TEMPERATURE CONTROL OF CRYSTAL OPTICS FOR ULTRAHIGH-RESOLUTION APPLICATIONS

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The temperature control of crystal optics is critical for ultrahigh-resolution applications such as those used in meV-resolved Inelastic X-ray Scattering (IXS). Due to the low count rate and long acquisition time of these experiments, for 1-meV energy resolution at ~10 keV, the absolute temperature stability of the crystal optics must be maintained below 4 mK for days to ensure the required stability of the lattice constant, thereby ensuring the energy stability of the optics. Furthermore, the temperature control with sub-mK resolution enables setting the absolute temperature of the individual crystal, making it possible to align the reflection energy of each crystal's rocking curve in sub-meV precision thereby maximizing the combined efficiency of the crystal optics.

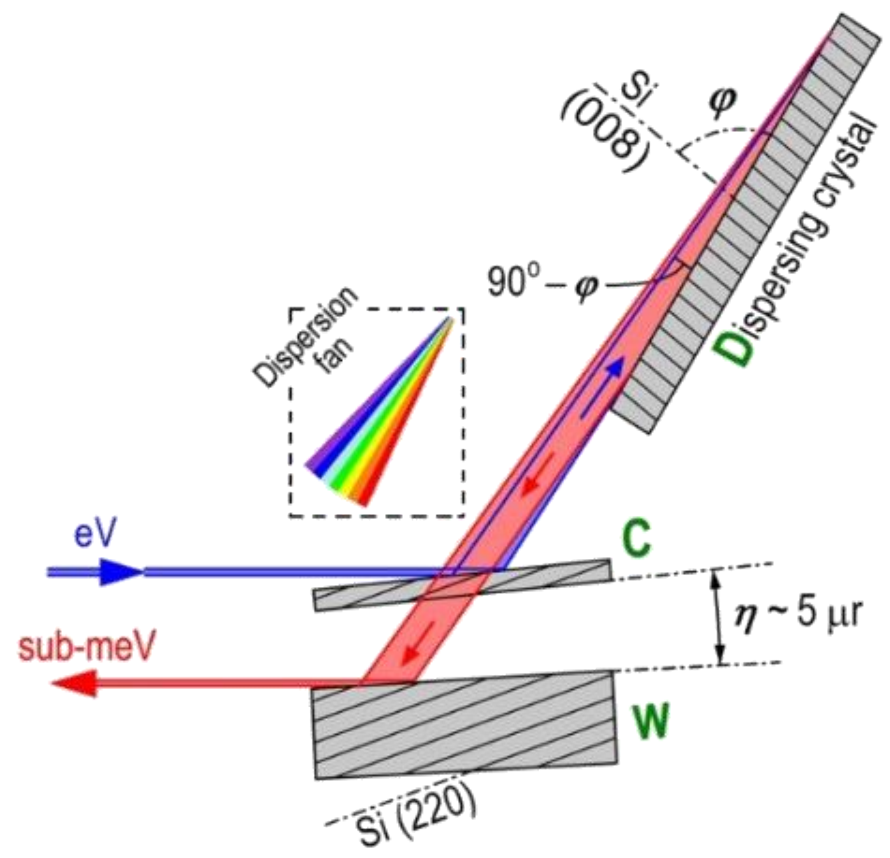

Figure 1. Schematic layout of the analyzer crystal optics employed at the meV-IXS spectrometer of the IXS 10-ID beamline at NSLS-II.

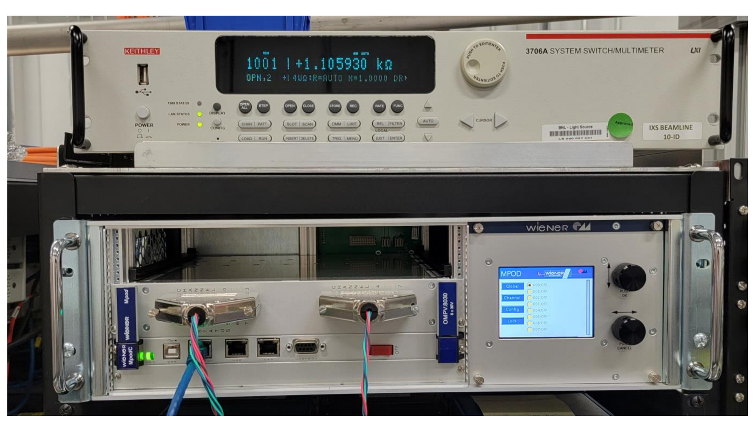

Figure 2: Keithley 3706A (top), and MPOD power supply (bottom).

