Vibration measurement of the KAGRA radiation shield

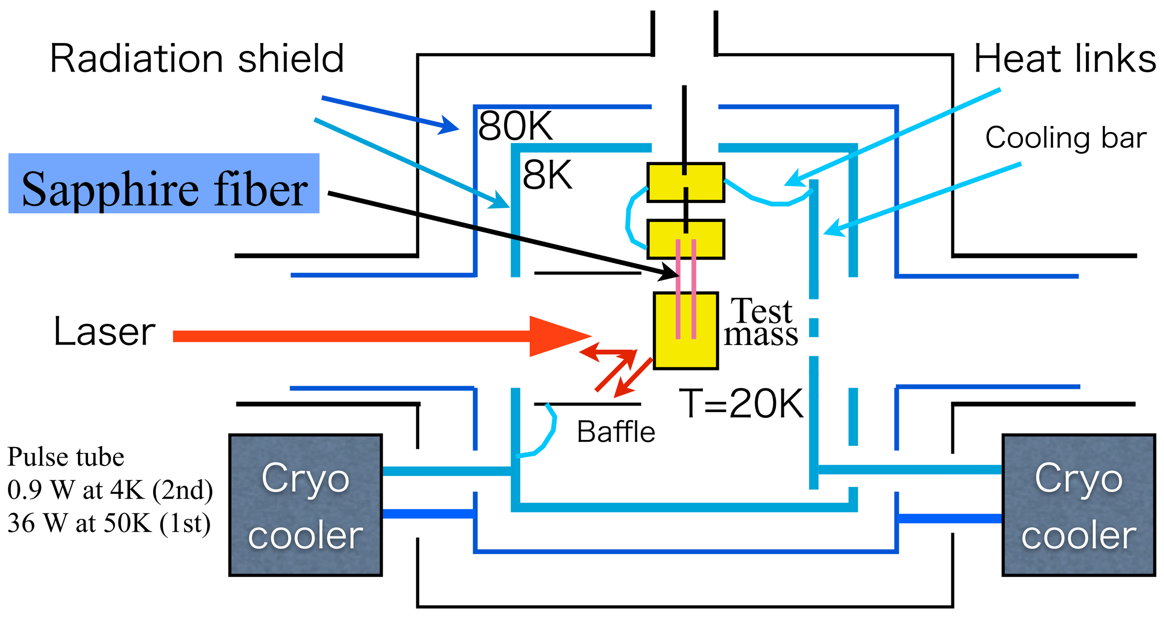
Dan Chen, K. Yamamoto, Ettore Majorana[B], Luca Naticchioni[B], T. Suzuki[A], N. Kimura[A], Andrea Conte[B], S. Koike[A],
chendan@icrr.u-tokyo.ac.jp T. Kume[A], C. Tokoku, Y. Sakakibara, Alexander Khalaidovski, S. Kawamura and KAGRA Collaboration
ICRR The University of Tokyo, KEK[A], INFN[B]

1.Introduction

The Large-scale Cryogenic Gravitational Wave Telescope named KAGRA is under construction in the Kamioka mine in Japan. The main interferometer mirrors will be cooled down to 20K in order to decrease the thermal noise. For cooling, each of these mirrors will be surrounded by a double-stage radiation shield to prevent propagation of 300K radiation and will be connected to two cryocoolers through heat links. The shield vibration can couple into the detector signal via the heat links and scattered light. In order to investigate the impact on the KAGRA sensitivity, we measured the radiation shield vibration while operating the cryocoolers. Then we estimated the influence on the sensitivity of KAGRA. Here, we report the measurement result for the KAGRA cryogenic radiation shield vibration and analysis result.

2.Cryogenic payload

Cryogenic payload: cooled suspension system and mirror



Impact of the radiation shield vibration on the interferometer noise:

1.The vibration of the radiation shield may excite an oscillation of the test mass through the heat links.

2.The scattered laser light is partially reflected by the baffle (connected with shield) and might find its way back into the main laser beam, contaminating the output of detector.

