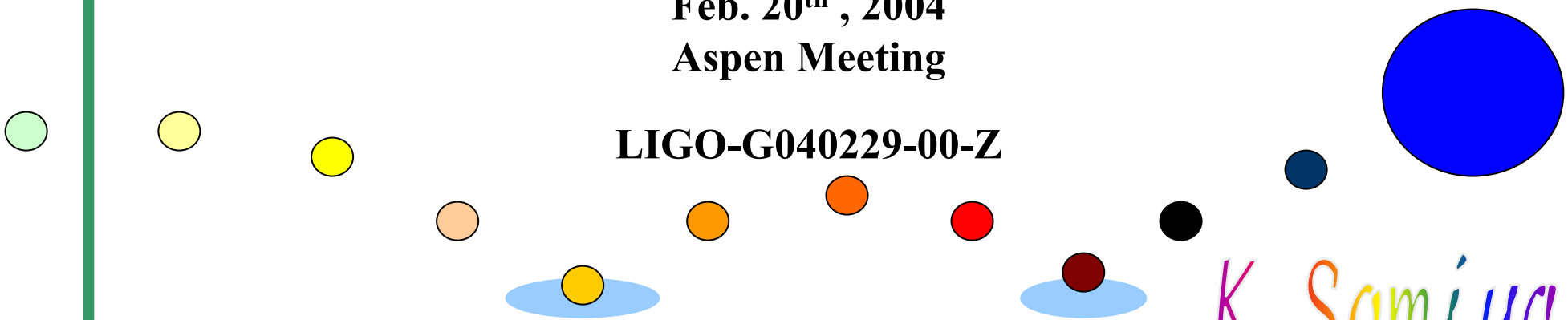
RSE Experiment in Japan

K.Somiya, O.Miyakawa,
P.Beyersdorf, and S.Kawamura

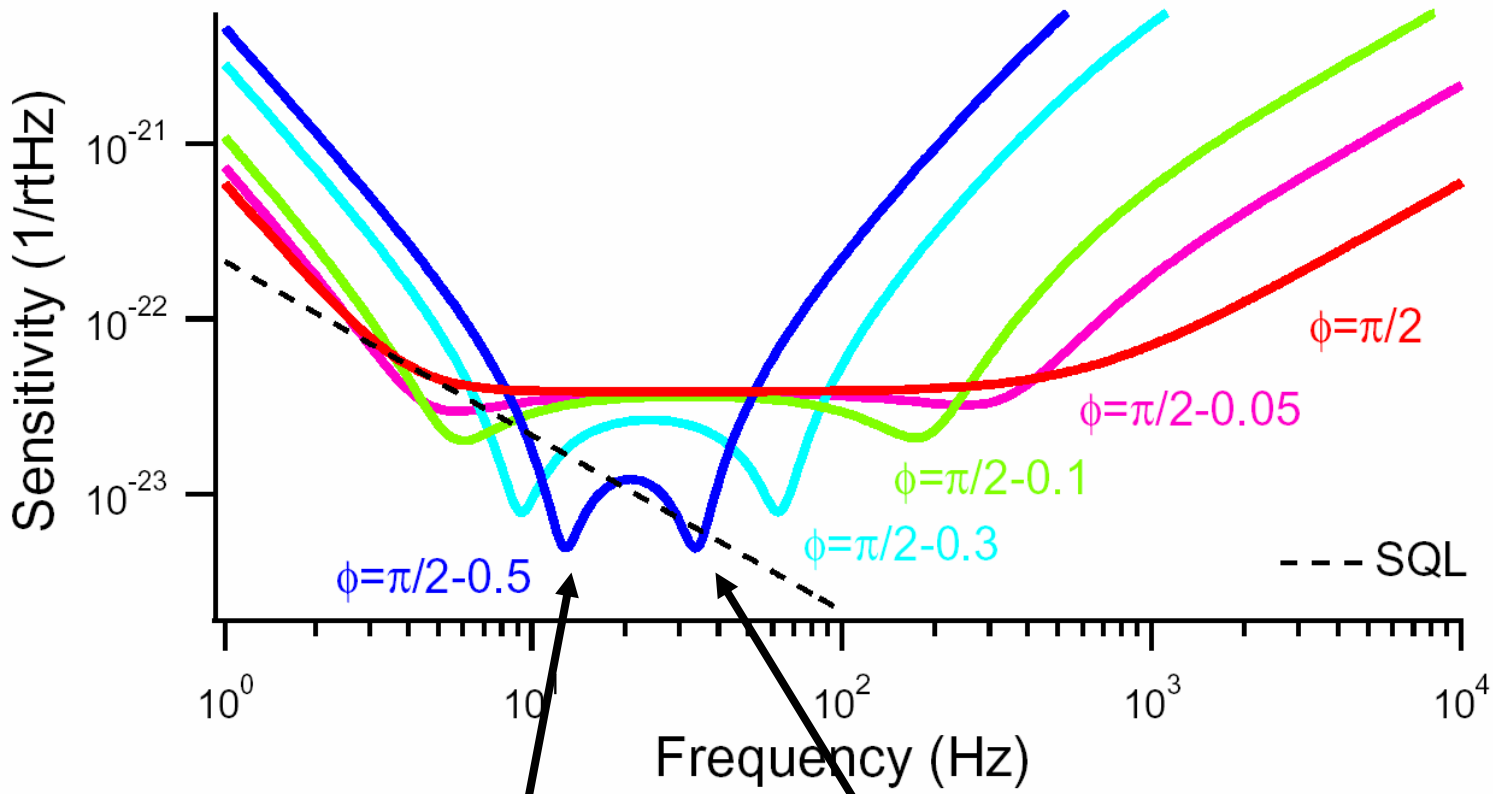
Feb. 20th , 2004
Aspen Meeting

LIGO-G040229-00-Z



Detuned RSE Spectrum

