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The SLS Optics Beamline

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Abstract. A multipurpose beamline for tests and developments in the field of x-ray optics and synchrotron radiation instrumentation in general is under construction at the Swiss Light Source (SLS) bending magnet X05DA. The beamline uses a newly developed UHV compatible, $100\,\mu$m thick, brazed CVD diamond vacuum window. The very compact cryogenicly cooled channel cut Si(111) monochromator and bendable 1:1 toroidal focusing mirror at 7.75 m from the source point are installed inside the shielding tunnel. The beamline covers a photon energy range of about 6 to 17 keV. We expect $5 \cdot 10^{11}$ photons/s within a $100\,\mu$m spot and a resolving power of 1300. The monochromator and focusing mirror can be retracted independently for unfocused monochromatic and focused "white" light operation respectively.

Keywords: synchrotron radiation, beamline optics, channel cut monochromator, cryogenic cooling
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INTRODUCTION

The SLS optics beamline has been planned to allow quick beam access for instrumentation tests and developments in the field of optics or detectors, feasibility experiments and training of operators and students. We aimed for maximum flexibility and balanced performance. We chose a design which is basically a copy of the x-ray diffraction beamline at the Advanced Light Source (ALS BL 11.3.1.) [1, 2]. The characteristic features of the beamline are the very compact[1] assembly of a cryogenicly cooled channel cut Si(111) monochromator, a slit system and a bendable 1:1 toroidal focusing mirror carried by a single support structure. The complete assembly is installed inside the radiation shielding of the storage ring. The installation close to the source point combines a relative high angular acceptance with compact size of the crystal and mirror and allows a 1:1 focusing in both directions with one toroidal mirror[2]. The evident drawback coming from the limited access times to the storage ring tunnel can be restricted to an acceptable level with reliable remote control and excellent survey, alignment and extensive testing. This has been successfully demonstrated at the ALS.

The main components for the beamline are delivered, characterization measurements of the mechanics are under way. The front end parts, vacuum window and support structure are already installed at the final position. The installation of the monochromator and mirror unit is scheduled for June 2006.

CVD DIAMOND VACUUM WINDOW

A special CVD diamond vacuum window has been developed at the PSI for this beamline to separate the vacuum systems of the machine and beamline. The window dimensions are (6×18) mm, $100\,\mu$m thick. The CVD diamond is *brazed* to a water cooled copper support structure (figure 1). Due to the brazing the window is fully UHV compatible and bakable up to 250 °C. Roughness, pressure resistance and x-ray absorption have been measured. In a test setup the window withstood pressure waves up to 4 bar. The measured x-ray absorption was in good agreement with calculations.

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[1] The total length is less than 2 m and the width about 0.5 m.

[2] In our case we share the experimental hutch with the diagnostics beamline of the SLS machine. Therefore we had to restrict the total length of the beamline to < 20 m. A toroidal mirror has no coma at 1:1 magnification.

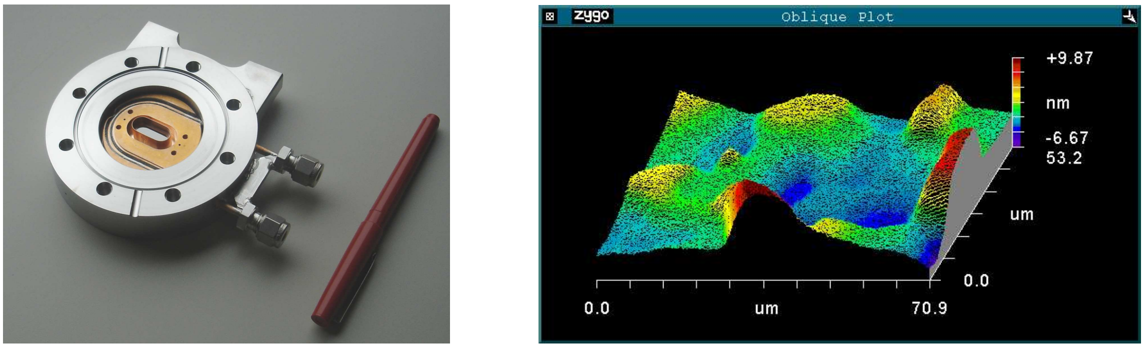

FIGURE 1. Left: photograph of the CVD diamond vacuum window prior installation. Window dimensions: (6×18) mm, 100 μm thick. Right: roughness measurement, root mean square (rms): 2.4 nm, peak to valley (pv): 16 nm.

XAFS measurements at selected absorption edges[3] did not reveal any contamination from the brazing process[4]. The advantages of CVD diamond over the commonly used Be windows are the better thermo-mechanical and optical properties in particular the absence of inhomogeneities and the reduced roughness[5].

