LCGT design review

Cryogenic suspension
Heat link design
Temperature

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- Point mass model
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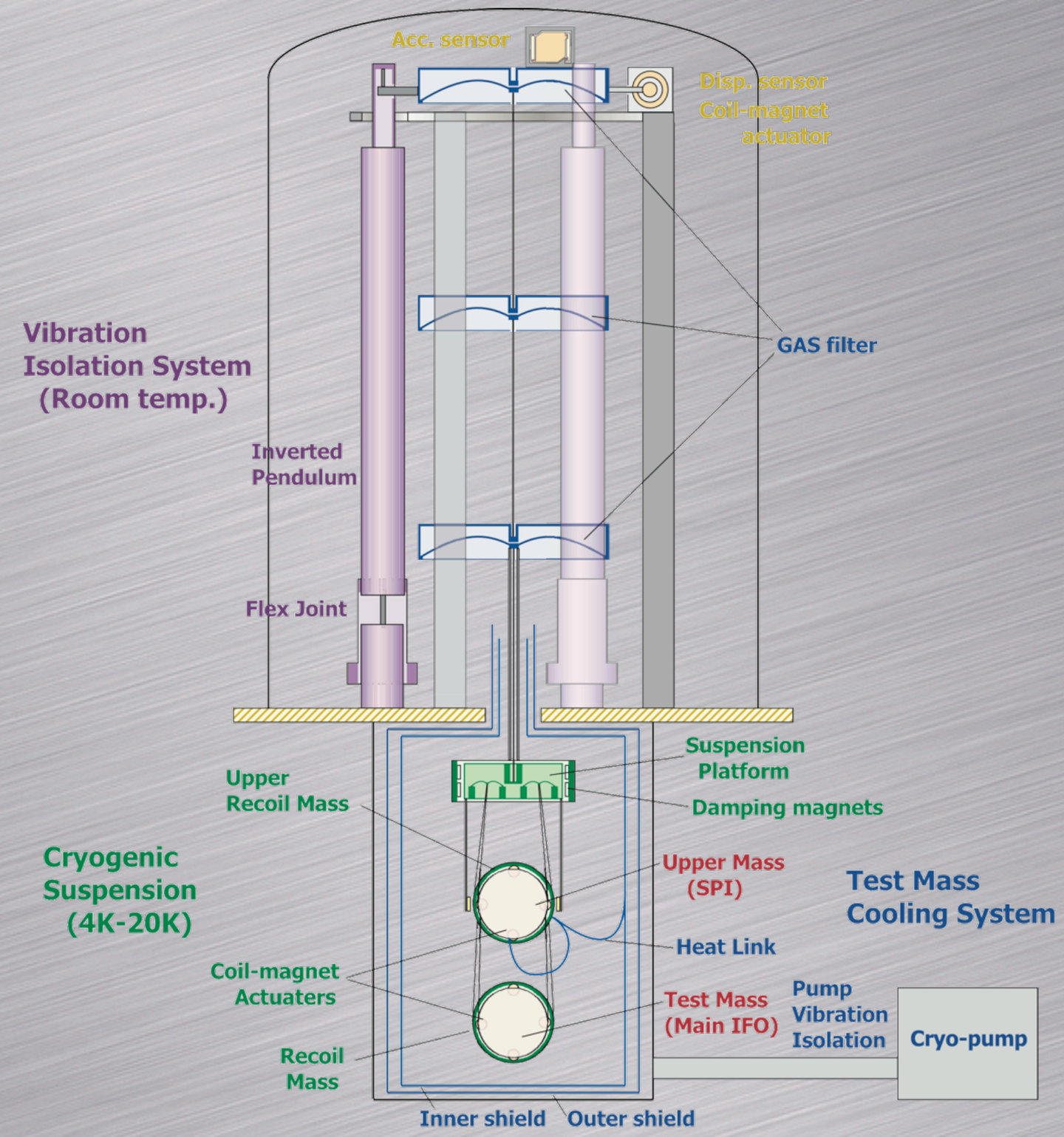
- Heat link design
- Summary

What is designed?

- The cryogenic suspension is refereed to the picture.
- Temperature distribution.
- Major item is the heat links design.



Flowchart of designs

Point mass model of
the cryogenic suspension

heat in the mirror
mirror temperature
thermal conductivity

Cooling mirror by sapphire fibers

Temperature of
upper mass

Heat link design

Temp. of cryostat
length of heat link
thermal conductivity

Minimum cross section

change diameter of wires

Number of the wires
vibration isolation ratio

No

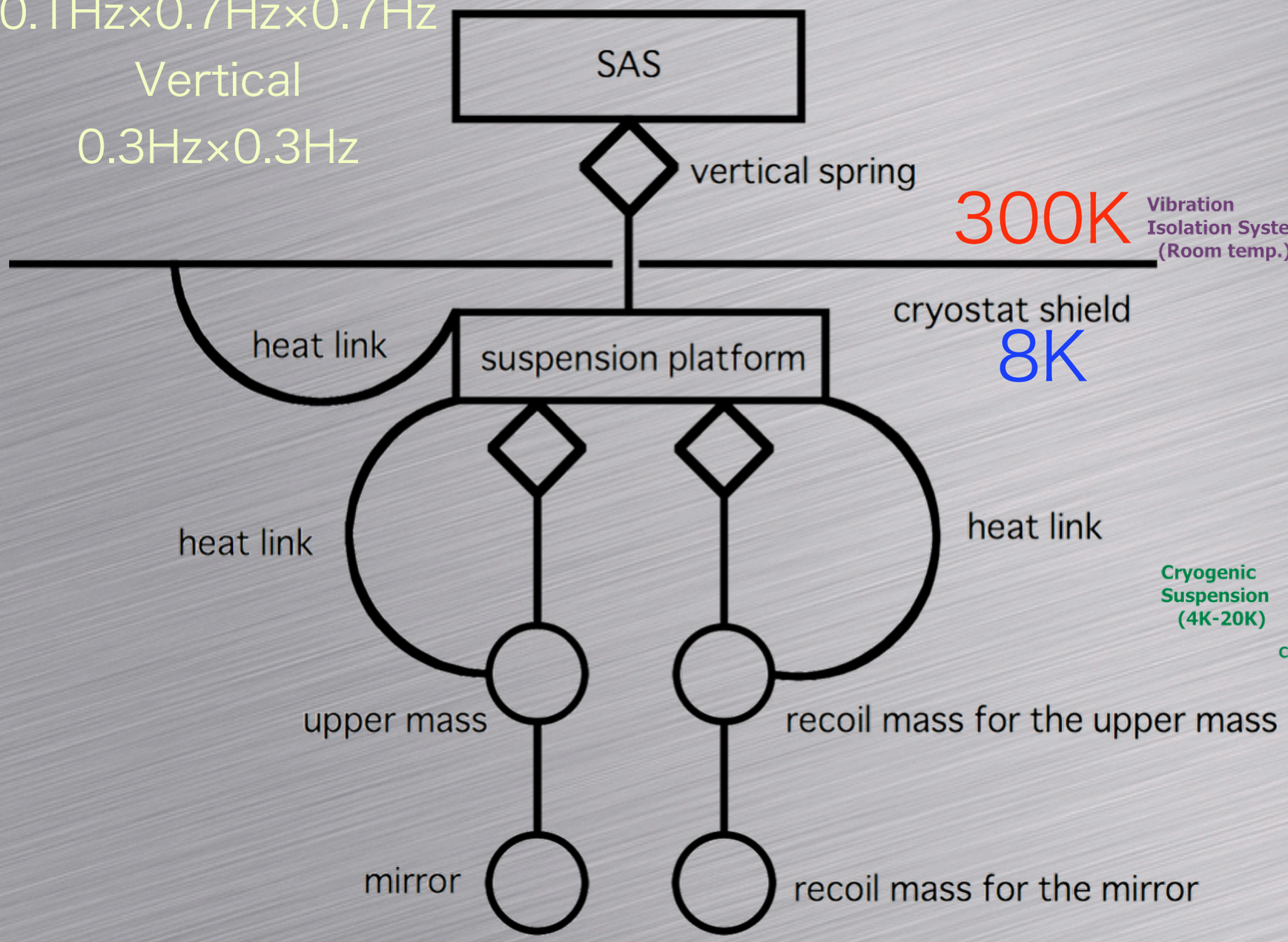
estimate seismic noise

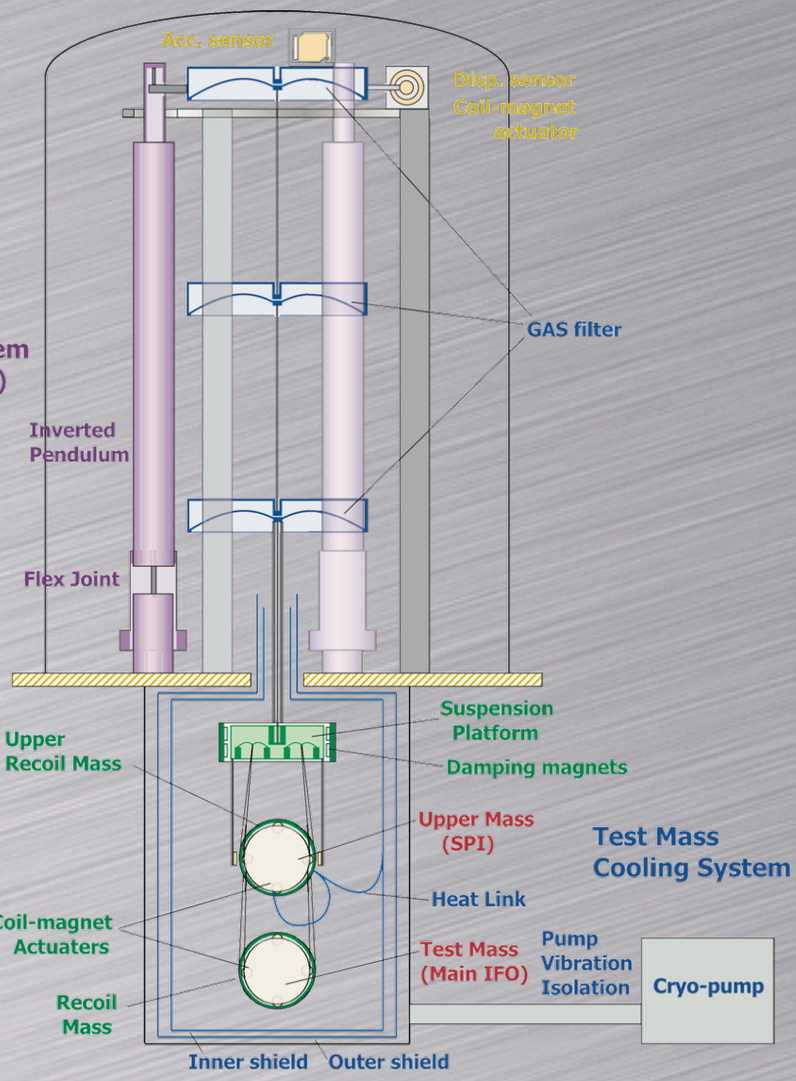
satisfied

Goal!!

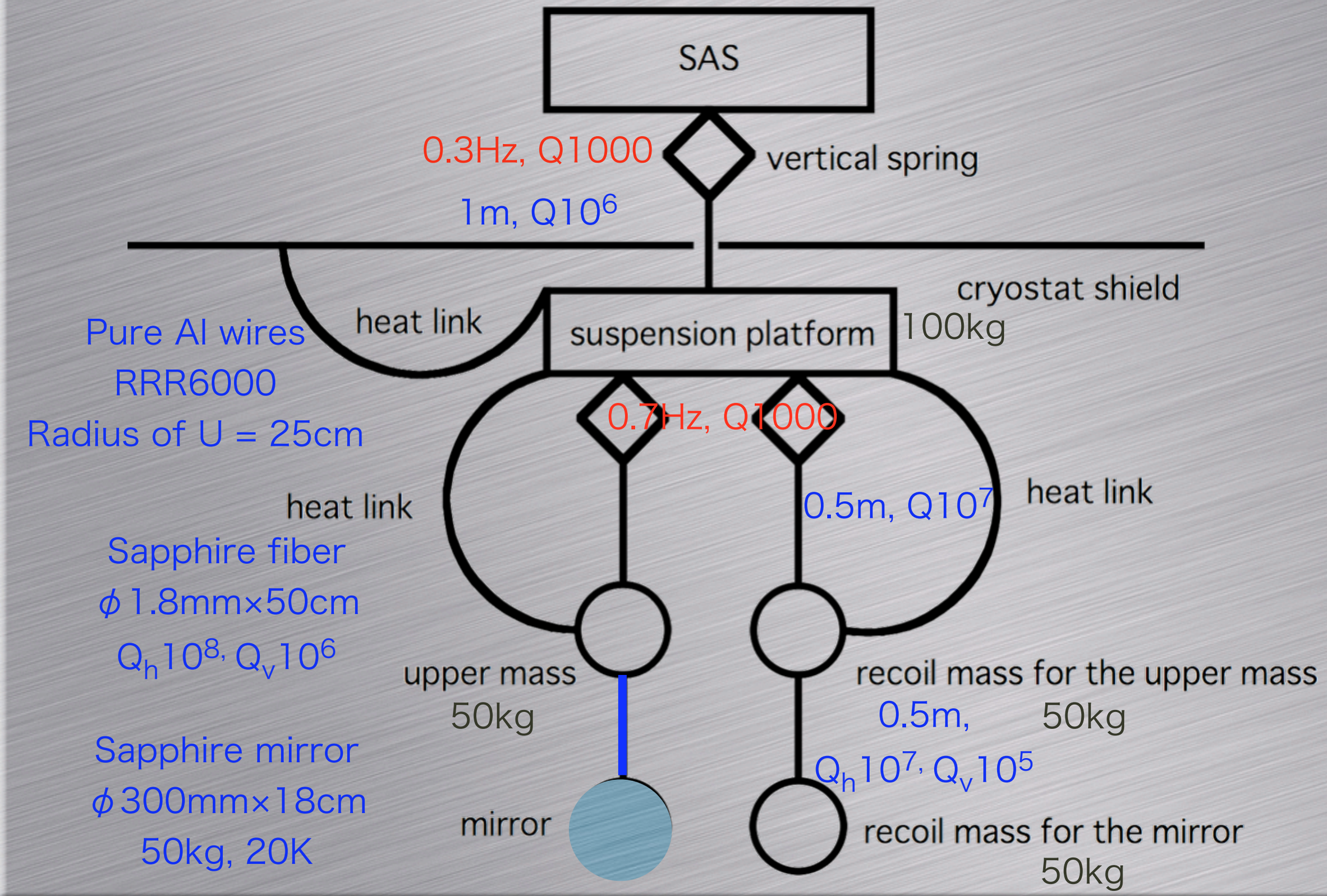
Point mass model

Horizontal
0.1Hz×0.7Hz×0.7Hz
Vertical
0.3Hz×0.3Hz





Point mass model 2



Sapphire mirror cooling

- The mirror substrate
  - Sapphire cylinder
  - 50 kg, ϕ300×180
  - cooled under 20K
- The sapphire fiber suspension
  - 4 wires, ϕ1.8×500
  - Sapphire - Sapphire bonding technique