Figure 3: Temperature PVs read from Keithley 3706A for each PT1000 sensor.

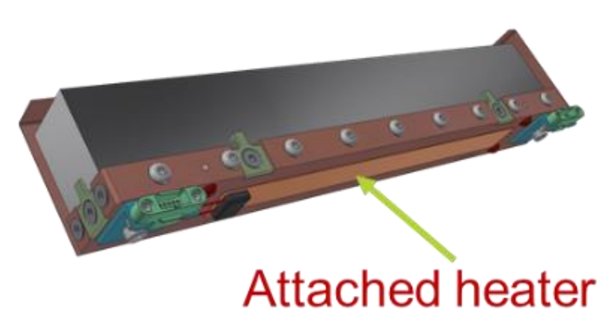

Figure 6: Crystal housing assembly showing the heater and sensor attachment to the D-crystal.

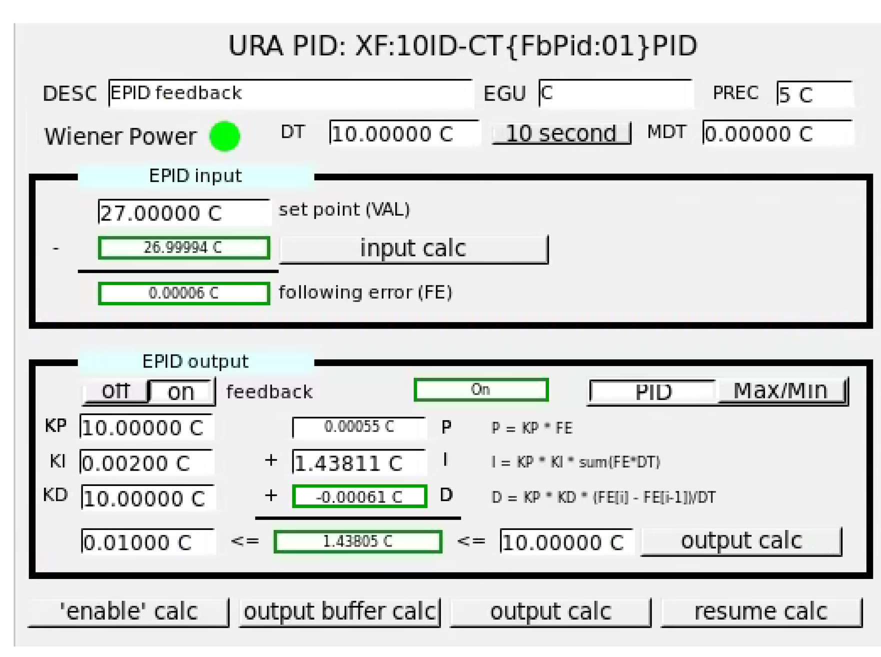

Figure 4: ePID EPICS record computes output power to specific MPOD power supply channel.

