A MHz sampling DAQ system for sub-second Quick XAFS at the SLS-2.0 "Debye" beamline

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Abstract

The new “Debye” beamline[1] at the SLS-2.0 will provide continuous sub-second X-ray absorption spectroscopy and co-located X-ray diffraction under operating conditions with a photon energy range of 4.5 to 60 keV. Based on a highly successful design at the SuperXAS beamline, the Debye QEXAFS monochromator is designed to produce spectra of monochromatic X-rays at up to 10 Hz by continuous oscillation of the Bragg axis. In order to improve the resolution and signal-to-noise ratio of the bandwidth limited analog input channels (i.e. ion chambers), synchronized continuous oversampling is performed on the monochromator Bragg angle and detector channels using National Instruments (NI) hardware. Low level software controls are provided by the NI supported Python API for the NI-DAQmx library. High level controls of the DAQ pipeline are implemented in a GUI and allow for fine control over DAQ parameters, along with selection of input channels. Lossless data reduction of the data stream and optional descriptive statistics are generated in real-time, after which the resulting signals I0 and I1 signals can be ratioed to produce XAFS spectra that are readily analyzed using data analysis software available in the community, or displayed on consoles.

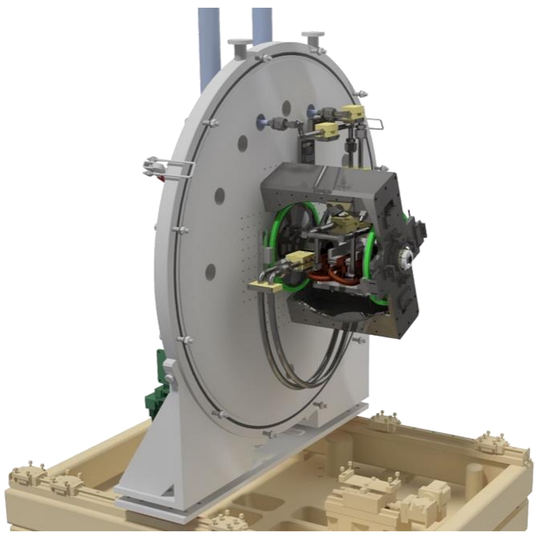

Figure 1. The QEXAFS monochromator utilizes a direct-drive torque motor to facilitate scan speeds for a specific energy range with up to 20 spectra per second (full EXAFS), but can also be operated in step-scanning mode by using the same motor. The monochromator is a further development of the proven and successful monochromator initially built by the University of Wuppertal and further developed by PSI[2].

Figure 2. The Debye DAQ hardware is based on the National Instruments PXIe line. The PXIe-6396[3] multifunction I/O module 18 bit analog input sampling at 14 MS/s on up to 8 channels, while the PXIe-6614[4] counter/timer module provides quadrature encoder position sampling. The system is configured to sample based on a common clock generated by the backplane, and ensures both long term hardware-level synchronization of data acquisition and simultaneous triggering of data acquisition.

