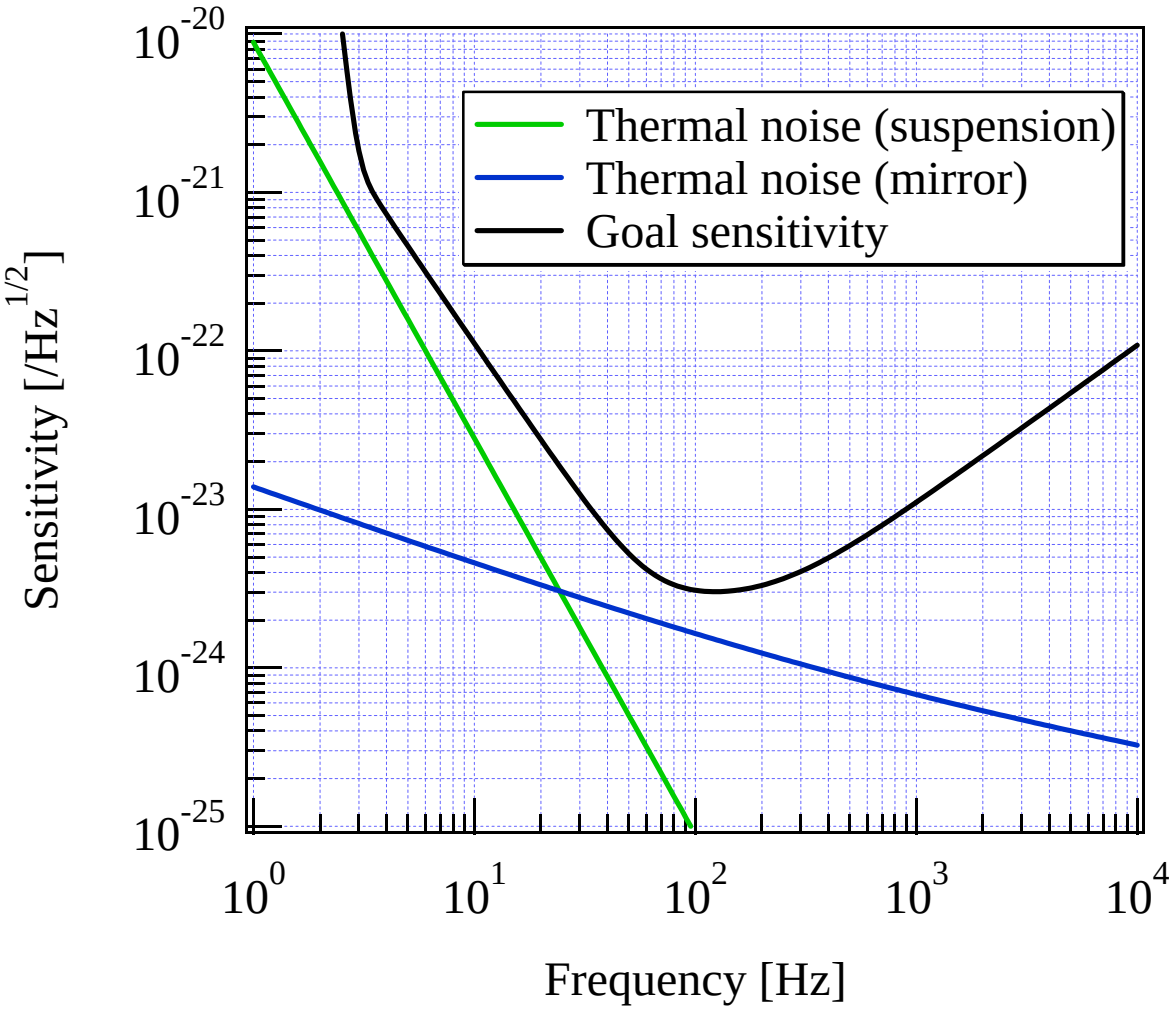
Thermal noise of LCGT interferometer

ICRR Univ. of Tokyo

K. Yamamoto

2004 April 26
The meeting of LCGT design working group
@Hongo campus, University of Tokyo

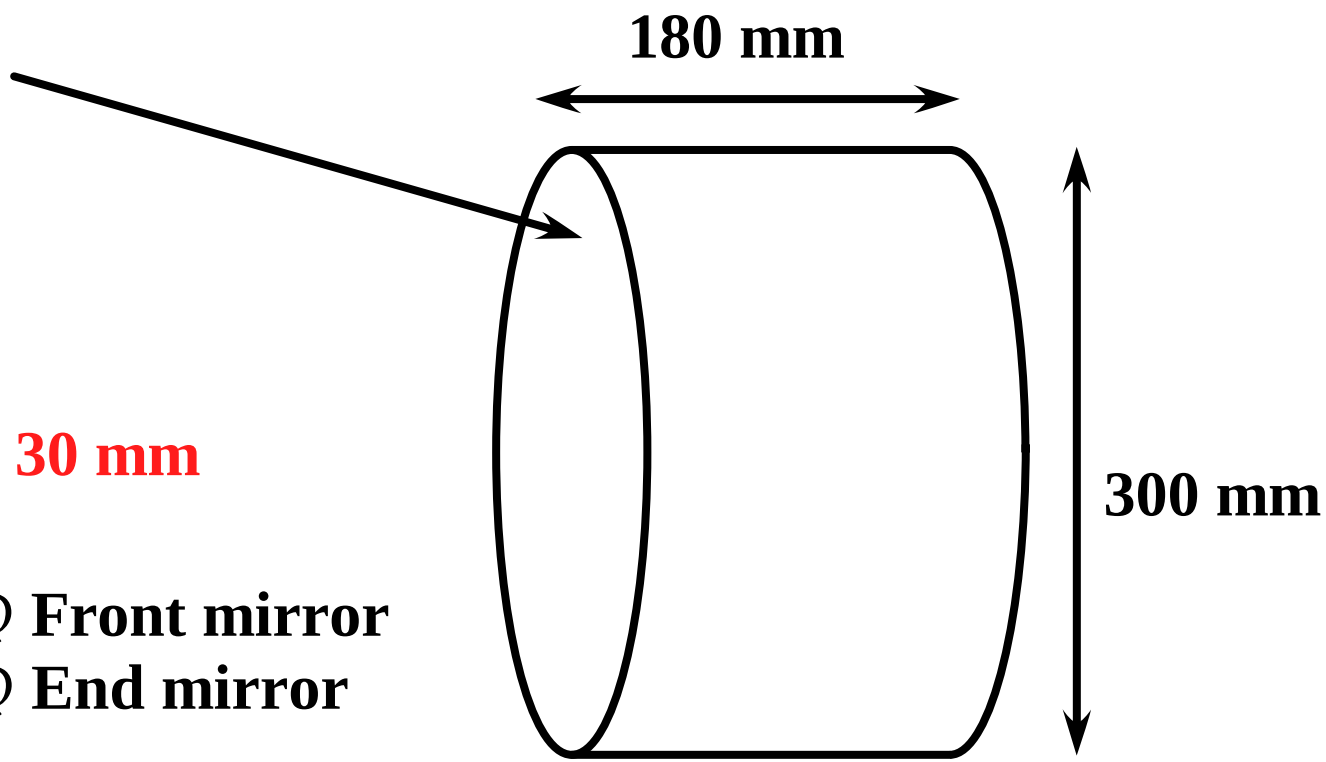
