Nanoradian Angular Stabilization of X-ray Optical Components

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In collaboration with

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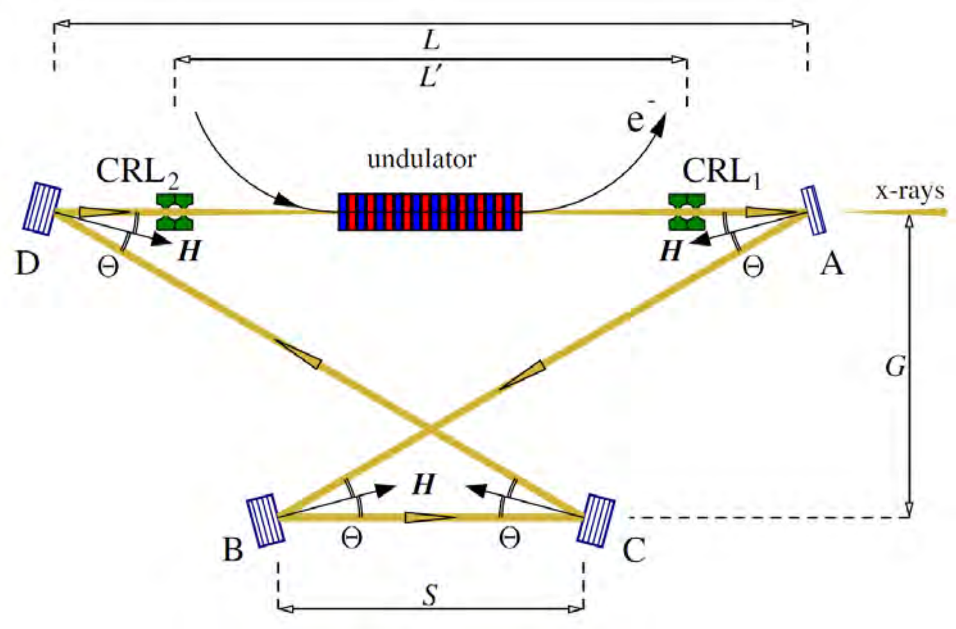
Outline

- **Stabilization of high resolution x-ray optics.**
- **Automatic adjustment of Bragg angle: principle of operation**
- **Implementation at Sector 30**
- **Performance**
- **Operation**
- **Conclusions**

Motivation: feasibility studies of XFELO

Precise control of the cavity geometry is needed



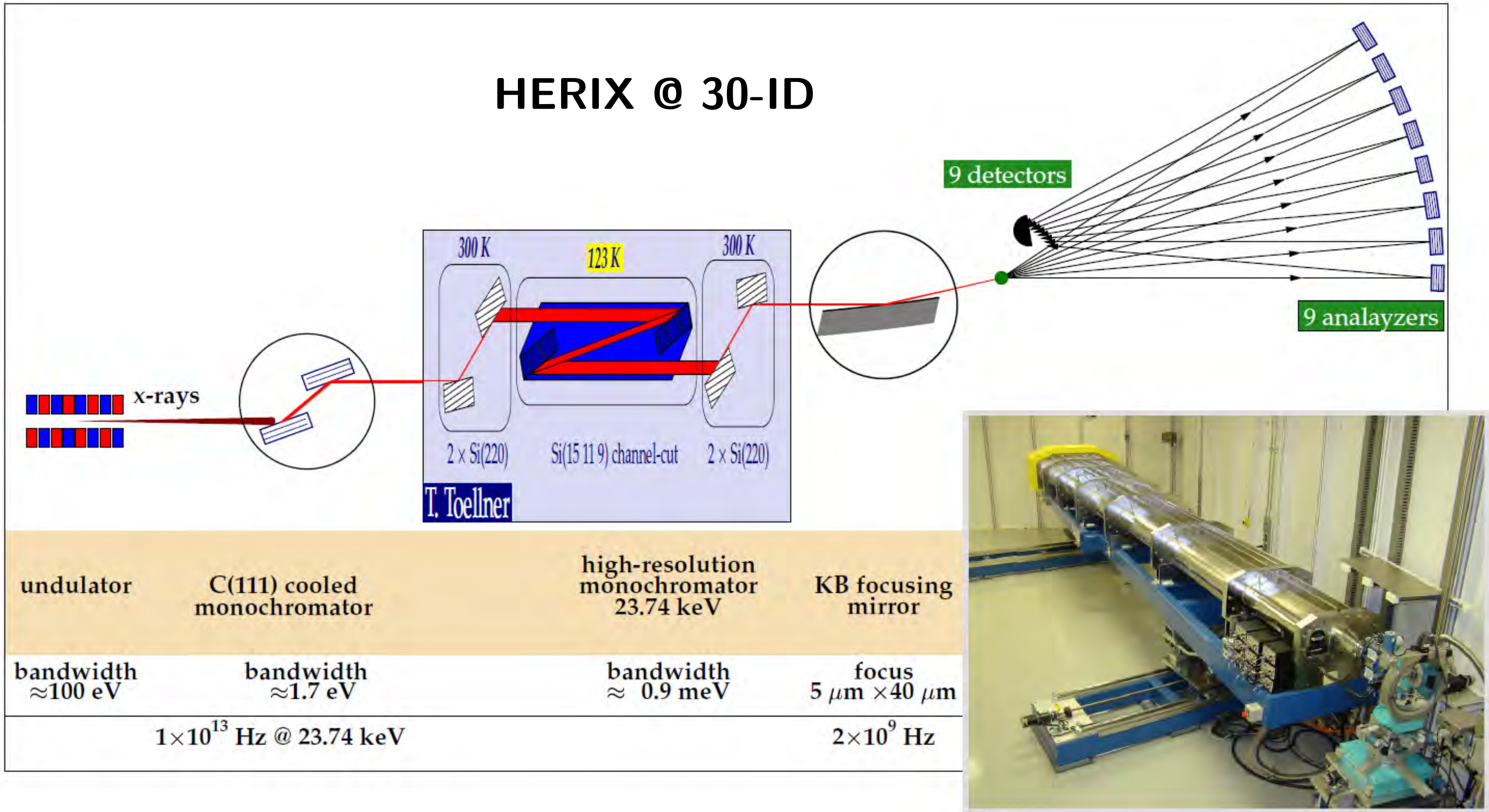
K.-J. Kim and Yu. Shvyd'ko, Phys. Rev. STAB (2009)