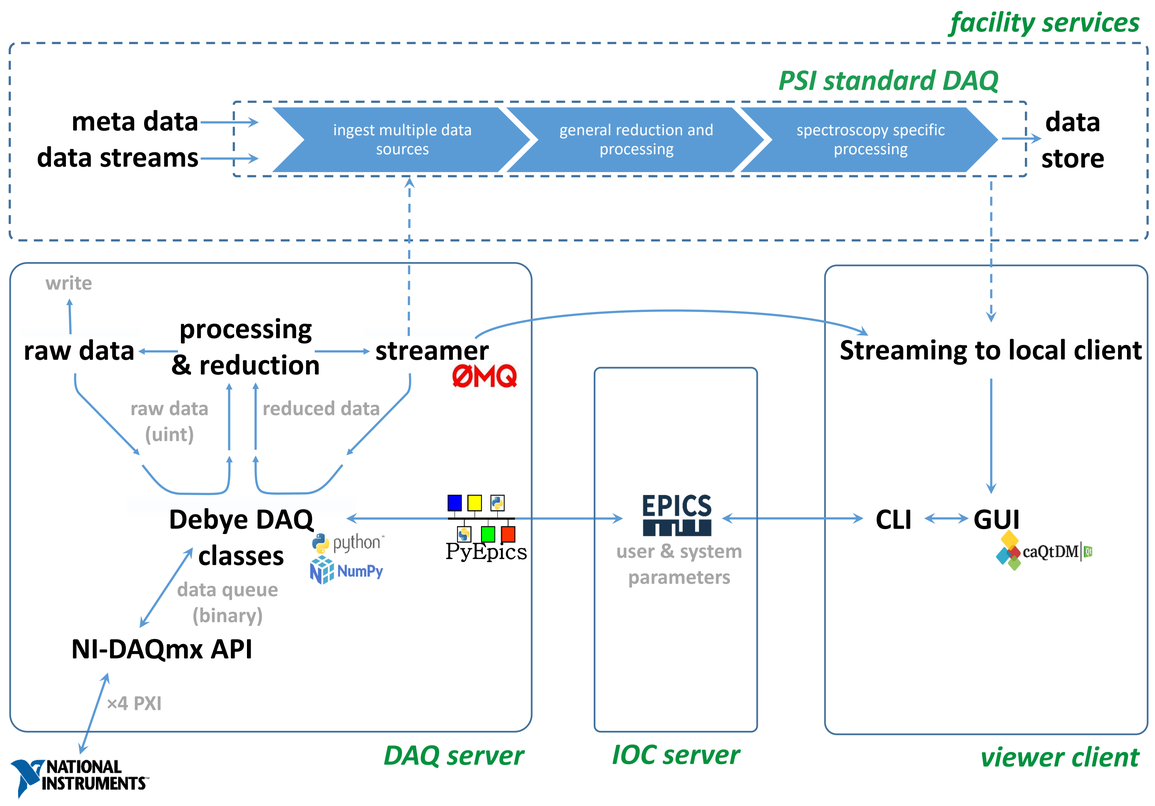

Figure 3. High level DAQ Scheme based on National Instruments' Python nidaqmx API for the NI-DAQmx driver[5]. The *DAQ server* runs custom Python scripts to perform high rate data acquisition, provides a low level hardware control interface, and performs initial reduction of data to reduce the data stream by a factor of 1000. The *IOC server* provides an interface to the low level hardware control interface via channel access to clients and optionally other acquisition control systems. The *viewer client* provides a real-time plot of individual data streams and allows for ratio-ing of data streams to produce preview quality XAS spectra. Work is in progress to integrate this DAQ system into the PSI standard DAQ pipeline, which provides more data processing capability, file storage, and streaming to multiple clients.

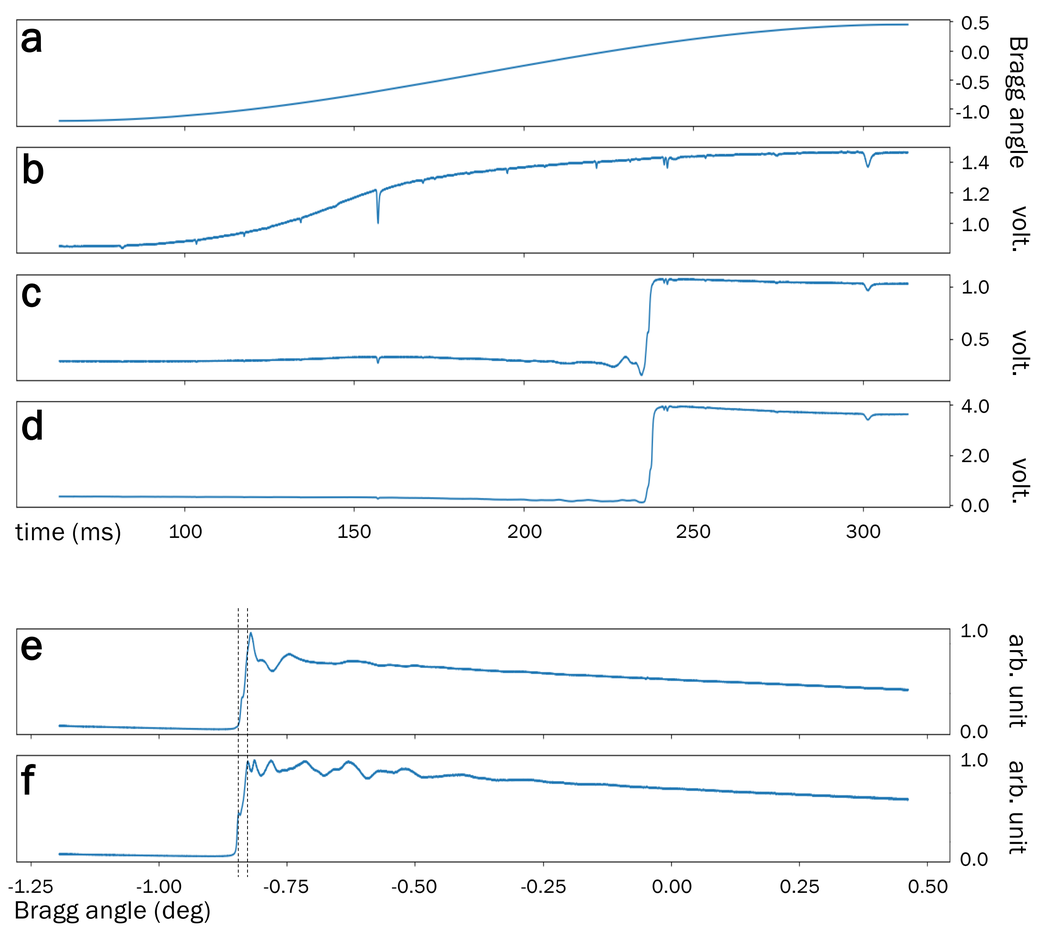

Figure 4. a) Bragg angle vs time; b) I0 voltage vs time; c) I1 voltage vs time; d) I2 voltage vs time; e) ln(I0/I1) vs Bragg angle of a Cu(II) standard; f) ln(I1/I2) vs Bragg angle of a Cu-foil.

Sampling test of the Debye DAQ prototype at the SLS SuperXAS beamline using a Copper(II) standard and Copper Foil. The Debye DAQ was used to read in Bragg angle and ion chamber voltages at 200 kHz. Data were collected over 1 sweep of the monochromator Bragg axis over a range of ~2.0 deg during ~500 ms. Spectra for the Cu standard and foil were collected simultaneously. Since spectra were not offset corrected in the energy axis, the data are plotted against Bragg angle (deg).

References:

1) SLS-2.0 Debye beamline (psi.ch/sls/debye)
2) Quick-EXAFS setup at the SuperXAS beamline for *in situ* X-ray absorption spectroscopy with 10ms time resolution (doi:10.1107/S1600577515018007)
3) PXIe-6396 Multifunction I/O Module (https://www.ni.com/en-us/support/model.pxie-6396.html)
4) PXIe-6614 Counter/Timer Module (https://www.ni.com/en-us/support/model.pxie-6614.html)
5) Python API for interacting with NI-DAQmx (https://github.com/ni/nidaqmx-python)