

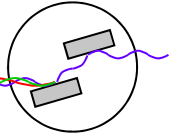
Refinements of SPring-8 Standard Monochromators with Cryogenically cooled Silicon Crystals toward 50 nrad-Stability

JASRI / Optics and Transport Channel Group

Hiroshi Yamazaki, Yasuhisa Matsuzaki, Yasuhiro Shimizu, Ichiro Tsuboki, Yuki Ikeya, Tomoyuki Takeuchi, Masayuki Tanaka, Takanori Miura, Hikaru Kishimoto, Yasunori Senba, Haruhiko Ohashi.

Acknowledgement : beamline scientists and technical staff who use SSMs.

Outline



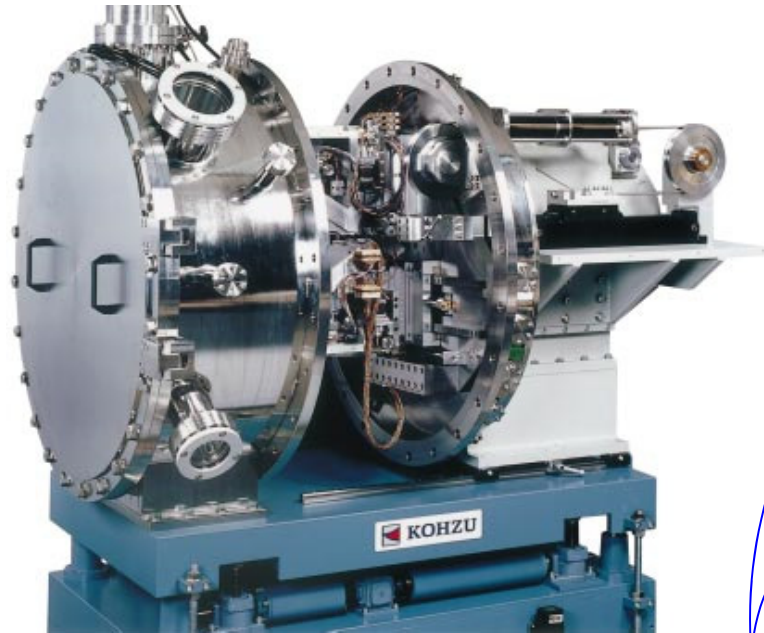
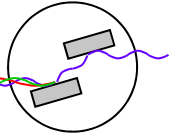
About SPring-8 Std. Mono. (SSM)

Target value of stability

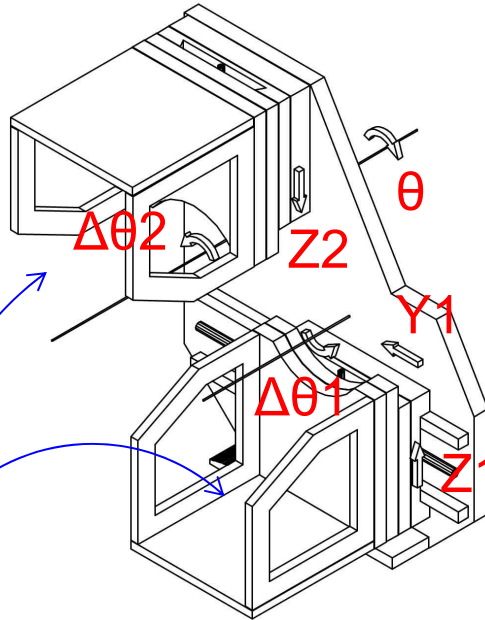
Improvements

Results (present status)

SPring-8 standard monochromator (SSM)



Common base unit

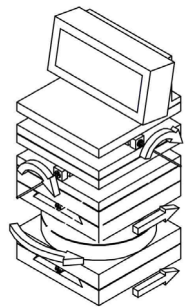


- Bragg angle : 3 ~ 27°
Higher energy x-rays :
4.4 ~ 37.8 keV for Si 111
- Rotation center : 2nd crystal surface

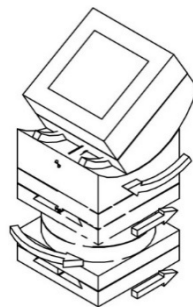
Lower heat load
Smaller thermal strain

Used as base of photon energy

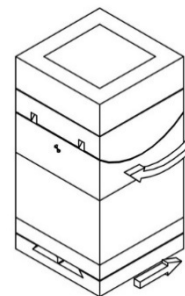
Crystal + adjustment stages



Rotated inclined



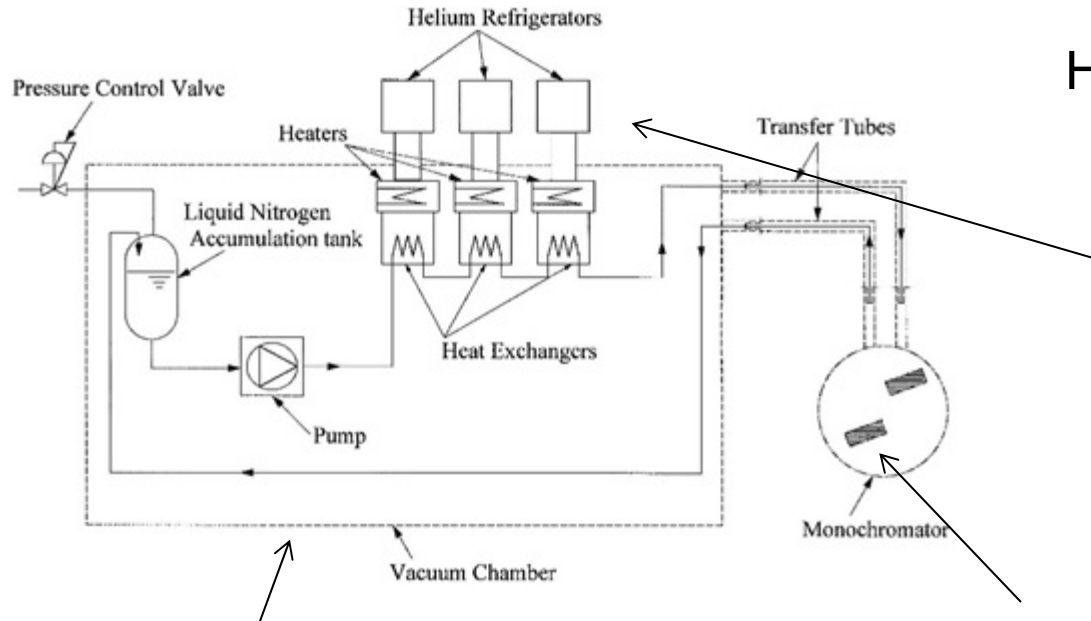
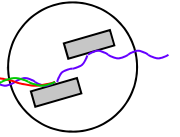
Switch of net planes



Symmetry

- Fixed exit
270 mm translation stage (Y1)

