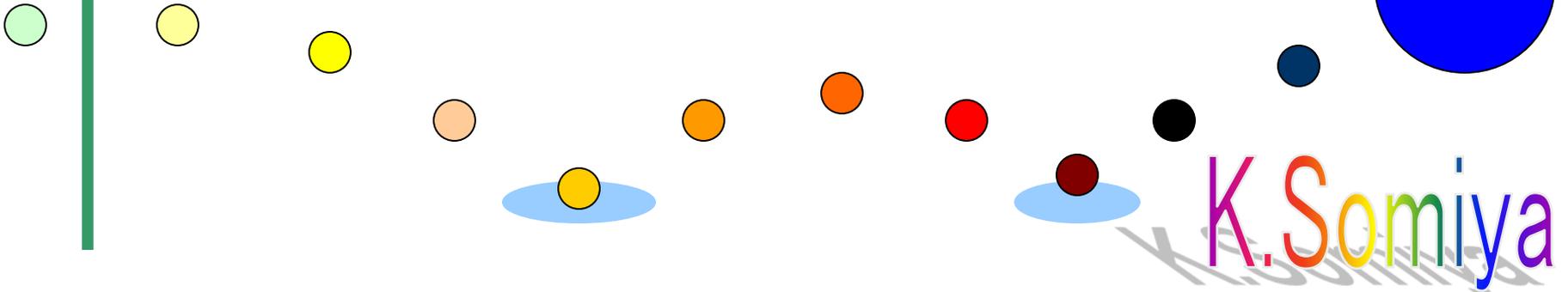


How does cryogenics improve the sensitivity of interferometers?

Elba
May 24, 2013

Tokyo Institute of Technology

Kentaro Somiya

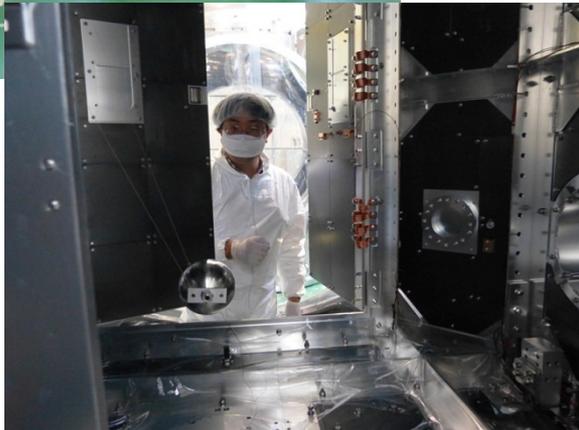


Overview

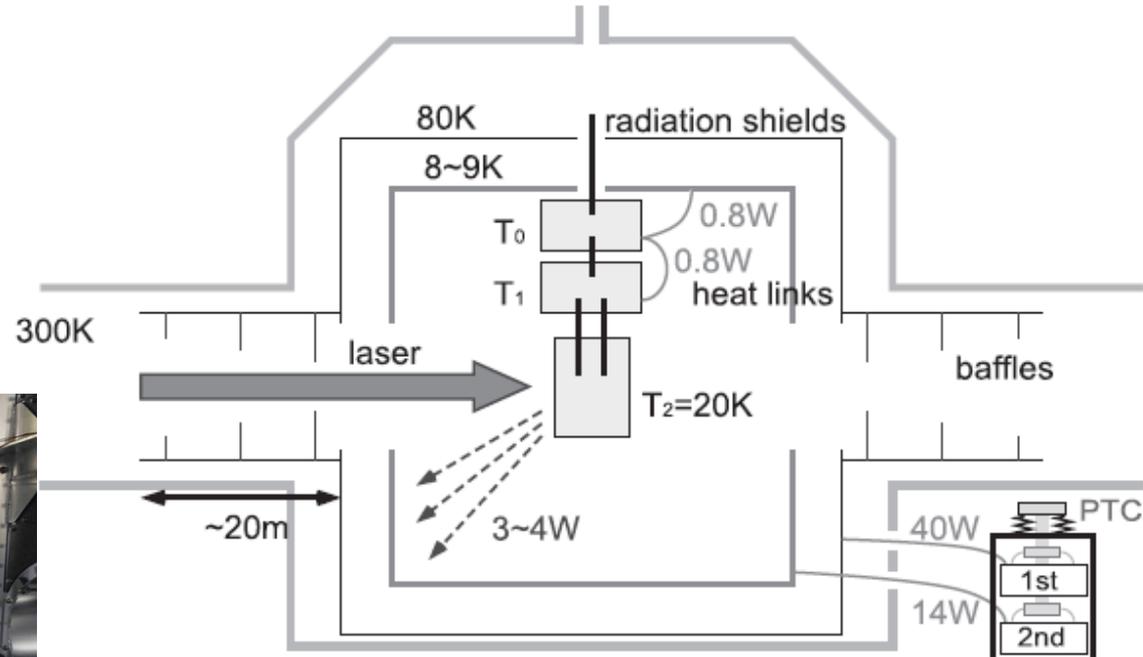
~ This is an introductory talk for the session ~

