Technical Commissioning Plan

for the ISR Beamline

NX-C-XFD-ISR-PLN-003

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Acronyms 3
1 Overview 3
2 Beamline Components 3
3 Phases of Technical Commissioning 5
3.1 First Phase Commissioning at Ring Current < 5 mA 5
3.1.1 Activities before beam 5
3.1.2 Activities with beam 6
3.1.2.1 Section A (BPM1, HFM, VBD1) 6
3.1.2.2 Section B (DCM, BPM2, VFM, VBD2) 6
3.1.2.3 Section C (BPM3, DHRM, SSA) 7
3.1.3 Closeout of First Phase 7
3.2 Second Phase Commissioning (ramping to 85 mA) 7
3.3 Third Phase Commissioning at 250 mA 7
3.3.1 Initial Setup 7
3.3.2 HFM 8
3.3.3 DCM 8
3.3.4 VFM 8
3.3.5 DHRM 9
4 Deliverables from Technical Commissioning 9

Acronyms

BPM1	Beam Position Monitor 1
HFM	Horizontal Focusing Mirror
VBD1	Visual Beam Diagnostic 1
DCM	Double Crystal Monochromator
BPM2	Beam Position Monitor 2
VFM	Vertical Focusing Mirror
VBD2	Visual Beam Diagnostic 2
BPM3	Beam Position Monitor 3
DHRM	Double Harmonic Rejection Mirror
SSA	Secondary Source Aperture
FAM	Fixed Aperture Mask
WBS	White Beam Stop
C1	Endstation 1 Location in C Hutch
C2	Endstation 2 Location in C Hutch
D1	Endstation 1 Location in D Hutch
D3	Backwall in D Hutch

1 Overview

Here we present a living document that will capture plans to commission the ISR, 4-ID Beamline. There will be three phases of the technical commissioning. In the first phase, there will be low ring current during x-ray studies that will allow a preliminary alignment of the optical components safely. Since this will be the first time that any of the components will see photons, in this first phase we will closely monitor temperatures and pressures in the beamline in order to protect equipment. In the second phase, the goal will be to commission the beamline at increasingly higher ring currents until the beamline can safely operate during normal x-ray operations. In this second phase, radiation safety will be the primary focus, while diagnostics for equipment protection are monitored. In the third phase, beamline staff will be able to do detailed and final commissioning of all the key optical components during normal operations.

2 Beamline Components

Below is a diagram of the ISR beamline, which labels all the main optical components. This diagram has sufficient resolution so that if this document is being viewed in electronic form, one can expand the image sufficiently to see the labels of all the components.

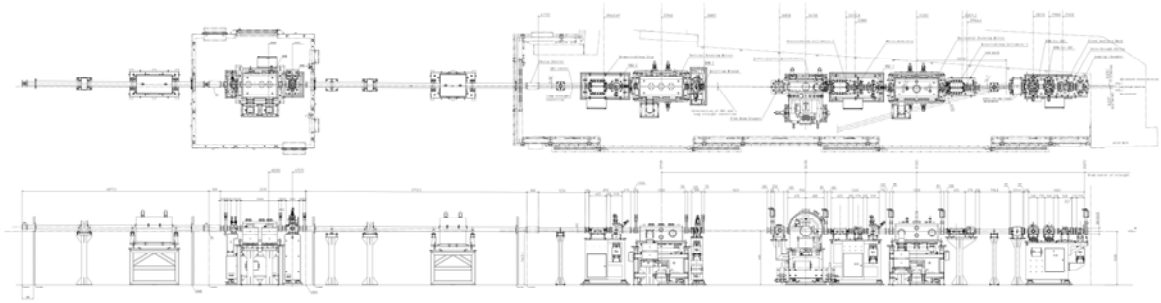

Figure 1: *Beamline Component Layout*

The minimum undulator gap (MING) for the ISR beamline is 6.1 mm, and the maximum usable undulator gap (MAXG) is 25mm. Figure 2 plots the photon energies for the first nine, odd undulator harmonics as a function of gap.

