

Vibration measurement in the cryogenic interferometric gravitational wave detector (CLIO interferometer)

ICRR Univ. of Tokyo, Dept. of geophysics Kyoto University^A,
KEK^B, Dept. of advanced materials science Univ. of Tokyo^C,
Sumitomo Heavy Industries Ltd.^D

K. Yamamoto, T. Uchiyama, S. Miyoki, M. Ohashi, K. Kuroda,
H. Hayakawa^A, T. Tomaru^B, N. Sato^B, T. Suzuki^B, T. Haruyama^B,
A. Yamamoto^B, T. Shintomi^B, S. Moriwaki^C, Y. Ikushima^D,
T. Koyama^D, R. Li^D

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0. Abstract

Measurement of the vibration

at the top of suspension and inner shield of CLIO interferometer

Contents

1. Introduction

2. Outline of experiment

3. Results

4. Future works

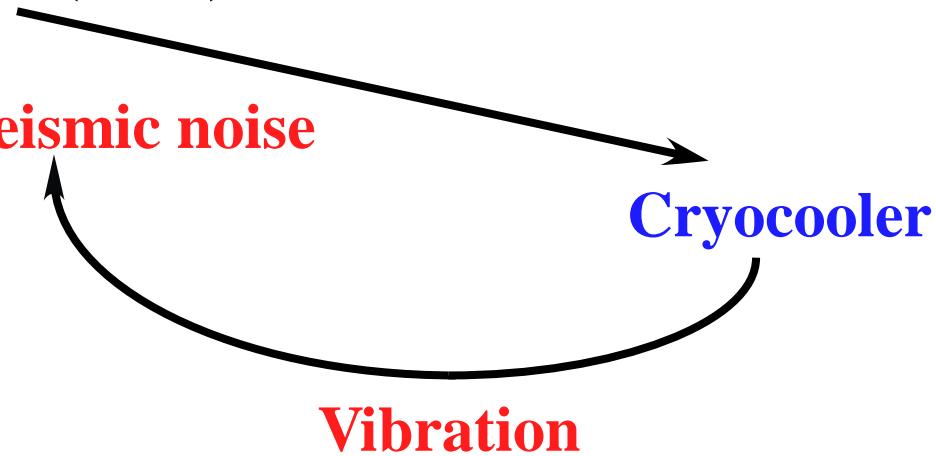
5. Summary

1. Introduction

**LCGT and CLIO : future and current Japanese project
to construct the interferometric gravitational wave detector**

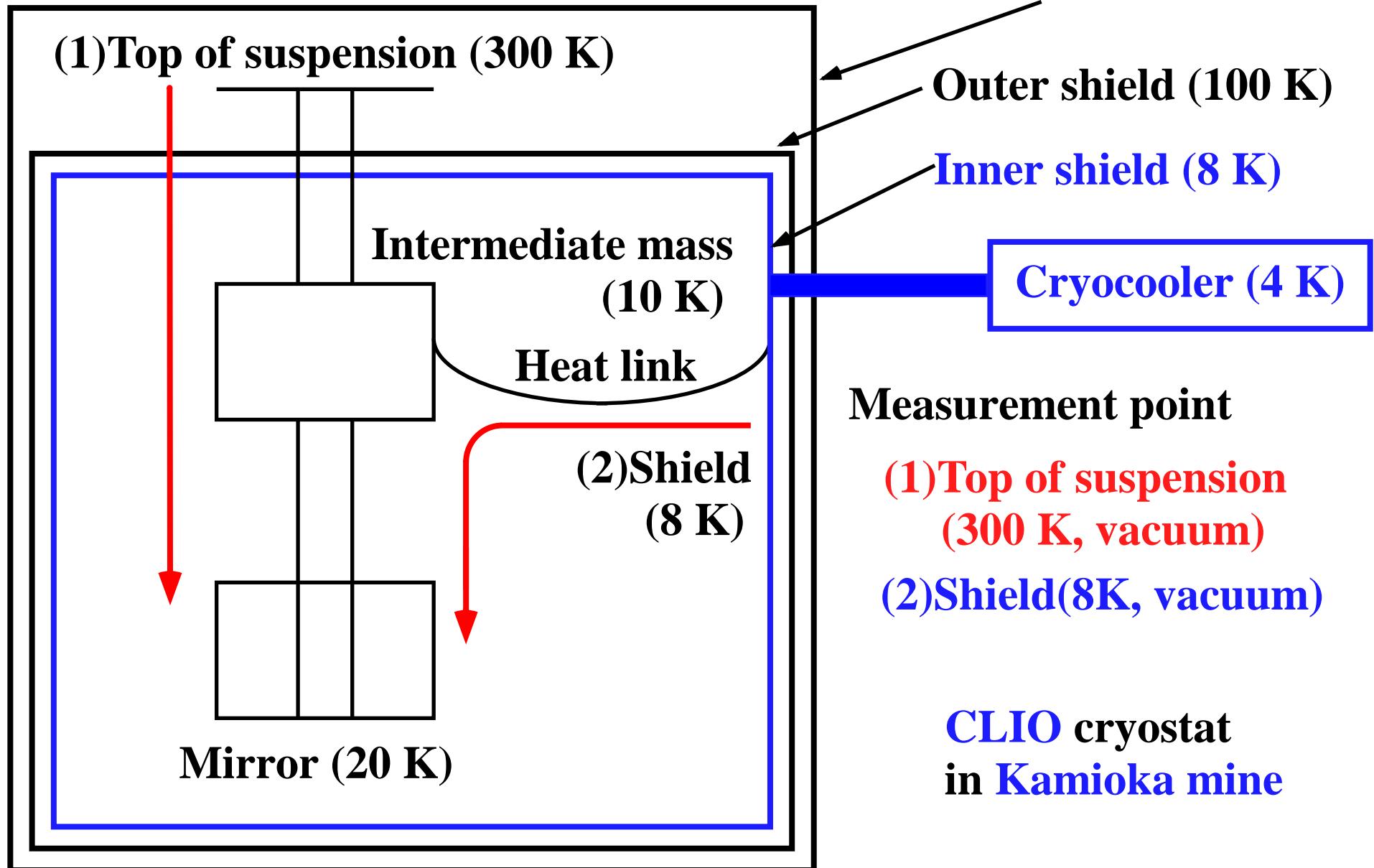
(1) Cryogenic interferometer (20 K) : reduction of thermal noise

(2) Kamioka mine : small seismic noise



Measurement of vibration with operating cryocooler is necessary.

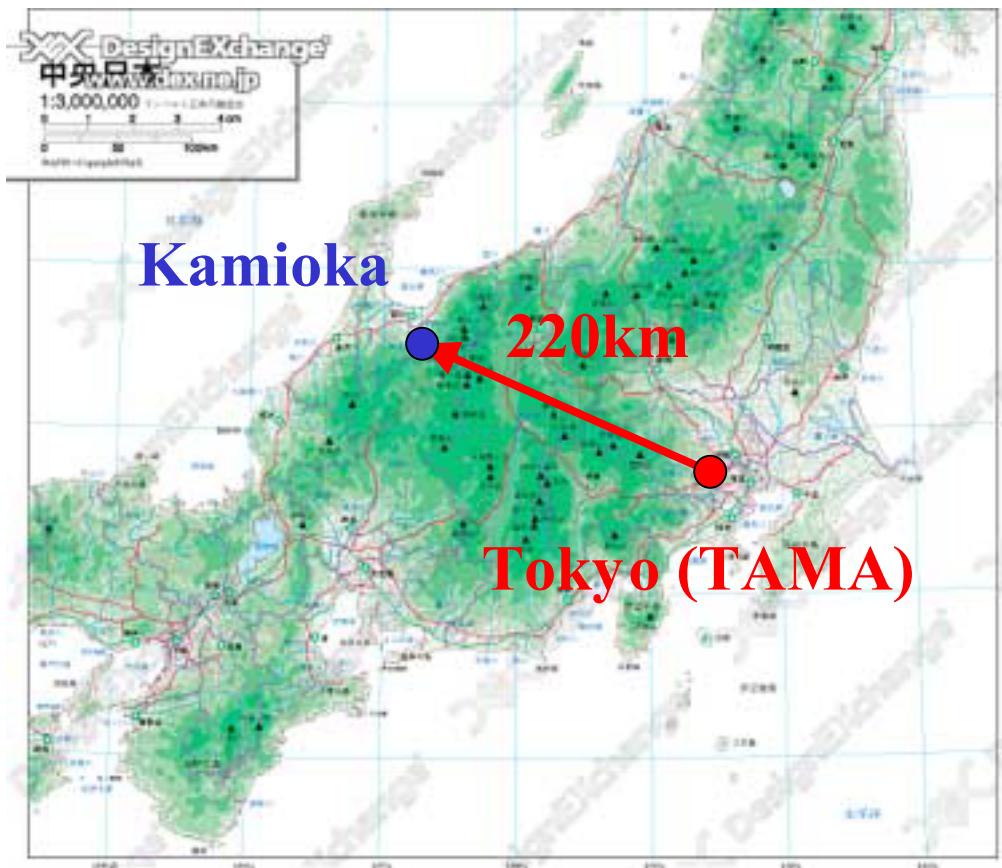
Schematic view of cryogenic apparatus



2. Outline of experiment

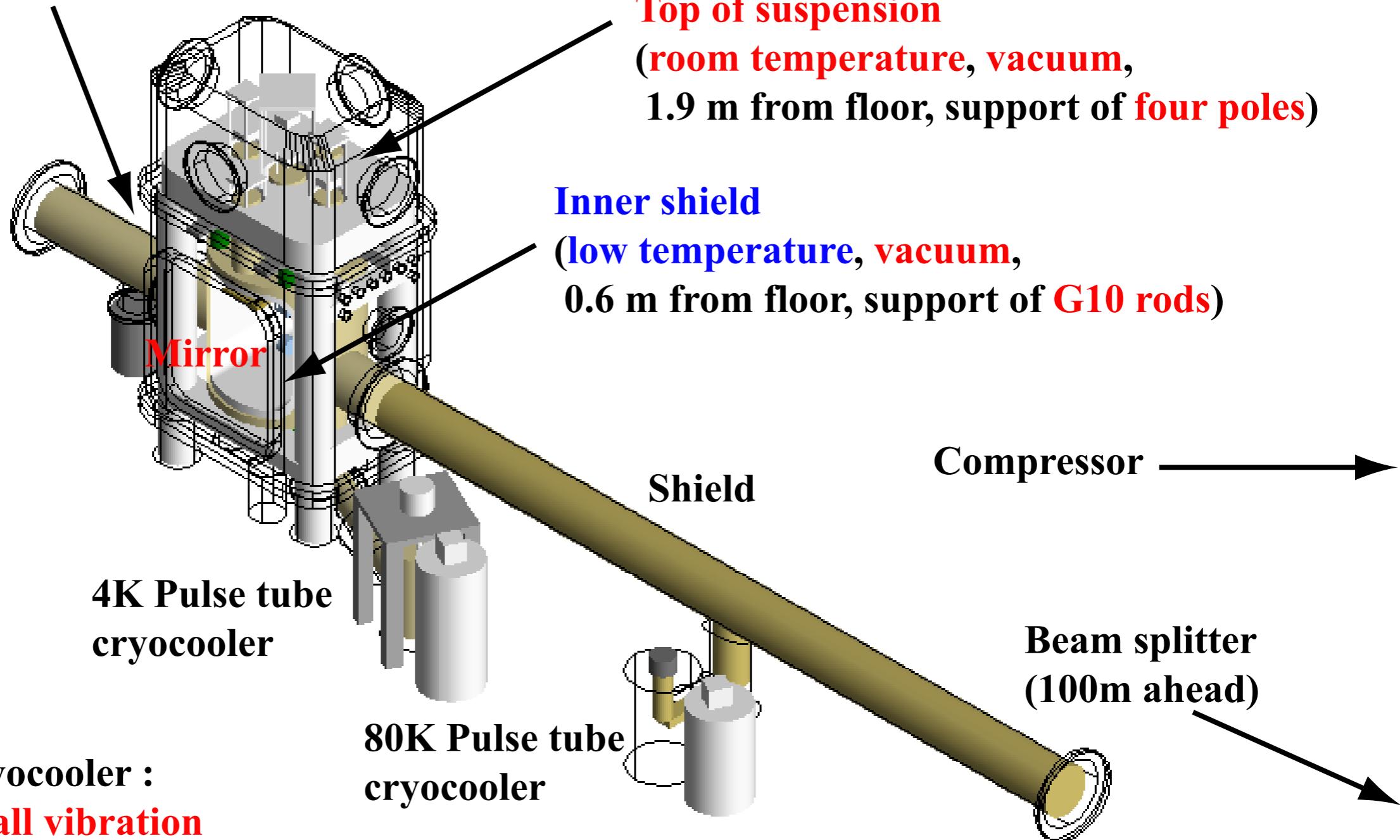
2-1. Location

Kamioka mine (LCGT,CLIO site)
220km west from Tokyo



2-2. Cryostat of CLIO interferometer (end)

Gifford-McMahon refrigerator
(removal)



Pulse tube cryocooler :
extremely small vibration

(developed by KEK and Sumitomo Heavy Industries Ltd.)

Class. Quantum Grav. 21(2004)S1005.