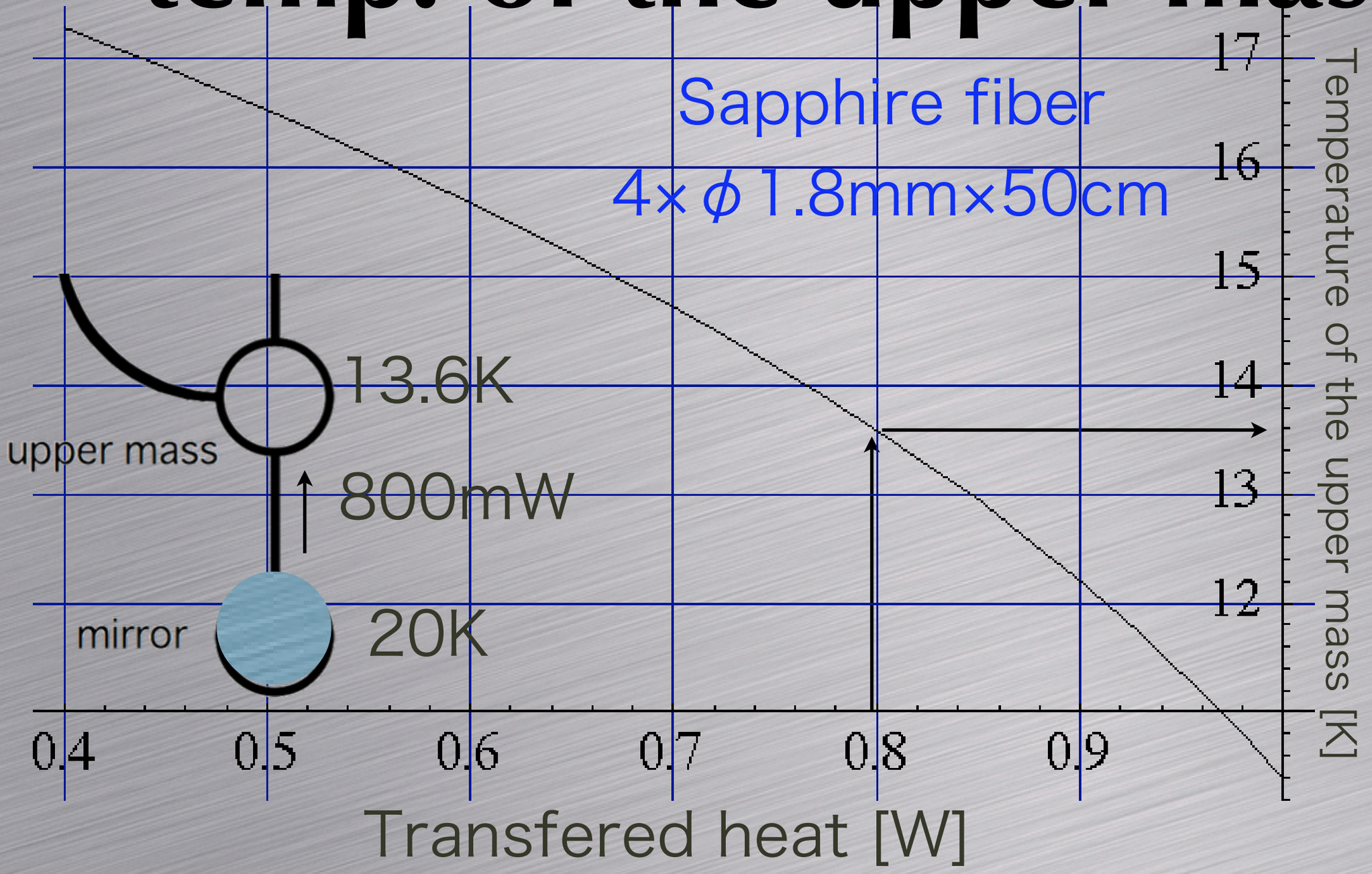
Sapphire mirror cooling 2 - heat in the mirror-

- Laser absorption in the substrate
  - 20 ppm/cm laser absorption ratio.
  - 360 mW
- Laser absorption in the coating
  - 0.1 ppm laser absorption ratio.
  - 40mW
- Other heat source
  - radiation from laser holes..... not considered.
- Margin

800 mW = 2×(360 mw + 40 mW)

is design heat.

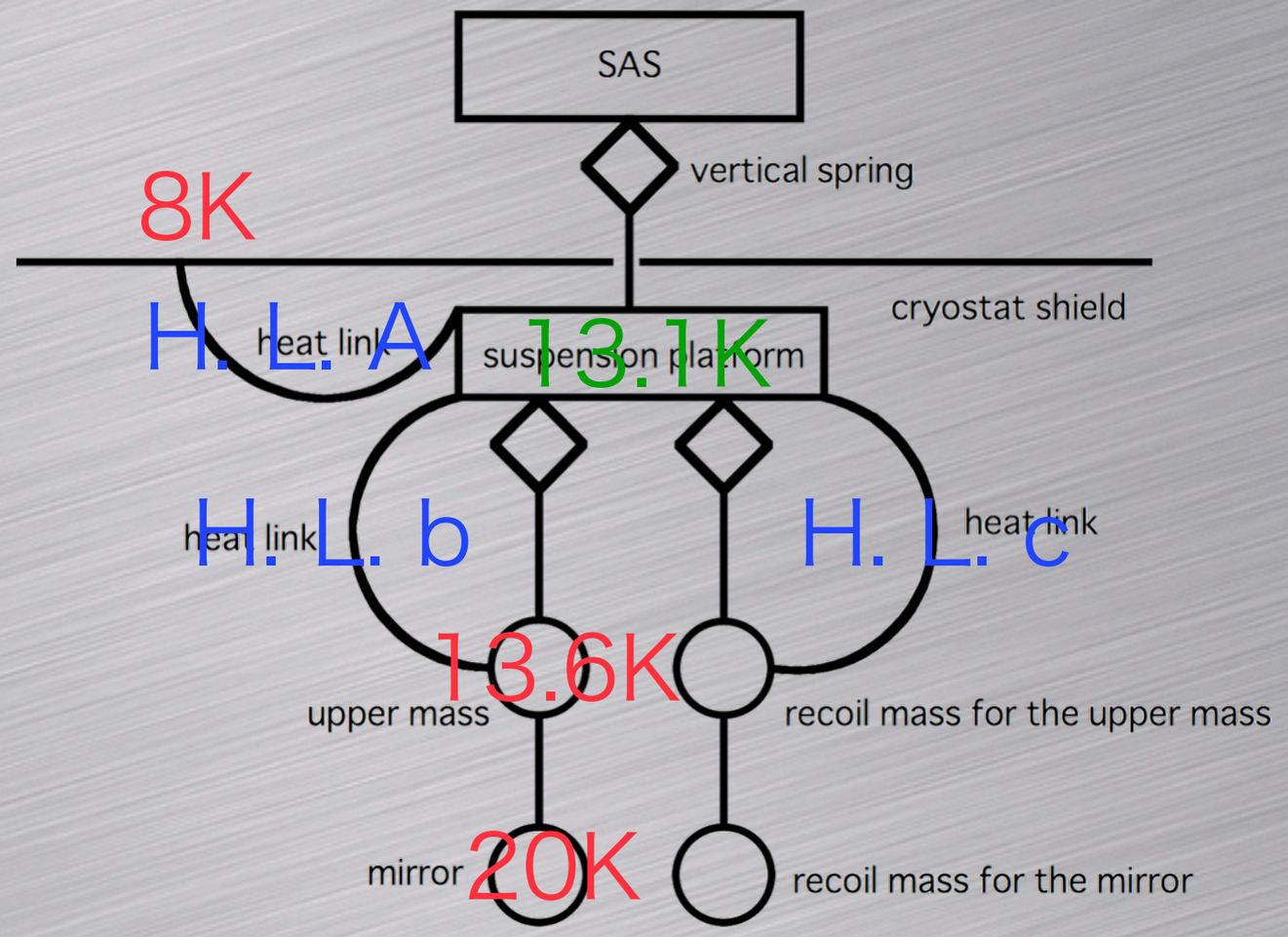
Sapphire mirror cooling 3
- temp. of the upper mass-



Temperature of the upper mass is 13.6K.

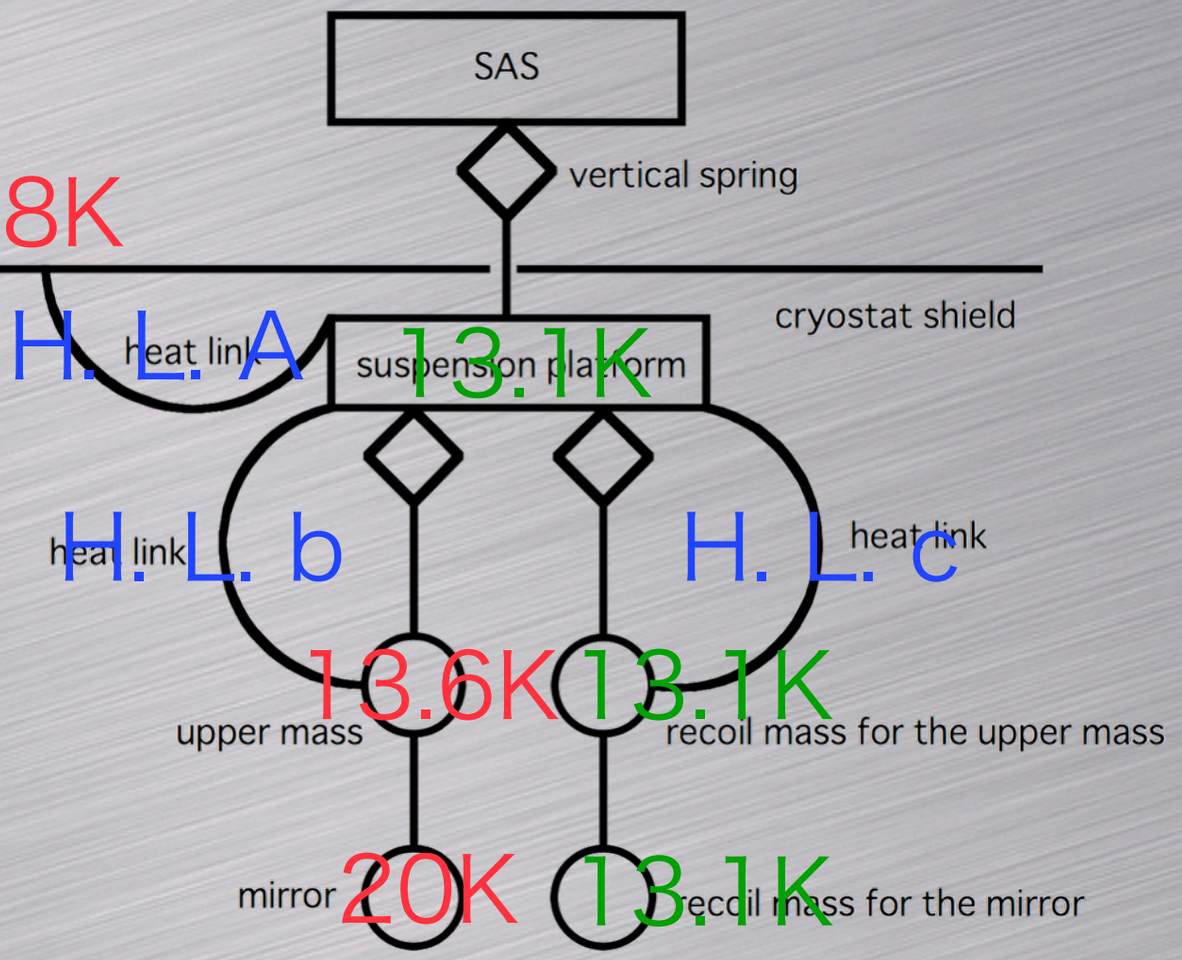
Heat link design
-3 heat links-

- H. L. A
  - vibration isolation
  - thermal conduction
  - large temperature difference.
- H. L. b & c
  - thermal conduction



