I20; the Versatile X-ray Absorption Spectroscopy Beamline at Diamond Light Source

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Abstract. The Versatile Spectroscopy beamline at Diamond Light Source, I20, is currently under construction and aims to begin operation in late 2009 and early 2010. The beamline aims to cover applications from physics, chemistry and biology through materials, environmental and geological science. Three very distinctive modes of operation will be offered at the beamline: scanning X-ray Absorption spectroscopy (XAS), XAS in dispersive mode, and X-ray emission spectroscopy (XES). To achieve this, the beamline has been designed around two independent experimental end-stations operating from a pair of canted wigglers located in a 5m diamond straight section. One branch of the beamline will deliver monochromatic x-ray radiation of high spectral purity to one of the experimental hutches, whilst the other branch will constitute an energy dispersive spectrometer. The novel design of the beamline allows both branches to operate simultaneously.

1. Introduction
I20 is the versatile x-ray absorption spectroscopy beamline under construction at Diamond Light Source. It is part of the facility’s spectroscopy village, that includes a microfocus XAS beamline, I18, in use since 2007, and the core EXAFS beamline, B18, that aims commence operations in April 2010.

I20 is divided into two independent spectrometers that take their radiation from two different insertion devices. The first branch of the beamline is a wiggler-based scanning x-ray absorption spectrometer, focused on the delivery of an x-ray beam with high flux and high spectral purity. The second branch is also a wiggler-based instrument, but works in a dispersive configuration optimized for time resolved XAS experiments.

The radiation source for the scanning branch of I20 is a variable gap ex-vacuum hybrid wiggler, of 83mm period and approximately 2m length. When working at low energies, the gap of the wiggler will be opened to reduce the emission of high energy photons and heat load on the beamline optics. The dispersive branch of I20, also makes use of a similar wiggler, though this second device is shorter at 0.7m in length which will operate at three pre-set gap settings, in order to reduce heat load when working in the low energy range.

The two different photon beams allow the simultaneous operation of the two branches, which is achieved by adopting a canted configuration of the two insertion devices. The scanning branch wiggler is canted 0.8mrad outwards from the storage ring with respect to the machine centre line, whilst the dispersive branch wiggler is canted inwards by 2.9mrad. This configuration gives a total separation angle of the two photon beams of 3.7mrad, measured from the centre of their emissions.
The separation of the two photon beams is performed in the front end though their close separation requires them to share the same vacuum space in the optics hutch. Once the beams exit the optic hutch, their separation is large enough to have the two branches completely divided and each is delivered to a different experimental hutch, as shown in Figure 1.

![Figure 1. Schematic layout of the I20 beamline showing the two operational branches](image)

2. I20 scanning branch
The scanning branch of the I20 beamline is optimized for the XAS investigations of elements present in low concentration, and/or in unfavourable heavy matrices. The beamline aims to be particularly useful for application in the fields of catalysis, biology, environmental science and material science. The scanning branch covers the energy range from 4keV to 34keV and the schematic layout is shown in Figure 2.

2.1 Optics design.
The first optical element of the beamline is the primary slits, a set of cooled vertical and horizontal blades placed in the front end that will define the size of the beam to be used in the beamline. The beamline is then separated from the machine vacuum by a cooled diamond window that has a thickness of 100µm. This is designed to help reduce the heat load on the subsequent optical elements and allow more simple maintenance of the main optical components.

After the window, a pair of vertically deflecting mirrors operates at a 2.3mrad incidence angle to condition the beam for the monochromator. Both mirrors are coated with two different stripes to provide optimized performance in two energy ranges. A rhodium stripe will be used for operation up to 20keV, and a platinum stripe for operation from there up to 34keV. The first mirror is an upwards deflecting collimating mirror that is important for the optimization of the flux throughput of the monochromator. The second mirror is a flat downwards deflecting mirror that restores the horizontal trajectory of the beam, in order to simplify the alignment and operation of the monochromator.

The next optical element forms the heart of the beamline and is a four bounce monochromator [1]. This device provides a true fixed exit for the monochromatic radiation by simple counter rotation of two primary rotation axes. A particular advantage of the four bounce configuration is that the energy resolution is solely given by the intrinsic crystal cut being used, and is independent of the vertical divergence of the incident beam. If the synchrotron beam is subject to any angular movements, the four bounce configuration ensures that this is only translated into flux variations and not movement of the beam at the sample position, whilst the set of monochromatic slits placed after the monochromator performs the same action for any positional variations of the synchrotron beam. This is particularly important if absorption measurements are being made on inhomogeneous samples.