by T. Uchiyama

Cryostat of CLIO interferometer

Top roof

Door



Top of suspension



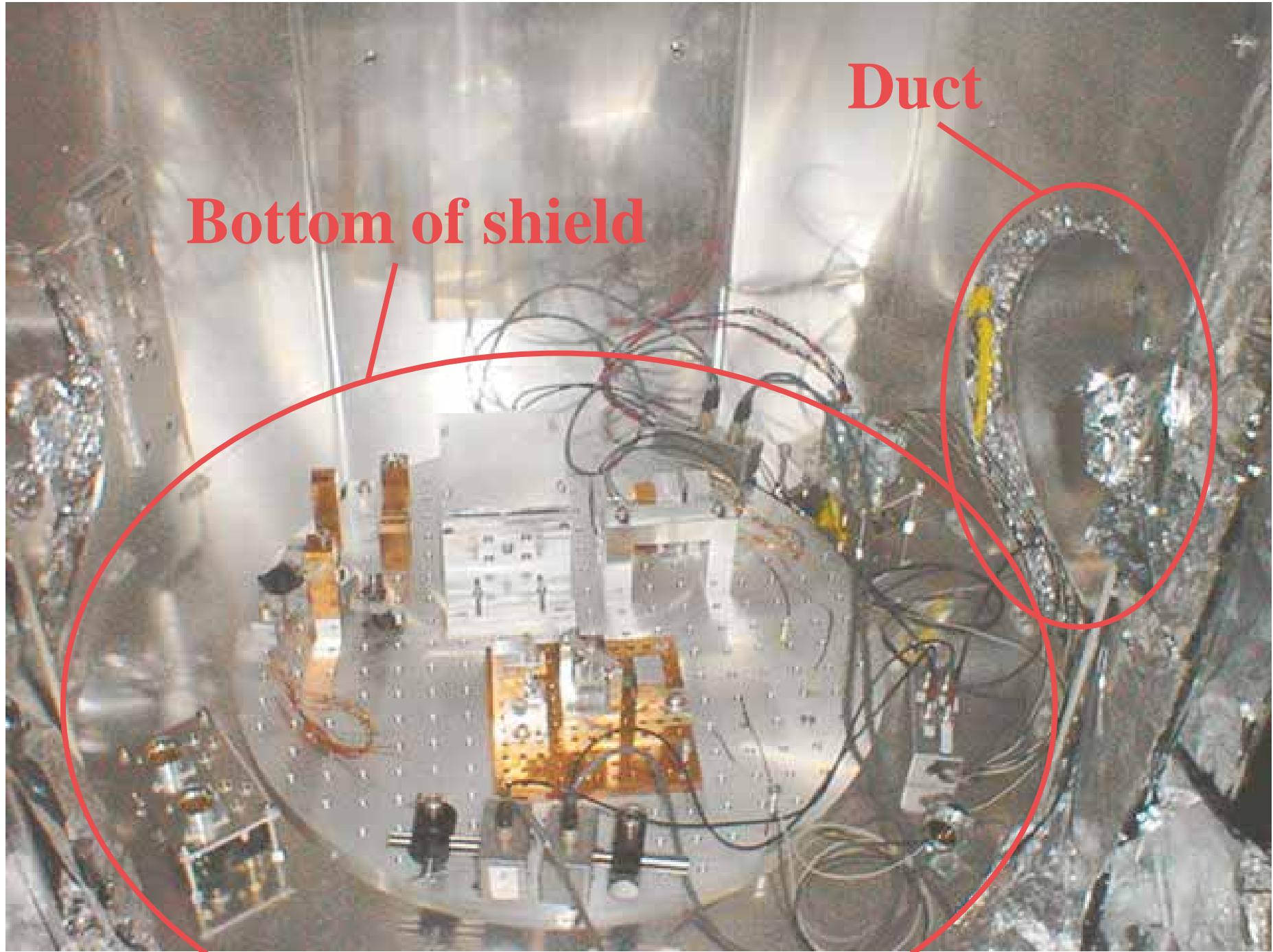
Cryostat of CLIO interferometer

Top roof

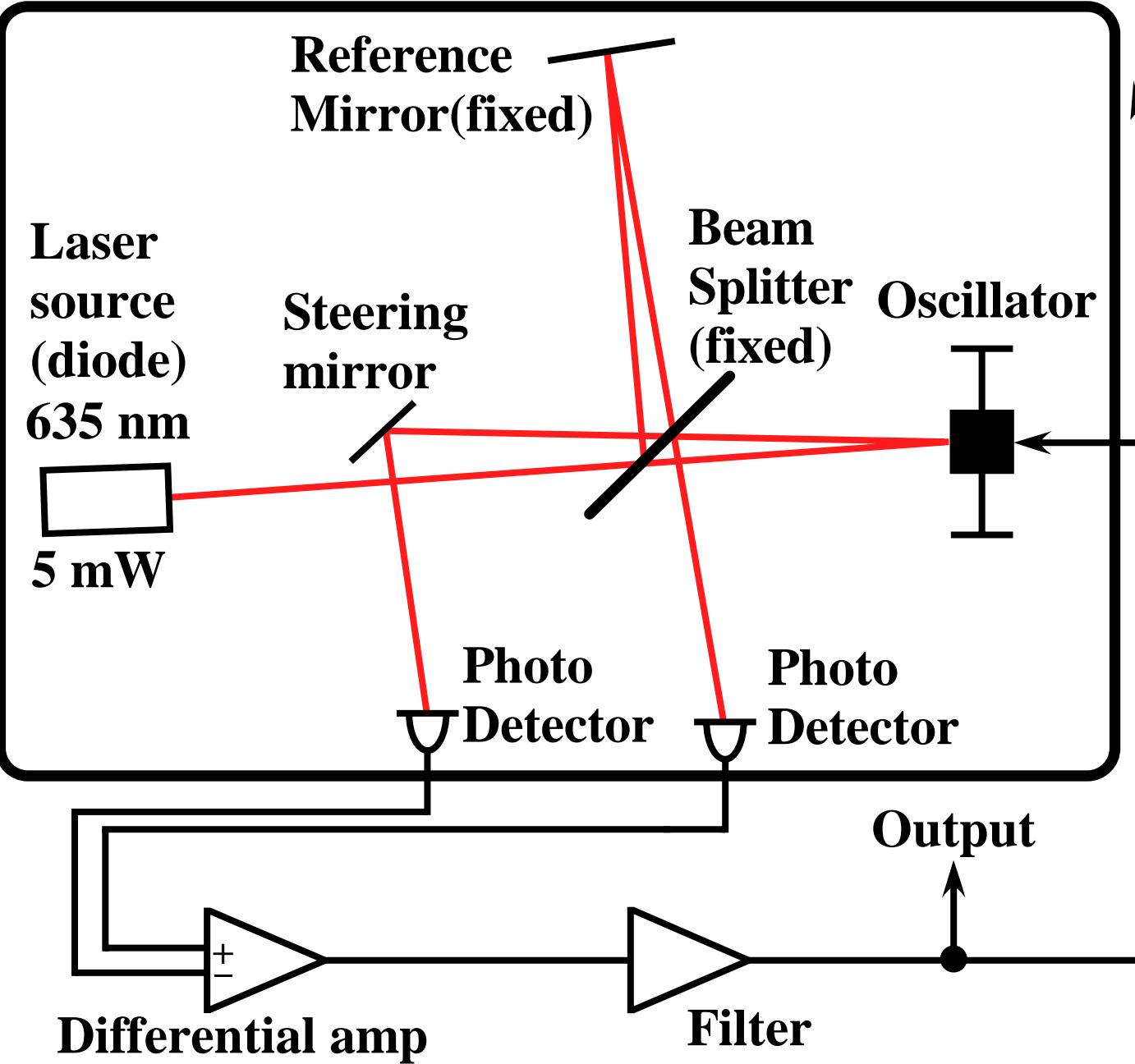
Door



Inner shield



2-3. Accelerometer



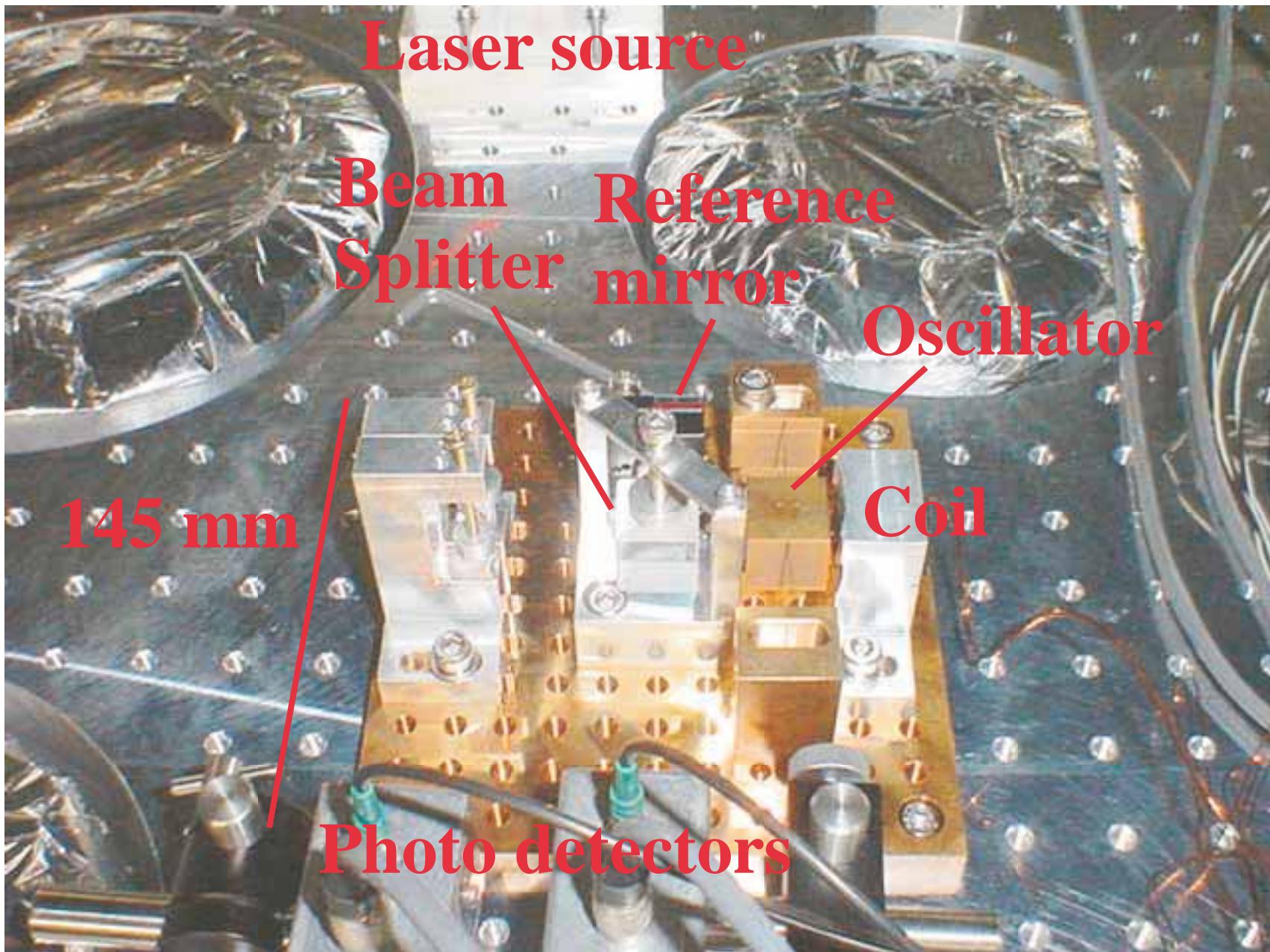
Vacuum chamber
(Laser source and photo detectors are in vacuum chamber. Sound does not affect accelerometer directly.)

Only room temperature

Observation band

< 400 Hz (horizontal)
< 250 Hz (vertical)

Accelerometer



3. Results

3-1. Top of suspension (Horizontal:optical axis)

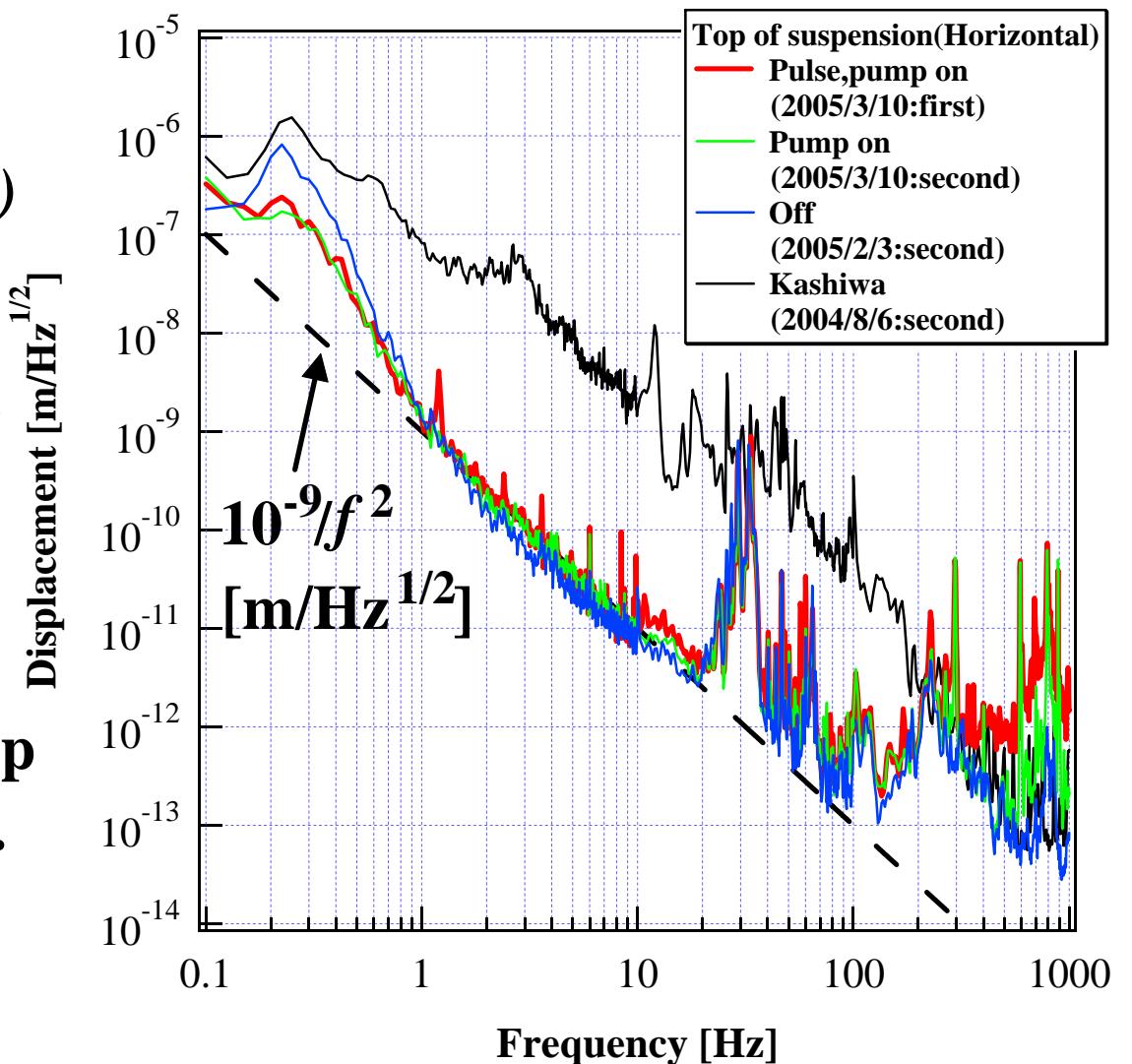
< 200 Hz

Cryocoolers and pump
do not increase
vibration.

> 200 Hz

Cryocoolers and pump
increase vibration.

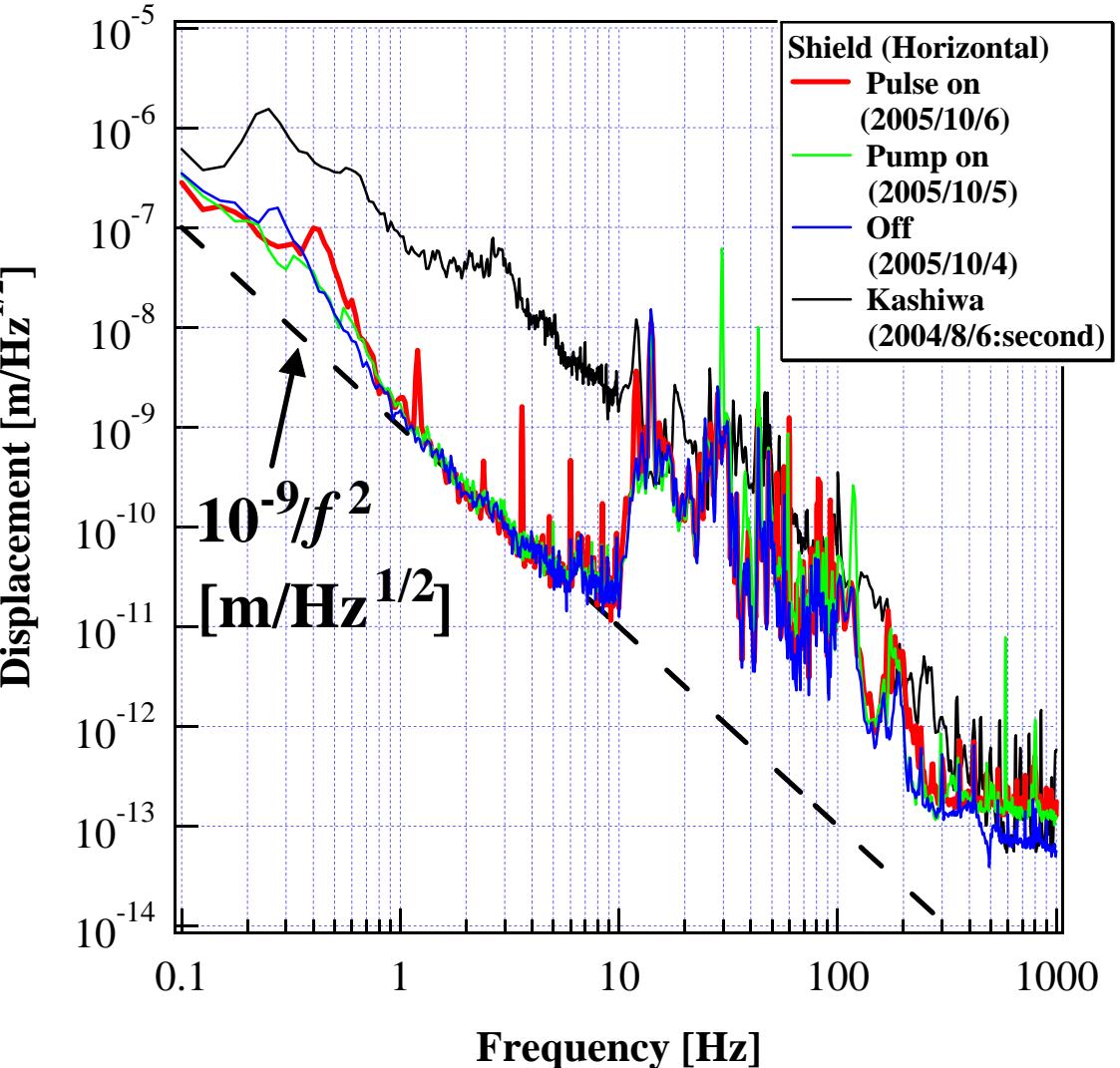
Vertical : similar



3-2. Inner shield (Horizontal:optical axis)

Cryocoolers and pumps
do **not increase**
vibration.

> 200 Hz
G10 rods
vibration isolation

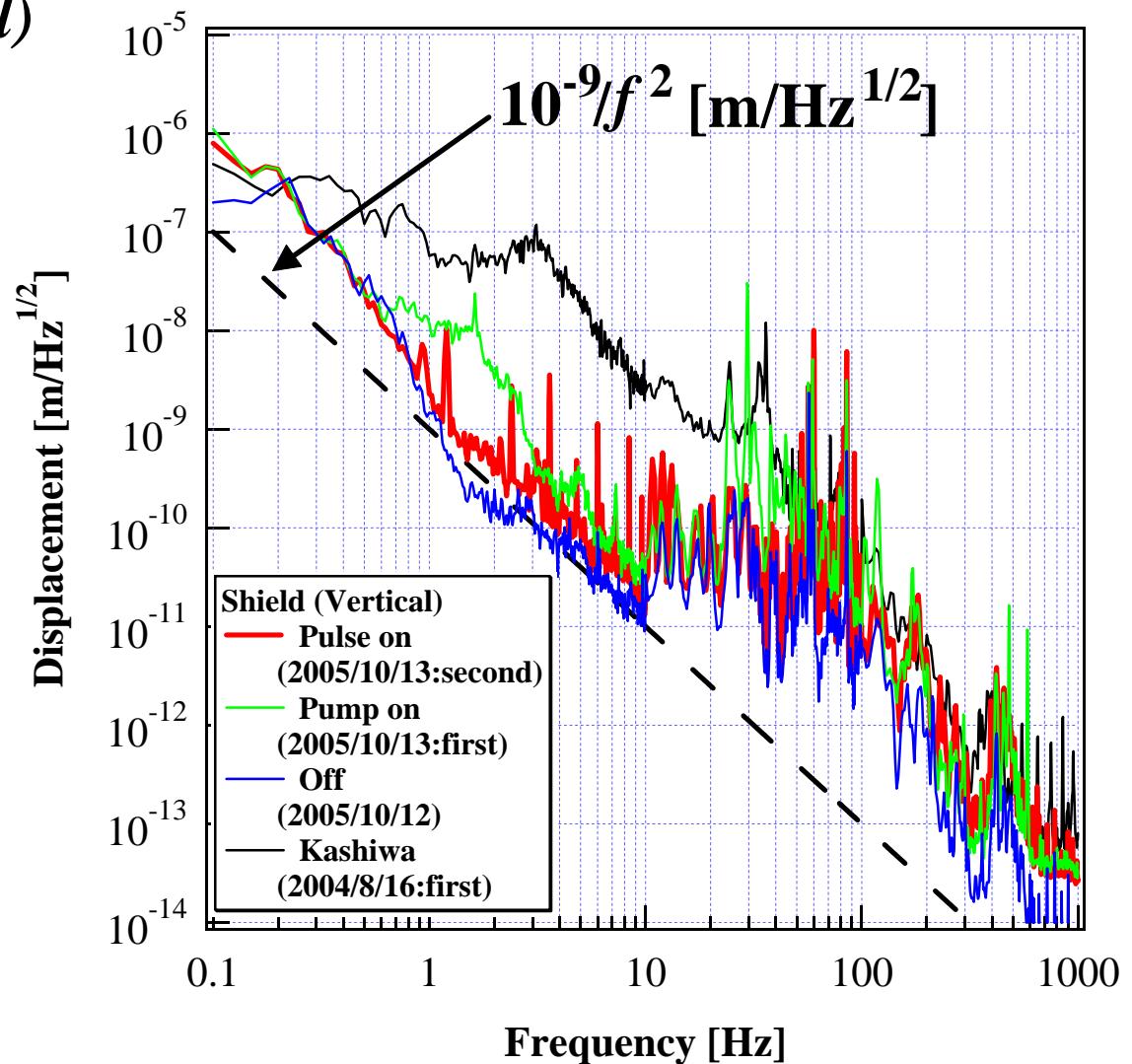


3-3. Inner shield (Vertical)

Vacuum pumps
increase vibration.