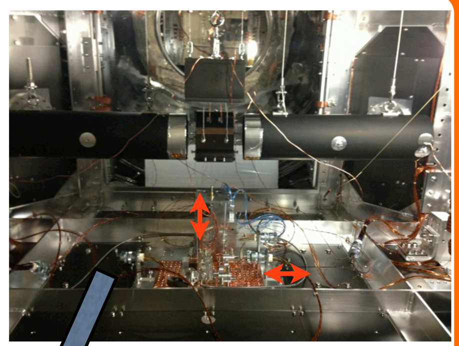
The main sources of the shield vibration:
1. **Seismic motion**
2. **Cryocoolers**

Measure the vibration of the radiation shield at low temperature, and estimate the influence on the sensitivity of KAGRA.

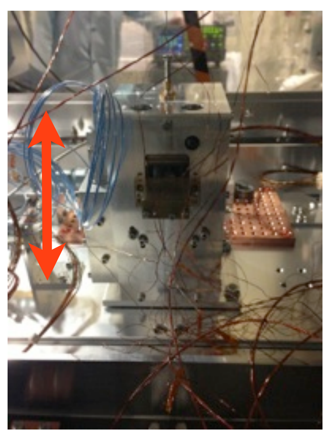
(Measurement @Toshiba Keihin Product Operations, Yokohama-city).

3.Measurement in Toshiba

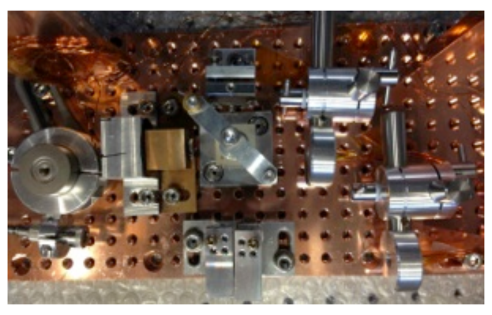
We used an accelerometer developed in Rome Univ. for vertical direction and a Michelson interferometer as an accelerometer developed in ICRR for horizontal direction.



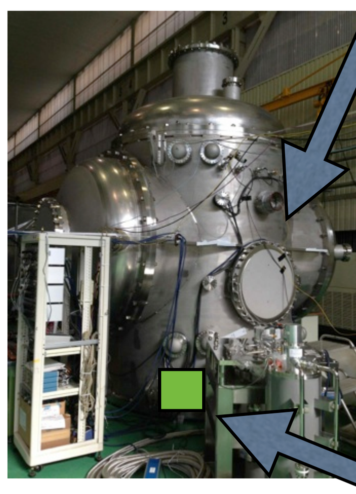
Inside the shield

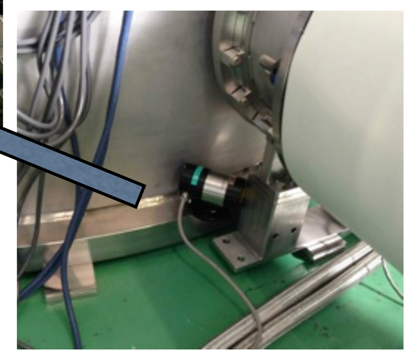


INFN acc.



ICRR acc.