- What is the benefits of cryogenics?
- What are the issues?
- Possible solutions/ideas for the issues

KAGRA's cryogenic system



Toshiba factory in Yokohama

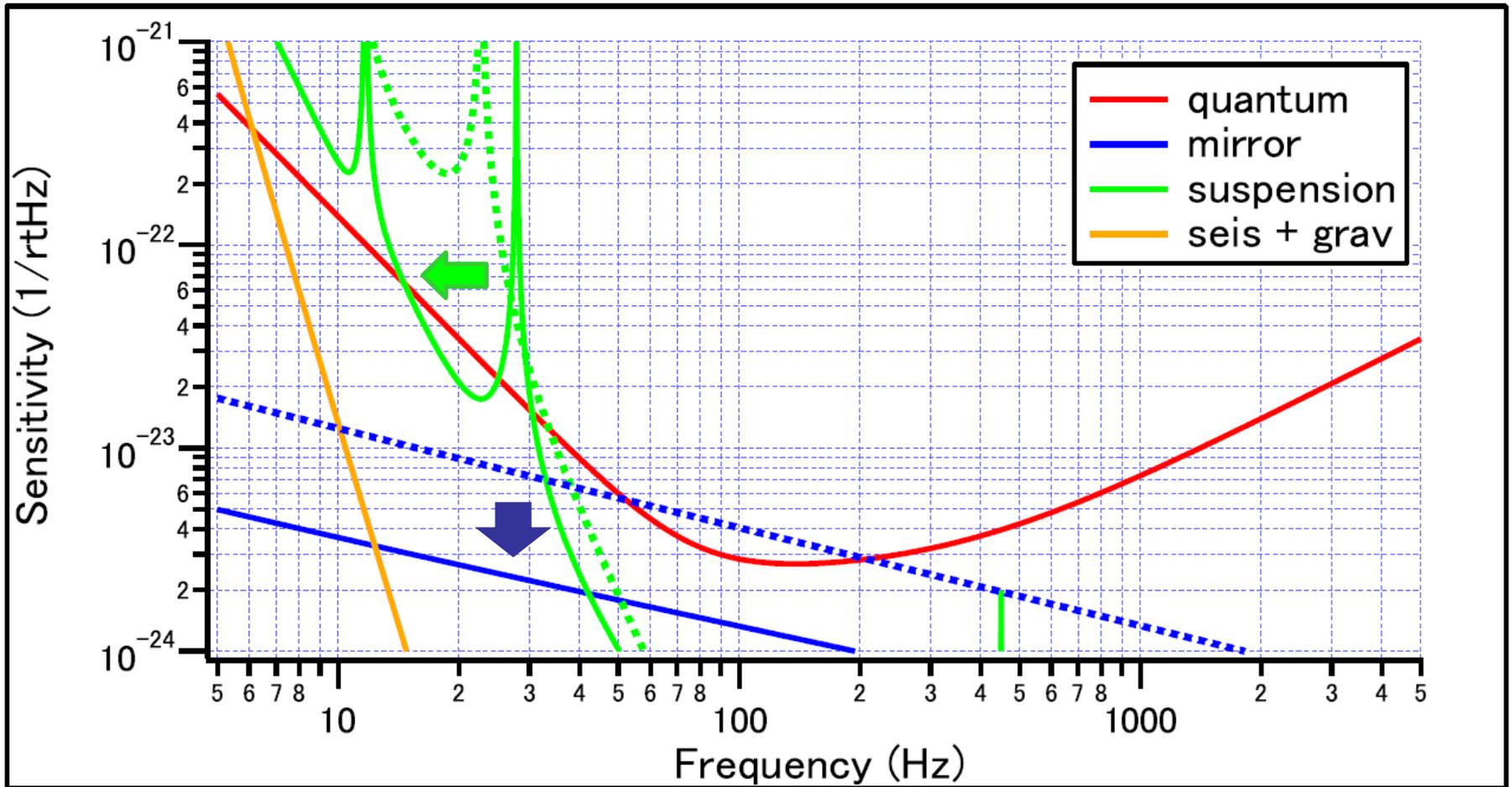