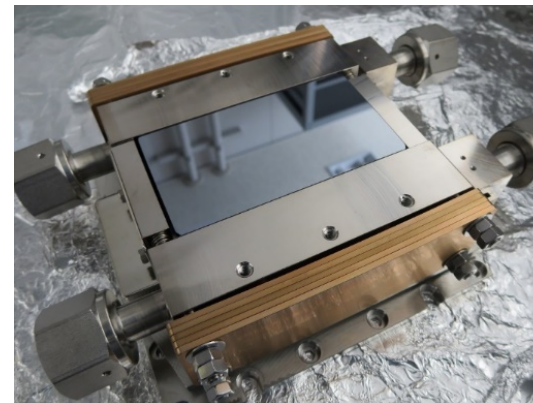
Cryogenic cooling of silicon crystals



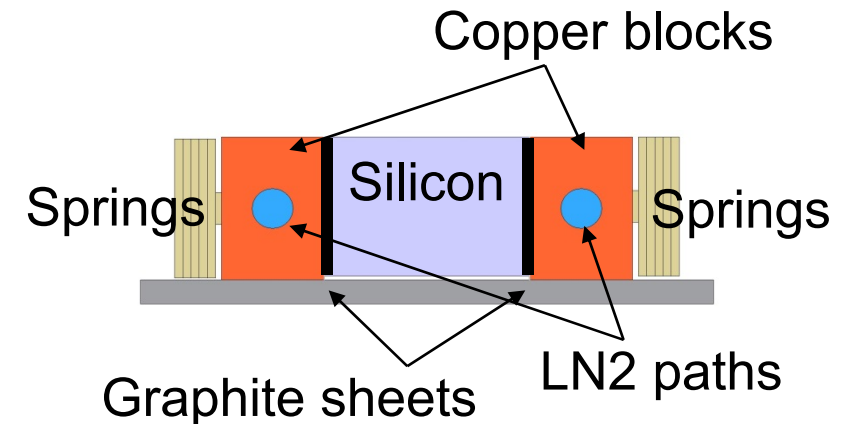
Helium refrigerators (220 W x 3)



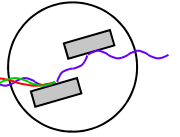
Pump & controller



Crystal and holder



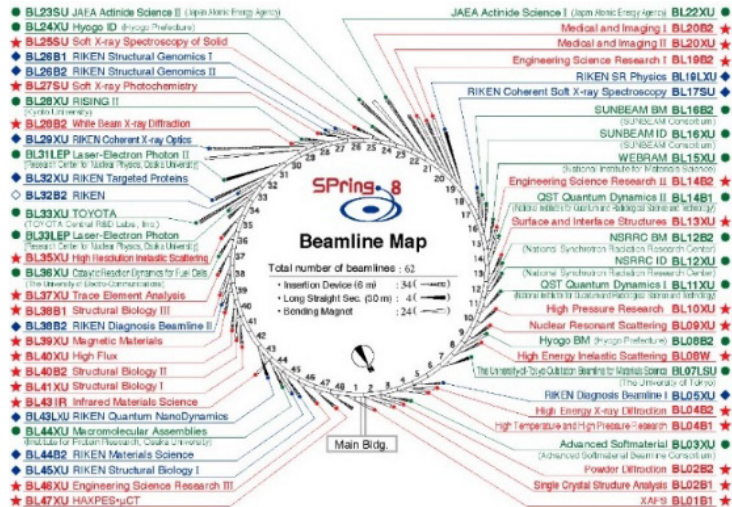
Refinement of SSMs



SPring-8



SPring-8-II



- Low emittance in horizontal direction
- Photon energy : unchanged, or higher
- Heat load : unchanged



Basic design of DCM will remain unchanged.
Refinement and reuse

- 28 X-ray undulator beamlines
- 21 SSMs with LN2-cooled silicon crystals
(21 / 28 = 75 %)

Element development with an off-line test DCM



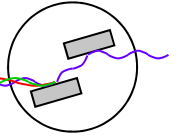
Trial use in several beamlines



Spread into the other beamlines



Effects of instability

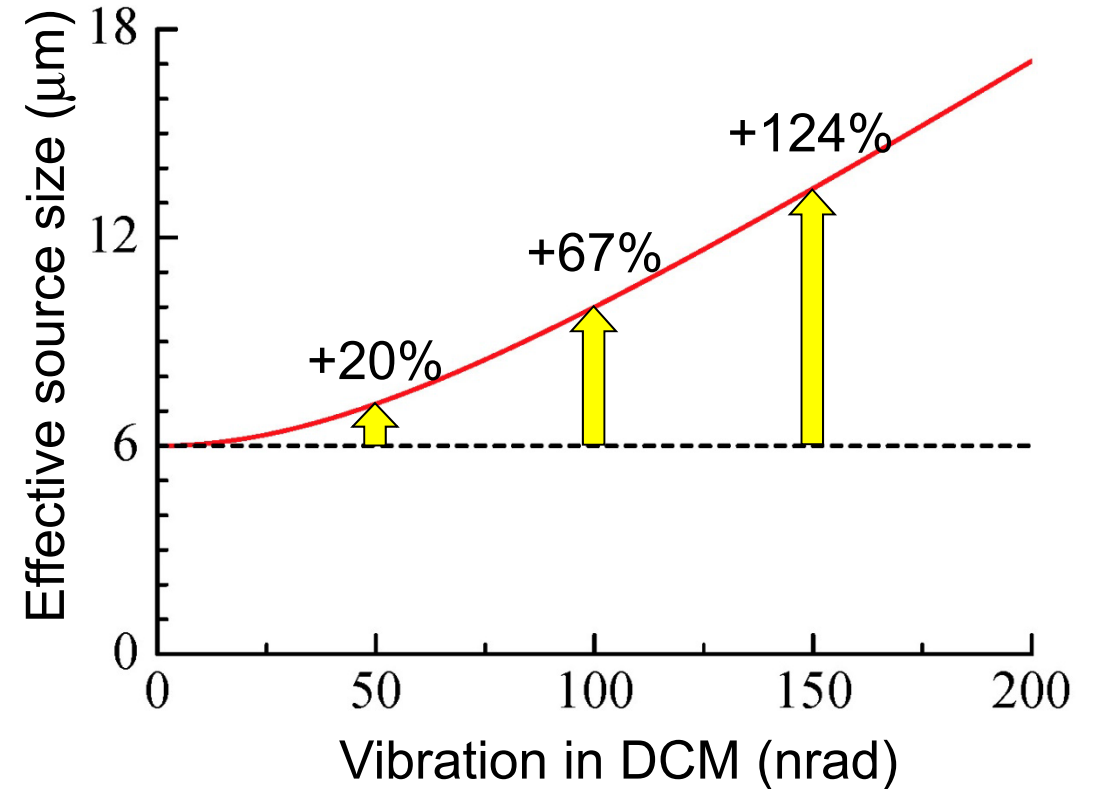
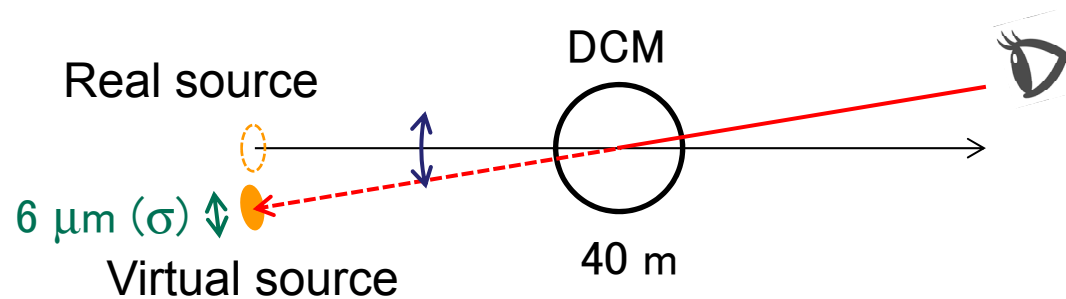


(1) Fluctuation of beam position

Its effect $<$ beam size / 10 is OK.