Cryocoolers : peaks

> 200 Hz
G10 rods
vibration isolation



3-4. Comparison with floor (Horizontal:Optical axis)

Floor

$$10^{-9}/f^2 \text{ [m/Hz}^{1/2}\text{]}$$

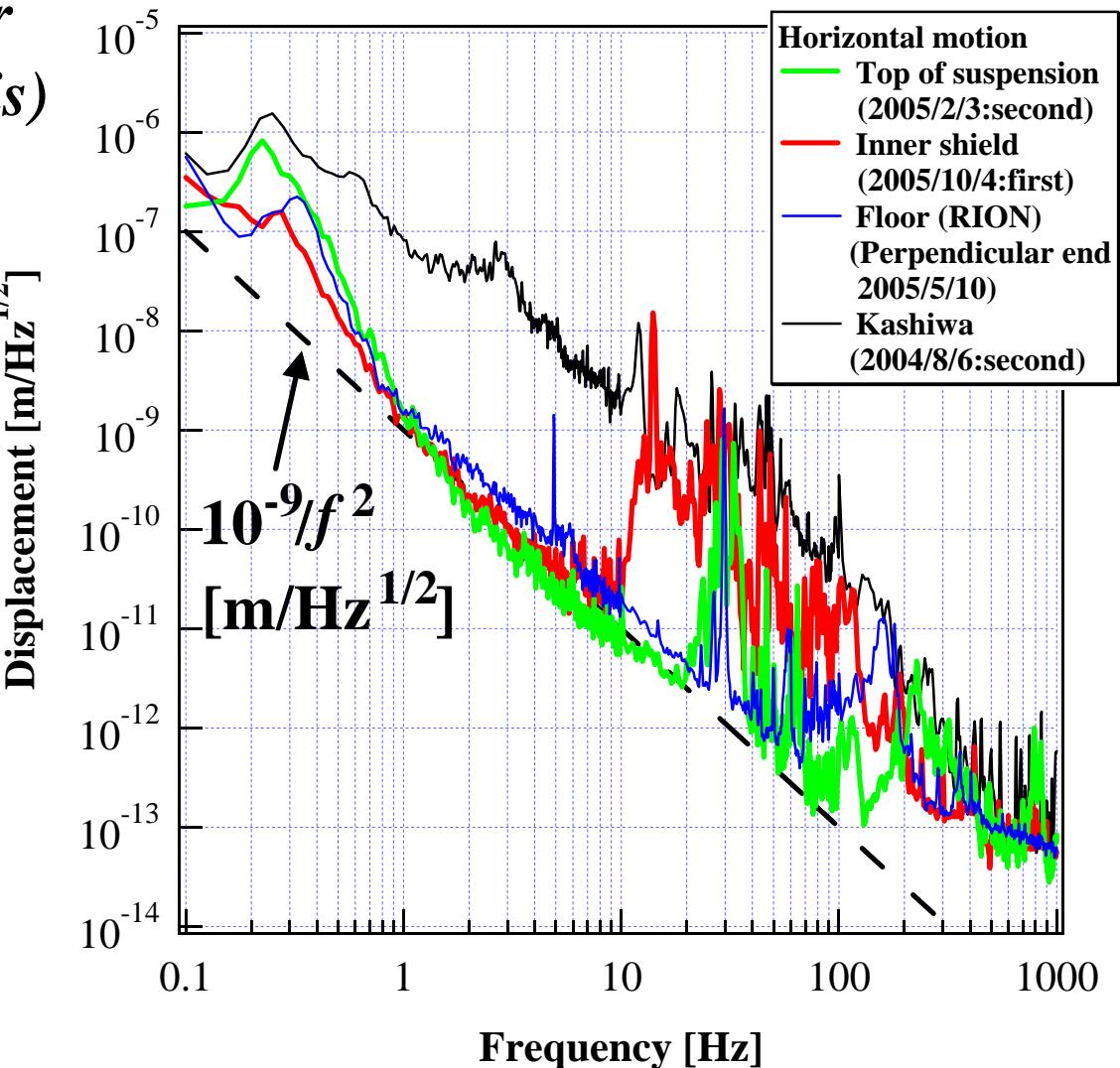
Suspension top

$$\text{peak : } 30 \text{ Hz}$$

Inner shield

10 Hz - 200 Hz

100 times



3-5. Comparison with floor (Vertical)

Floor

$$10^{-9}/f^2 \text{ [m/Hz}^{1/2}\text{]}$$

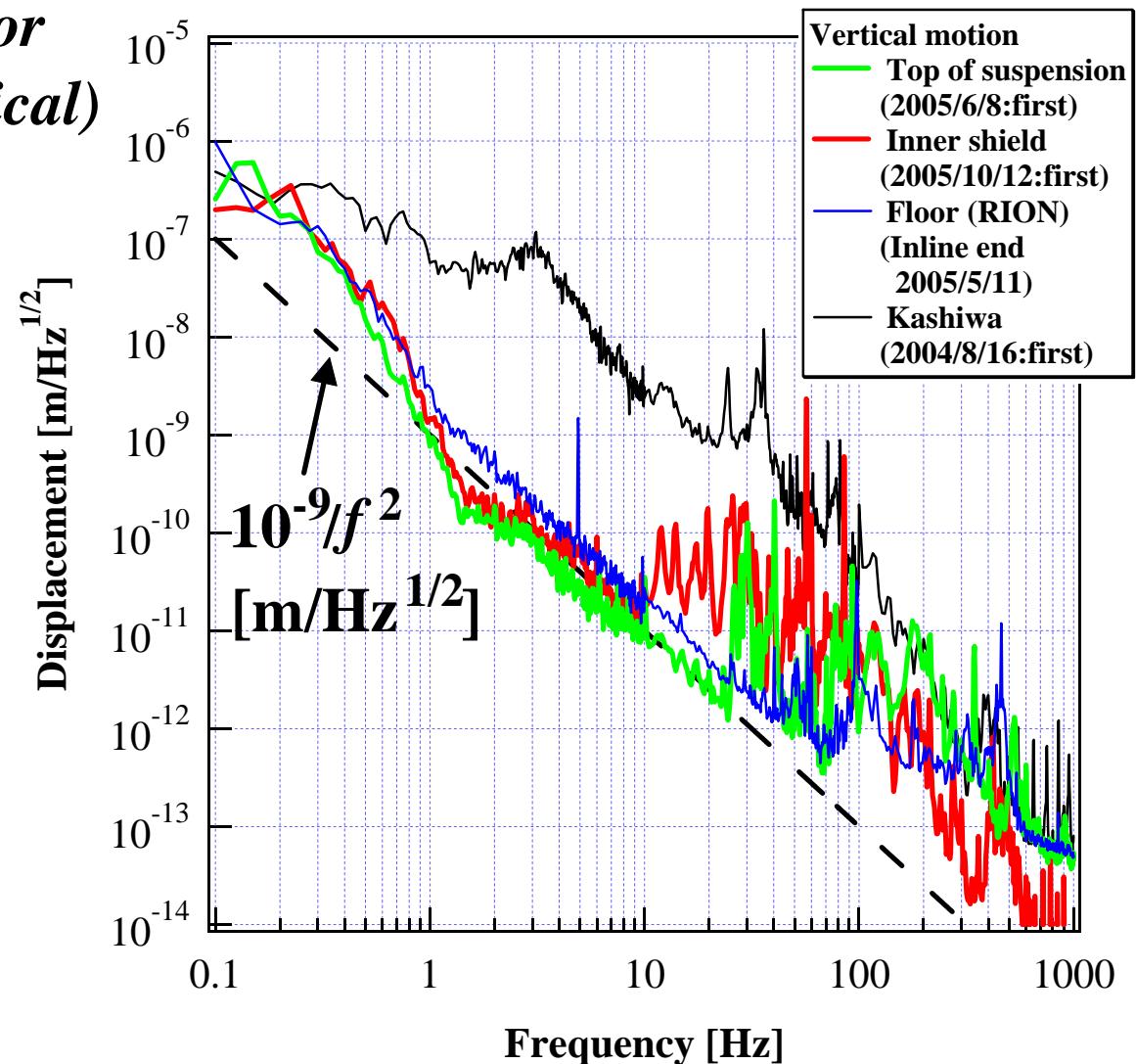
Suspension top

peak : 30 Hz, 40 Hz

Inner shield

10 Hz - 200 Hz

10 times



3-6. Sensitivity of CLIO interferometer

External vibration does
not limit sensitivity

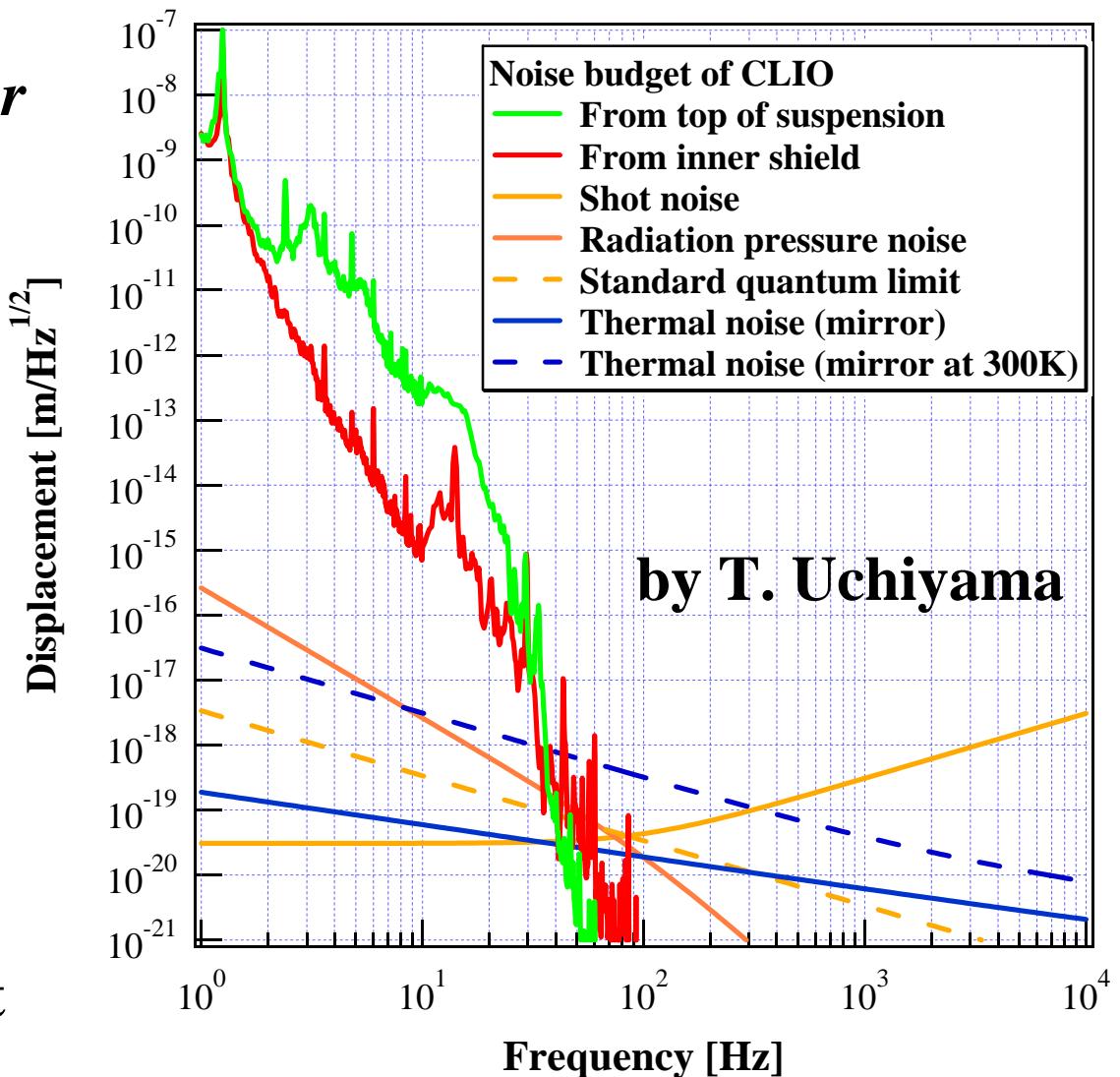
above 40 Hz at 300 K.

above 60 Hz at 20 K.

< 40 Hz

Suspension top

dominant



4. Future works (For LCGT)

(1) Cryocooler : **no serious problem**

(2) Vacuum pump : **some problems** (inner shield, vertical motion)

(Dry pump) < (Rotary and turbo pump)

Connection with cryostat

(3) Suspension top : **peak (30 Hz)**

→ **SAS**

(4) Inner shield : **large vibration (10 Hz - 200 Hz)**

→ **SPI**

Study of inner shield vibration

5. Summary

(1) Measurement of the **vibration** at **top of suspension** and
inner shield of **CLIO interferometer**

(2) Cryocooler : **no serious problem**

Vacuum pump : **some problems** (inner shield, vertical motion)

(3) Suspension top : **peak** (30 Hz)

Inner shield : **large vibration** (10 Hz - 200 Hz : 10 - 100 times)

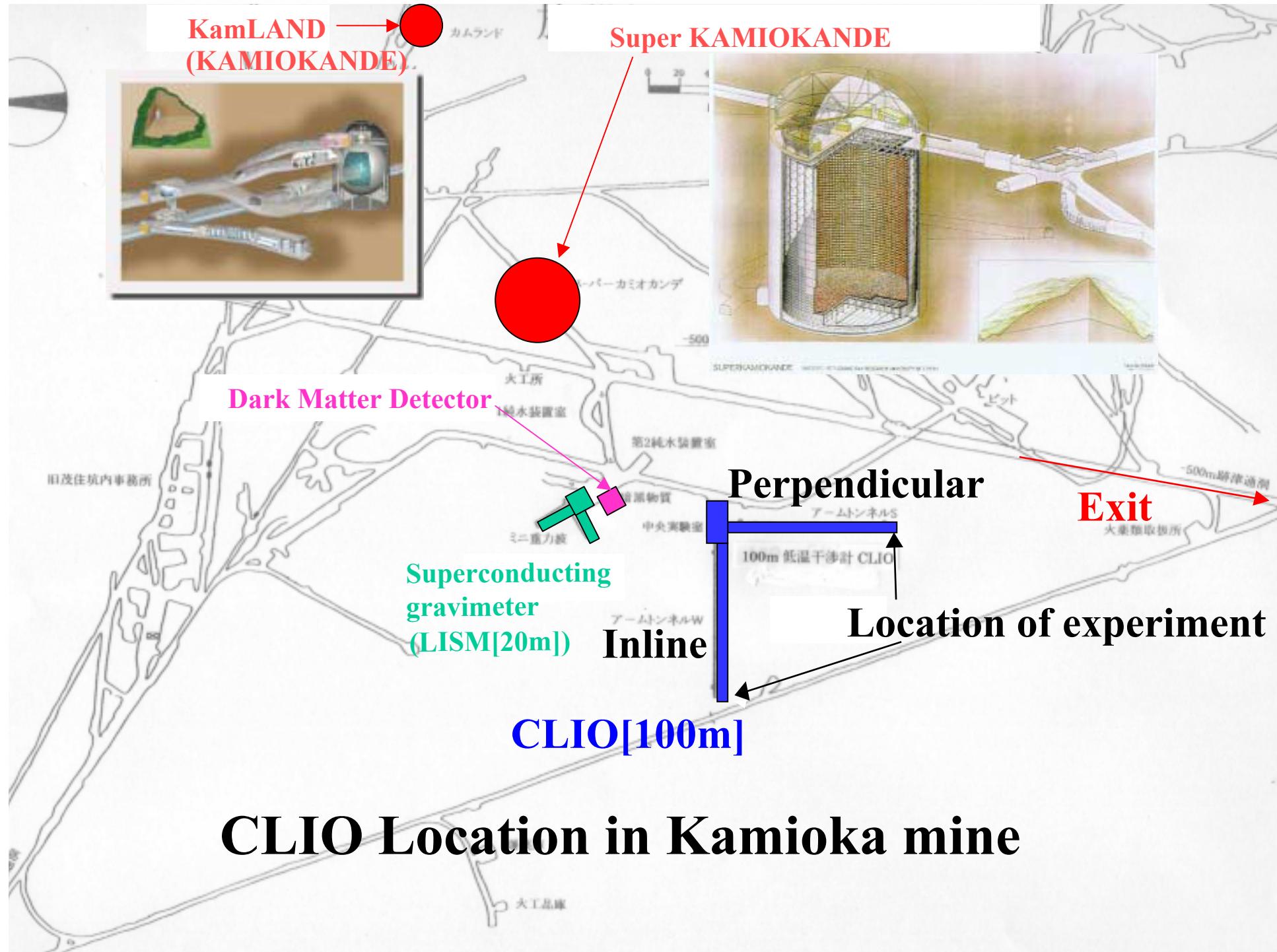
(4) CLIO interferometer sensitivity :

External vibration does **not limit** sensitivity **above 40 Hz at 300 K.**

above 60 Hz at 20 K.

