Australia-Italy Cnference
@Gingin, Australia
4, October 2005

LCGT project

Kazuaki Kuroda
LCGT Collaboration

LIGO-G050511-00-Z

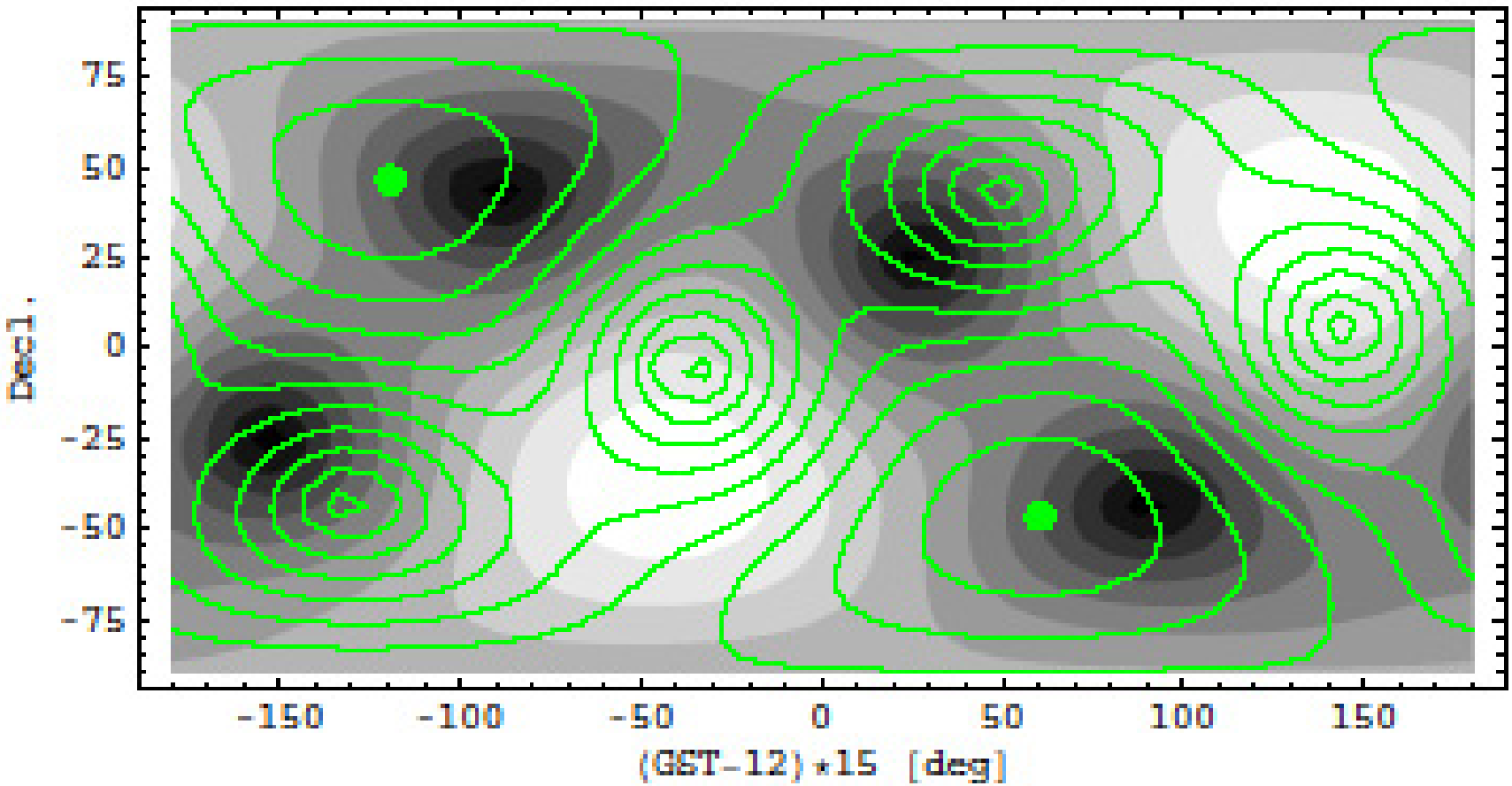
Target sensitivity of LCGT

- First phase of LCGT is realized by the sensitivity designed by the report.
- Second phase of LCGT is not shown in the report because it is beyond the scope of budget asking.
- Rough estimation of the second phase sensitivity exceeds 300Mpc for the binary neutron star coalescence.

Expected sources of LCGT

- Binary inspiral signals
- Merger phase of coalescence of BNS
- Ringdown signal of the merged black hole
- Continuous waves from pulsars
- Burst waves from collapsed stars
- Waves from LMXB
- Other unexpected gravitational waves

LCGT contributes the international observation by
the coverage of a complimentary sky to other detectors:
LCGT, grey scale, LIGO (Hanford), green contour curves.



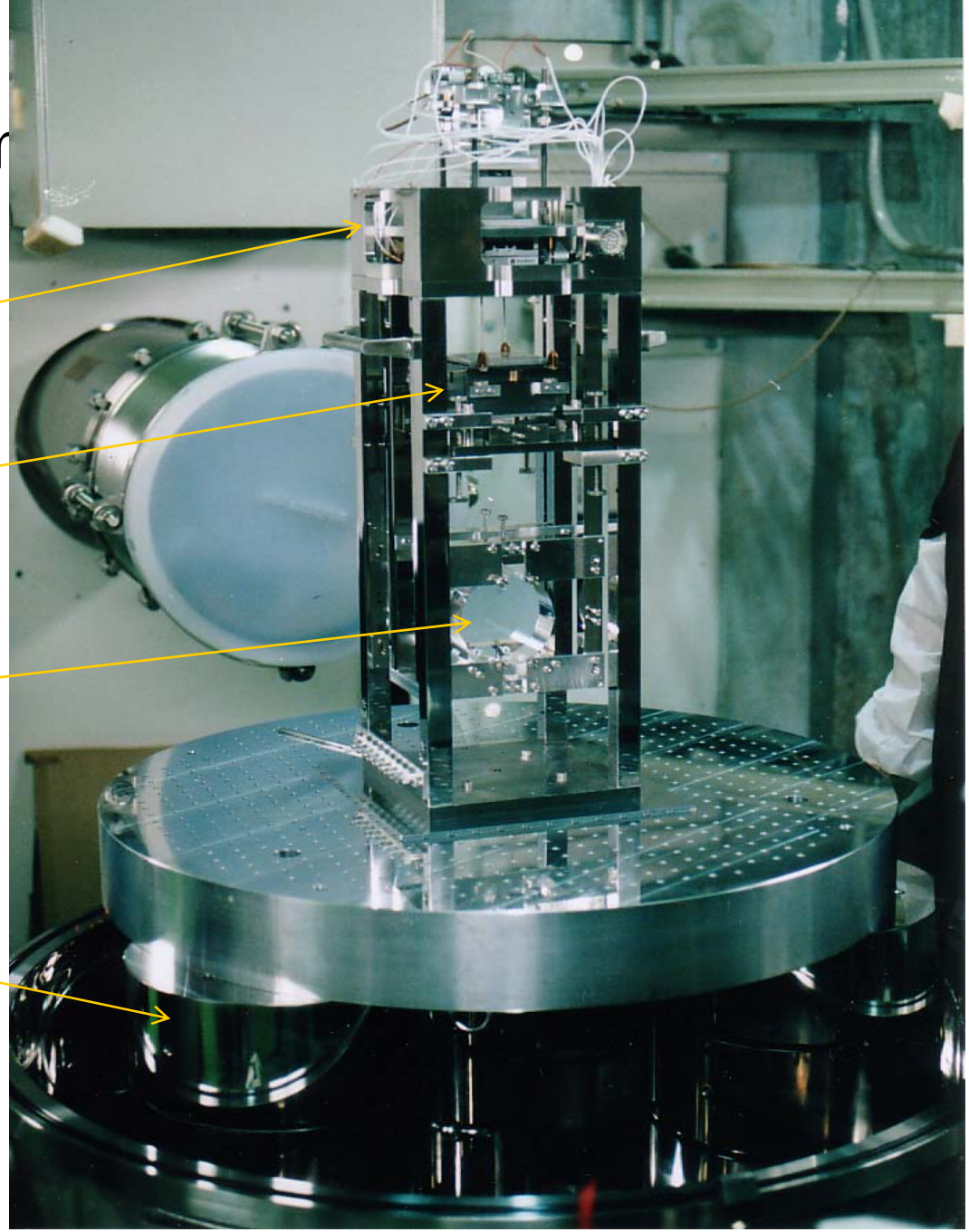
TAMA and LISM

TAMA

The Objective of TAMA is to develop advanced technologies for km scale interferometer and to observe possible .. events in our Galaxy.

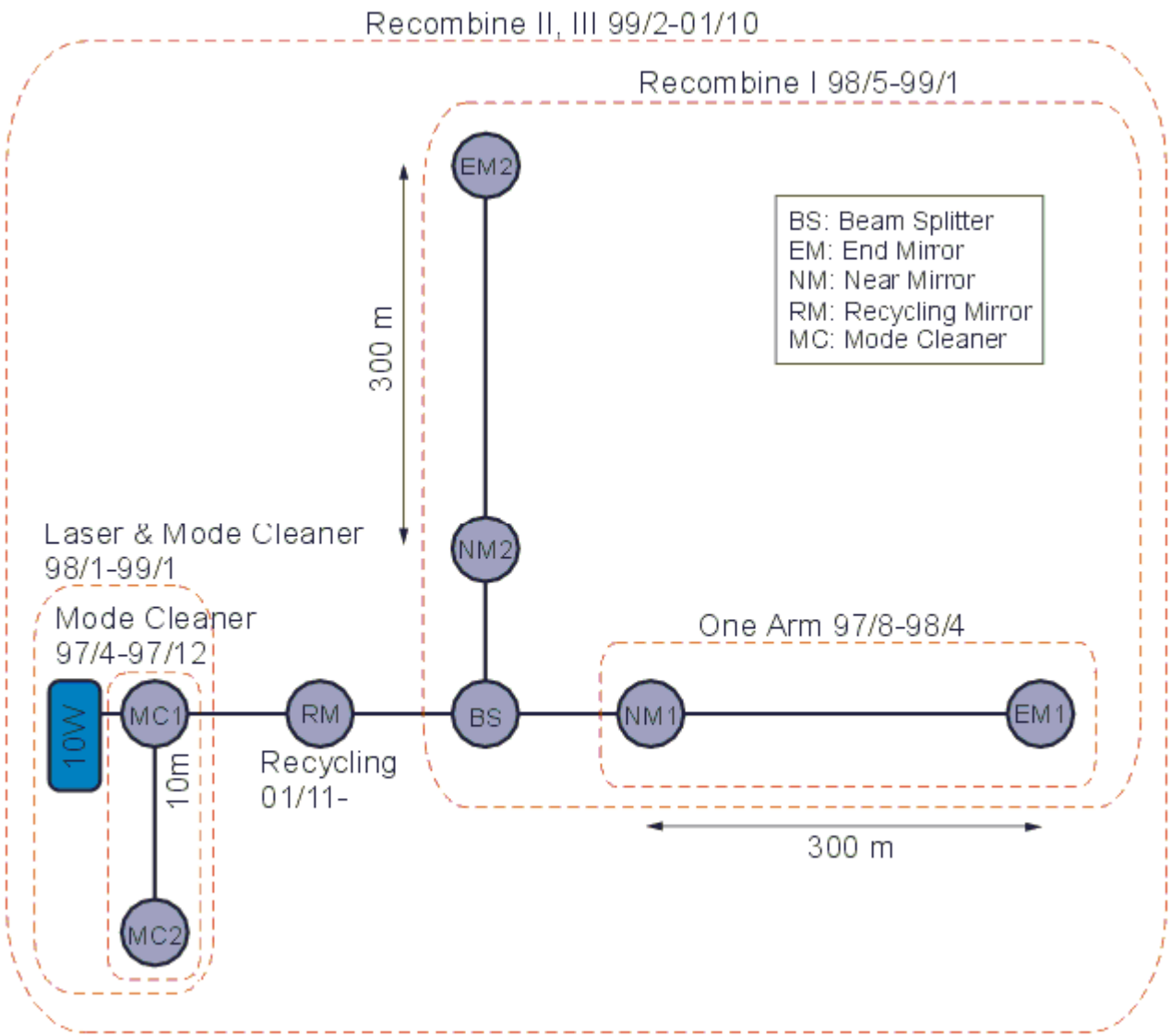
The funding originally covered five years. We began its construction in April of 1995. It ended in March, 2002 after two years extension. Four year research money was approved from April, 2002.