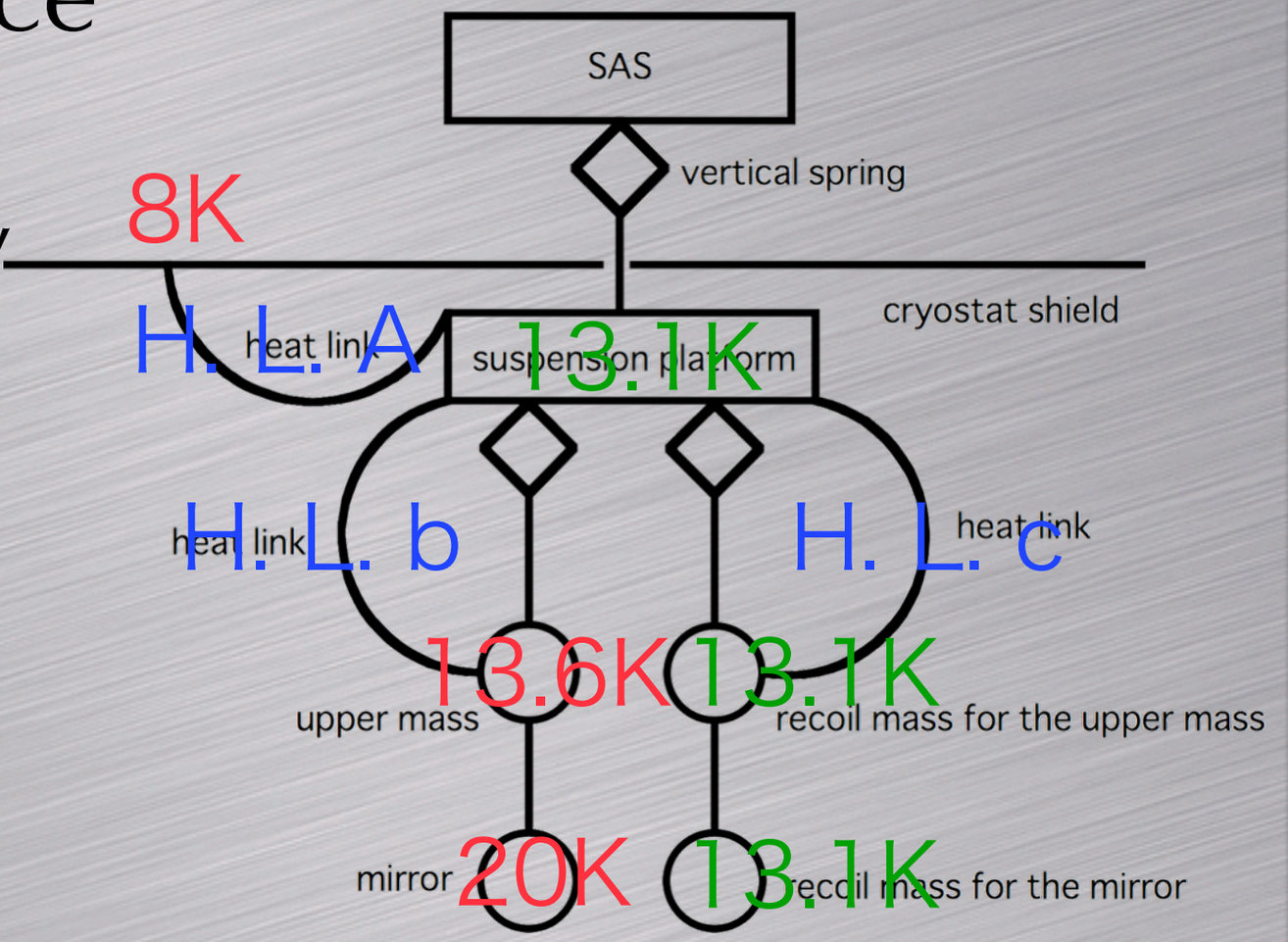
Heat link design 2 -heat of coil-

- If use high RRR Al or Cu wire for the coils, heat in the coils may be mW.
  - 300K: 1A×1V=1W
  - 4K: RRR=1000, 1A×1mV=1mW
- At present, the heat in the coils is not considered.
- H. L. b = c in the design.



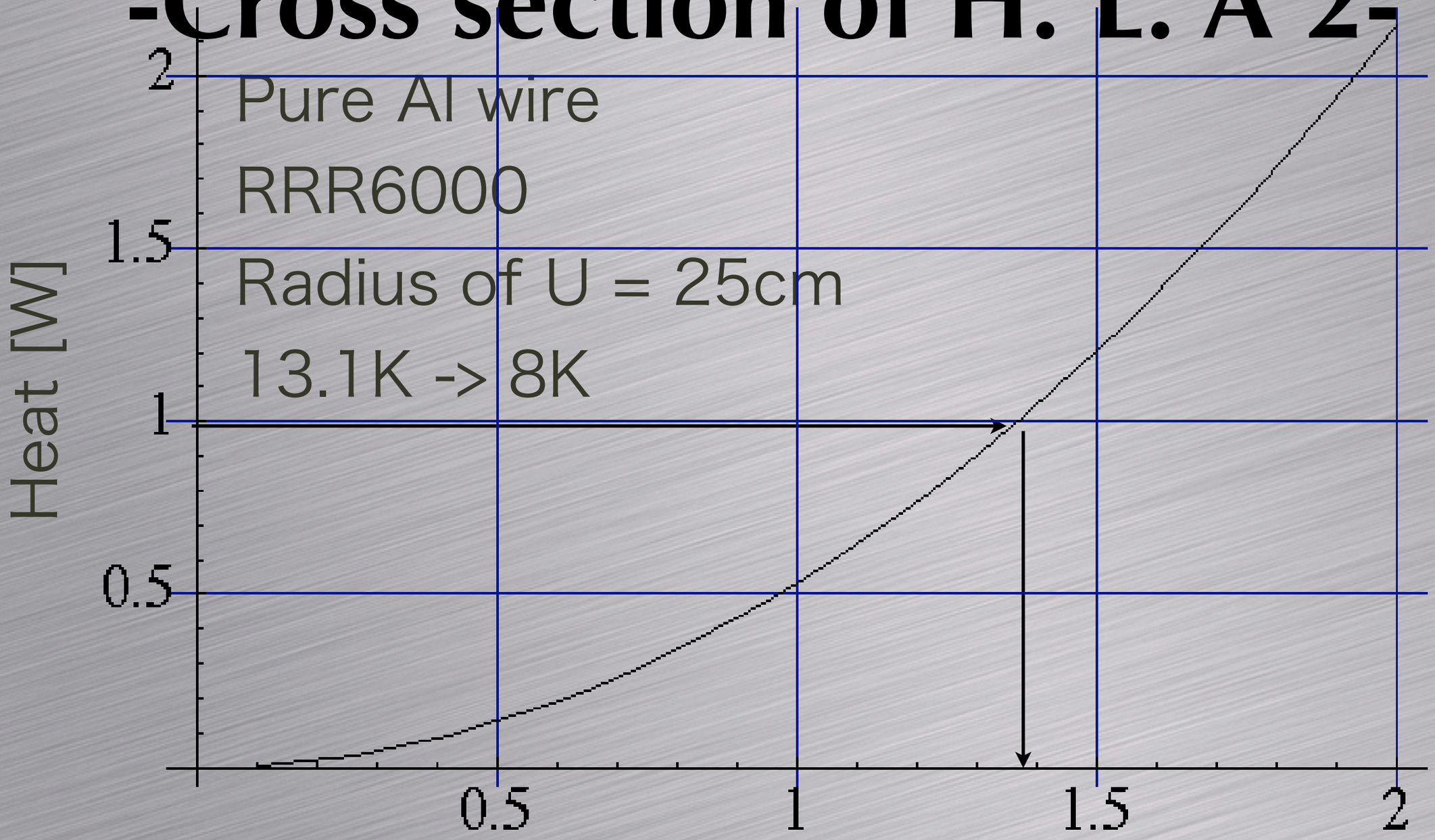
Heat link design 3
-Cross section of H. L. A-

- Temperature difference
  - 13.1K -> 8K
- Thermal conductivity
  - RRR6000, pure Al wire
- Length of wire
  - radius of U = 25cm
  - 0.8m
- Heat
  - 1W=800mW + SPI + etc.



Heat link design 4

-Cross section of H. L. A 2-

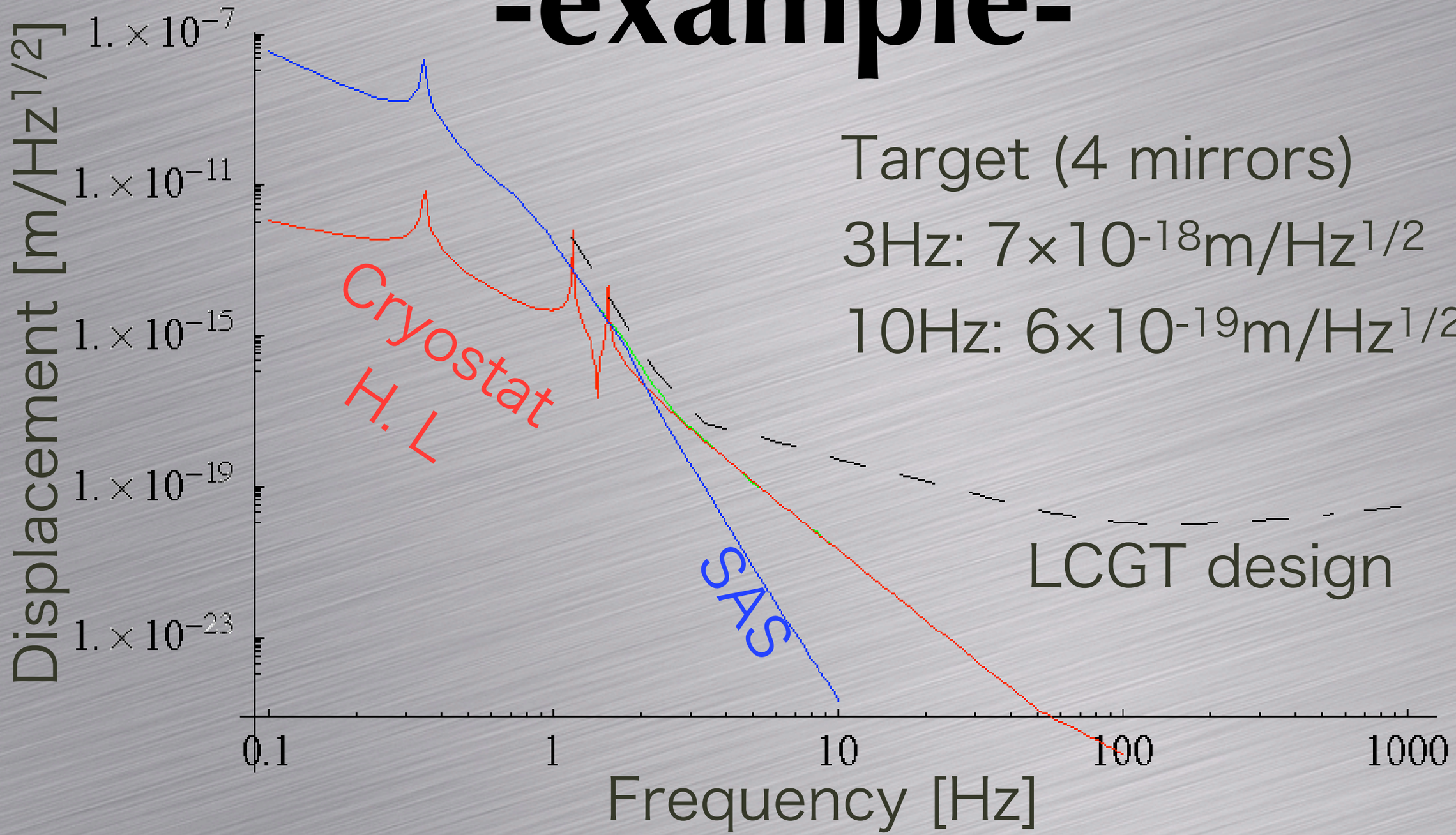


Radius of 1.4 mm is needed.

Heat link design 5 -seismic noise-

- Change diameter and number of wires.
  - must keep cross section for cooling.
- Estimate seismic noise at the mirror.
  - X (light axis), Y, Z direction.
- SAS is excited by normal Kamioka level.
- Cryostat is vibrating 10 × Kamioka level.
- SPI: -40 dB isolation ratio in both X & Z.
- Coupling: 1% is assumed in both Y & Z.
- Design two cases: 3Hz cross & 10Hz cross.
- H. L. b & c are not important for seismic noise.

