X-ray Beam Stabilization by MOSTAB

MOSTAB = Monochromater Stabilization

Yoshinori Nishino

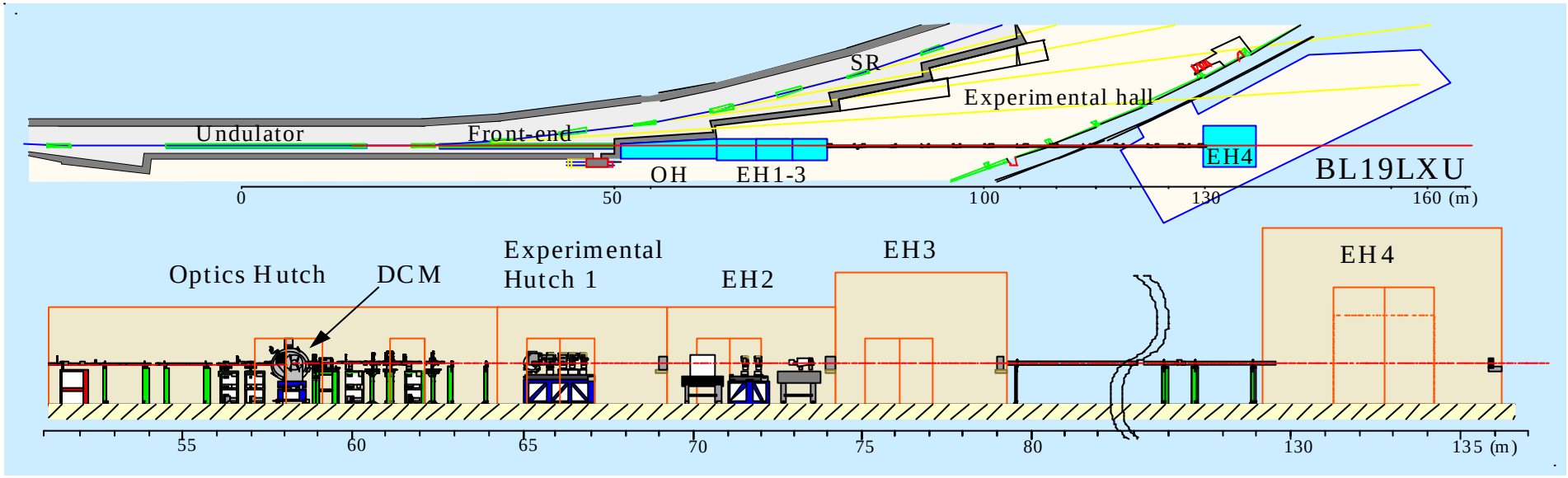
SPring-8 / RIKEN

Collaborators

- Throughout the Work
  T. Kudo, T. Ishikawa
- Experiment at BL29XU
  M. Suzuki, T. Hirono, K. Tamasaku
- Experiment at BL38B1
  Y. Furukawa, H. Tanida
- Manufacturing the MOSTAB Module
  E. Ohtake (Teikoku Denki)
  I. Morimoto (Mitsubishi Electric Engineering)

- Private Communication
  D. Novikov (HASYLAB, DESY)

Layout of Beamline

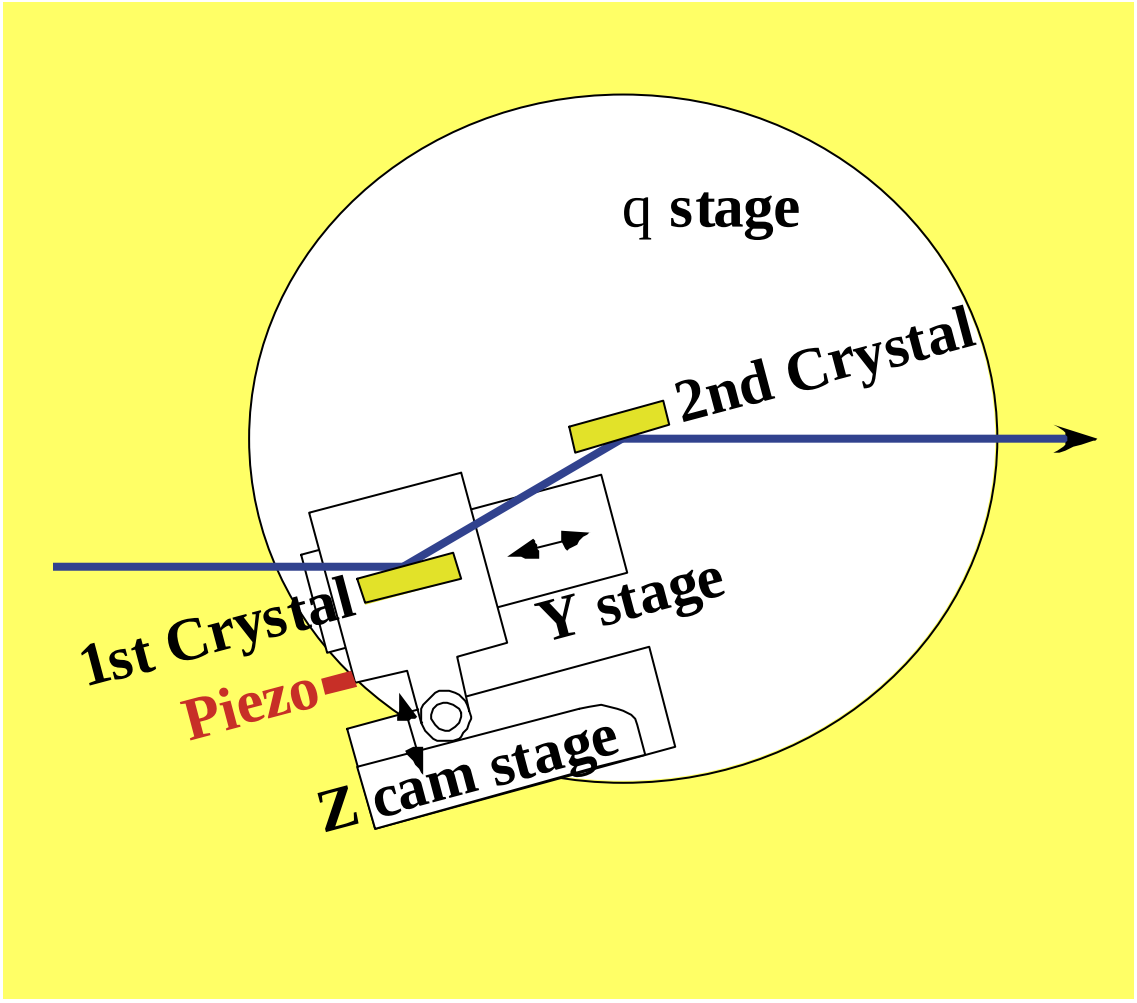


BL19LXU: M. Yabashi *et al.*, NIM A **467-468**, 678 (2001).

