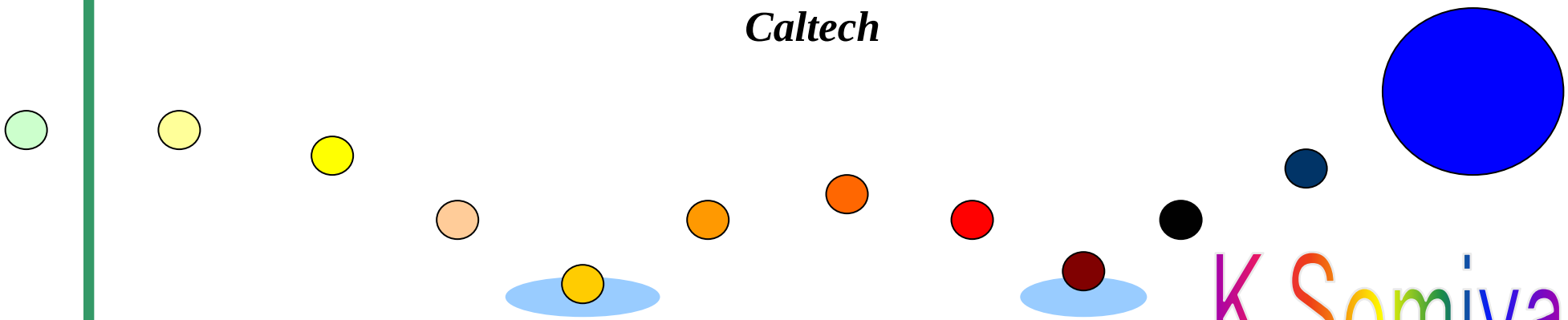
Application of techniques for LCGT to the Einstein Telescope