ϕ : detune phase



Low freq. peak :
Optical Spring

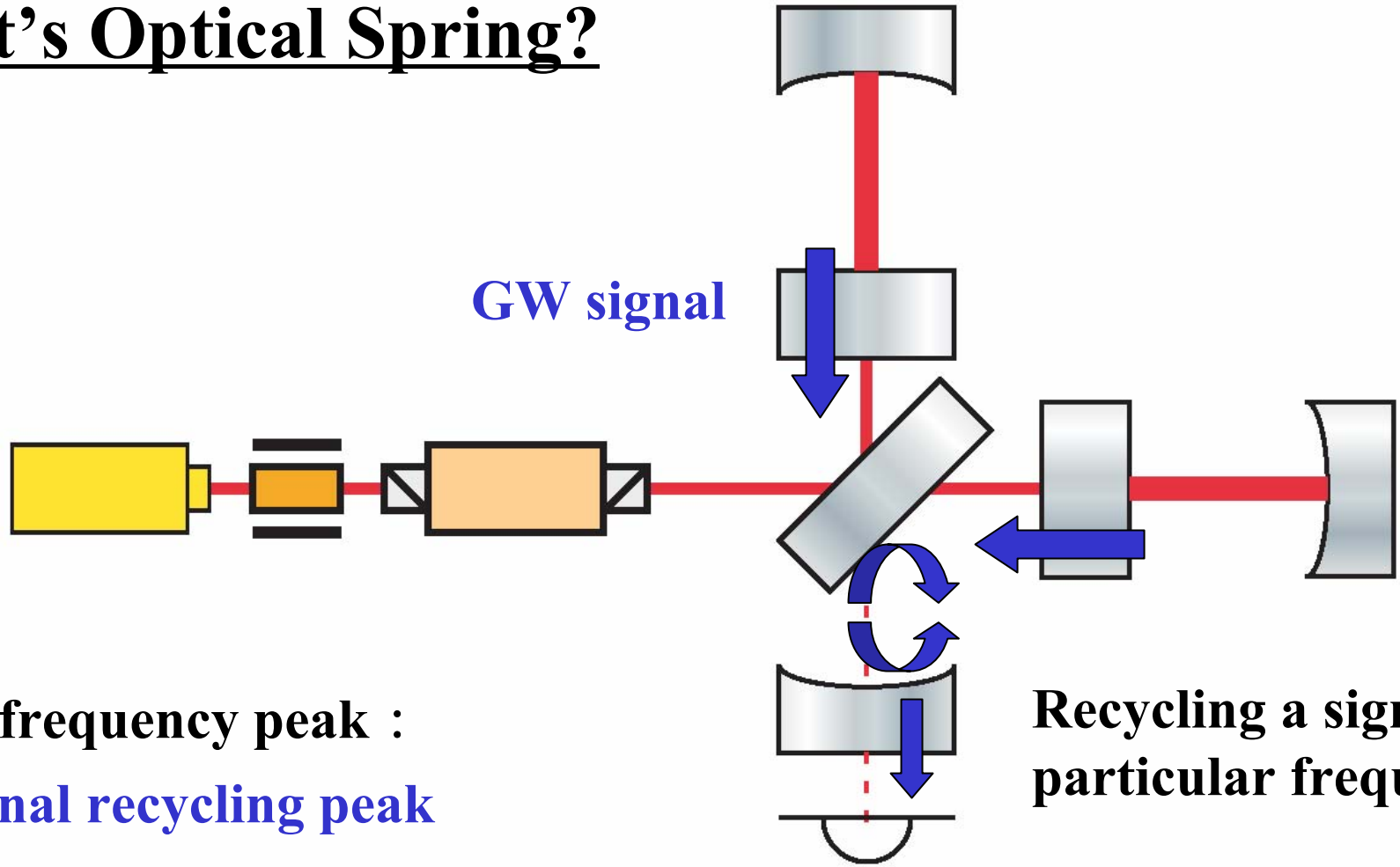
radiation pressure effect

High freq. peak :
signal recycling peak

This has been measured.

Let's see this effect!!

What's Optical Spring?