(2) **Virtual fluctuation of light source**

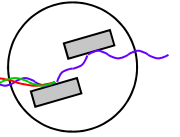
➔ increase of effective source size



Present target : suppression of the source size by 20%

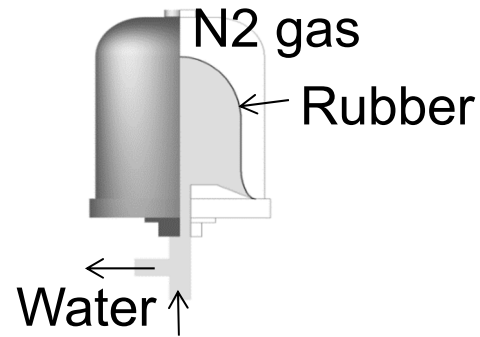
➔ Loss of parallelism between two crystals $<$ **50 nrad**

Target : 50 nrad ... feasible?

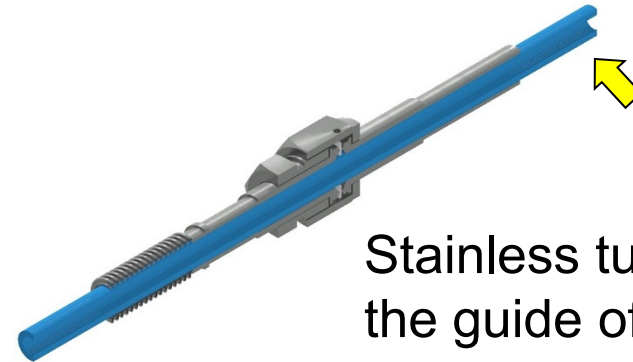


Stabilization of water flow for pin-post crystals (Oct. 2008)

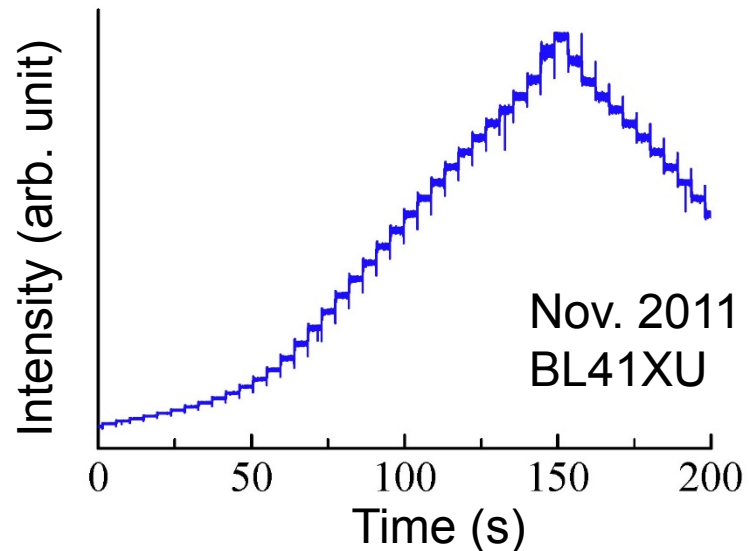
Accumulators to absorb pressure pulsation



Jointless polyurethane tubes for smooth flow



Stainless tubes are used as the guide of polyurethane tubes.

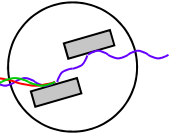


➔ Vibration : 56 nrad

The mechanism has the potential for stability.

(Analysis method is described later.)

Critical issues



Deformation of crystals → deterioration of beam images

Thermal strain

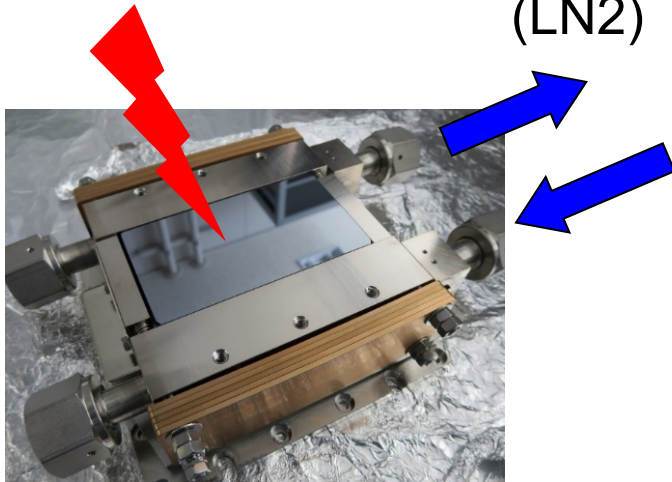
Strain originating from cooling methods
(Hard clamp, coolant pressure, etc.)

Various heat load

0 ~ 400 W

0 ~ 500 W / mm²

Coolant
(LN₂)



Instability of mechanism

> 200 K temperature difference in DCM

Slow shrinkage of stages

Change of photon energy → change of heat load

→ Intensity decrease with time

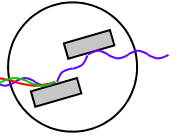
Turbulent coolant flow → vibration of transfer tubes