[Heat flow]

laser -> Sapphire mirror -> Sapphire fiber
-> Al heat link -> shield -> cryo-cooler

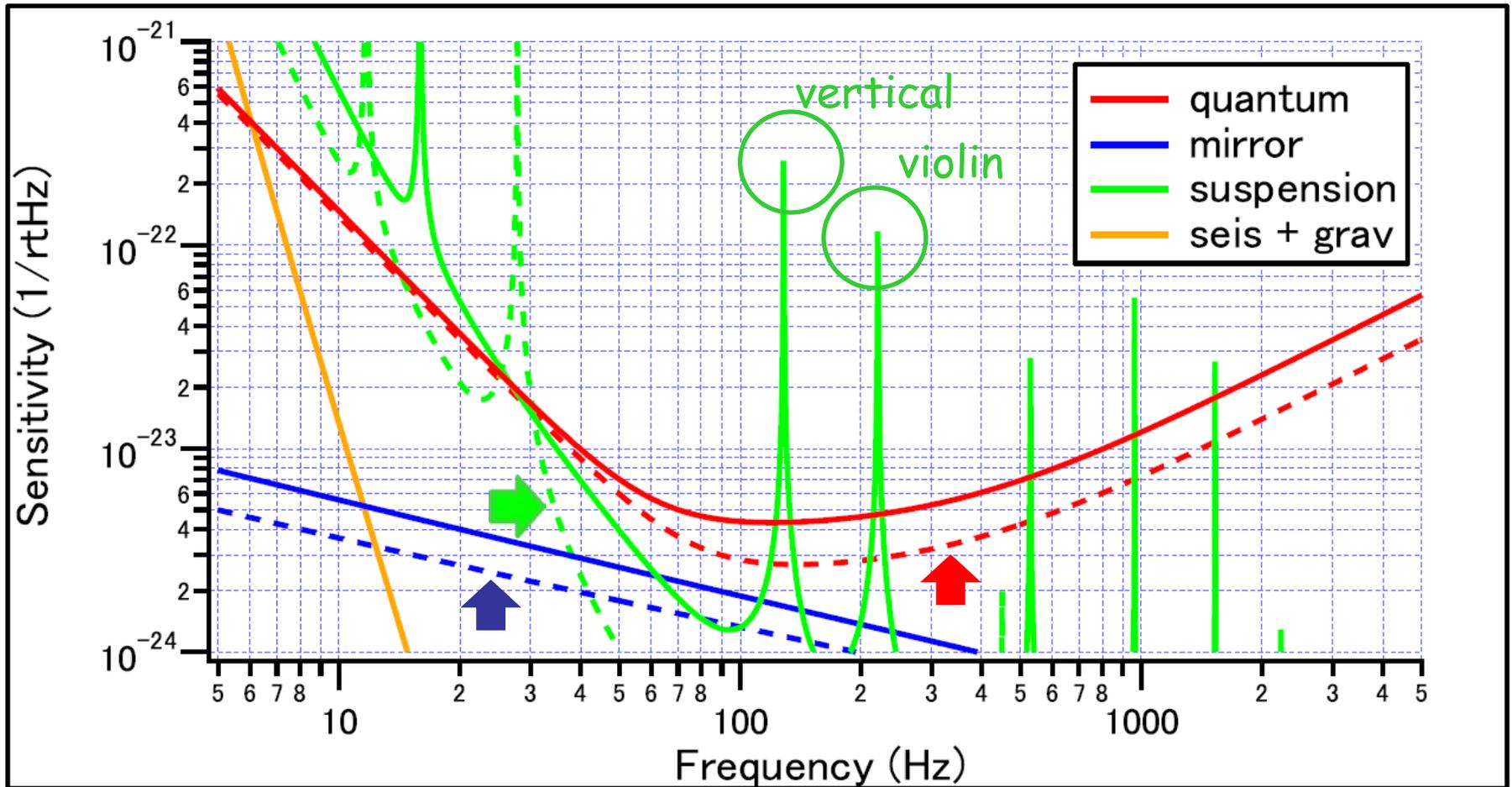
Sapphire test masses are cooled down to 20K