(5) Future works for **LCGT** : Vacuum pump

Inner shield vibration



Dry pump



Dry pump

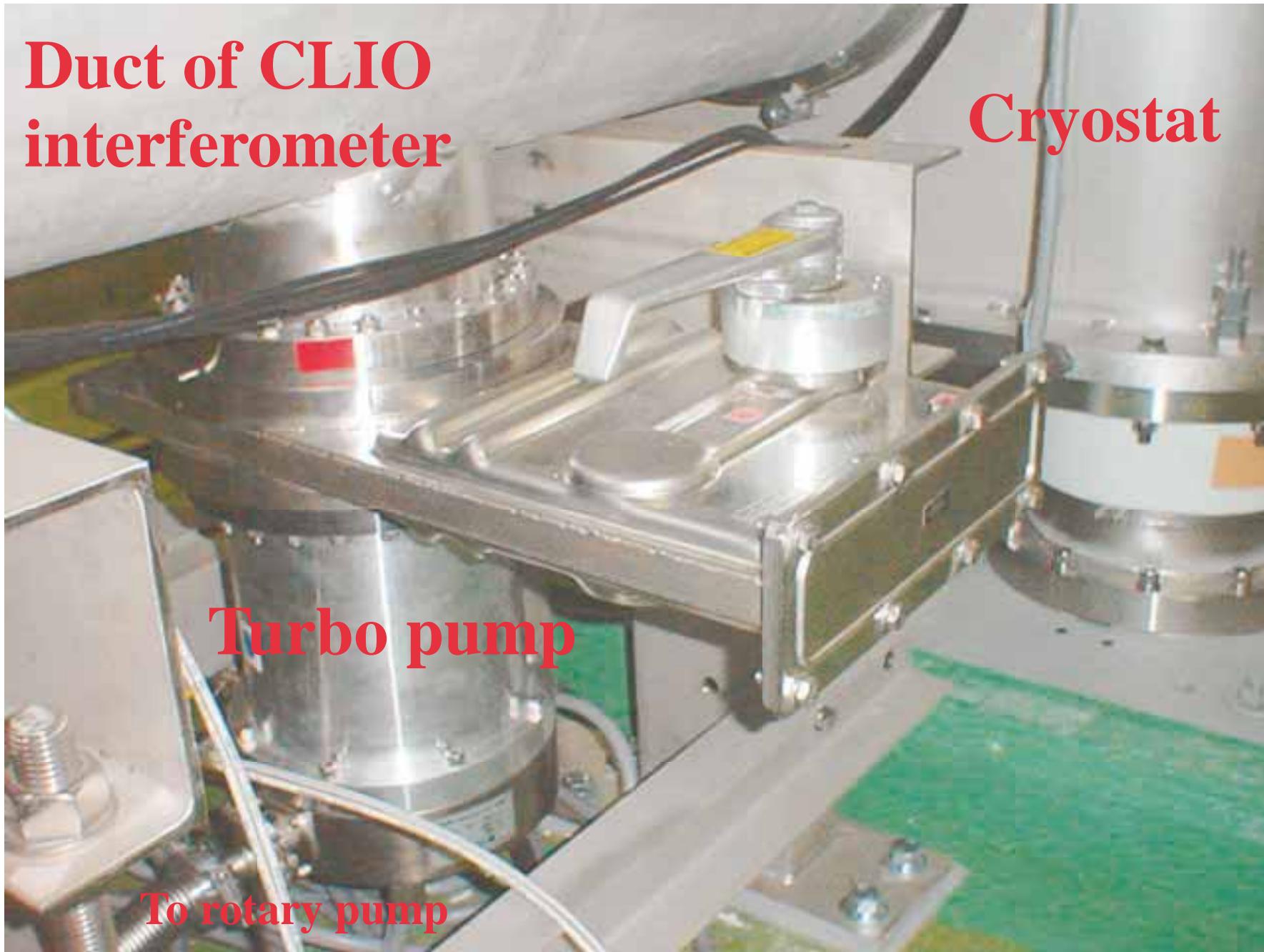


Duct of CLIO
interferometer

Cryostat

Turbo pump

To rotary pump



4K Pulse tube refrigerator

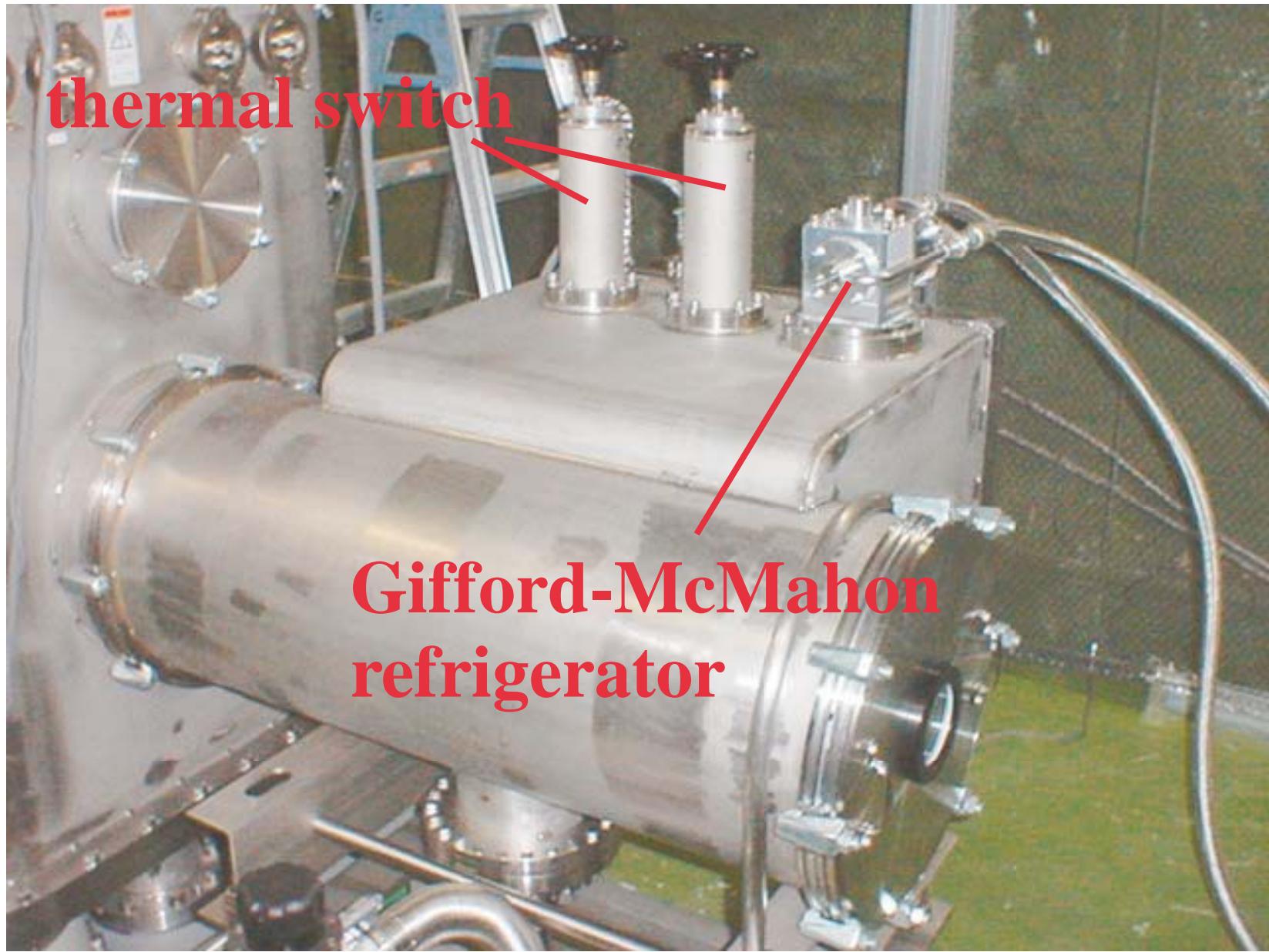


80K Pulse tube refrigerator



Compressor

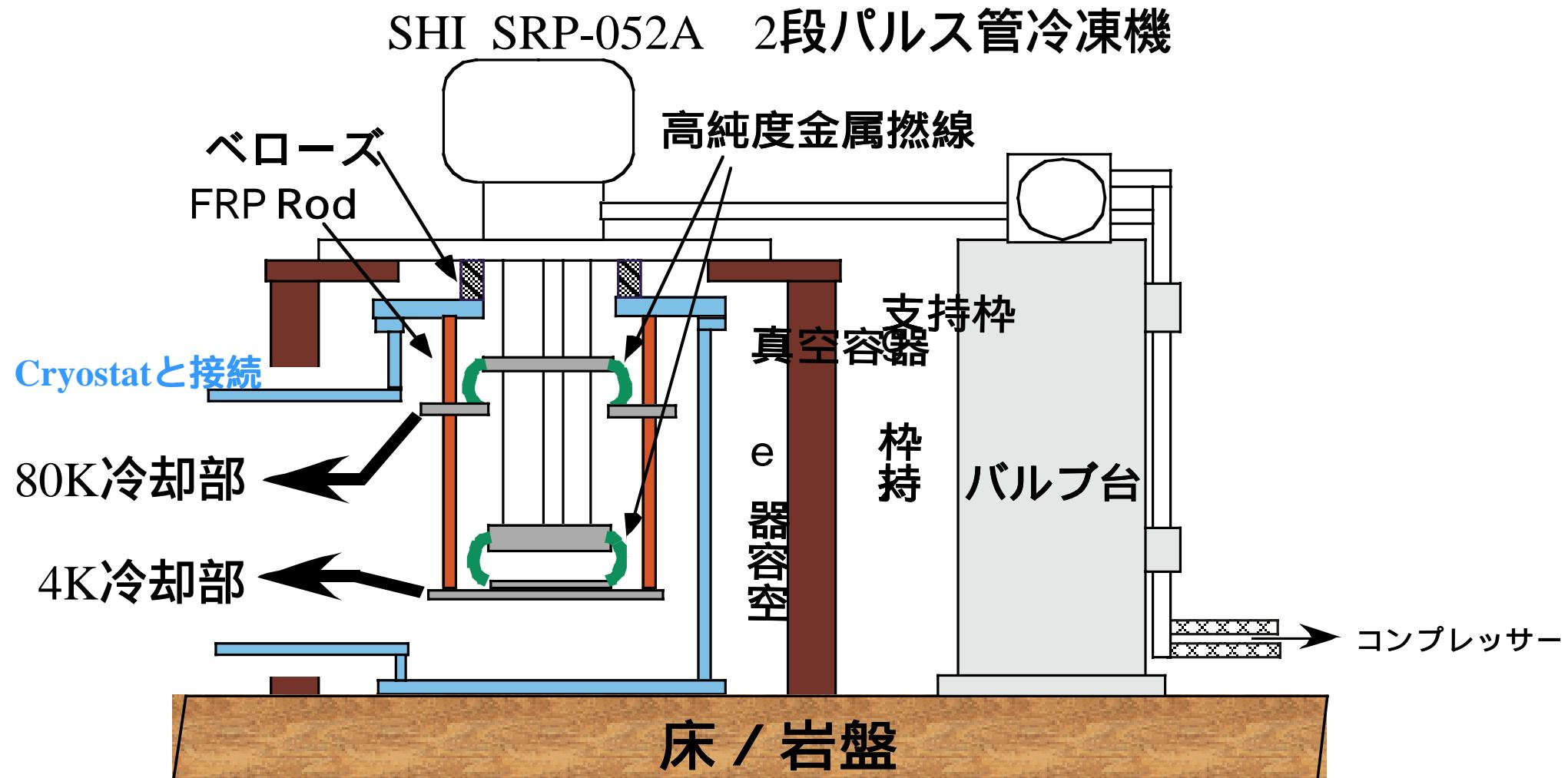




thermal switch

Gifford-McMahon
refrigerator

低振動冷凍機システムの構成



2. Outline of Experiment

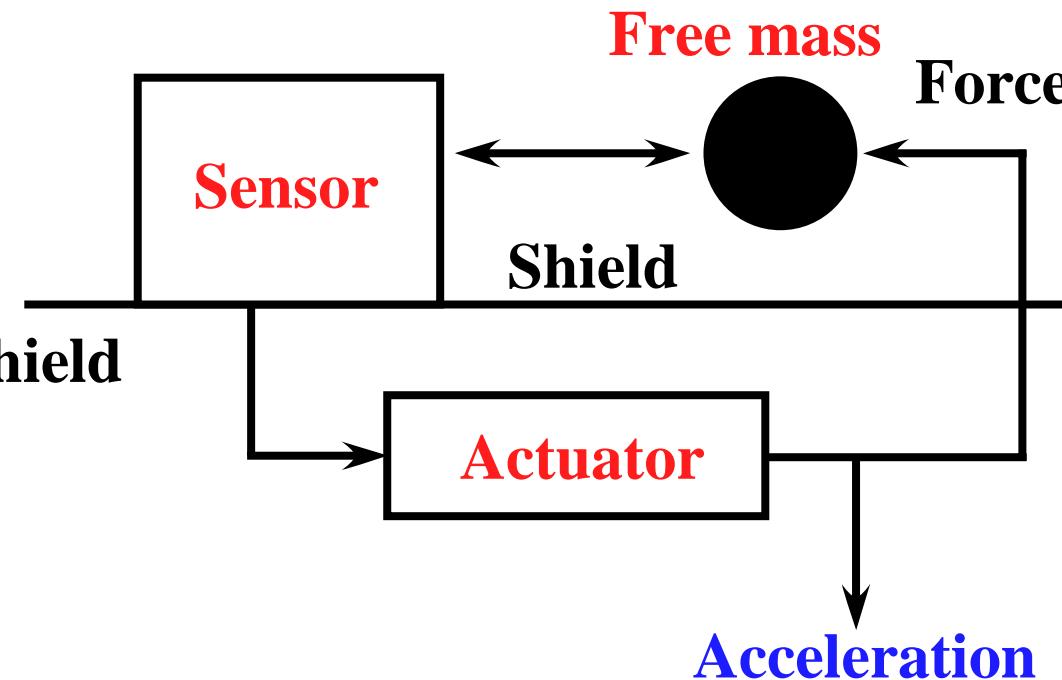
2-1. Outline of accelerometer

(i) Free mass : reference

(ii) Sensor : displacement
between free mass and shield

(iii) Actuator : feedback

Mass follows shield.



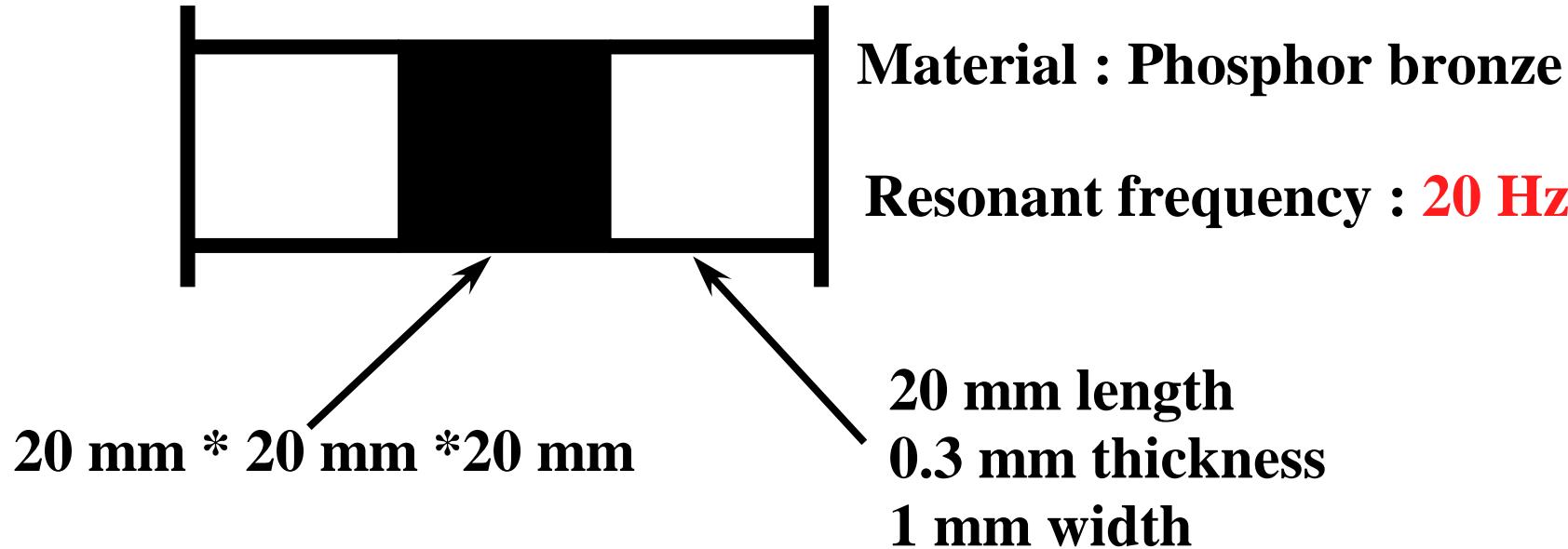
→ Acceleration of shield is derived from feedback signal.