TAMA double suspension system

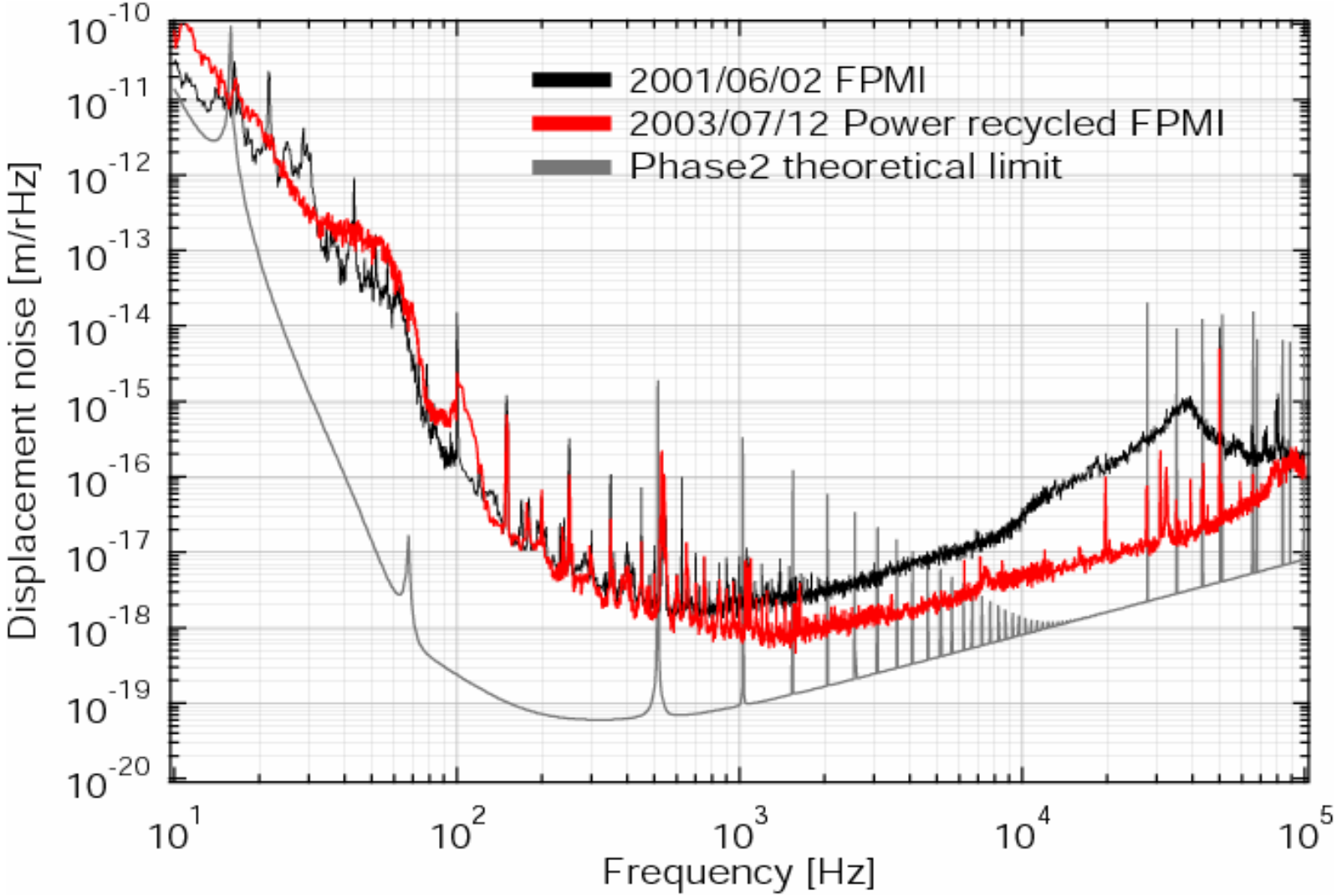


Test & Observation runs with data taking

- DT1 6-Aug --- 7-Aug 1999 7 hr
- DT2 17-Sept --- 20-Sept 1999 31
- DT3 20-Apr --- 23-Apr 2000 13
- DT4 21-Aug --- 4-Sept 2000 160
- DT5 2-Mar --- 8-Mar 2001 111
- DT6 15-Aug --- 20-Sept 2001 1038


Recombine II, III 99/2-01/10
Recombine I 98/5-99/1
EM2
BS: Beam Splitter
EM: End Mirror
NM: Near Mirror
RM: Recycling Mirror
MC: Mode Cleaner
300 m
Laser & Mode Cleaner
98/1-99/1
NM2
Mode Cleaner
97/4-97/12
One Arm 97/8-98/4
10W
MC1
RM
BS
NM1
EM1
10m
Recycling
01/11-
300 m
MC2

Improvement of Sensitivity by the installation of the power recycling mirror



Observation after installation of RM

Run	Period	Year	Data (hr)
DT7	30-Aug --- 4-Spet	2002	100
DT8	14-Feb --- 15-Apr	2003	1158
DT9	28-Nov --- 10-Jan	2004	557

Current Works

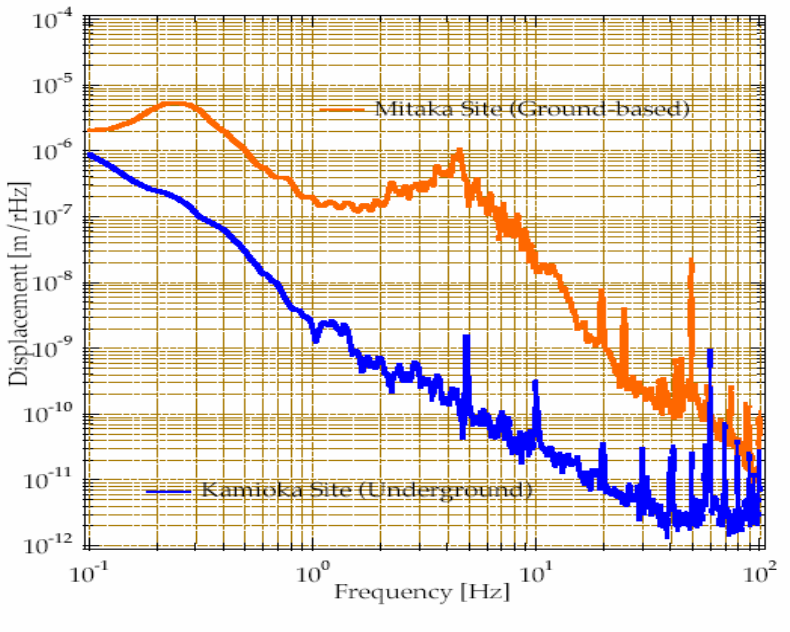
Improvement of sensitivity

- Investigation of the noise from Michelson part at <1kHz
- Recovery to FPMI
- **Investigation to be continued**

Seismic attenuation system (SAS)

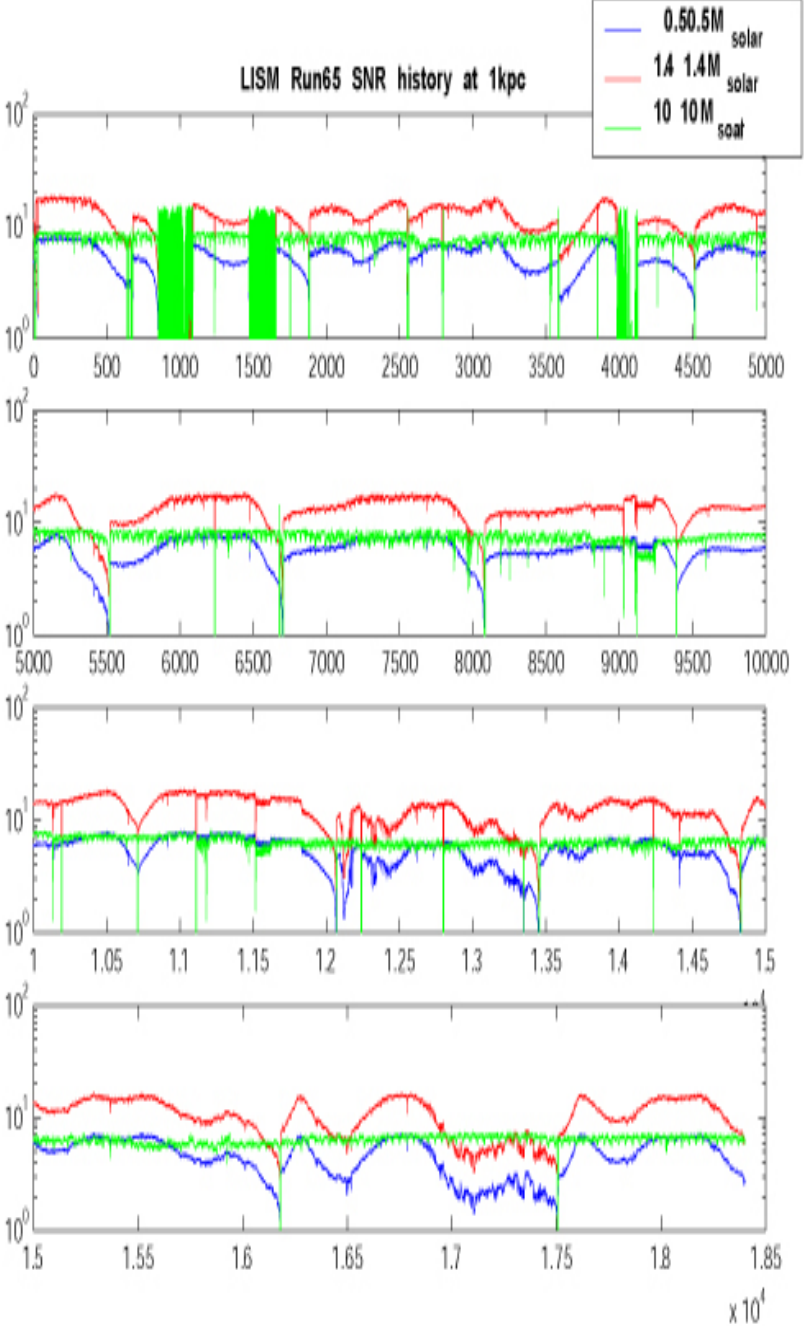
- For low frequency (0.1. 10Hz)
- R&D with Caltech and Univ. of Pisa

LISM - 20m FPI -



20m FPI was moved from Mitaka to Kamioka underground for the one of R&D for LCGT.
Seismic noise is less by 2 orders at 1Hz. Temperature is stable during a year.