Heat link design 6 -example-



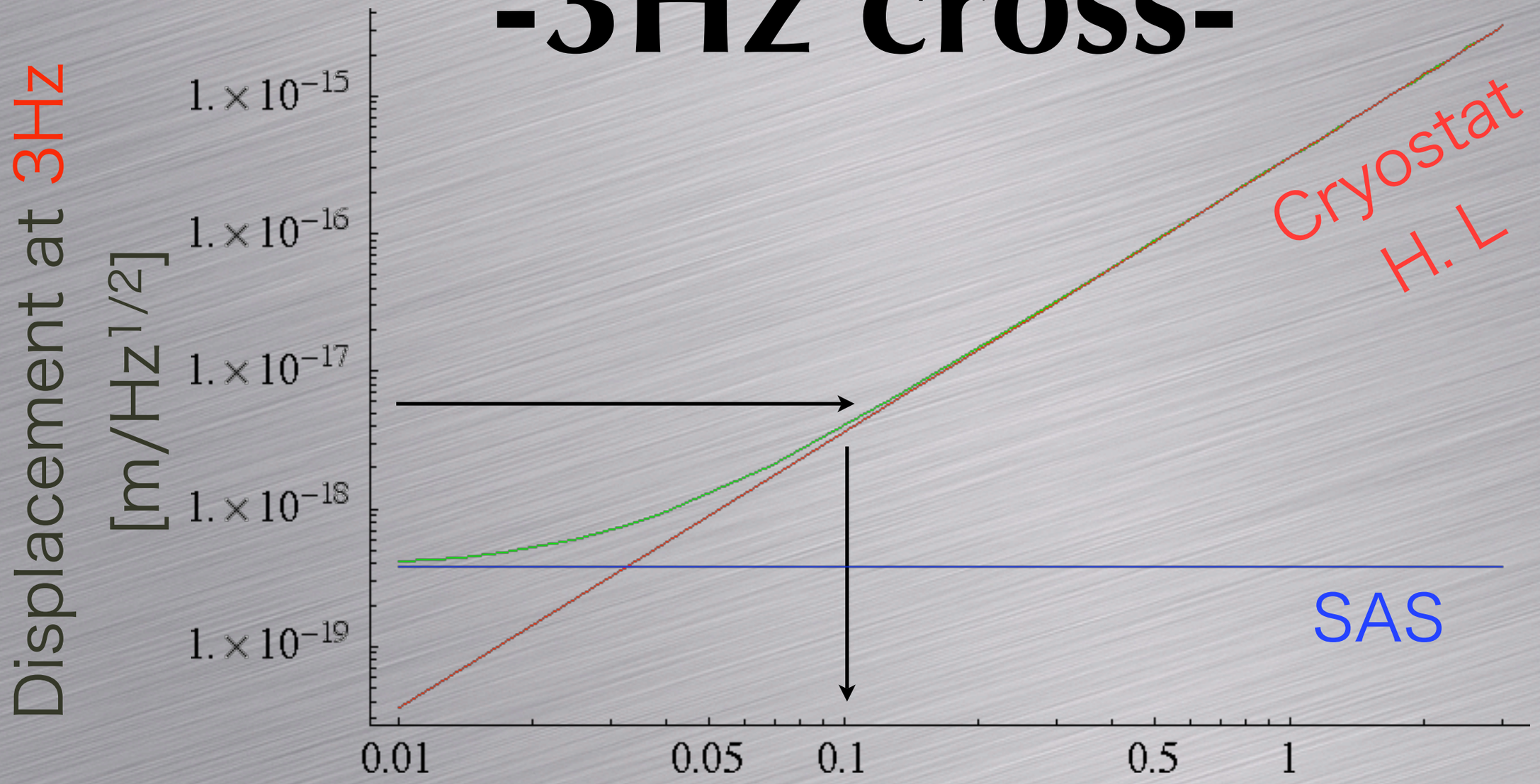
Target (4 mirrors)

3Hz: 7×10^{-18}m/Hz$^{1/2}$

10Hz: 6×10^{-19}m/Hz$^{1/2}$

Search for optimal diameter for H. L. wires.

Heat link design 6
-3Hz cross-

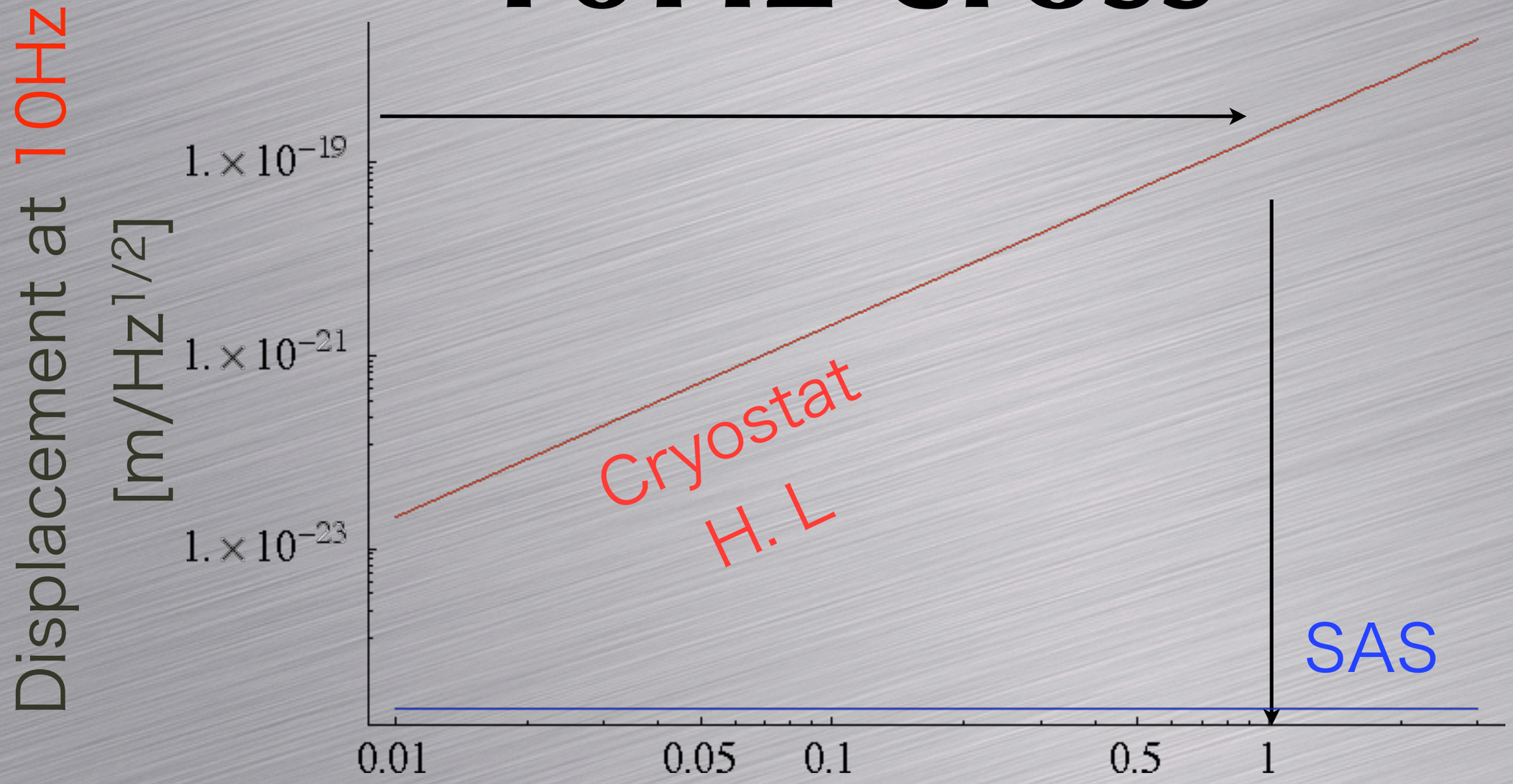


Diameter of wires [mm]

Diameter of 0.1mm is satisfied.

Number of wires 800.

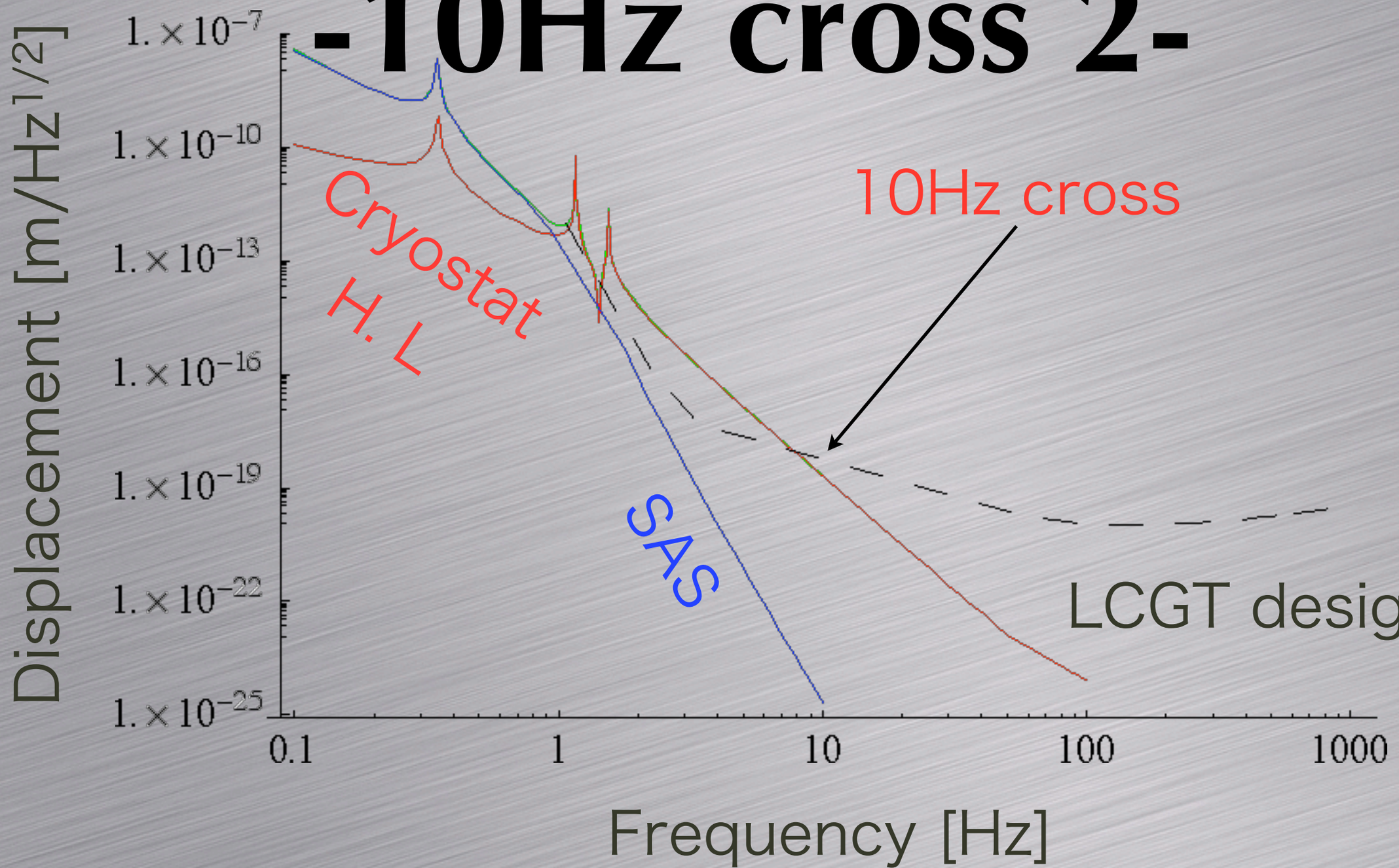
Heat link design 7
-10Hz cross-



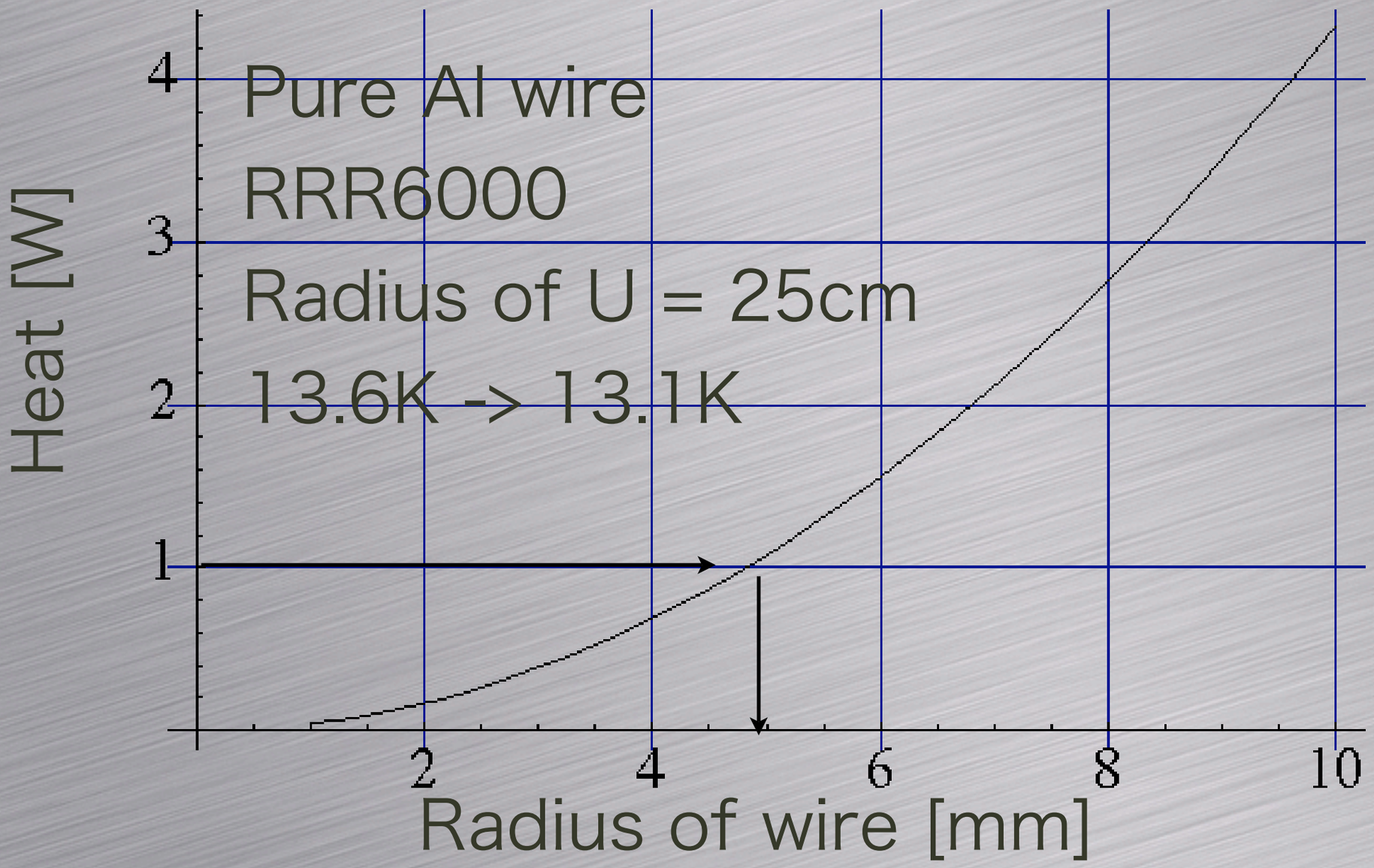
Diameter of 1mm is satisfied.

