A Novel UHV Double Crystal and Multilayer Monochromator

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Abstract

A novel UHV double crystal and multilayer monochromator has been designed and constructed for the VESPERS beamline at the Canadian Light Source. This monochromator can select pink beam, monochromatic beam ($\Delta E/E \sim 10^{-4}$), or broader bandpass beams for experiments. The key elements are large Si (111) crystals with two multilayers stripes. A periodic structure multilayer provides 1.6% bandpass and a depth graded multilayer provides 10% bandpass. An uncovered section of each crystal surface is used to produce highly monochromatic radiation. The bandpass can be changed by motorized lateral translation of the monochromator across the path of the incident X-ray beam. An adjustable stepped slit is placed in front of the crystals/multilayers which moves with lateral translation of the monochromator to ensure that, (a) in polychromatic beam mode, a lower beam passes by the monochromator without intercepting the crystal/multilayer pair and the upper beam is stopped; and (b) in monochromatic and broad bandpass modes, the lower beam is stopped and only an upper beam is passed onto the crystals/multilayers where it is downwardly deflected by ~1 mm. The monochromator can serve two branch lines by lateral translation.

Keywords: Synchrotron Radiation, Monochromator, Multilayer, Crystal, Bandpass

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Introduction

VESPERS (VEry Sensitive Elemental and Structural Probe Employing Radiation from a Synchrotron) beamline is a hard X-ray microprobe beamline dedicated to micro-diffraction and micro-fluorescence analysis [1-3]. It is one of the Phase II beamlines at the Canadian Light source, which have completed the construction and moved into commissioning phase.

Laue diffraction is the principal technique for structural analysis on this beamline [1-3]. It uses polychromatic X-rays to diffract from many crystallographic planes in a material without the necessity of rotating the sample in the X-ray beam. However, to determine absolute lattice parameters and to simplify indexation of reflections, there is an additional requirement to be able to switch the bandwidth of the incident X-ray from pink to near monochromatic in a routine manner. Therefore, the VESPERS monochromator is equipped to produce X-rays with several widely differing bandwidths. X-ray fluorescence is used to detect the presence of different chemical elements within the analytical volume. The sensitivity and speed with which a particular element is detected depends on many factors: the X-ray flux, the excitation energy of the fluorescence line used, the background from X-rays scattered from other elements and so on. Since the VESPERS monochromator can produce a range of X-ray energies *and* bandwidths, it is possible to optimize the excitation conditions to suit the analytical requirement: for example, for highest analytical counting speed and multi-element detection, a band pass of 10% or even pink radiation might be selected, while for higher sensitivity (but lower counting speed), a bandpass of 1.6% or even 0.01% could be chosen. The availability of a very

narrow bandpass setting also allows the absorption edge of a particular element to be scanned, thereby permitting the chemical state of a particular element to be sensed [1-3]. VSEPERS beamline is designed to have a two-branch capability. In addition to switching between different bandpasses, the monochromator is able to be switched between two branches [1-3].

Design

VESPERS monochromator design is UHV compatible and based on flexure pivots, which allow for very repeatable rotations. Figure 1 gives an overview of the monochromator assembly, while Figure 2 illustrates a schematic of major working components. As illustrated, the monochromator uses a sine bar drive with an optical encoder to ensure accurate settings of the overall angle.

As mentioned elsewhere [1-3], there are two parallel beams, with 1 mm separation in vertical, entering the monochromator. The first component of the monochromator is an adjustable stepped slit, in front of the optics, which moves with horizontal translation of the monochromator. This slit ensures that, in the polychromatic mode, a lower beam passes through the monochromator without intercepting the diffracting crystal pair and the upper beam is stopped. The slit also ensures that, in monochromatic mode, the lower beam is stopped and only an upper beam is passed onto the monochromator diffracting pair. The diffracting pair deflects the beam downwards by ~1 mm. This ensures that the different beams (polychromatic and monochromatic) are collinear and coincident at the microscopic spot at the sample. The VESPERS beamline uses these features to select between polychromatic and monochromatic beams (0.01%, 1.6%, and 10% bandpass).

In order to obtain different bandpasses, two stripes of Mo/B_4C multilayers were deposited onto a Si (111) crystal [2]. A periodic structure multilayer provides 1.6% bandpass and a depth graded multilayer provides 10% bandpass. An uncovered section of each crystal surface is used to produce highly monochromatic radiation with a bandpass of 0.01%. The bandpass can be changed by lateral translation of the monochromator across the path of the incident X-ray beam.

Considering the requirements from the beamline, VESPERS monochromator is designed as a small-displacement fixed offset/overlap device [2]. The gimbal assembly contains two ~100 mm long and 25 mm wide crystal substrates. The two matched substrates have a gap of 0.50 mm and an overlap of 3.75 mm. The center of rotation is set 1.5 mm upstream of the downstream edge of the first crystal substrate. As illustrated in Figure 2, main Bragg (pitch) angle with an angular range of 0-16.8˚ is controlled by a NanoMotion Micropositioning System through a sine bar drive and read back by an optical encoder on the opposite side. The pitch angle of the first crystal/multilayer and the roll angle of the second crystal/multilayer are further adjustable by two in-vacuum motor plus piezo actuator assemblies. Also, piezo actuator is integrated into a beam-position feedback system to stabilize the beam position. The opening of the stepped slit is adjustable through an in-vacuum motor actuator.

The vacuum chamber of the monochromator is supported by a structure stand, where the vertical and lateral positions of the chamber can be controlled by a three-jack motor assembly and a horizontal translation stage, respectively. While vertical motion provides fine adjustment of alignment, lateral motion gives the capability to switch between the different beam modes, different bandpasses and to serve two branches of the beamline.

Indirect cooling of crystal/multilayer substrates and the stepped slit is provided by attaching two sets of metal braids to two water-cooled copper blocks.

Commissioning

VESPERS monochromator was installed on the beamline and pumped down to 10^{-10} torr. Monochromatic beam was delivered into the experimental hutch. All the control parts were tested. Performance test experiments are underway.

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