Horizontal and vertical vibration measurement

Goal sensitivity : Seismic motion in Kamioka mine

2-2. Components of accelerometer

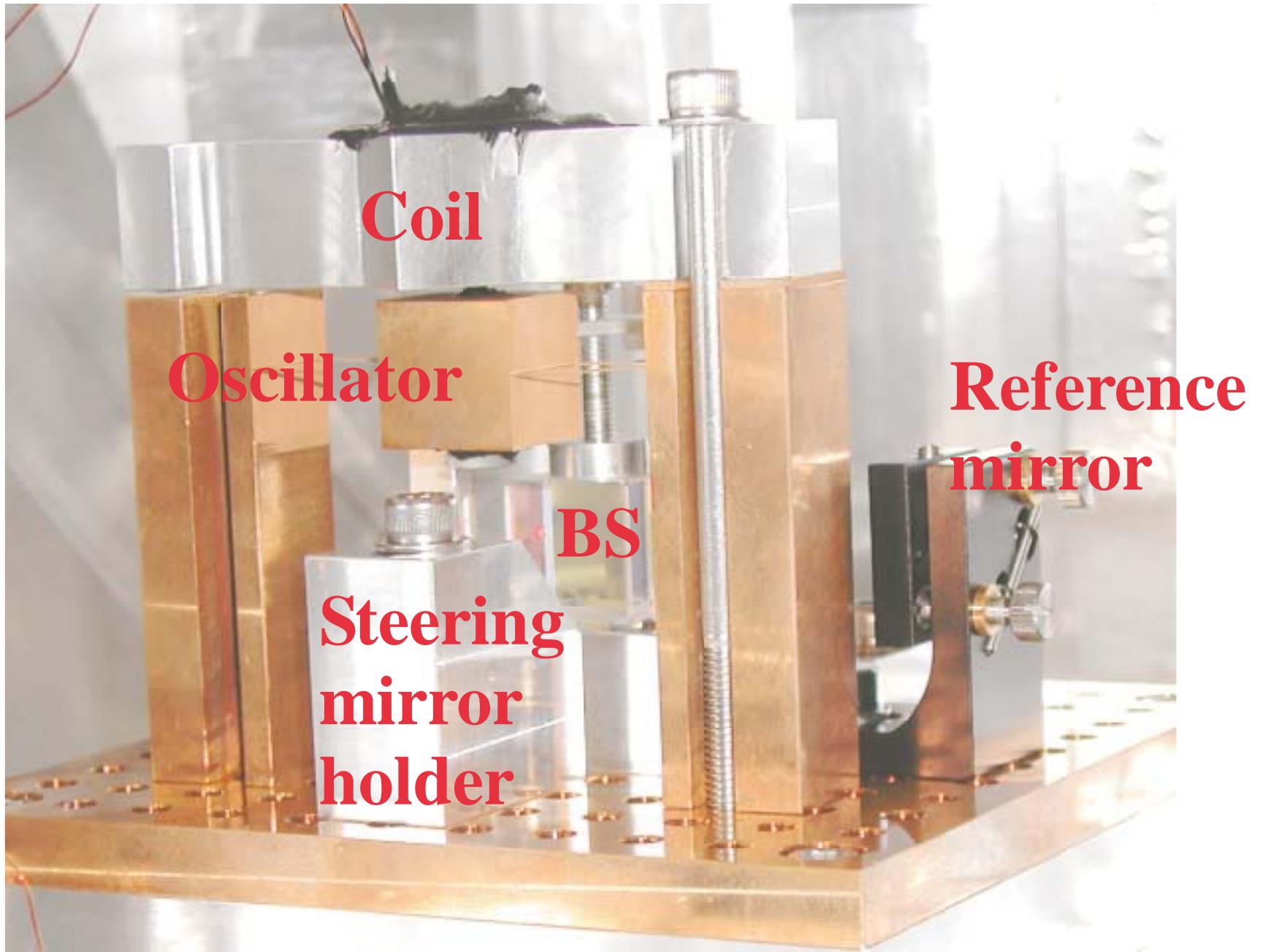
(i) Free mass : Mechanical **harmonic oscillator**



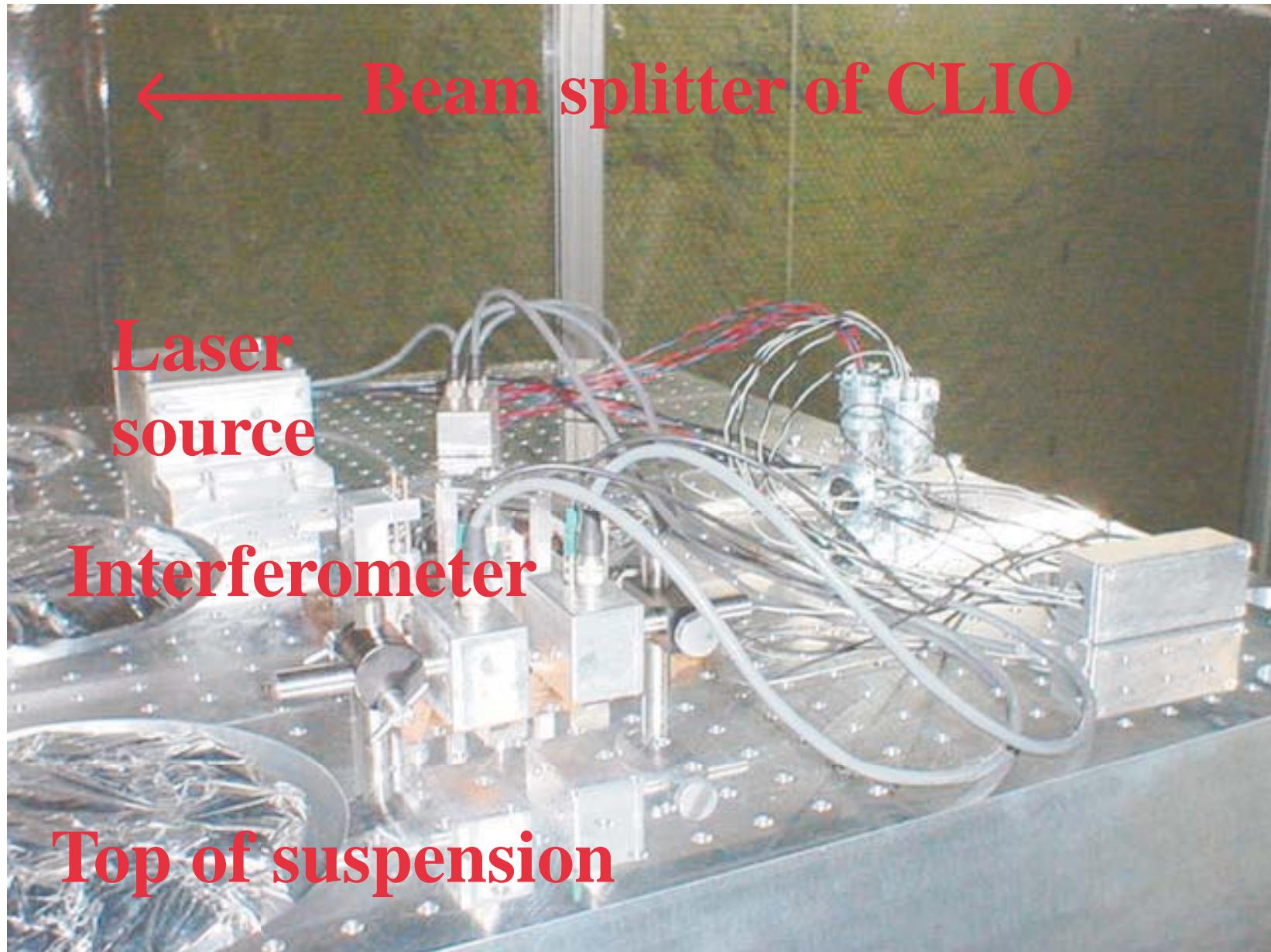
(ii) Sensor : **Michelson interferometer** (Calibration)

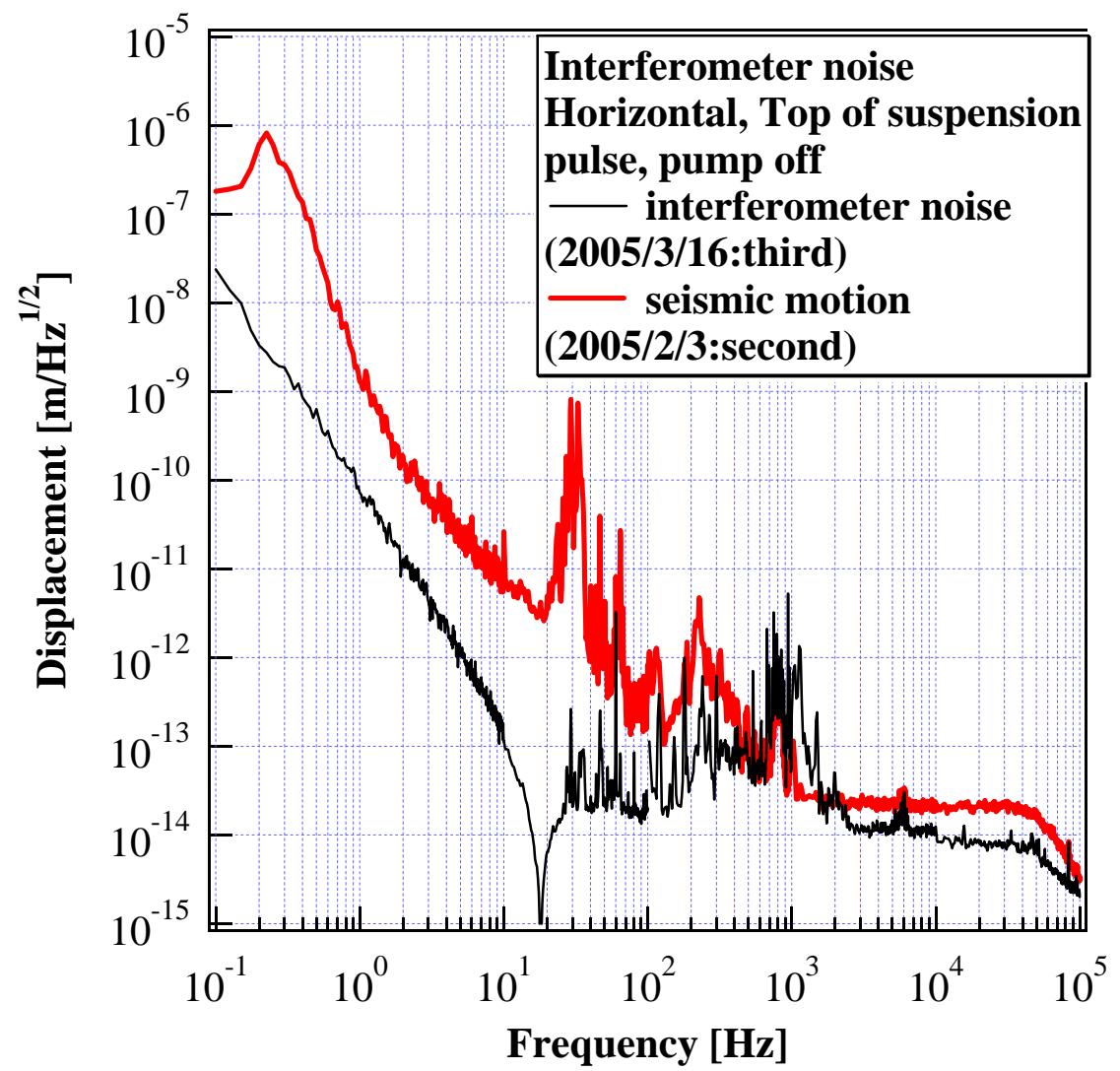
(iii) Actuator : **Coil-magnet actuator** (Operation at low temperature)