Boil of coolant

→ Fast intensity fluctuation

Today's topic

Improvements



Against intensity decrease with time,

$\Delta\theta$ feedback system

Precise temperature control of LN2

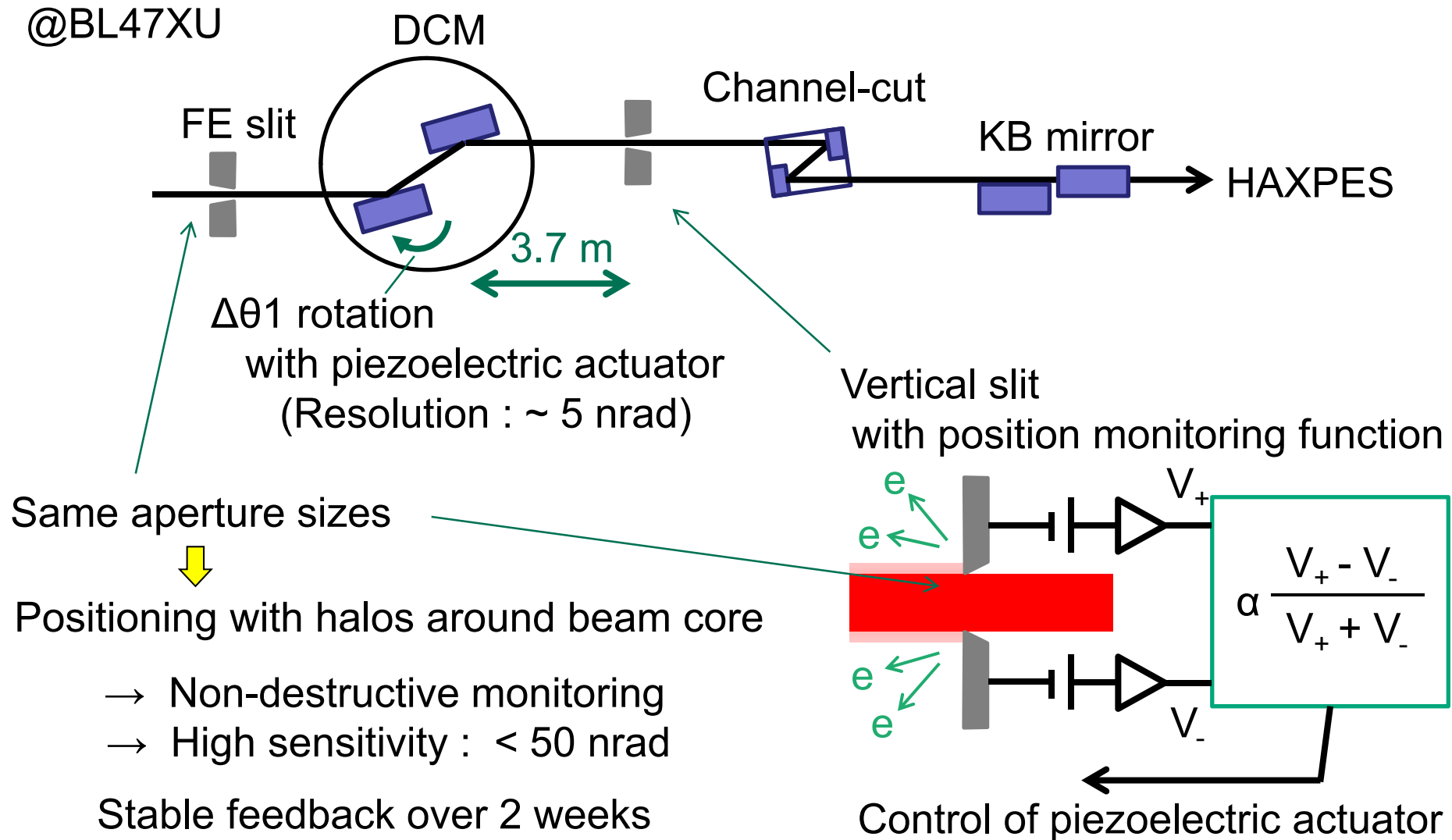
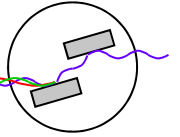
Against fast intensity fluctuation,

Low-vibration flexible tubes

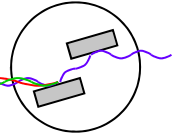
Optimization of LN2 paths

High-rigidity tilt stage

$\Delta\theta_1$ feedback system

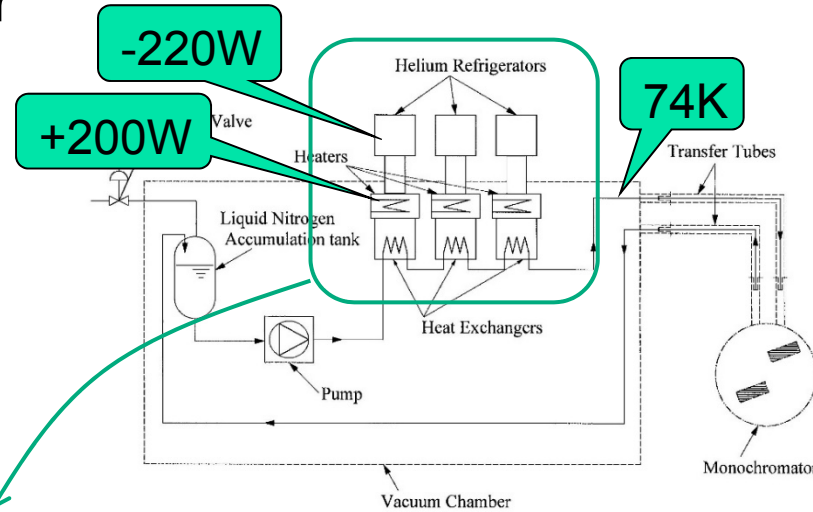
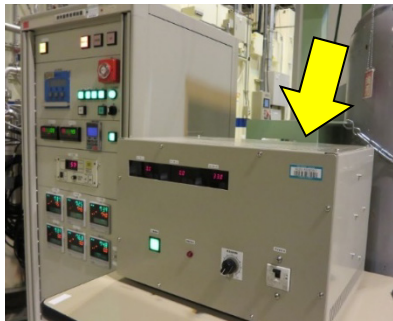


Precise temperature control of LN2

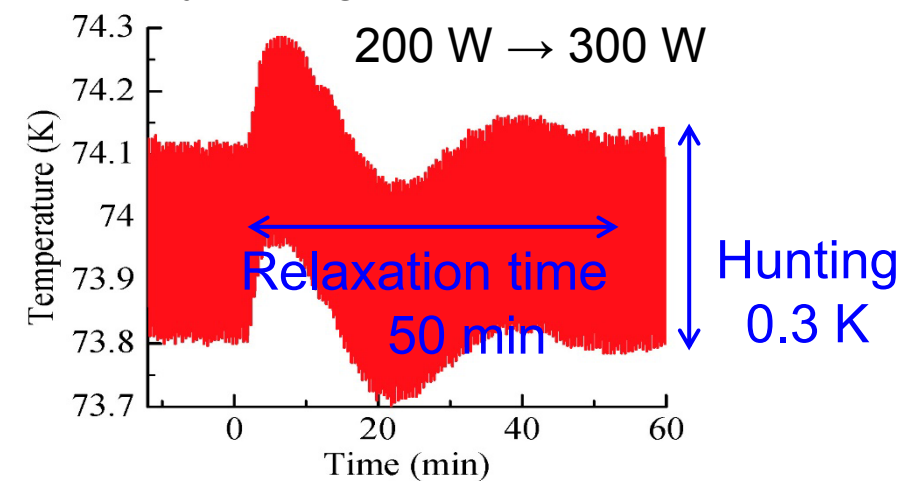


Minimization of waiting time after change of heat loads

LN2 Thermo-controller
(BL20XU, 39XU)



Factory setting (PID)

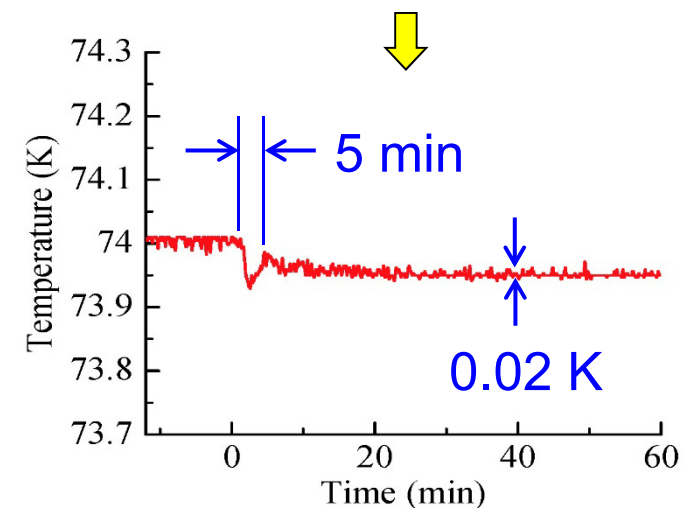
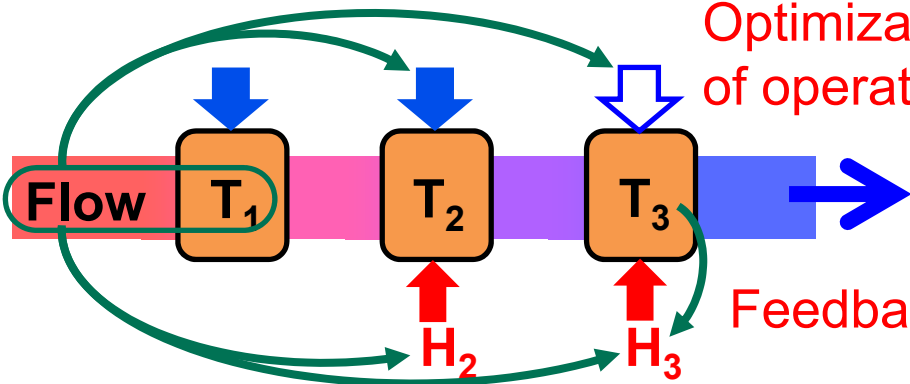