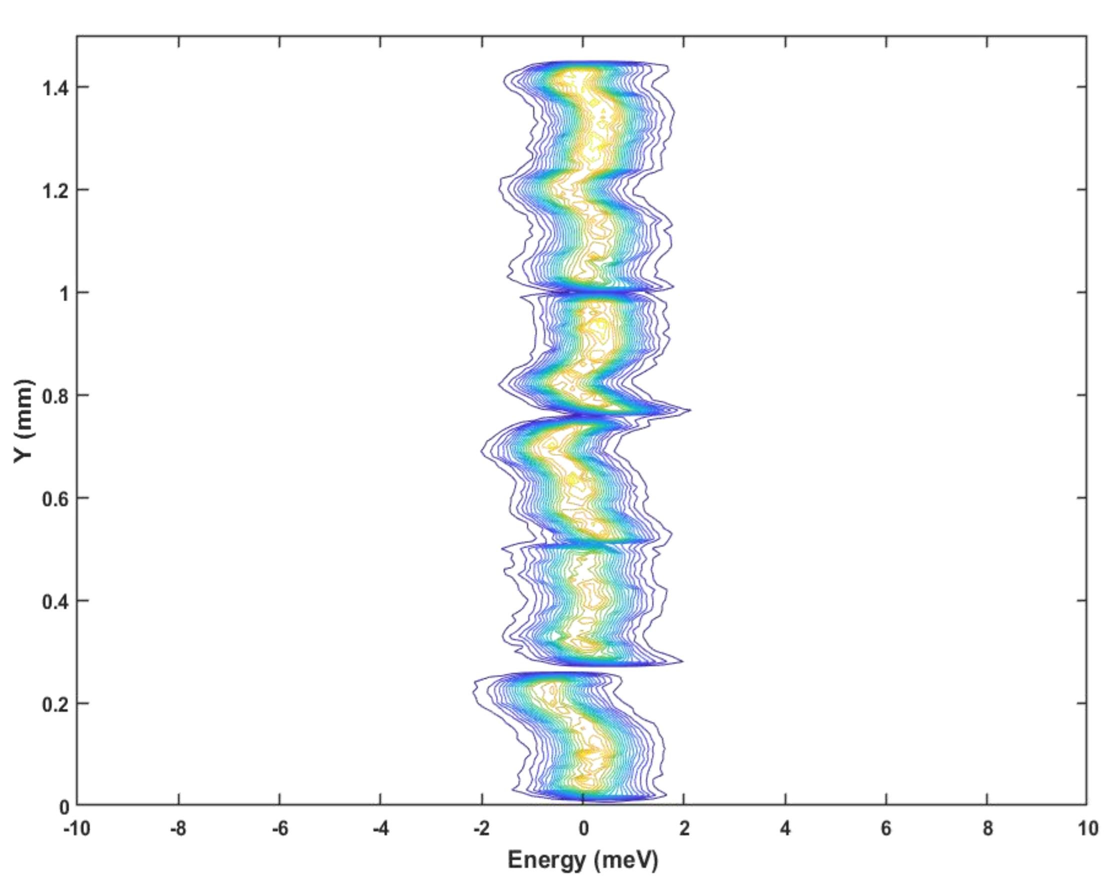

Figure 7: The reflectivity contour of the temperature-stabilized and energy-aligned D-crystals vs. energy resolution. The Y axis corresponds to the beam height for each of the 6 D-crystals in the analyzer.

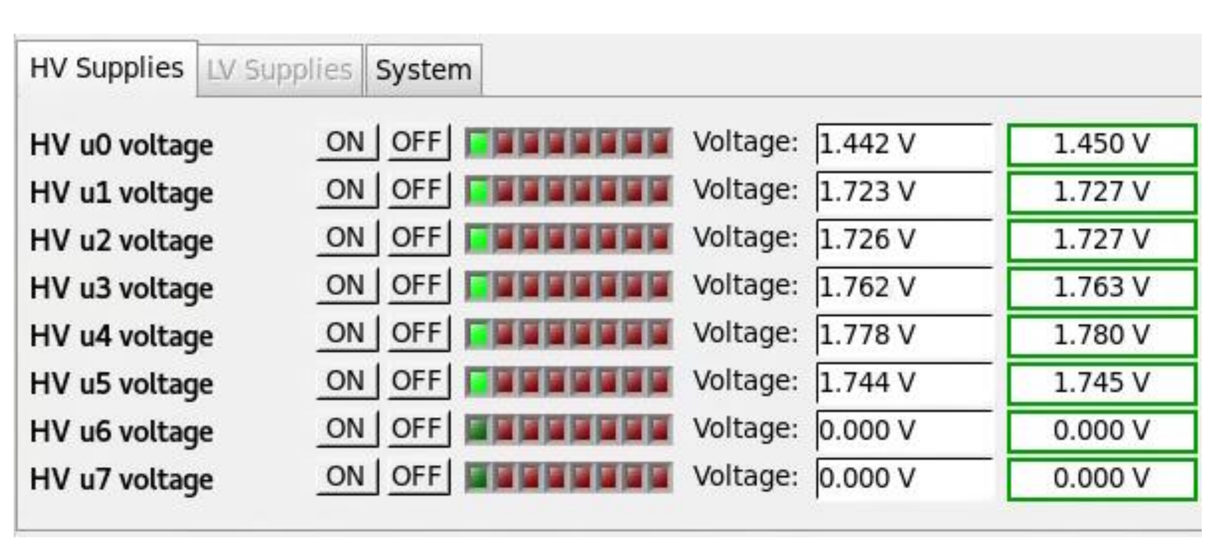

Figure 5: MPOD Power supply voltage fed from the ePID EPICS record controls the power delivered to the D-crystals.