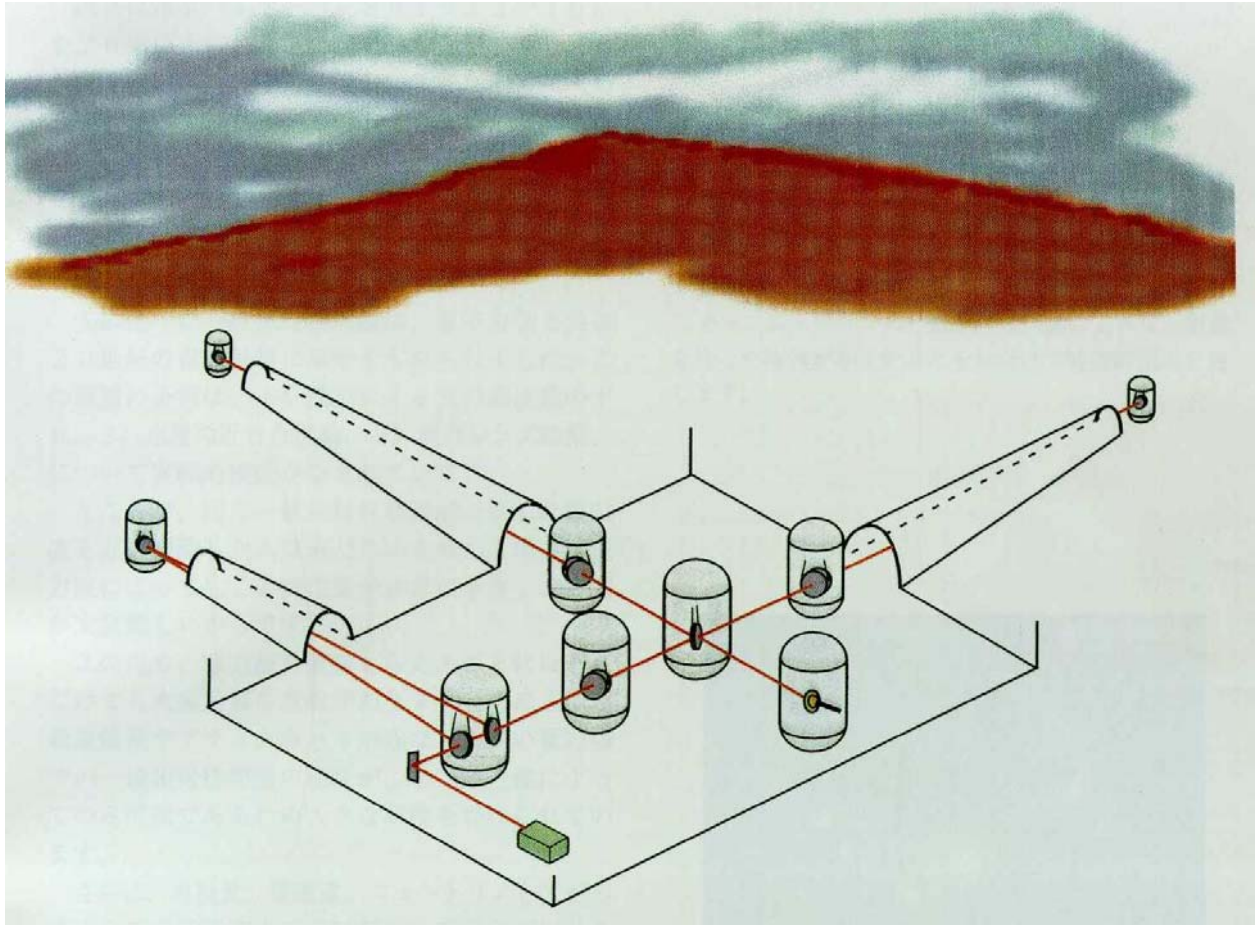
WP3 meeting @ Hannover

Jan. 2009

Kentaro Somiya
Caltech



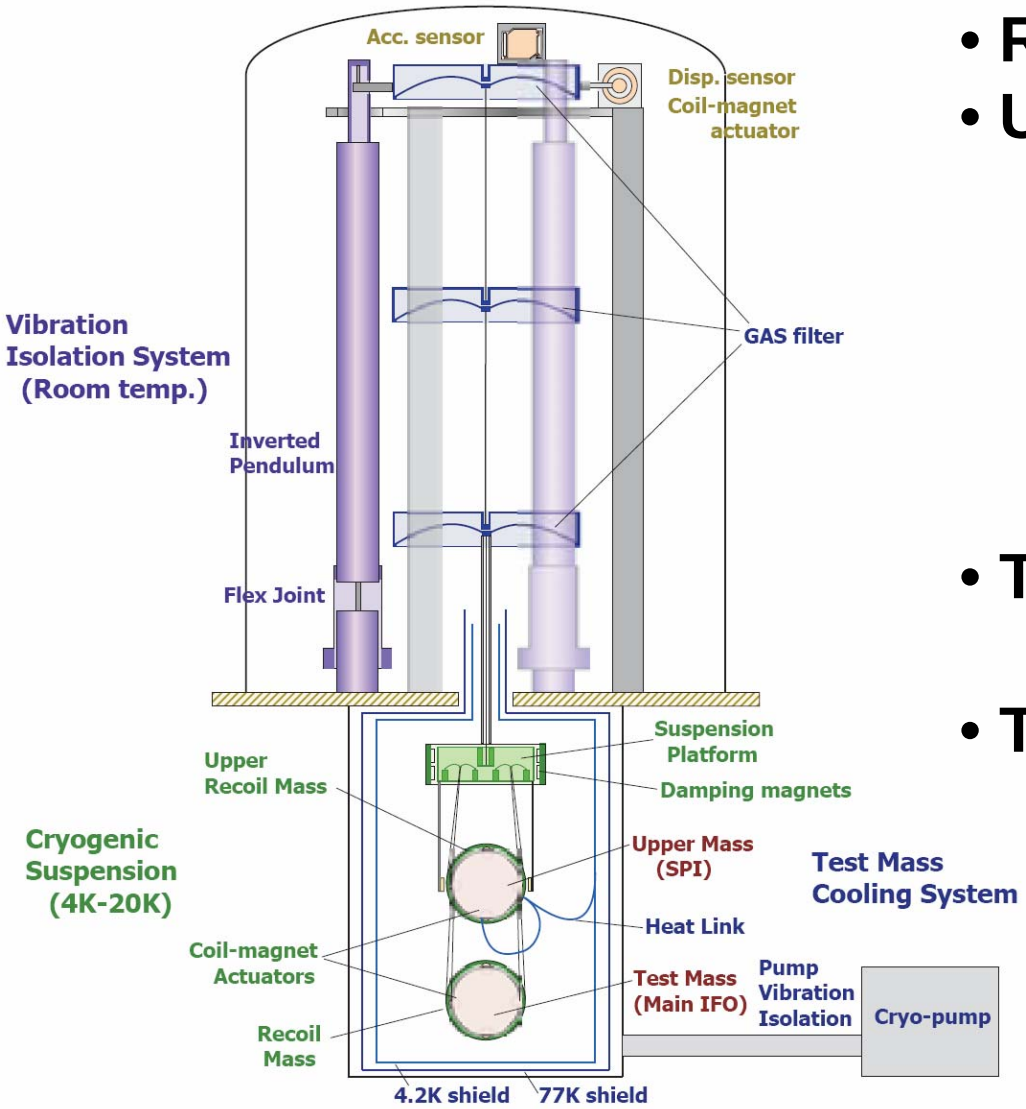
Review of LCGT



- Underground
- Cryogenic
- 3 km
- RSE
- Not yet funded

Probably many things to learn for ET

Review of LCGT ~ cryogenic



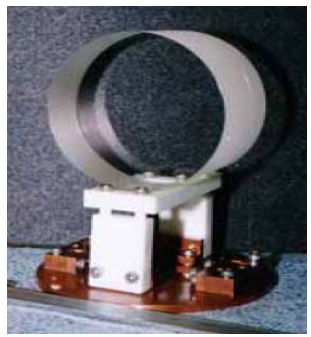
- **Radiation shield**
- **Upper mass cooled via heat link**