Number of wires 8.

Heat link design 8
-10Hz cross 2-

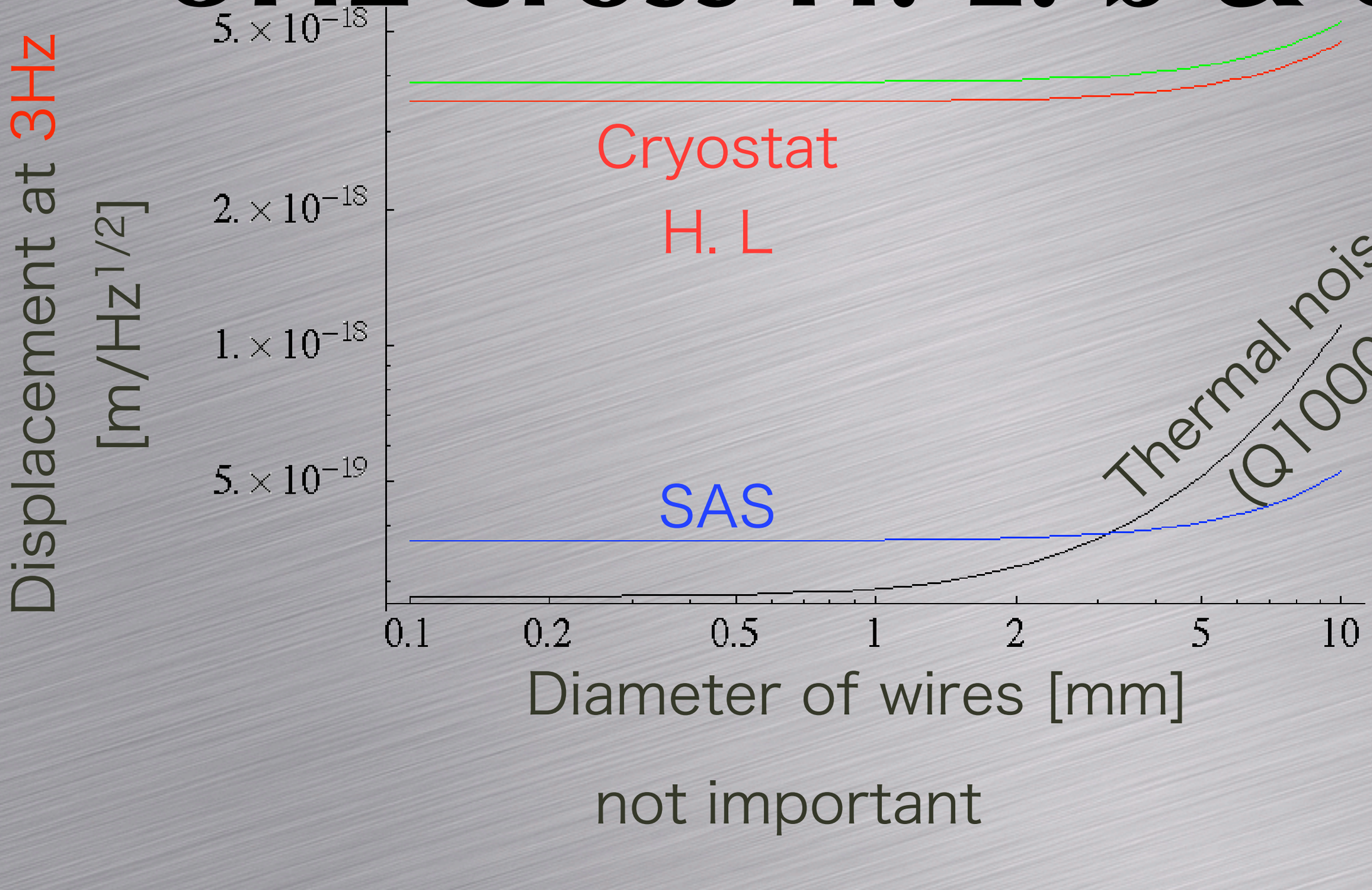


Heat link design 9
-cross section H. L. b &c-



Radius of 5 mm is needed.

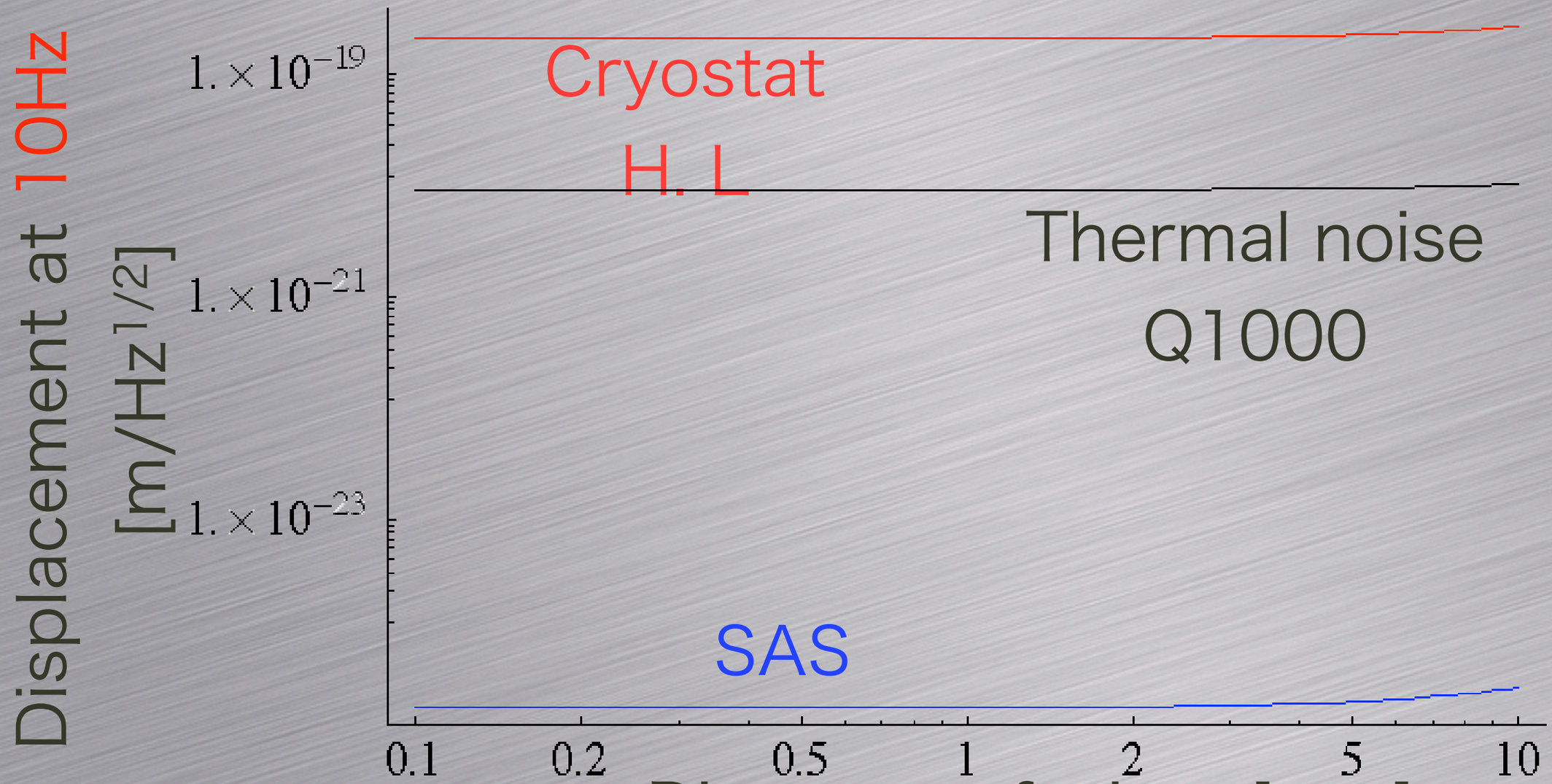
Heat link design 10
-3Hz cross H. L. b & c-



