SPring-8 Standard Monochromators (SSMs)

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Outline

Design of SSMs

Mechanisms

Crystals & Cooling

Stability

Concept of SSM

SPring-8 optics R&D started in 1994.

Technical issue : high heat load (8 Gev electrons + in-vacuum undulators)

» Try the limit of water cooling !
- Direct cooling of silicon crystal in rotated-inclined geometry
- Indirect cooling of diamond crystal

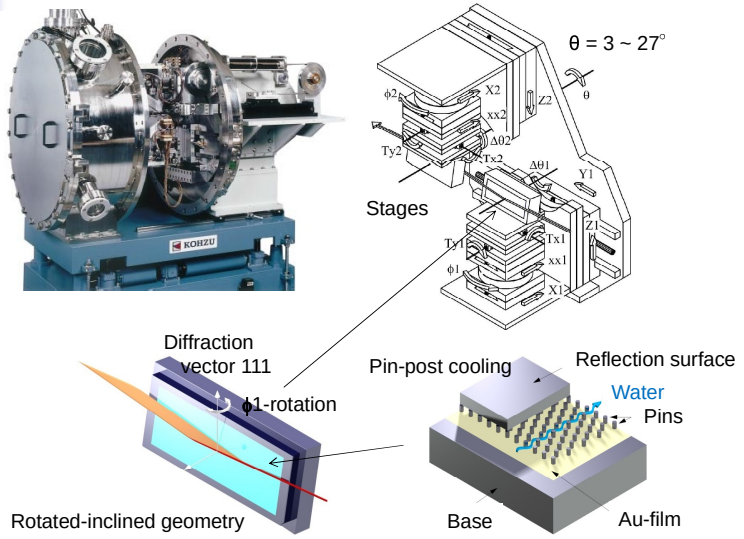
Social needs : many beamlines, in a short period of time

» Commonization of optical and transport components
- “Standard” monochromator, shutter, vacuum unit, etc.

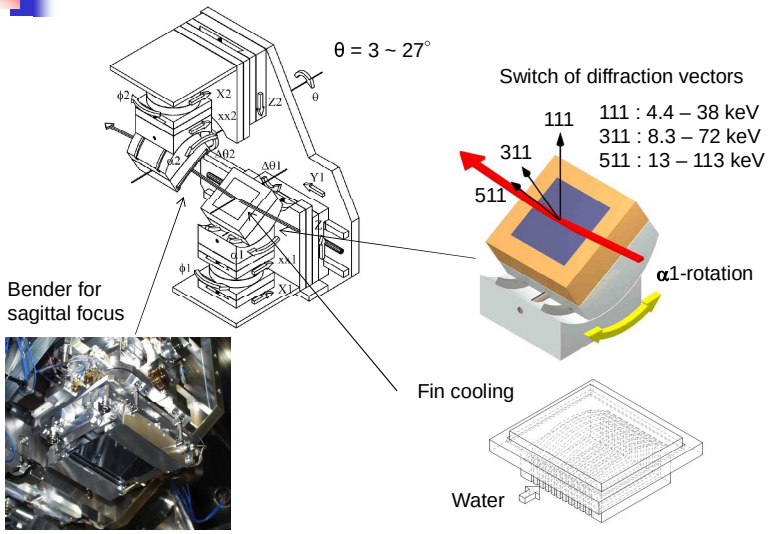
Standard monochromator should have flexibility in use.

The first user operation was in 1997.