- Photon Source
- Frontend
- Optics Hutch

  DCM = Double Crystal Monochromator
- Experimental Hutches

Fixed Exit Double Crystal Monochromater (DCM)



- Bragg reflection from two crystals
- Tuning the energy by changing the incident angle

$$l = 2d \sin q_B$$

- Energy Resolution

$$\frac{\Delta E}{E} \approx 10^{-4}$$

- Diffraction planes of the two crystals should be parallel.
- Piezo actuator to control the parallelity

Question:
What happens when the two crystals of DCM are not parallel?

Answer:

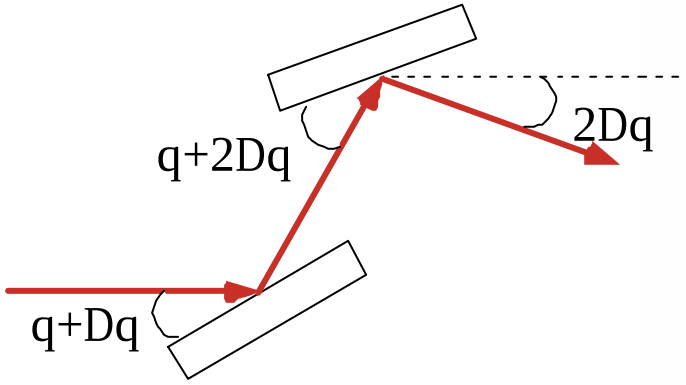
- decrease in intensity
- shift in position
- shift in energy

Dependence of X-ray Beam Intensity and Position on Detuning Angle

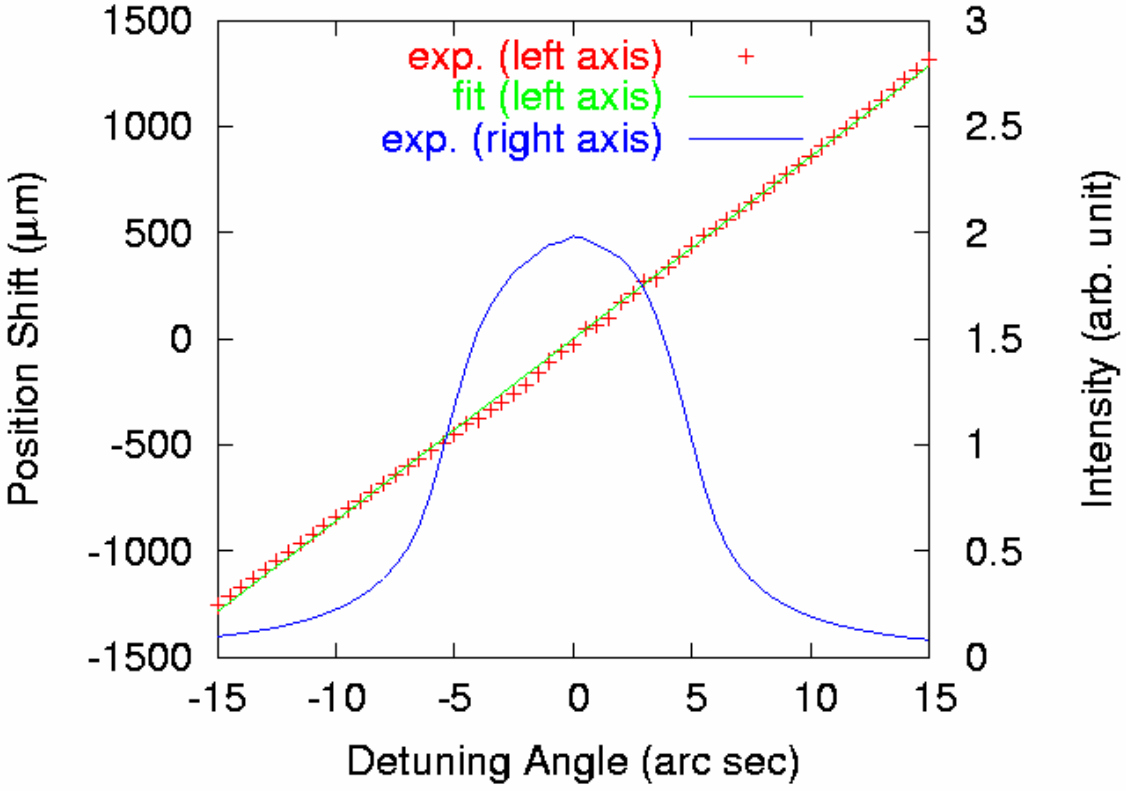
Detuning Angle = Δθ

↓

Exit Beam Angle = 2Δθ



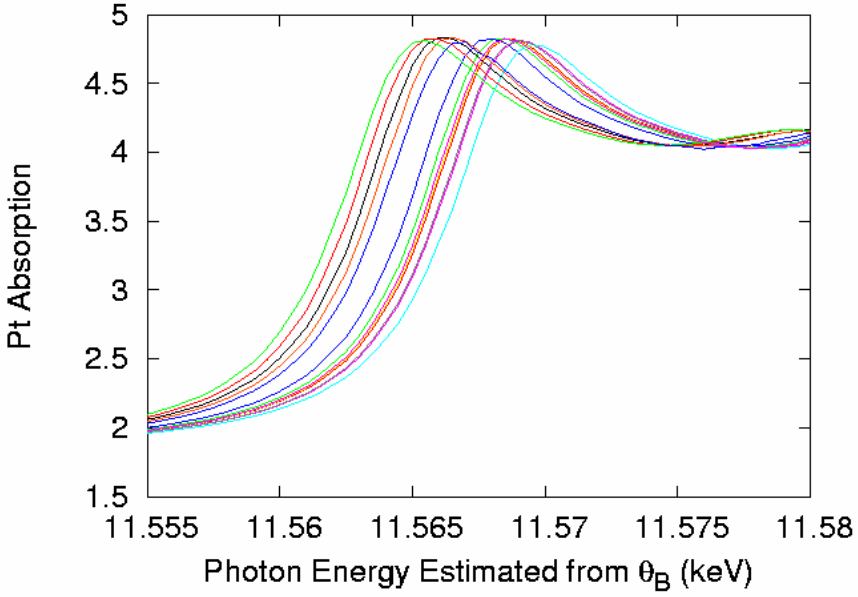
X-ray Beam Intensity and Vertical Position
(EH1, BL29XU)