not important

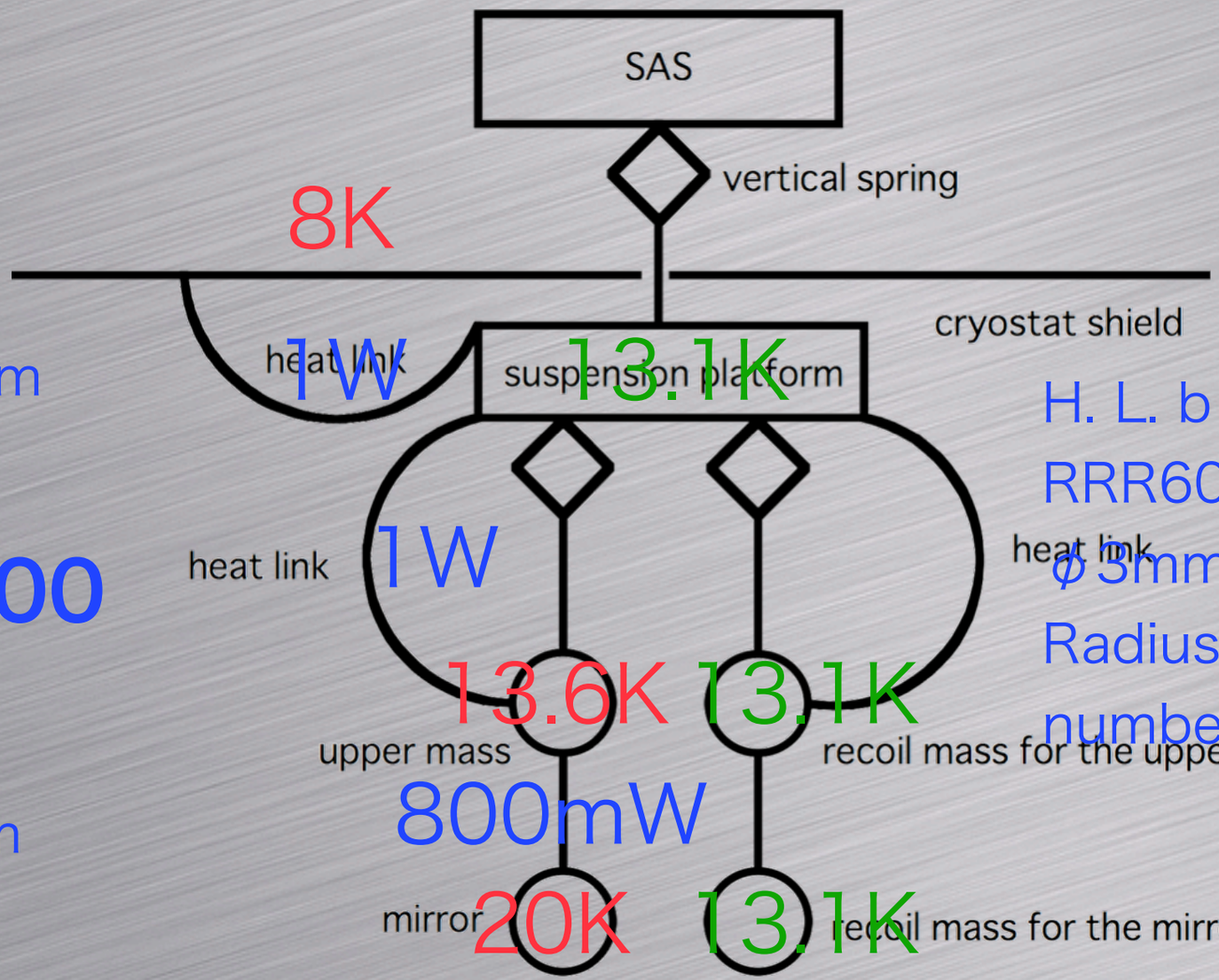
Heat link design 11

-10Hz cross H. L. b & c-



not important

Heat link design 12
-summary of parameter-
3Hz cross



H. L. A
RRR6000
Radius of U: 25cm
ϕ0.1mm
number: 800

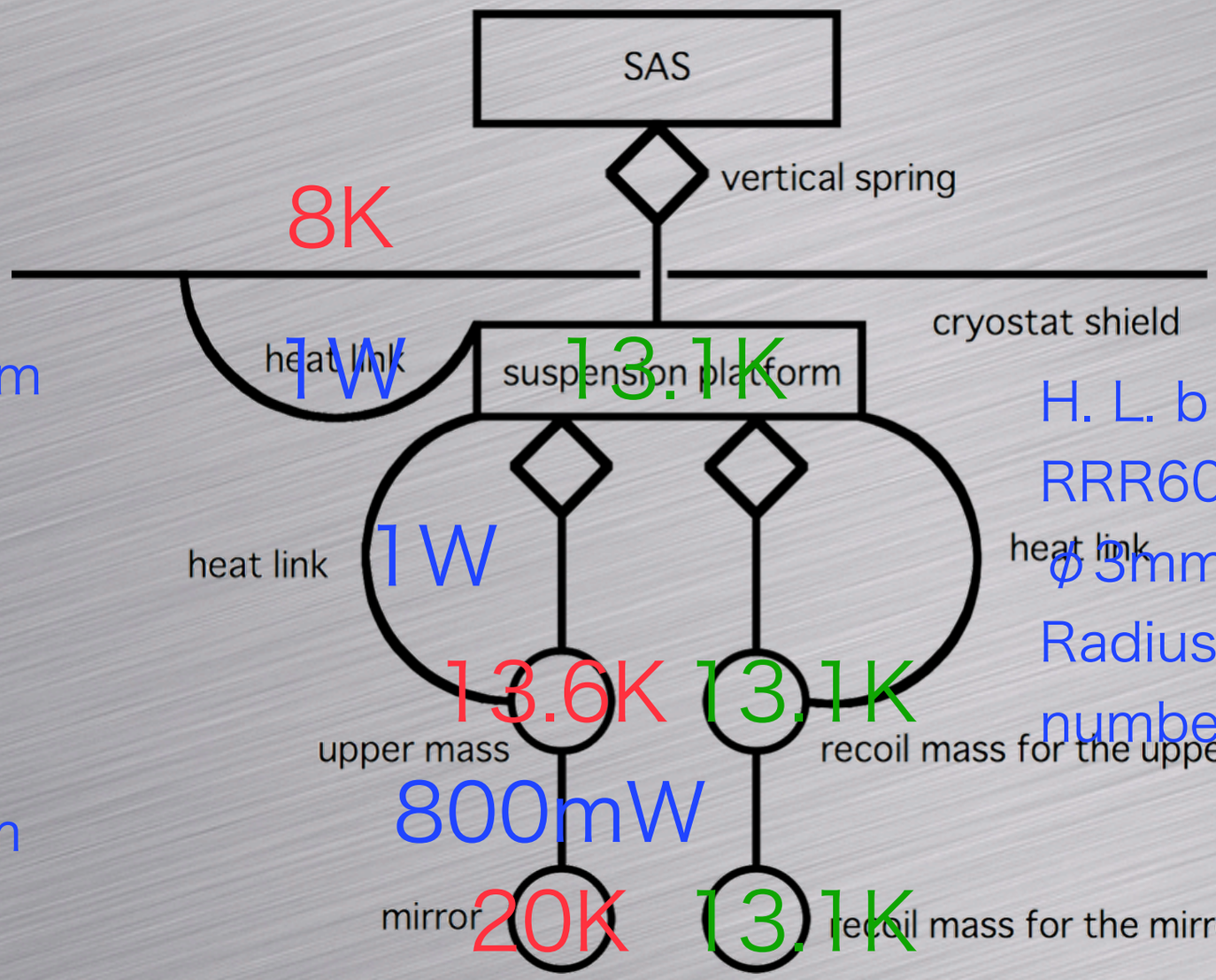
Sapphire fiber
4×ϕ1.8mm×50cm

H. L. b & c
RRR6000
ϕ3mm
Radius of U: 25cm
number: 12

Heat link design 13
-summary of parameter-
10Hz cross

H. L. A
RRR6000
Radius of U: 25cm
φ1mm
number: 8

Sapphire fiber
4×φ1.8mm×50cm

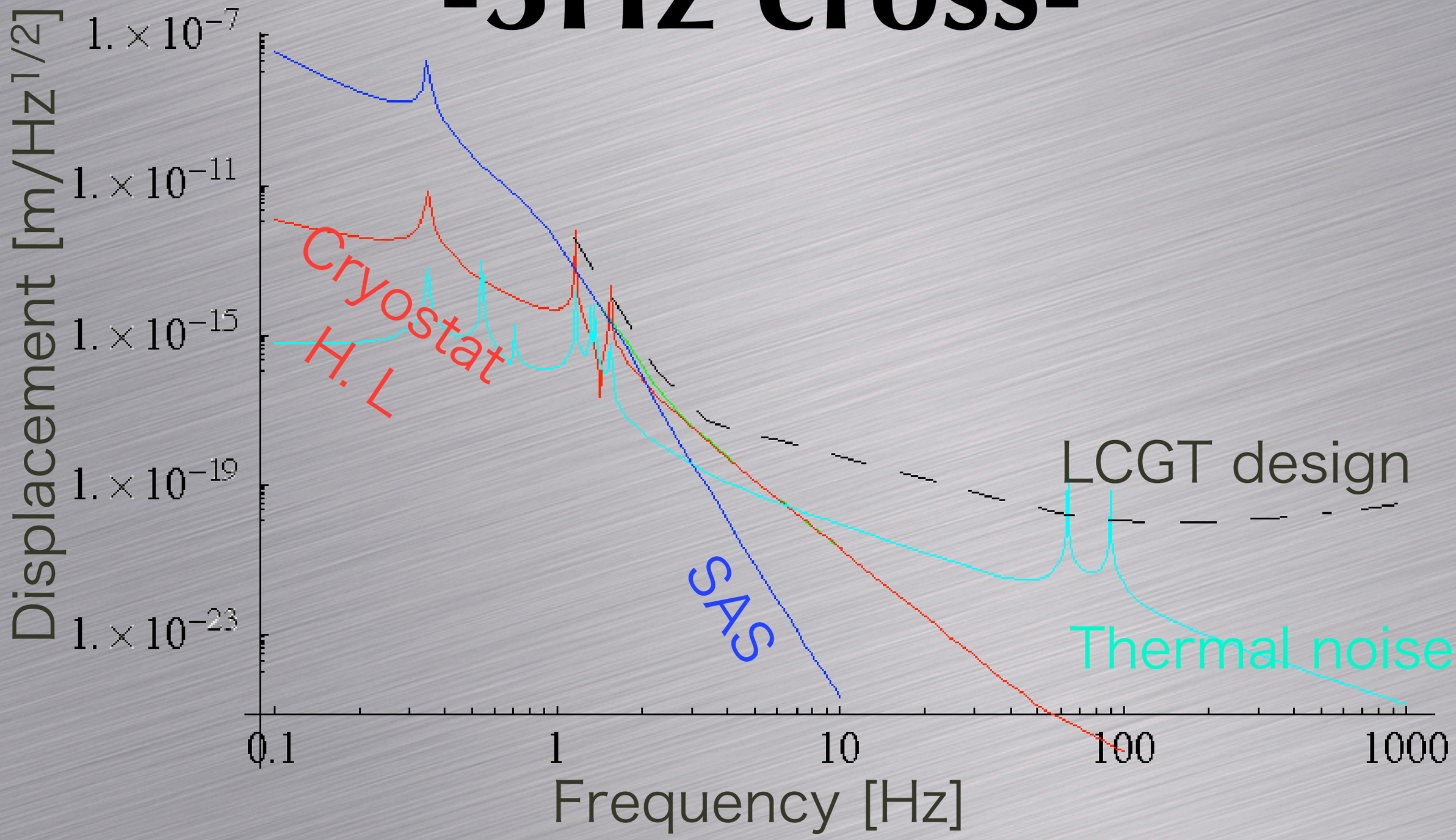


H. L. b & c
RRR6000
φ3mm
Radius of U: 25cm
number: 12

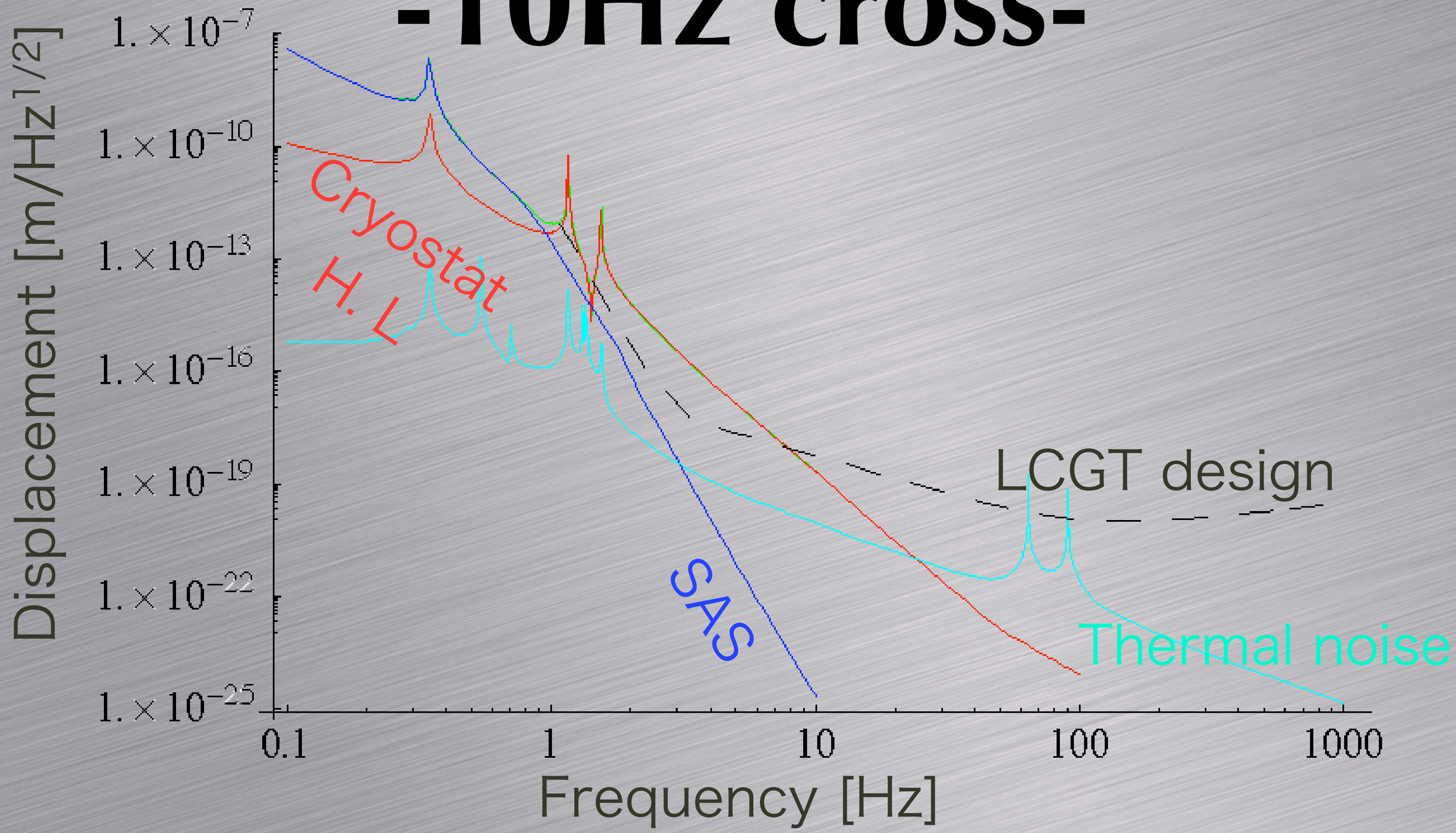
Summary

- Design the heat links for two cases.
  - including design of the cryogenic suspension and temperatures.
- Obviously, 10Hz cross is much easier than 3Hz cross.