Goal sensitivity of LCGT



1. Mirror

1-1. Specification

Sapphire, 20K
(Uchiyama)



Beam radius : 30 mm

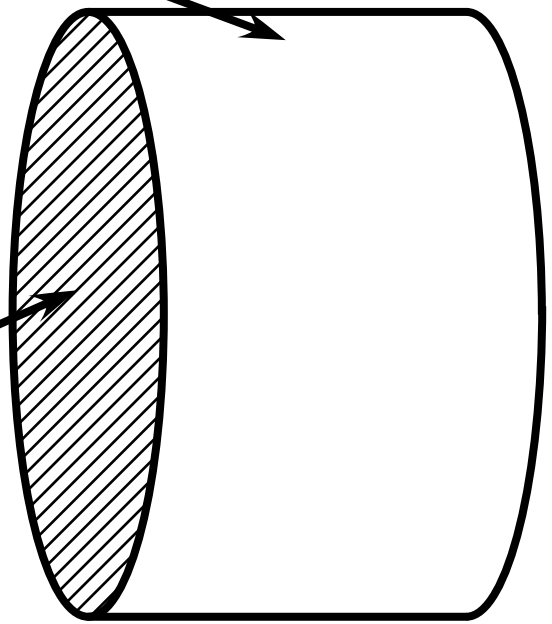
26.8 mm @ Front mirror
46.4 mm @ End mirror

1-2. Mechanical loss

Substrate

(i) structure : Q=10^8 (Uchiyama)

