Experimental stations at I13 beamline at Diamond Light Source

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Abstract. The I13 beamline of Diamond Light Source has been operational since December 2011. The beamline encompass two fully independent branches devoted to coherent imaging experiments (coherent x-ray diffraction, coherent diffraction imaging and ptychography) and x-ray imaging (in-line phase contrast imaging, tomography and full-field microscopy). This paper gives an overview of the current status of experimental stations on both branches and outlines planned developments.

1. Introduction

High-resolution imaging and tomography with synchrotron radiation has been employed to a variety of scientific fields, among them biology and biomedicine, material science and engineering, geology and palaeontology etc [1]. Two I13 beamline branches, named in following imaging beamline and coherence beamline, are built to utilize the high brilliance of the 3rd generation synchrotron Diamond Light Source [2-6]. The imaging beamline employs well established imaging techniques as in-line phase contrast imaging and tomography to achieve micrometer scale resolution over the relatively large field of view of 100 mm². The full-filed X-ray microscope [7], providing the resolution down to 50 nm, is under commissioning. The I13 coherence branch aims to develop coherent X-ray diffraction techniques as a standard tool to overcome the limitation of real-space imaging sets primarily by the imperfect x-ray optics and detector resolution [8-10].

The layout of 250 m long beamlines has been already discussed and will be only briefly summarized here [4]. Two undulators are installed under a canting angle of 4 mrad in one of the long straight sections of the Diamond storage ring. The so-called mini-beta layout is employed [6], which allows a smaller undulator gap and focusing of x-rays into the front-end slits, which is used to adjust the size of the x-ray beam on the coherence branch. The energy range is from 6-20 keV, selectable by the four-bounce crystal monochromator (coherence branch) and double-crystal monochromator (imaging
branch). A total coherent flux of about $10^{10}$ photons/s/0.1%BW at 8 keV at the sample was estimated [4], which is confirmed using an ion chamber (3.4e photons/s/0.1%BW into a 200x200 µm aperture).

The design of the both end stations provides the versatility to host users experiments with different sample environment, including high/low temperatures and stress. In following, the present setups available to users on both branches will be described in chapters 2.1 and 2.2, including a planned upgrade.

2.1 The imaging station

The layout of the imaging station is shown in Figure 1. Emerging through the 300 microns thick CVD diamond window, the beam size is defined by set of horizontal and vertical slits to match the sample size (5x5 mm currently, up to 6x16 mm in the near future). In order to perform experiments with both pink beam and monochromatic beam, the experimental table height is adjustable using motorized jacks, to compensate for about 12 mm vertical offset introduced by the double crystal monochromator.

![Figure 1. Schematics of the experimental stage for the imaging branch of the I13 beamline. A KB mirror system which will be implemented later is also shown.](image)

Two independent setups are placed on the lateral motorized stage. This layout allows to quickly switch between experiments with different sample environments. The small load sample stage contains the XYZ stages below two-circle segments (+/- 15 degree motion range) for aligning the sample perpendicularly to the beam. On top of them sits a high performance air bearing stage. The radial and axial parasitic motions (wobbling) were measured to be below 1 µrad. The sample is mounted on a long range piezo XYZ stack with the resolution of about 20 nm. The maximum load is about 7 N, which allows installing a small heating element or a stress rig. The second sample stage is based on a hexapod and can accept user’s tomography setups weighting up to 90 kg.

The detector to sample distance can be freely adjusted from 0-2000 mm in order to modulate the edge enhanced contrast. The X-rays are transformed into visible light by a scintillation screen, which is imaged on the detector sensor (PCO 4000, PCO Edge and PCO Dimax for fast pink beam imaging) using a optical microscope objectives and tube lenses. The magnification could be chosen from 4X to 40 X, and the resolution close to 1 µm has been determined using a Siemens star). More details about detector system are given in [11] of this proceeding. The commissioning of the detector stage on the long rail (2-9 m sample to detector distance, which will increase the magnification) is scheduled for the end of this year.
The full field microscope is under commissioning is planned for later this year. The details of the instrument are described elsewhere [7]. Similar to a visible light microscope its main components are a capillary used as a condenser and a Fresnel-zone plate acting as an objective lens. As an indication, a FZP with 40 nm outermost zone width provides 50 nm spatial resolution. The microscope can be currently placed on the movable platform attachable to the sample stage, and the addition of the stand alone table is planned as the next phase to reduce mechanical vibrations.

2.2. The coherence station

The development of coherent diffraction imaging with the resolution down to 10-20 nm requires an excellent mechanical and thermal stability of both the detector and sample stages. In addition, coherent x-ray crystal diffraction entails a large working envelope detector positioning system, which consists of two industrial robots [5].

The sample stage is similar to the one described previously for the imaging branch (Figure 2 left), consisting of sub-micrometer resolution XYZ stages, +/- 15 degree two-circle segments aligned with an air bearing rotation stage and a XYZ assembly of slip-stick piezo motors with 5 nm resolution. The metrology performed on the piezo stages shows a parasitic motion of the order of 30 µrad over a few mm travel range, which makes them suitable for the ptychography scanning.

In addition to a tomography sample manipulation, the setup is suitable for the positioning of crystalline samples: together with the industrial robot it acts as a “3+2” circle diffractometer (ω, χ, φ, δ and γ, see [12] for the crystallography notation). Although, the angular range of the χ φ circles is limited, an independent movement of the detector arm with respect to the sample makes possible to cover a wide range of hkl diffractions. The distance sample to detector can be set to up to 5 m, thus providing sufficient sampling. In the case of forward direction experiment, this distance can be set to up to 19 m. A photon counting detector system based on the MediPix chip is currently under development [4].

![Figure 2](image.png)

**Figure 2.** The current sample stage on the coherence branch (left). The far field detector positioning system that is under commissioning is shown on the right.

Particular attention has been paid to ensure a long term stability of the detector arm. Recent experiments show that in spite of the temperature variation of +/- 0.2°C, the robot’s end effector does not drift more than 5 microns over more than 20 hours, as shown in Figure 3. Details about metrology performed on robotic arm can be found in [5]
Figure 3. The long term drift of the robotic arm, measured using optical length gauges. In spite of the temperature variation of +/- 0.2°C, the end effector does not drift more than few microns.

3. Summary

We report the current status of the I13 beamline end stations for imaging and coherence applications. The layout provide the flexibility to switch between different imaging techniques and adopt various sample environments. For all details about the beam line, please refer to [13].

4. References

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