Design Requirements:

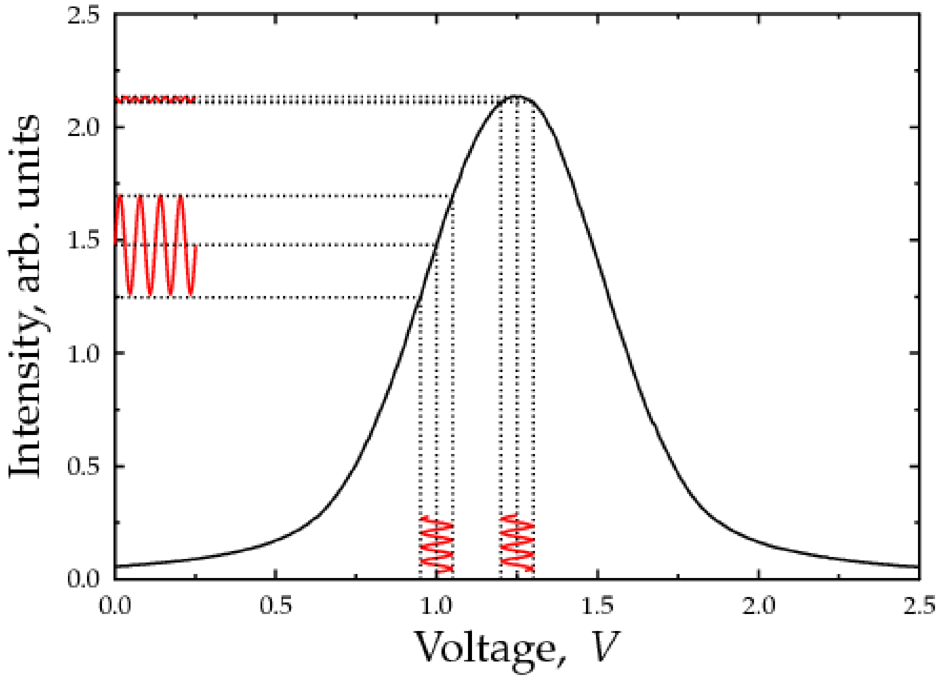
- Angular stability - $\delta\Theta \lesssim 10$ nrad
- feedback on the signal of interest - the XFELO output
- Stabilization of multiple optical axes using one common detector

High Resolution X-ray Optics

A similar problem: stable operation of the state of the art high resolution optics at the 3^{rd} generation synchrotron sources



Automatic control of Bragg angle: null-detection feedback



L.J. van Mellaert and G.H. Schwuttke, Phys. Stat. Solidi (1970)