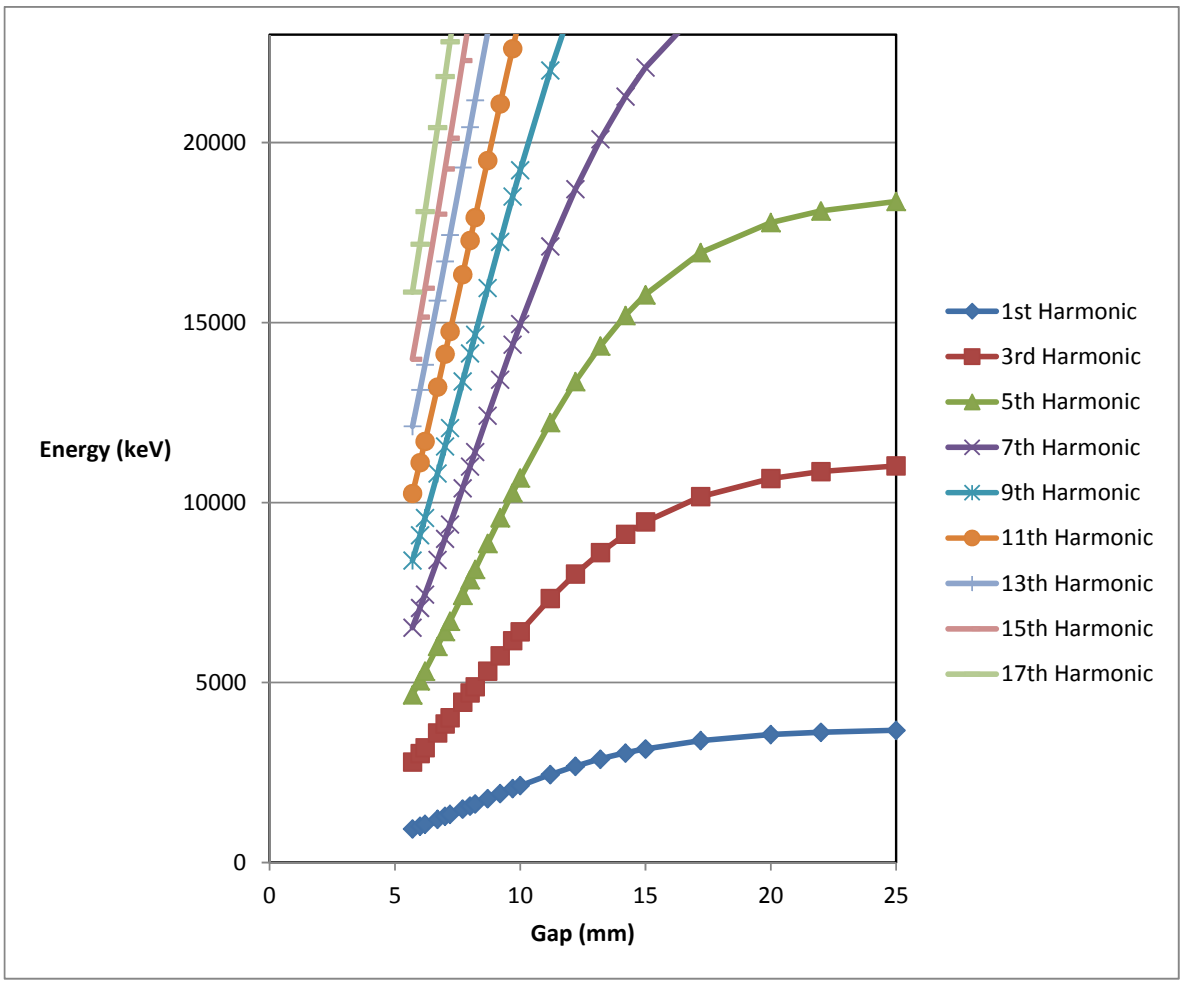

Figure 2: *Photon Energy versus Gap*

3 Phases of Technical Commissioning

3.1 First Phase Commissioning at Ring Current < 5 mA

The goal of the first phase at low current will be to position and orient all the optical elements to allow the beam to get to the experimental hutches. Ideally these positions and orientations would be the surveyed nominal positions, but we expect to make adjustments away from the surveyed positions that will reflect the actual beam path as opposed to the nominal designed beam path. In section 3.1.1, we list the preparatory activities needed before beam is enabled in order to efficiently use the studies beam. In section 3.1.2, we list the commissioning steps with beam enabled. These activities naturally break up into three sections— 3.1.2.1, 3.1.2.2, and 3.1.2.3— due to the locations of diagnostics in the beamline. In the title of each section heading, we list the key optical components in the section. Finally, in 3.1.3 we close out this first phase of commissioning.

3.1.1 Activities before Beam

For all the main optical and diagnostic components, there will be a pre-beam controls check to make sure the motions of the components can be controlled remotely through the controls interface. For any given component, all the motions and limits should be tested to make sure the motion can run into the limit and be recovered without jamming of any axes. This is what we refer to as the motion and controls Pre-Check, below.