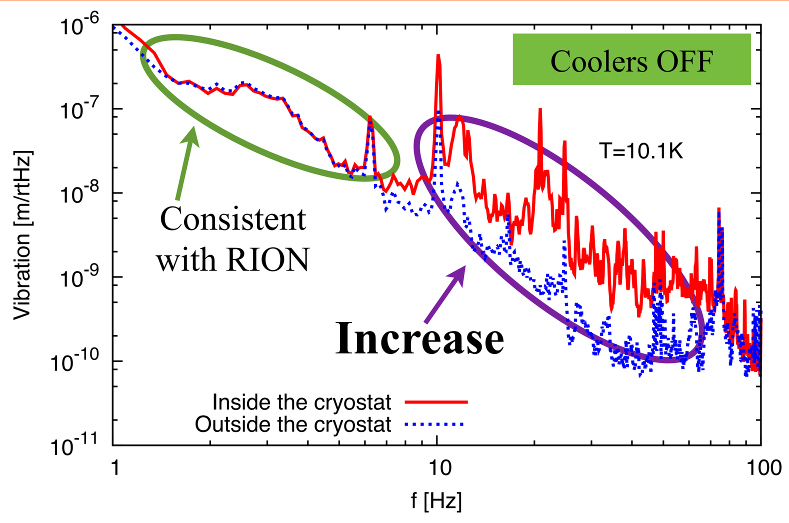




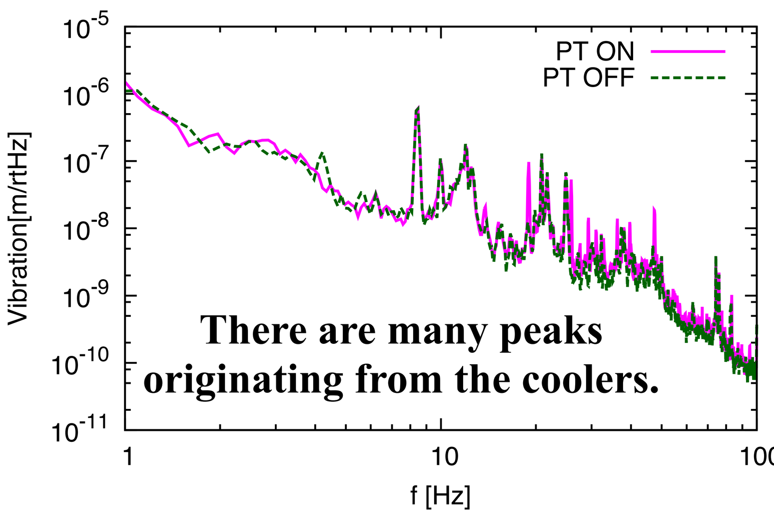
RION

We used a commercial accelerometer(RION) to measure the vibration outside the cryostat. We measured the vibration at low temperature with cryocooler ON/OFF.

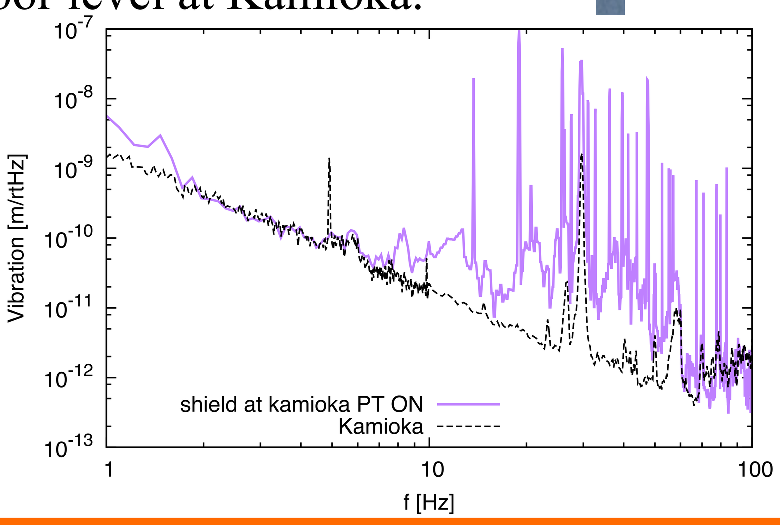
4.Measurement result and analysis



Coincidence measurement with RION (horizontal)
Calculate the ratio to estimate the floor level at Kamioka.