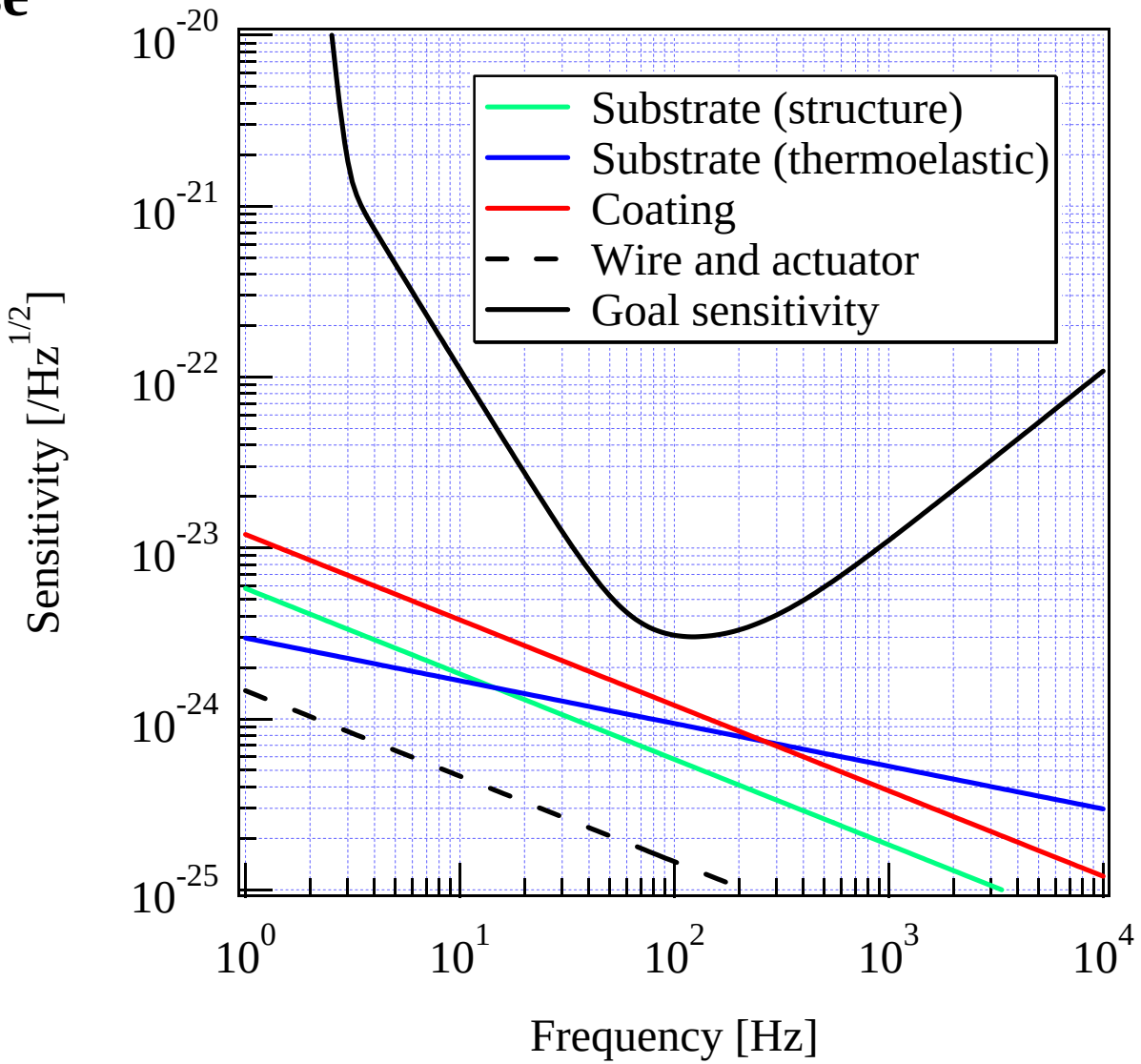
(ii)thermoelastic



Coating : ϕ=$4*10^{-4}$ (Yamamoto)

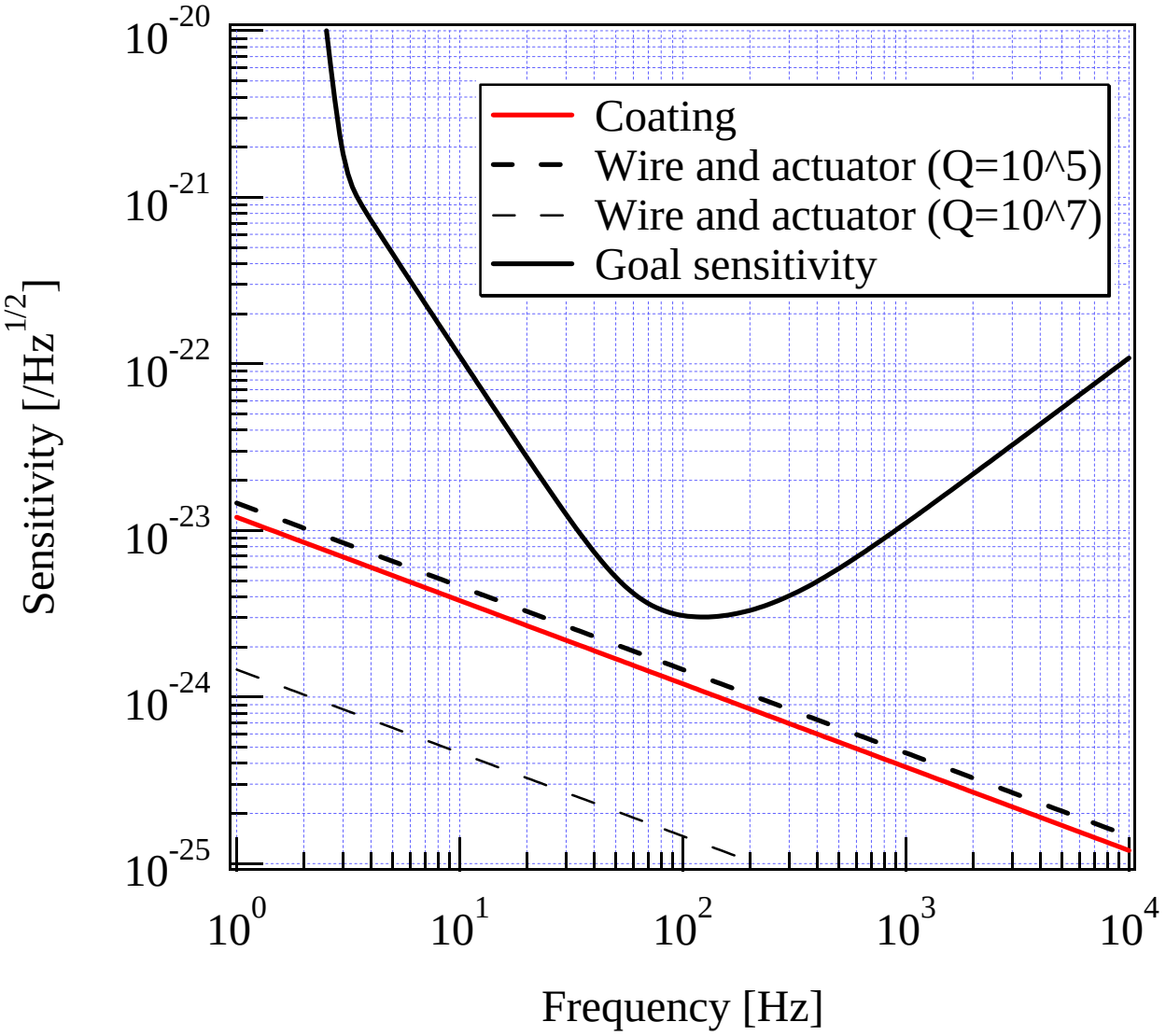
Wire clamps and actuator: Q=10^7 (Miyoki)