~ pure Aluminum
(99.999%)
ϕ=0.15 mm

- **Test mass cooled via suspension**

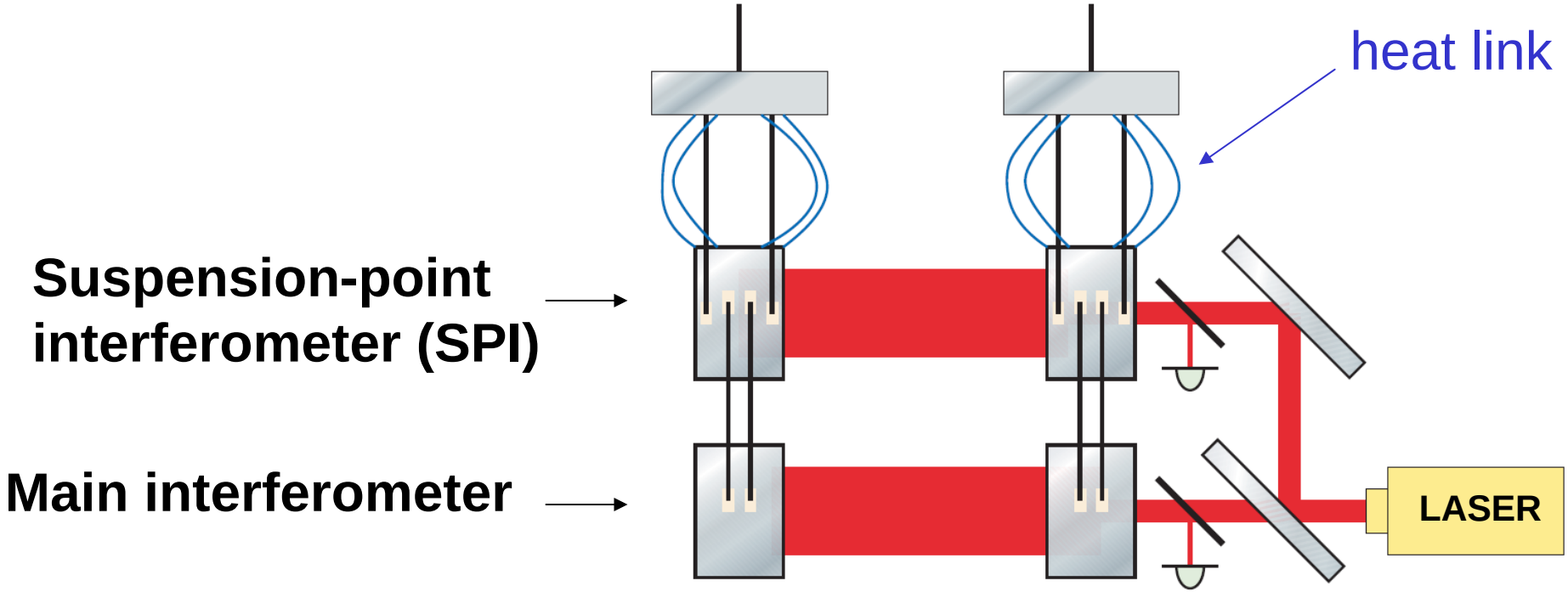
~ crystallized sapphire ϕ=100um

- **Test mass temperature 20K**



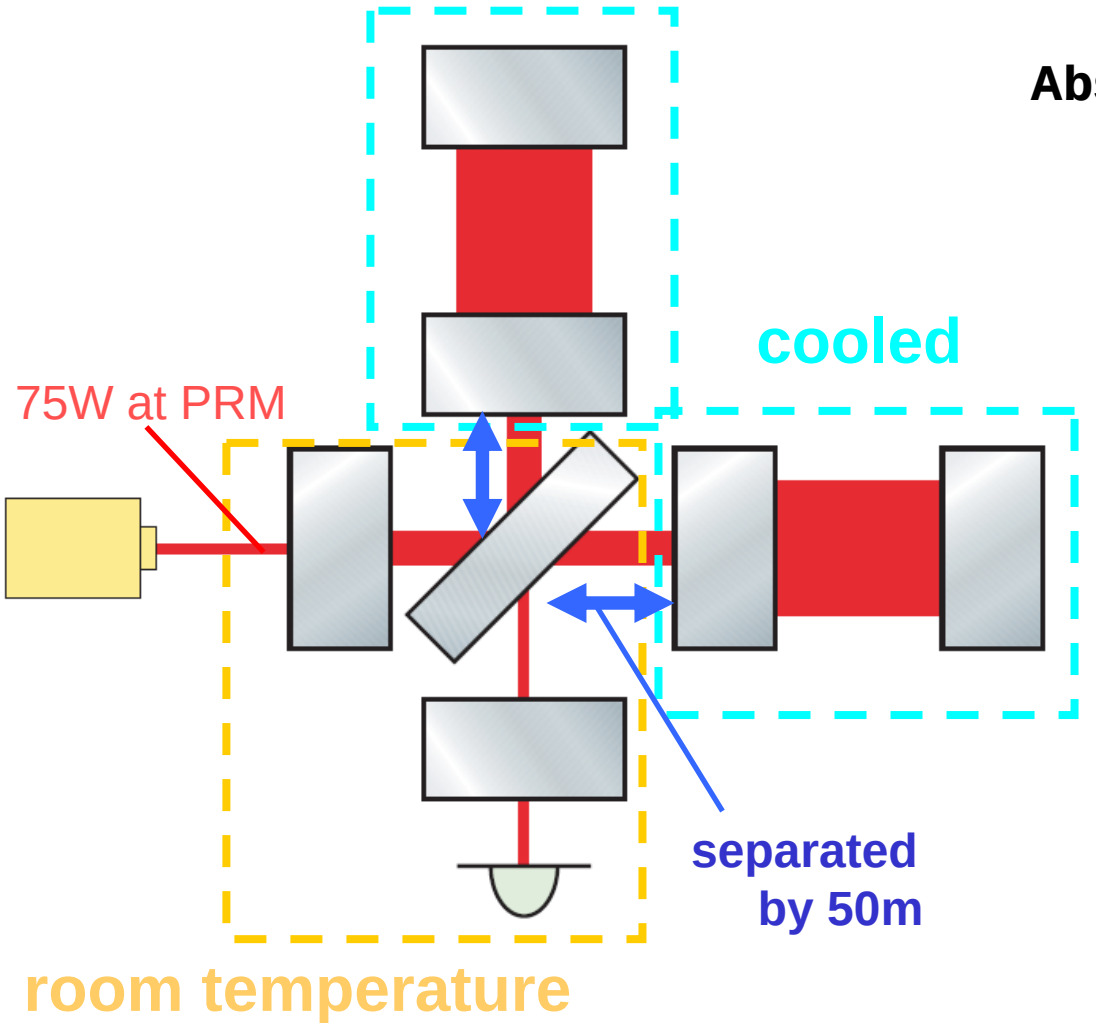
~ sapphire crystal
30kg, Q=1e8

Review of LCGT ~ SPI



- SPI for the isolation of the vibration thru the heat link
- SPI may not be employed for LCGT (expensive)

Review of LCGT ~ RSE



Absorption in sapphire substrates

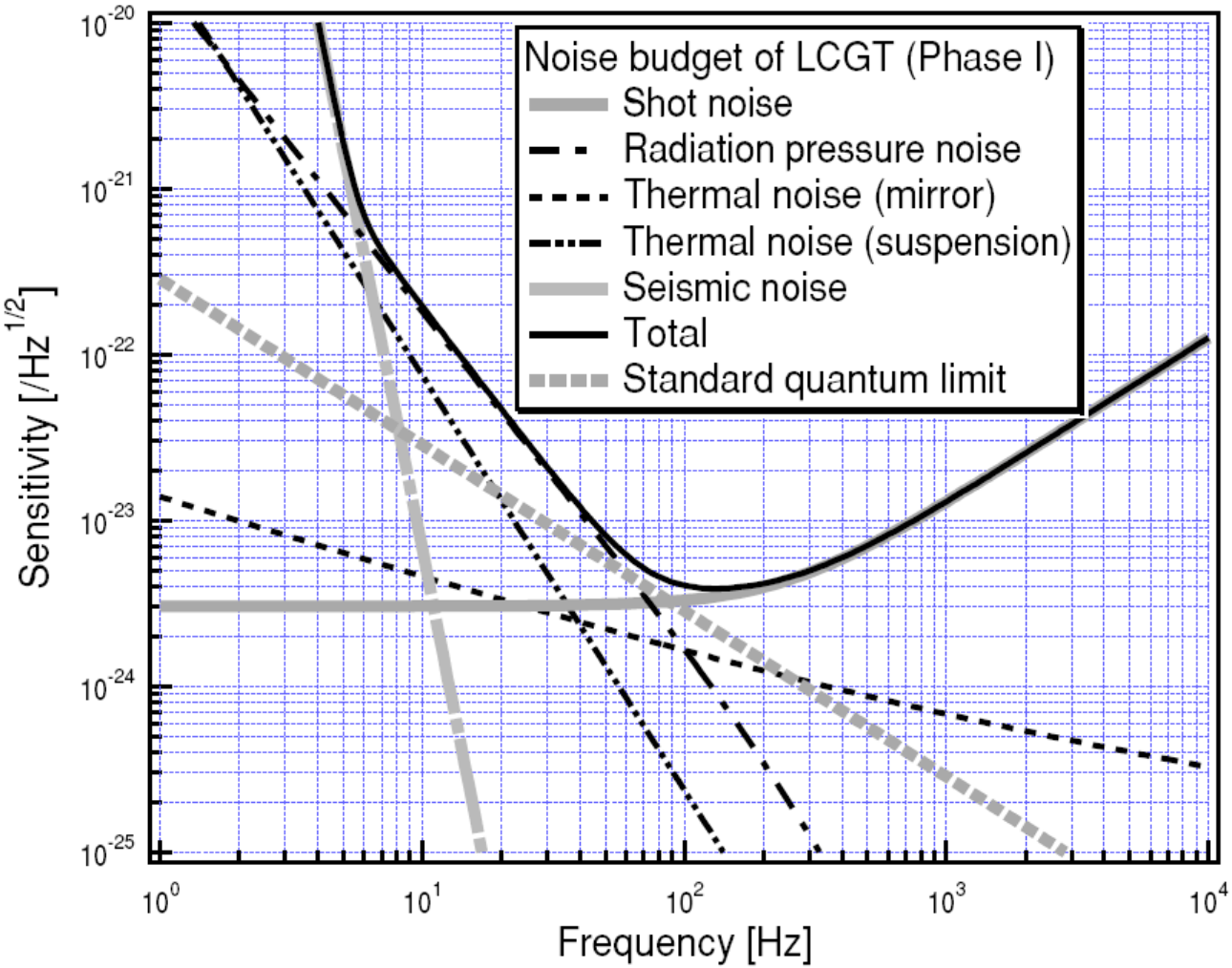
Heat absorption :
20ppm/cm x 15 cm = 300 ppm
Cooling power : 1W for each mirror