D. Mills and V. Pollock, Rev. Sci. Inst. (1980)

F. Bridges, Nucl. Inst. and Meth. A (1987)

M. Ramanathan et al., Nucl. Inst. and Meth. A (1988)

R. Fischetti et al., J. Synch. Rad. (2004)

O. Proux et al., J. Synch. Rad. (2006)

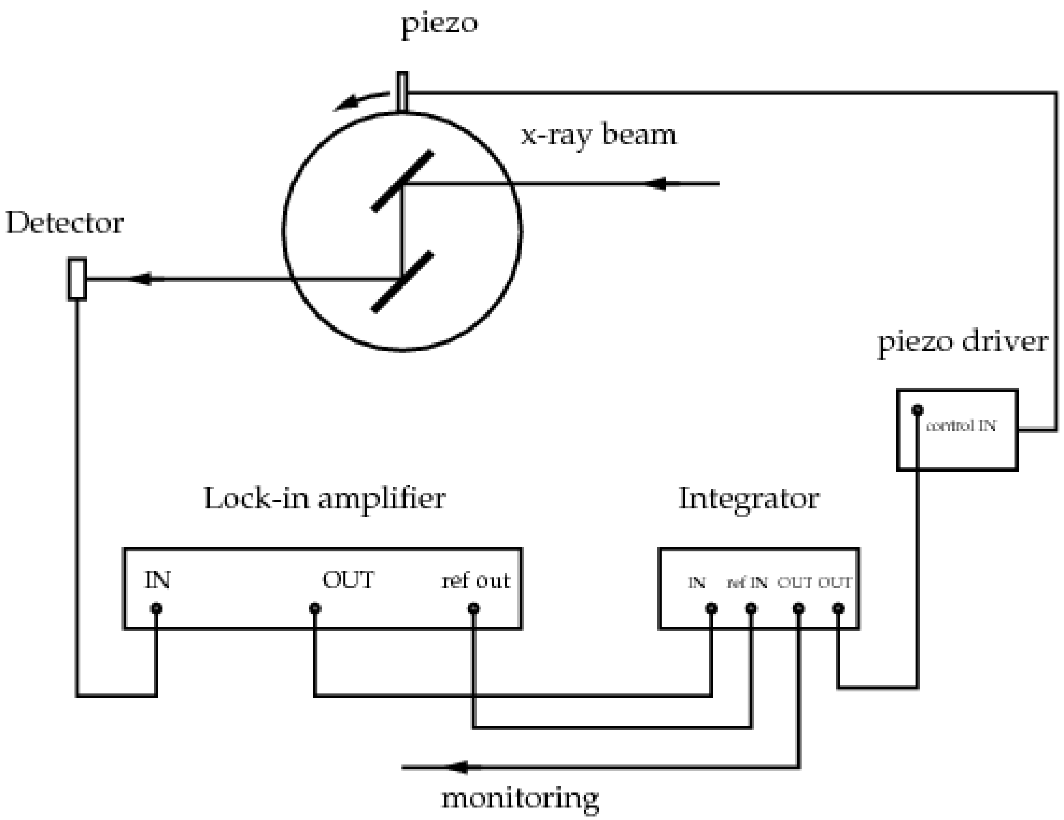
Variation in x-ray intensity due to modulation with $v(t)$: $I(t) \simeq R(V_0) + \frac{dR}{dV}(V_0)v(t)$

For a quadratic profile of the rocking curve, $R(V) = R_{max} - B(V - V_{max})^2$,

the derivative is proportional to deviation from the optimal voltage V_{max}: $\frac{dR}{dV}(V) = -2B(V - V_{max})$

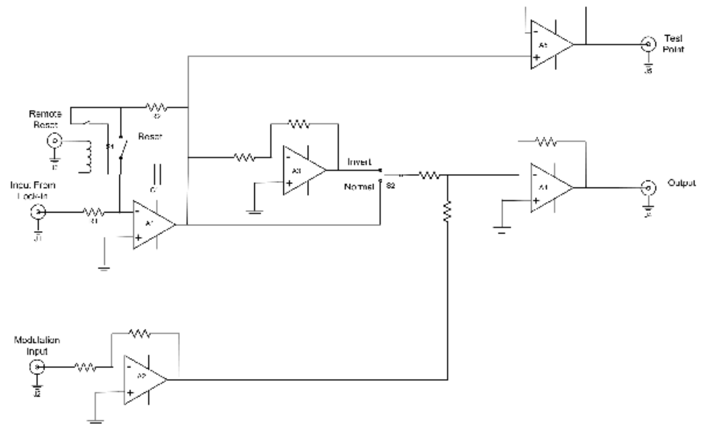
The amplitude of $I(t)$ is extracted by demodulation (lock-in detection) and used to form a correction signal