1-3. Thermal noise



1-4. Upper limit of loss of wire clamps and actuator

Q > 2*10^5



1-5. Future works

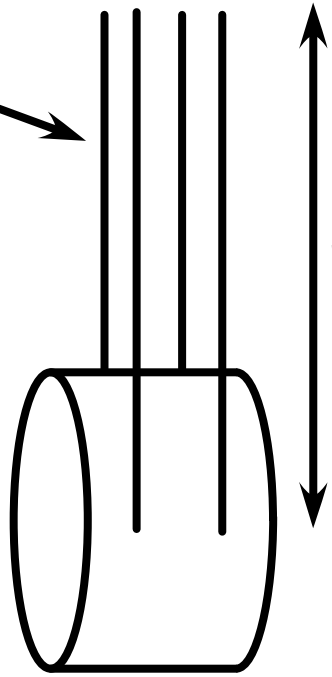
Measurement of the loss of wire clamps and actuator

2. Suspension

Final stage, pendulum and violin modes

2-1. Specification

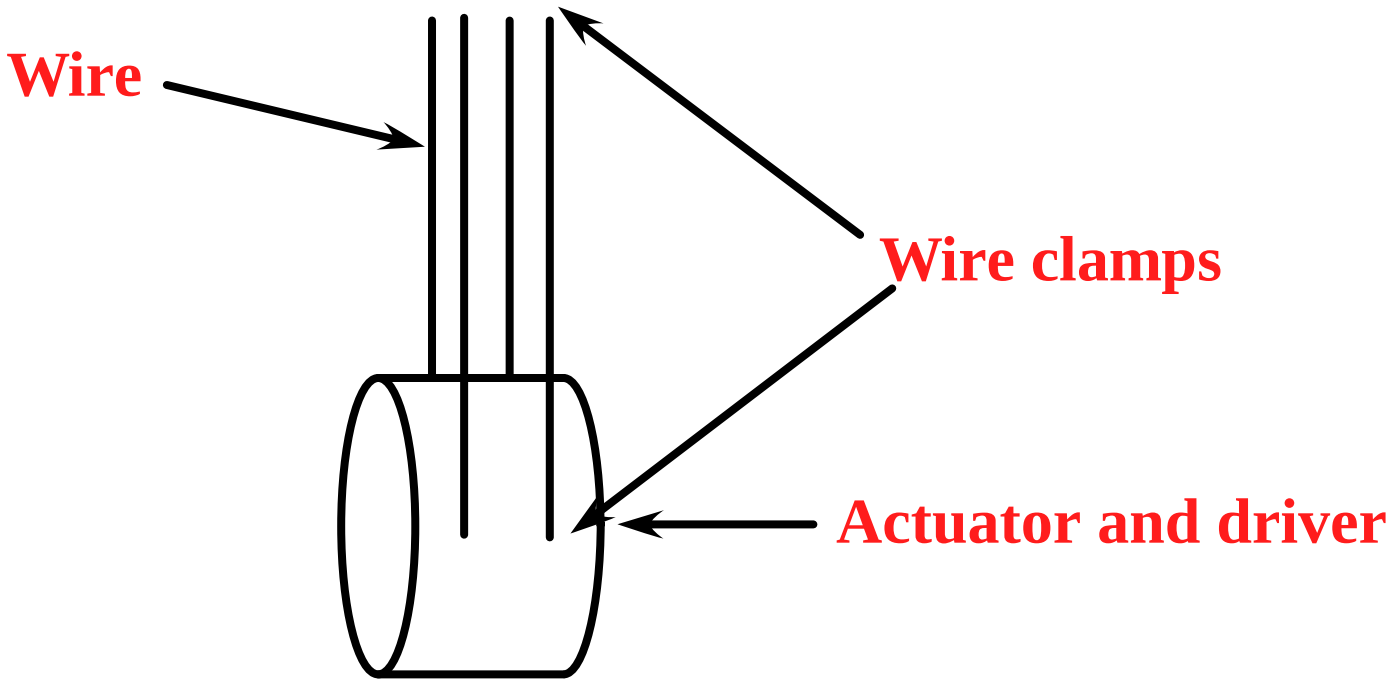
4 sapphire fibers
(Uchiyama)
ϕ=1.8 mm



Pendulum mode : 0.705 Hz
n-th violin mode : 111*n Hz
(problem
in detuned interferometer)