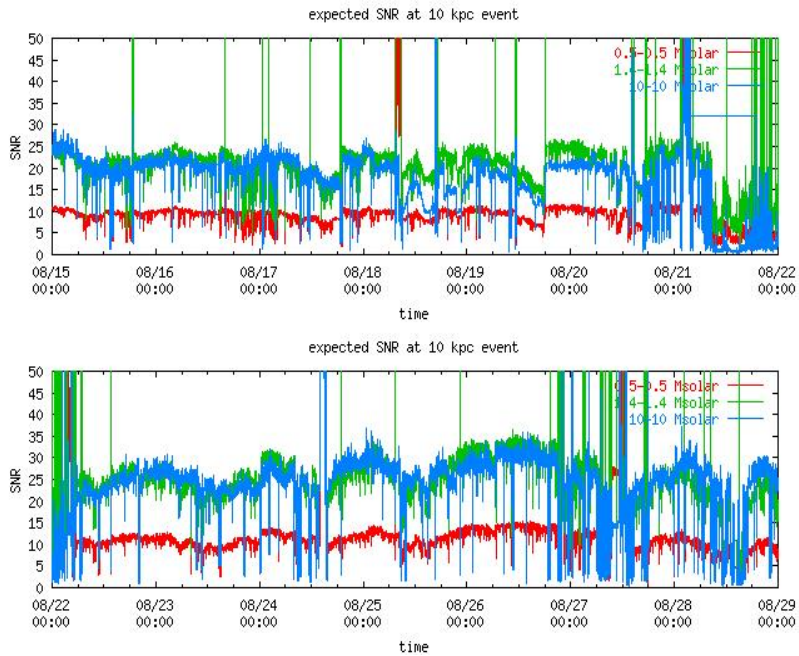
The construction was done in 1998. The system has been shut down in 2002 for CLIO.



LISM

SNR for three kinds of masses are plotted with time.
Stability of sensitivities are evaluated by smoothness of the curves.

TAMA

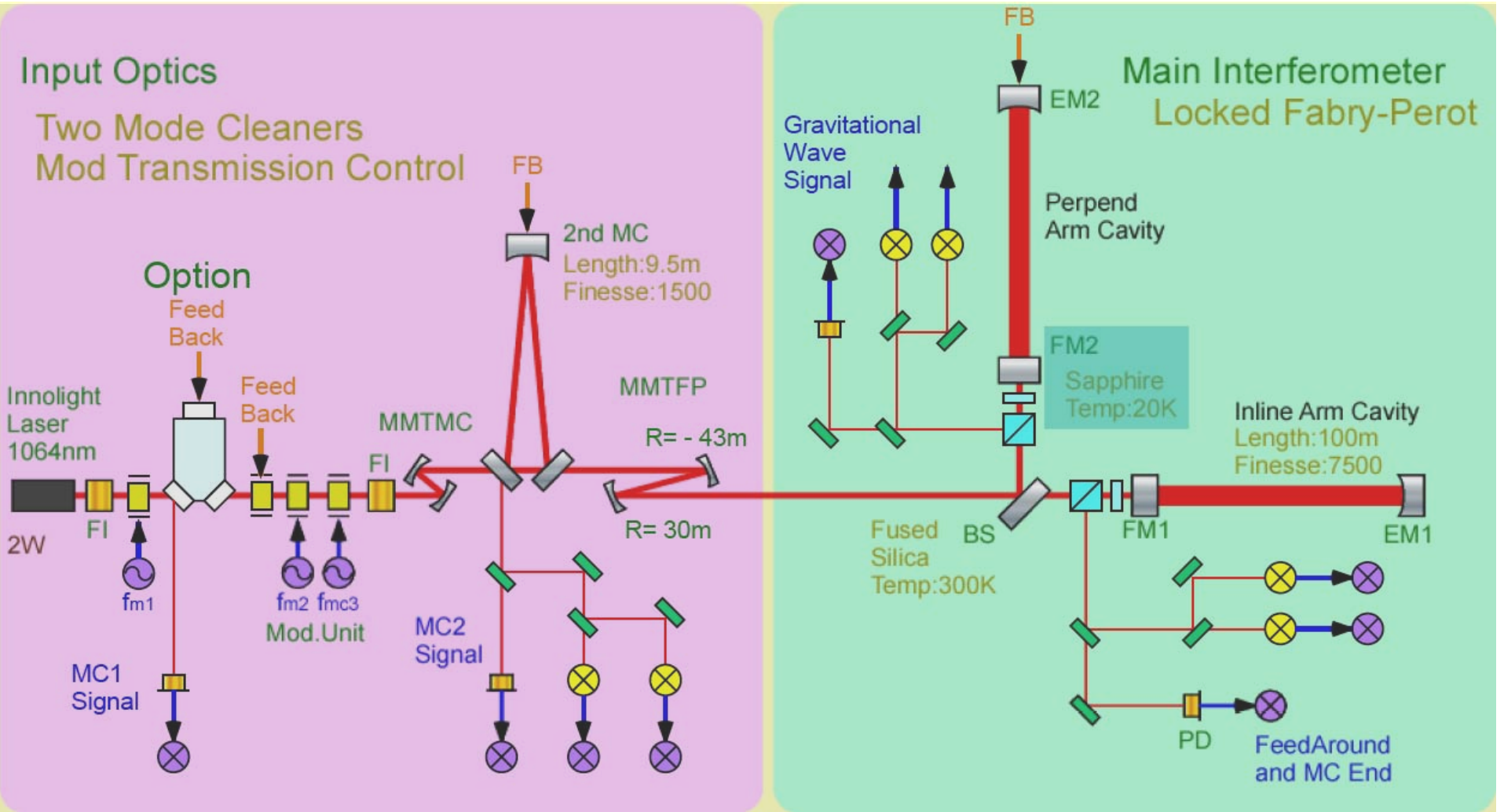


CLIO

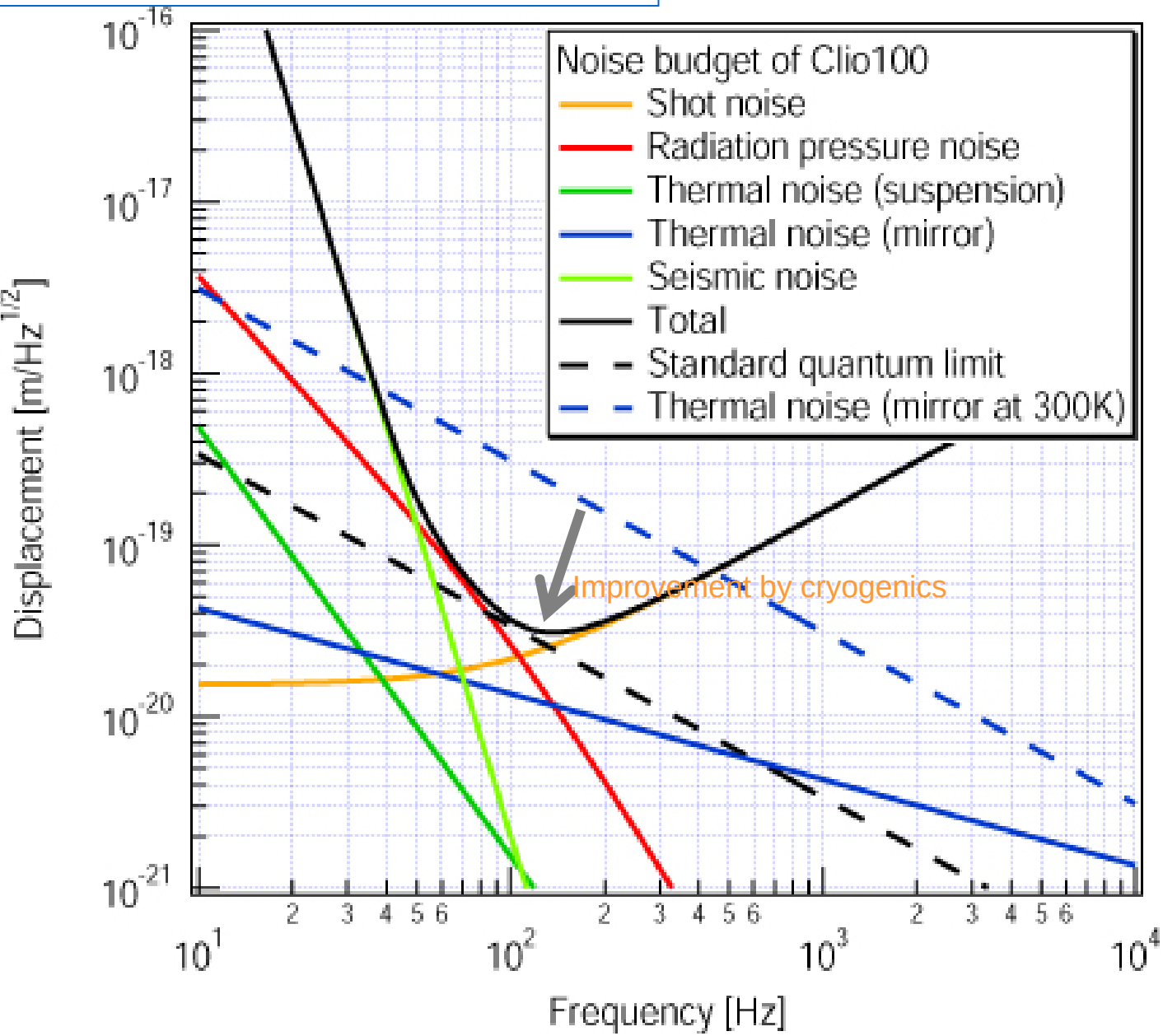
Overview of CLIO project

- Practical version of a cryogenic laser interferometer
- Baseline length100m.Locked FP Interferometer
- Laser 2W.Cavity Finesse 7500
- 3-stage isolation system
- ..K Sapphire mirror.TAMA size, .10cm, 6cm.
- 4K cryogenic refrigerator 4.shield refrigerator 6
- Plan to make a continuous operation up to the establishment of LCGT