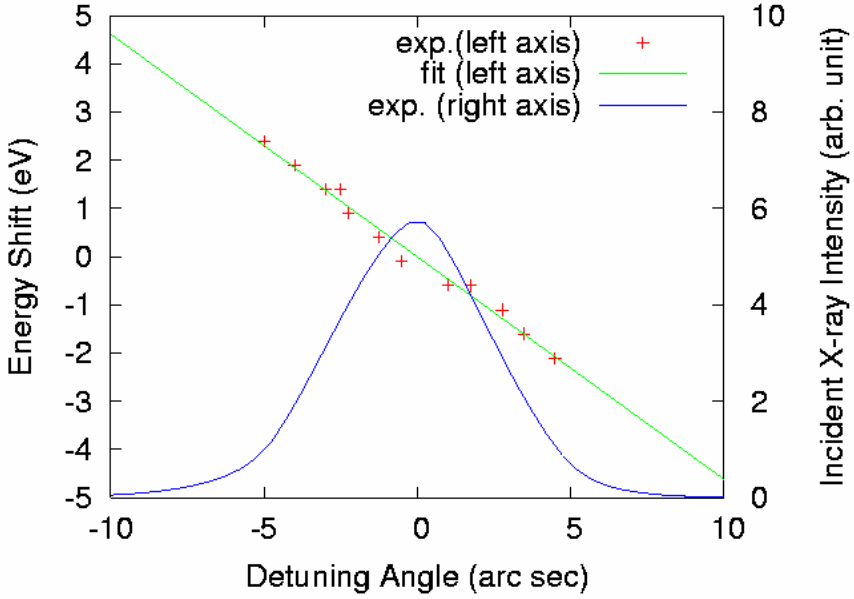
linear fit: 85.7 mm/arc sec = 17.7 m/rad
distance from monochromator to BPM: ~ 9 m

Dependence of X-ray Beam Energy on Detuning Angle

Pt L_{III} absorption edge scan with different detuning angle



Energy Shift of X-ray Photons (EH1, BL29XU)



binding energy of $2p_{3/2}$ state = 11.564 keV

linear fit: -0.46 eV/arc sec

theoretical value:

$$\frac{3}{2} E \cot q_B = -0.48\,\text{eV} / \text{arc sec}$$

Question:
What happens when the two crystals of DCM are not parallel?

Answer:

- decrease in intensity
- shift in position
- shift in energy

Intensity, position and energy of x-rays can be simultaneously stabilized by stabilizing the parallelity of DCM.

Necessary Condition: Electron beam is stable.