Optimization of number
of operating refrigerators

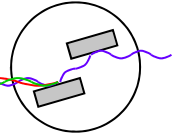
→ energy saving
(9 kW / refrigerator)

Feedback → precision

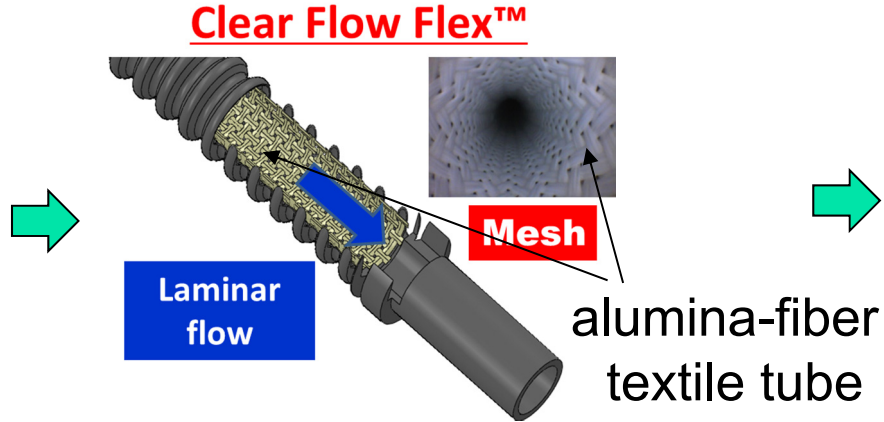
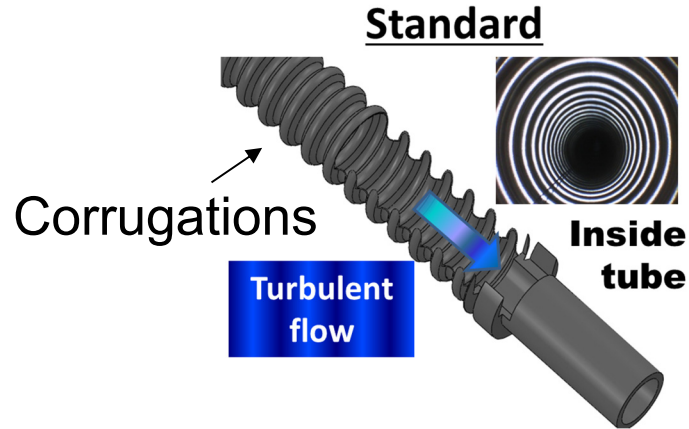
Feedforward → rapid response



Low-vibration flexible tubes



Cause of turbulence : corrugations of flexible tubes → Shield them from coolant !

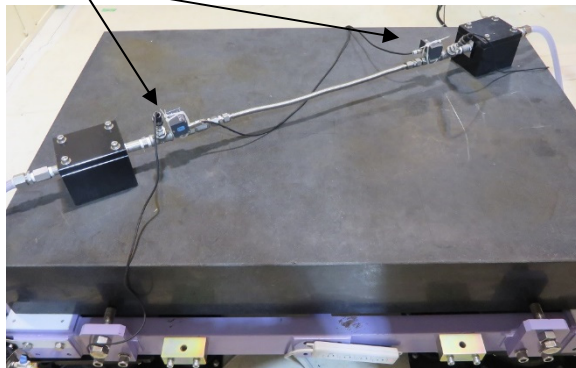


CFF4

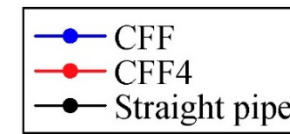
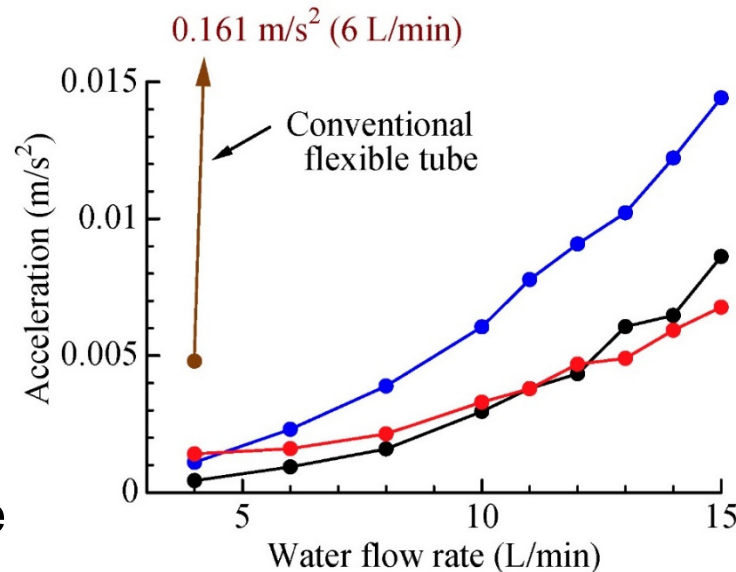
Improved inner tube
1/2 inch, 1/4 inch

Collaboration with
Osaka Rasenkan Kogyo,
RIKEN, and JASRI
(Patent pending)