- Motion Pre-Check for BPM1, HFM, VBD1.
- Confirm that BPM1 detector electronics and software controls are activated.
- Position BPM1 to be centered on the nominal beam position, using survey information.
- Position HFM nominally to be as flat as possible (radius of curvature as large as possible).
- Position HFM parallel to beam direction and retracted out of the way of the beam.
- Position HFM mirror so that when it is inserted in beam path, the Pd stripe is illuminated.
- Controls and video check of VBD1.
- Open Front End Slits.
- Setup StripTool from Control System Studio or equivalent software tool from BlueSky to create a “chart-recorder” of all the thermocouples in this section (Process variable names; MSK:1, MSK:2, Mir:HFM, BS:WB).
- Setup StripTool for monitoring vacuum pressures in this section (*CCG*).
- Position DCM at the smallest angle possible, to spread the heat load out.
- Motion and controls Pre-check of DCM, BPM2, VFM, VBD2.
- Detector electronics and software controls check of BPM2.
- Position VFM retracted from beam path.
- Position VFM surface nominally parallel to beam.
- Position VFM so that the Pd stripe is illuminated when VFM is translated into the beam.
- Controls and video display check of VBD2.

- Position VBD2 into beam path.
- Setup StripTool on relevant thermocouples (Mono:DCM, BS:PB).
- Setup StripTool on relevant vacuum pressure readings (*:CCG:*)
- Position DHRM nominally flat and out of the way.
- Open SSA wide.
- Position ion chamber and associated electronics in Hutch C, and confirm that the controls allow one to record the values.
- Position a YAG screen and camera in Hutch C.
- Position and motorize analyzer crystals in Hutch C.
- Photon Shutter 1 and Photon Shutter 2 closed.

3.1.2 Activities with Beam

3.1.2.1 Section A (BPM1, HFM, VBD1)

- Enable the Front End shutter at low current, with insertion device gap at MAXG.
- Position VBD1 into the beam.
- Observe beam position with BPM1. Adjust BPM1 position to “zero” beam position. If the beam is not visible, increase the incident power down the beamline by closing the undulator gap.
- If possible, visually verify that the beam is centered within the upstream apertures. It may be that there is so much light even at the lowest possible commissioning current that the VBD is saturated, and one cannot discern any positional information.
- Monitor for safe temperatures of the FAMs and WBS.
- If possible to visually discern the center of the beam, close Front End slits around the beam.
- Translate HFM into beam, using VBD1 as visual feedback. Iterate on the motors to orient the surface of the HFM to be as parallel as possible to the beam direction, and cut half the visible beam.
- Monitor for safe temperatures on the HFM thermocouples, particularly the disaster mask.
- Rotate HFM to nominal 0.15 degrees. If possible find real zero visually on VBD1.
- Scan the mirror through the beam to determine the middle of the mirror using VBD1.
- Remove VBD1 from the beam path.

3.1.2.2 Section B (DCM, BPM2, VFM, VBD2)

- Set the DCM Bragg angle to 11.020 keV and scan DCM second crystal theta angle slowly to determine the precise offset for the theta angle of the second crystal using VBD2.
- Repeat this second crystal theta alignment with quantitative signal from BPM2.

- Monitor that the DCM thermocouple readings are within a safe range.
- Translate VFM into beam, using VBD2 as visual feedback. Iterate on the motors to orient the VFM mirror surface to be parallel to the beam, and cut half the visible beam.
- Monitor for safe temperatures on the VFM thermocouples (process variable names; Mir:VFM).
- Rotate VFM to nominal 0.15 degrees. If possible find real zero visually on VBD2.
- Scan the mirror through the beam to determine the middle of the mirror using VBD1.

3.1.2.3 Section C (BPM3, DHRM, SSA)

- Open Photon Shutter 1.
- Observe BPM3 respond to the beam.
- Open Photon Shutter 2 to allow beam to pass into C Hutch.
- Close SSA to a small opening (1 mm x 1 mm or smaller), and observe the SSA position that is centered on the beam. Verify that opening the SSA wide allows all the x-ray beam to pass.

3.1.3 Closeout of First Phase

At the close of the first phase, which has been at a low ring current and with a wide undulator gap, we now close the gap to maximize the power delivered to the beamline at this current. We monitor all the relevant indicators: thermocouples on the masks and optical elements, vacuum, and beam position. We will measure the total flux at 10 keV with the ion chamber in Hutch C.

3.2 Second Phase Commissioning (ramping to 85 mA)

In the second phase, the ring current is ramped up with the goal to obtain permission for the beamline to operate during standard operations as quickly as possible. Still in a studies period, we will step up the ring current, for example, to 25 mA, 50 mA, and ultimately 85 mA. The undulator gap will be opened to MAXG at each step in ring current, and then it will be closed toward MING until pressures and temperatures of masks, stops, and optical elements stabilize. The critical elements that need to be monitored are the first FAM through the pink beam stop, because those masks, stops, and optical elements take the brunt of the power from the undulator. The critical test will be when the beamline is exposed to the maximum heat load from the undulator at MING. The beamline components should not need to have their orientations adjusted, since they were already determined in the first phase. Once a ring current of 85 mA is reached, the Comprehensive Radiation Survey (CRS) will be carried out to qualify for operations at 250 mA. The only motions of beamline components needed during the CRS are the insertion and retraction of optics from the beam path. Beamline slits will also need to be fully opened, and the undulator gap closed to MING.