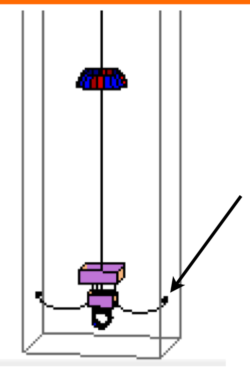


Measurement with coolers ON/OFF (horizontal)
Assume the same peak level at Kamioka as Yokohama

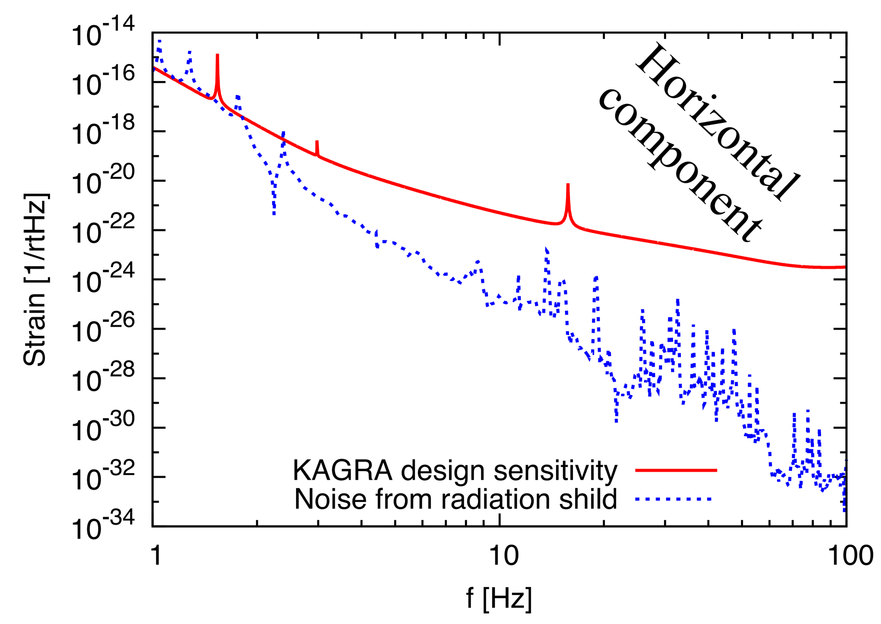


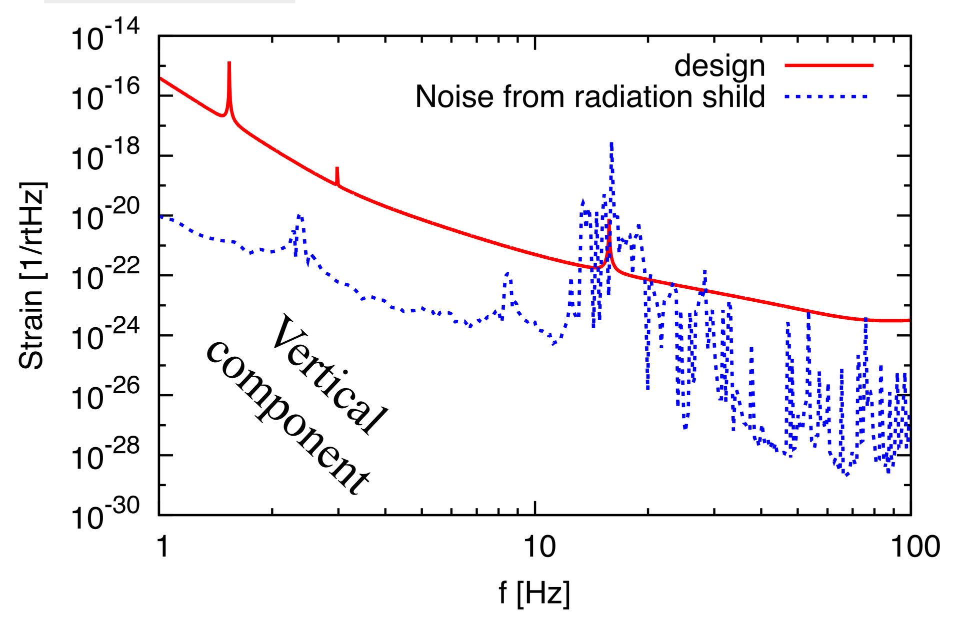
The estimated vibration of the radiation shield at Kamioka has peaks from cryocoolers.