Pickups

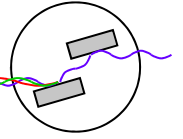


Test with water at room temperature

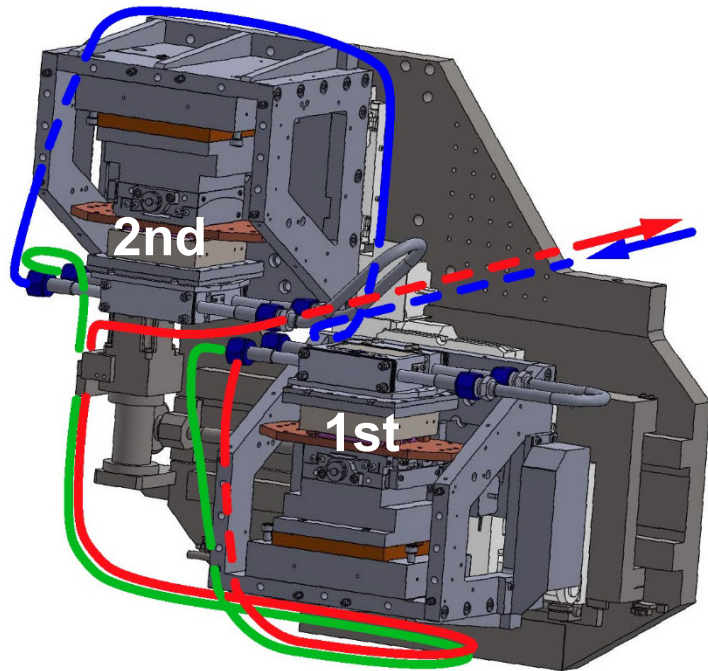


} Same level

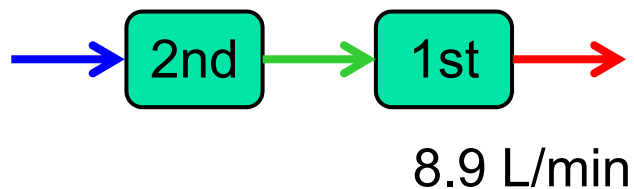
Optimization of LN2 paths



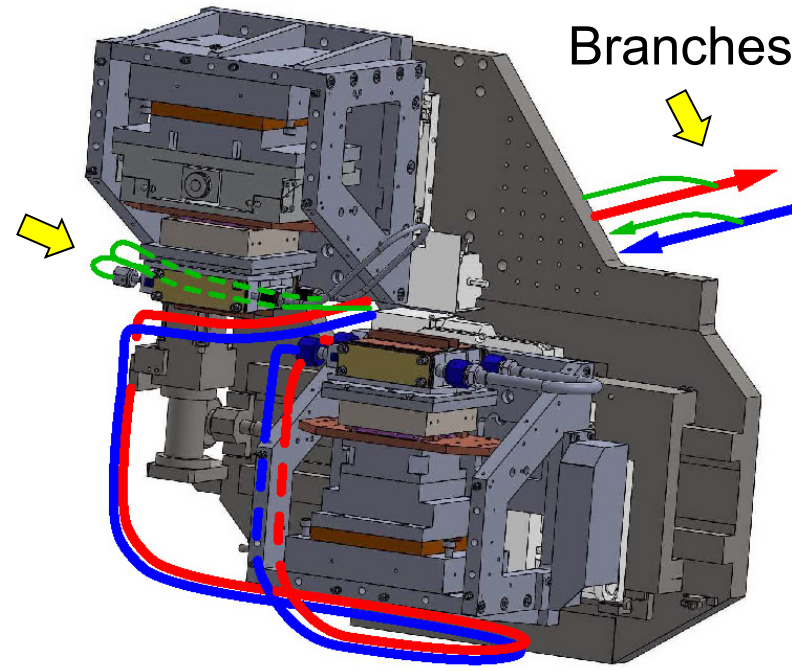
Increase the flow rate of LN2 for the 1st crystal to prevent boil.



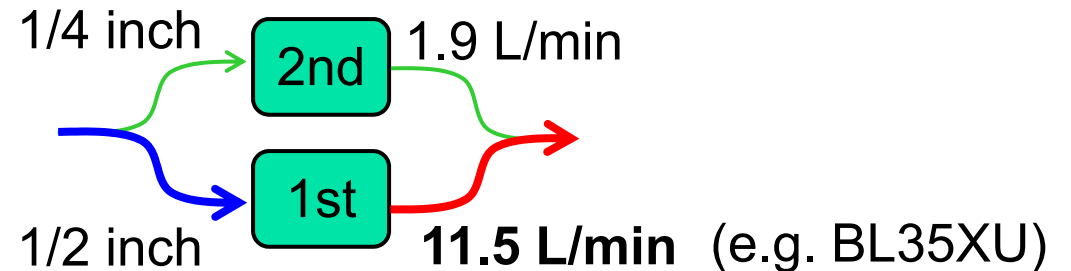
One-stroke path with 1/2 inch tubes



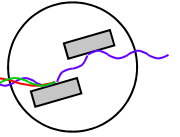
1/4 in.
tubes



Branched paths

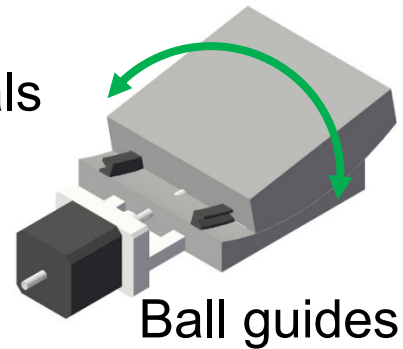
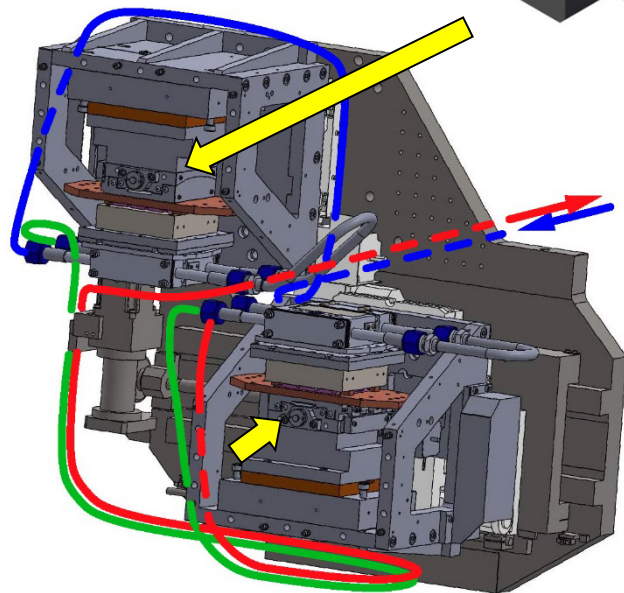


High-rigidity tilt stage

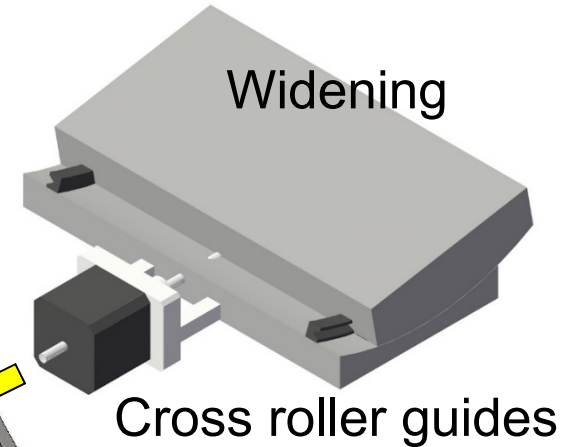
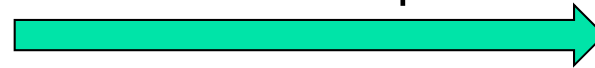


Improvement in mechanism that suffers the vibration

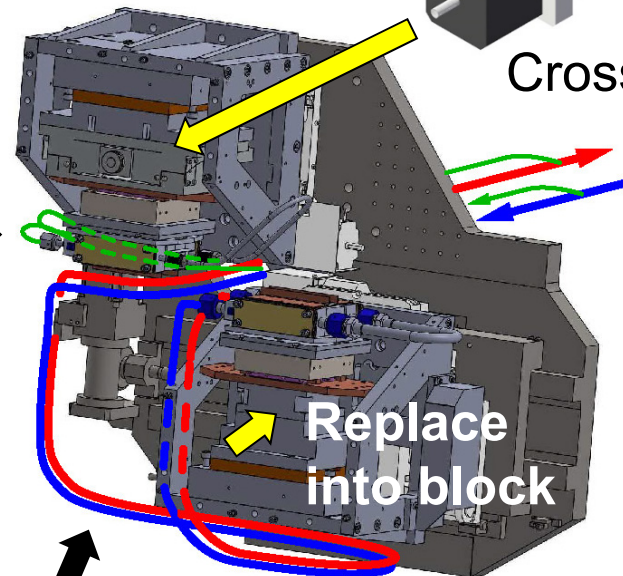
Individual tilt stages
for both 1st and 2nd crystals
Redundant configuration
for LN2-cooled crystals