Due to the very demanding technical specifications of the four bounce monochromator, the design was undertaken in-house. Two different silicon crystal cuts will be used: Si(111) for energy operations from 4keV to 19keV, and Si(311) for operations between 7keV and 34keV.
After the monochromator, two more vertically deflecting mirrors are installed on the beamline to focus the beam at the sample position. Both of these mirrors are designed to operate at an angle of 2.3 mrad. The first mirror is an upwards deflecting horizontally focusing mirror of cylindrical geometry. In order to cover the whole energy range of the beamline this mirror consists of two interchangeable cylinders, the first is rhodium coated whilst the second is platinum coated. The second focusing mirror also has two stripes and provides vertical focusing at the sample point.

**Figure 2.** Schematic drawing showing the source and the main optical components for the scanning branch of I20

The last optical element of the beamline is a pair of harmonic rejection mirrors, positioned approximately four meters in front of the sample. These are vertically deflecting flat mirrors and will be used when the beamline operates at energies below 18keV. These mirrors have two coatings for optimal performance, rhodium and silicon, and the mirror pair can operate at angles between 3.5 mrad and 5 mrad to ensure the rejection of higher harmonics over the entire energy range of operation.

After each optical element a series of viewers have been incorporated into the beamline design to help with alignment and to provide essential beam diagnostics. Before the monochromator, these viewers are cooled diamond windows, whilst post-monochromator, YAG crystals are used. To complete the optical configuration of the beamline, a series of selectable filters are placed in front of the monochromator, in order to control the maximum heat load on the first crystal. After the monochromator, a set of horizontal and vertical slits will be used to define the monochromatic beam before the focusing mirrors.

2.1. **Experimental end-station**

The end-station for the scanning branch of the beamline consists of two modules, the first is an X-ray absorption spectroscopy module (XAS) for transmission and fluorescence measurements, and the second is an X-ray emission spectrometer (XES).

The design of the XAS module aims for easy operation. The different experimental setups to be used in the beamline will be pre-aligned and assembled on dismountable breadboards of dimension 600mm x 600mm. These boards can be removed and replaced on the experimental table with high reproducibility and they can be preconfigured for experiments that require different conditions: room temperature, cryostat, furnaces, etc…

The experimental table supports the transmission and fluorescence detectors. Three 30cm long OKEN ion chambers will be used to measure the incident and transmitted intensity of the x-ray beam whilst a 64 element monolithic germanium solid state detector will be used for the fluorescence measurements (Canberra). The read-out of the multielement detector will be implemented using the XSPRESS-II adaptive event filter system, developed at STFC [2].

The X-ray emission spectrometer is based on a 1m diameter Rowland circle that operates in the Johann configuration in the vertical plane. The spectrometer will work at angles as close as possible to
backscattering in order to achieve the best energy resolution. This is important as the I20 source size is relatively large. The spectrometer will be used for energies from 4keV to 20keV, and a large set of crystals with different cuts will be available to cover the Kα and/or Kβ emission lines.

An avalanche photodiode detector, APD, will be used for high count rate applications whilst an energy discriminating silicon drift detector (Vortex) will be available and can be used to reduce the background radiation for lower count rate samples.

3. I20 Dispersive branch
The design of the dispersive branch of I20 is tailored to deliver a broad energy bandpass and a high flux to the sample. These characteristics will allow the collection of extended XAFS spectra in a single shot and make this branch particularly suited to follow processes that occur on sub-second timescales down to milliseconds and microseconds.

The dispersive branch of I20 is planned to start operation in 2010, and due to space constraints only a brief description will be given in this paper.

3.1. Optics design
The first optical element of the beamline is a 500µm cooled beryllium window that will separate the dispersive branch of the beamline from the machine vacuum. Upstream of the window, a set of cooled primary slits will define the beam in the horizontal and vertical directions.

The first mirror of the beamline is housed in the optics hutch and is a downwards deflecting mirror used to focus the beam in the vertical direction at the sample position. This mirror will operate at an incidence angle of 3mrad, and it is coated with Rh and Pt stripes, in order to cover the operating energy range of the beamline, from 6keV to 26keV.

The white beam is then transferred to the polychromator hutch, where it is polychromatized via a single bounce curved crystal working in the horizontal plane. With this configuration, a broad range of energies is selected. In order to reduce the heat load on the polychromator, a combination of a flat mirror with three different stripes operating at different incident angles and a set of filters will be used. The polychromator will operate in a Bragg geometry, and two different crystal cuts will be used, Si(111) and Si(311). A Laue configuration polychromator is planned as a future upgrade.

3.2. Experimental end-station
As with the scanning branch, the end-station of the dispersive branch is designed for easy operation, with modular setups that will allow off-line alignment and simple installation on the beamline.

A critical element of any dispersive branchline is the position sensitive detector. I20 will be equipped with two 1024 pixel micro strip detectors that are each capable of collecting data in 1µs with a read out time of 10µs. For low energies, a silicon strip detector will be used, XSTRIP [3], whilst for high energies, the detector sensor material is substituted for germanium in the XH detector [4].

References

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