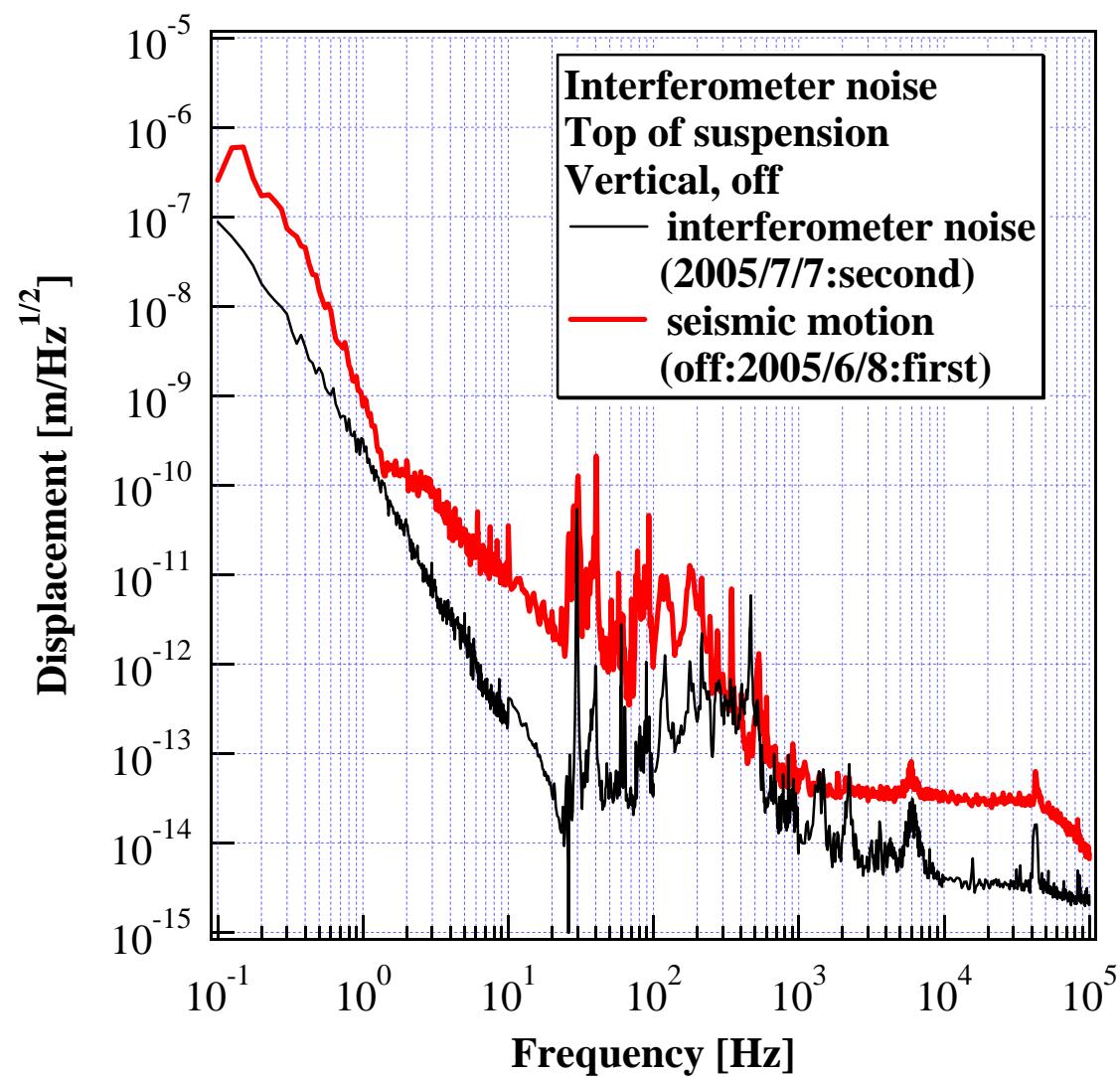
Vertical oscillator

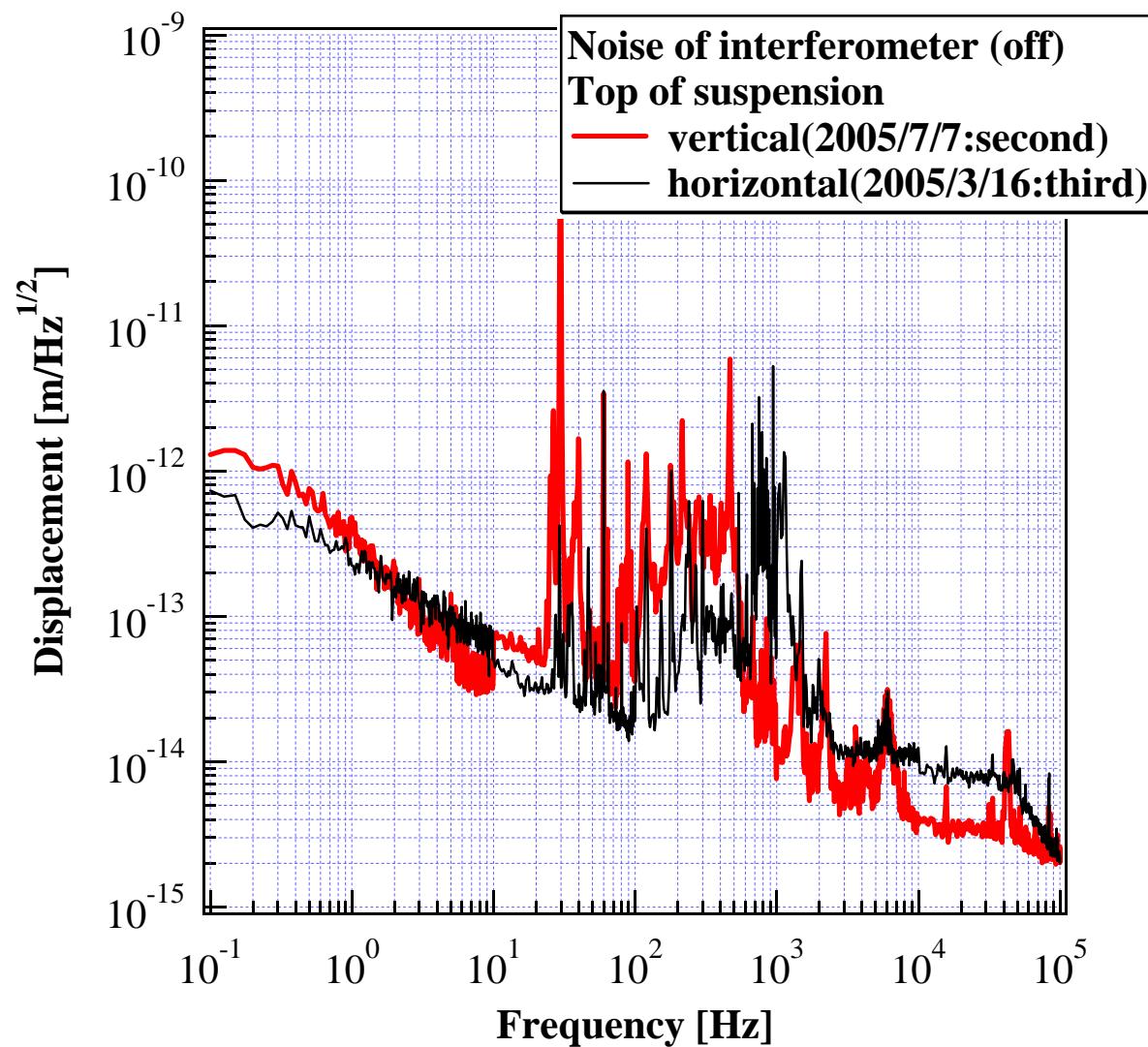


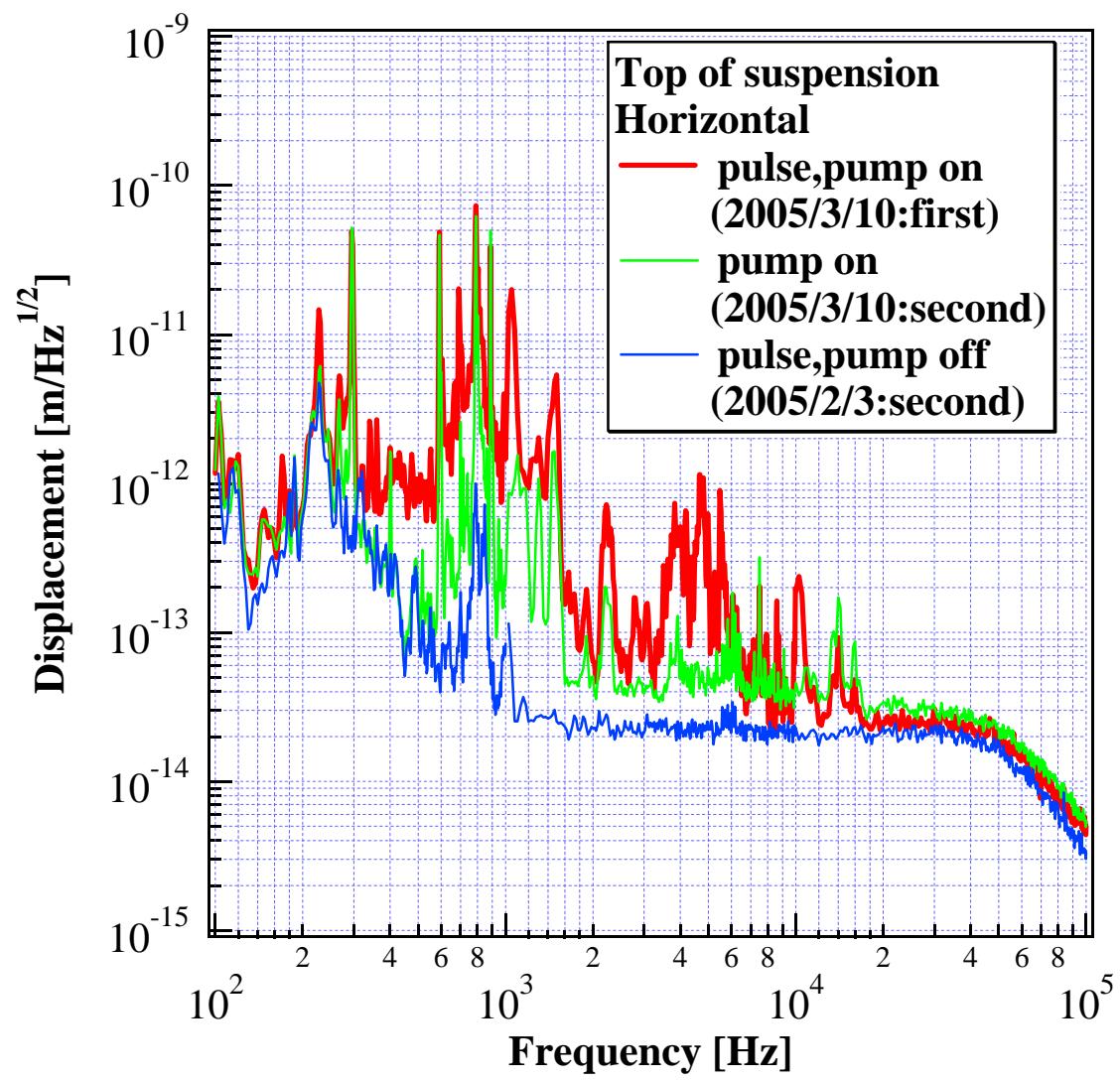
Accelerometer

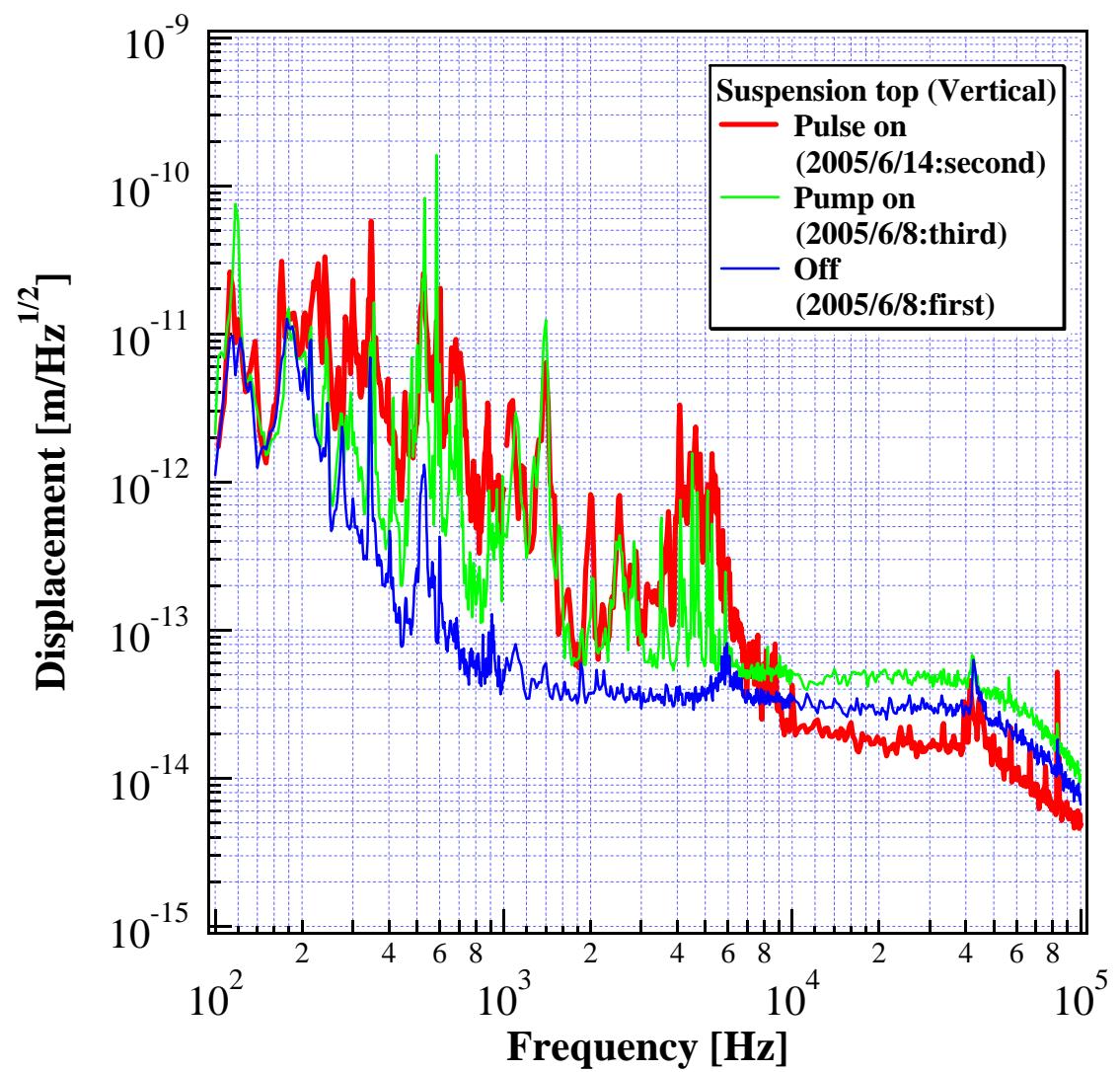










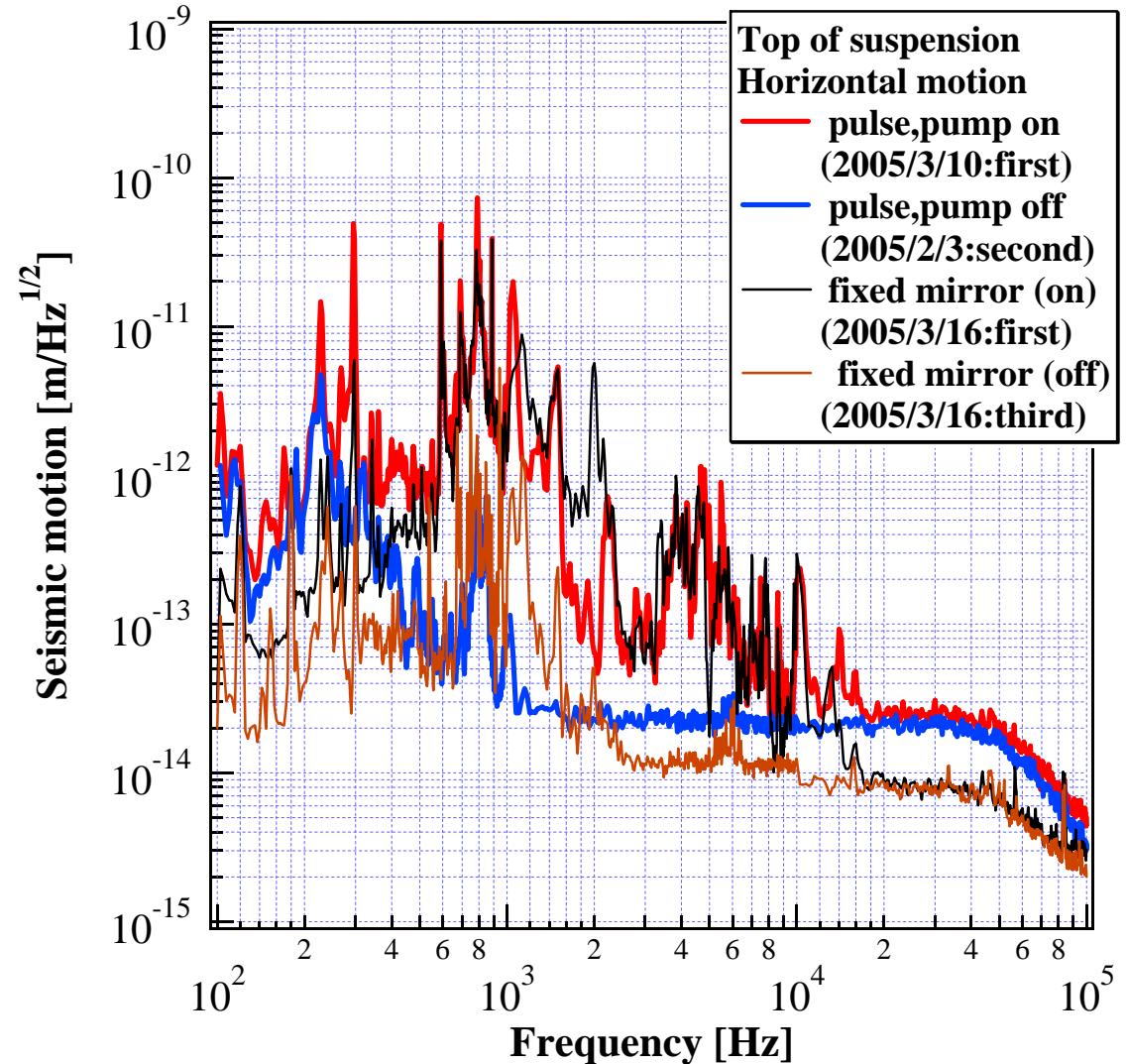


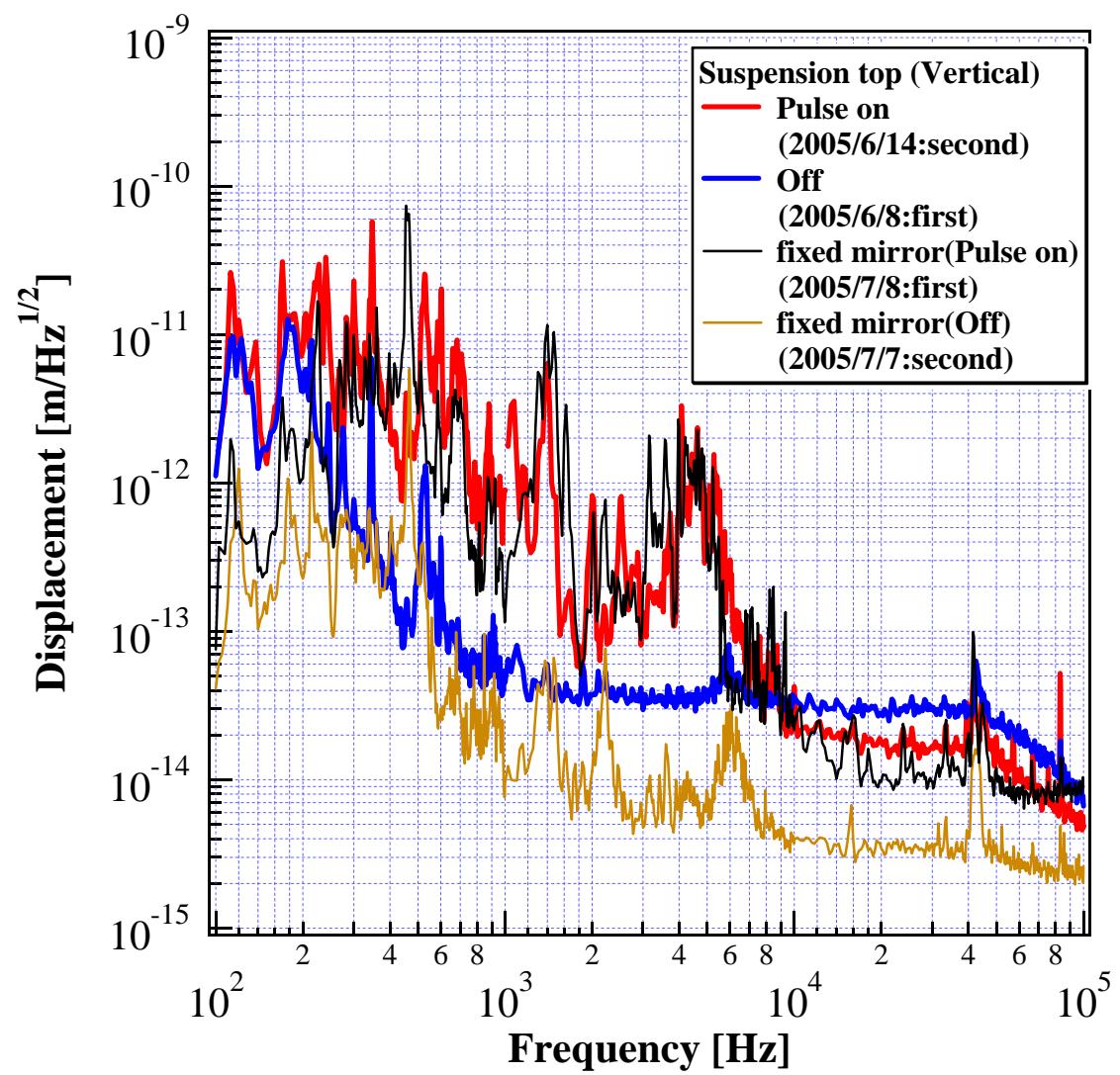
3-2. Horizontal motion (optical axis:>100Hz)

>400Hz

Upper limit

Refrigerator
increases vibration
100 times (1 kHz).