Initial design for U



Design for BM



SPring-8

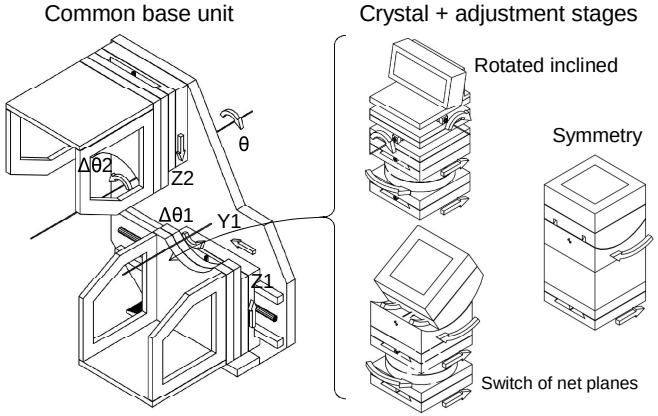
Design of SSMs

⋙ Mechanisms

Crystals & Cooling

Stability

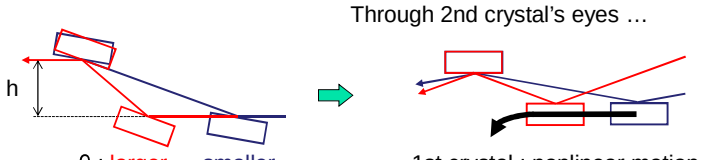
Configuration of SSM

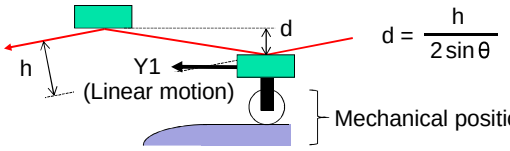


Why is the rotation center of DCM on 2nd crystal surface ?

The 1st crystal suffers heat loads of maximum 500 W.
The thermal stability of the 1st crystal cannot be expected.

Fixed exit operation of SSM (1/3)



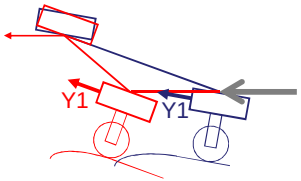


$$d = \frac{h}{2\sin\theta}$$

The cam changes the height automatically in response to Y1 position.

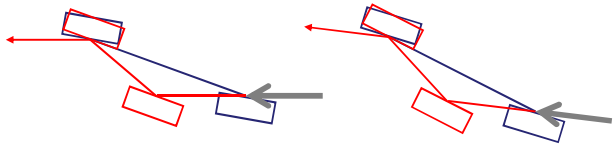
Fixed exit operation of SSM (2/3)

Y1 and cam stages attach on θ stage.
The moving directions are rotated in response to θ. ⋯ Why ?



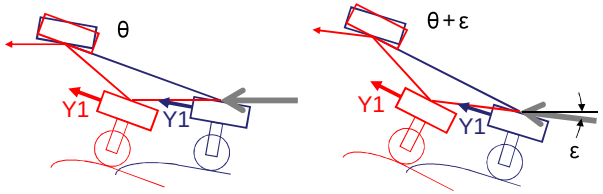
θ : larger ↔ smaller

Position of fixed exit depends on the direction of incident SR.

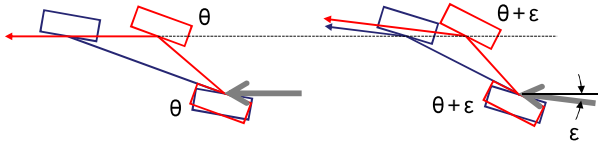


Fixed exit operation of SSM (3/3)

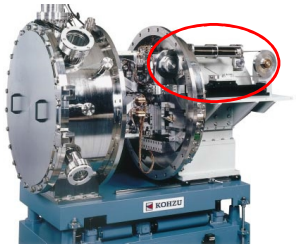
SSM can follow change of incident direction by giving an offset to θ.



cf. 1st crystal : rotation, 2nd crystal : rotation + horizontal translation

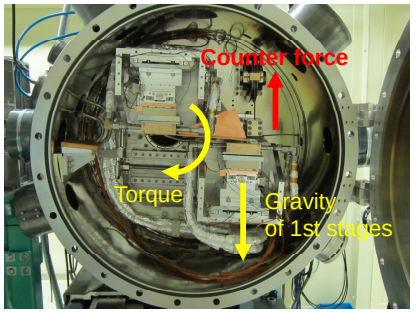


Precise energy tune

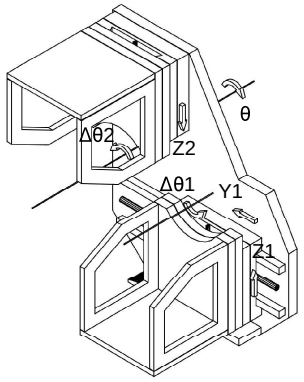


Air cylinder unit ⋯ Why ?

Y1 long travel for small θ
↓
θ torque by gravity
↓
Shift of wavelength
↓
Compensation
with counter force



Typical parameters



Name	Range	Resolution
θ	-1 ~ 27°	0.2”
Y1	30 ~ 290 mm	1 μm
Δθ1	> ±2°	0.01”
Δθ1 (P)	±15”	0.001”
Z1	> ±2 mm	1 μm
Δθ2	> ±2°	0.01”
Z2	> ±2 mm	1 μm

Fixed exit operation : θ = 3 ~ 27 degrees.
Δθ1 stage contains a piezoelectric actuator for finer adjustment and for feed back.