MONOCHROMATOR AND FOCUSING SECTION

The cryogenicly cooled channel cut Si(111) monochromator, a slit system and a bendable 1:1 toroidal focusing mirror is located at 7.5 m from the source point. A 3D model of the complete assembly is shown in figure 2. The surfaces in

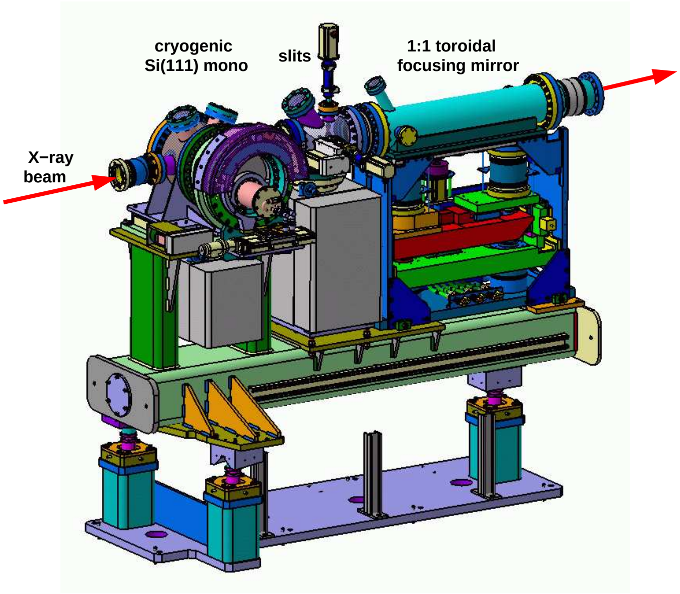

FIGURE 2. 3D model of the monochromator and focusing section of the X05DA beamline.

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[3] We measured at the following photon energies: 25.514 keV (Ag), 8.979 keV (Cu), 27.940 keV (In), 16.388 keV (Bi), 15.861 keV (Pb).

[4] An off-the-shelf CVD diamond window based on this design is being brought to market through Diamond Materials GmbH .

[5] Imaging and coherence applications will benefit in particular from the absence of inhomogeneities. From the reduced roughness we expect significantly less stray light. For comparison: Our backup solution was a 75 μm thick hand buffed Be window with a measured roughness of 630 nm rms and 7 μm pv.

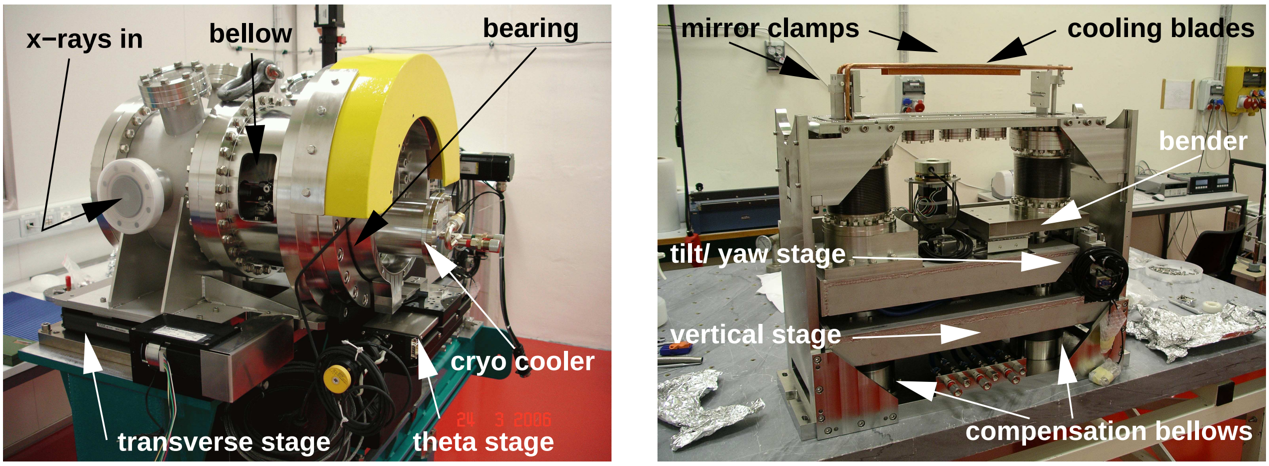

FIGURE 3. Left: photograph of the monochromator unit. Right: photograph of the mirror mechanics (mirror is not installed).

the channel cut crystal are separated by only 3 mm and have an offset angle of 0.28° to minimize the small vertical beam movement while scanning the energy [2]. The 400 mm long toroidal mirror has a 4 mrad grazing angle. The mirror is coated with a bilayer of 30 nm of Pt under 5 nm of Rh. The bilayer approach allows suppression of the Pt L edges at about 13 keV by the Rh, while maintaining the higher energy cut off of Pt compared to Rh alone. The following modifications have been applied to the ALS design:

- The Monochromator and focusing mirror can be retracted to allow the following options: "white" beam, focused "white" beam, unfocused monochromatic beam and focused monochromatic beam.
- The motorized roll adjustment for the monochromator has been abandoned.
- The differentially pumped rotary feedthrough for the cryo cooler in the monochromator has been replaced by an off-axis bellow which is loaded with torque. A bellows vendor demonstrated more than 10000 cycles over the full range of ±10° in a realistic test setup[6]. This simplified the design, although the successful routine operation of such a solution has to be demonstrated.
- Cooling has been added to the focusing mirror to allow focusing of the "white" beam. The mirror reflects upwards.
- The mirror and bender system has been modified to have an almost complete balance of the vacuum forces.

