescence station with a microprobe of only 50 × 50 μm due to the limitations of beam intensity. In the case of 3W1*A*, a scanning spot of 10 × 10 μm was successfully obtained. Fig. 7 shows the results from a standard reference of thin metal foil at a beam current of 49 mA. It shows that the amounts of elements Cr, Fe and Ni are 2.1×10^{-12}, 7.4×10^{-12} and 1.6×10^{-12} g, respectively. The fluorescence microprobe analysis technology at the BSRF has been upgraded.

4.3. *Extreme-high-pressure diffraction*

Previously, the record high-pressure level was limited to 76 GPa due to the low photon intensity at the existing beamlines. Now, however, a pressure of 113 GPa has been reached in a spot of 30 × 30 μm for a sample of CsBr at 3W1*A*. Fig. 8 shows the results. The ⟨110⟩ peak of CsBr split at around 76 GPa. The success of the experiments opens new opportunities for extreme-high-pressure diffraction experiments.

4.4. *Soft X-ray optics*

Results from one of the experiments performed using the reflectometer are shown in Fig. 9. An Mo/Si multilayer with a period of 10.5 nm was used as a reference sample sitting in the reflectometer to check the energy calibration of the monochromator. The wavelength-scanning mode was taken at a fixed incidence angle of 45° with respect to the beam axis for determining the reflectivity of the multilayer. By scanning the wavelength with a monochromator between 13 and 17 nm, the maximum reflectivity of the multilayer appeared at around 14.7 nm, which is consistent with calculation.

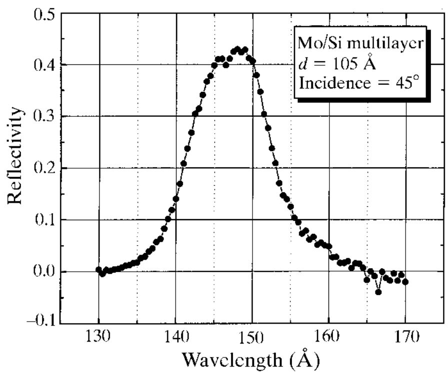

Figure 9
Reflectivity of the Mo/Si multilayer.

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