Design of SSMs

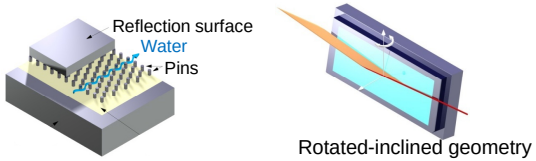
Mechanisms

» Crystals & Cooling

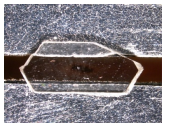
Stability

SSM crystals for U

A) Pin-post water-cooled silicon (1997 – 2013)



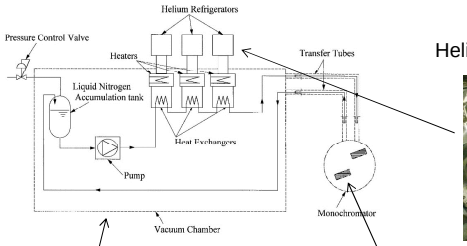
B) Indirectly-water-cooled diamond (2005 – 2013)



Thickness : 0.4 – 0.6 mm

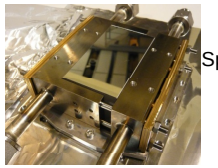
C) Indirectly-LN2-cooled silicon (2000 – present)

Indirect cooling with LN2

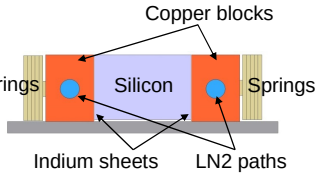


Helium refrigerators (200 W x 3)

Pump & controller

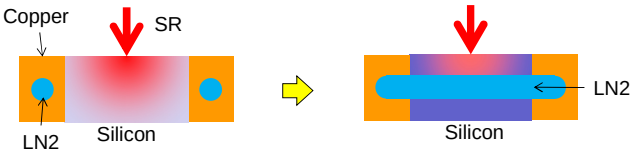


Crystal and holder



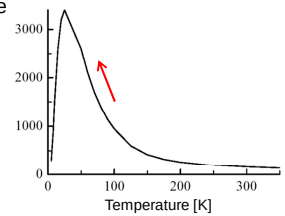
R&D of direct cooling with LN2

Merit of direct cooling

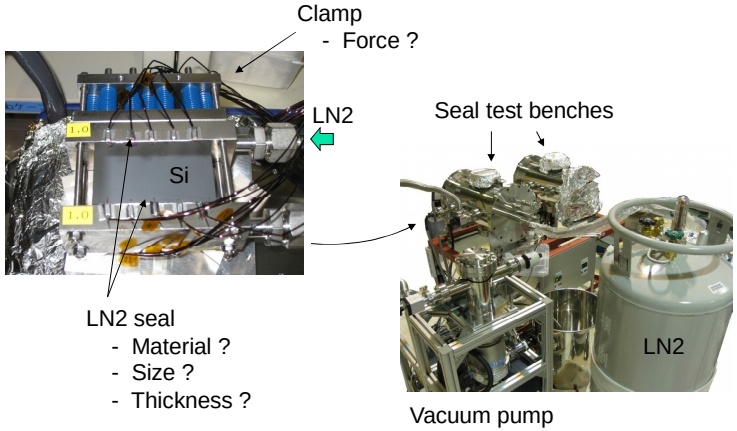


Shortening of thermal path → Reduction of temperature gradient → Reduction of thermal strain

Increase of heat transfer → Lowering of temperature → Increase of thermal conductivity