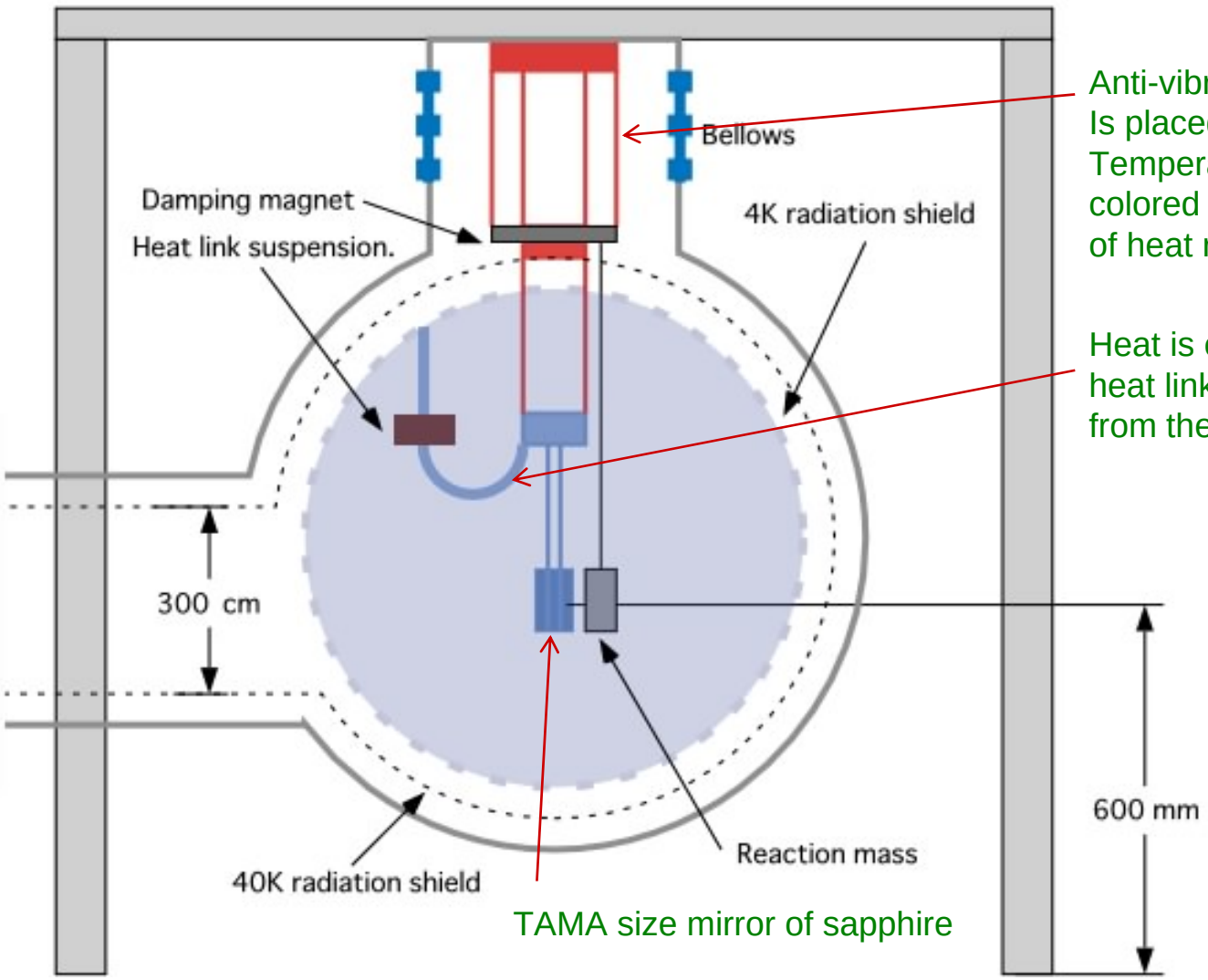
CLIO is a locked Fabry-Perot Interferometer with cryogenic mirrors



CLIO proves the effect of cryogenic mirror.



Basic idea of CLIO suspension & cooling system



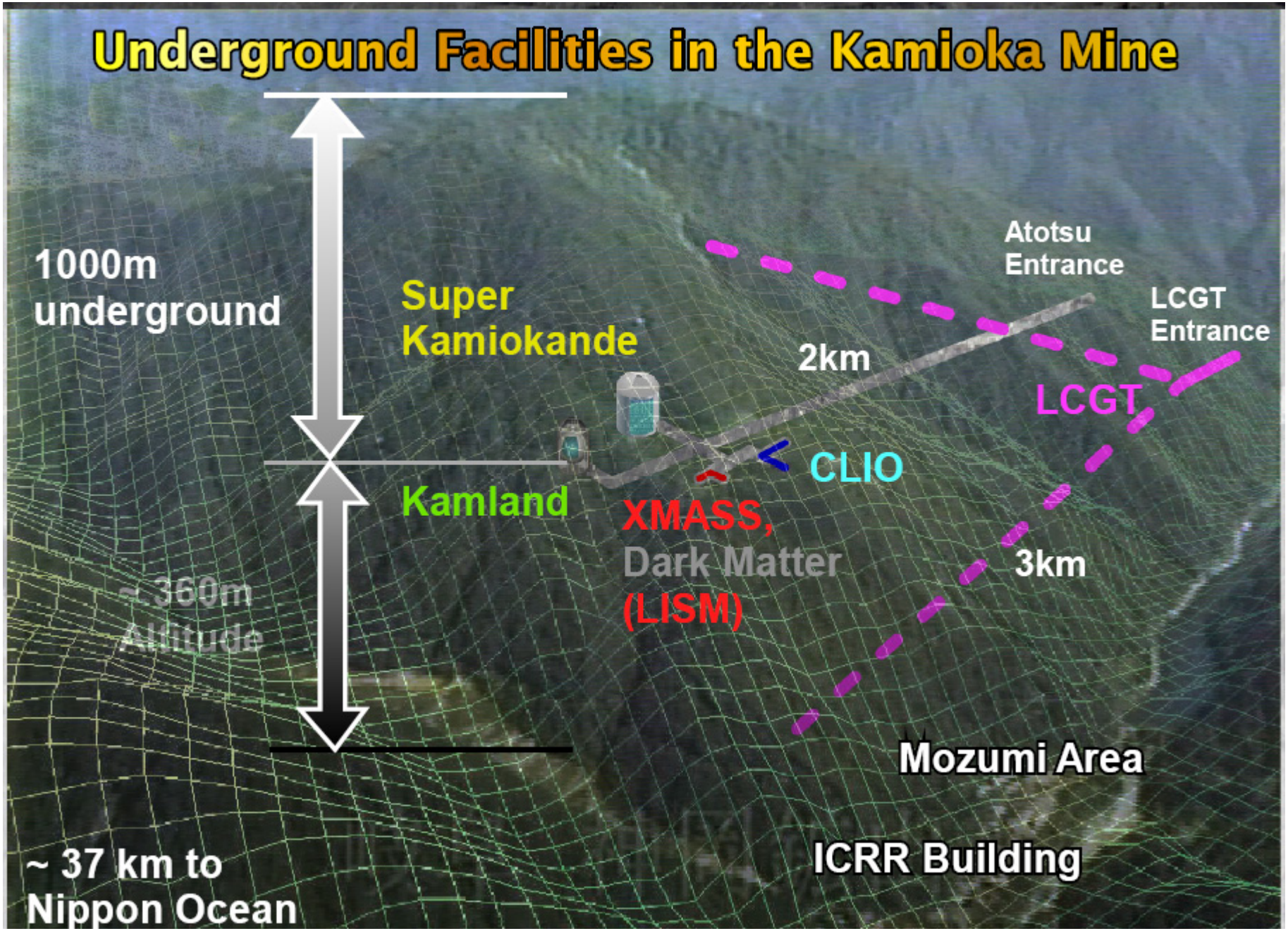
Anti-vibration system
Is placed at room
Temperature. Parts
colored by red are made
of heat resistive material.

Heat is extracted through
heat links of pure aluminum
from the second mass

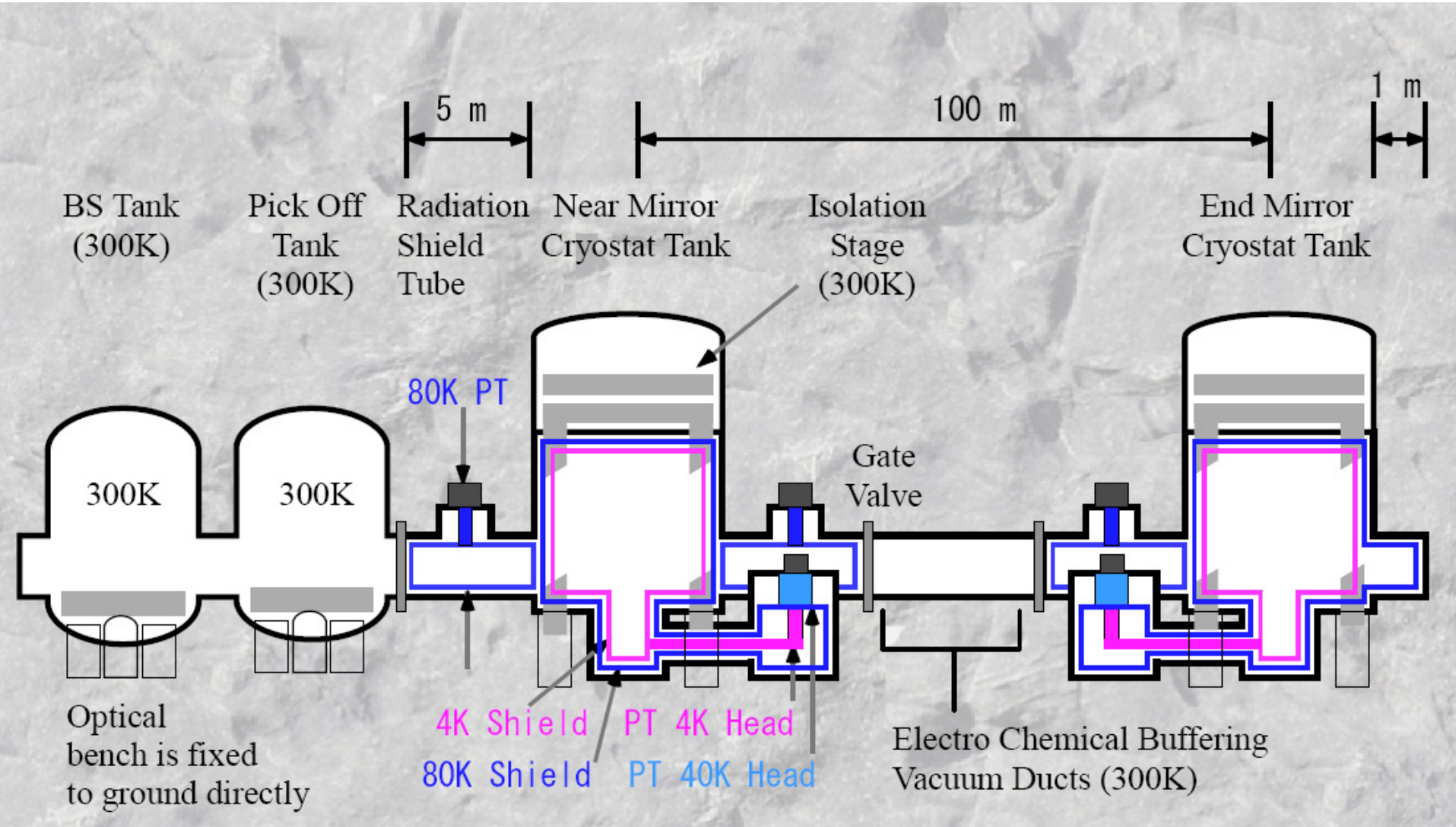
Schedule and Budget of CLIO

- FY2002-FY2005 Construction
- FY2006 Operation
- Research budget 645 Million yen (US$5.4M)
- Extra facility construction money

(120Million yen~US$1M)


Underground Facilities in the Kamioka Mine
1000m underground
Super Kamiokande
Kamland
~ 360m Altitude
~ 37 km to Nippon Ocean
Atotsu Entrance
LCGT Entrance
2km
LCGT
CLIO
XMASS, Dark Matter (LISM)
3km
Mozumi Area
ICRR Building

Four main mirror tanks are cooled down to 4 K.
The connection tubes are maintained at room temperature.



