Precision Insertion Device Control and Simultaneous Monochromator Fly Scanning for NSLS-II

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Introduction

Eight of the 10 In-Vacuum Undulators (IVU) at NSLS-II underwent in-house in-situ control system upgrades allowing for control of the magnetic gap during motion down to the 50 nm level with an in-position accuracy of nearly 5 nm. Direct linking of Insertion Devices and beamline monochromators allows precise, simultaneous, nonlinear motion of both devices and provides a fast hardware trigger for real-time accurate insertion device and monochromator fly scanning. The precision achieved for simultaneous motion is detailed here. Particular attention is given to the precision at which undulator energy harmonic peaks can be tracked and the variation of the peak flux in motion.

IVU Control Systems Upgrade

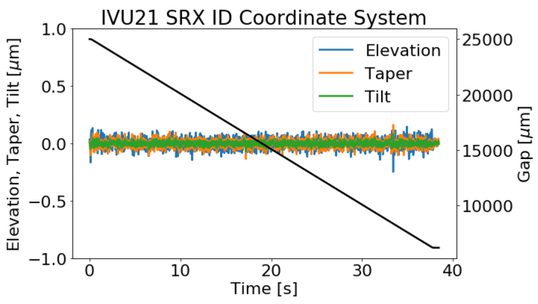
In-house upgrades were performed for
- Two 3 [m] long 20 [mm] period (IVU20)
- Three 2.8 [m] long 23 [mm] period (IVU23)
- Three 1.5 [m] long 21 [mm] period (IVU21)

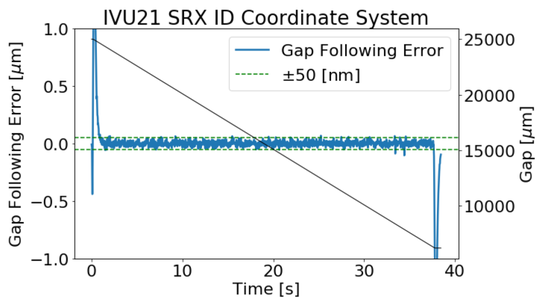
For IVU23s and IVU21s, the 4 motor axes (TU, TD, BU, DB) are mapped as

$$\begin{bmatrix} gap \\ elevation \\ taper \\ tilt \end{bmatrix} = \begin{bmatrix} \frac{1}{2} & \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \\ \frac{1}{4} & \frac{1}{4} & -\frac{1}{4} & -\frac{1}{4} \\ 1 & -1 & 1 & -1 \\ \frac{1}{2} & -\frac{1}{2} & -\frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} TU \\ TD \\ BU \\ BD \end{bmatrix}$$

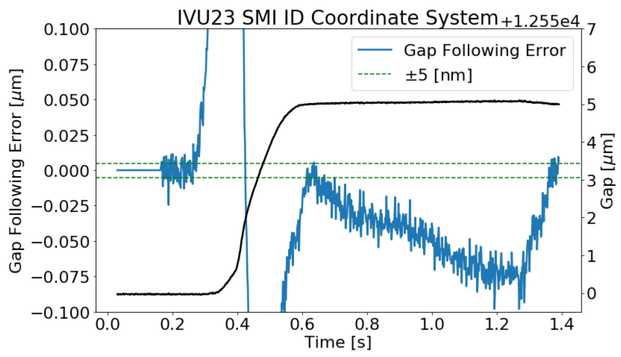
Where T, B, U, D are: Top, Bottom, Upstream, Downstream.
The same transformation is used in the forward and inverse kinematics.

The accuracy of magnetic gap control during motion is nearly 50 [nm] (left). Other virtual motions (right) are similarly accurate.



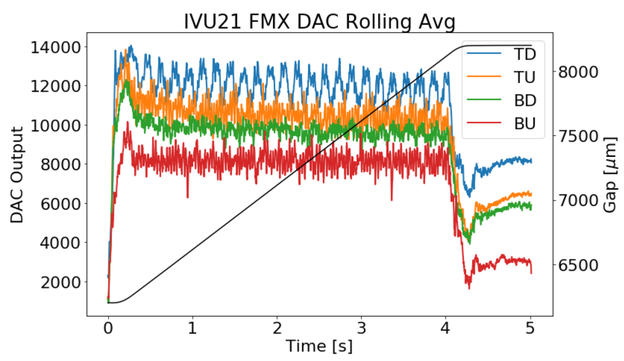


Final positional accuracy is nearly 5 [nm] (by encoder).