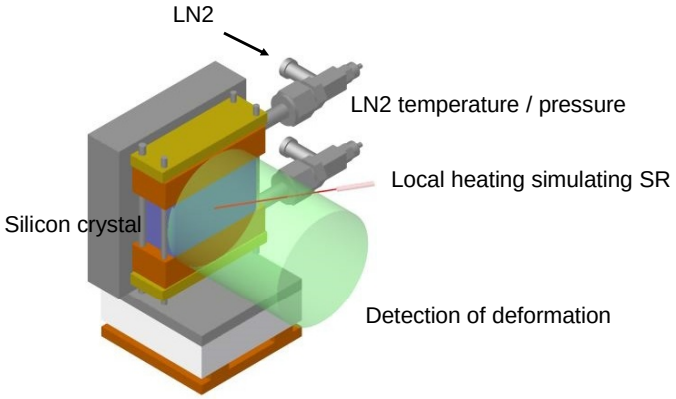


LN2 seal test

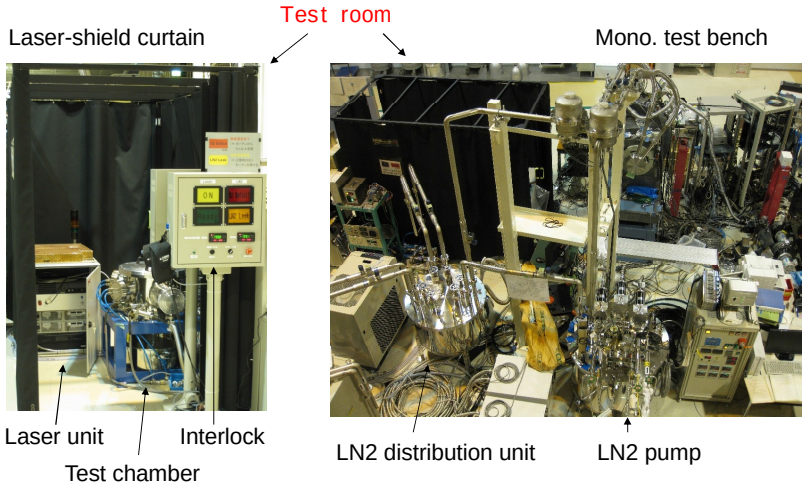


Indium gasket works for LN2 seal, but cramping force is too strong …

Schematic of heat-load test



Test bench for Heat load test



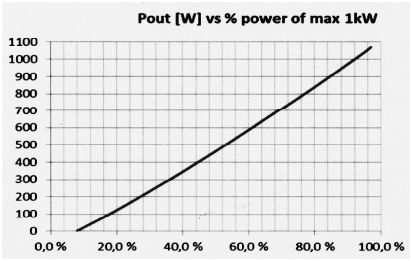
Local heating

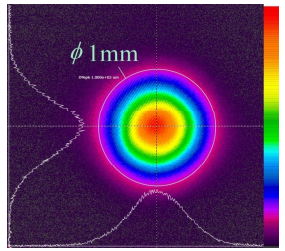
Laser specification

Fiber laser : 1070 nm
CW, Single mode
Maximum power : 1 kW

+ Optics (collimator)
Beam diameter (D4σ) : 0.5 ~ 2.5 mm

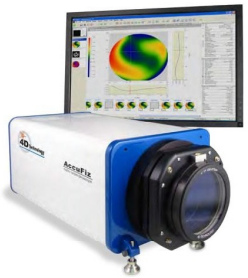
FO-1000 (Mitsui Electronics Inc. OEM)



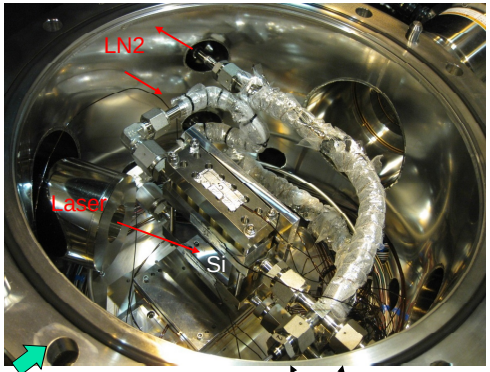


Test chamber + interferometer

Fizeau interferometer



AccuFiz (4D Technology)