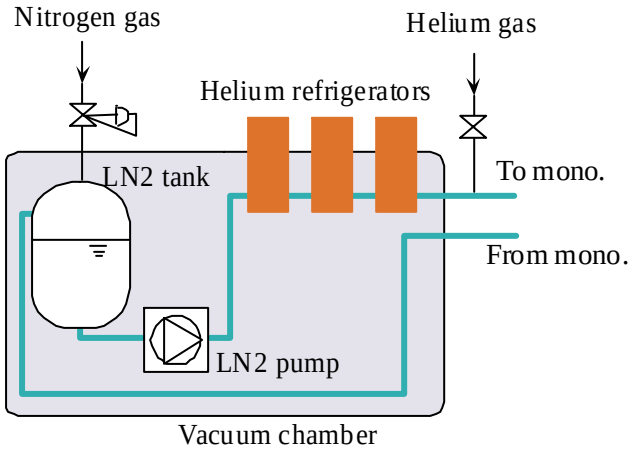
Improvements of Hardware

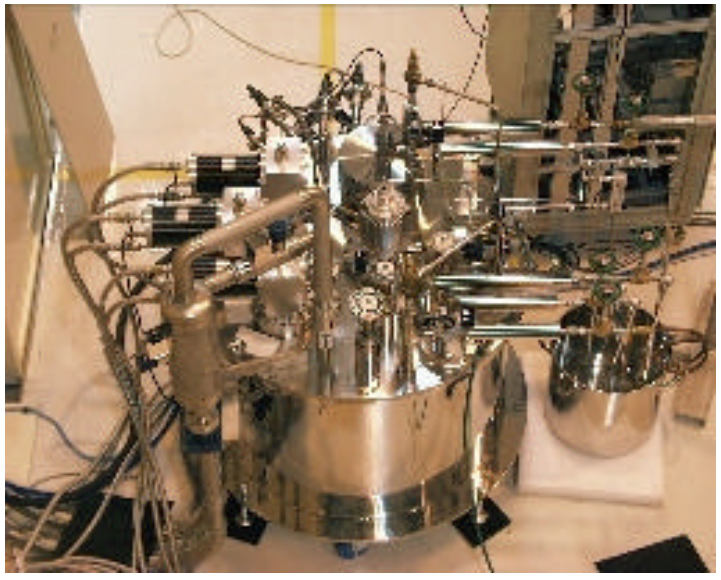
- Pin-post water cooling

  T. Ishikawa, H. Yamazaki, K. Tamasaku, M. Yabashi, M. Kuroda & S. Goto, Proc. SPIE **3448**, 2 (1998).

- Cryogenic cooling

  K. Tamasaku, M. Yabashi, D. Miwa, T. Mochizuki, T. Ishikawa, Proc. SPIE (2002).

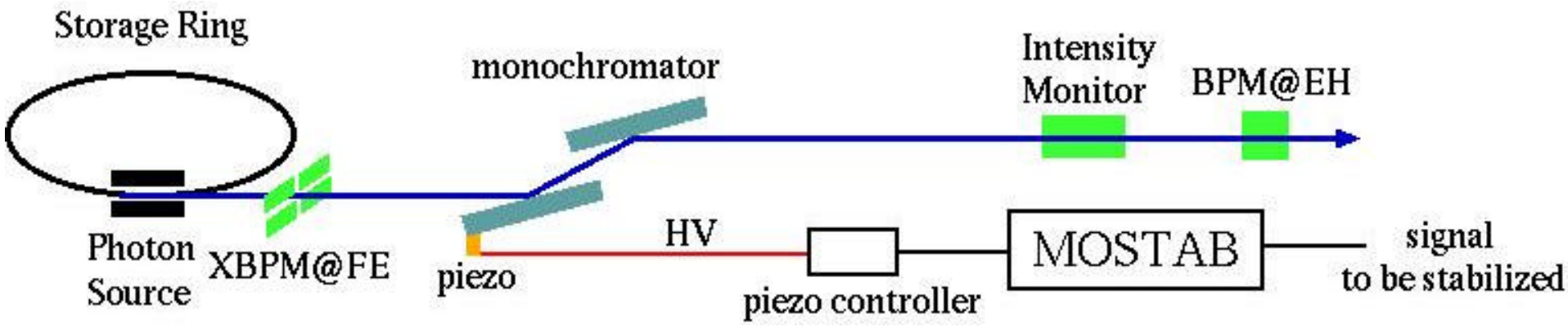




High Head Load on Monochromator 1st Crystal

g=9.6 mm
FE slits 1x1 mm^2
E=16.4 keV (Si 111)
P=478 W @100 mA
p_m=27 W/mm^2

MOSTAB



MOSTAB (Monochromator Stabilization) module applies a feedback voltage to the piezo actuator of DCM.

Reference:
Krolzig, Materlik, Swars & Zegenhagen, NIM **219**, 430 (1984).

Digital MOSTAB with PID-Control

Operation Modes

- Intensity (I_0) Stabilization
  - $\Delta\theta$ drifts in time
- I_0/I_{ring} Stabilization
  - $\Delta\theta$ is stabilized at a fixed energy
- Position Stabilization
  - Stabilization at any $\Delta\theta$ (including $\Delta\theta=0$) and at any energy

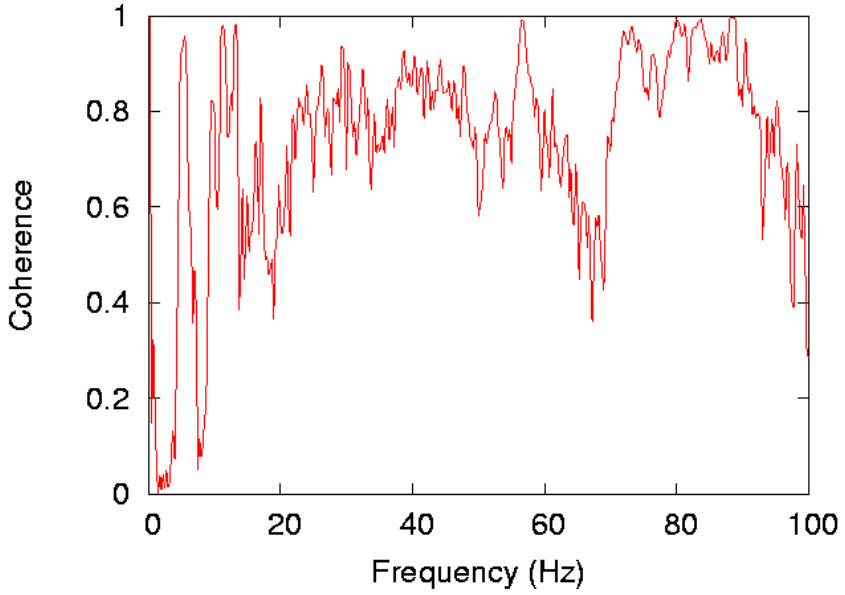
R. F. Fischetti *et al.*, RSI **73**, 1518 (2002).

Ethernet connection for remote control, and to obtain I_{ring} from the database system.

Sources of Instability

Oscillation of intensity and vertical position are caused by the same source.

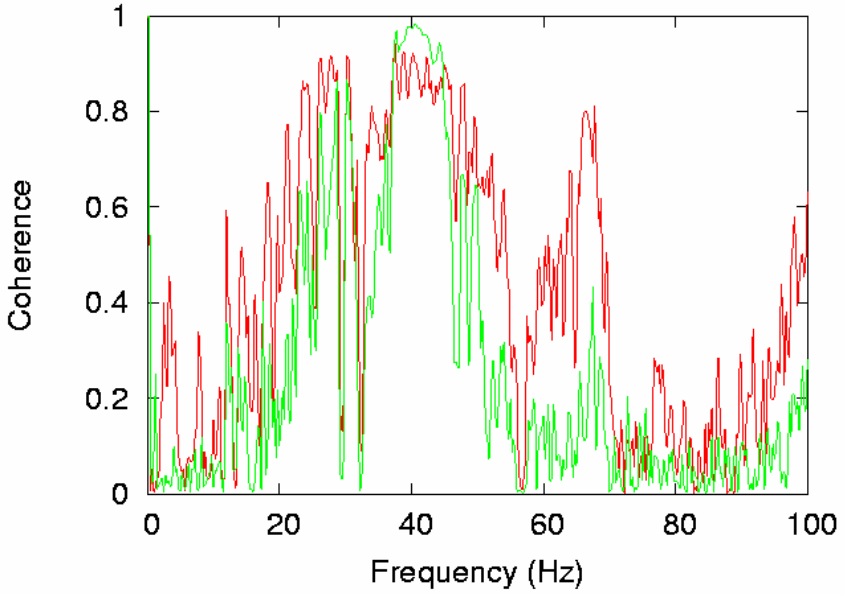
(EH1, BL29XU, March 2002)



Intensity & Vertical Position

The common source of instability around 40Hz is storage ring.