Temperature
10K ⟶ 20K

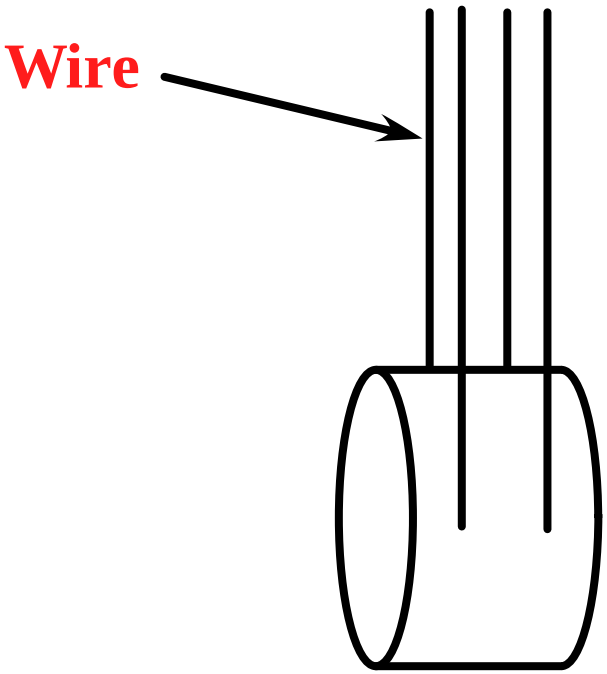
2-2. Mechanical loss



Goal sensitivity : only pendulum mode of wire loss

2-3. Wire

(i)Q-values

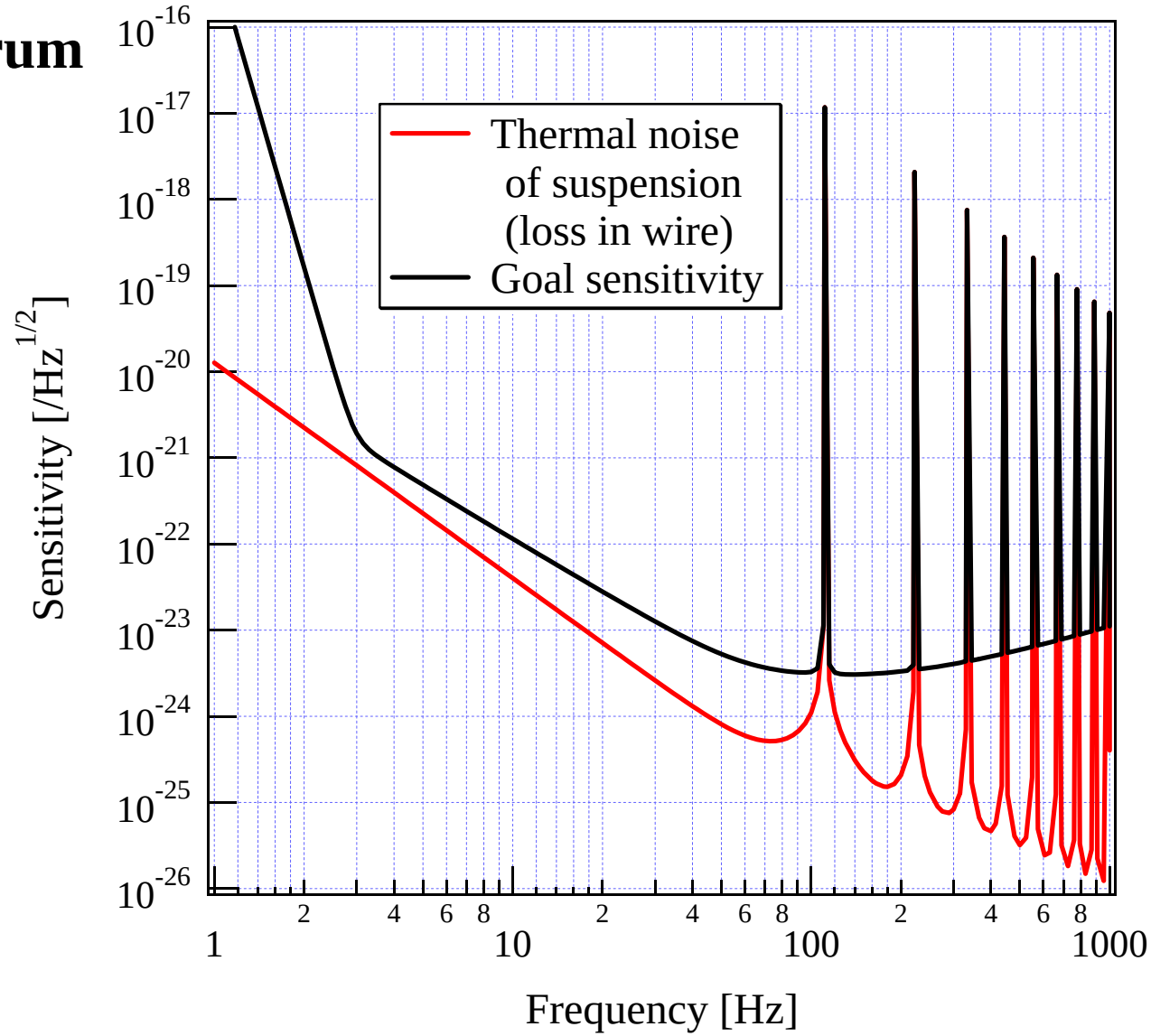


Q **of wire :** $5*10^6$ **(Uchiyama)**

Q **of pendulum :** $1.2*10^8$

Q **of violin :** $6*10^7$

(ii) Power spectrum



(iii)Observable distance of binary coalescence

Width of violin peaks

1st (111 Hz) : 7 Hz
2nd (221 Hz) : 2.3 Hz
3rd (332 Hz) : 1 Hz
4th (443 Hz) : 0.6 Hz