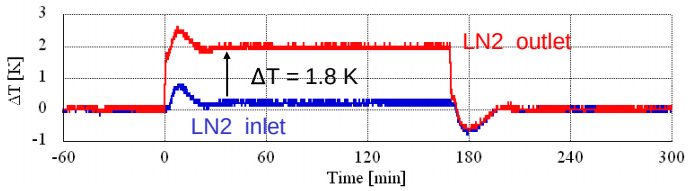


LN2 pressure / temperature

Preliminary test

Indirect cooled silicon crystal used in undulator beamlines

Temperature changes of LN2 for 300 W laser

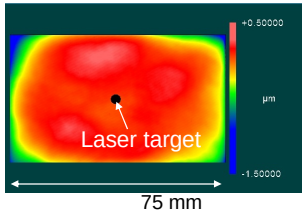


Temperature difference 1.8 K → 250 W absorption into LN2

Radiation of 300 W laser ~ radiation of 300 W SR

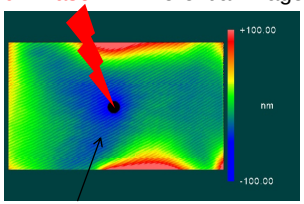
Deformation of crystal surface

Original shape



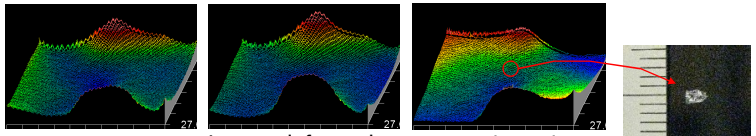
75 mm

300 W laser Differential image



Negative thermal expansion

300 W 500 W 1000 W



Larger deformation

Twist & damage

Next step : design of LN2 paths to suppress thermal deformation

SPring-8

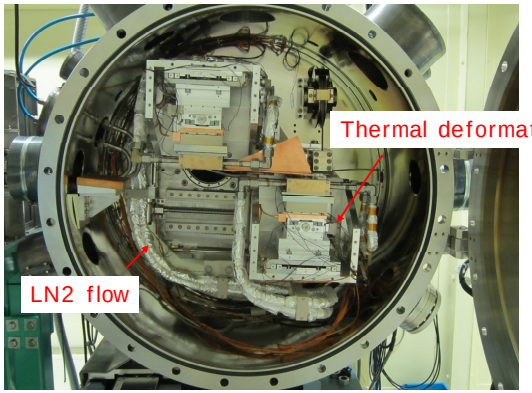
Design of SSMs

Mechanisms

Crystals & Cooling

» Stability

Causes of instability



Double-crystal monochromator at BL13XU

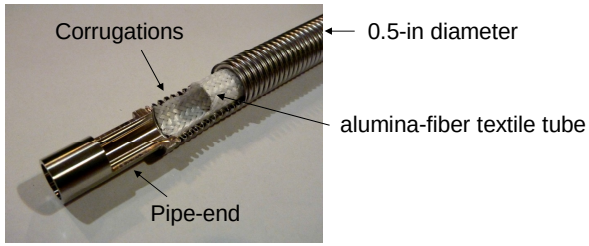
Improvement for LN2 flow (1/3)

Use of stainless-steel flexible tubes for LN2 flow in the monochromators

Flexibility, cold resistance, and radiation tolerance

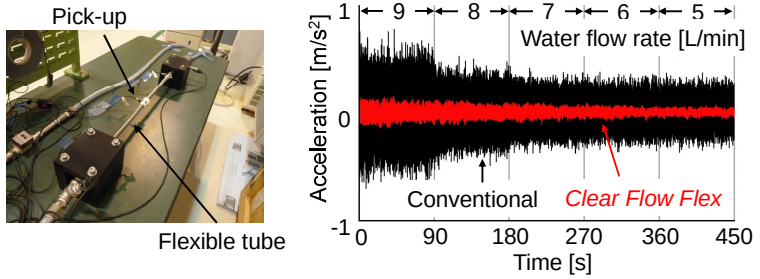
The corrugations of the tubes make turbulent LN2 flow → vibration.

If the corrugations are hidden with something smoother, …



Improvement for LN2 flow (2/3)

Preliminary test of new flexible tube



"Clear Flow Flex", PAT. Pending

(JASRI / RIKEN / Osaka Rasenkan Kogyo)

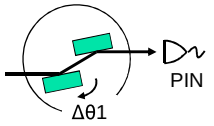
Improvement for LN2 flow (3/3)

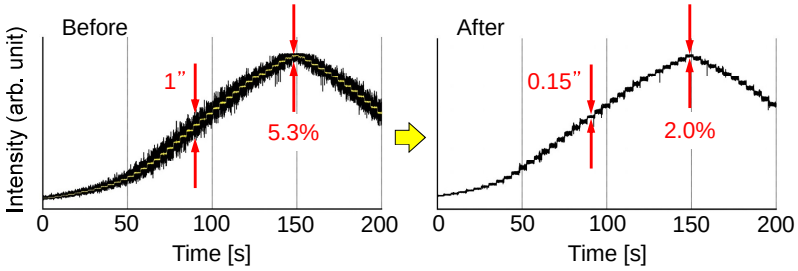
Measured Intensity fluctuation of 1 Å x-rays at BL13XU