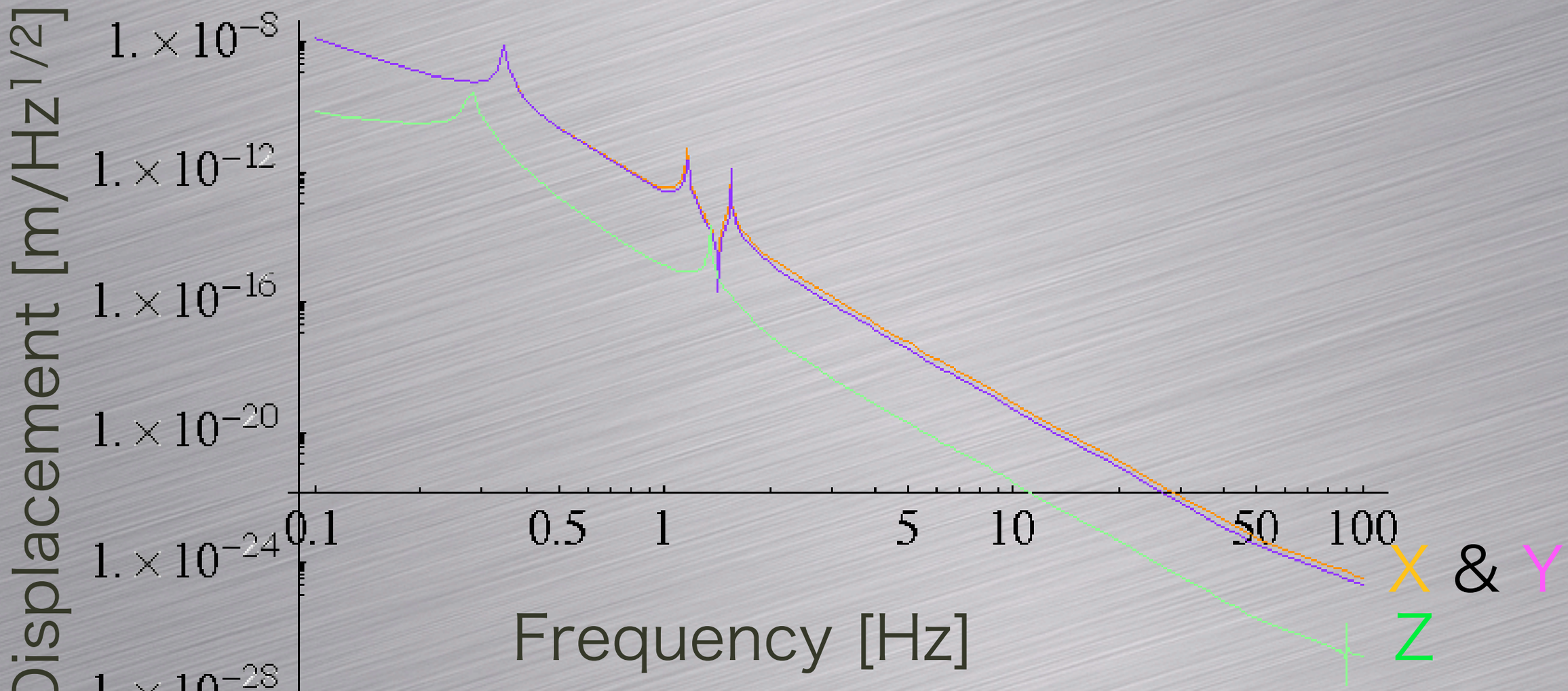
All component -3Hz cross-



All component -10Hz cross-



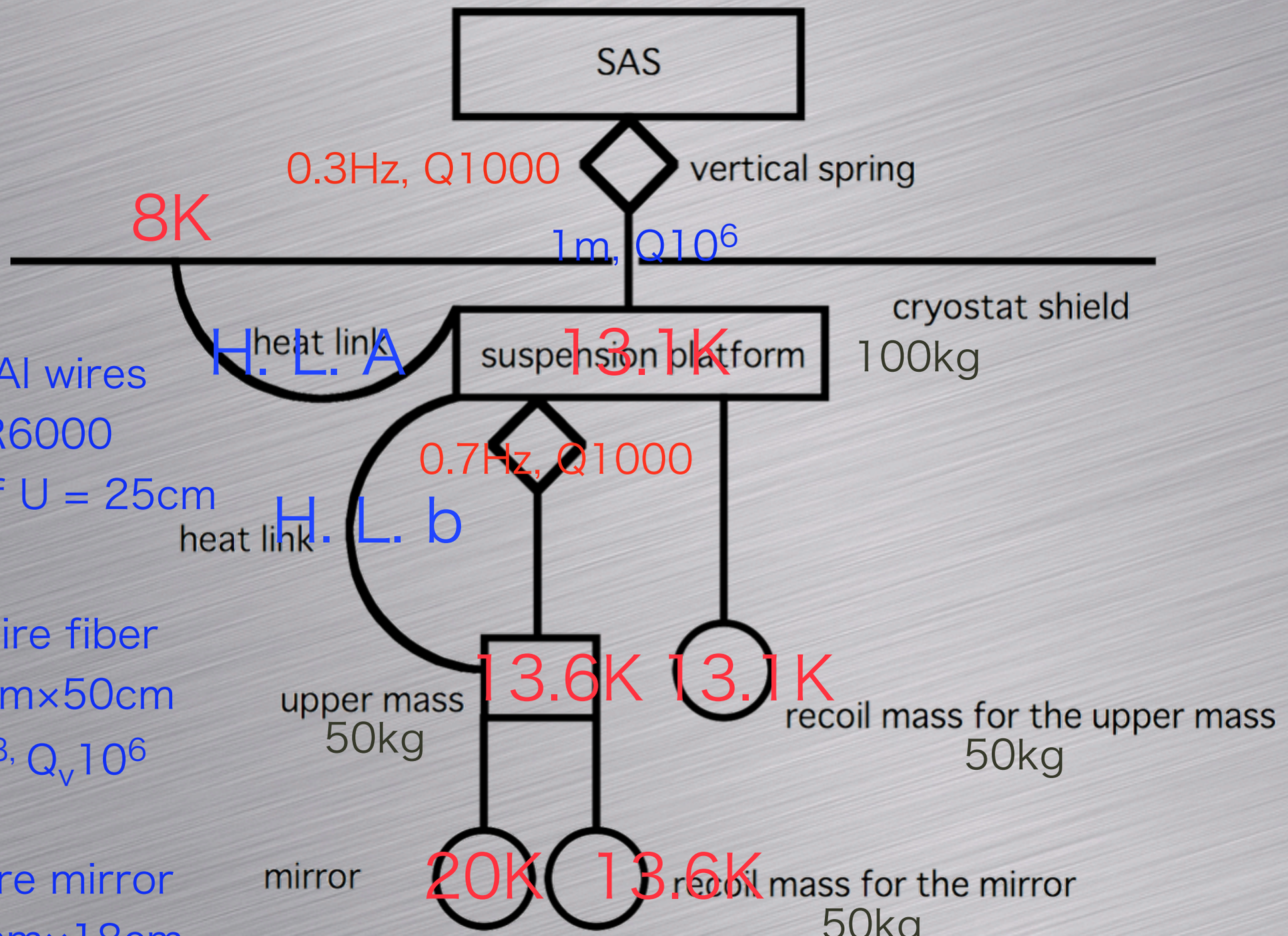
Contribution by each directions



Vertical is not serious.

use VSPI or a mGAS (platform) is enough.