Feedback implementation



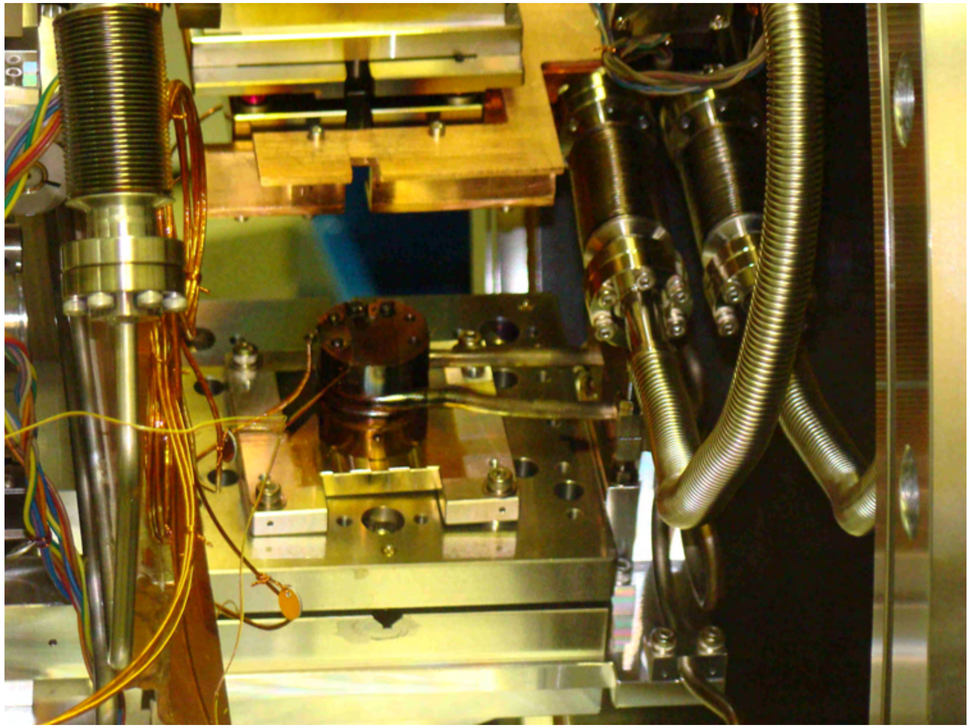
Lock-in amplifier (SR830)

Integrator (built in-house)

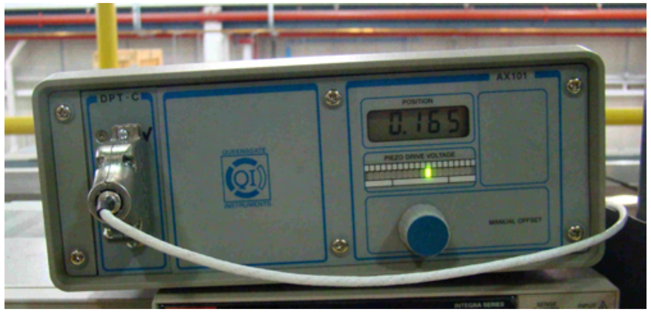


Feedback implementation: C(111) high heat load mono

Inside the mono: 1^{st} crystal

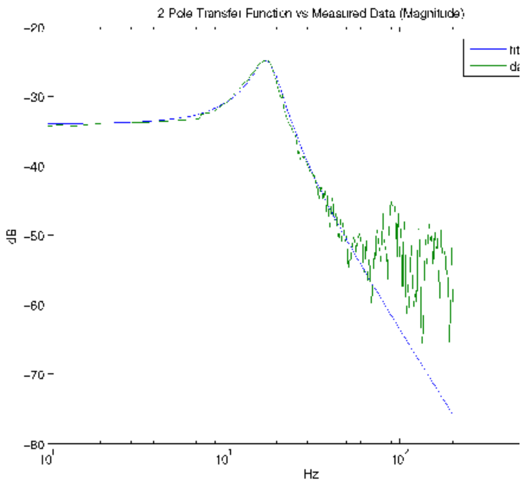


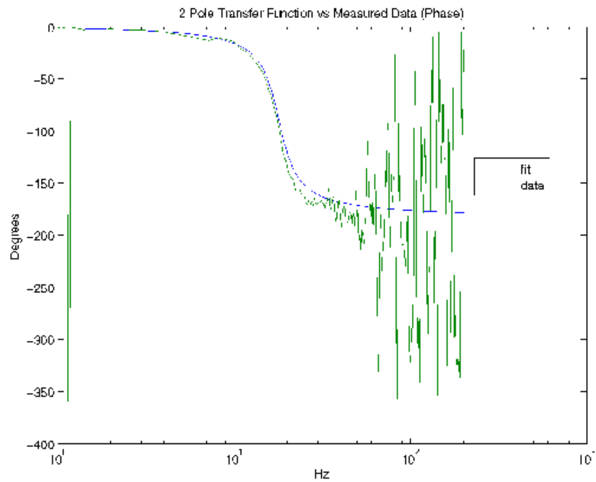
Piezo driver (Queensgate AX101)