Laser power on BS should be less than ~1kW (safety factor 3)

Arm cavity Finesse :	1550
Power Recycling Gain :	11
Signal Band Gain :	15
Stored Power :	771kW
Signal band :	230Hz

Benefit of RSE = less heat at ITM/BS

Expected sensitivity of LCGT

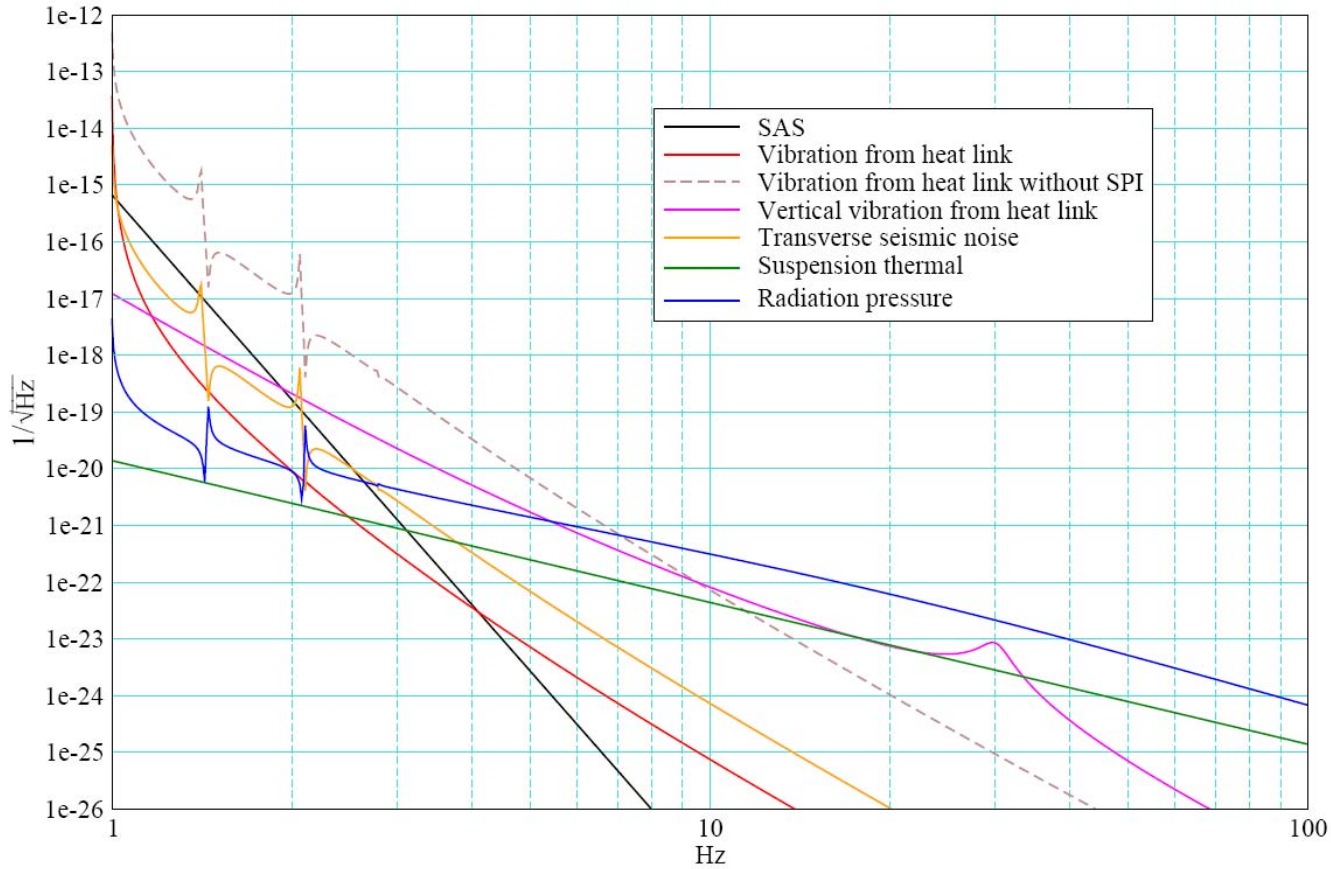


- **SN=10@188Mpc**
- **Could be better with detuning (SN=10@250Mpc)**

Comparison of LCGT and ET

	LCGT	ET
Location	Underground	Underground
TN reduction	Cryogenic	Cryogenic
Configuration	Tuned RSE	Variable detuning?
Suspension	50cm, ϕ=1.8mm	100m?, ϕ=?
SPI	Maybe not	Probably necessary!
Mass	30kg	Heavier?
Others		Squeezing?
		Filter cavity?
		End-mirror cavity?