Cryogenic Vacuum System Complete

2005/6/17

Acheved Pressure

- 100m Arm -

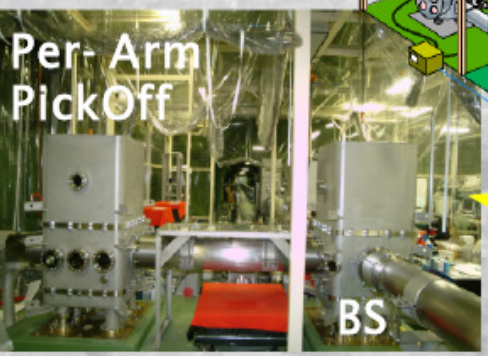
6×10^{-5} Pa

by a 800 litter Turbo

- Cryostat -

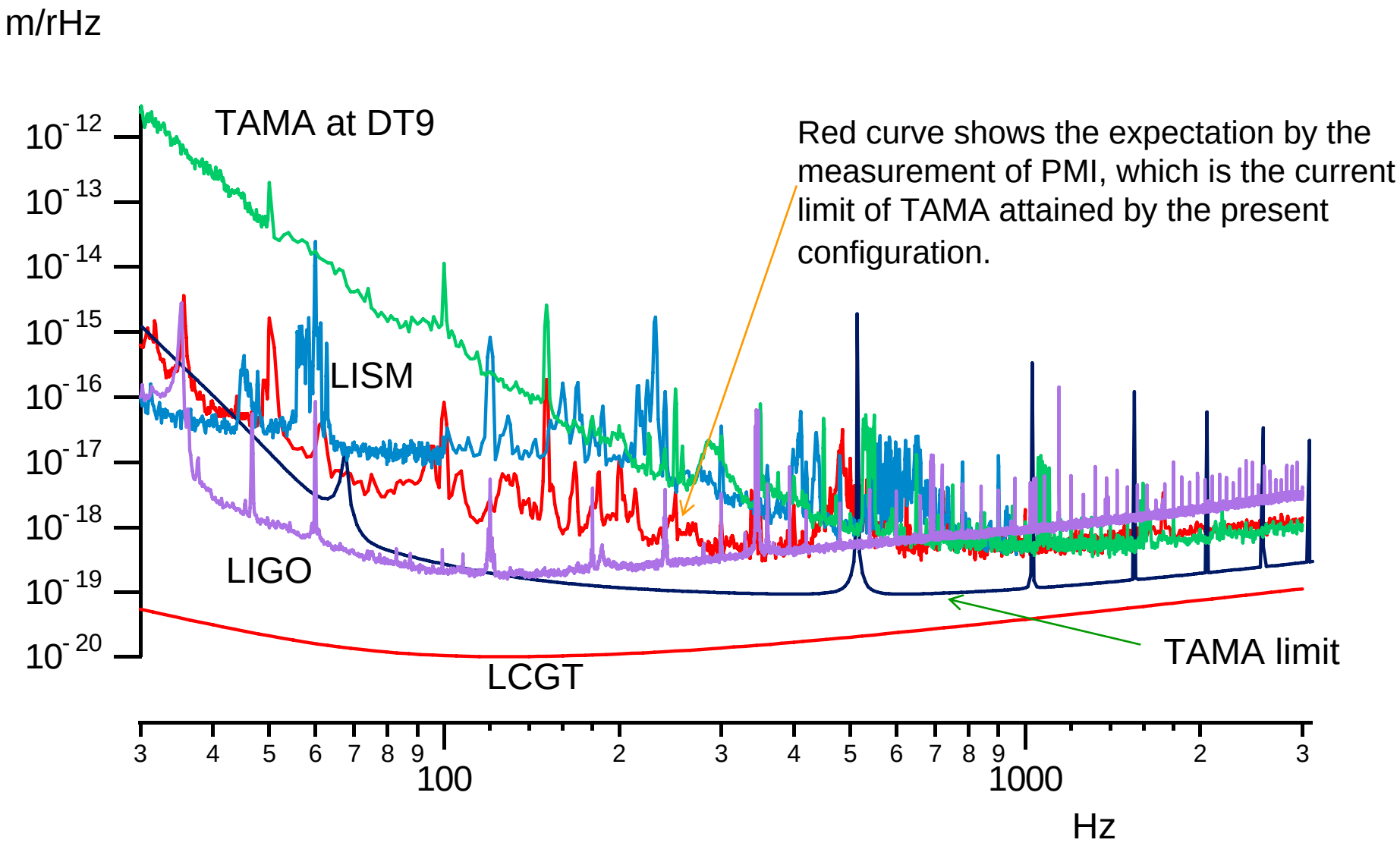
2×10^{-6} Pa

by Cryostat itself



LCGT

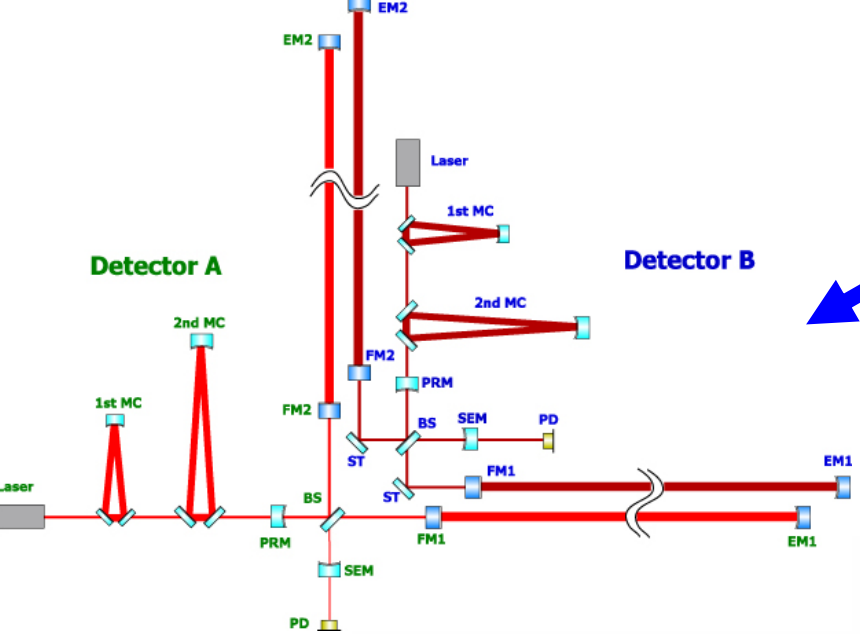
Displacement Sensitivities of interferometers

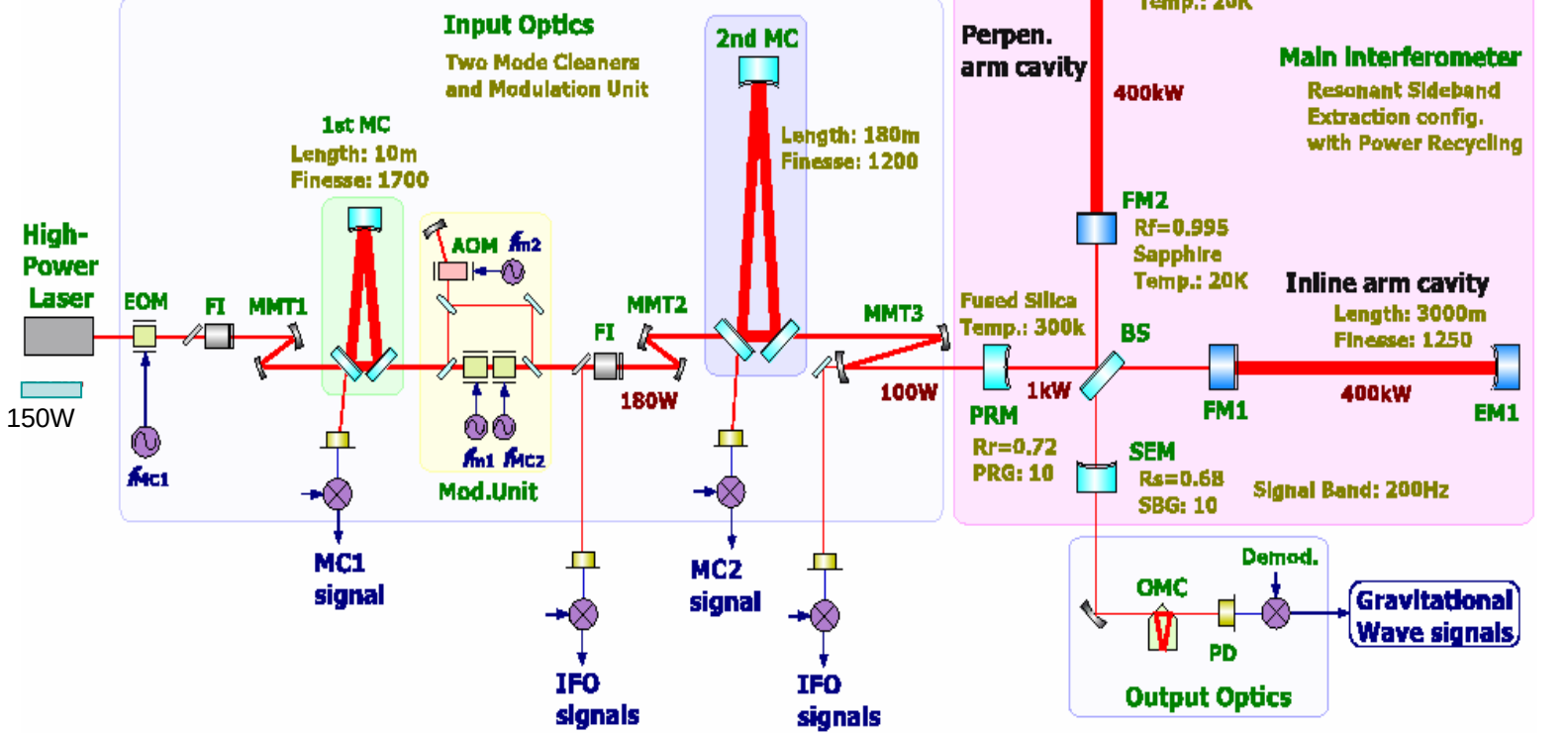


Optical design of LCGT

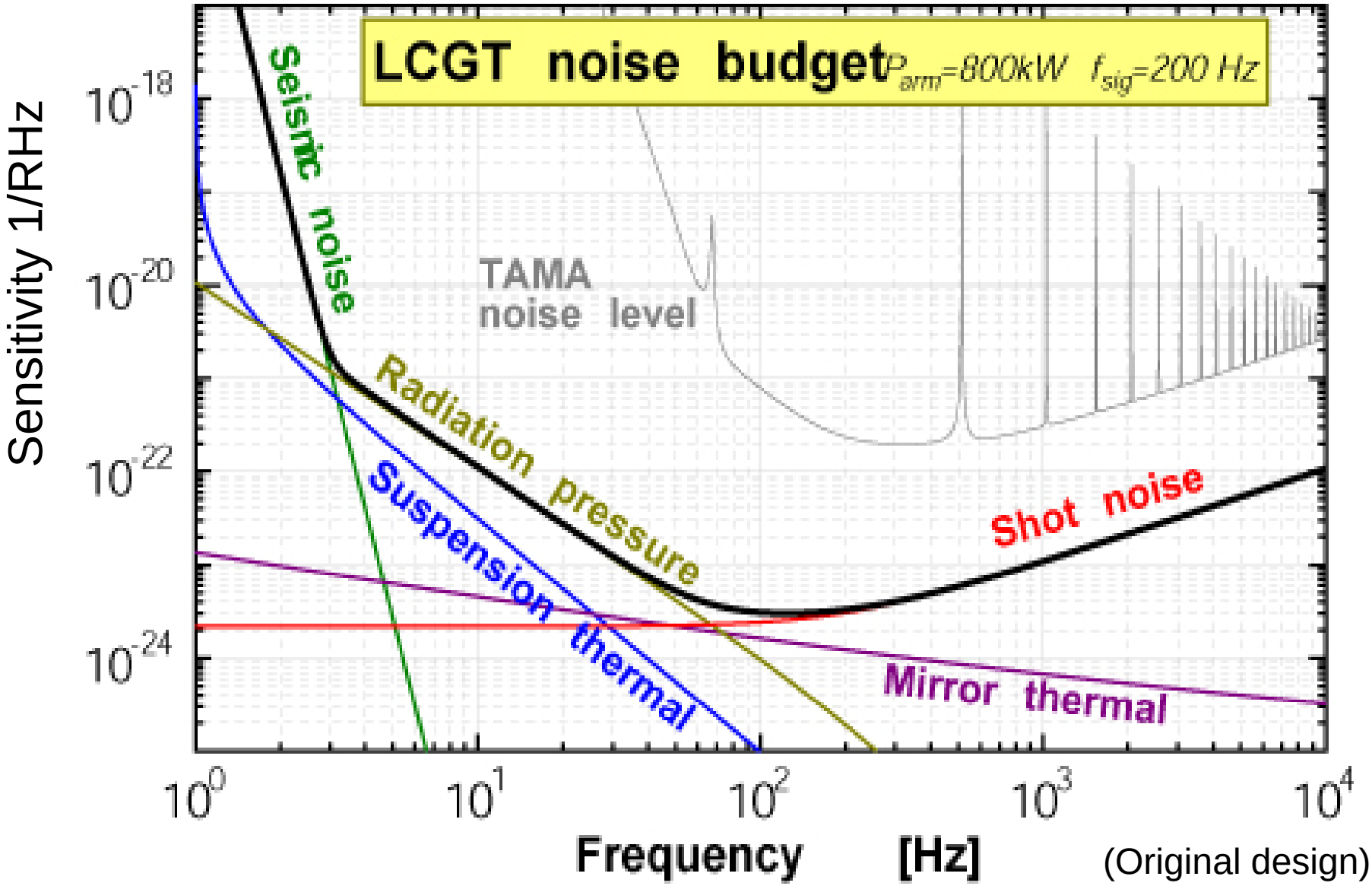
Two interferometers are arranged not to interfere in the same vacuum system.