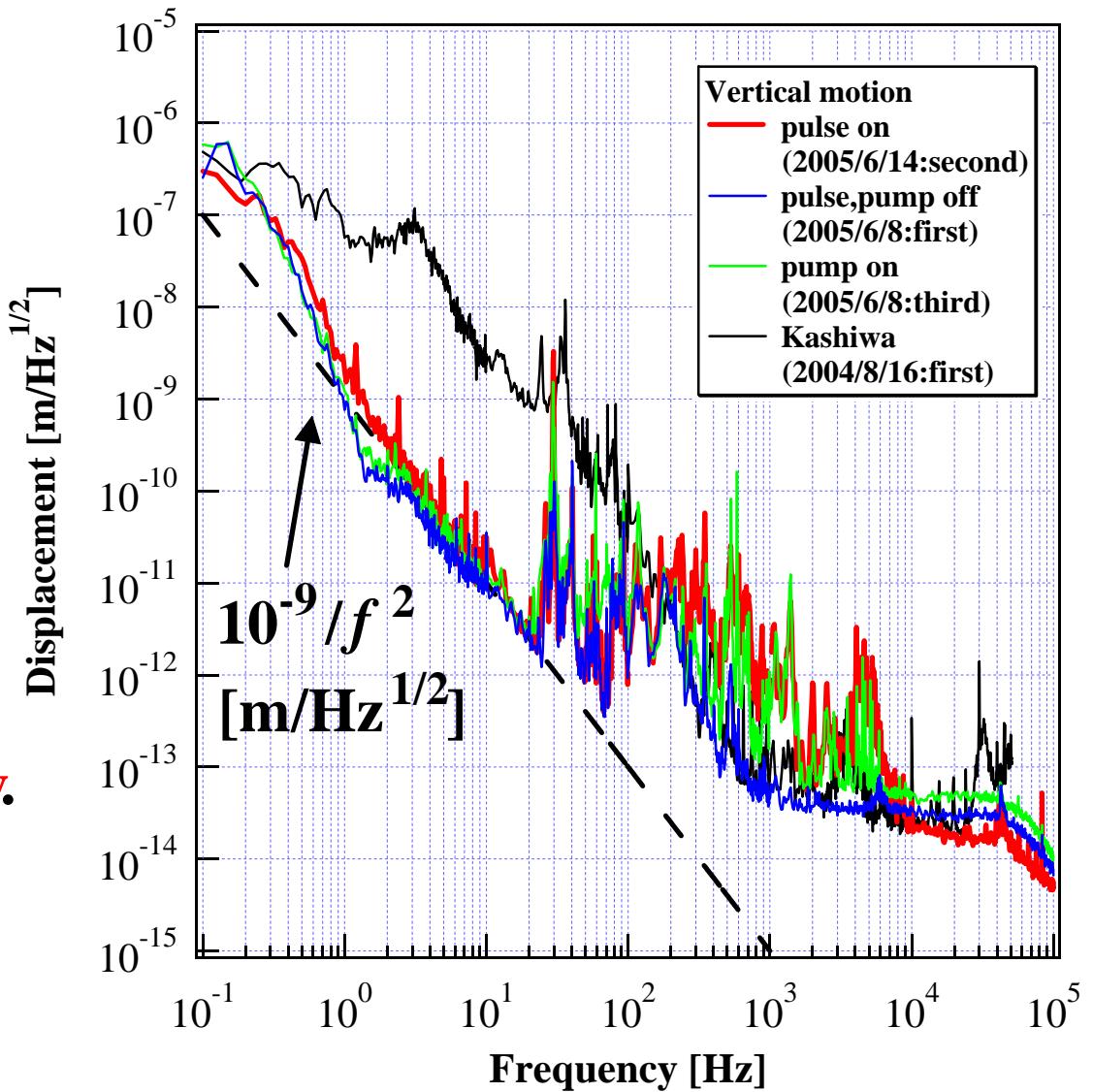
3-2. Vertical motion ($< 1 \text{ kHz}$)

floor level (1 Hz-70 Hz)

$$10^{-9}/f^2 \text{ [m/Hz}^{1/2}\text{]}$$

$< 200 \text{ Hz}$

Cryocoolers
do **not increase**
vibration seriously.



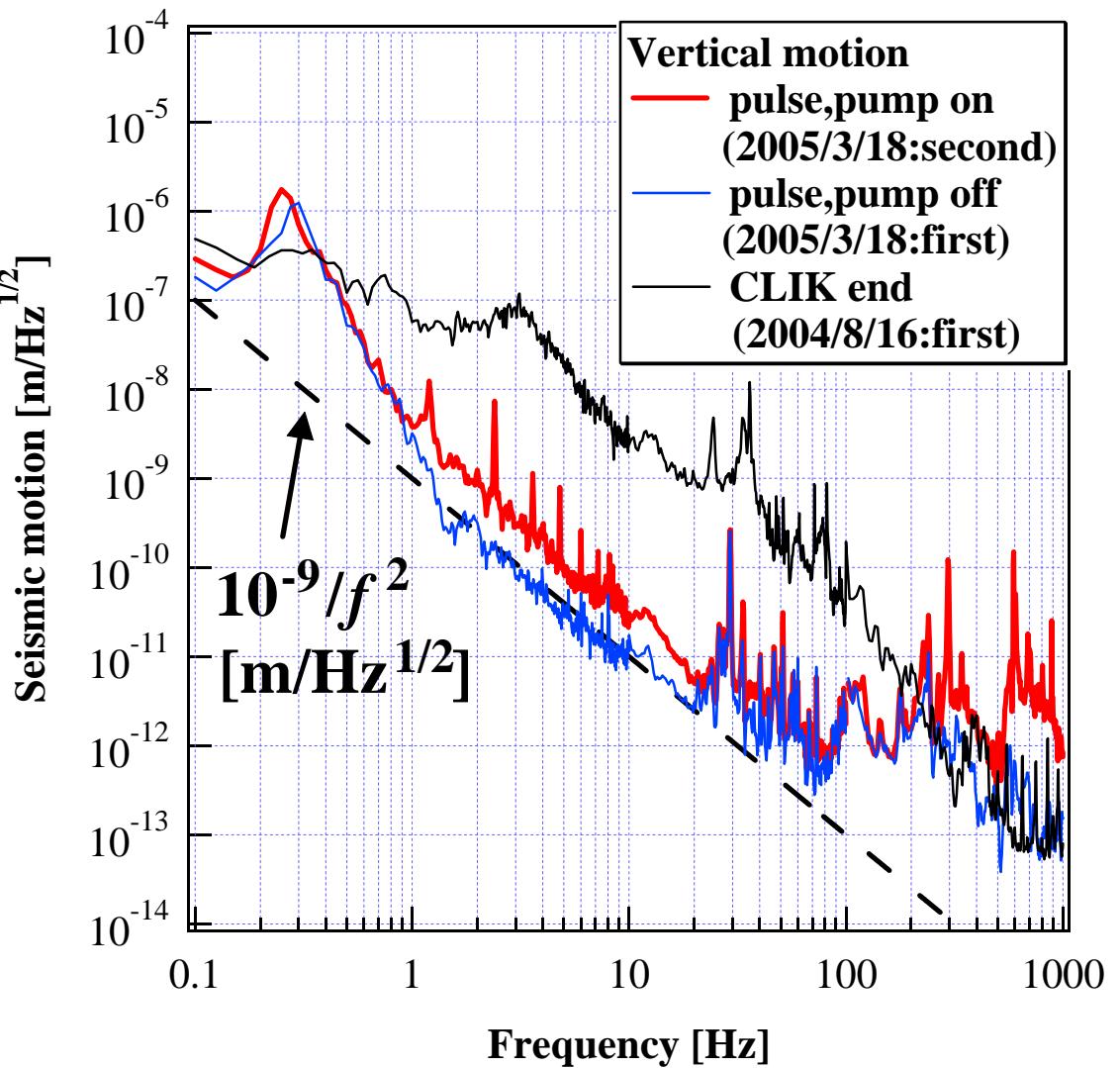
3-3. Vertical motion ($< 1 \text{ kHz}$)

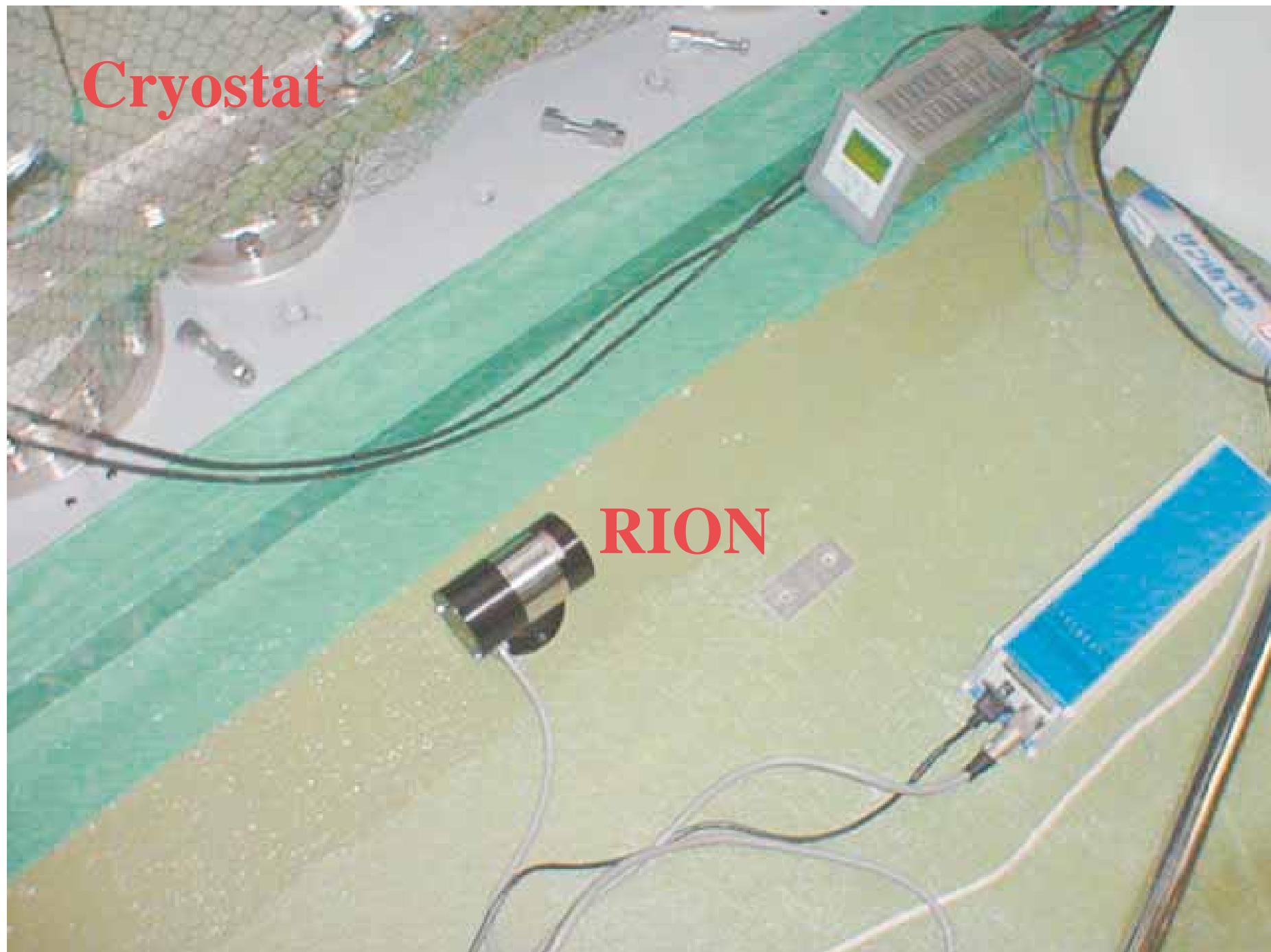
floor level (1 Hz-100 Hz) $^{1/2}$

$$10^{-9}/f^2 [\text{m}/\text{Hz}^{1/2}]$$

$< 200 \text{ Hz}$

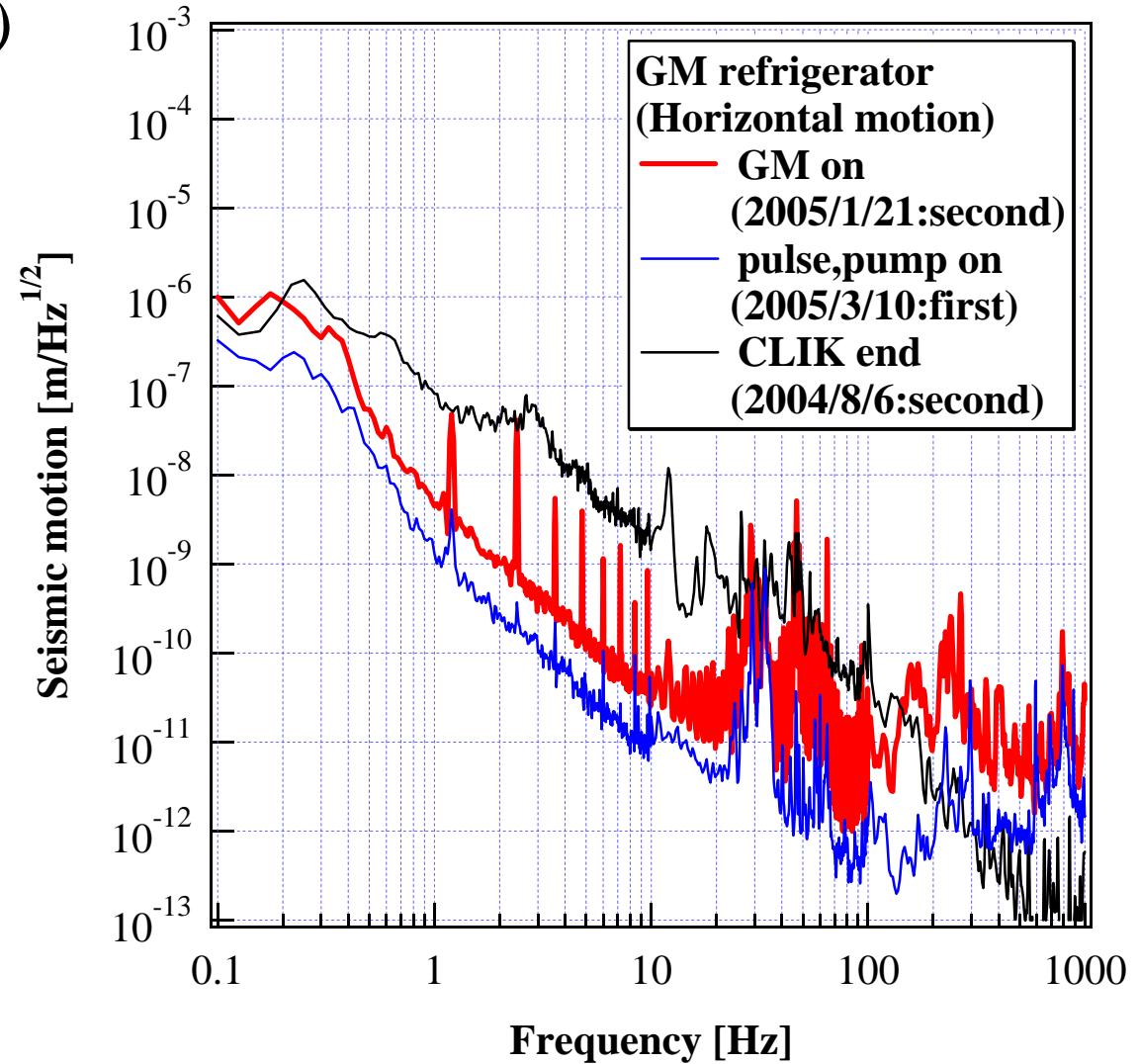
Refrigerator
does **not increase**
vibration seriously.