Increase of rigidity
in diffraction plane



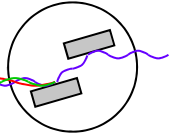
1/4 in.
tubes



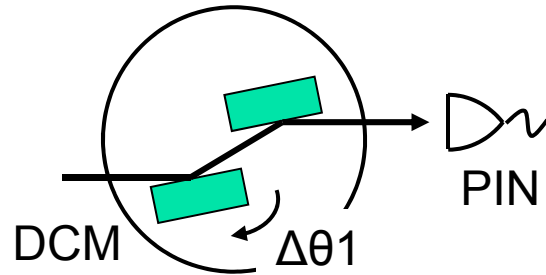
Replace
into block

1/2 in. tubes : larger vibrational energy

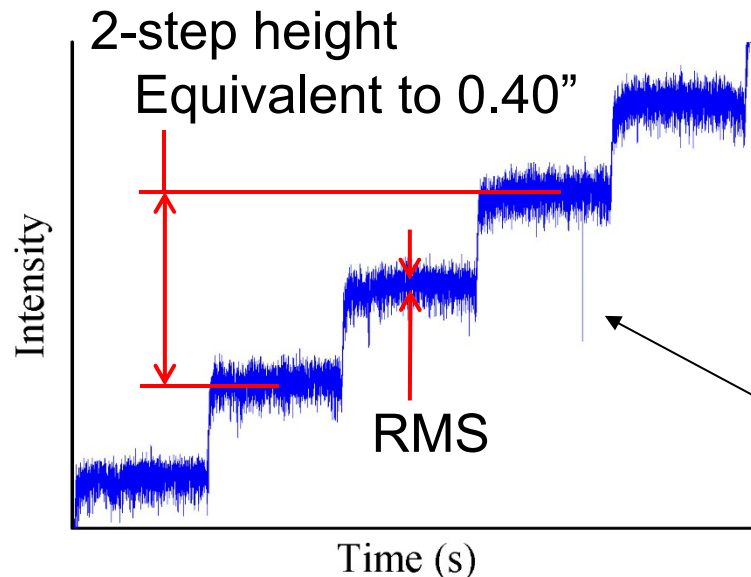
Performance tests



Method



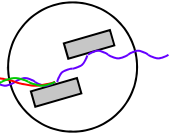
- (1) Output is averaged during 1 ms.
- (2) Recorded at 1 kHz sampling rate.
- (3) 1st crystal is rotated every 0.20" at a time interval.
(~ 1 μrad)



- (4) Calculations of
 - RMS of intensity during 4 s
 - Conversion factor from intensity to angle at half the maximum intensity.
- (5) Convert RMS to angular unit (nrad).

A-few-millisecond intensity decrease
caused by the injection of electrons for the top-up operation

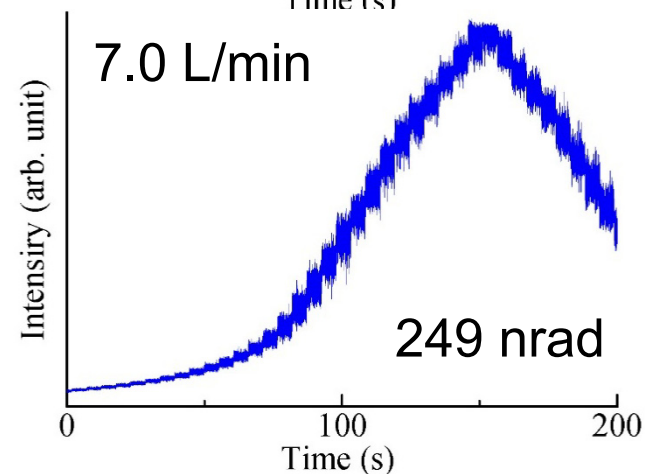
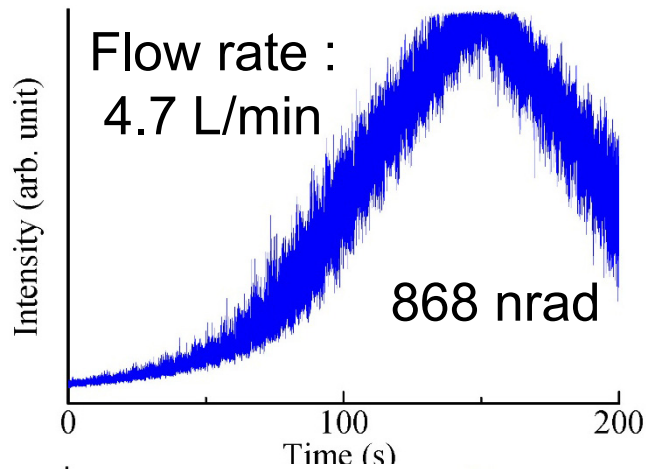
Result : boil of LN2 (@BL35XU)



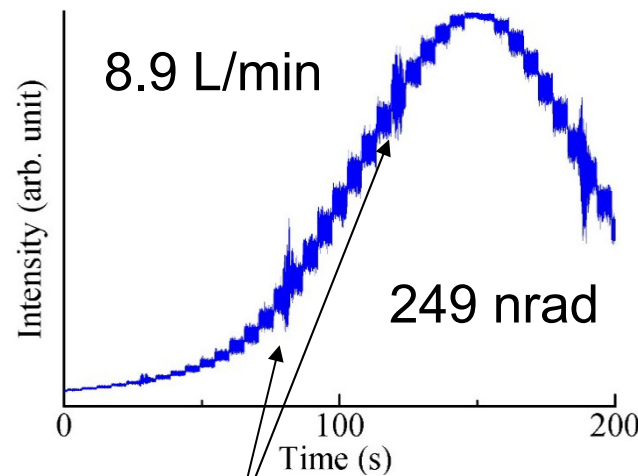
Oct. 2011
Power : 382 W
21.7 keV beam

Apr. 2015
412 W

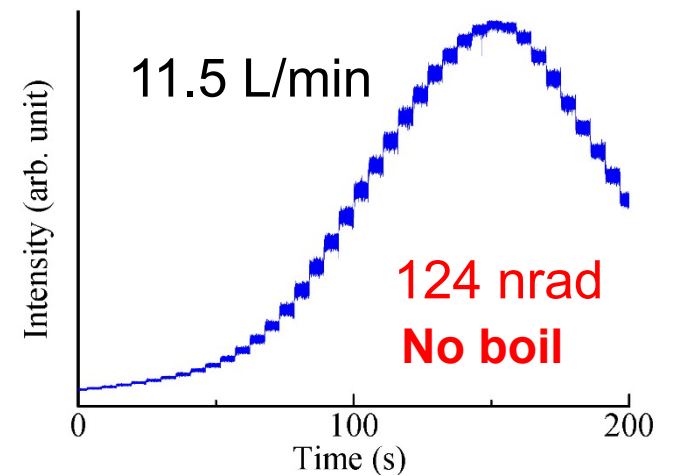
Apr. 2018
412 W



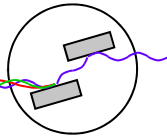
Change of LN2 tubes
outside the DCM
Inner diameter :
14.9 → 18.4 mm