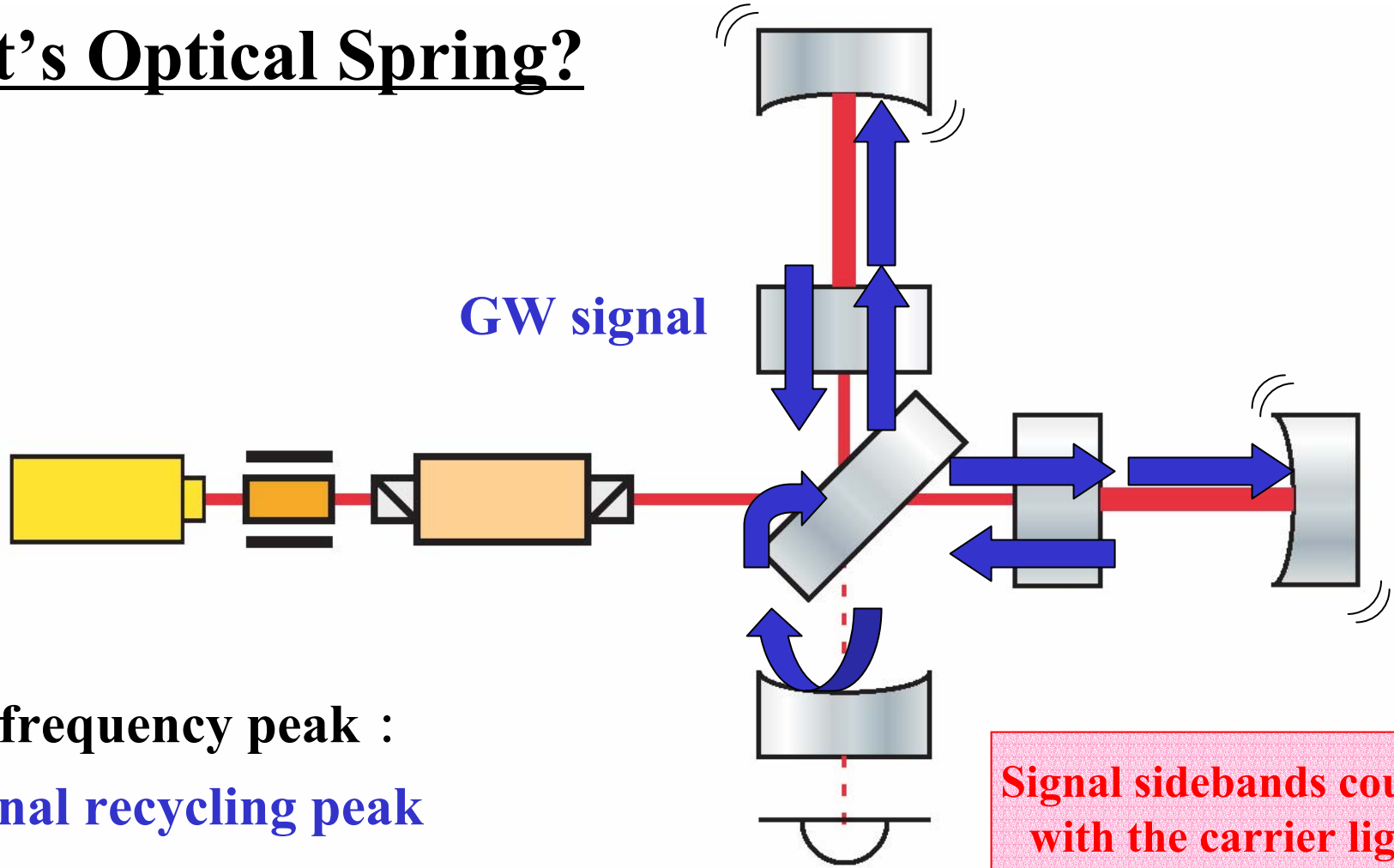


High frequency peak :

Signal recycling peak

Recycling a signal at particular frequency

What's Optical Spring?



High frequency peak：

Signal recycling peak

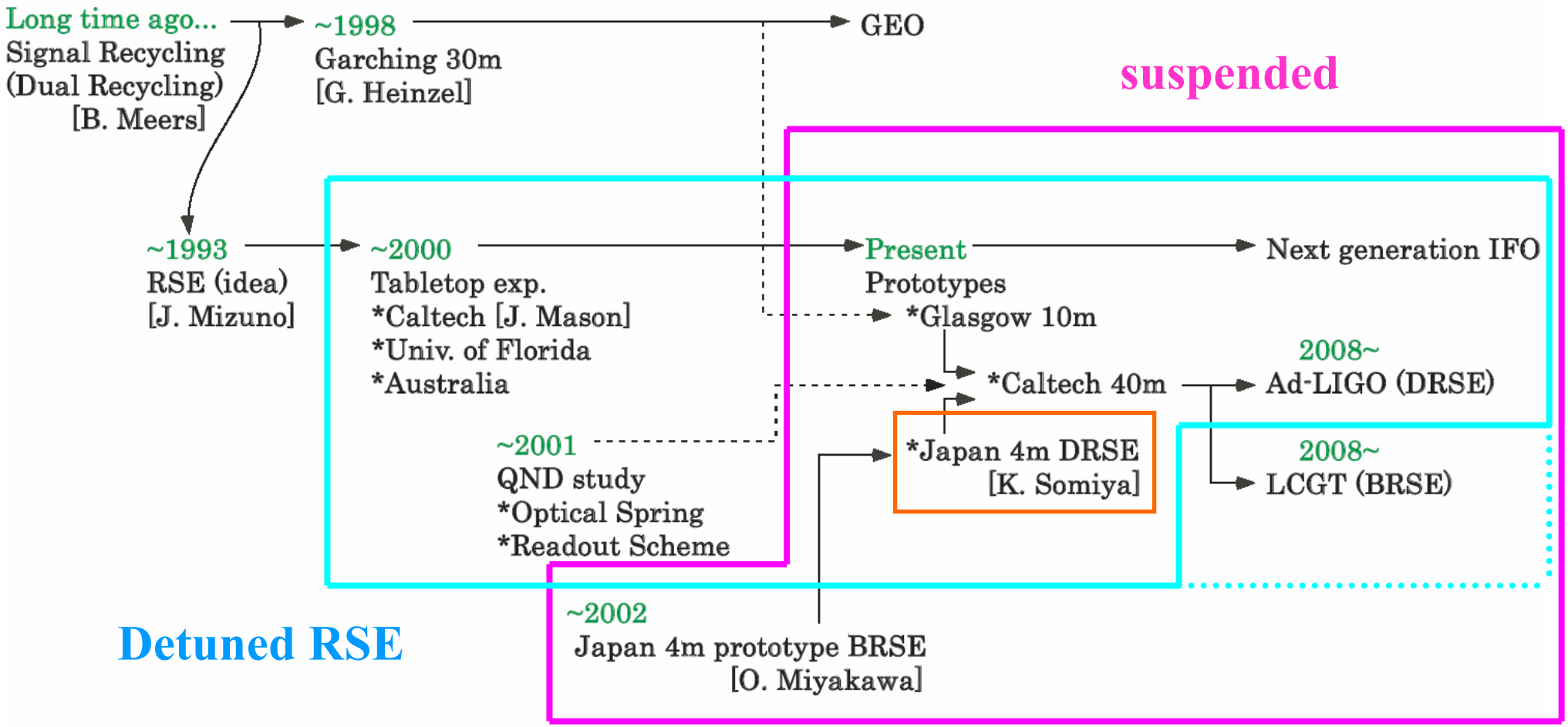
Low frequency peak:

Radiation pressure generated by signal sidebands moves the mirrors and enhances the signal.

Signal sidebands couple with the carrier light

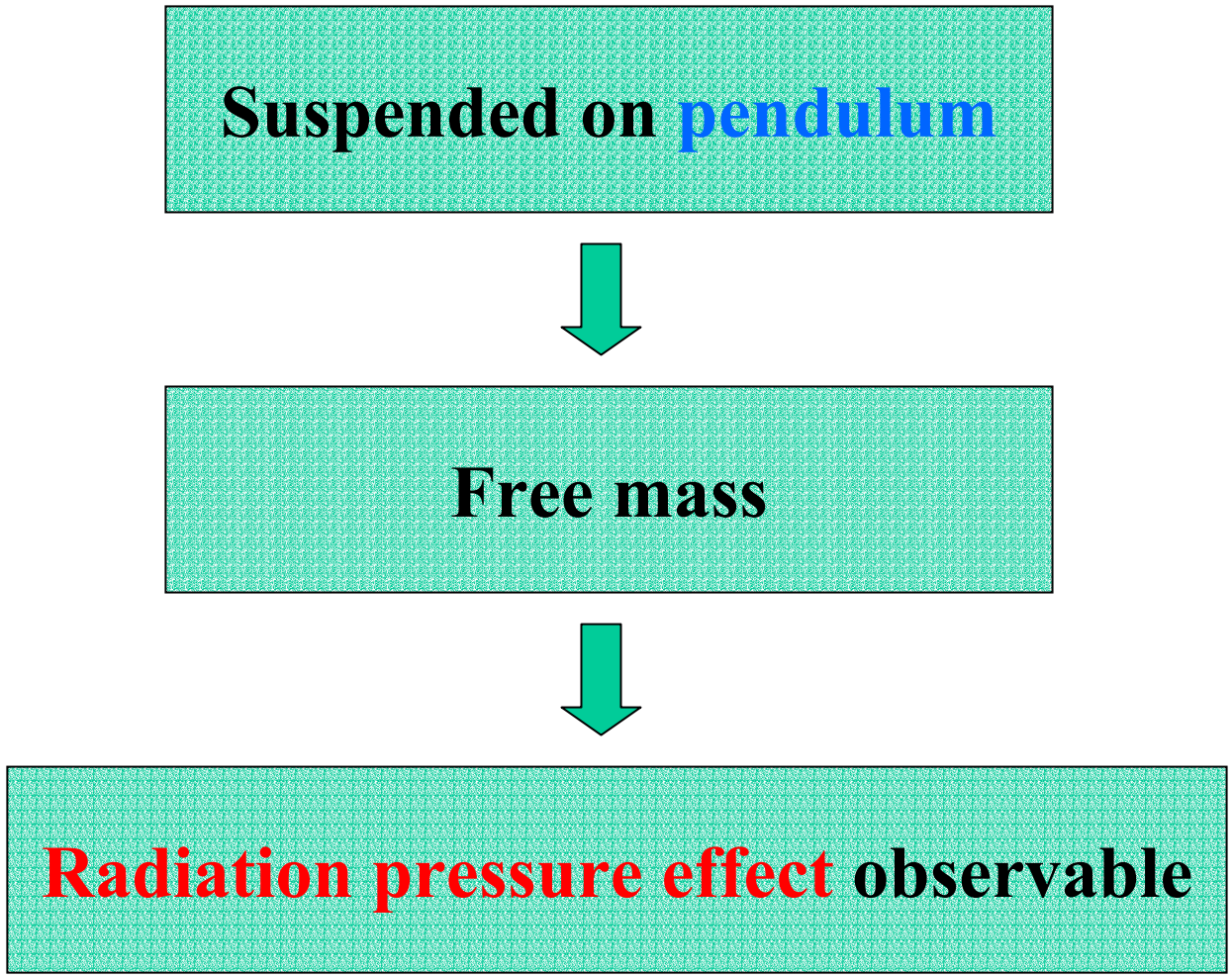
Differential-mode radiation pressure moves the mirrors

Historical Review of RSE Experiment



First operation of Detuned RSE with suspended mirrors.

Why suspended?