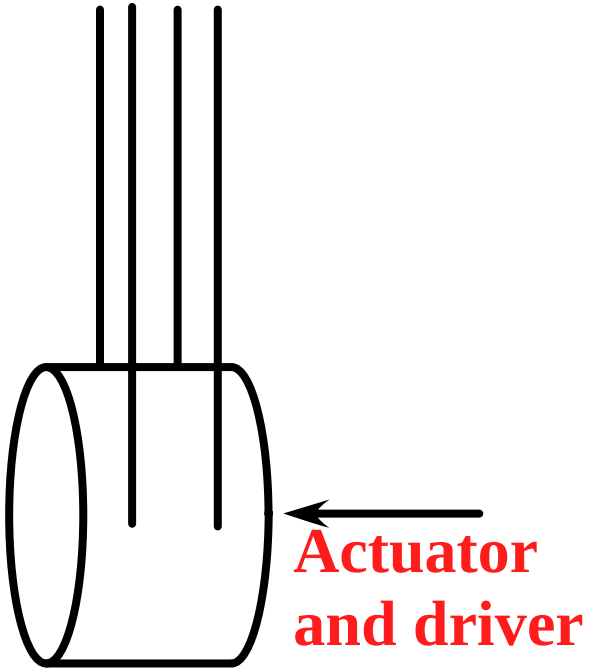
Observable distance

without violin peaks : 255 Mpc
with violin peaks : 248 Mpc (event rate : -9%)
split : 245 Mpc ? (event rate : -11%)

2-4. Actuator and driver

(i)Specification

Actuator = Coil + Resistance (50 Ω, 300K)



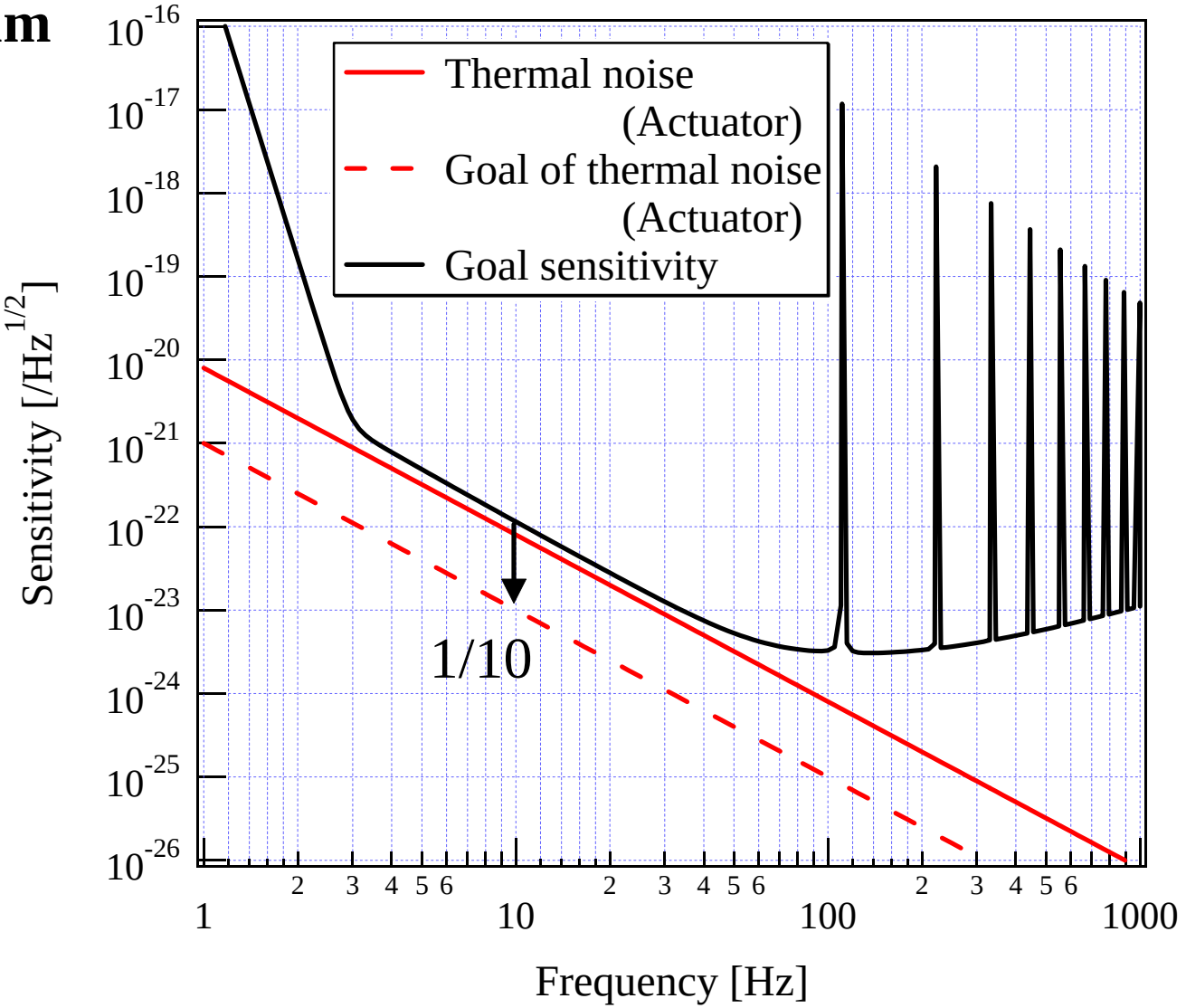
Dynamic range of actuator : 1 μm
Max of current : 0.2 A
4 actuator

