Thermal-noise-limited underground interferometer CLIO

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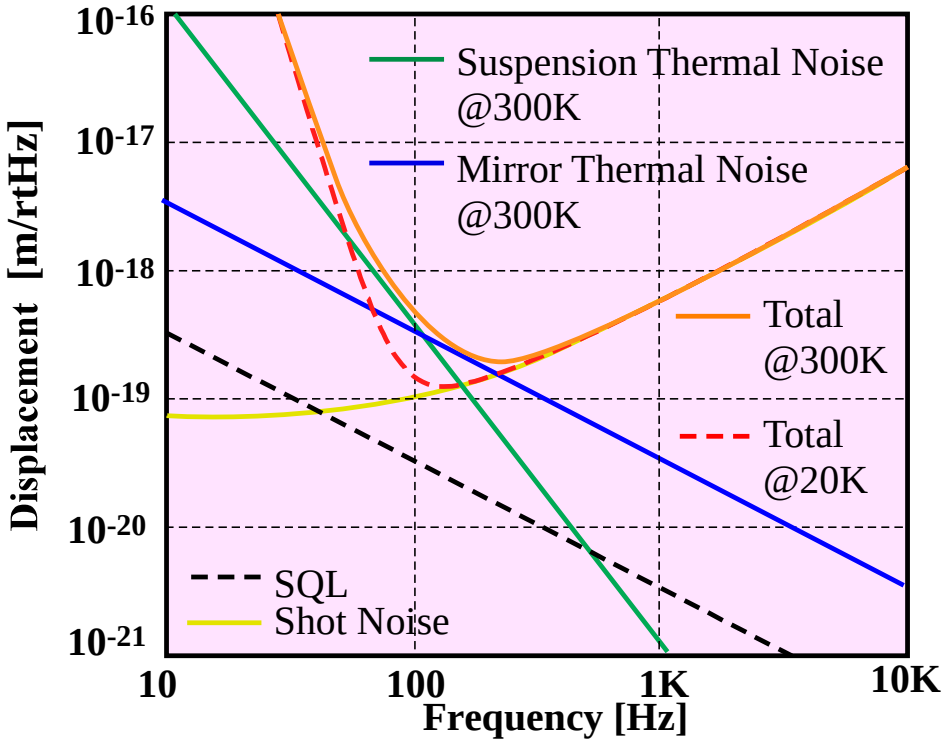
CLIO Overview

CLIO (Cryogenic Laser Interferometer Observatory)
100m long Locked-FP Interferometer, Proto-Type for LCGT.

=> talked by Prof. Kuroda

= Main goal =

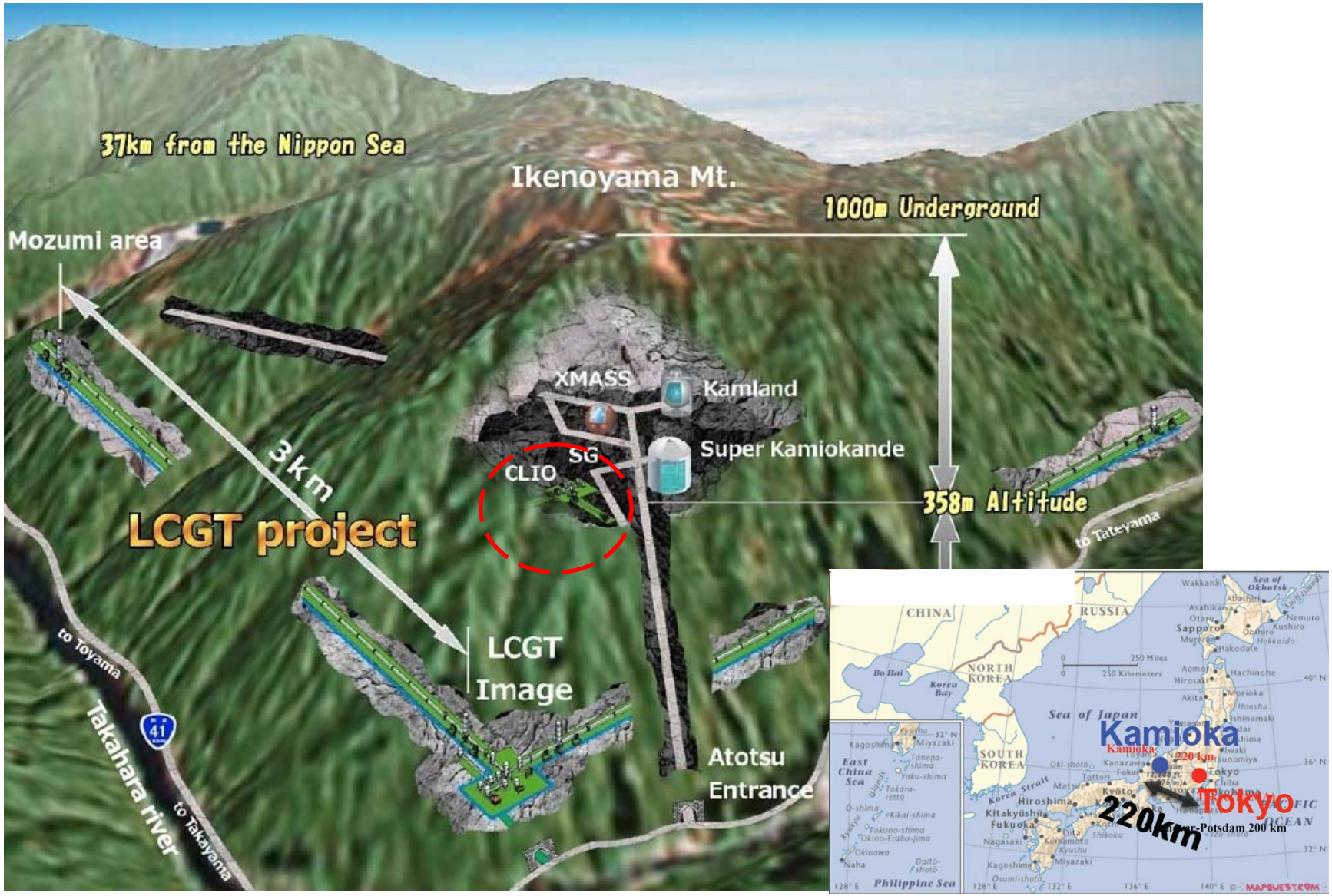
- To demonstrate an improvement of sensitivity through the reduction of the mirror thermal noise by cooling the mirrors.