Dynamic response:

magnitude **phase**

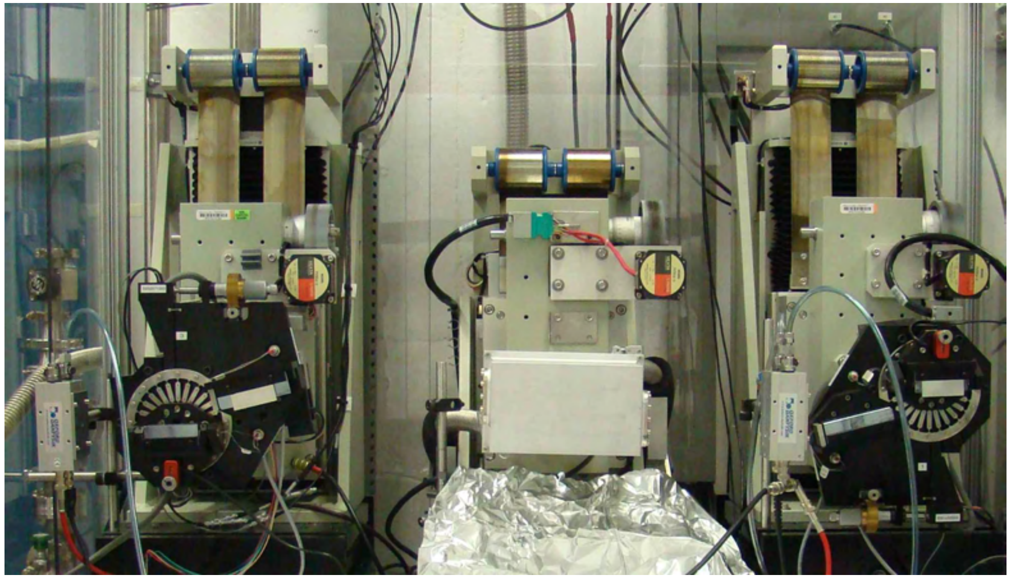




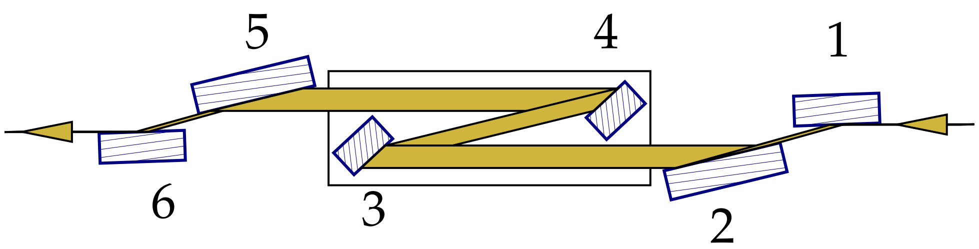
- first resonance at ≈ 16 Hz
- inherent servo loop at 30-70 Hz

Feedback loop is operated with
with ref. oscillator frequency of 2 Hz

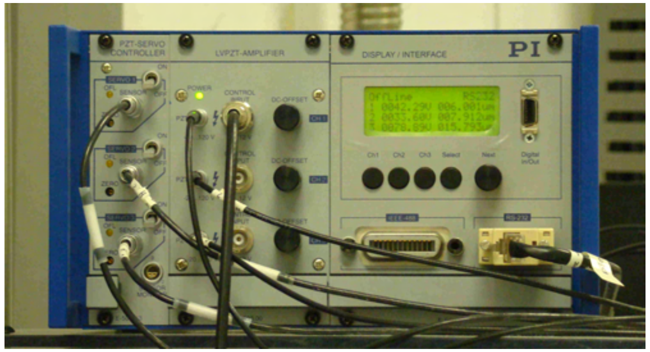
Feedback implementation: 6 bounce high resolution mono