Ideal cryogenic detector



290K Silica -> 20K Sapphire
m=40kg, d=0.5mm, $I_c=700\text{kW}$

In reality...



$m: 40\text{kg} \rightarrow 23\text{kg}$, $d: 0.5\text{mm} \rightarrow 1.6\text{mm}$, $I_c: 700\text{kW} \rightarrow 250\text{kW}$

Issues and reasonable solutions

- A big good Sapphire is still not available
(c-axis: ϕ 22-25cm, a-axis: $\sim\phi$ 30cm) susp rpn
- Absorption is still high (30-60ppm/cm) shot
- Coating mechanical loss may increase at 20K mirror
- Suspension peaks in the observation band susp

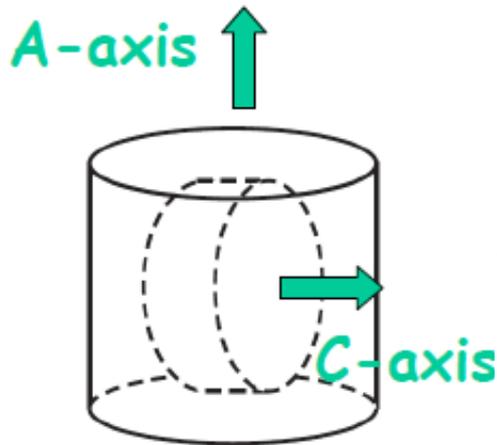
Issues and reasonable solutions

- A big good Sapphire is still not available (c-axis: $\phi 22-25\text{cm}$, a-axis: $\sim \phi 30\text{cm}$)

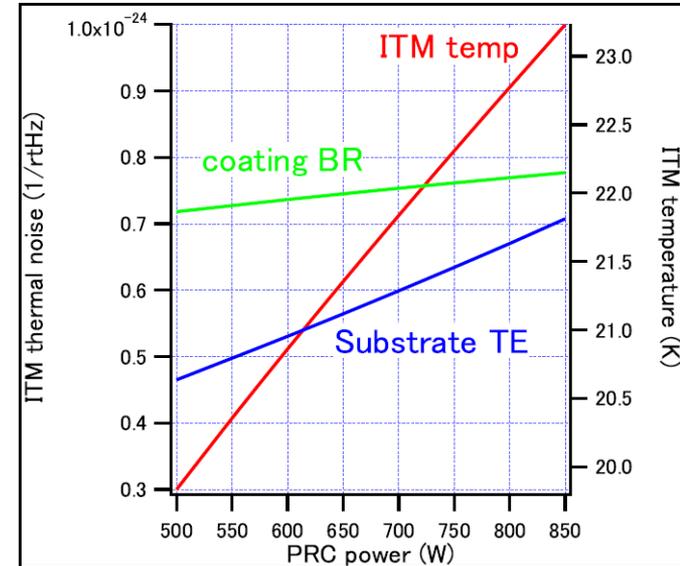
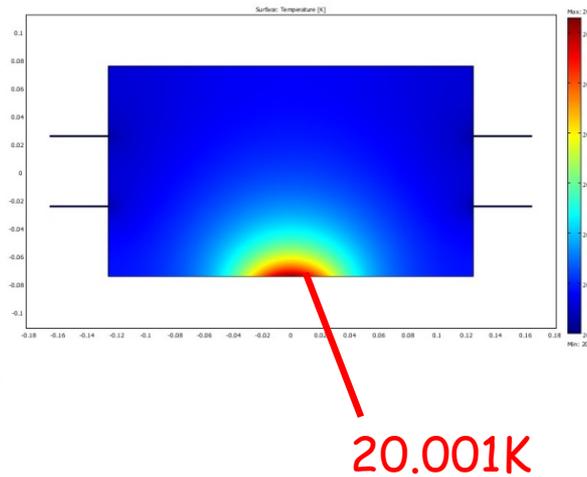
susp rpn