(EH1, BL29XU, March 2002)

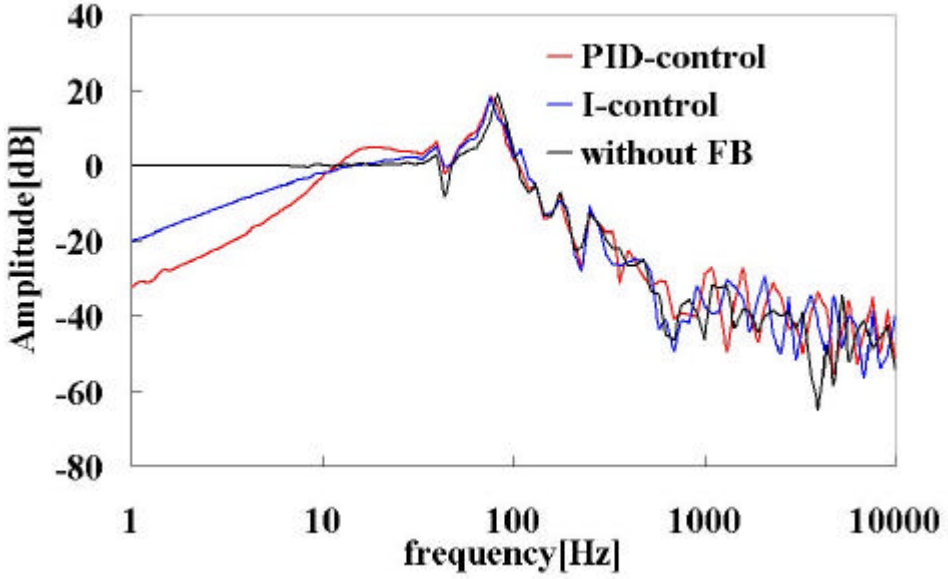


BPM @ FE & BPM @ EH

BPM @ FE & Intensity

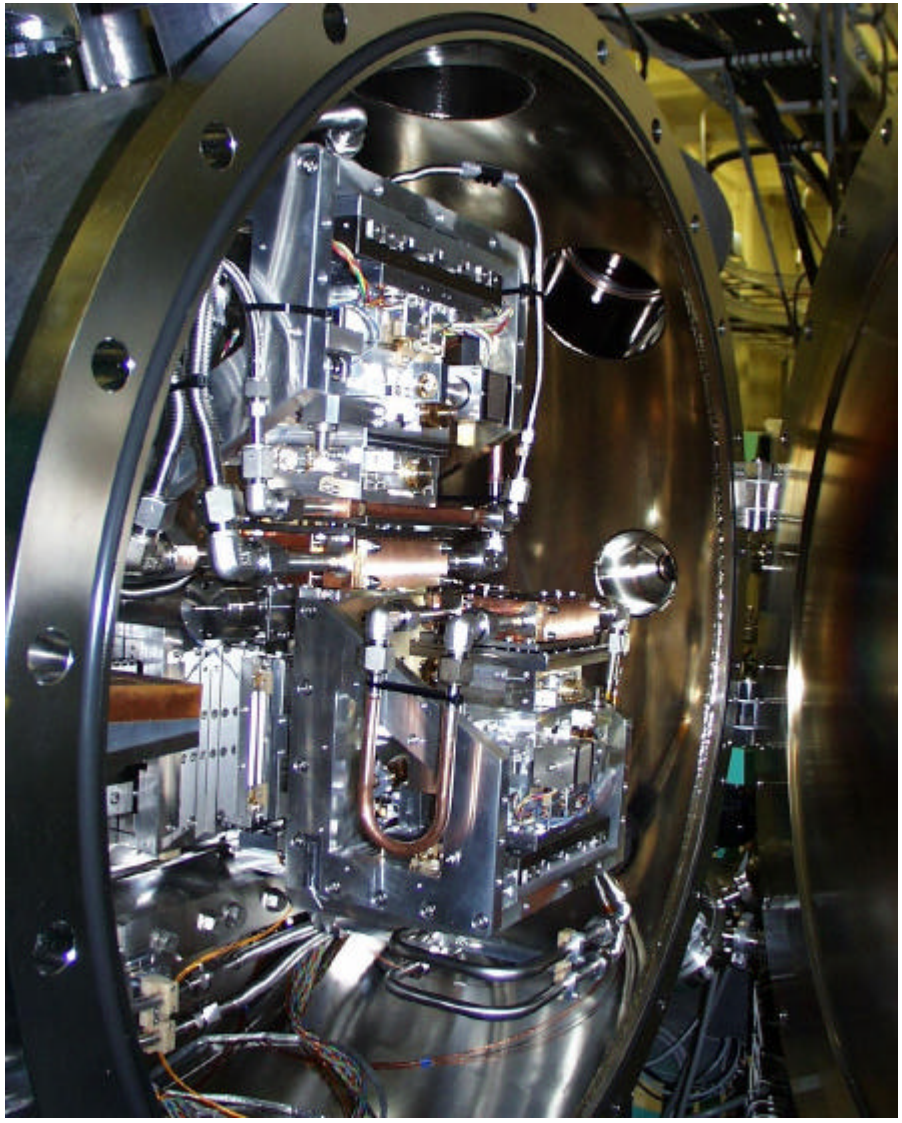
Frequency Response

Response of X-ray Intensity to Piezo Voltage
(BL38B1, Sep. 2002)



Feedback is effective below 10 Hz.