Laser power :
250mW for one arm
Mirror Mass :
1.8 kg

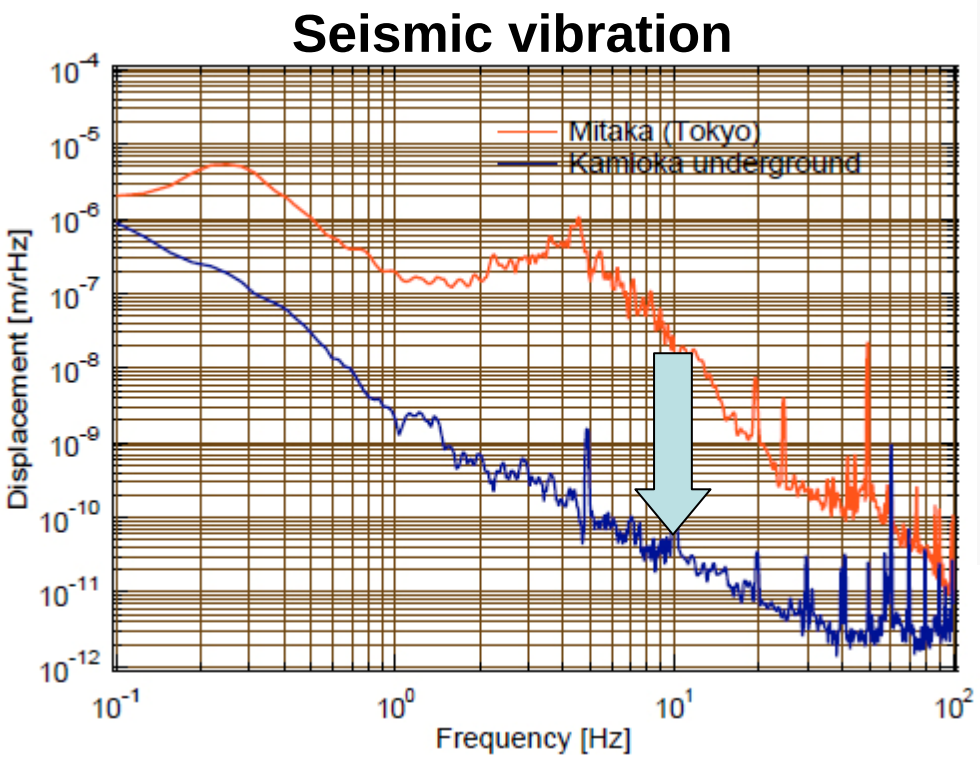
Thermal Noises limit the sensitivity around 100Hz, and they will be reduced after cooling.

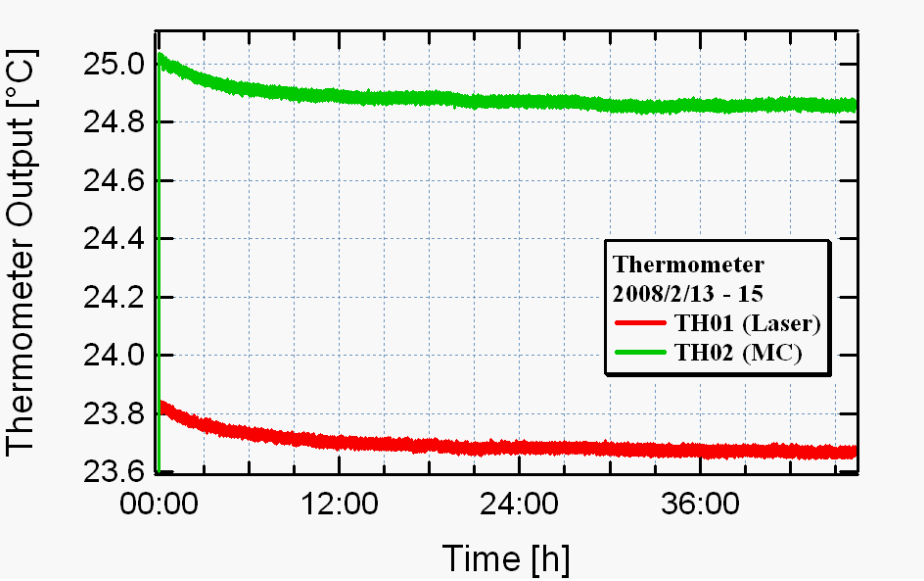
Underground of Kamioka Research Facility