- Absorption is still high (30-60ppm/cm)

shot

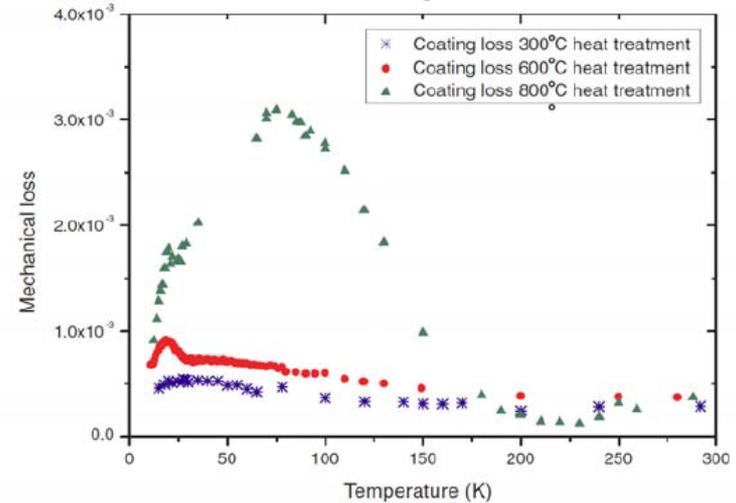
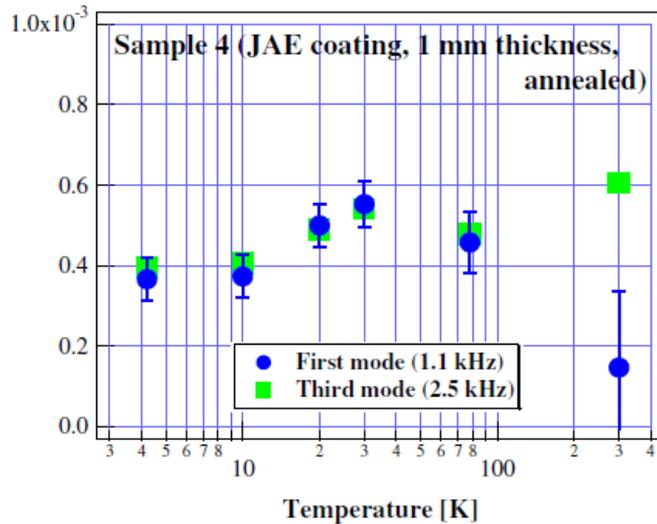