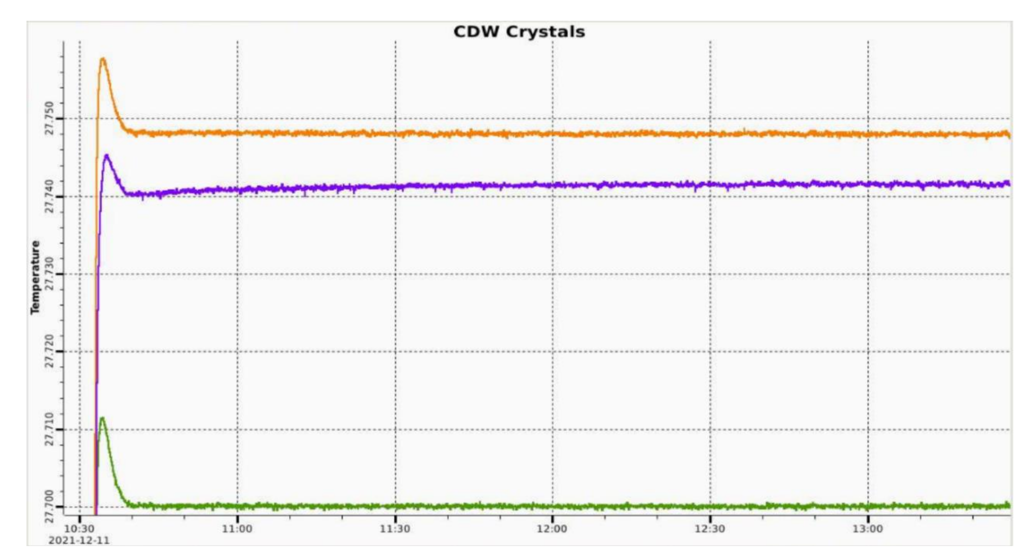

Figure 8: Temperature response of one of the D-crystals. The three PT1000 sensors were mounted at the control point, and each of the two crystal ends respectively

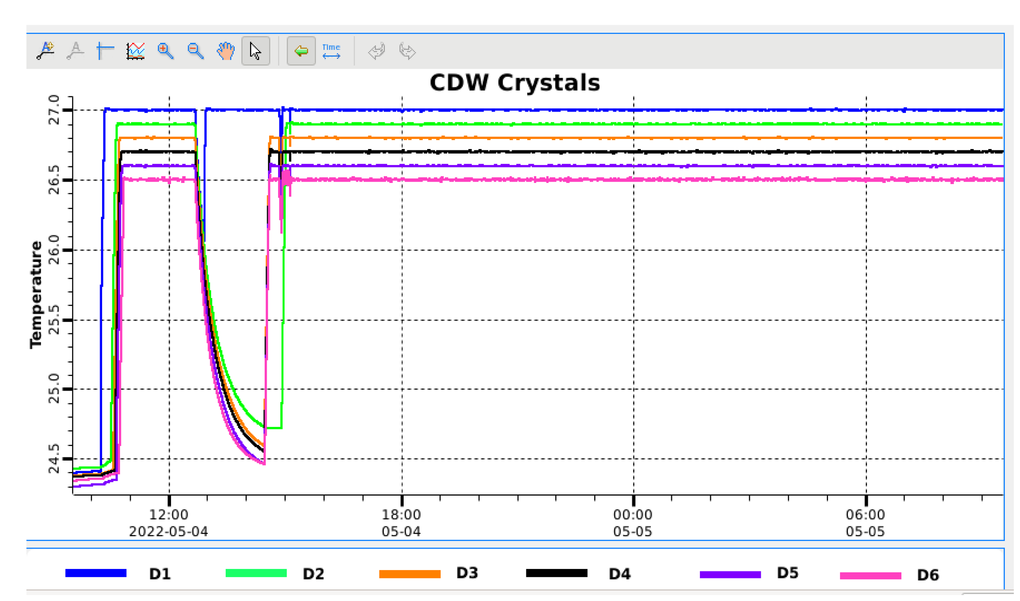

Figure 9: Temperature response of the 6 D-crystals with and without ePID temperature control.