Google Earth

Advantages of Underground Site





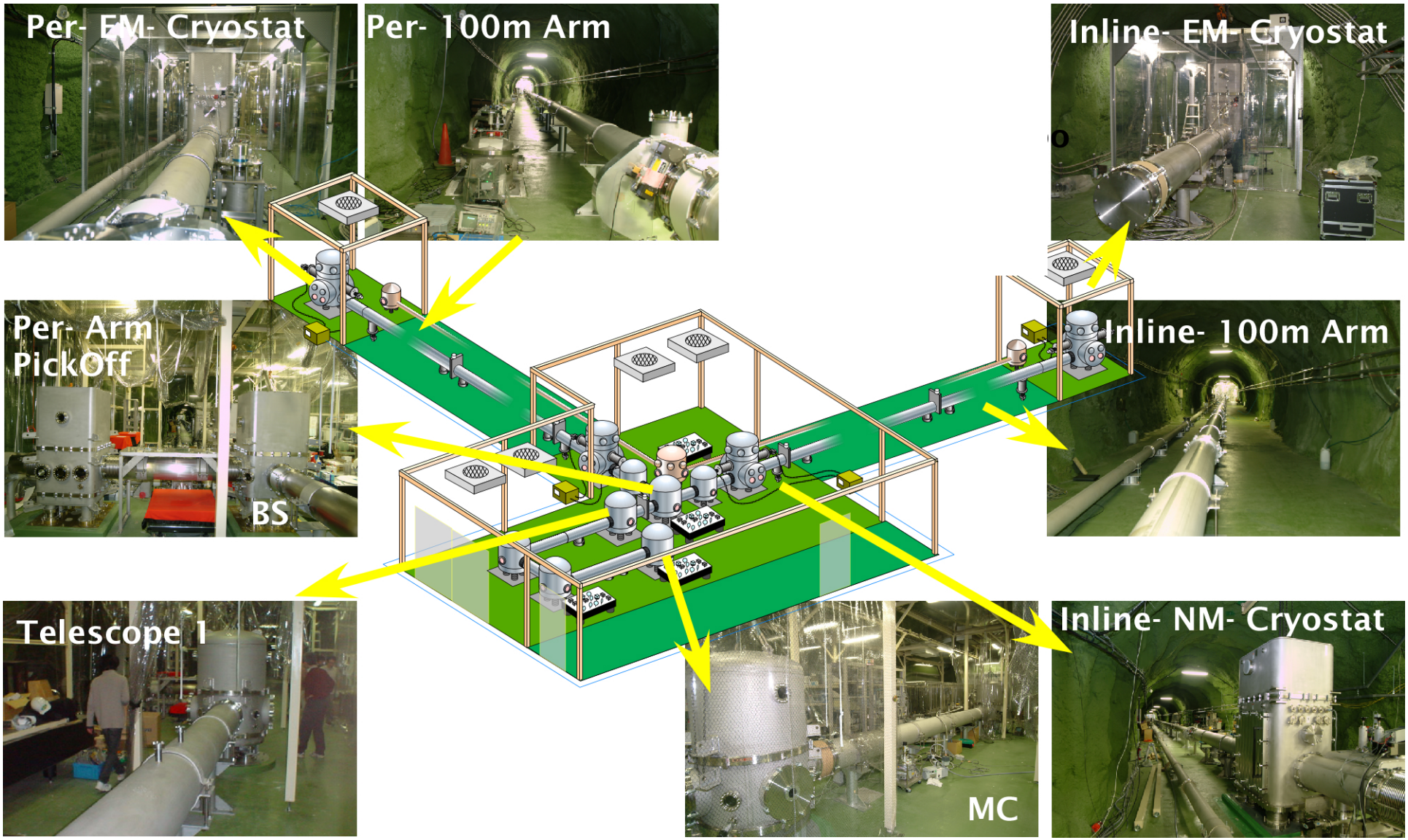
Its variance for 46 hours is about **0.1～0.2 degree** without controlling temperature.

Seismic vibration of CLIO site is quieter than that of TAMA site by order of 2~3.

Merits for an interferometer
-Lower seismic noise.
-Very stable temperature.
-Enhanced stability.