Japan 4m RSE

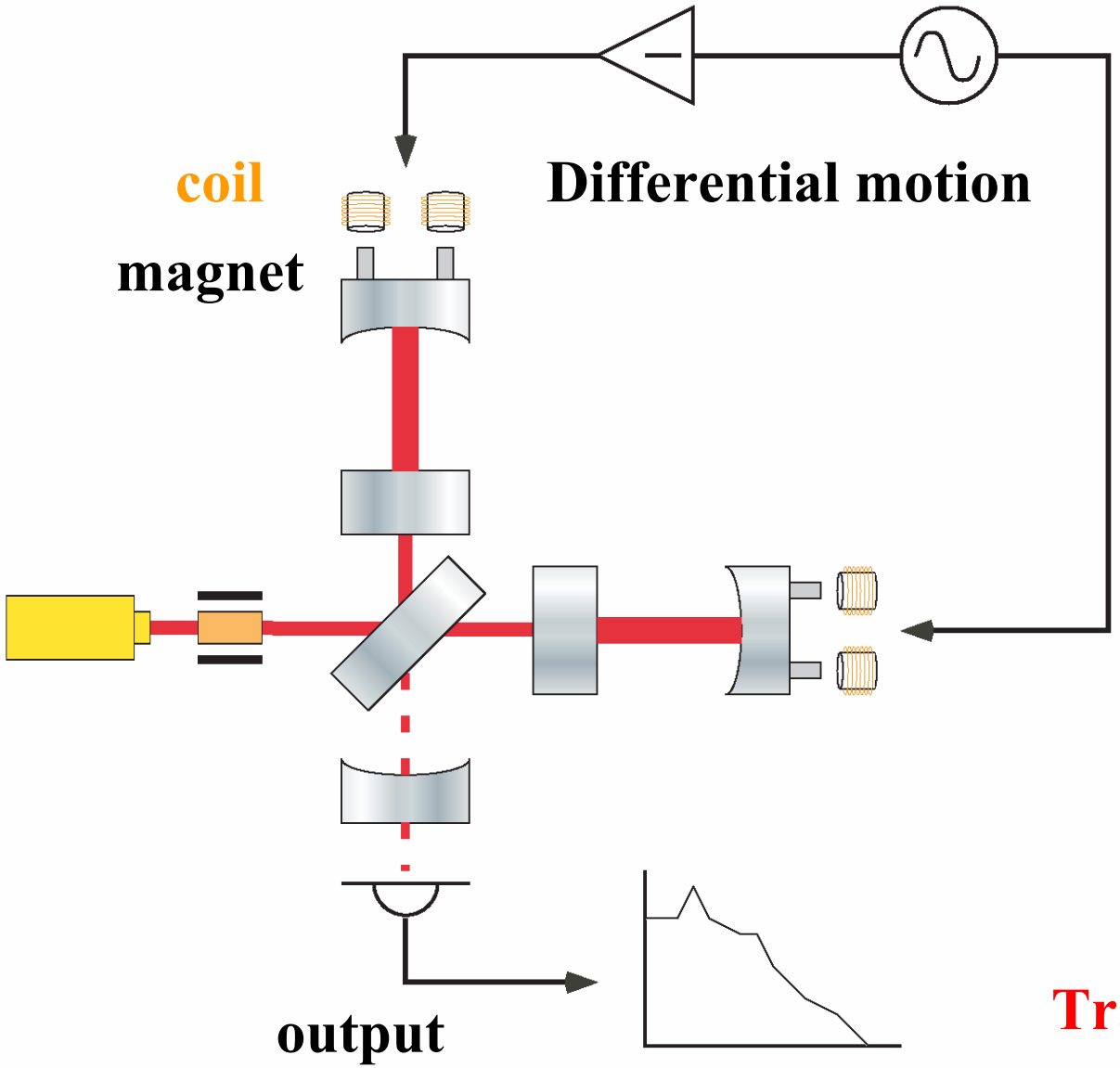
Detuned RSE
Prototype interferometer

Built near TAMA site
in 2001

500mW LASER,
40g light mirrors

Vacuum system:
3.4e-7 torr (w/o optics)
1.0e-6 torr (with optics)