Suspension-point Interferometer (SPI)

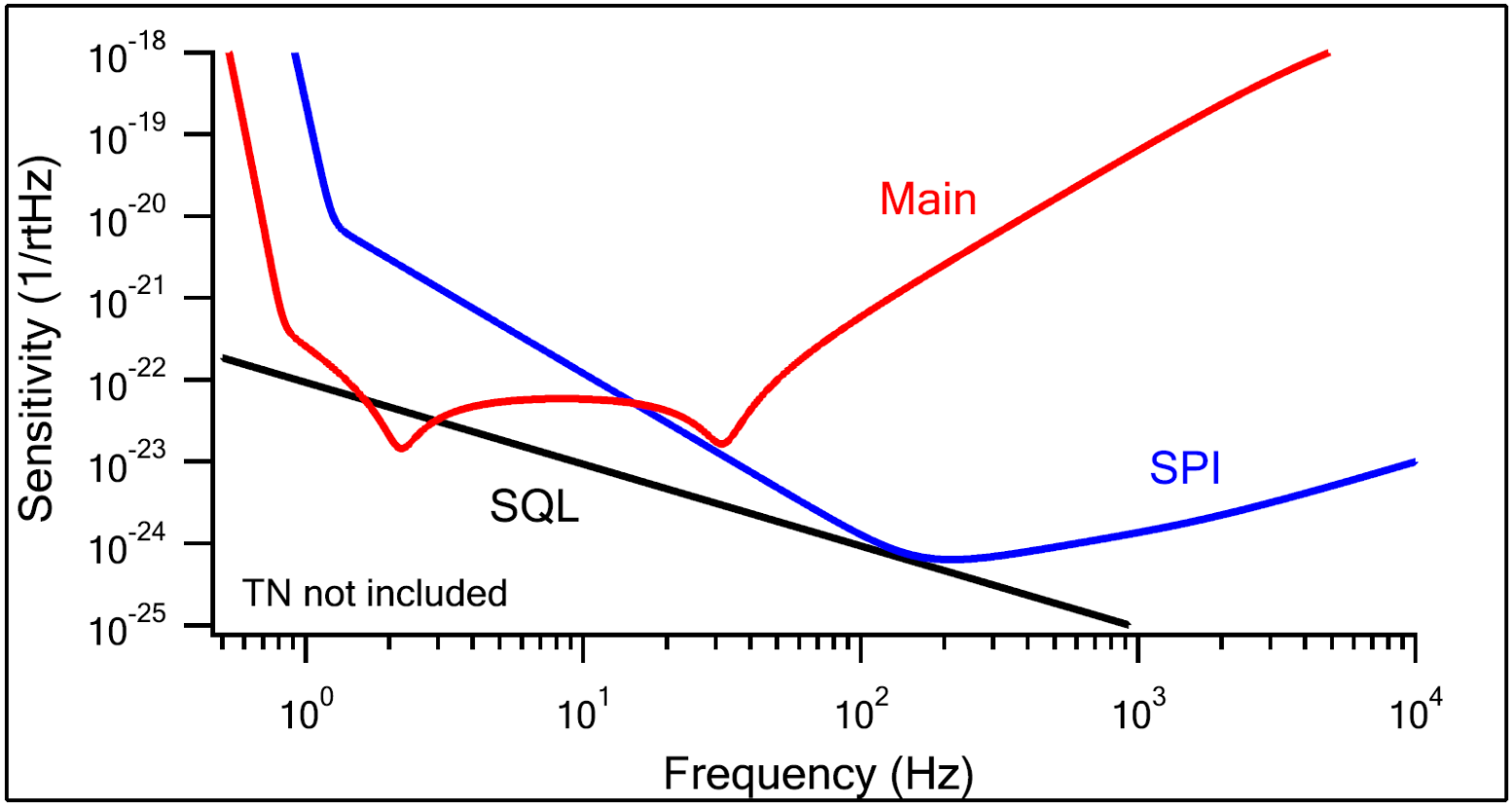


[Aso 2004]

- **Not indispensable for LCGT ($10\mathrm{Hz} < f_{obs}$), but probably necessary for ET ($1\mathrm{Hz} < f_{obs}$)**
- **Vertical-SPI is also possible**

Dual-band interferometer with SPI

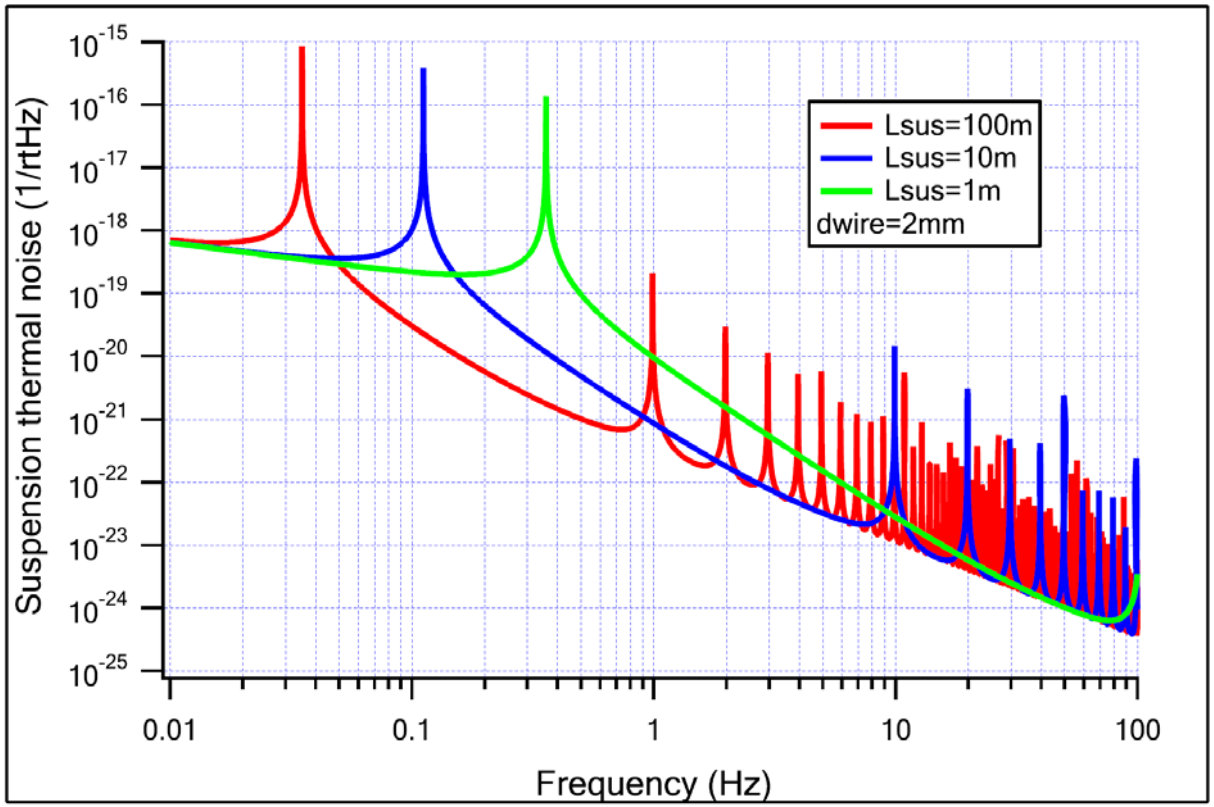
[Aso 2004]