helpful to achieve the target sensitivity

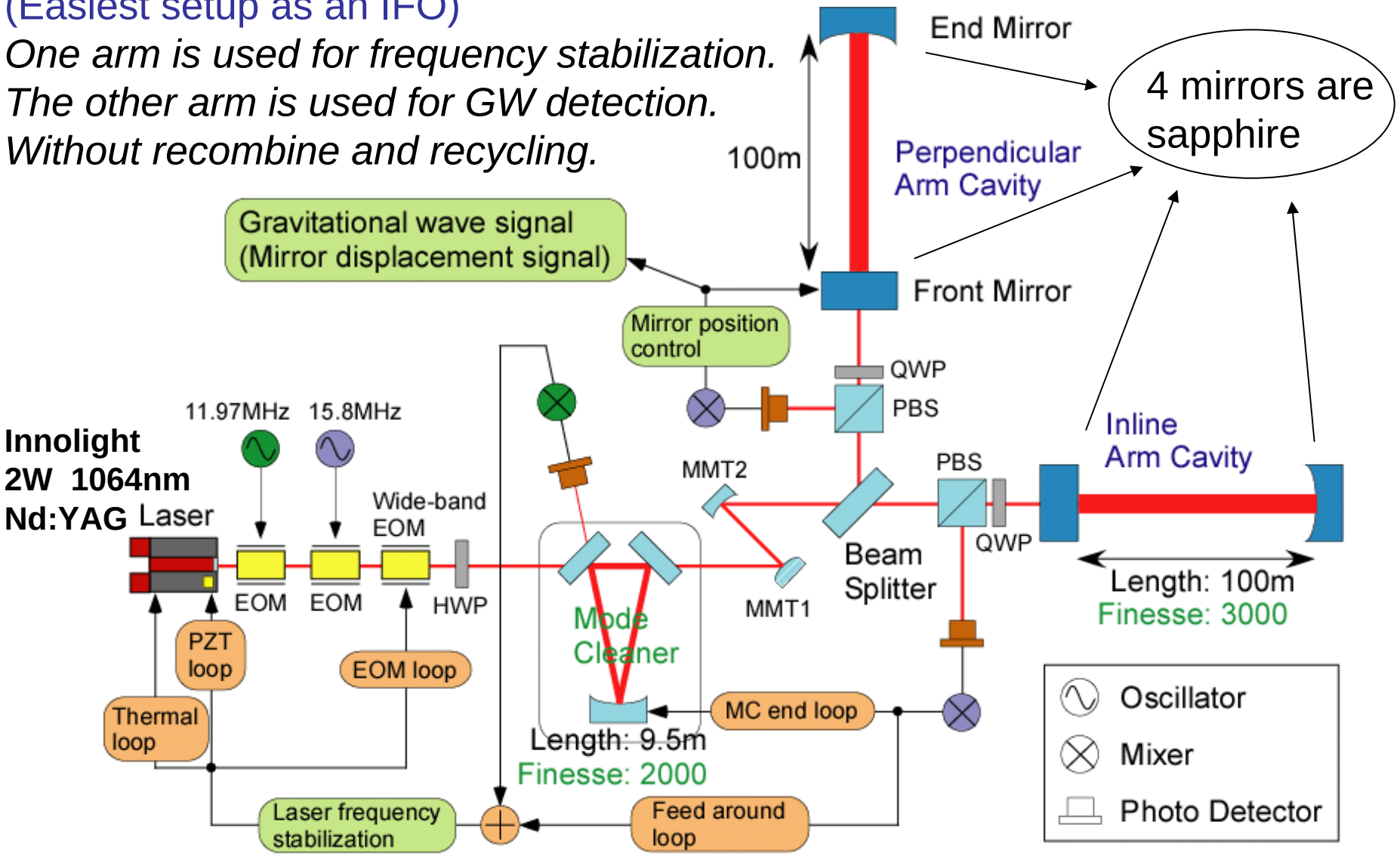
Tour to CLIO


Per- EM- Cryostat
Per- 100m Arm
Inline- EM- Cryostat
Per- Arm PickOff
BS
Inline- 100m Arm
Telescope 1
MC
Inline- NM- Cryostat

Locked FP Interferometer

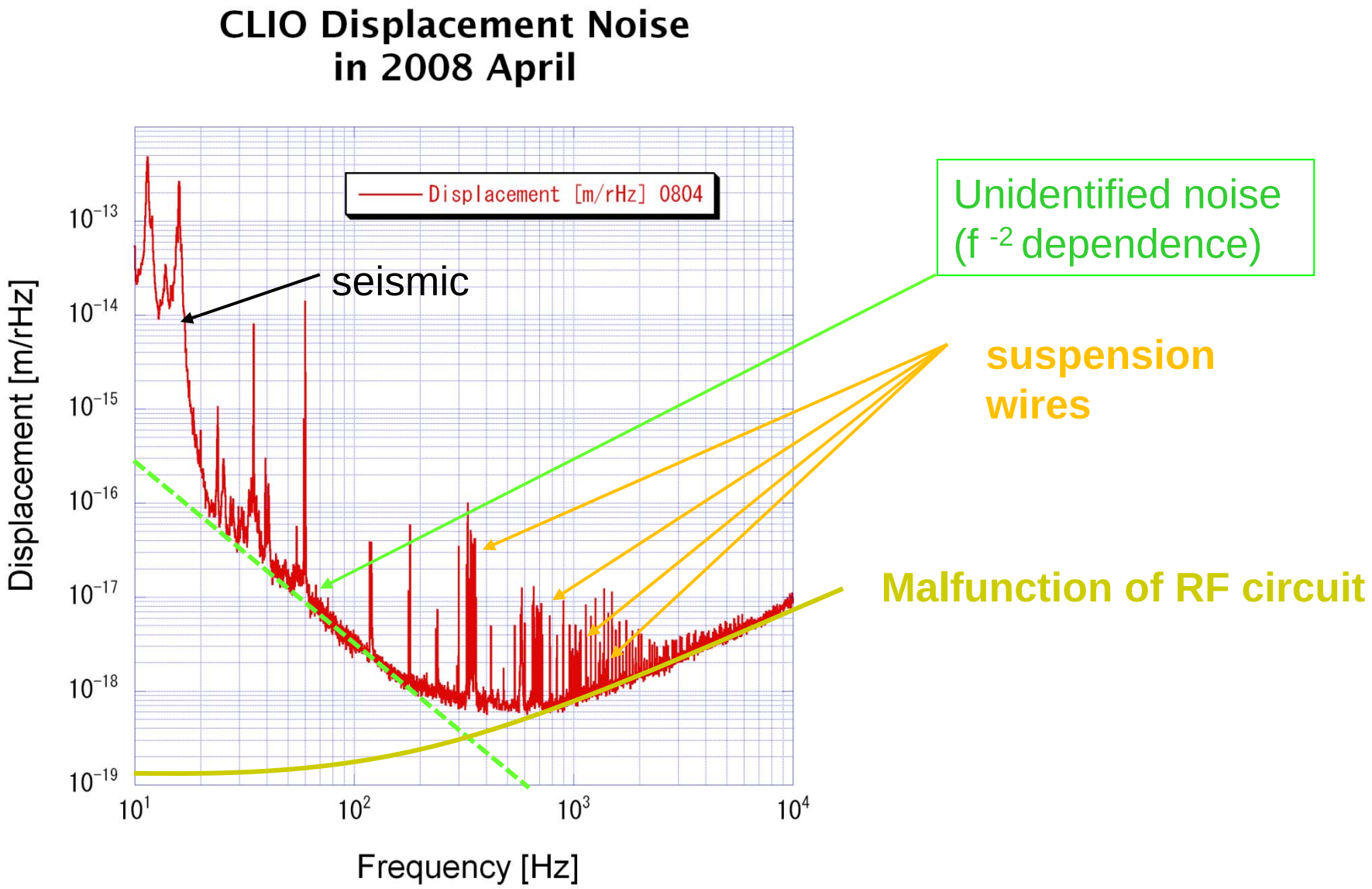
(Easiest setup as an IFO)

One arm is used for frequency stabilization.
The other arm is used for GW detection.
Without recombine and recycling.