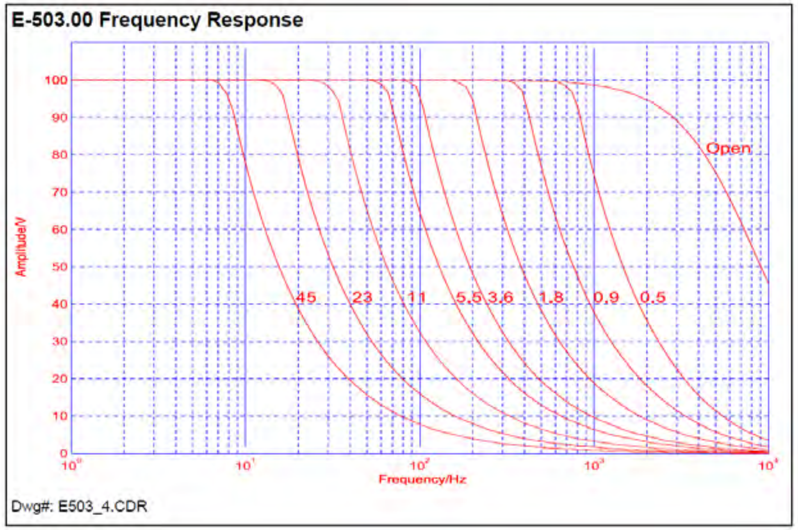


T. Toellner et al., $\Delta E \simeq 0.9$ meV @ 23.725 keV



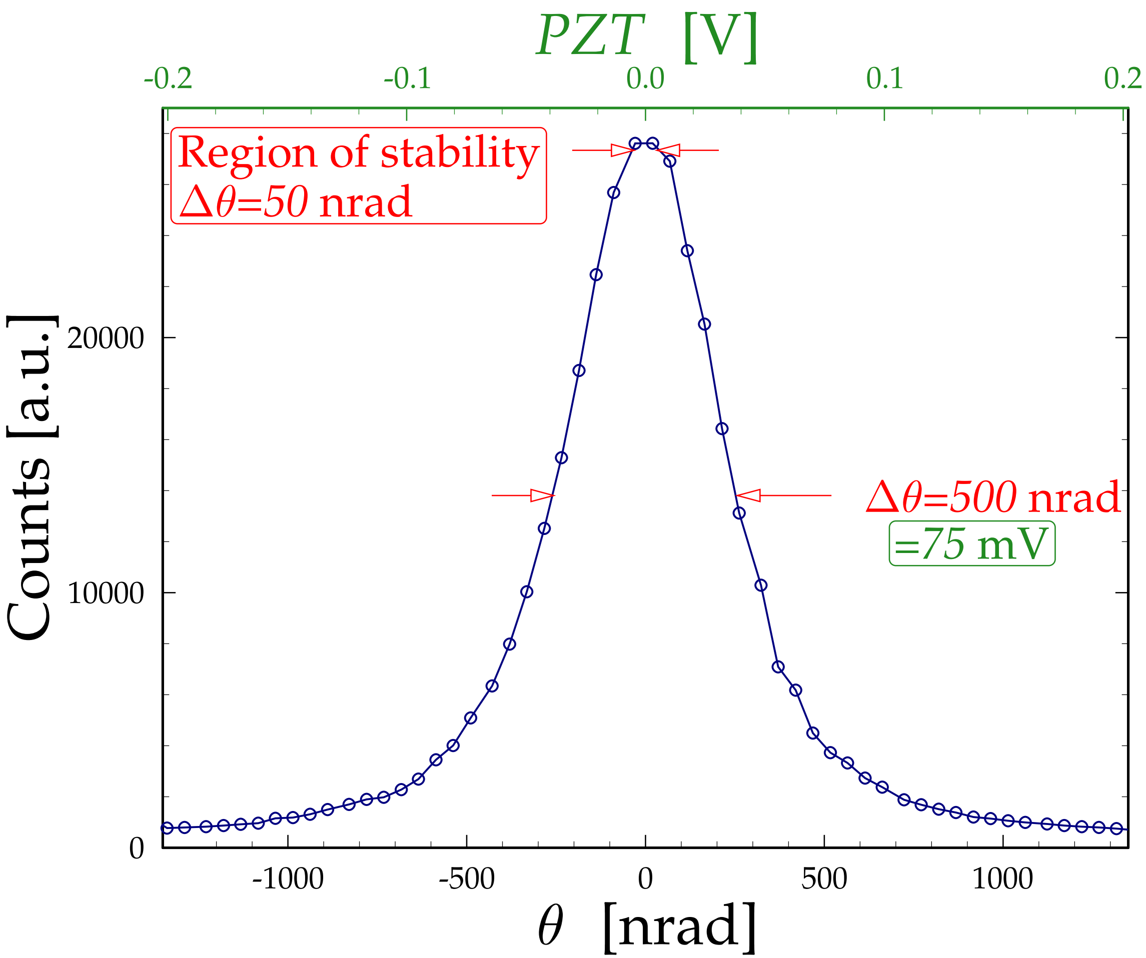
Piezo driver (PI E-503)





Feedback loop is operated on the 3^{rd} pair (crystals 5 and 6) using ref. oscillator frequency of 10 Hz