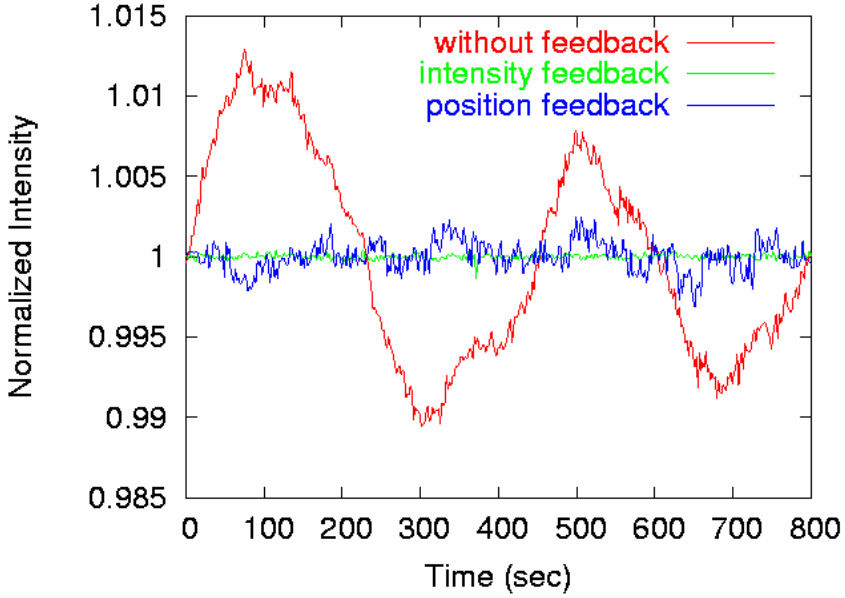
SPring-8 Standard Monochromator



Monochromator
at BL29XU

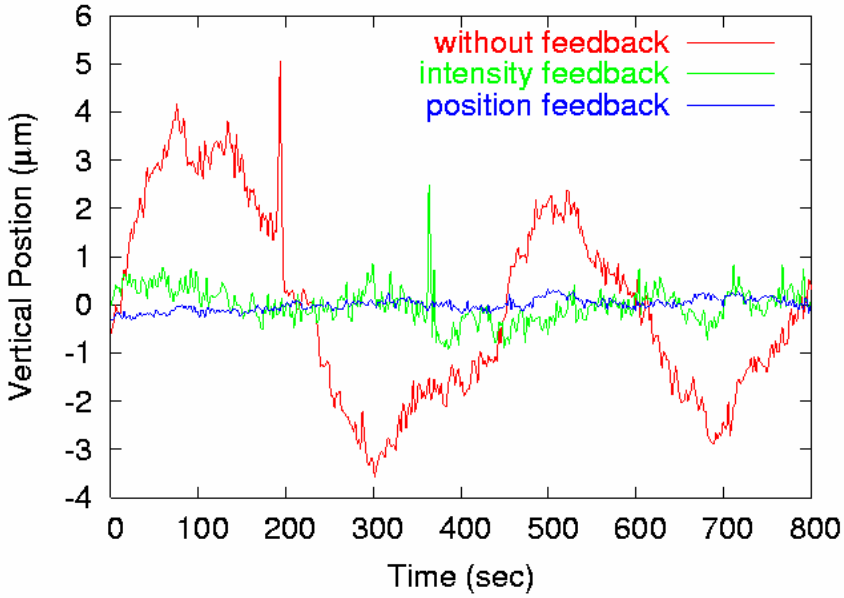
Simultaneous Stabilization of Intensity and Position of X-ray Beam

Stability of X-ray Intensity
(EH1, BL29XU, March 2002)



RMS: 6.4×10^{-3}, 1.7×10^{-4}, 9.4×10^{-4}

Stability of X-ray Beam Position
(EH1, BL29XU, March 2002)



RMS: 1.98μm, 0.37μm, 0.13μm

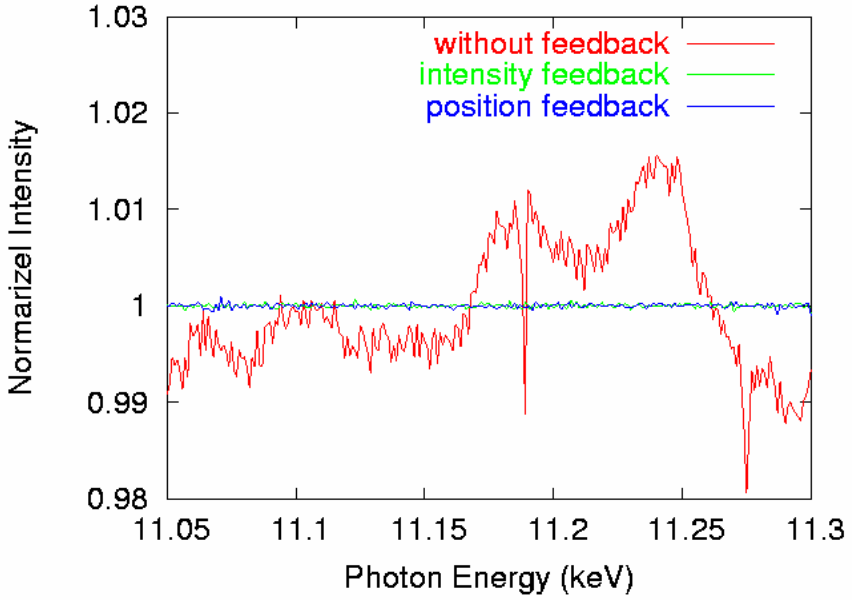
N.B. Data was taken at rocking curve shoulder, where the intensity oscillation is large.

Stabilization in Energy Scan

Stability in Energy Scan

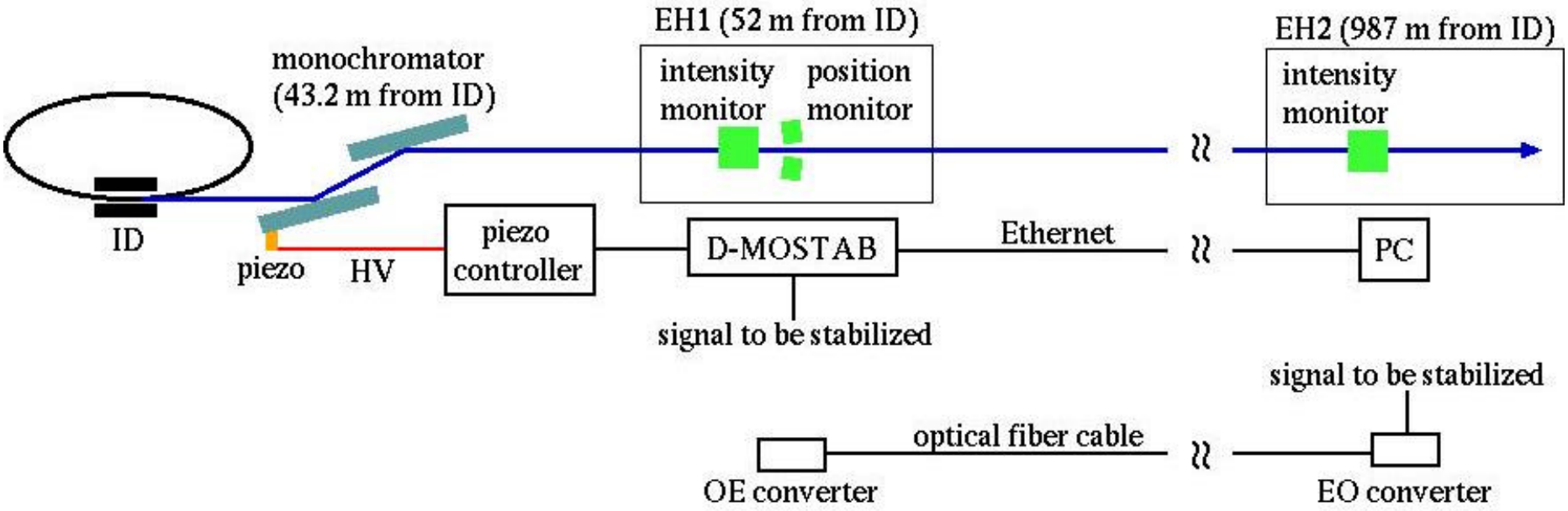
ID Gap was optimized at each energy.