SPI: high power + squeezing (HF)

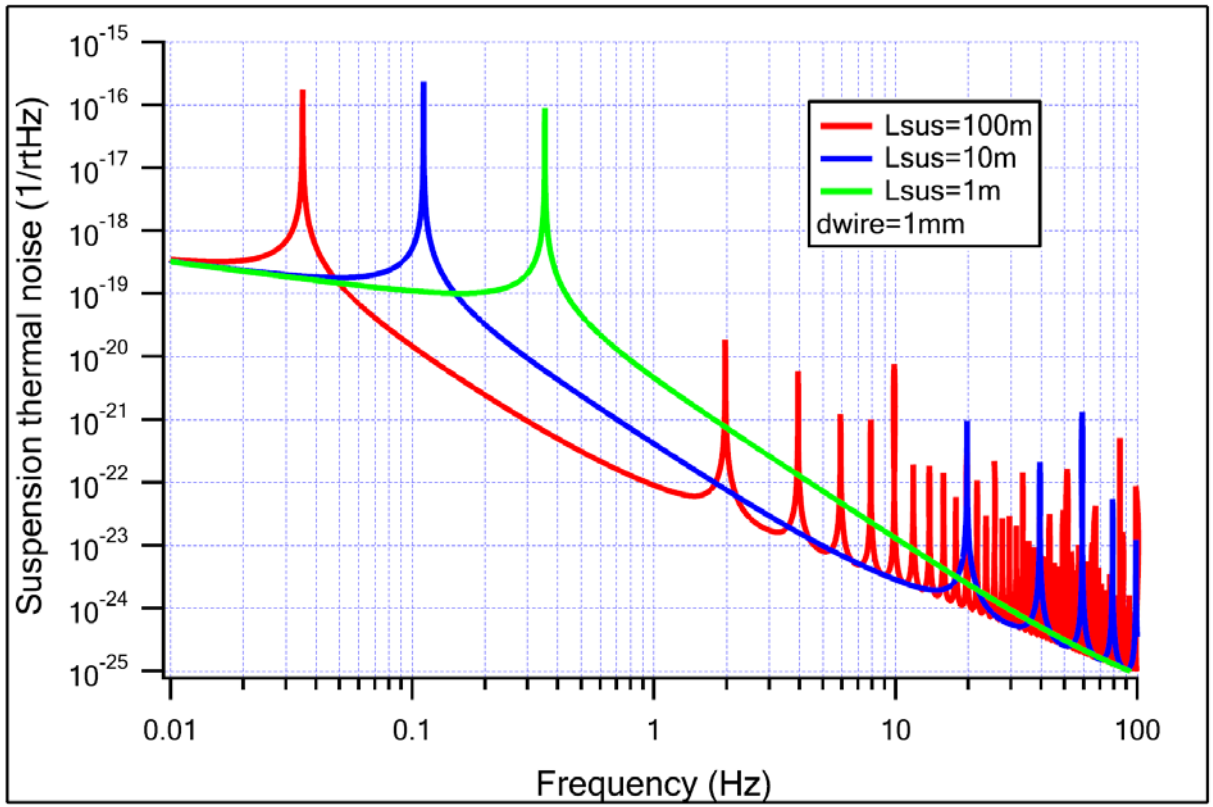
Main: low power + QND, seismic isolation + SPI (LF)

Issues for the 100-m suspension



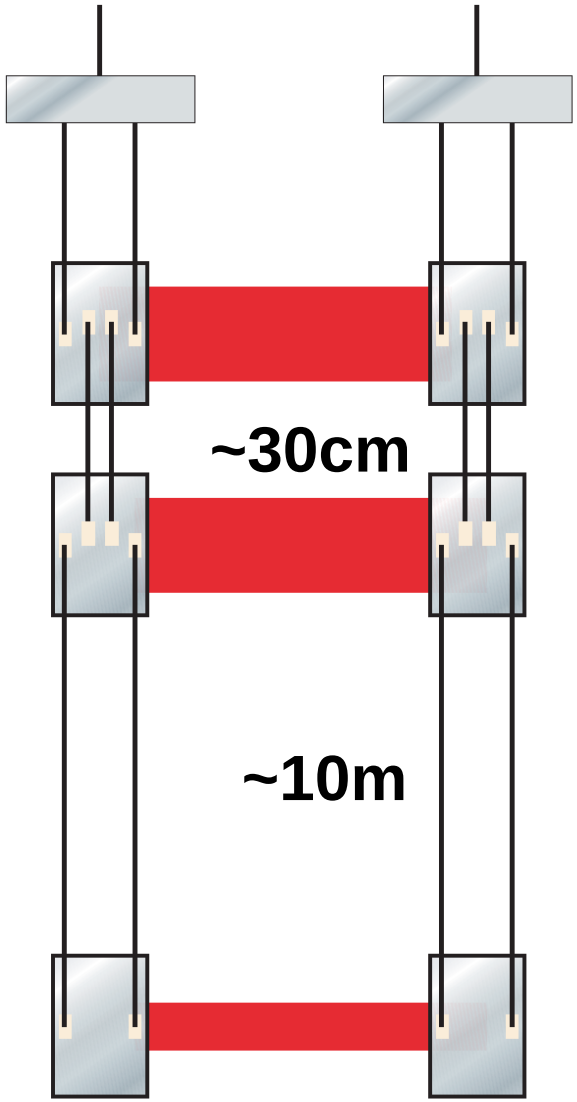
- **Violin modes prevent improvement**
- **The thinner the wire is, the higher the violin modes are**
  (but the cryogenic ability gets weaker)

Issues for the 100-m suspension



- **Violin modes prevent improvement**
- **The thinner the wire is, the higher the violin modes are**
  (but the cryogenic ability gets weaker)
- **The dual-band idea will be effective for this issue**

Triple-band interferometer



- **Top stage: MF 10-100Hz**
  - fewer coatings with end-mirror cavity
  - low finesse + detuning
- **Mid stage: HF 100-10kHz**
  - isolation of the violin modes
  - tuned (broadband) + squeezing
- **Bottom stage: LF 1-10Hz**
  - 10m suspension
  - low power + detuning