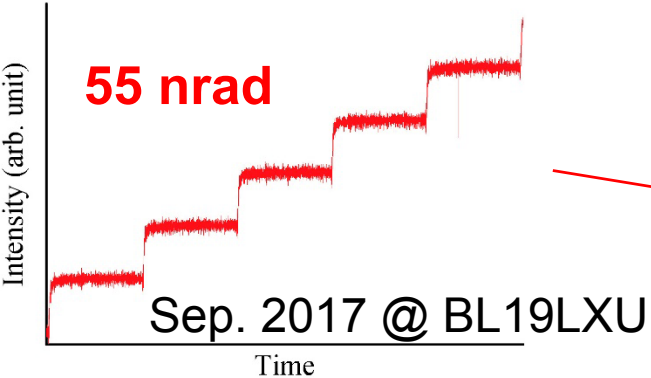
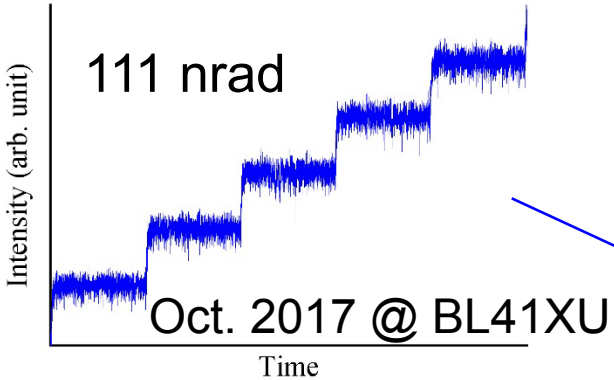
Clear Flow Flex 4
Optimization of LN2 paths
High-rigidity tilt stage



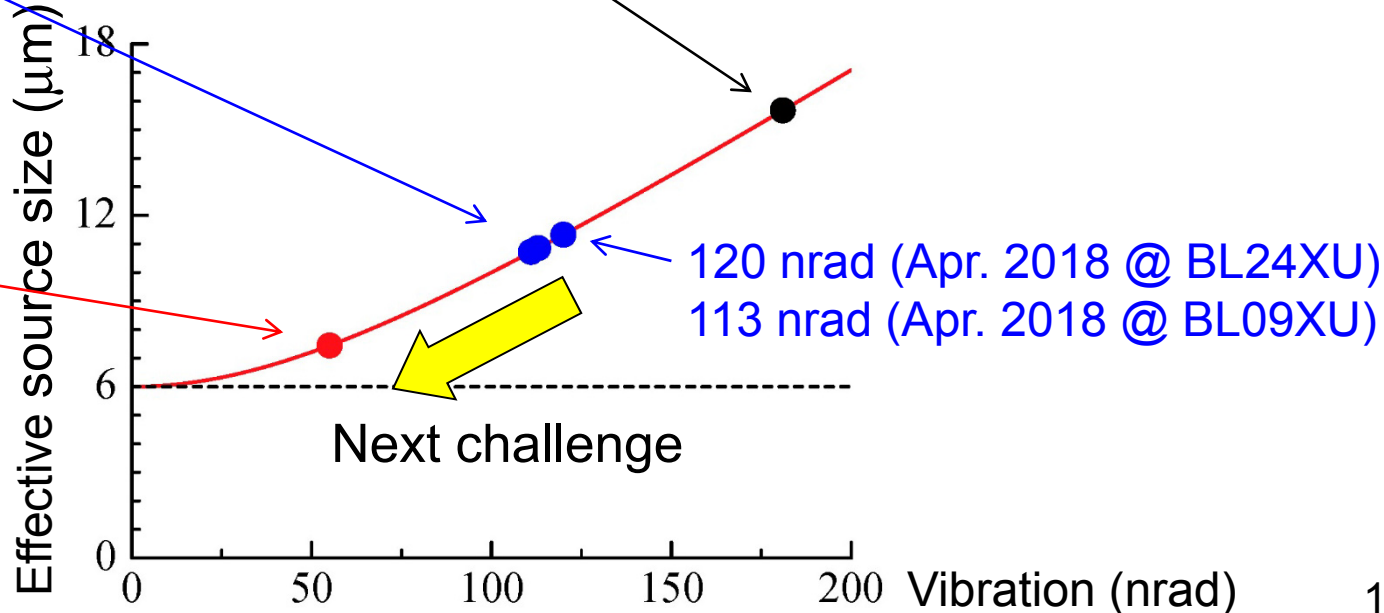
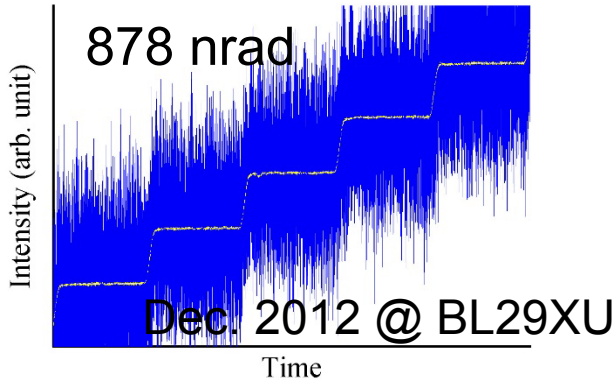
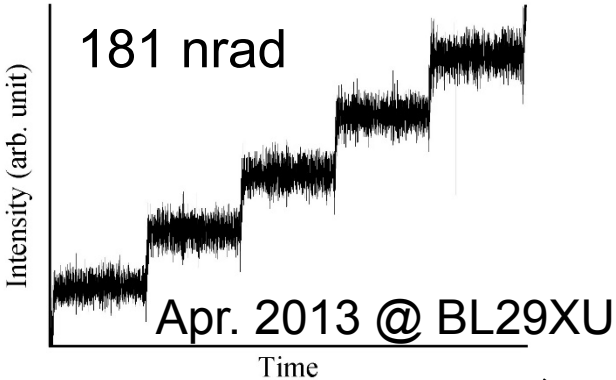
Result : turbulence



Clear Flow Flex 4
Optimization of LN2 paths
High-rigidity tilt stage

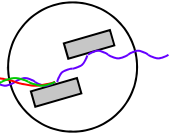


Clear Flow Flex



12.4 keV beam, heat load < 100 W

Summary



We are refining the SPring-8 standard monochromators. Our target of stability is 50 nrad, which will suppress the source size by 20% in SPring-8 and SPring8-II.

Against intensity decrease with time, we made

- $\Delta\theta 1$ feedback system,
- Precise temperature controller of LN2.

Against fast intensity fluctuation, we improved

- Low-vibration flexible tubes,
- LN2 paths (from one-stroke path to branched ones),
- High-rigidity tilt stages.

The vibrations were reduced to approximately 120 nrad for several monochromators. The best stability of 55 nrad was achieved for a monochromator.