We estimated the influence on the sensitivity of KAGRA using a code made by T. Sekiguchi.
The scattered light effect is not considered.



We inputed our estimated vibration to the attachment points between heat links and shield.





The noise from the horizontal vibration component is significantly lower than the requirement. But the noise from the vertical component is higher than the design sensitivity around 20Hz.

We have to take care of vertical vibration when we design the cryo-payload.

Measurement of sapphire Q for KAGRA mirror suspension

1.Purpose

We will use **sapphire fibers** (φ 1.6 mm) to suspend cooled sapphire mirrors(20K).

High thermal conductivity → lower cooling time
High Q value → lower thermal noise

Requirements

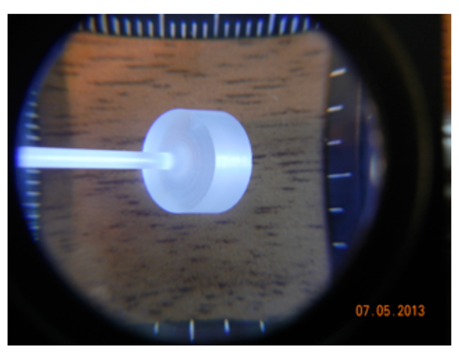
Thermal conductivity: 5000 W/m/K
Q value: $5x10^6$ etc...

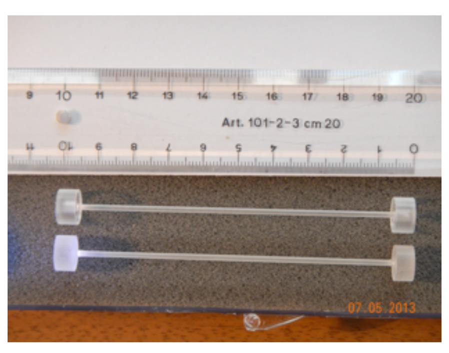
In Rome we tested two samples with good thermal conductivity.

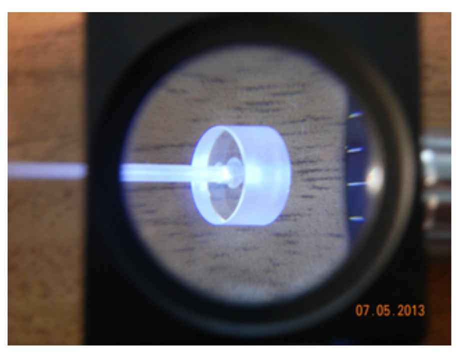
Fiber 1: 5000 W/m/K @20K
Fiber 2: 9000 W/m/K @20K