Figure 3 shows photographs of the monochromator and mirror system. To retract the crystal the whole monochromator chamber will be moved transverse to the beam on a linear stage. The crystal is connected to the cryo cooler by a long manipulator. The manipulator is basically a thick tube which carries the thermally isolated crystal holder and a copper rod as an insert for the thermal connection of the crystal holder to the cold head of the cryo cooler. The whole assembly is carried by a big bearing outside of the vacuum and rotates (theta) to change the photon energy. The vacuum interface is realized with a 100 mm long DN63 bellow mounted $\approx$ 50 mm off axis.

The cylindrical mirror is bent to a toroidal shape with a long radius of about 2 km by a motorized bender system [3]. In addition there is a motorized height-, tilt- and yaw- adjustment. The vacuum chamber is fixed in place, the adjustments are done with stages outside vacuum. A scheme with two bellows underneath the vertical stage and flexible joints has been applied to compensate the vacuum load of 750 N for the DN100 bellows, i.e. there is no vacuum load on the linear stages.

The mirror is cooled via water cooled copper plates which are immersed into an In-Ga eutectic in two long grooves directly adjacent to the optical surface [4, 5].

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[6] The tests were done under vacuum. The geometry was identical to the final setup.

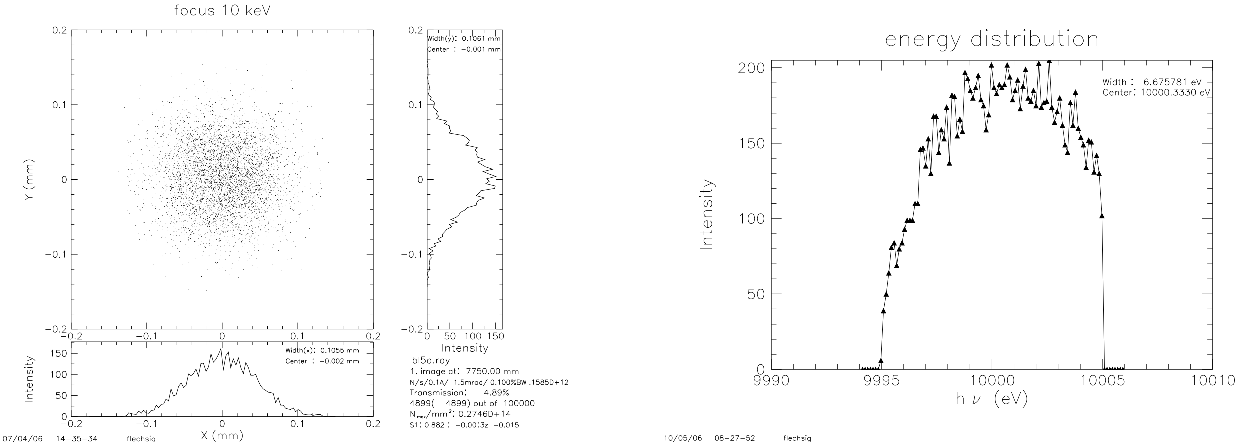

FIGURE 4. Ray tracing results for the focus at 10 keV. Left: spatial distribution, spot size: 100 μm FWHM, photon flux: $1.5 \cdot 10^{11}$ photons/(s 100 mA 0.001 BW). Right: calculated spectral distribution, resolving power $E/\Delta E = 1300$.

EXPECTED PERFORMANCE

We did ray tracing simulations to determine the photon flux, energy resolution and spot size. The source size in the bending magnet is $\sigma = (23 \times 45)\ \mu$m (v × h). The vertical acceptance of the beamline is 0.2 mrad which correspondes to 2σ at 10 keV. Horizontally we accept 1.5 mrad to avoid exceeding the cooling capacity of the cryo cooler[7]. Figure 4 shows the results for a photon energy of 10 keV with the monochromator and the focusing mirror in the beam. We can expect $5 \cdot 10^{11}$ photons/s with a resolving power of 1300 in a round spot of 100 μm FWHM for the default electron current at the SLS of 400 mA. With the retracted monochromator we expect a power of about 10 W in the 100 μm FWHM spot which corresponds to a power density of 1 kW/mm^2.

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[7] The cooling capacity of the chosen cryo cooler is 25 W at 120 K. The vertically integrated heatload of the SLS bending magnet is 33 W/mrad (400 mA electron current). About 50% of the power will be absorbed in the CVD diamond window.