How to see the optical spring



Hard to see quantum noise

⇩

Mirror motion represents gravitational-wave effects

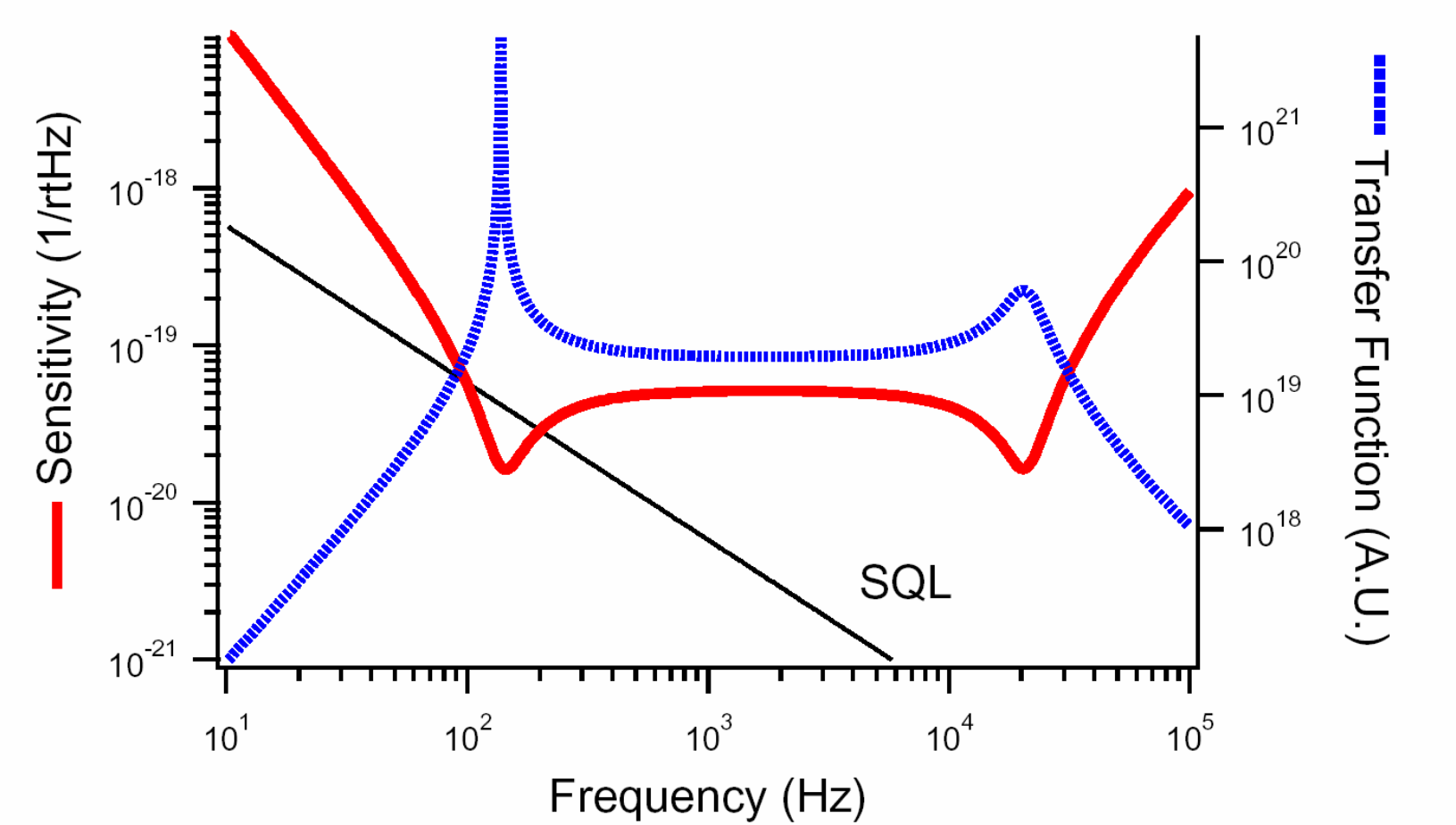
⇩

Output shows response to gravitational-wave signals

||

Transfer function measurement

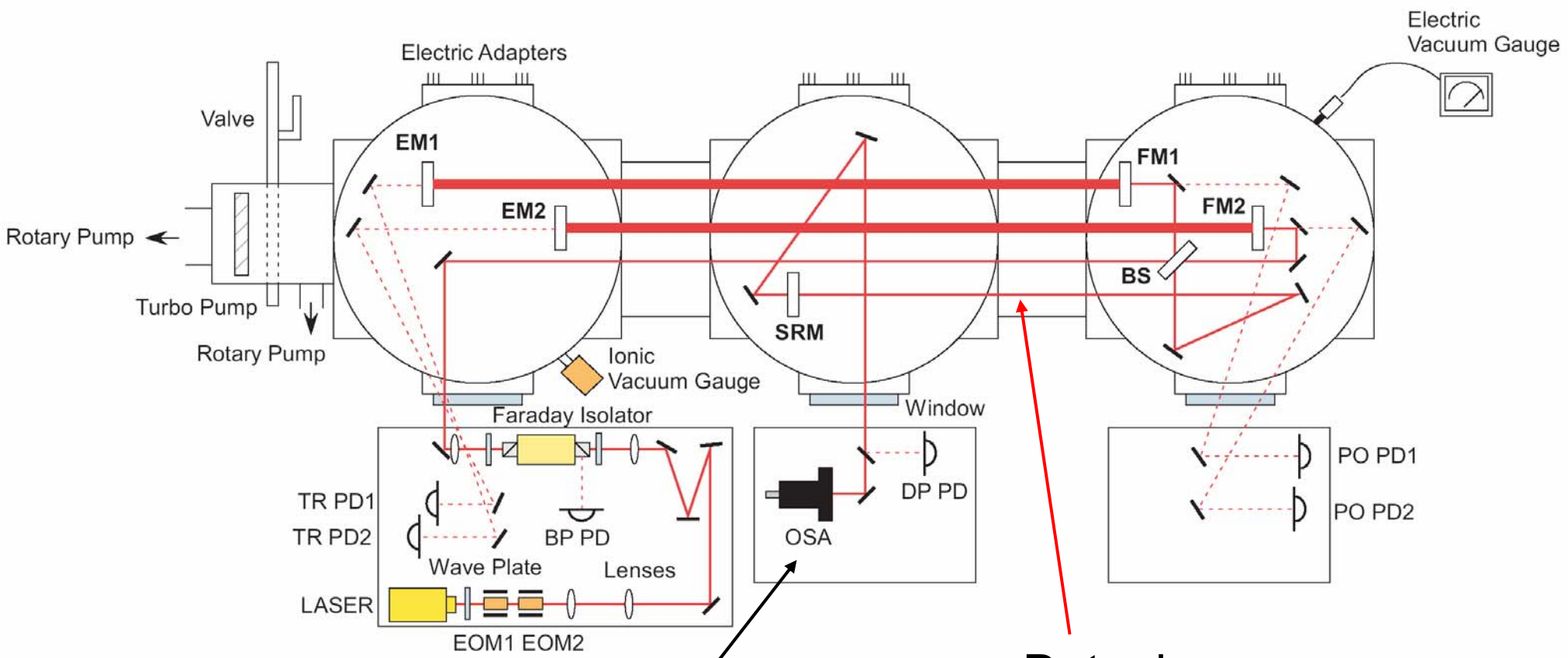
Quantum noise and transfer function



Peak appears at the frequency of the QND dip.