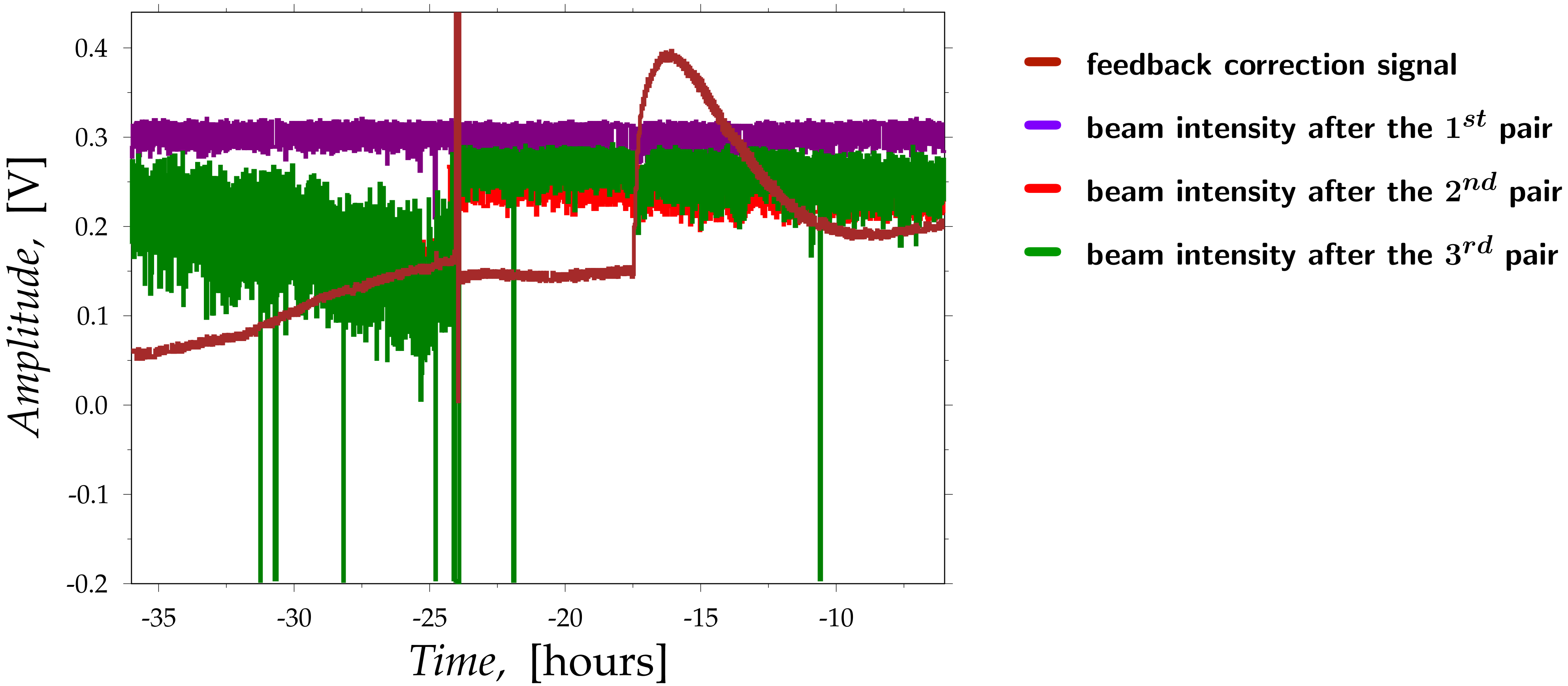
Angular stability of the 3^{rd} pair



Voltage to angle conversion factor: $\gamma \simeq 7\mu$rad/Volt

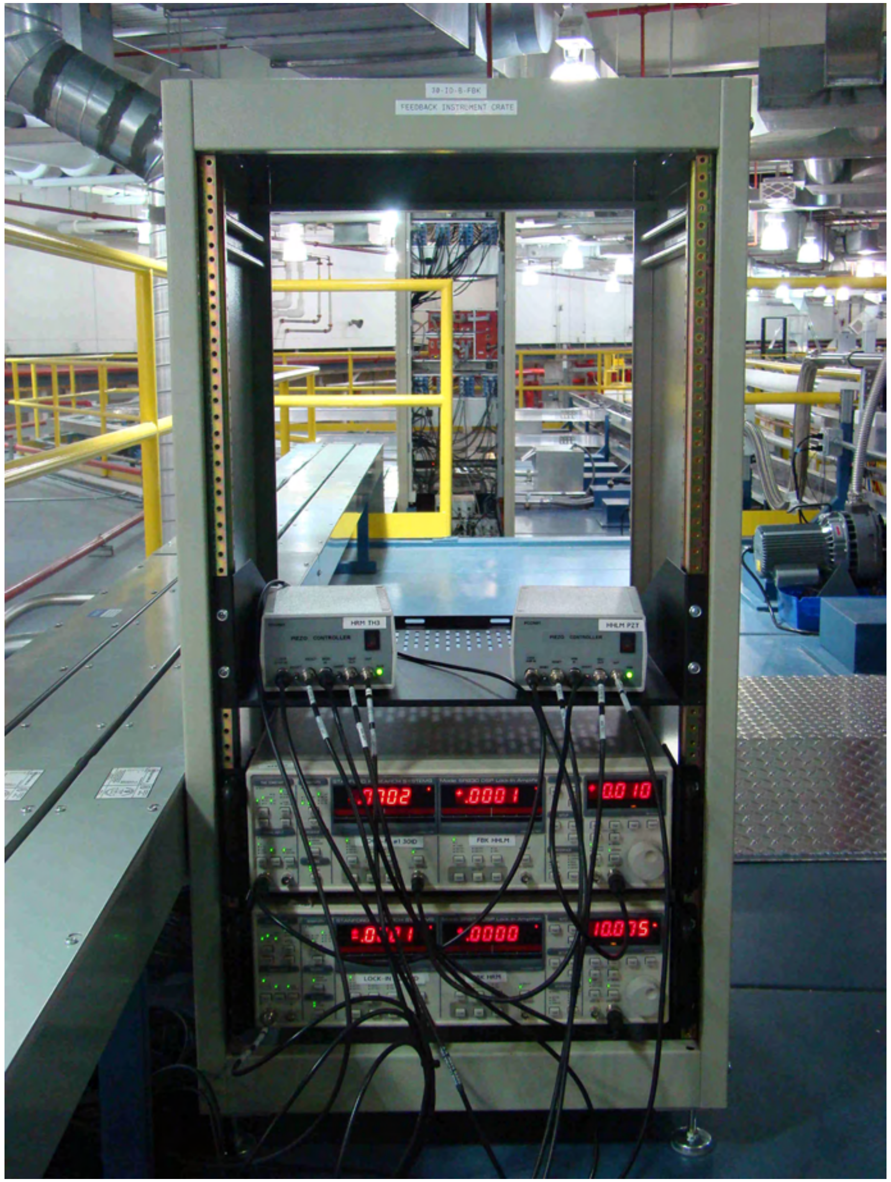
Reliable operation of the feedback is achieved with 4-6 mV amplitude of the ref. oscillator $\longrightarrow$ 50 nrad angular fluctuations