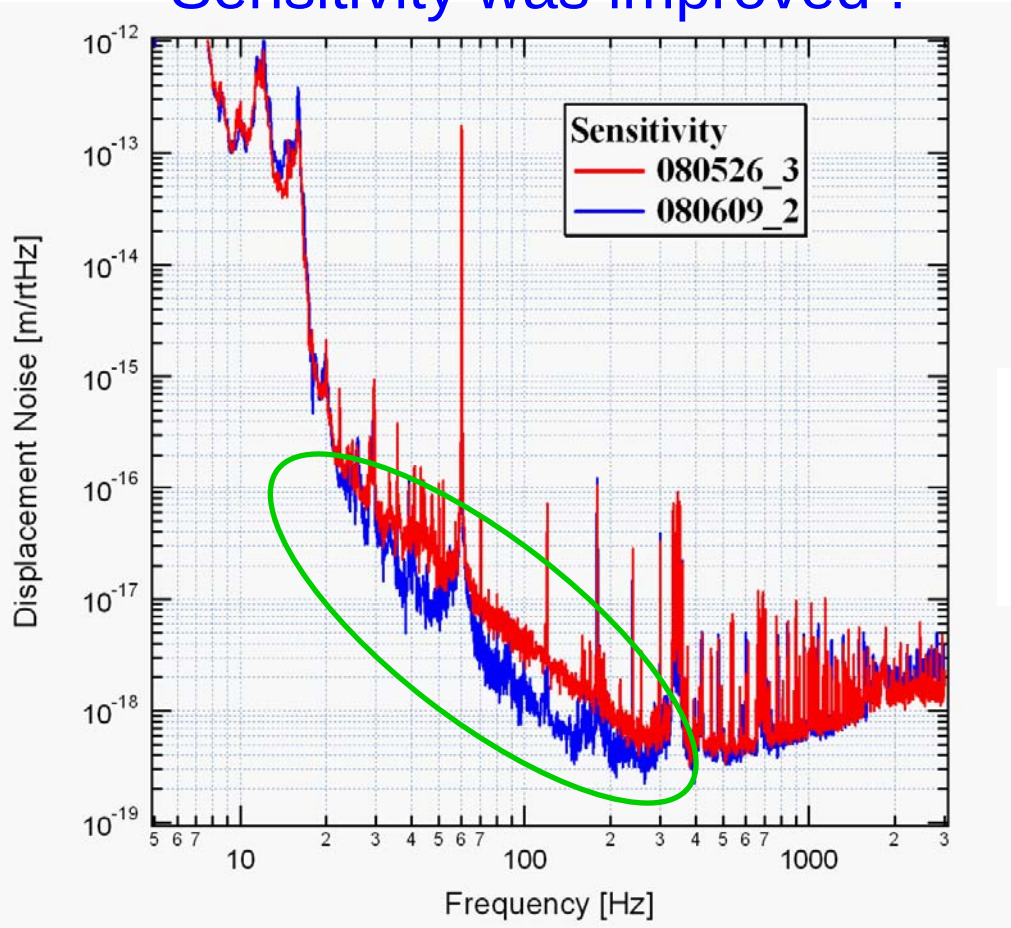
Sensitivity at Room Temperature

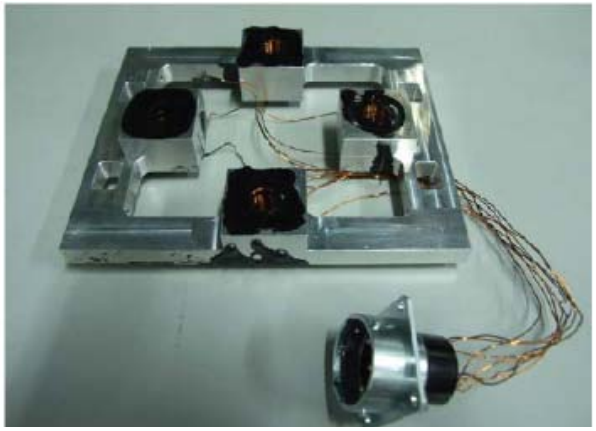
Factors Limiting Previous(Apr.08) Sensitivity



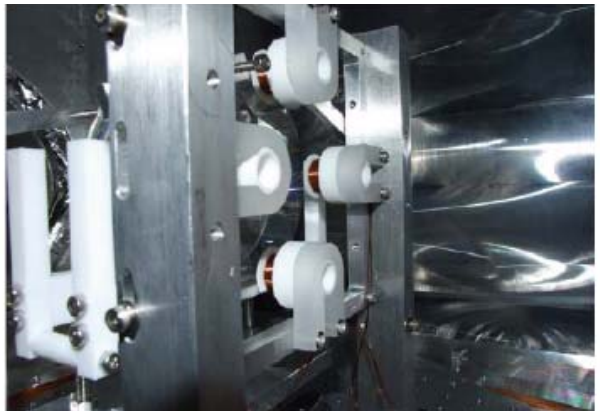
We Identified the Noise Source !

Sensitivity was improved !