60% reduction of mass



Issues and reasonable solutions

(L) Measurement in Tokyo (R) Measurement in Glasgow



- Coating mechanical loss may increase at 20K

mirror

- Suspension peaks in the observation band

susp

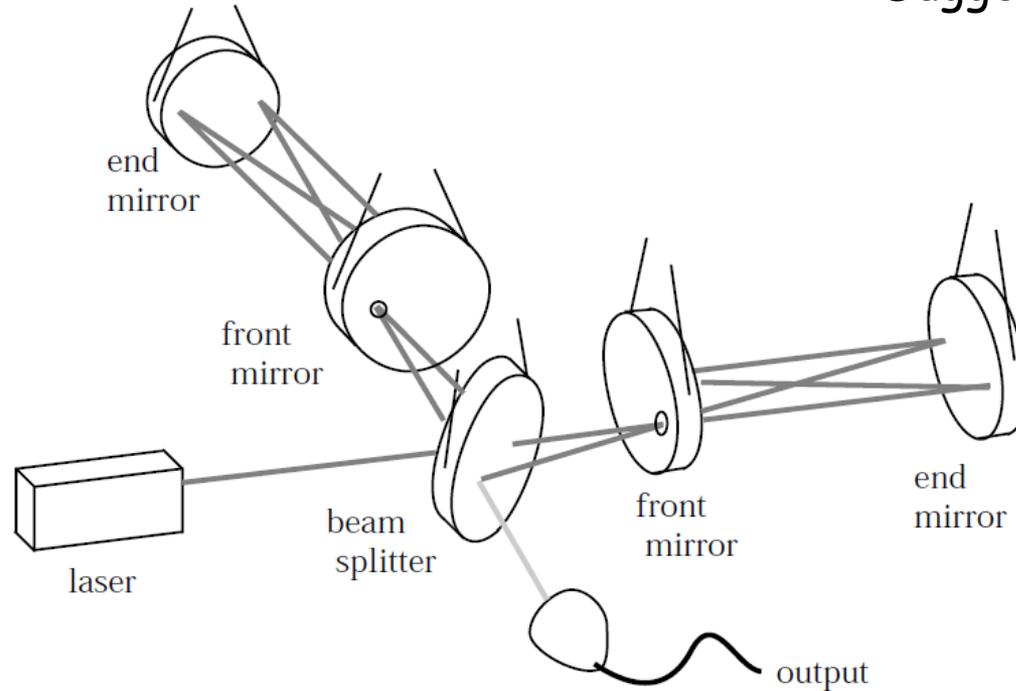
Issues and reasonable solutions

- A big good Sapphire is still not available (c-axis: ϕ 22-25cm, a-axis: $\sim\phi$ 30cm)
 - > Silicon? A-axis Sapphire? Non-cylindrical?
- Absorption is still high (30-60ppm/cm)
 - > Silicon? Squeezing? [Julius, Alexander]
[Roman]
- Coating mechanical loss can increase at 20K
 - > Crystalline coatings? [Garrett, Angie]
- Suspension peaks in the observation band
 - > Sapphire/Silicon blade spring? [Ettore, Eric]