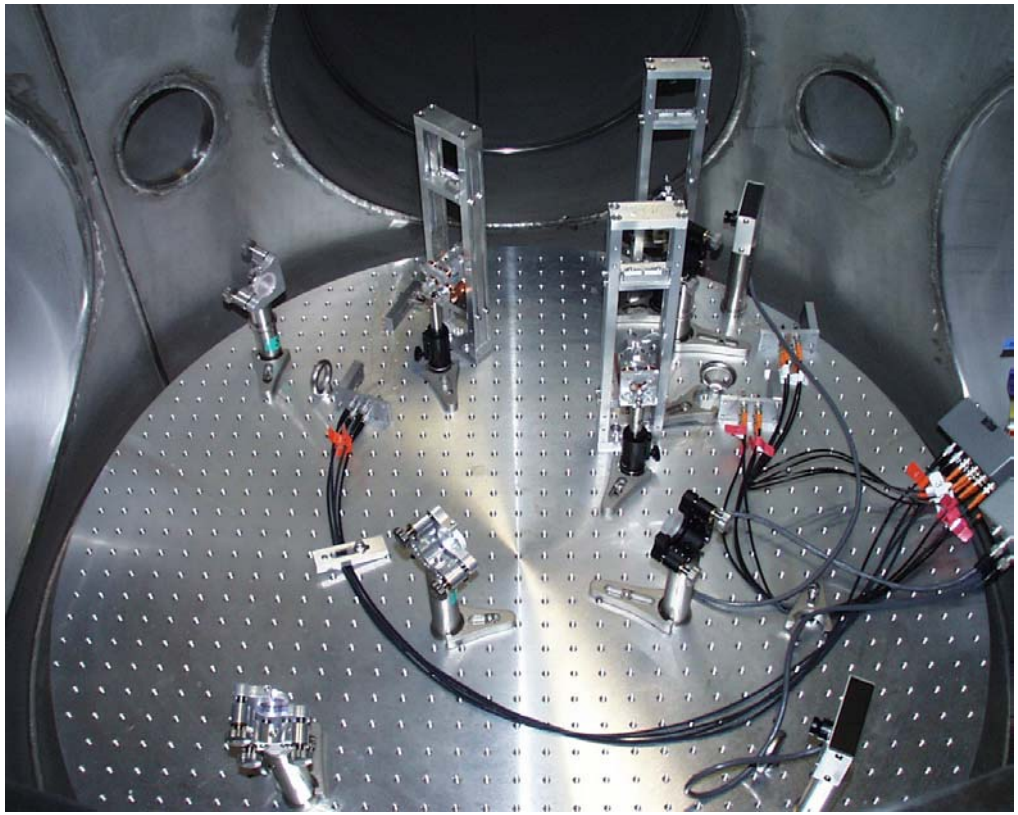
⟶ **We can see this peak in our interferometer.**