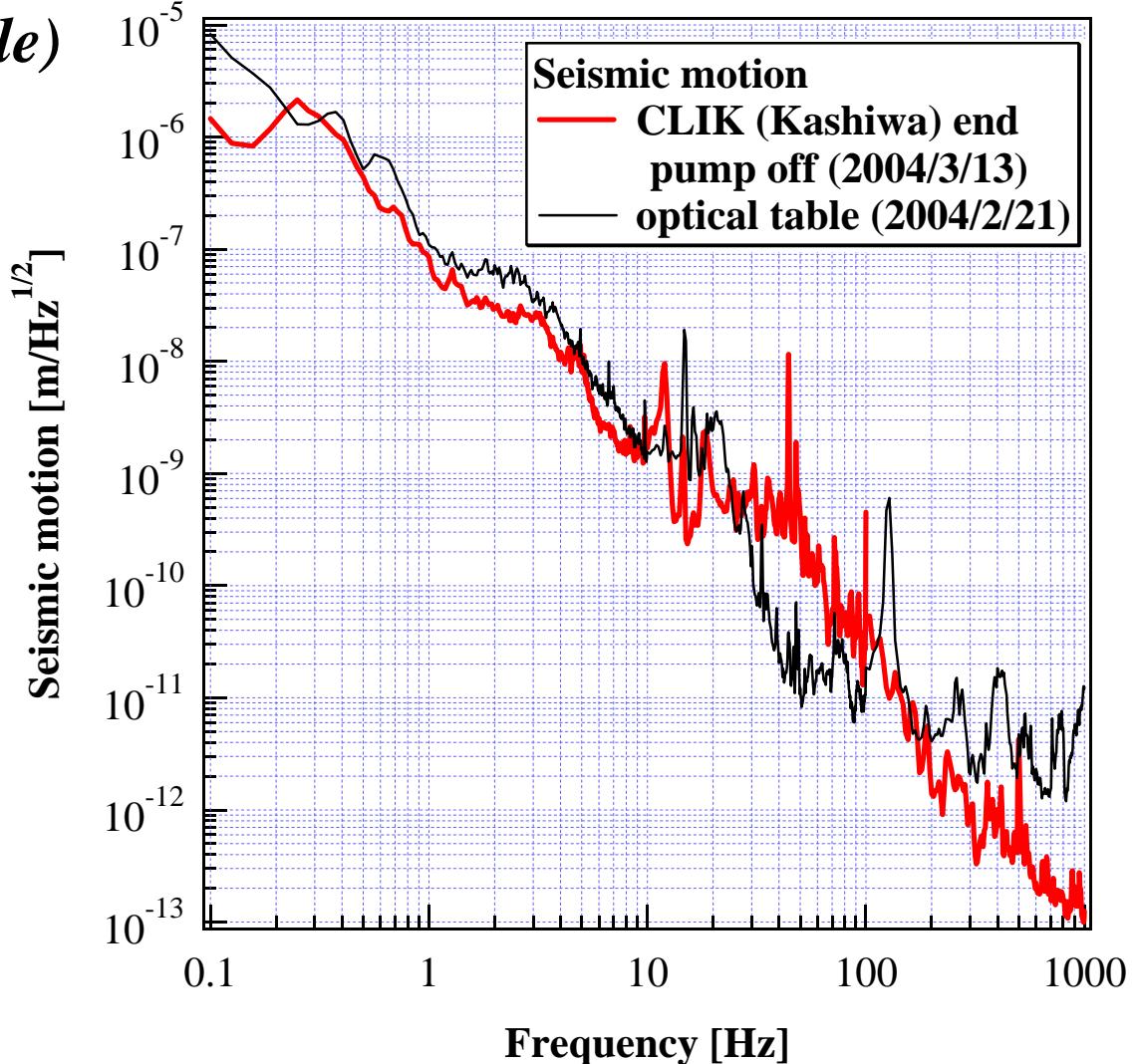
3-5.Gifford-McMahon refrigerator (Horizontal motion)

GM refrigerator
increases vibration.
30 Hz-400 Hz
Kashiwa level !



3-2. Operation at room temperature (2) *(Cryostat vs optical table)*

- 30 Hz : about **same**
- 30 Hz -100 Hz :
larger motion
in cryostat
- 100 Hz - :
better sound isolation
in cryostat

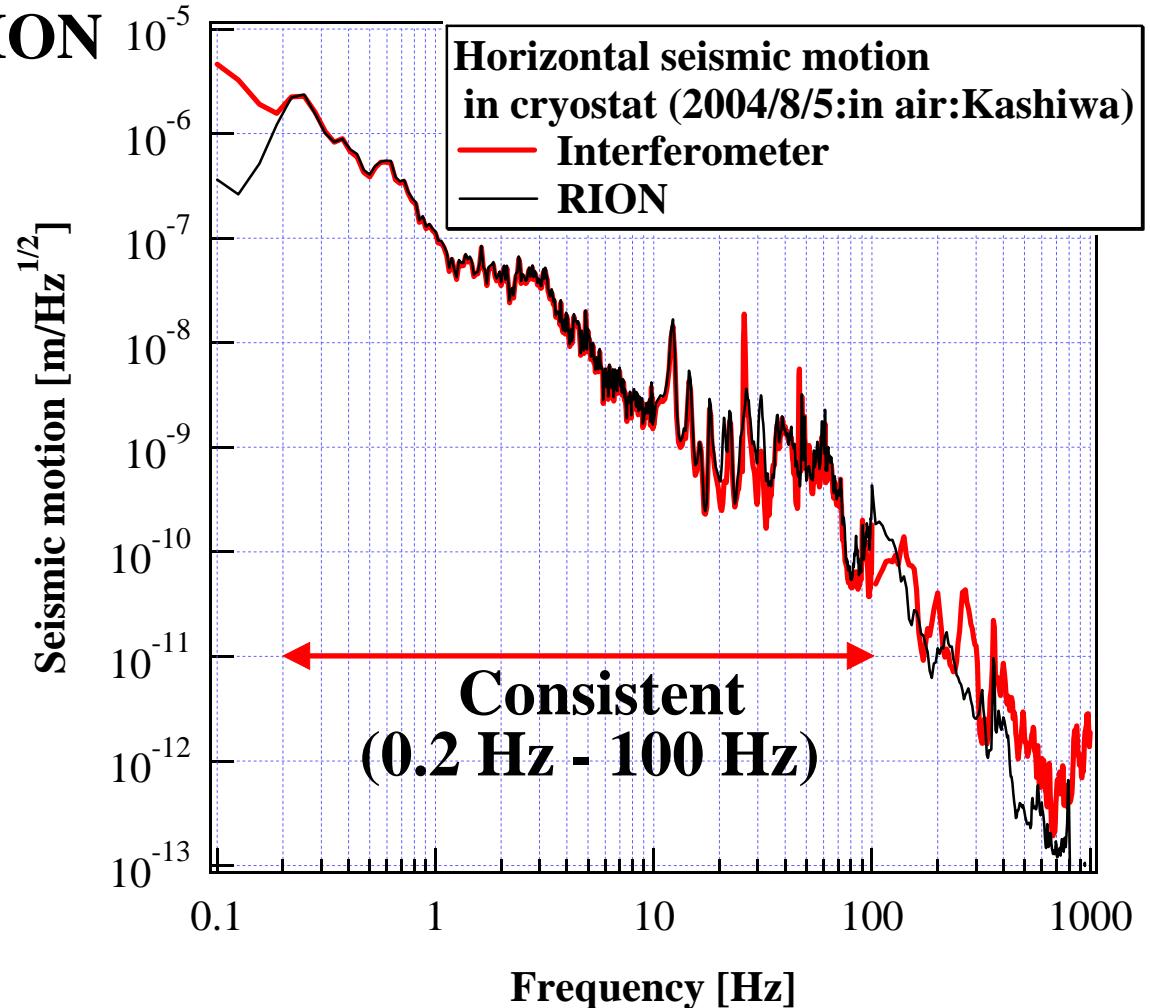


3. Results

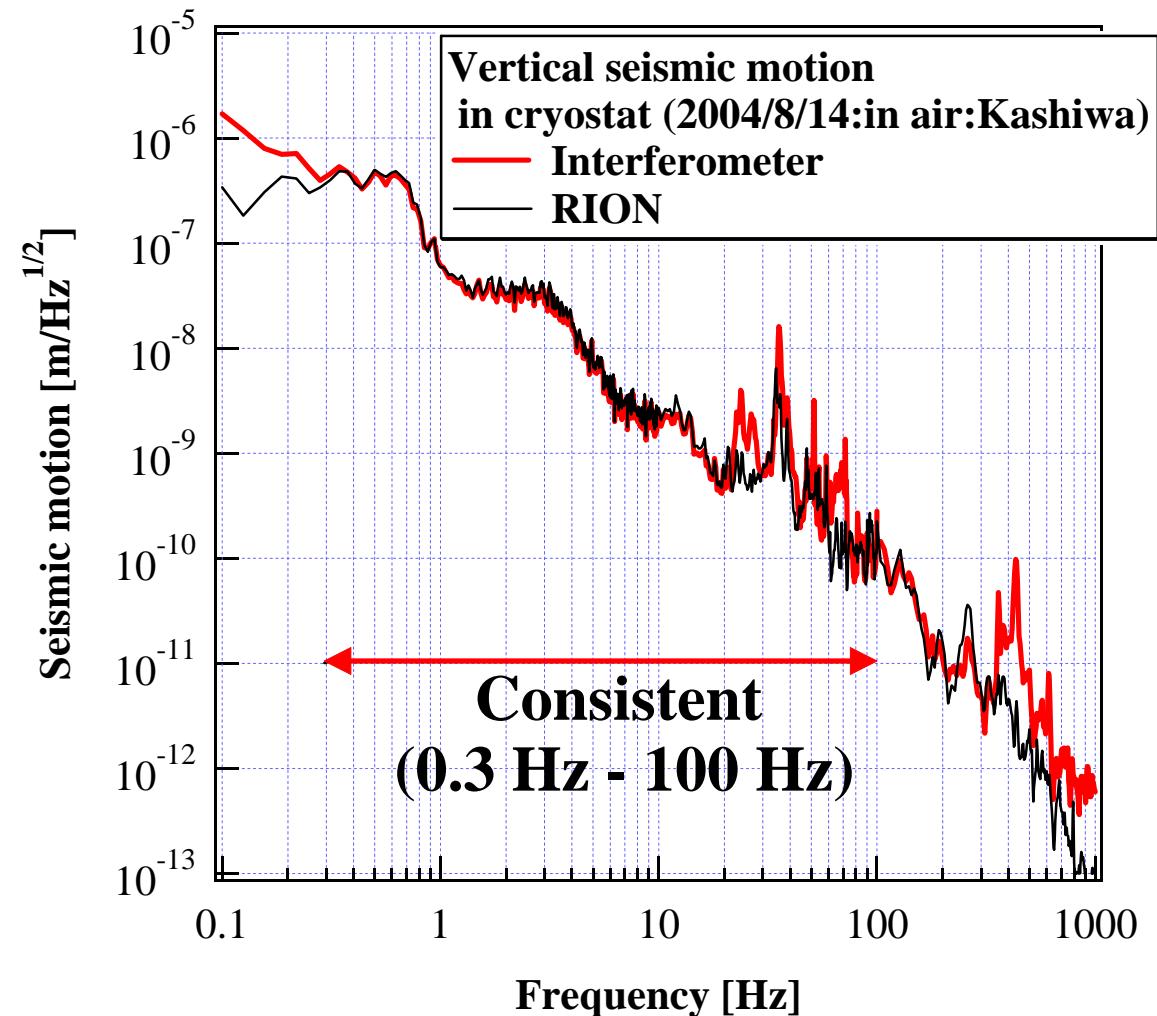
3-1. Operation at room temperature

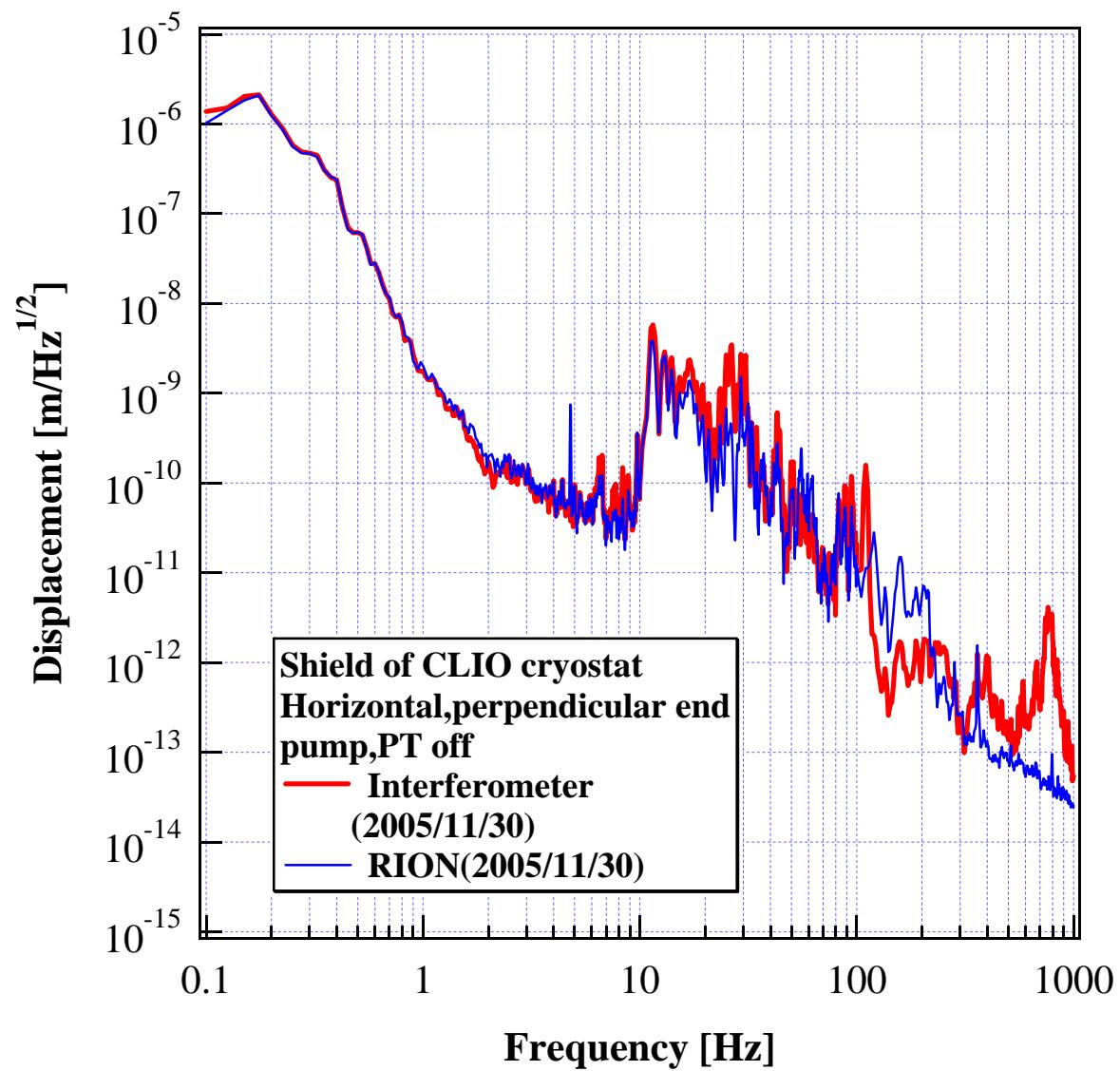
3-1-1. Comparison with RION

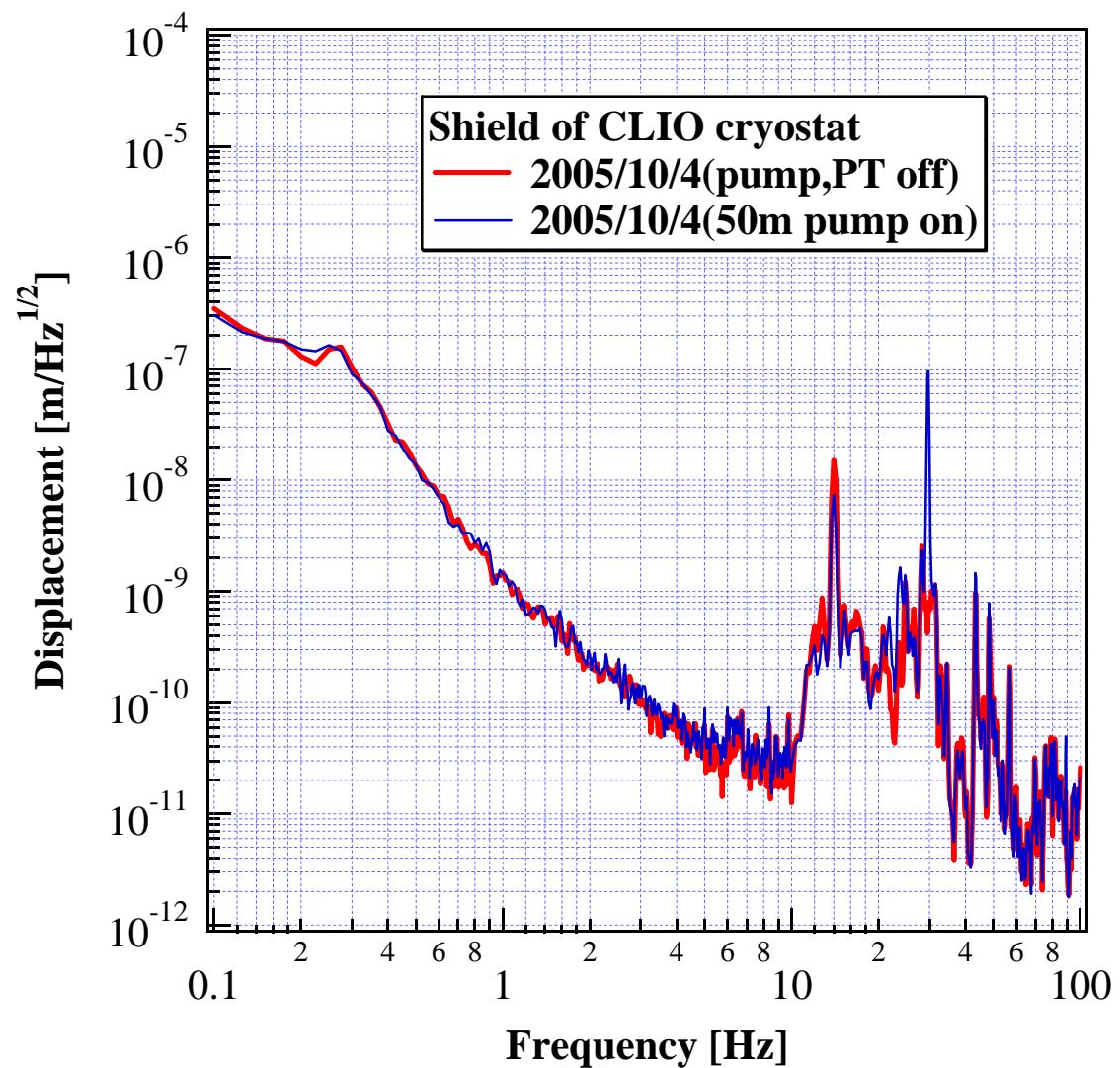
(i) Horizontal motion



(ii) Vertical motion







50 m pump