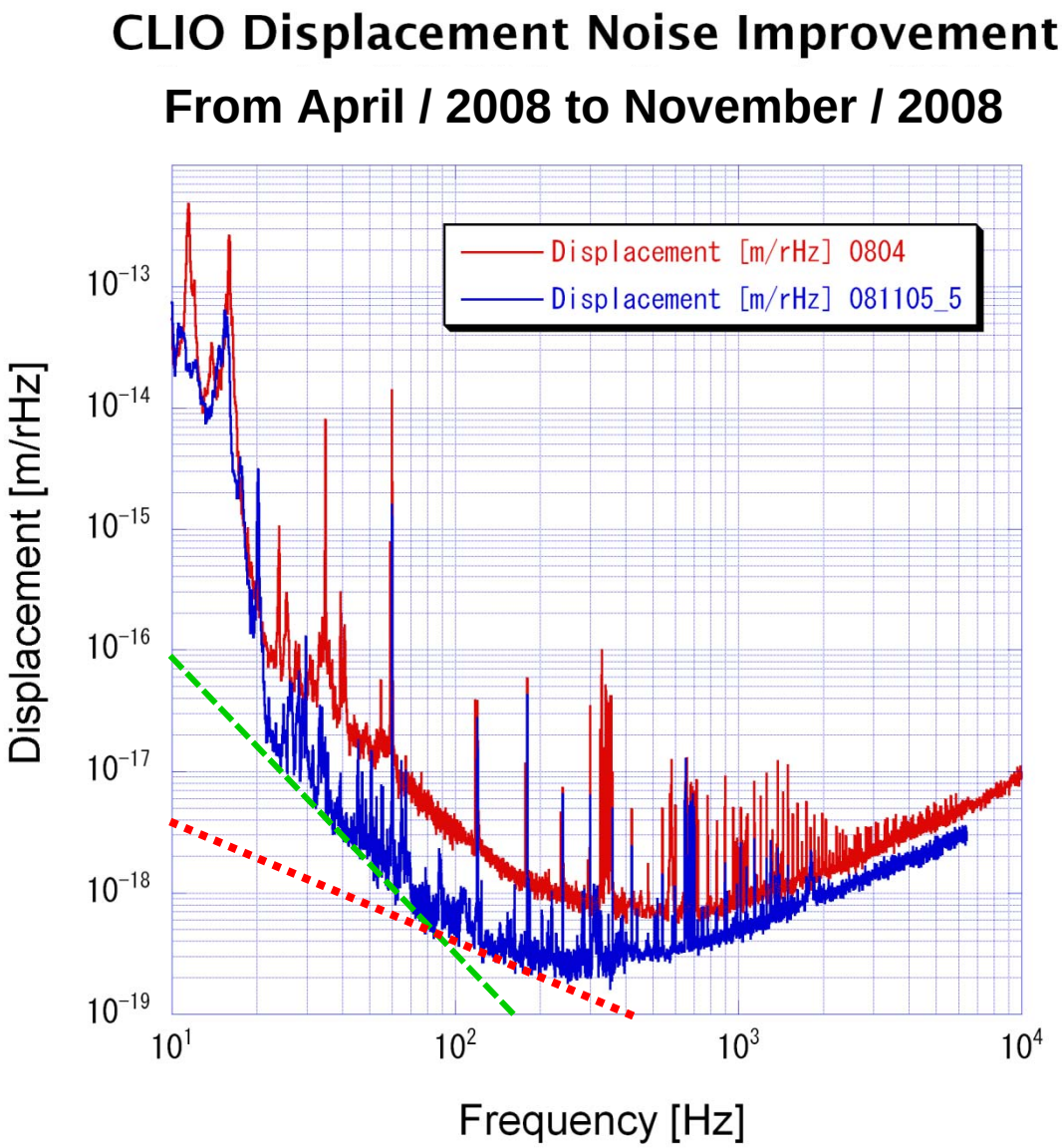
Problem: Eddy current in an aluminum coil holder was induced by magnets that were attached on a mirror, then it added mechanical loss to the pendulum.



Solution: The aluminum holder was replaced with a ceramic and daifron holder.

Eddy current increases the mechanical loss of the pendulum. Then it increases the thermal noise.

Improvement of Sensitivity at Room Temperature



- Improvement -

♦ Identification and elimination of noise source appearing from 20Hz to 400Hz.

=> Pendulum thermal noise due to eddy current force

♦ Using thinner suspension wires shifted the violin modes to higher frequencies.
(Bolfur wire ϕ0.1mm => ϕ0.05mm)

♦ Finer beam centering reduced noisy structure (20Hz- 300Hz).

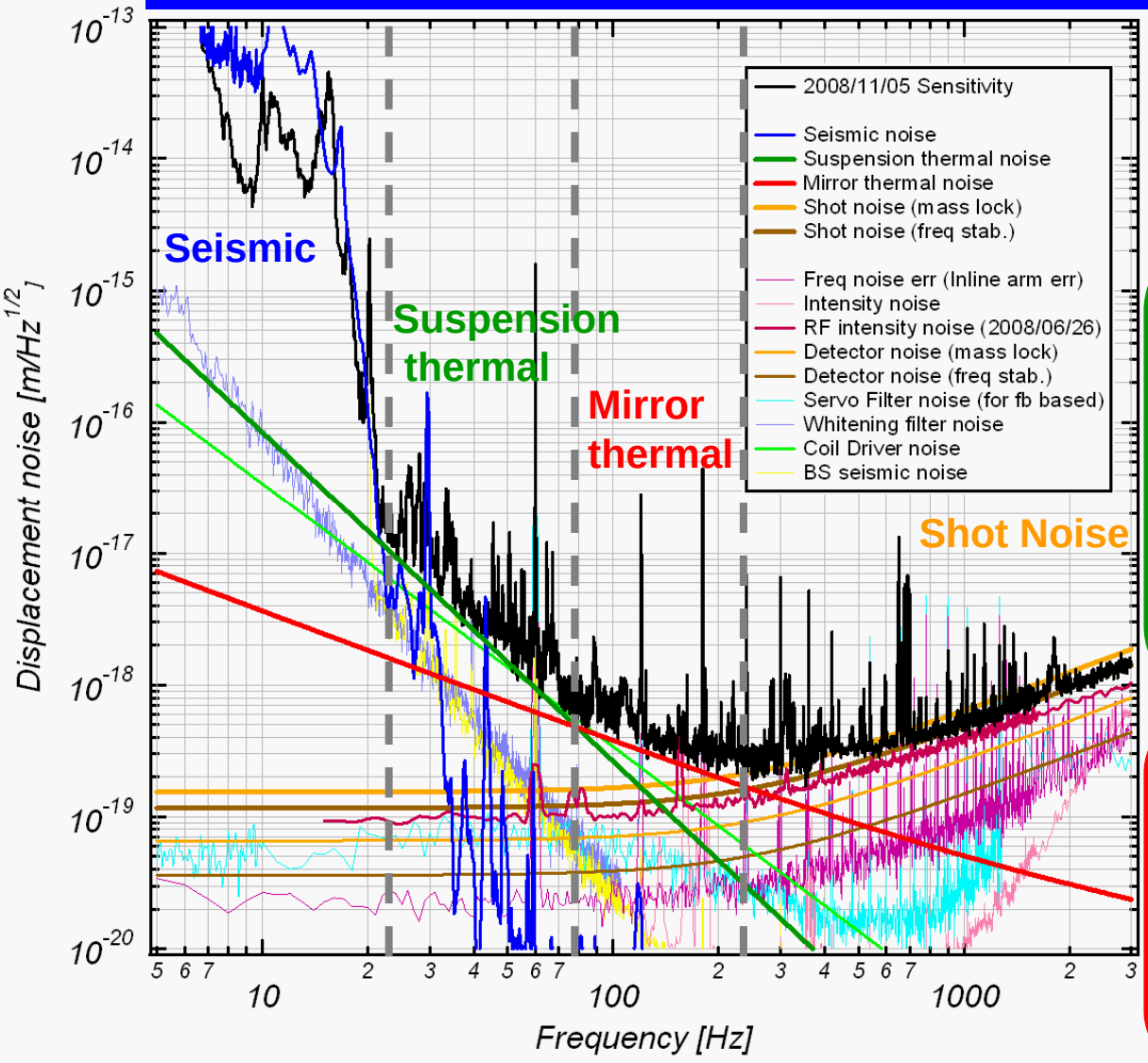
CLIO displacement noise reached the predicted thermal noise levels.