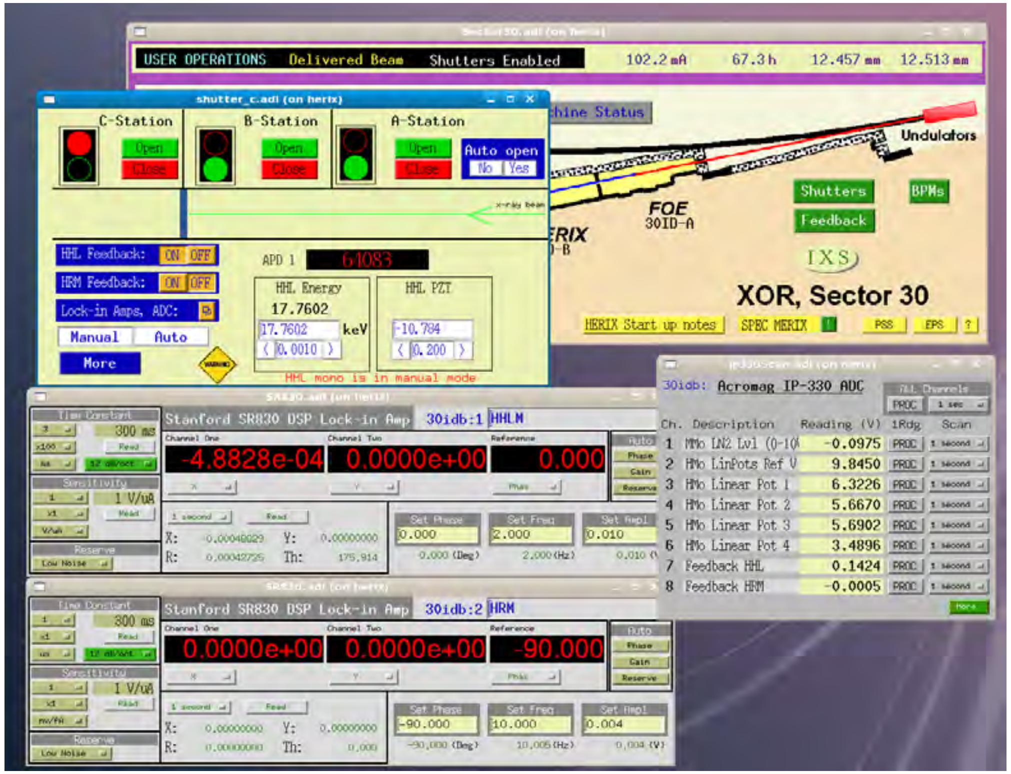
Performance



- **The output intensity (green) is tracking an input x-ray intensity on the 3^{rd} pair (red) while the correction signal (brown) drifts slowly to provide compensation.**
- **The large peak in the correction signal - refill of liquid N_2 for the 2^{nd} pair: the output intensity remains stable.**

Operation





- two feedback channels
- remotely controlled (EPICS,SPEC)
- now employed in user operations

Summary

- $\approx$ 50 nrad stability is demonstrated
- the old simple technique is applicable to high resolution optics
- substantial improvement in beamline performance
- encouraging first step towards stabilization of the XFELO cavity

Future work:

- demonstrate 10 nrad stability
- development of a multi-channel feedback system
- stabilization of multiple optical axes using one common detector

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