↓

Coil efficiency : $6.6*10^{-4}$ N/A

***Q* of pendulum : $6.4*10^{9}$**
***Q* of n-th violin : $1.2*10^{16}*n^{3}$**

(ii)Power spectrum



(iii)Solutions

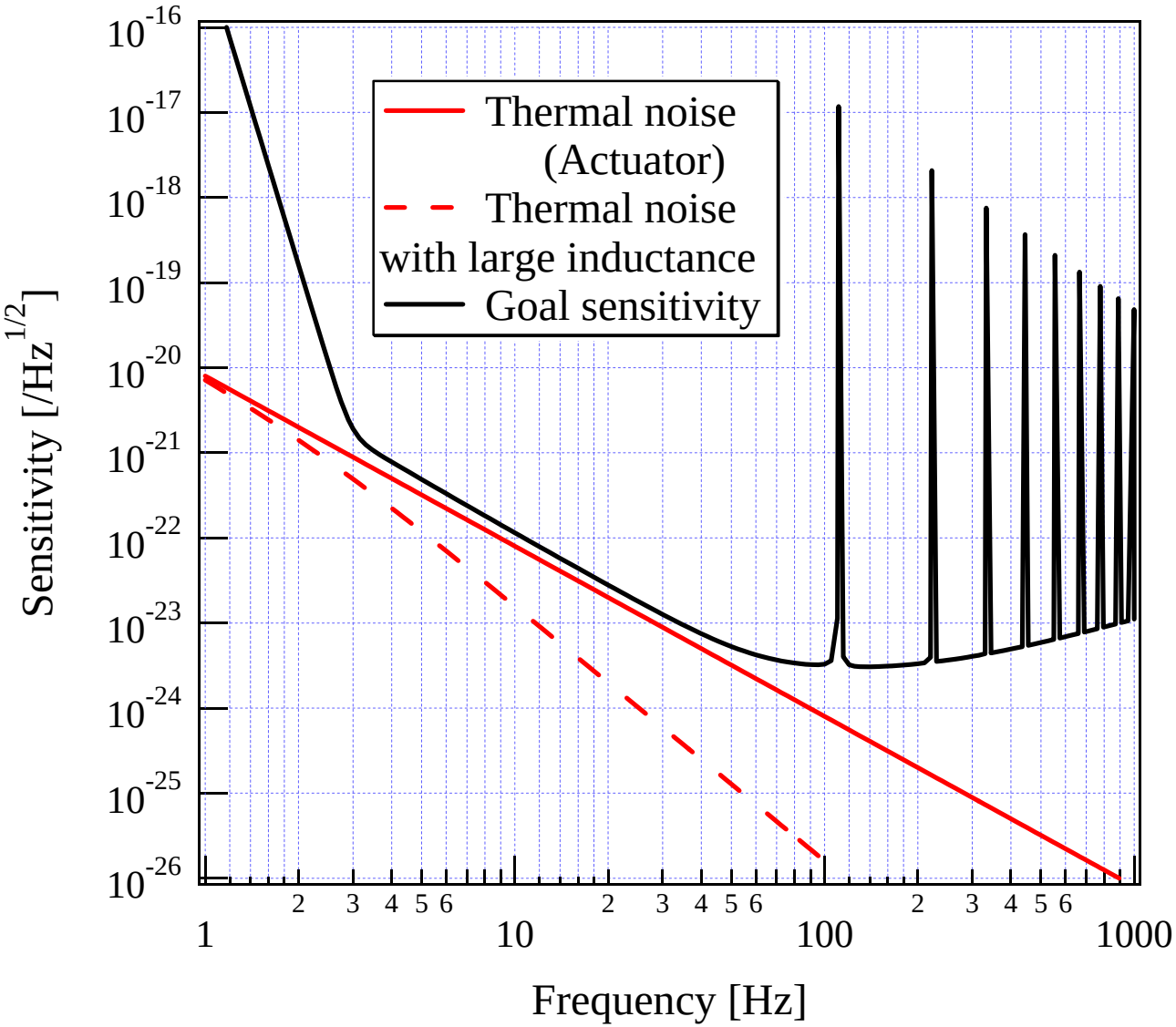
(1) Larger resistance : 5 kΩ

(2) Larger max of current : 2 A

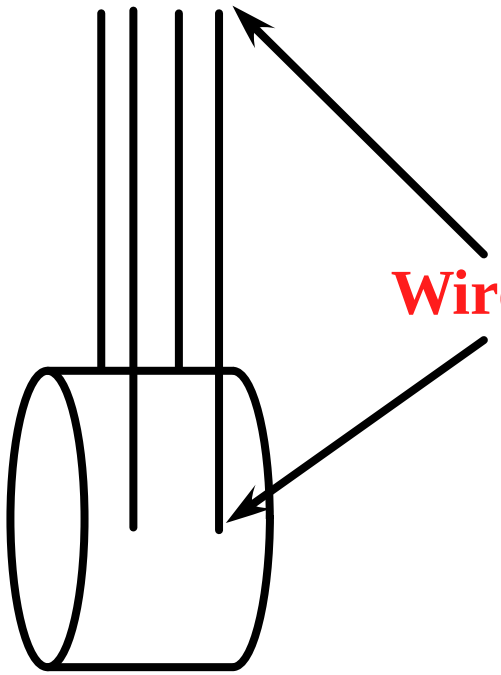
driver noise and heat

(3) Cryogenic driver : 4 K

(4) Larger inductance : 4 H


Thermal noise
(Actuator)
Thermal noise
with large inductance
Goal sensitivity
Sensitivity [/Hz^1/2]
10^-16
10^-17
10^-18
10^-19
10^-20
10^-21
10^-22
10^-23
10^-24
10^-25
10^-26
1
2 3 4 5 6
10
2 3 4 5 6
100
2 3 4 5 6
1000
Frequency [Hz]