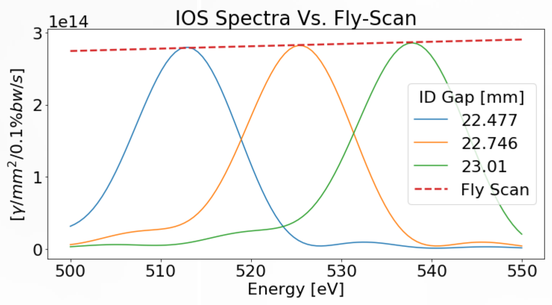
Diagnostics

The DAC output to the amplifier can be monitored as a diagnostic tool for mechanical misalignment or wear over time.



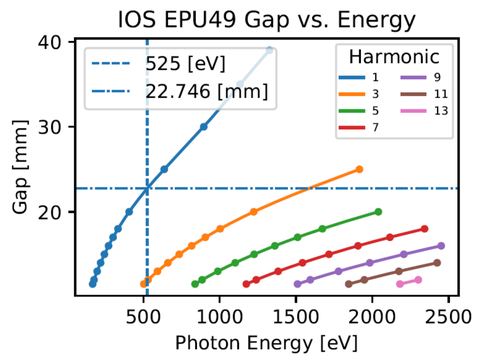
Fly Scanning

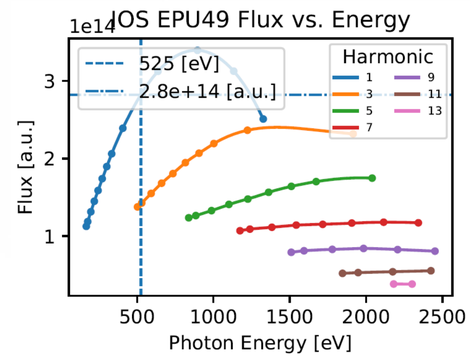
Challenges:
- Stay on undulator spectral peak
- Maintain highest possible flux
- Non-linear coordinated motion due to magnetic field non-linearity with magnetic gap



Gap and Flux vs Energy

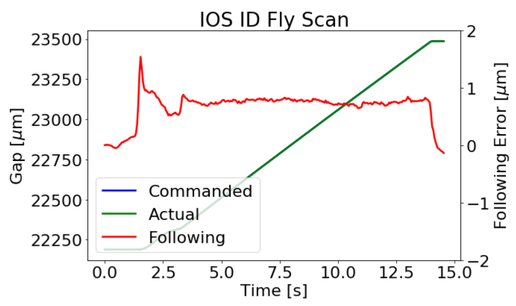
Gap / flux vs photon energy curves for insertion devices can be calculated from magnetic field measurements and from beamline data. Below is an example showing the non-linear behavior for both magnetic gap and output flux for different harmonics of the IOS EPU49

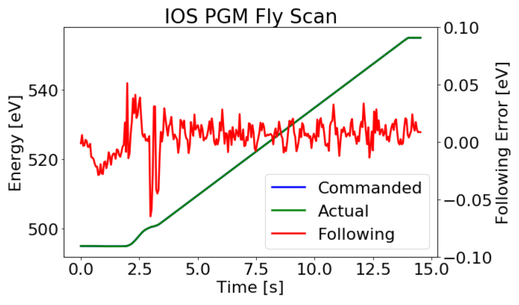




ID and Monochromator fly scan performance

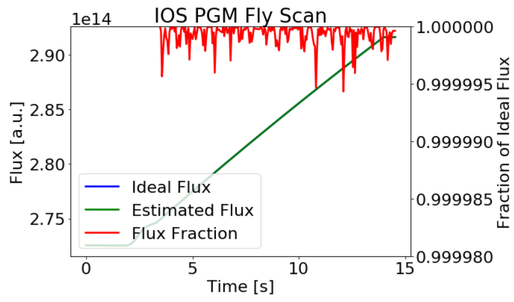
Position data was collected in real-time on the ID and monochromator controllers during fly scans. The following errors in terms of gap and monochromator energy are shown below.





Fly Scan Estimated Flux

The estimated fraction of the ideal flux based off of a 10 [eV] width Gaussian (artificially small to exaggerate the effect) shows less than 10 PPM in flux variation.



Control Systems

- EPICS, Control System Studio, and Bluesky Data Collection Framework
- Controllers operate in individual mode or a linked mode coordinated through Delta Tau PLC scripts via MACRO Ring.
- User enters energy Start, Stop, Speed [eV/s] and independently defines trigger outputs similarly.
- Bluesky manages detector staging, fly scanning parameters, and data and meta data acquisition and storage.

Future Work

- Improved trigger resolution
- Improved monochromator tuning and mechanical stability
- IVU21 and double crystal monochromator fly scanning

Acknowledgements

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