Our purpose is measuring the Q value of these fibers @ 20K

2.Sapphire fiber at Rome





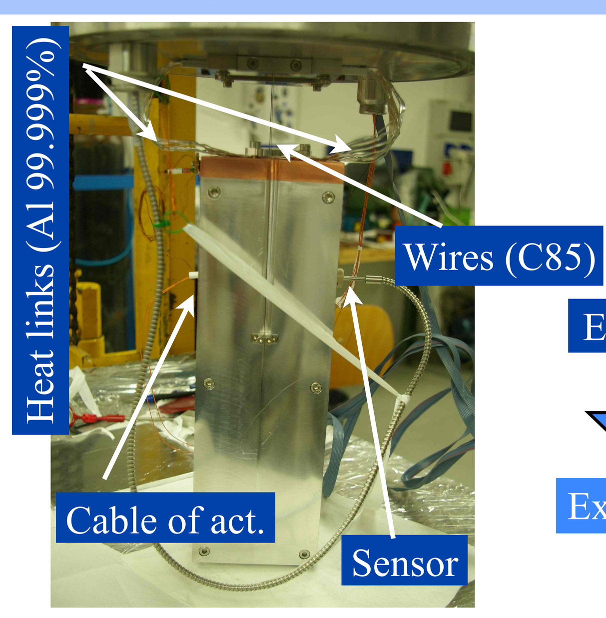


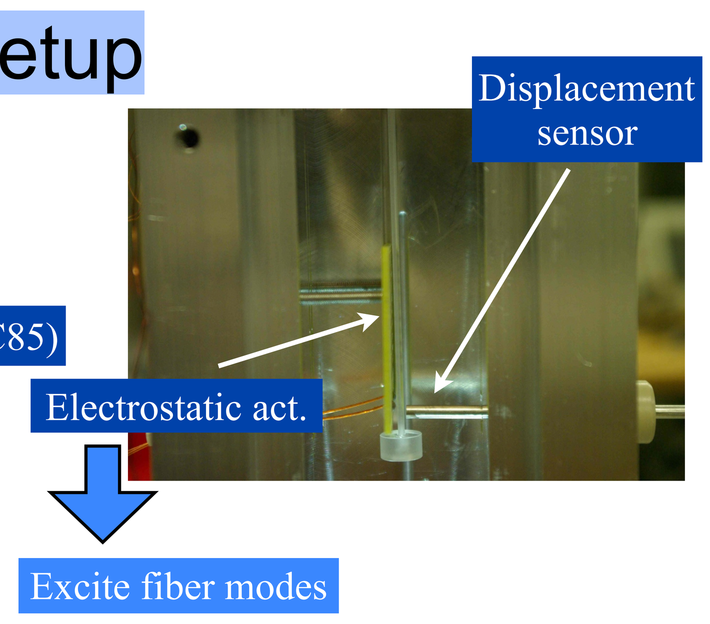
Fiber 1
- 5000 W/m/K @20K
- Monolithic

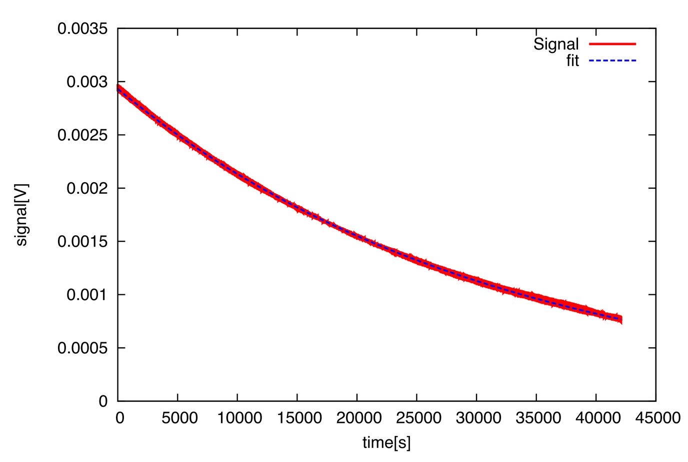
Fiber 2
- 9000 W/m/K @20K
- Non-monolithic
- Brazed through alumina