Optical design of the basic interferometer





Sensitivity is limited only by quantum noises around at observational frequency band.



(Original design)

Optical Design Parameters

- Main Interferometer
  - Resonant Sideband Extraction
    with power recycling, broad band configuration
  - Arm cavity length 3000 m
  - Power in arm cavities 600 kW
  - Signal bandwidth 200 Hz
  - Arm cavity finesse 1250
  - Power recycling gain 10
  - Signal band gain 10

Laser source
- Output power 150W
- Wavelength 1064nm

Input optics
- Power transmittance 33.3%
- Modulation sidebands 15 MHz, 50 MHz

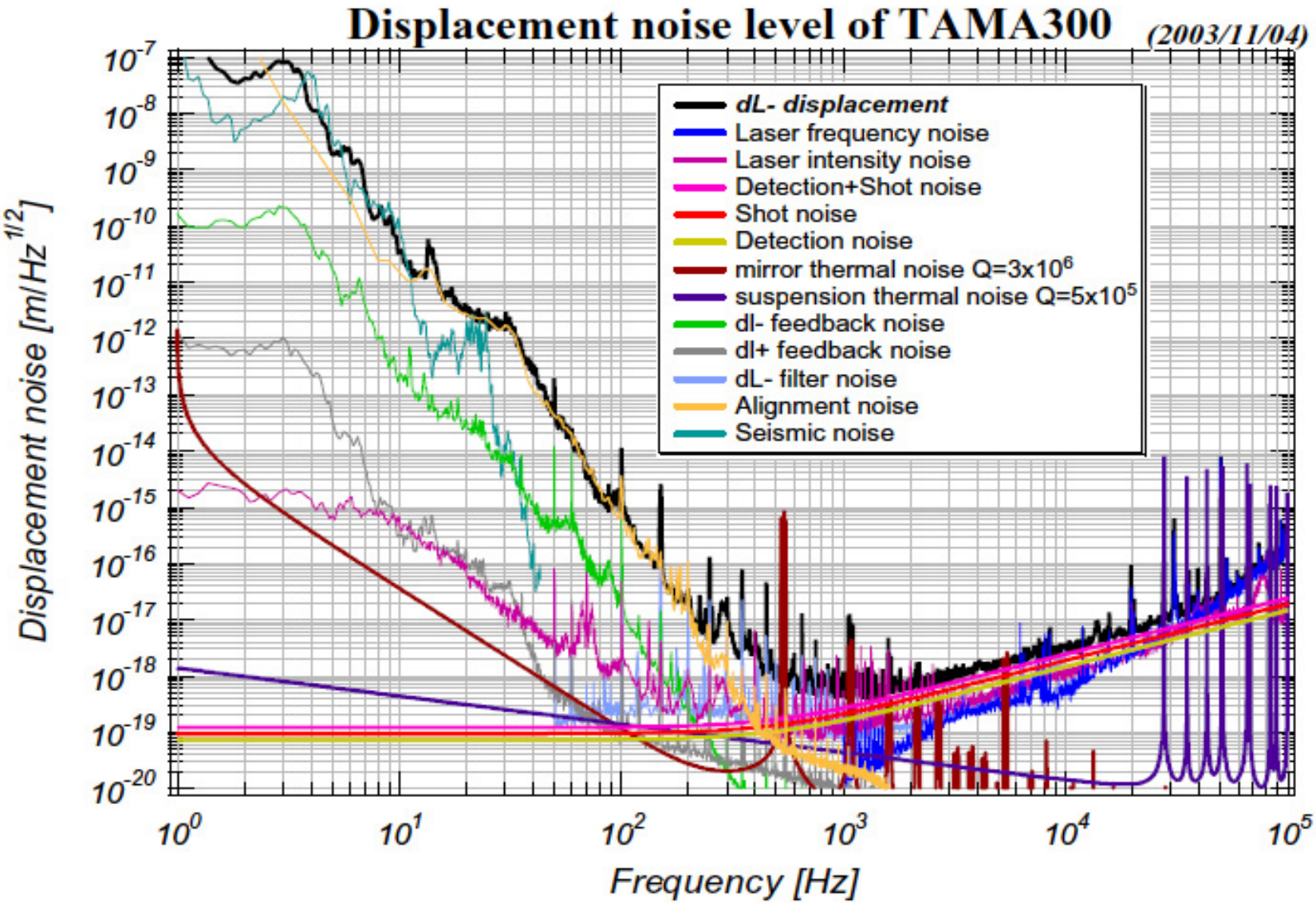
1st Mode cleaner: 10m Triangle ring cavity, 4.5kHz, FSR 15 MHz

2nd Mode cleaner: 180m Triangle ring cavity, 350Hz, FSR833kHz

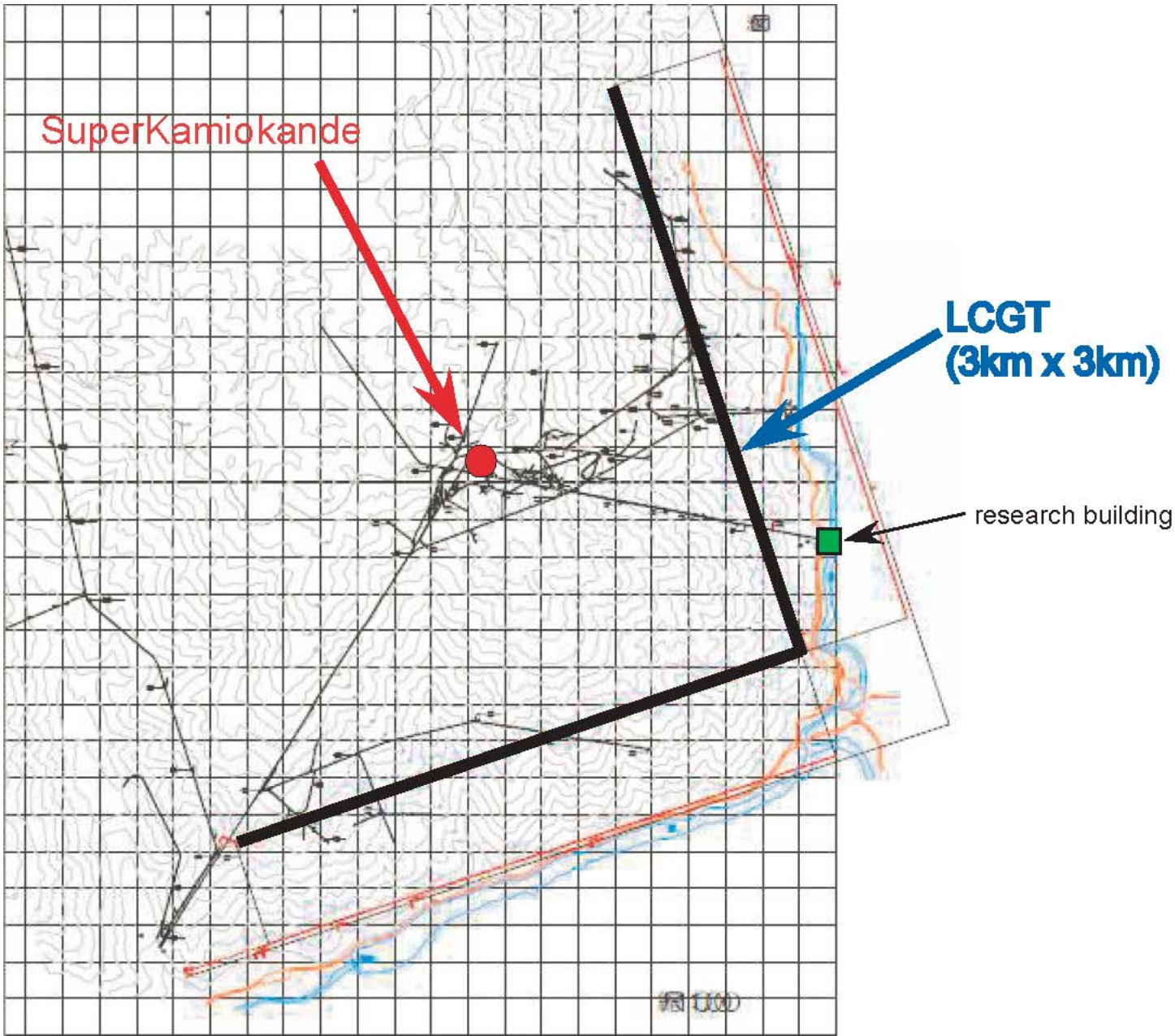
Core optics
- Main Mirror: sapphire, 20K, 25cm, 15cm, 30kg, curvature 4-5km
- Substrate optical loss 500ppm/15cm; heat absorption 33ppm/cm

