This proposal is supporting a proposal submitted by Glenn Decker, titled "X-Ray BPM System Enhancement", category "Beam Stability".

Science:

Data quality is paramount for the success rate of structure determination by macromolecular crystallography and a limiting factor for solving structures from weakly diffracting and micro-crystals. Beam stability over the duration of data acquisition is a major pre-condition for high data quality.

The high throughput of macromolecular crystallography beamlines is largely due to the static experimental set-up. Set-up times are minimal. A new user group could start to collect data within 10 minutes after the begin of their assigned beam time – provided there is high long term stability of the beam. More importantly, a complete data set for a single project can be collected in 5-10 minutes from well-diffracting crystals. Therefore, any re-aligning of the optics and end station made necessary to respond to beam drifts will reduce the overall productivity noticeably. After a one or two day maintenance period, the beam should be exactly in the same position as before, so that after a 10 minute thermal equilibration of the optics data acquisition can begin immediately without having to re-align the goniostat to the beam.

The experience of all macromolecular beamlines is that the current beam stability is degrading data quality and requires too much time spent on frequent re-alignments. The experience is that in hybrid mode, the beam stability is much worse than in standard mode. The situation will get worse with the trend to ever smaller samples and, consequently, smaller beam sizes. Experience tells us that stability will further deteriorate with any new special request operating mode of the storage ring.

Of the two components of beam stability, source position stability and angular stability of the x-ray emission, it is the latter that causes the problems. Since the optics is highly demagnifiying and the sample is close to or in the focus, source movements of a few micrometer result in beam movements of a few tenths of a micrometer at the sample and have little effect. However, the residual surface figure errors of the focusing mirrors make the beam position and beam profile at the sample extremely sensitive to the beam angle. A minute change in beam angle moves the footprint of the beam on the grazing angle mirror by a sizeable amount into an area with a fraction of a microradian different surface slope and the beam at the sample is off by several micrometers. In addition, local variations of the radius of curvature result in local over- and underfocusing

Establishing our requirements:
Source position stability:
The current level of source positions stability appears to be sufficient.

Angular stability:
Current state-of-the-art mirrors of ~1 m length have a surface figure error of ~1 µrad rms or ~2.5 µrad FWHM. Bimorph mirrors that allow to correct surface figure errors in situ by means of piezo actuators have 10 mm wide electrodes. The footprint of the beam should not move more

than ½ of an electrode period, or 5 mm pk-pk. At ~3 mrad glancing angle, this translates to ~15 μm vertical beam movement. At a distance of ~50 m from the source, this corresponds to ~0.3 μrad pk-pk change of beam angle. Equating "pk-pk" with about ±1.5 sigma, the angular stability requirement is 100 nrad.

Time domain:
Long term run-to-run stability should be about twice the requirements established above. The angular stability requirements established above apply for short term DC and frequencies up to 100 Hz. Instabilities at frequencies >100 Hz have not much effect even considering shutterless continuous rotation modes of data acquisition.

Expected User Community:
Macromolecular crystallography beamlines.

Enabling Technology:
X-ray sensitive white beam position monitors (XBPM) using back fluorescence which is blind to radiation from corrector magnets. White beam intensity monitors, to be inserted after the beam defining aperture for a beamline, to help establish and maintain long term stability of the precise centering of the beam on the aperture.
The first design of the back fluorescing XBPM was a copy of the successful high resolution back fluorescing BPM for the monochromatic beam. Based on extensive tests, the device has to be redesigned to fit the surprisingly large size of the white beam.

For further development about $130k will be needed for:

- CVD diamond targets with specially patterned coatings;
- In-vacuum water cooling of targets
- Mechanical stages and control
- Vacuum chamber
- Support stands

(The vacuum chamber, support stand, and additional water-cooling will be necessary when the device is moved from its current location downstream of a 4x2 mm aperture to a location where it can be tested exposed to the full beam.)

The costs for fabrication and installation of the developed X-ray white beam position monitors on all sectors and the upgrade of the global feedback system is covered by the proposal submitted by Glenn Decker.

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