- HEM quality
- Thermopolishing

3.Measurement setup



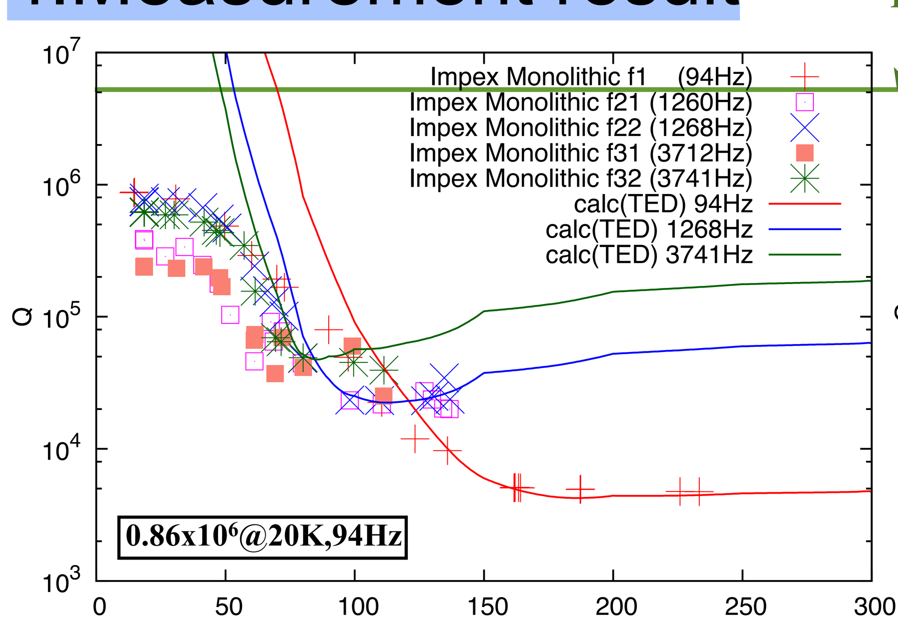




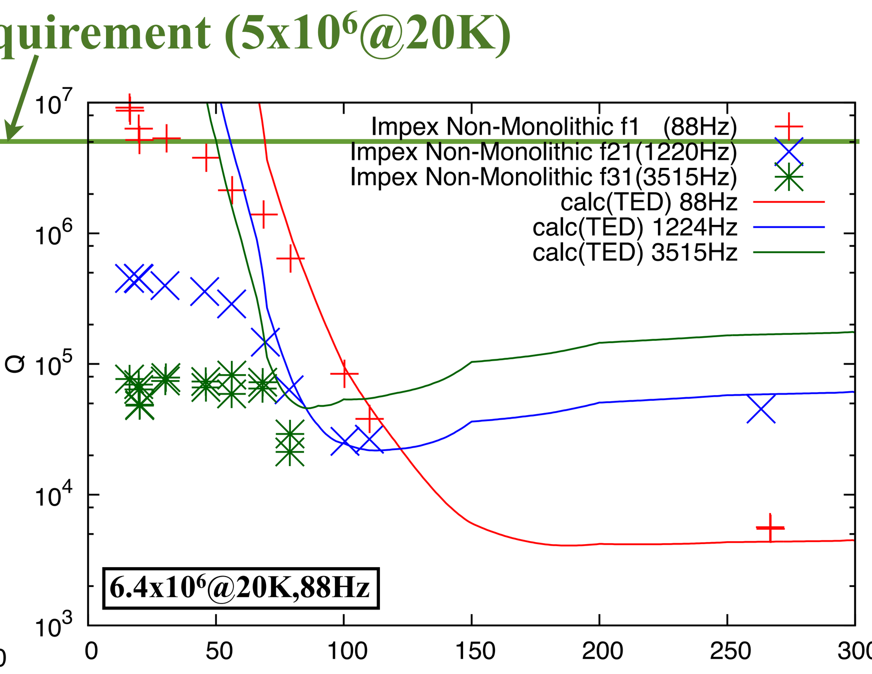
We calculated Q from the ring dawn signal.

4.Measurement result

Requirement ($5x10^6$@20K)

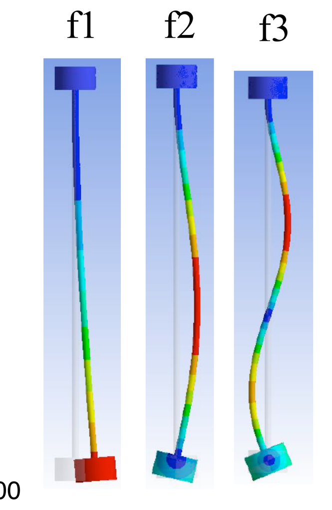


Fiber 1 Low Q



Fiber 2 High Q

Modal simulation



We measured Q values of two kinds of sapphire fiber whose thermal conductivity is higher than the requirement value. One of them (fiber 2) has high Q which is higher than requirement value. This means even non-monolithic fiber can have high Q. HEM quality and thermopolishing might improve Q value.