(EH1, BL29XU, March 2002)



RMS: 7.0×10^{-3}, 2.1×10^{-4}, 2.3×10^{-4}

Test of MOSTAB at 1 km Beamline

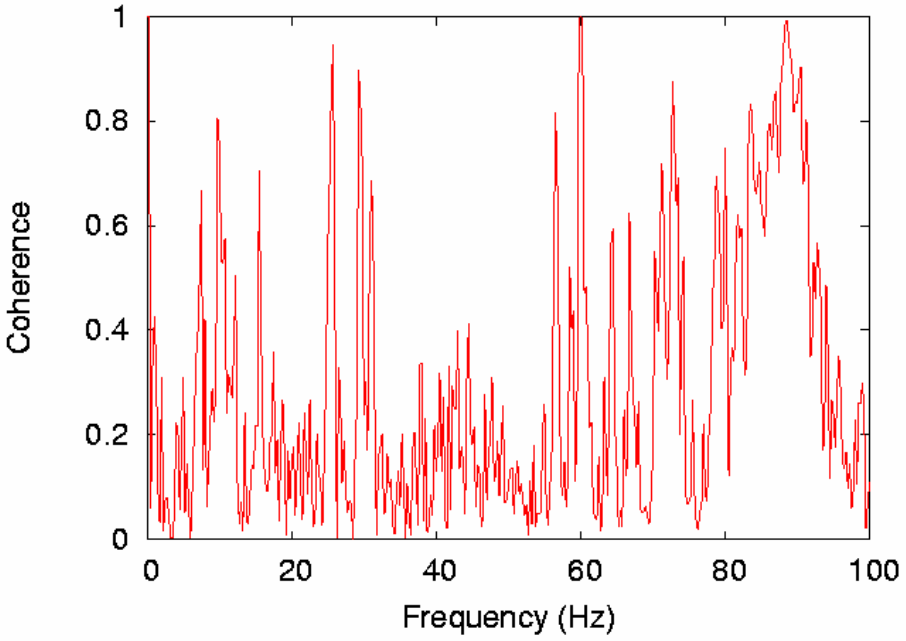


1 km Beamline
RIKEN BL29XU

Correlation among Oscillations

Oscillation of intensity and vertical position are NOT caused by the same source.

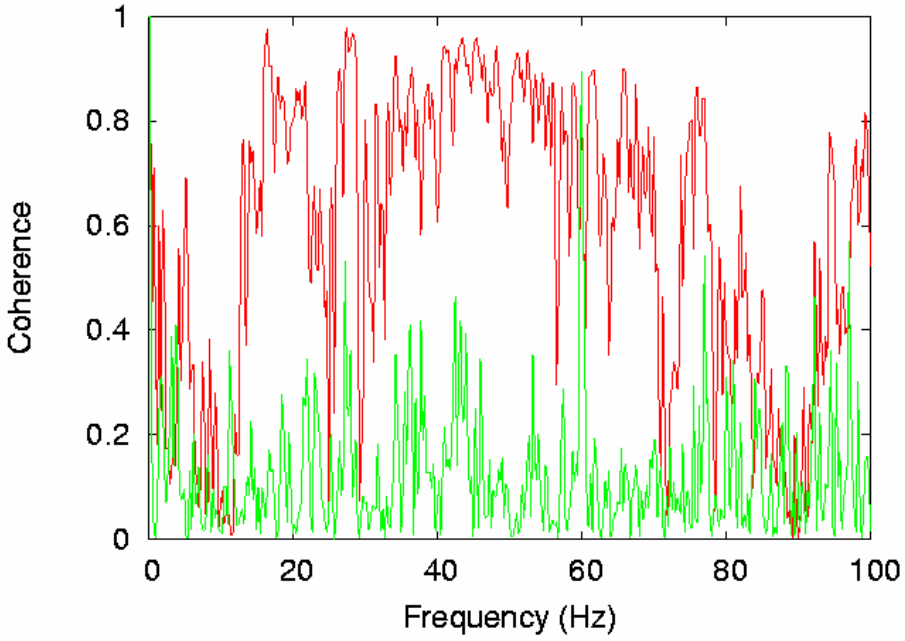
(EH1, BL29XU, Dec 2002)



Intensity & Vertical Position

Oscillation of x-ray beam position is due to storage ring.

(EH1, BL29XU, Dec 2002)