♦Mirror bulk thermal noise.

♦Suspension thermal noise (estimated from assumed structure damping and measured violin Q)

Thermal Noise Limited Interferometer

We achieved the target sensitivity at room temperature !



The sensitivity is limited by fundamental noises at all frequencies in Nov. 2008.

♦ The spectrum in 20Hz-80Hz is consistent with the estimated suspension thermal noise (green line) caused by wire structure damping
=> Using Q estimated by measured violin modes.

♦ The spectrum in 80Hz-250Hz is close to the estimated mirror thermal noise (red line)
=> Using the sapphire thermoelastic noise

We decided to move to a cryogenic experiment of sapphire mirrors since we believe the sensitivity is limited by thermal noises at room temperature.

Suspension System for Cryogenic Mirrors

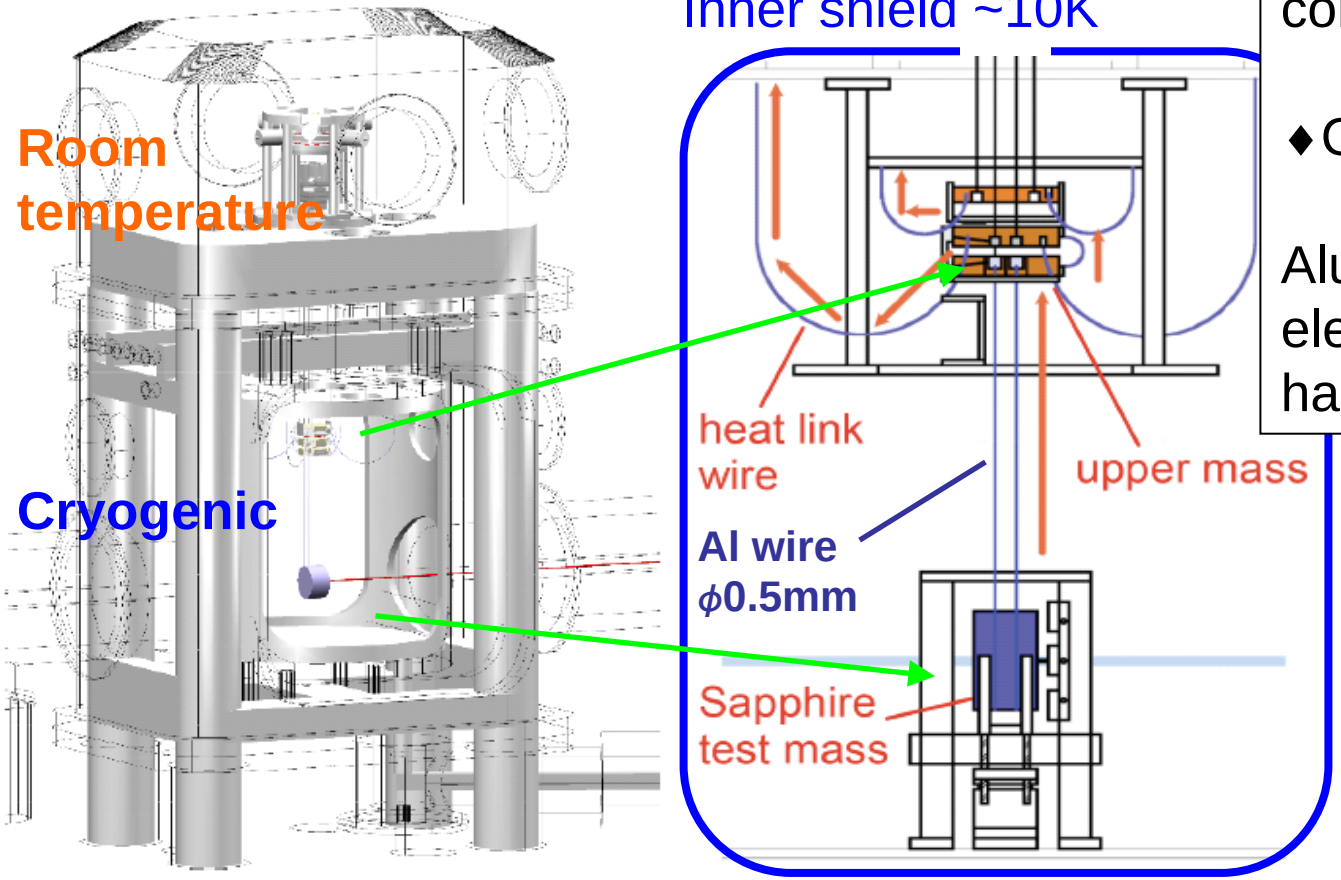
6-stage pendulum
Blade spring: 4-stages
Wire suspension: 2-stages