PRM, SEM, BS, MC mirrors: Fused silica

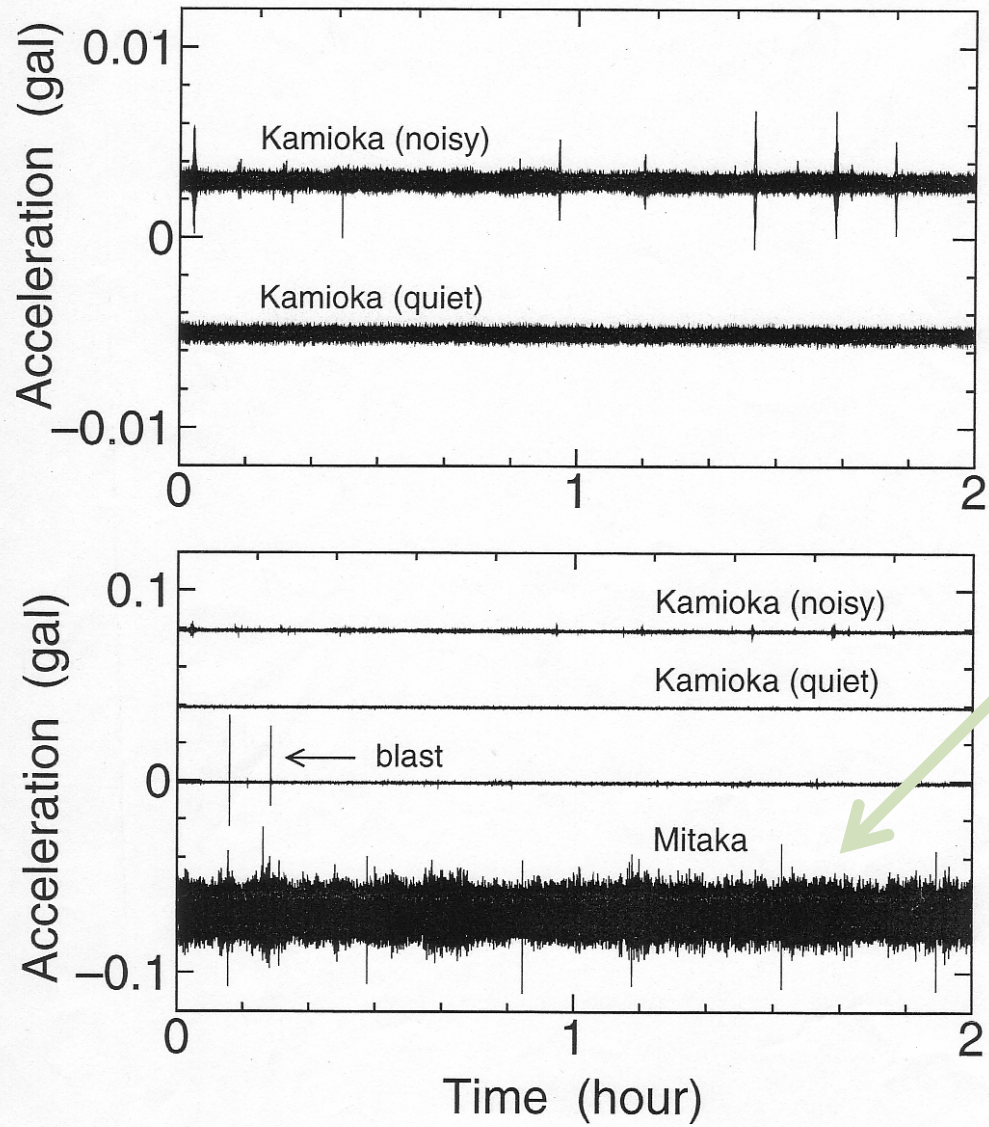
Interferometer techniques were developed by TAMA.
The demerit of TAMA site appears at the alignment control noise that can be reduced by moving to the underground.



LCGT is built underground at Kamioka.



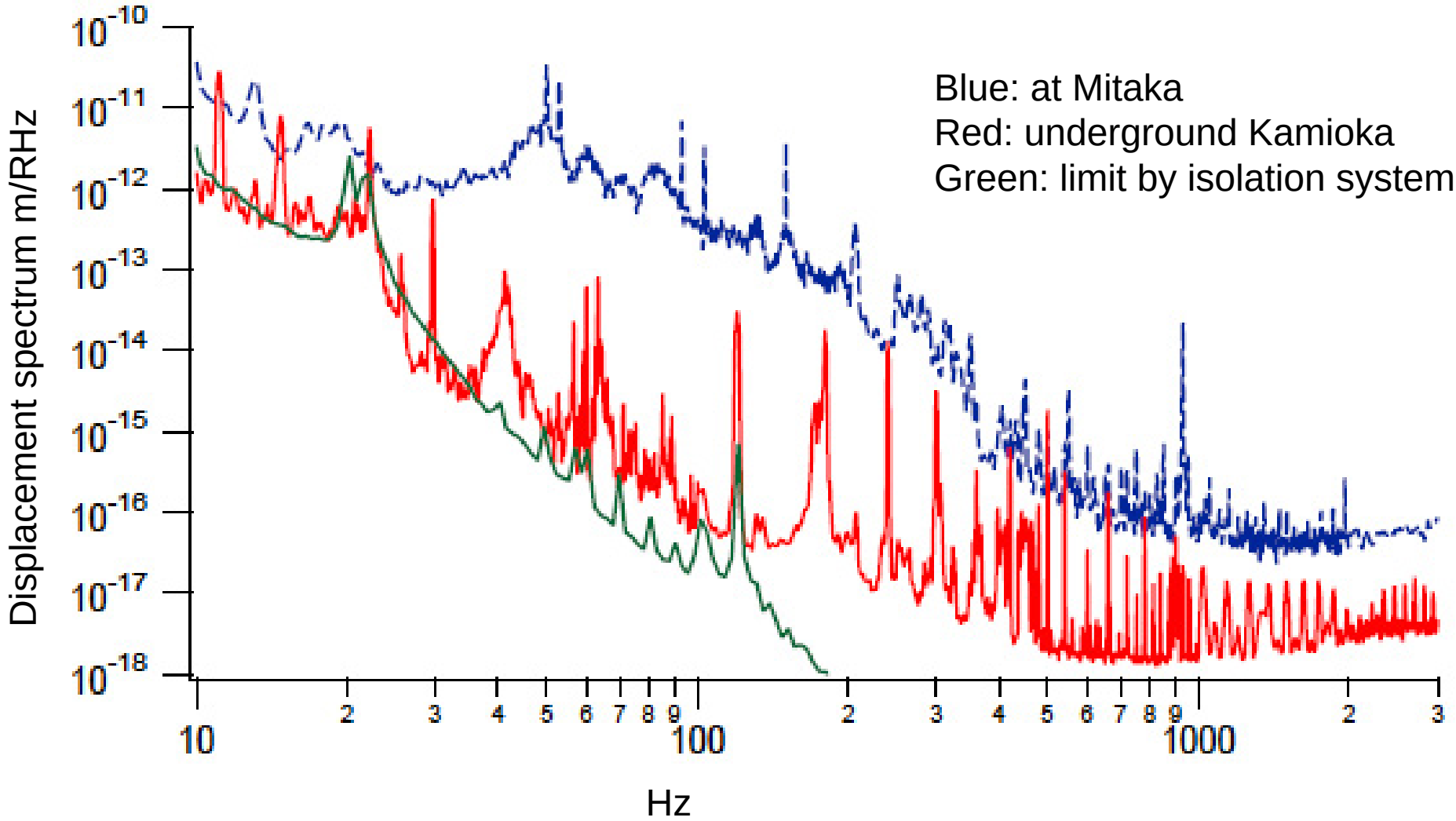
In Kamioka low frequency noise is less than Mitaka by 30 times.The actuator noise can be reduced by that amount.



The seismic noise of Mitaka is equivalent to continuous blasting in Kamioka underground.

Seismic measurement in Kamioka is presented by K. Yamamoto in poster session

When the … interferometer was moved from Mitaka to Kamioka mine, the noise at 100Hz was decreased by . orders and the spectrum limit by the anti-vibration system was achieved at frequencies less than 100Hz.

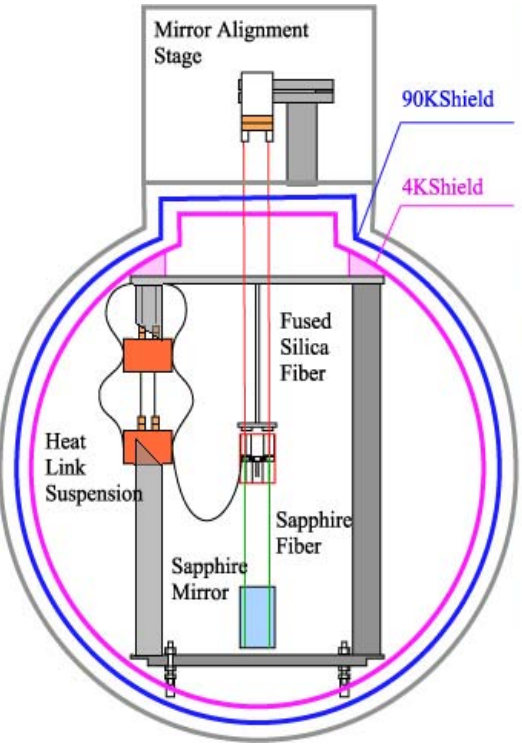


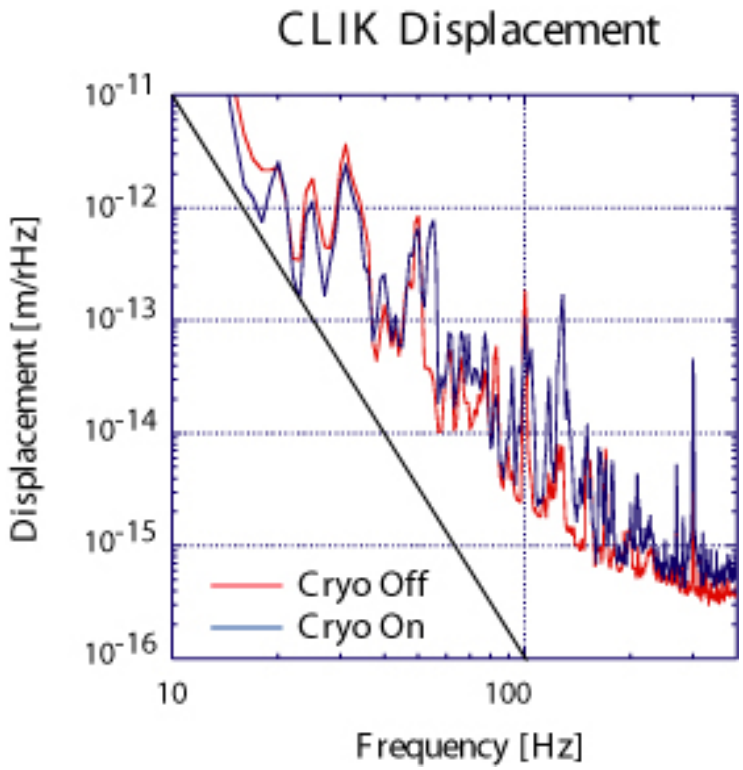
Why do we apply cryogenic?

- Direct way to reduce thermal vibration noise
- Optical coating loss of mirrors vanishes
- No thermal lens effect
- Good refrigerators have been developed
- A challenging technique

Suspension prototype was tested in Kashiwa campus in ICRR, in 2001.

Fabry-Perot cavity was locked under cryogenic temperature and requirements on refrigerator were studied.