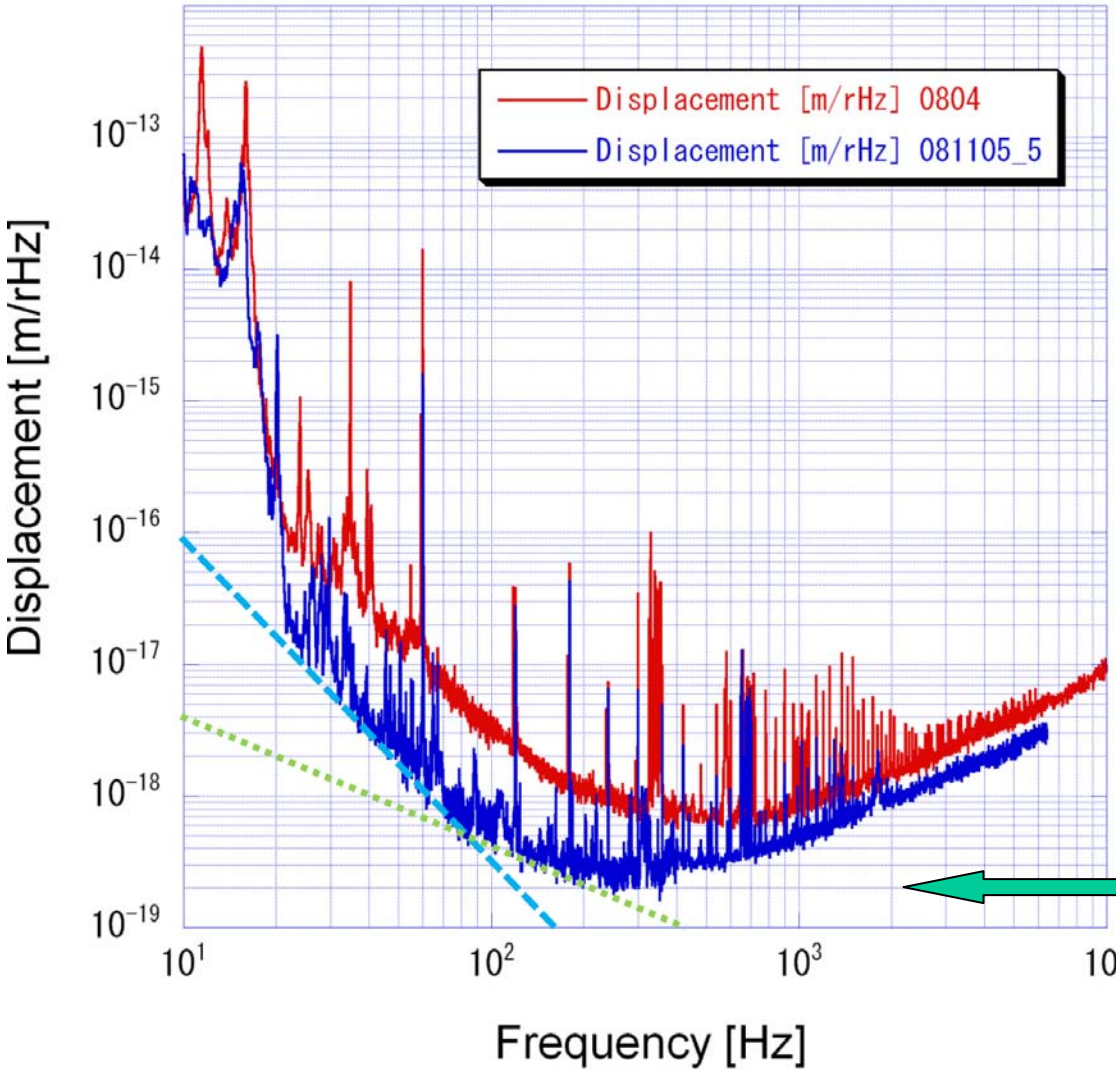
How to cool is another big problem!

Current status of LCGT project

- New Project Manager
- International workshop in May 2009
- More people in the CLIO (pre-LCGT) experiment
  - ~ Osamu has moved from the 40m
  - ~ TAMA people will join from this year
- CLIO is about to demonstrate the reduction of thermal noise

Current status of CLIO

[Miyoki 2008]