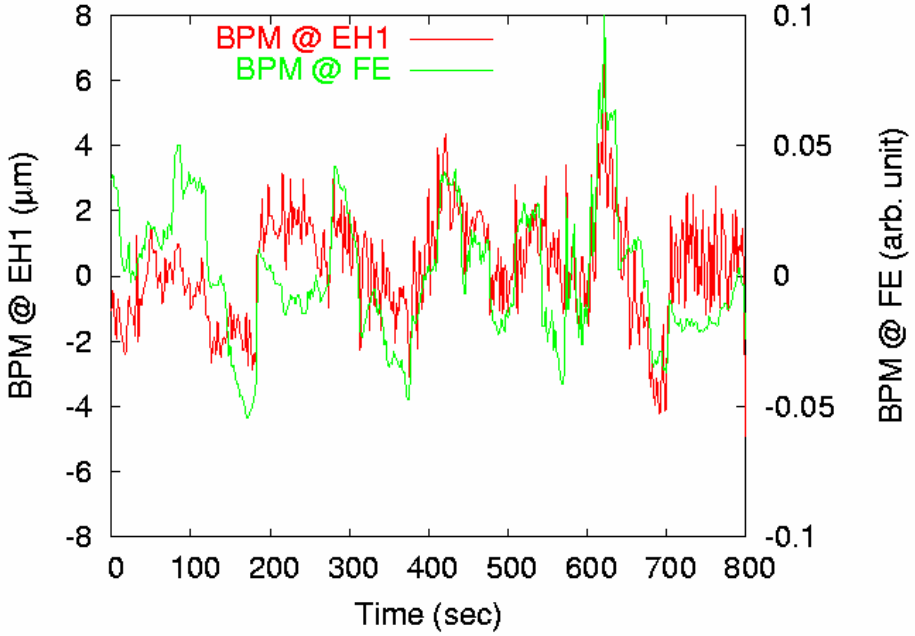


BPM @ FE & BPM @ EH

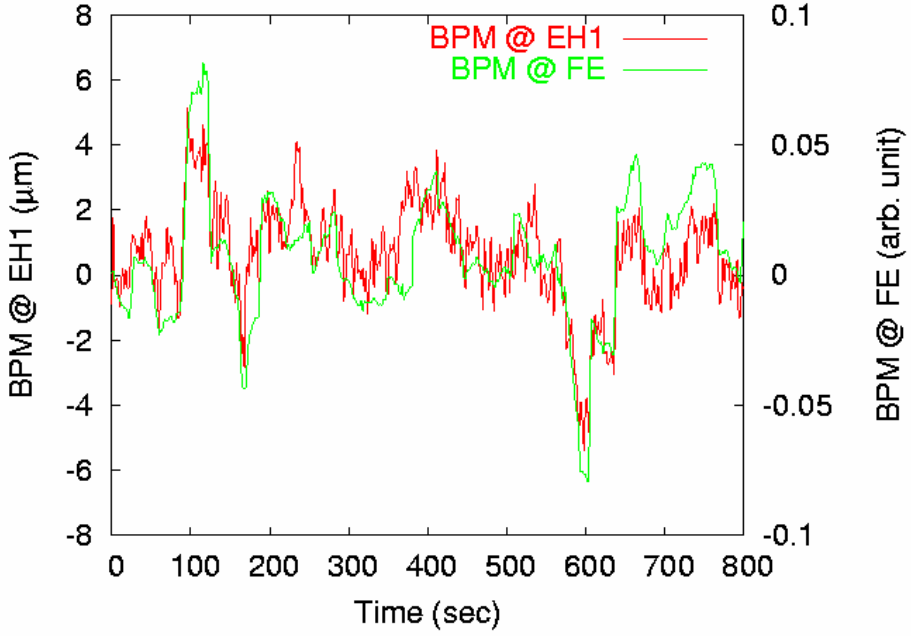
BPM @ FE & Intensity

Test of Simultaneous Stabilization

Without Feedback
(BL29XU, Dec 2002)

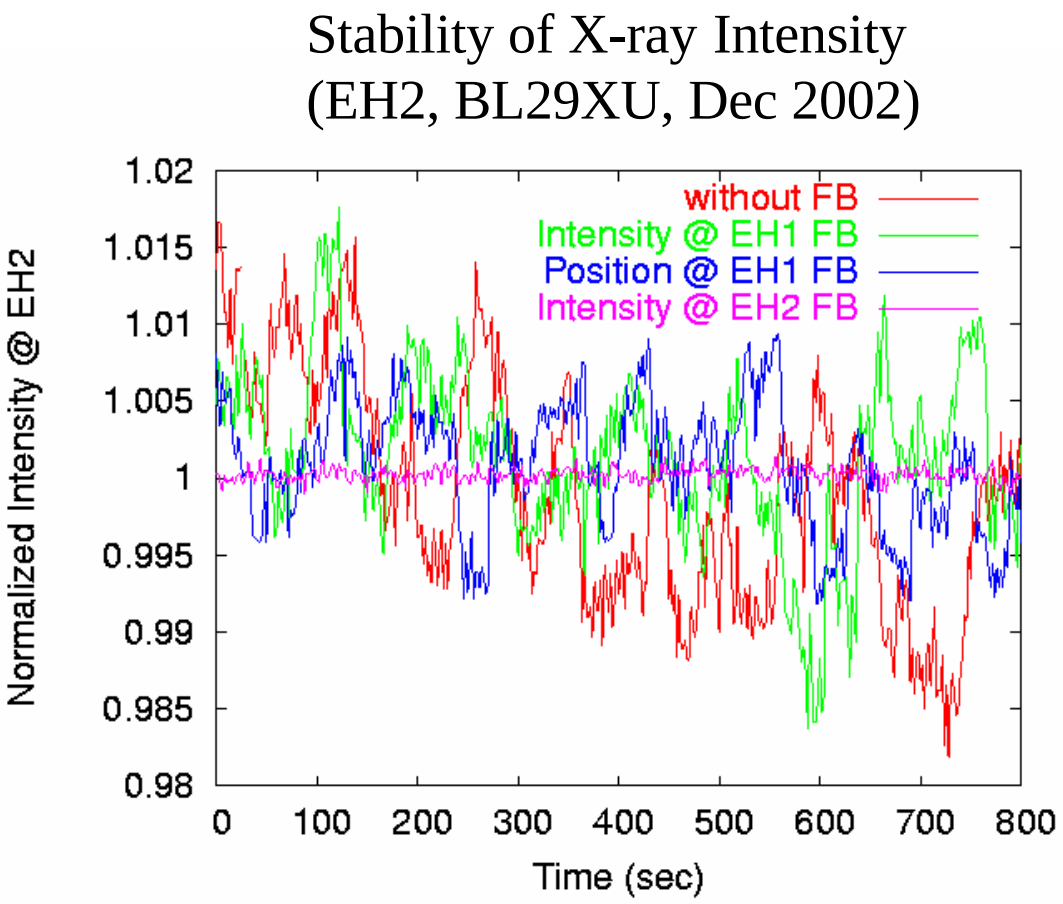


With Intensity @ EH1 FB
(BL29XU, Dec 2002)



Simultaneous stabilization of x-ray beam intensity and position was not possible due to electron beam instability.

Stability of X-ray Intensity at 1 km from Source



Applications of MOSTAB

- Users of synchrotron radiation need …
  - high flux (small signal)
  - coherence
  - tunable energy
- These requirements are closely related to the stability of x-ray beam.

My personal experience with MOSTAB

- Atomic Resolution Holography
- X-ray Absorption Spectroscopy

Installation of MOSTAB to Beamlines

- already installed (prototype analogue MOSTAB)
  - BL35XU (High Resolution Inelastic Scattering) A. Baron
  - BL12XU (Taiwan BL) Y. Cai
- planning to install
  - BL01B1 (XAFS) T. Uruga
  - BL13XU (Surface and Interface Structures) O. Sakata
  - BL29XU (RIKEN Coherent X-ray Optics) K. Tamasaku, M. Yabashi
  - BL38B1 (R&D) H. Tanida, K. Miura
  - BL39XU (Magnetic Material) M. Suzuki

Summary

- Simultaneous stabilization of intensity, position, energy of x-ray beam is possible with MOSTAB.
- Feedback is effective < 10 Hz.
- Intensity Stabilization: 6.4×10^{-3} — 1.7×10^{-4}
- Position Stabilization: 1.98μn — 0.13μm
- Stability of accelerator is crucial for a successful MOSTAB operation.