Other solutions

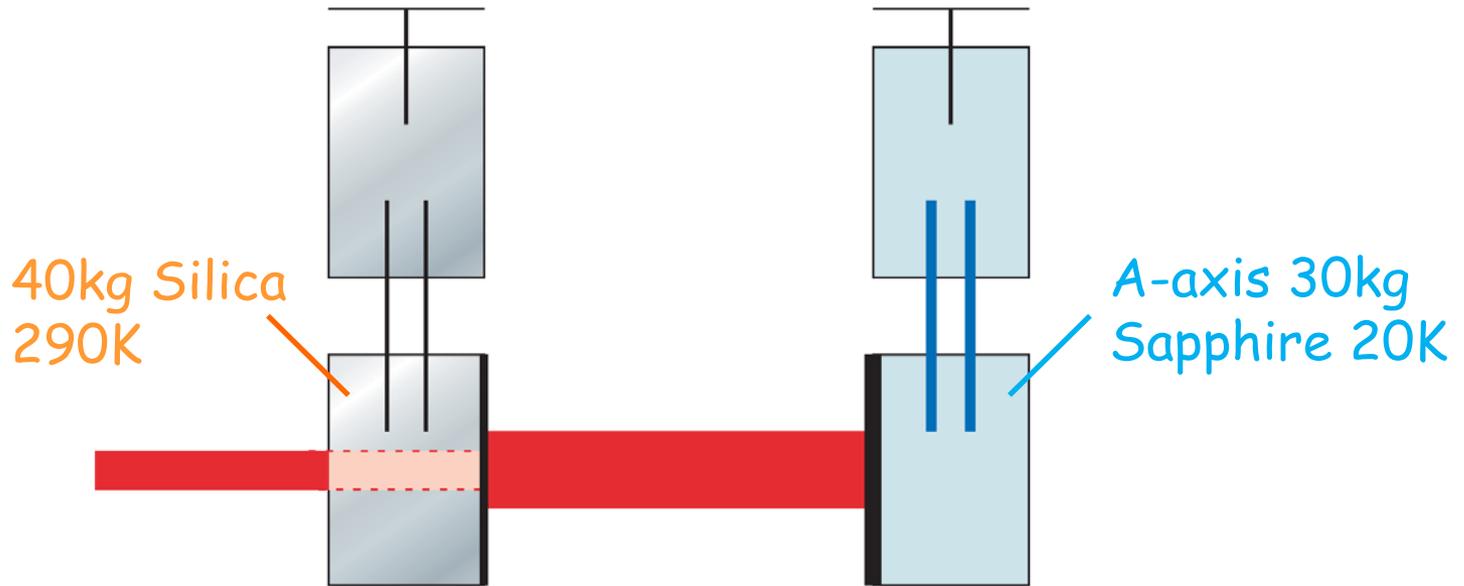
Cryogenic delay-line

Suggested by Kuroda



- No worry about the substrate absorption
- We can use big A-axis Sapphire mirrors

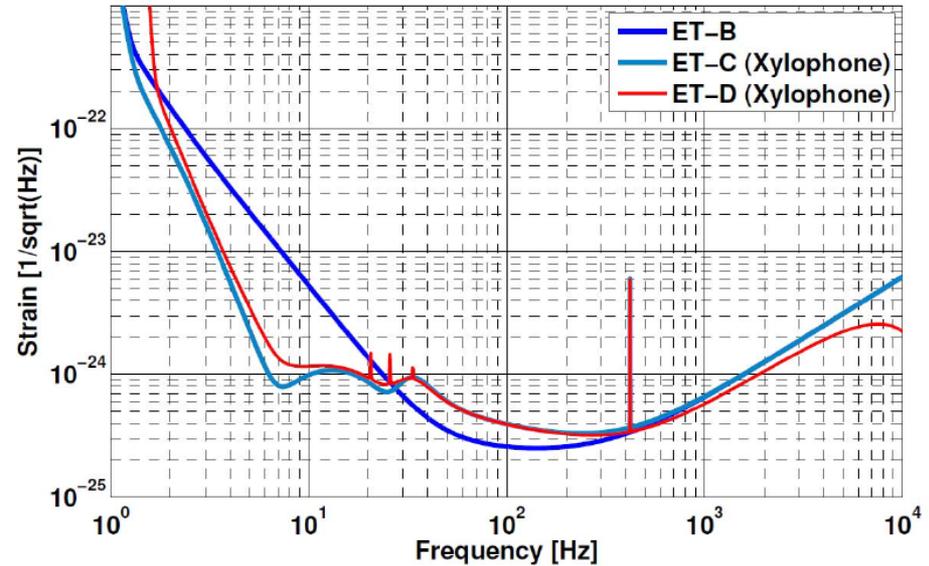
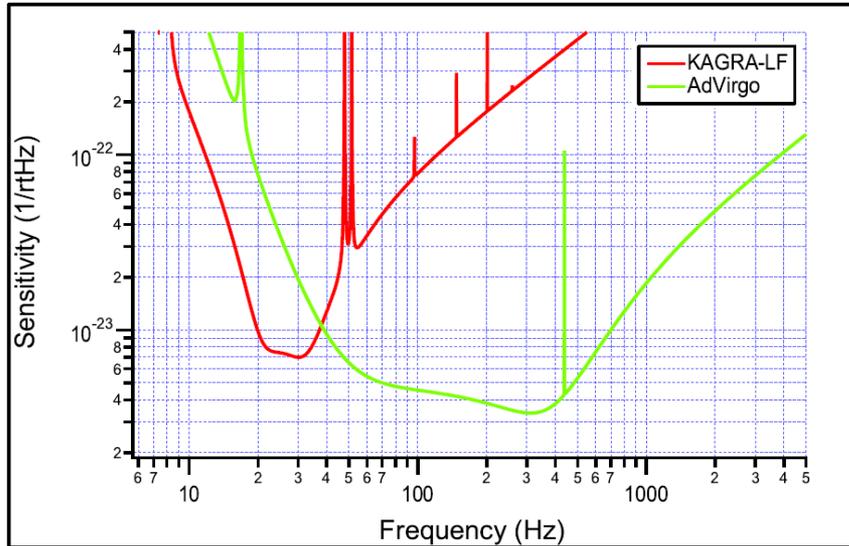
Half-cool