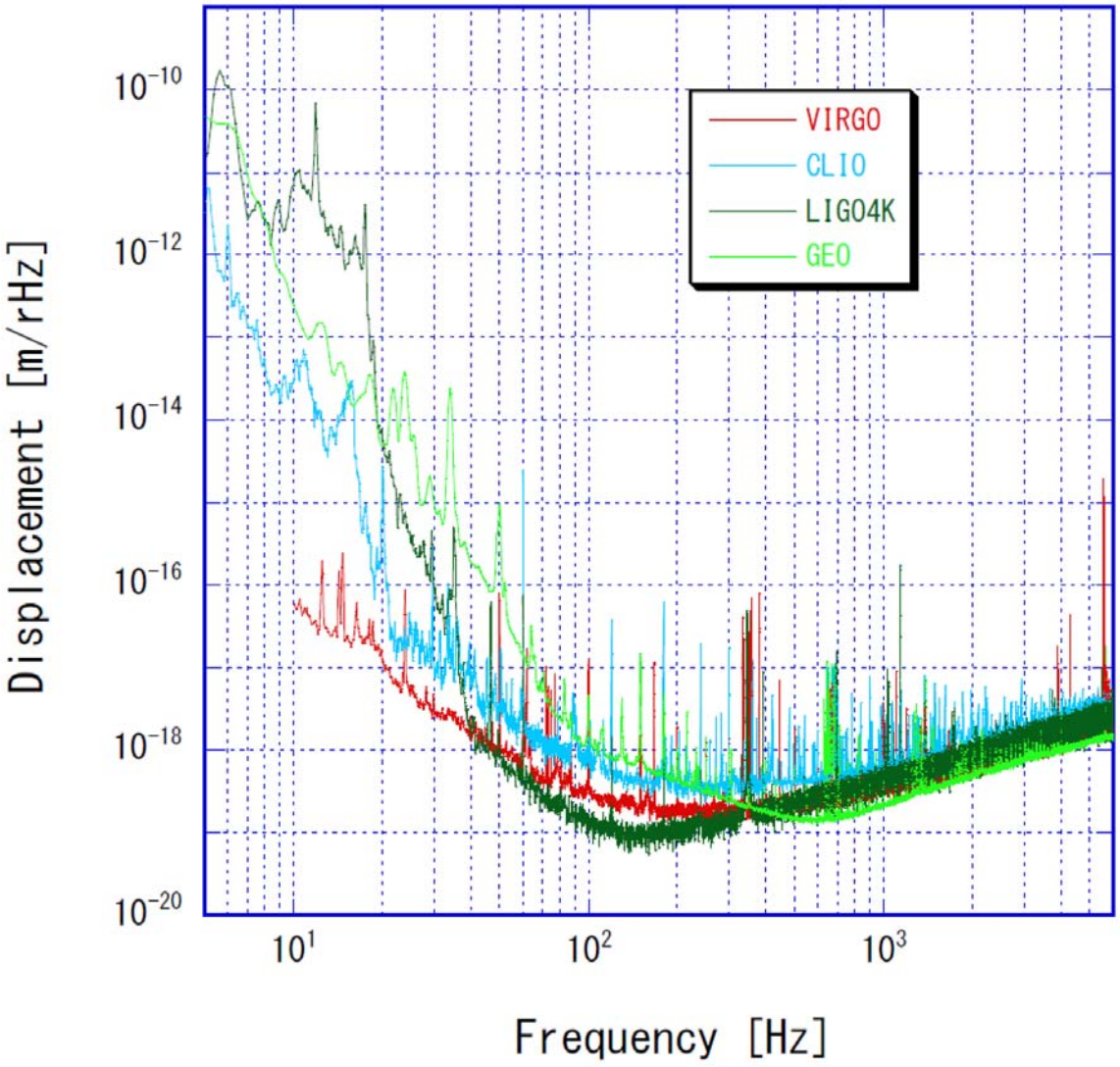


- **100-m locked-FP at Kamioka**
- **Now operated in room temp.**
- **Long-time mystery-noise problem was recently solved**
- **Sensitivity is limited by thermal noise**

suspension TN (20-100Hz)
mirror TN (100-300Hz)

Current status of CLIO

[Miyoki 2008]

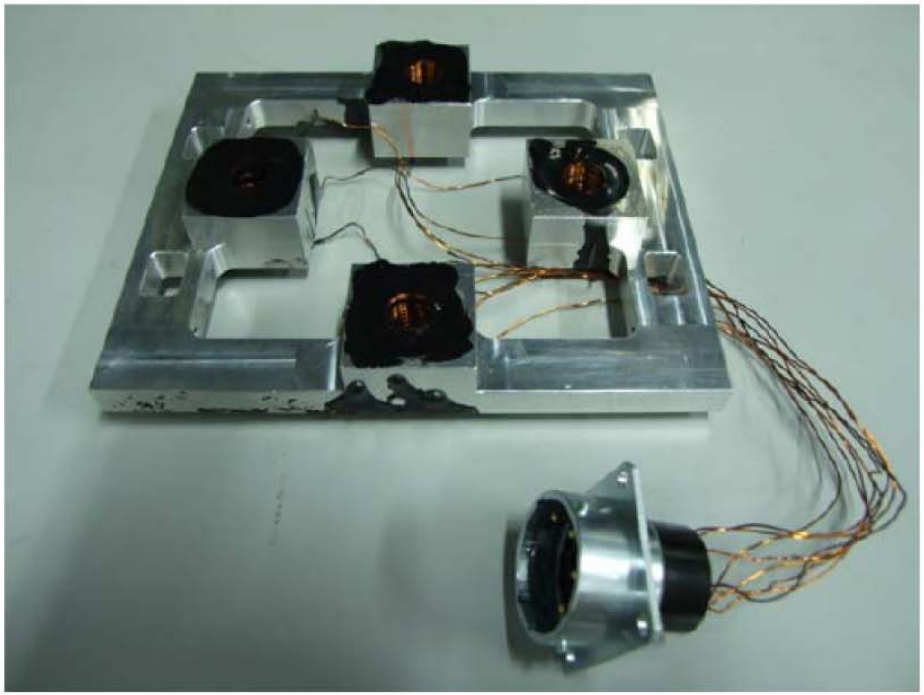


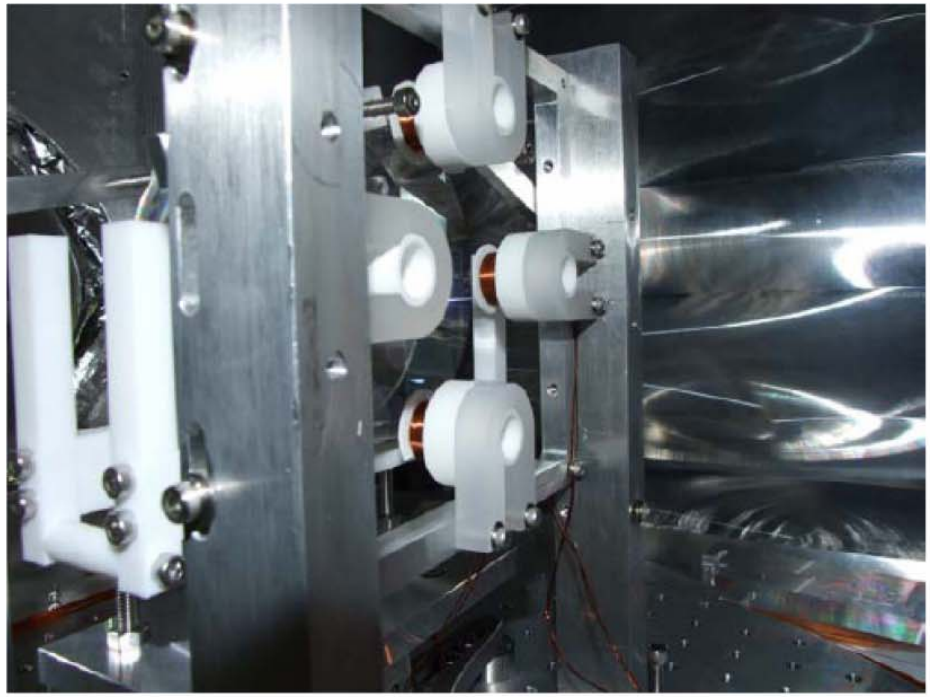
- **Comparable sensitivity to other detectors**
- **Cooling scheduled around June 2009**
  (~1week/mirror to cool)
- **Big hope for the LCGT funding this year**
  (possible approval in autumn)

Summary

- **What can we learn from LCGT study?**
  - **heat link, radiation shield, sapphire fiber, etc.**
  - **waiting for CLIO to be cooled this year**
- **Issues on the 100-m suspension**
  - **cooling capability**
  - **violin modes**
- **SPI and the multi-band interferometer**
  - **probably necessary for ET**

CLIO's mystery noise





- Coil holders used to be made of pure Al (low T)
- Eddy current thermal noise pushes the mirror
- Now it's changed to ceramic + resin

CLIO's sensitivity and the SQL

CLIO proves the effect of cryogenic mirror.

Kuroda, LIGO-DCC G050511-Z