2-5. Wire clamps



Unknown

↓

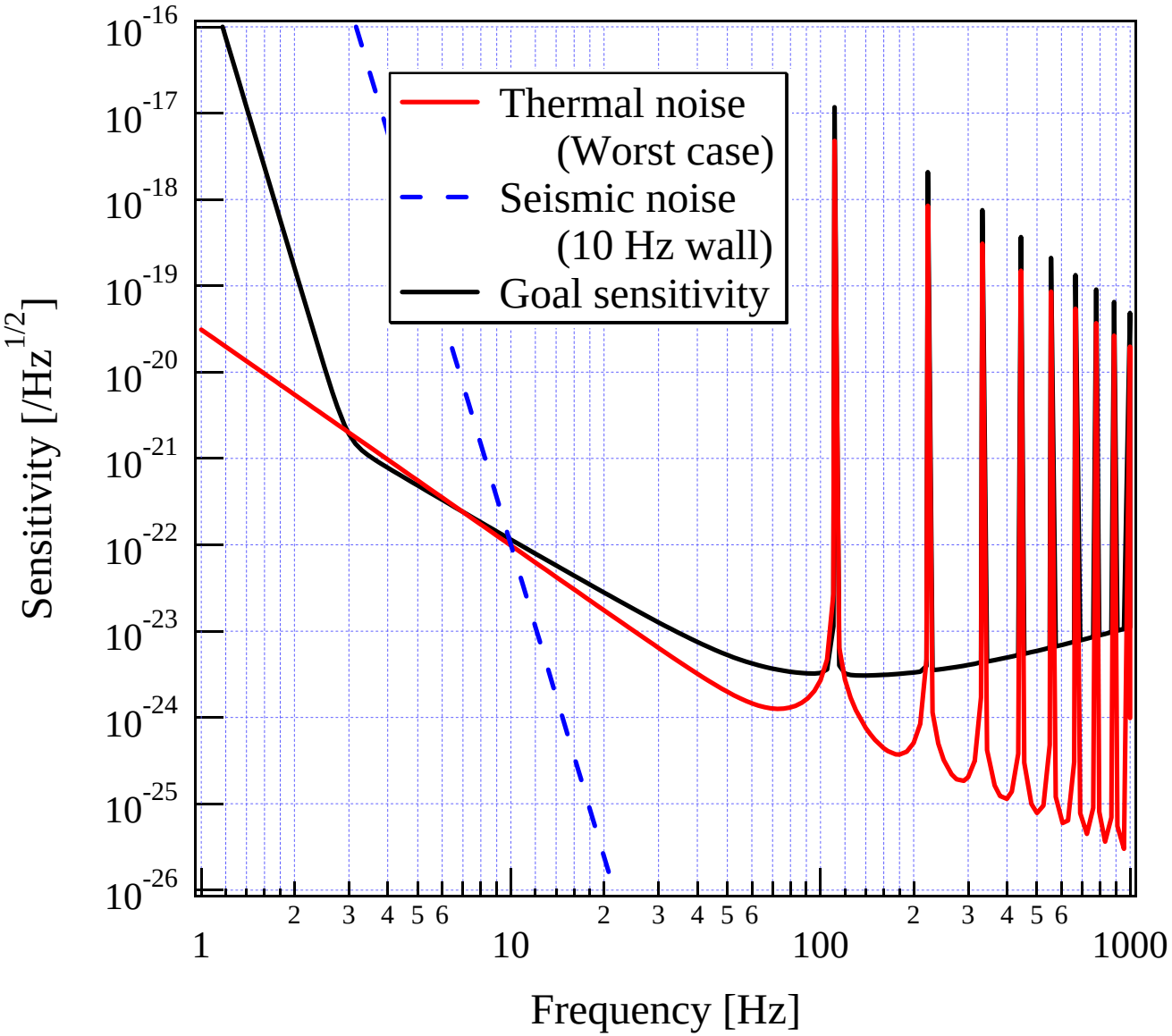
Lower limit of Q

Thermal noise
= Radiation pressure noise @ 10 Hz

***Q* of pendulum : $2*10^7$**
***Q* of violin : $1*10^7$**

Observable distance : 242 Mpc (event rate : -7%)

(only wire loss : 248 Mpc)


Thermal noise
(Worst case)
Seismic noise
(10 Hz wall)
Goal sensitivity
Sensitivity [/Hz^1/2]
10^-16
10^-17
10^-18
10^-19
10^-20
10^-21
10^-22
10^-23
10^-24
10^-25
10^-26
1
2 3 4 5 6
10
2 3 4 5 6
100
2 3 4 5 6
1000
Frequency [Hz]

2-6. Future works

(i) Calculation

(1) Vertical, Pitch, Yaw (Final stage)

Vertical : 60 Hz - 90 Hz

(2) Loss in other parts

Horizontal : no problem
(Vibration isolation and SPI)

Vertical : problem

(3) Other type of suspension : Hinge ?

(ii) Experiment

(1) Measurement of Q of suspension system

(2) Temperature gradient

(3) Direct measurement of thermal noise

3. Summary

(i) Mirror : no problem

(ii) Suspension : pendulum and violin

First violin mode : 111 Hz (detuned ?)

$Q_{pendulum} > 2*10^7$

Wire : no problem

Actuator and driver : some improvement

Wire clamps : ?

Many future works !