- More troubles to cool ITM, while thermal noise is bigger for ETM
- TCS would be necessary for ITM

Xylophone

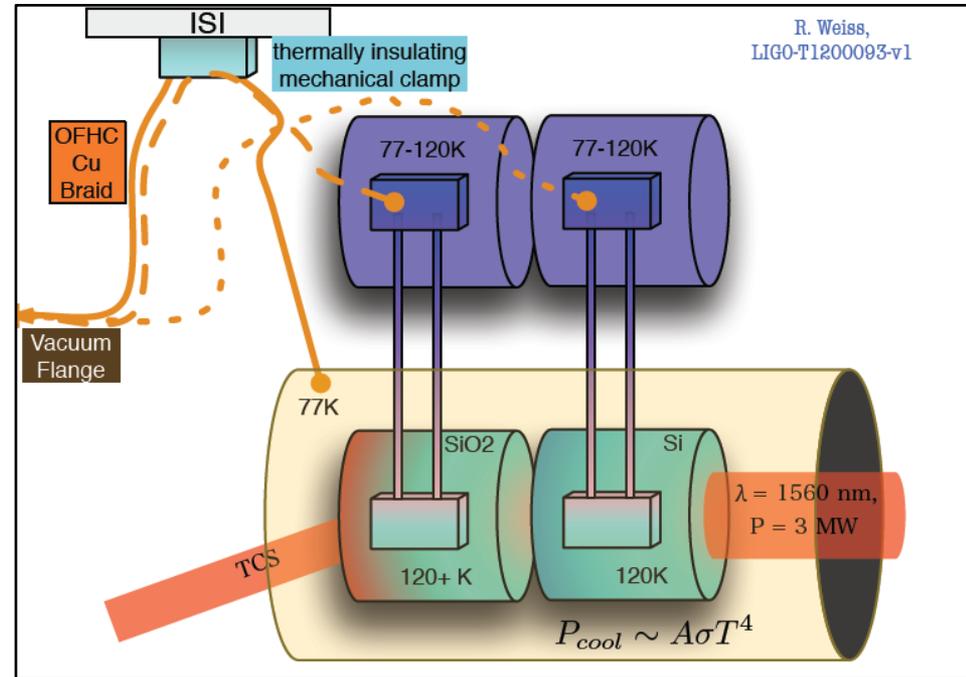
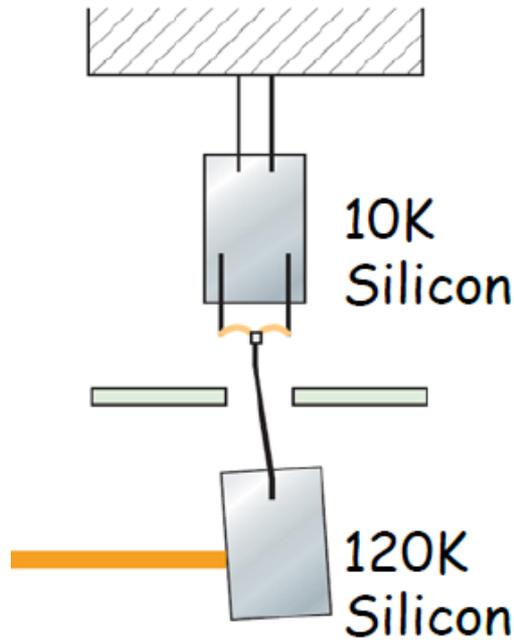
[S.Hild]



- LF: low-power + cryogenic
- HF: high-power + 290K
- High-power issue is not solved

120K Silicon

[Rana]



- ✓ High-power
- ✓ Thin fiber
- ✓ No Thermoelastic
- x Vertical suspension TN

- ✓ High-power
- ✓ Thin fiber
- ✓ No Thermoelastic
- ✓ Vertical suspension TN

Summary

- Many issues for cryogenic detectors
- Remarkable progress in the last few years
- Some new ideas

Talks in this session

- Cryogenic suspensions [Ettore] cancelled
- Crystalline suspensions [Eric]
- Cooling time reduction [Yusuke]
- Silicon for future LIGO [Nic]
- Optical measurements [Julius]
- Silicon and coatings [Massimo]

Comparison