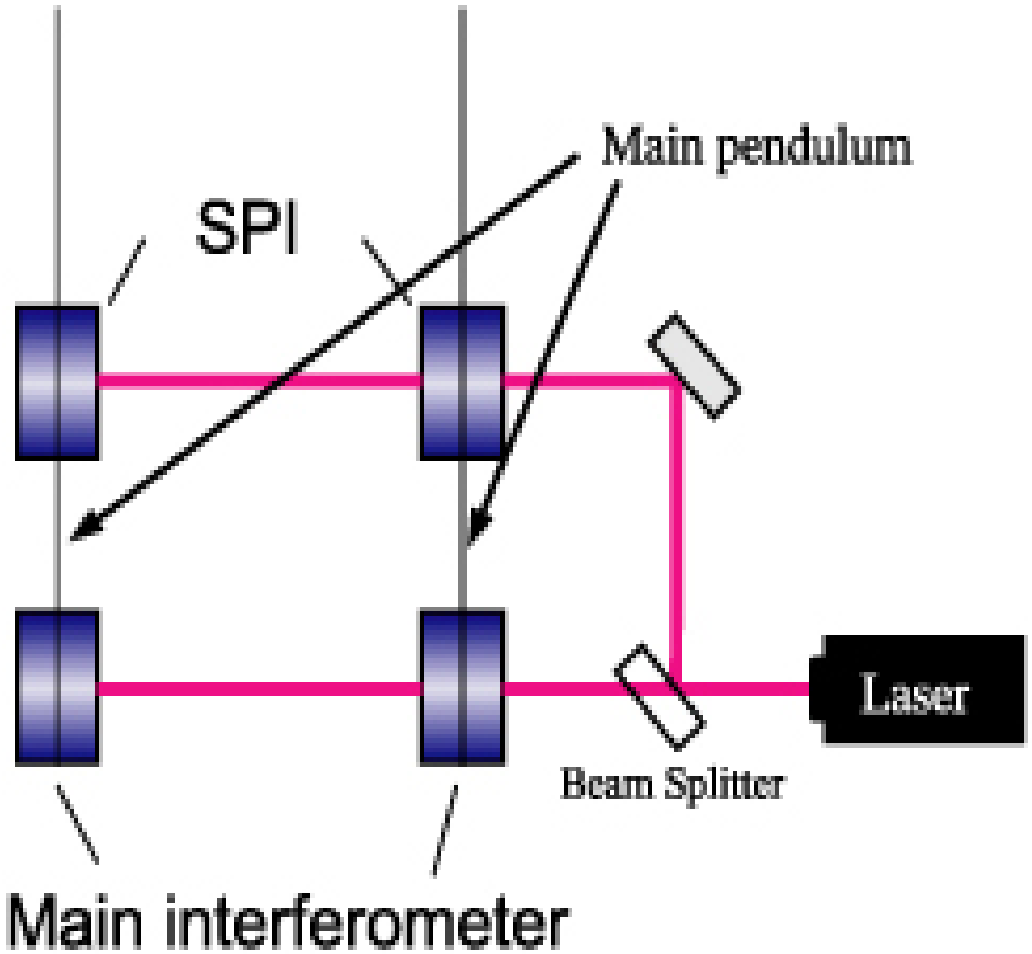
applied to CLIO presentation by Miyoki in poster session

Large heat production is avoided by RSE

- Broad band RSE is applied.
- Power recycling gain is set 10.
- Finesse of the cavity is 1250, which means that observational band must be lower than required.
- RSE keeps the frequency band unchanged.

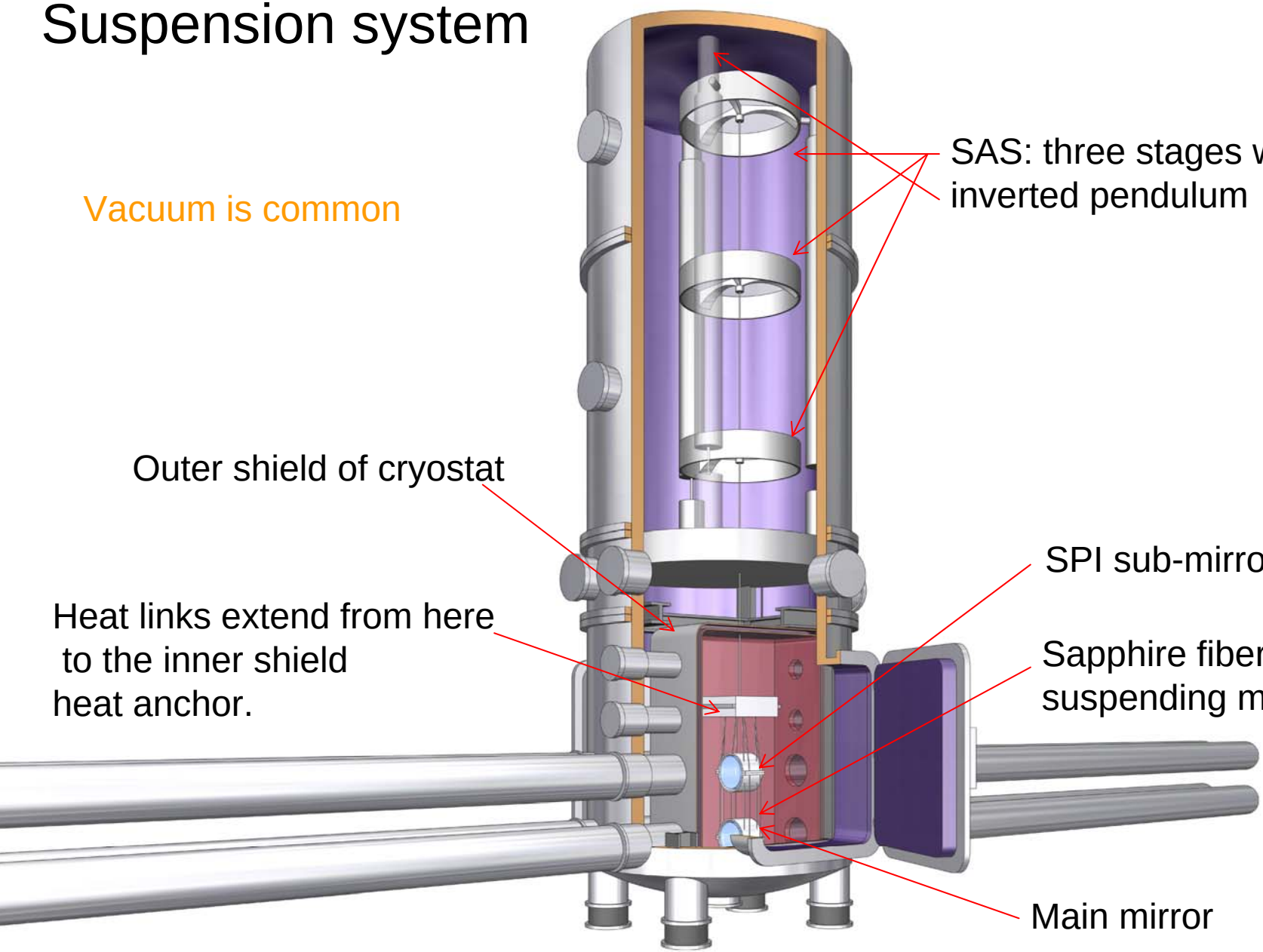
Refrigerator noise is avoided by SPI

Test mass of LCGT is connected to a cooling system by a heat link that introduces mechanical noise. A suspension point interferometer (SPI) is introduced to maintain high attenuation of seismic and mechanical noise without degrading high heat conductivity.



Suspension system

Vacuum is common



Schedule and Budget

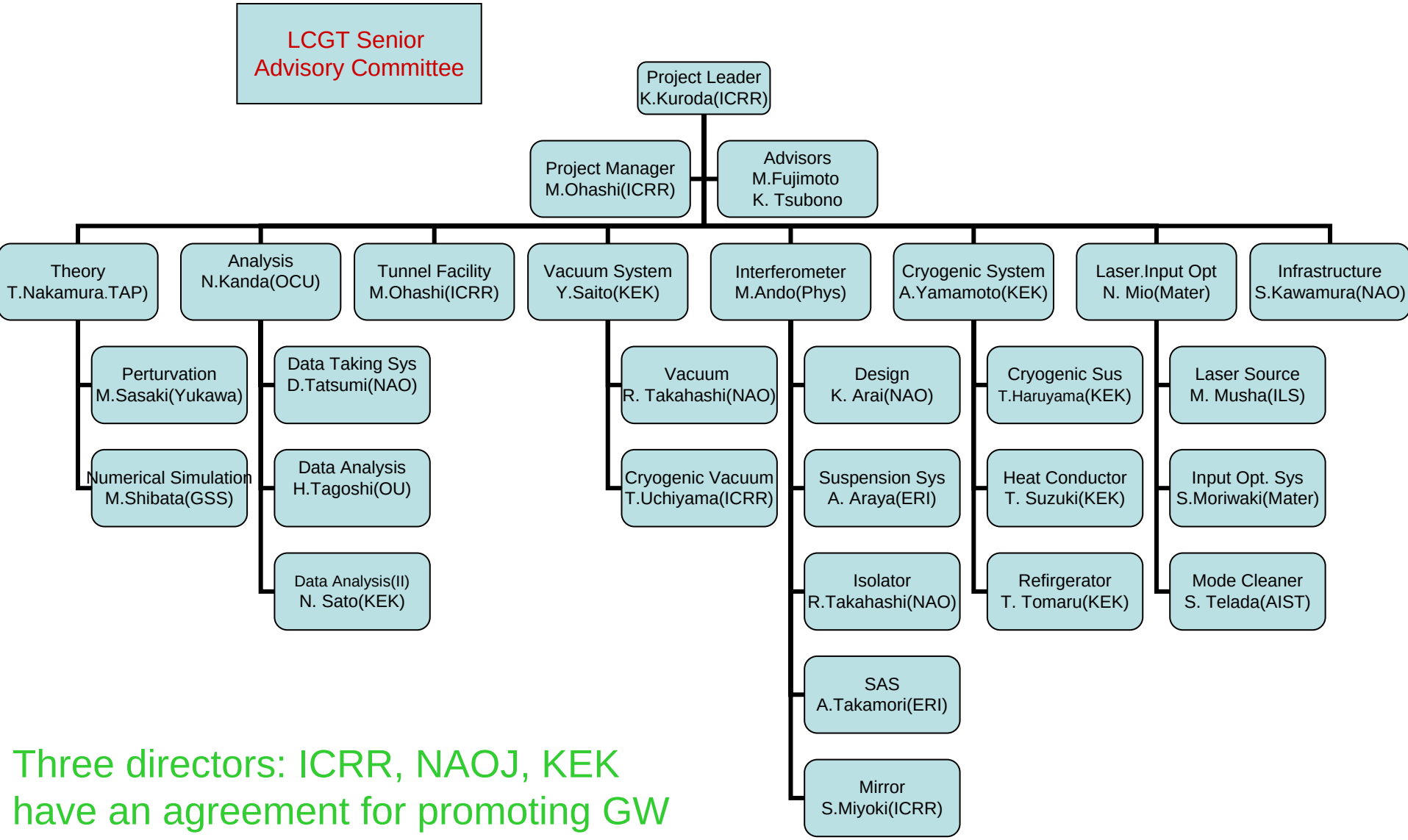
112 JpnYen=1 US$

Item	2006	2007	2008	2009	2010	2011	2012	Cost (Thousand Yen)
Tunnel	⇒	⇒	⇒					3,396,000
Buildings		⇒	⇒					500,000
Vacuum	→	→	→⇒	⇒				5,250,000
Optics	→	→	→	→⇒	⇒			925,420
Laser	→	→	→	⇒				802,780
Cryo-Suspension	→	→	→	⇒				2,630,000
Anti-vibration	→	→	→	⇒				230,000
Main Mirror	→	→	→	→	⇒Install			300,000
Data-taking			→	→	⇒Install			200,000
Observation						⇒	⇒	600,000
							Total	14,834,2000

US$ 132M

It does not include salaries & maintenances of facilities.

LCGT Organization



Three directors: ICRR, NAOJ, KEK have an agreement for promoting GW experiment.

International Collaborations

- Succeeding almost all MOUs exchanged under the name of TAMA
  - LIGO (GEO)
  - VIRGO
  - ROG, AURIGA, TWG
- Maintaining MOU with ACIGA
  - Laser, Cryogenic sapphire, etc.
- Initiating a new collaborative work
  - high quality sapphire

Summary of LCGT

- It is a 3km Fabry-Perot MI with a power recycling scheme and equipped with a broadband RSE. The laser power is 150W.
- Main mirrors made of sapphire are cooled at 20K. A SPI impedes the refrigerator- vibration.
- It is built underground in Kamioka.
- Two independent interferometers are installed in a vacuum system.
- The main target is the coalescence of BNS, which can be detected 1.2-27.8 events per year at confidence level of 95% for mass 1.4Msun and S/N=10.

Closing this talk

- Budget asking for FY2006 has been done in collaboration with ERI (geophysical strain meter project).
- Sadly to say, the financing agency is not happy to fund for FY2006.
- We strongly push LCGT to be financed in FY2007, which is regarded as the final chance in Japan.