Revised model

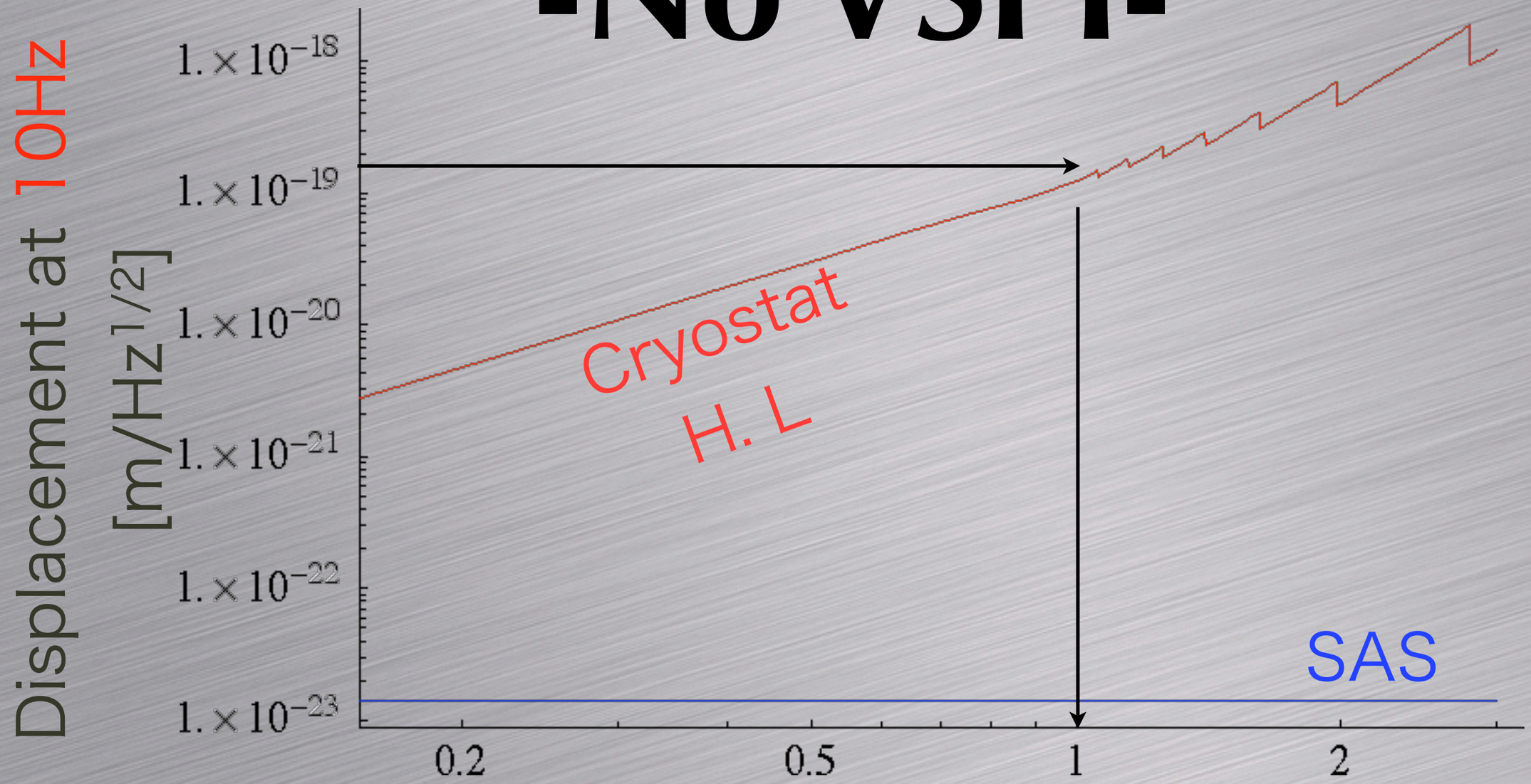


Pure Al wires
RRR6000
Radius of U = 25cm

Sapphire fiber
ϕ1.8mm×50cm
$Q_h 10^8$, $Q_v 10^6$

Sapphire mirror
ϕ300mm×18cm
50kg, 20K

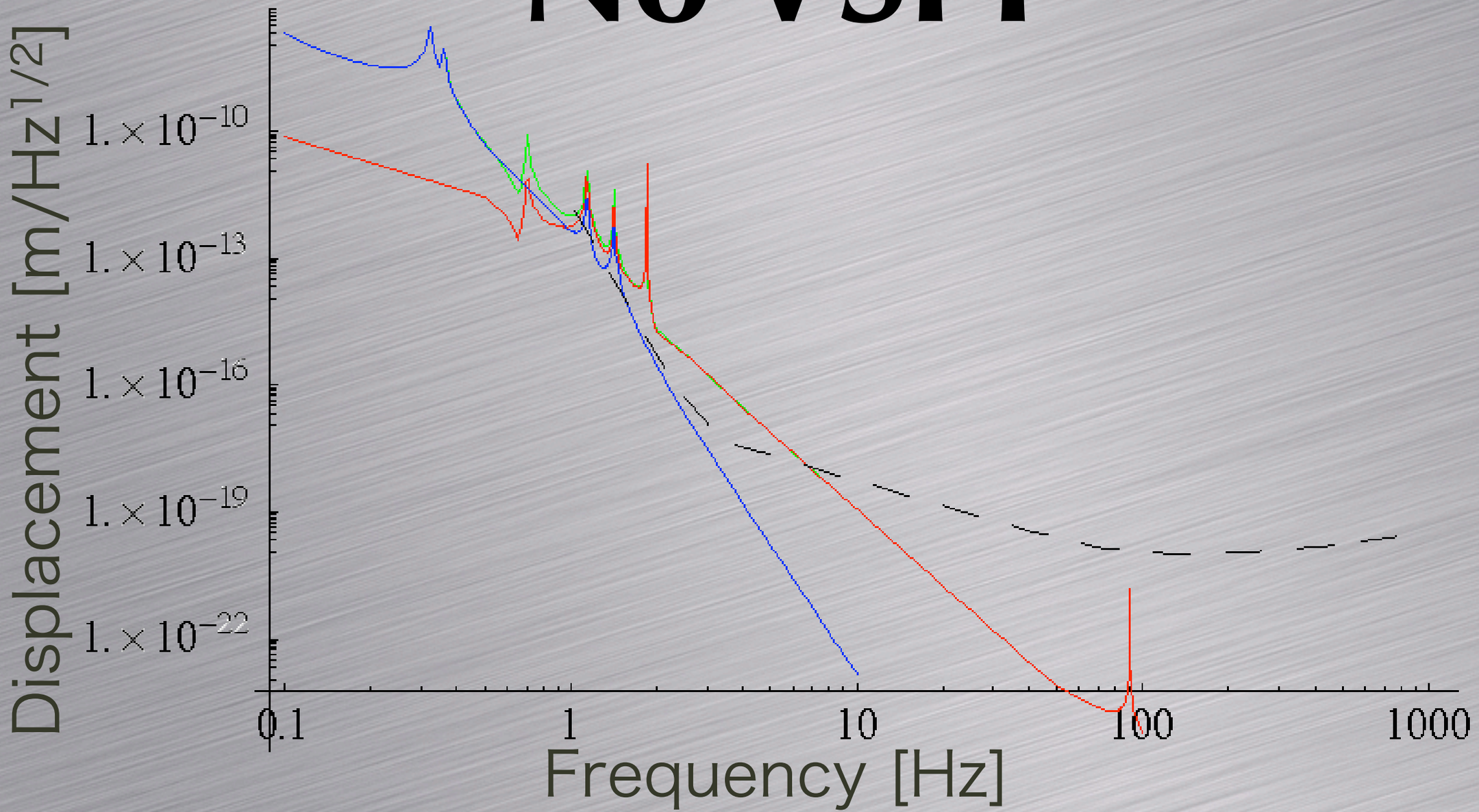
With mGAS (0.7Hz)
-No VSPI-



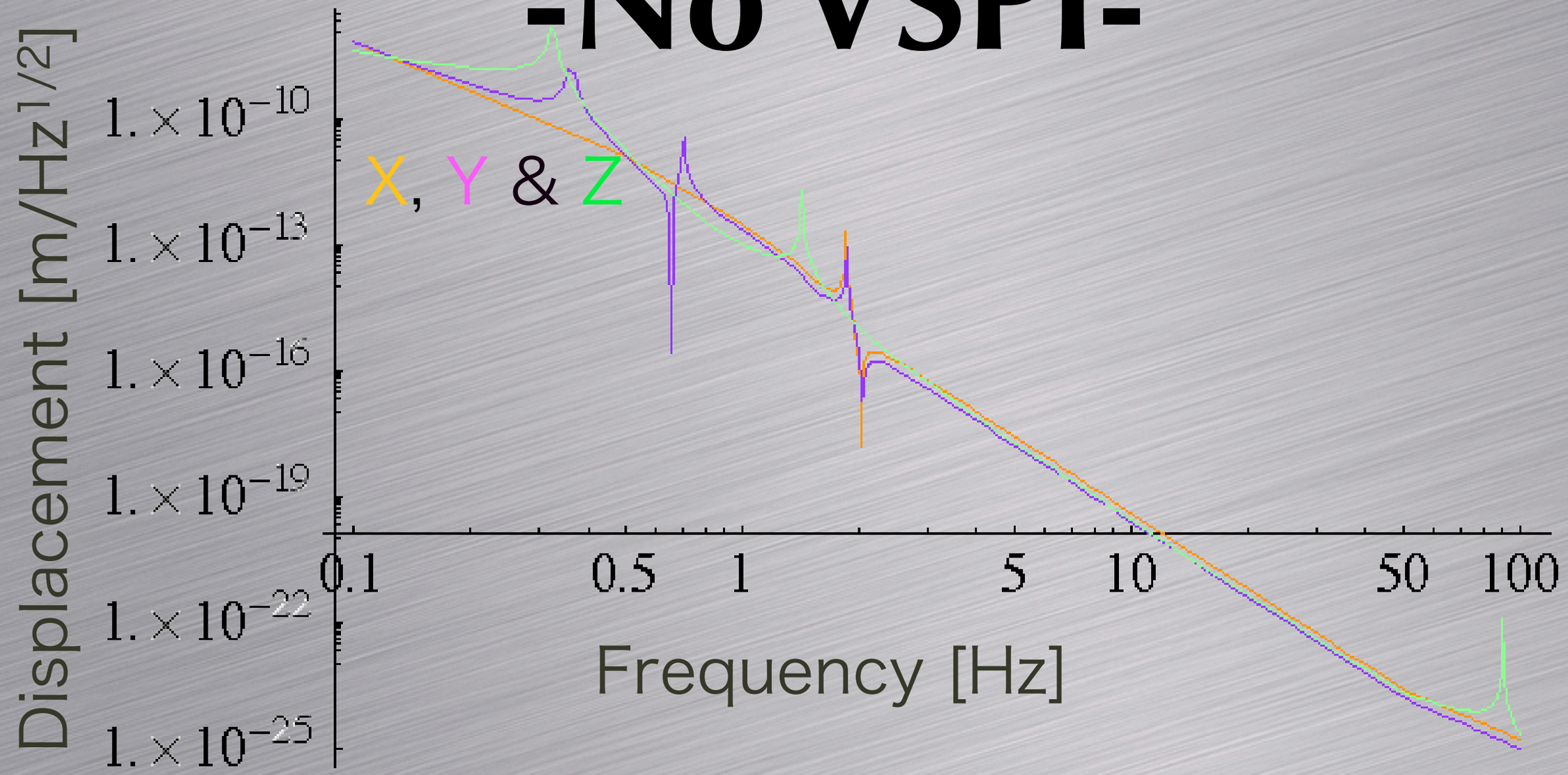
Diameter of 1mm is satisfied as well as the old model.

Number 8

With mGAS (0.7Hz) 2 -No VSPI-

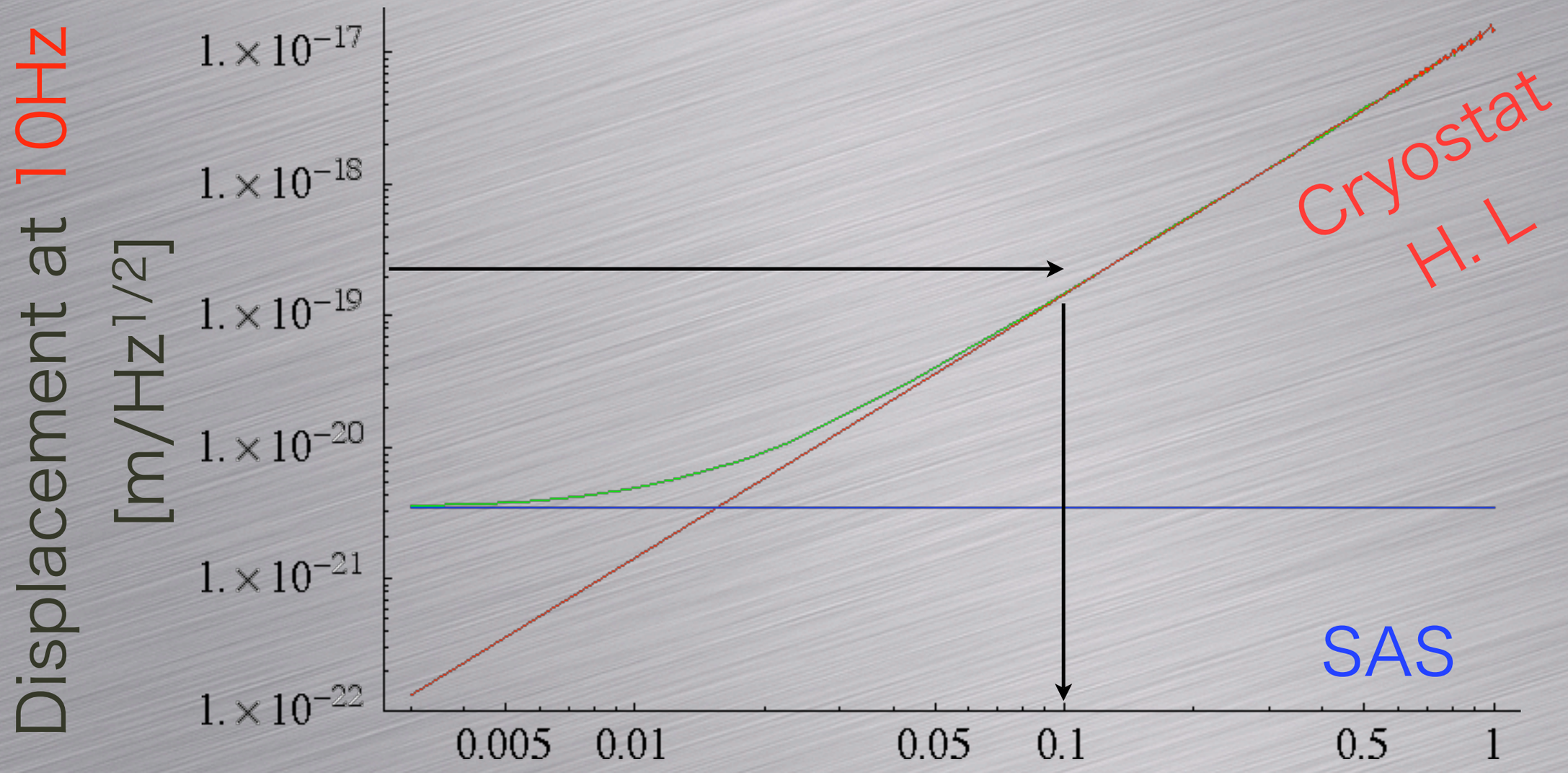


With mGAS (0.7Hz) 3 -No VSPI-



Contribution of all 3 directions are almost the same.

Without mGAS

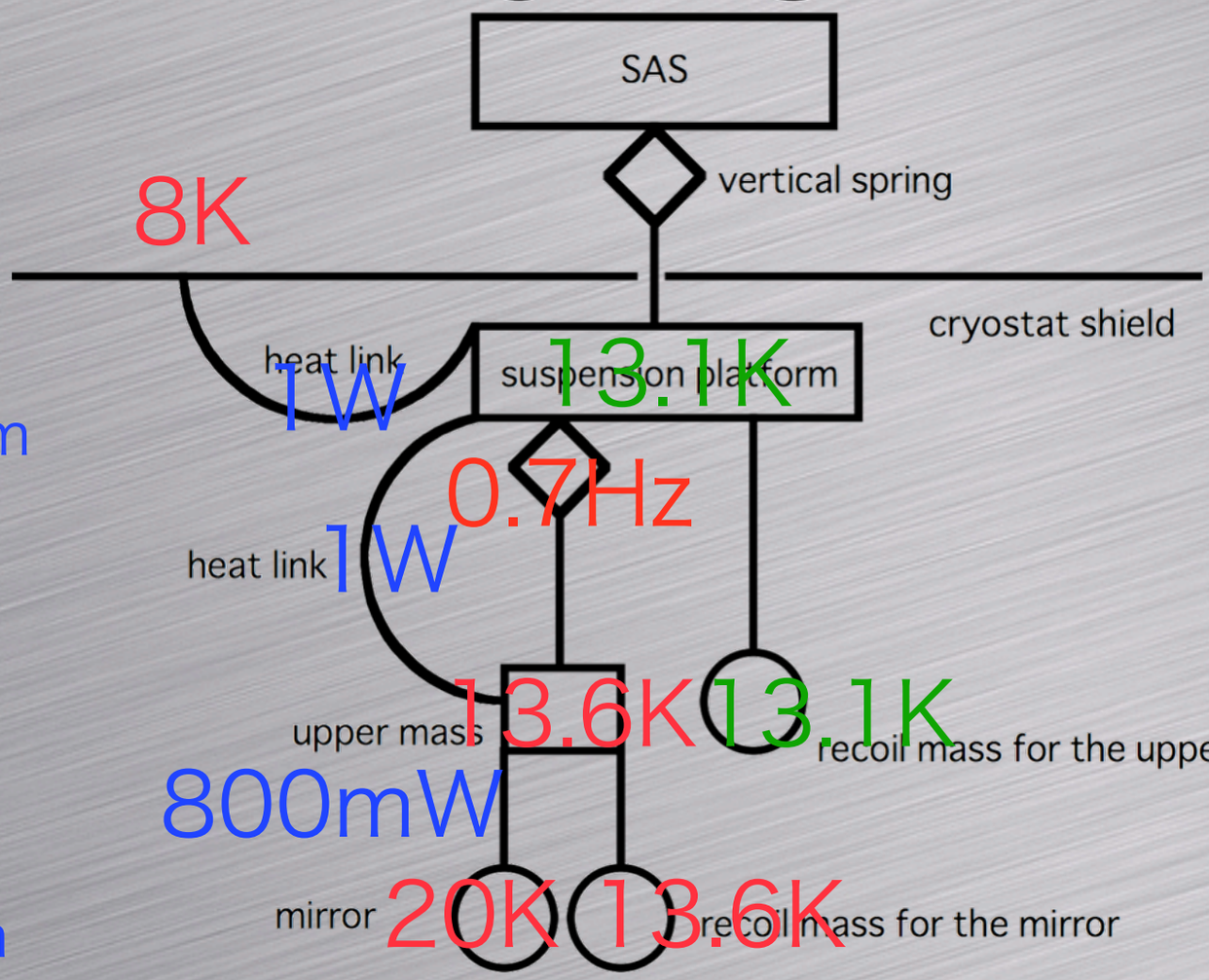


Diameter of wire [mm]

Diameter of 0.1mm is satisfied.

mGAS in the suspension platform has important roll for vibration isolation of the heat link.

Summary of parameters
New model
No VSPI



H. L. A
RRR6000
Radius of U: 25cm
ϕ1mm
number: 8

Sapphire fiber
4×ϕ1.8mm×50cm

H. L. b
RRR6000
ϕ3mm
Radius of U: 25cm
number: 12

New summary

- Design the heat link for the new model without VSPI.
- VSPI or the mGAS (0.7Hz) in the suspension platform is assisted the heat link design greatly.
- Without VSPI and the mGAS, we should consider an additional vibration isolation stage for the heat link.