Average time : 1 ms

Repetition frequency : 1 kHz

Δθ1 stage : 0.2″ stepping over a time interval of 5 s

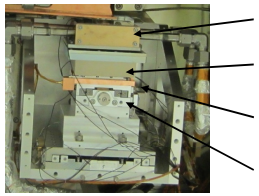




Angular fluctuation between the crystals : 1″ → 0.15″

Intensity fluctuation of 1 Å x-rays : 5.3% → 2.0%

Improvement for Thermal deformation



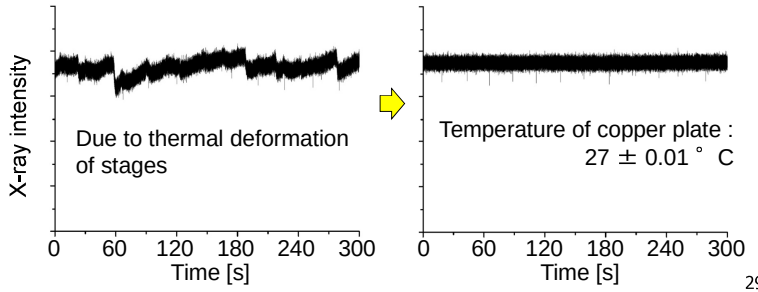
1st crystal holder with LN2 paths

Machinable ceramic block

Copper plate with sheet heater

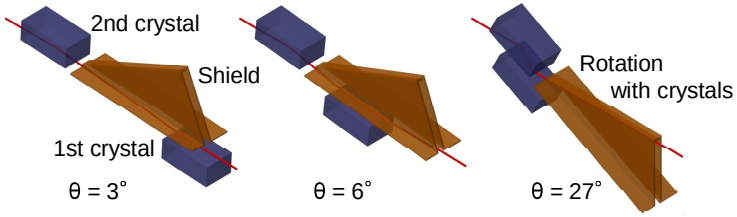
Tilt stage

Heater current control : ON/OFF → PID



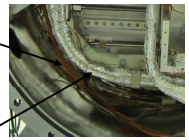
Other improvements

Radiation shield to block secondary radiations from the first crystal



Material of cable jacket :

cross-linked plastic → polyimide (for Radiation tolerance)



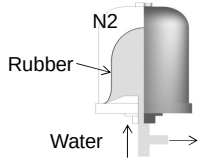
cryogenic insulator for thermal insulation from LN2 paths

ten-layer aluminum-deposition films spaced with nets

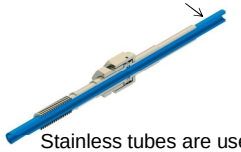
Next target : 0.05" ··· feasible ?

Exhaustive stabilization of coolant flow for water-cooled crystals

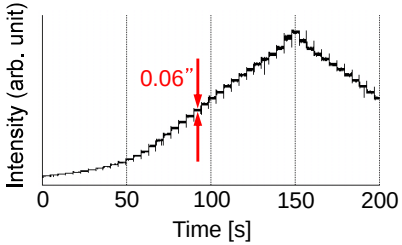
Accumulators to absorb pressure pulsation



Jointless polyurethane tubes for smooth flow



Stainless tubes are used as the guide of polyurethane tubes.



Vibration can be reduce to at least 0.06".

Summary

1. A SSM mechanism consists of two parts:
   - common base unit,
   - crystal adjustment stages.

   Bragg angles are covered from 3 to 27° in fixed exit operation.

2. SSM crystals for undulator beamlines are silicon blocks cooled with LN2 indirectly now. We are starting to develop a direct cooled silicon crystals for higher performance.

3. An amount of vibrations of the SSM with LN2 cooled crystals is 0.15" in terms of angular misalignment between the two crystals. The immediate target is to suppress it within 0.05".

Acknowledgement

JASRI / Optics Group

Yasuhisa Matsuzaki, Yasuhiro Shimizu, Masayuki Tanaka,
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RIKEN

Makina Yabashi, Tetsuya Ishikawa

Thank you very much for your attention.