3.3 Third Phase Commissioning at 250 mA

Once the beamline has been allowed to operate during standard operations, one turns to detailed commissioning of the key optical components working downstream.

3.3.1 Initial Setup

- Install visual monitoring of beam at position C1, C2, and D3

- Install ion chambers for quantitative measurement of beam at position C1

3.3.2 HFM

- Set gap so that there is a low power incident on the beamline with photon energy within the beamline bandwidth, i.e. between 2.4 keV and 23 keV.
- Adjust the benders to focus at C1, C2, and D3, using visual methods if possible. It may be necessary to do this quantitatively with a scanned pinhole. These measurements should generate a table that will allow us to focus the beam anywhere along the beamline, including at the SSA, by interpolating and extrapolating from this table of values. Since one does not have a visual diagnostic at the SSA, one can confirm the validity of this interpolation table at the SSA location by monitoring the flux through a small aperture setting of the SSA.
- Check the dependence of the table on incident power on the beamline. One will almost certainly need a "matrix" calibration, not just a "table", because the heatload effect will be significant for the HFM.
- Repeat the above calibration for both stripes.
- Measure the vibrational properties of the HFM as a function of water flow.

3.3.3 DCM

- Perform an energy calibration at binding energy of Ge with a foil that will be put in position C1. Repeat calibration at a distribution of between 3 to 5 chosen energy edges across the energy range of the DCM. The elements Cu, Ge, Zr, and Mo are good choices. This will not be the final energy calibration of the DCM. Adjust the zero of the DCM if needed.
- From VBD2, observe the sideways motion of the diffracted beam as one moves from the low energy cutoff to the high energy cutoff. Adjust chi2 to minimize sideways shift.
- Repeat at position C1, and also at D3 if possible. As one moves further downstream, sensitivity increases, and the two crystals can be made more parallel.
- When satisfied with the crystal parallelism, re-calibrate the DCM across the energy range, and calibrate all motions of the DCM, generating a table of all motors at the given energy.
- Turn on feedback control, using the signal from BPM3.
- Adjust the undulator gap to match the calibration energies, and record the motor positions. There will be some differences, because the heat load will increase as the gap is closed. Indicators of heat load should be monitored as one increases the heat load.
- Study the vibration signal as a function of LN2 flow, to determine maximum stable flow.
- Measure width of undulator harmonics.

3.3.4 VFM

- Pick a matching gap and DCM energy.

- Adjust the benders to focus at C1, C2, and D3, using visual YAG screen methods if possible. It may be necessary to do this quantitatively with a scanned pinhole, if the visual methods are not helpful. This should generate a table that will allow us to focus the beam anywhere including at the SSA. One can check the validity of the table at the SSA location by monitoring the flux through a small aperture setting of the SSA.
- Repeat the focus tests at different undulator gaps.
- Measure the vibrational spectral properties of VFM, using the most sensitive scale of the piezo sensor.

3.3.5 DHRM

- Calibrate the analyzer crystal in Hutch C, so that it can track the monochromator settings.
- Using a YAG screen in the C Hutch, translate the DHRM into the beam.
- Find the zero offset for DHRM angles.
- Identify optimal motor settings that put the DHRM in and out of the beam.
- Generate a matrix that one can program harmonic rejection ratio as a function of energy.
- Measure the transmission of DHRM as a function of energy.
- Measure the reduction of harmonic content of the beam using the analyzer crystals, as a function of DHRM angle.
- Measure the vibrational properties of DHRM. This is not adjustable; there are no cooling parameters to adjust.

4 Deliverables from Technical Commissioning

- Generate a matrix/spreadsheet of beamline parameters that optimize the flux through the SSA as a function of beamline energy. Parameters will include undulator gap, HFM motor settings, DCM motor settings, and VFM motor settings.
- Activate feedback based on BPM3.
- Study vibrational stability of main components.
- Generate a matrix of mirror parameters that will focus at SSA, C1, C2, and D1 as a function of beamline energy.
- Measure spot size at SSA, C1, C2, and D1.
- Measure transmission efficiency of each optical element on the beamline, and compare with simulations to identify underperforming elements.
- Measure net beamline transmission as a function of energy.
- Create a Harmonic rejection efficiency table of DHRM to allow interpolation at desired energies.
- Determine a stable flow rate of LN2 through the DCM.

- Determine a stable flow rate of water through the HFM.
- Using above information, choose best choice undulator/monochromator settings for beamline operation at specific energies.