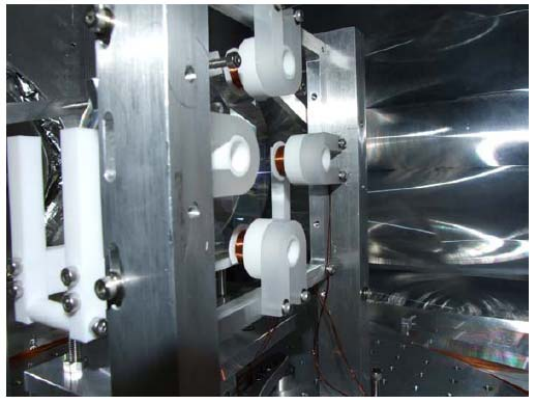
The sapphire mirror is cooled down to under 20K.

Cryogenic compatible

♦Wire material
Bolfur => Al
Al has good thermal conductivity.

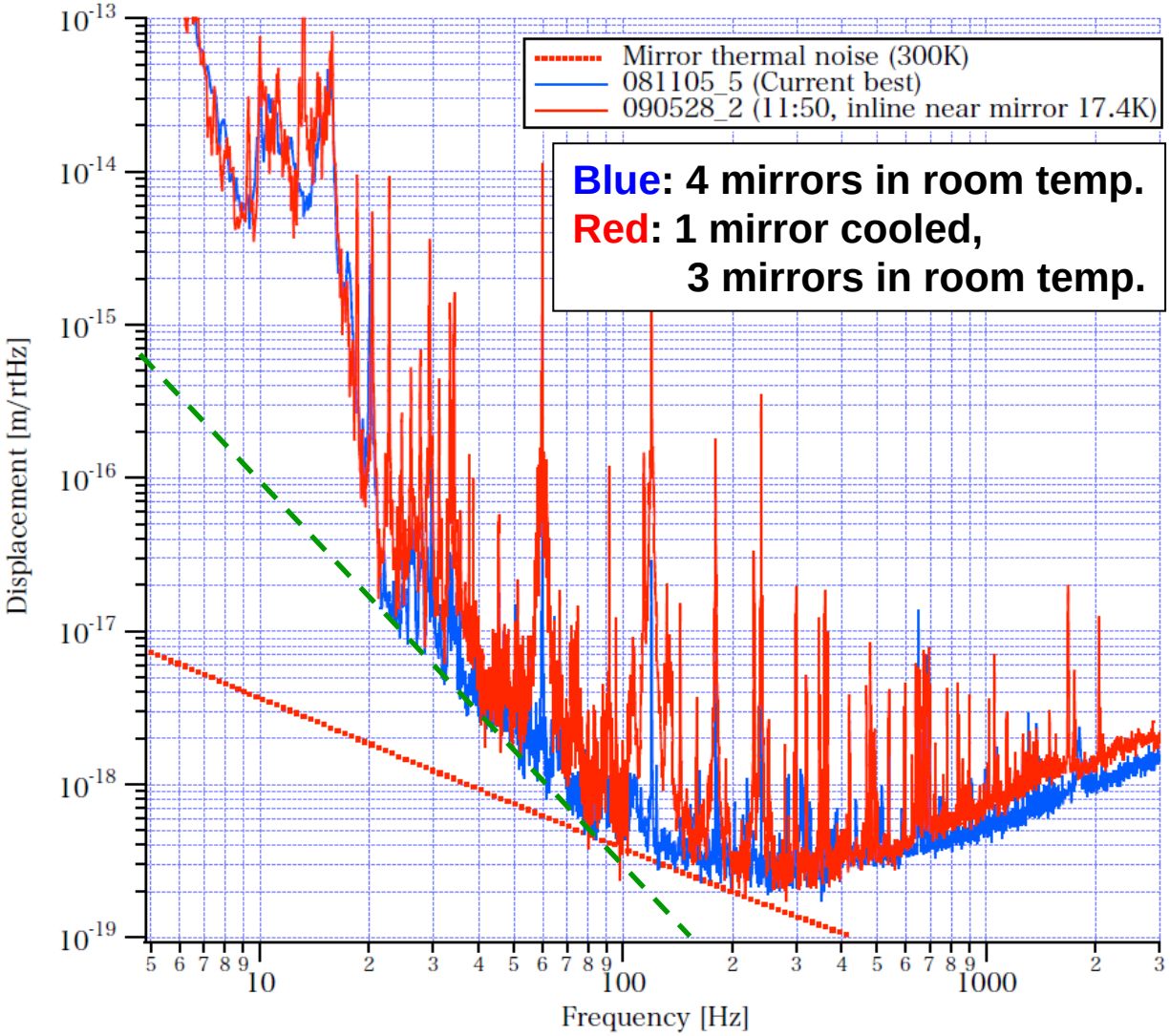
♦Ceramic coil bobbin
Macor => AlN
Aluminum nitride is an electric isolator, which has thermal conductivity.





One of the four mirrors has been cooled.

Promising result !



The floor level of the spectrum approached the thermal noises at room temperature.

♦ The cooling doesn't degrade the best sensitivity at room temp.

♦ The sensitivity is limited by thermal noises of other suspensions and mirrors because still the other three mirrors are at room temperature.

♦ In the near future, the second mirror will be cooled. We expect that the thermal noises will be reduced.

Summary

- The target displacement sensitivity of CLIO at room temperature was achieved.

  => By getting rid of the eddy current in the coil holder, the sensitivity reached the target thermal noise level around 100Hz.

  => The suspension thermal noise is estimated by measured violin Q and structure damping.

  => The mirror thermal noise is estimated by sapphire thermoelastic noise.

- Cryogenic experiment is going on.

  => One mirror is being cooled, and then the floor level approached the same as the thermal noise at room temp.

  => We can expect the thermal noise reduction when the second mirror is cooled.