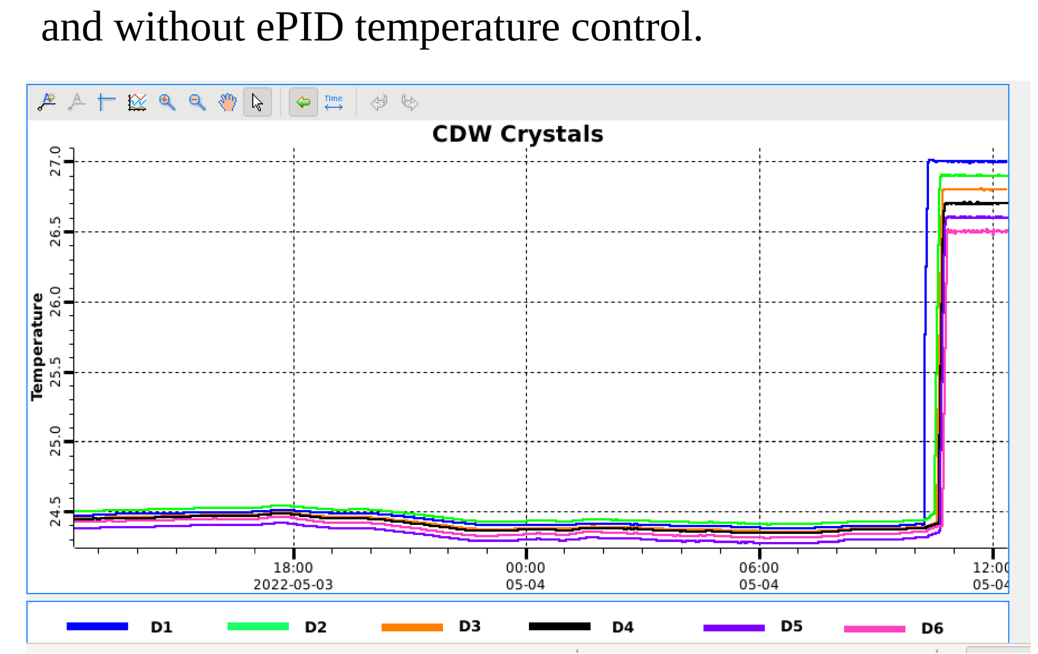

Figure 10: Temperature stability with and without ePID feedback.

Using EPICS ePID control we achieved the required 4 mK temperature stability of the D-crystals for the analyzer crystal optics of the meV-IXS spectrometer for the NSLS-II IXS 10-ID beamline. The temperature stability is less than 1 mK during a typical one-week measurement. Without ePID EPICS temperature control, the temperature stability has been within 100-500 mK. The resulting energy resolution of the IXS 10-ID beamline is now limited by the perfection of crystal optics to about 1.4 meV.

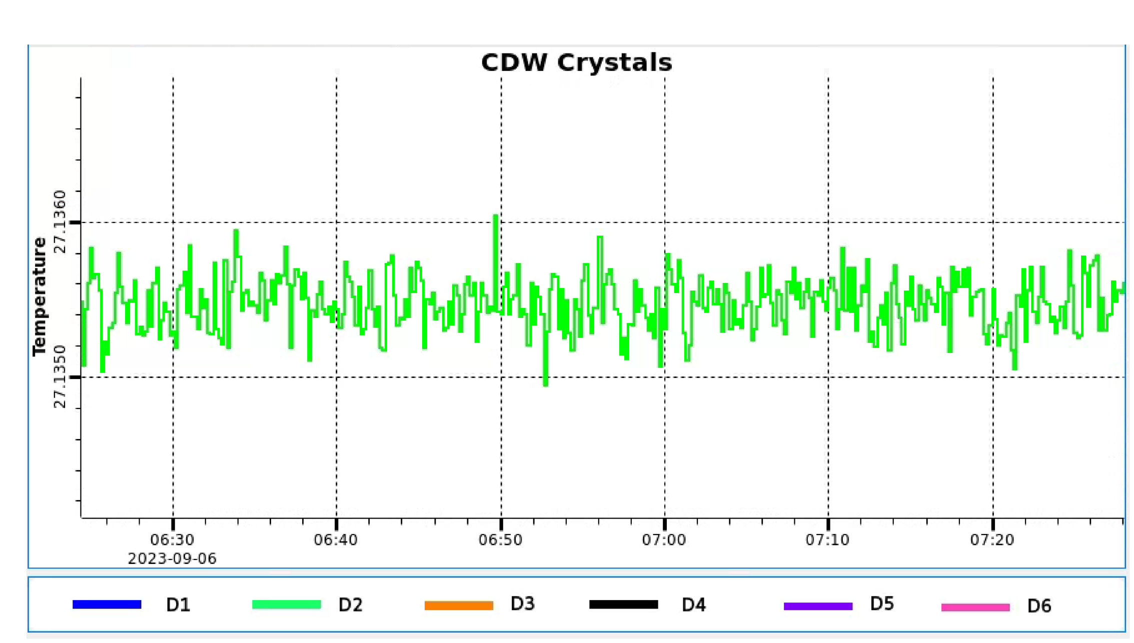

Figure 11: Temperature stability of one of the D crystals with ePID feedback, showing a stability of below 1 mK.

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