Setup of Japan 4m prototype RSE

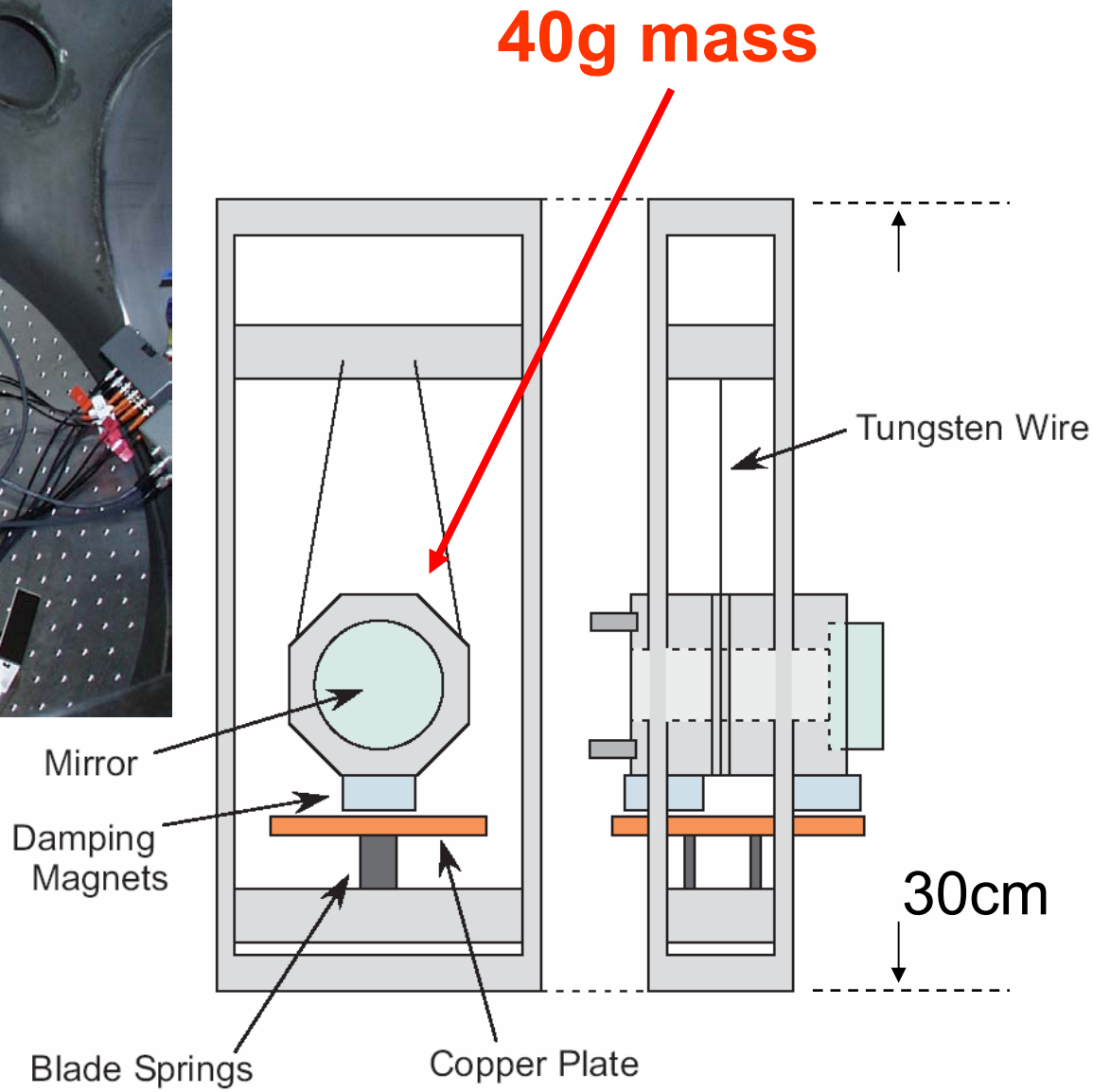


Laser:500mW, arm finesse:2000, R_{RSE} : 80%

Setup of Japan 4m prototype RSE

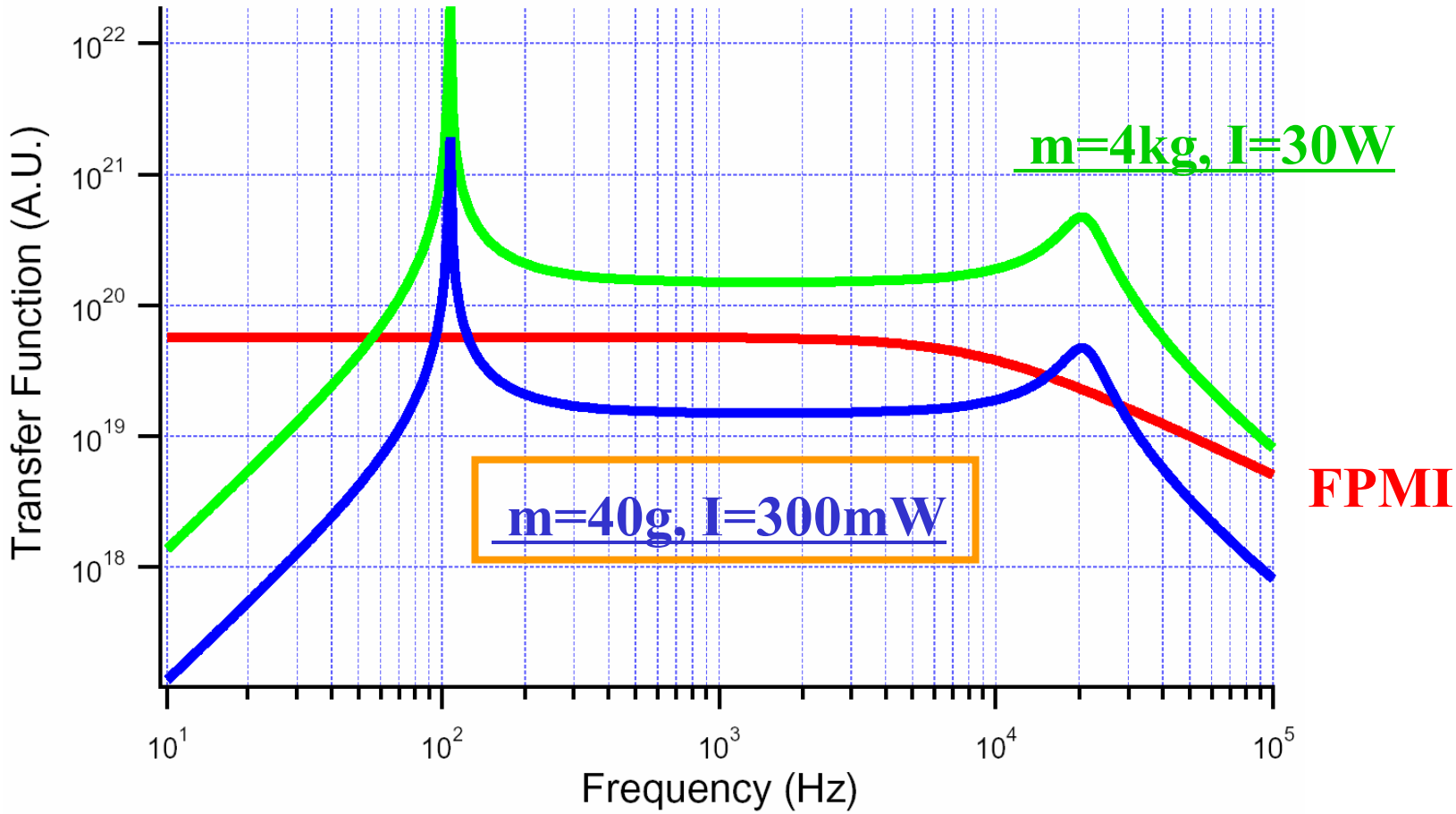


Diameter of
the vacuum chamber: 1m



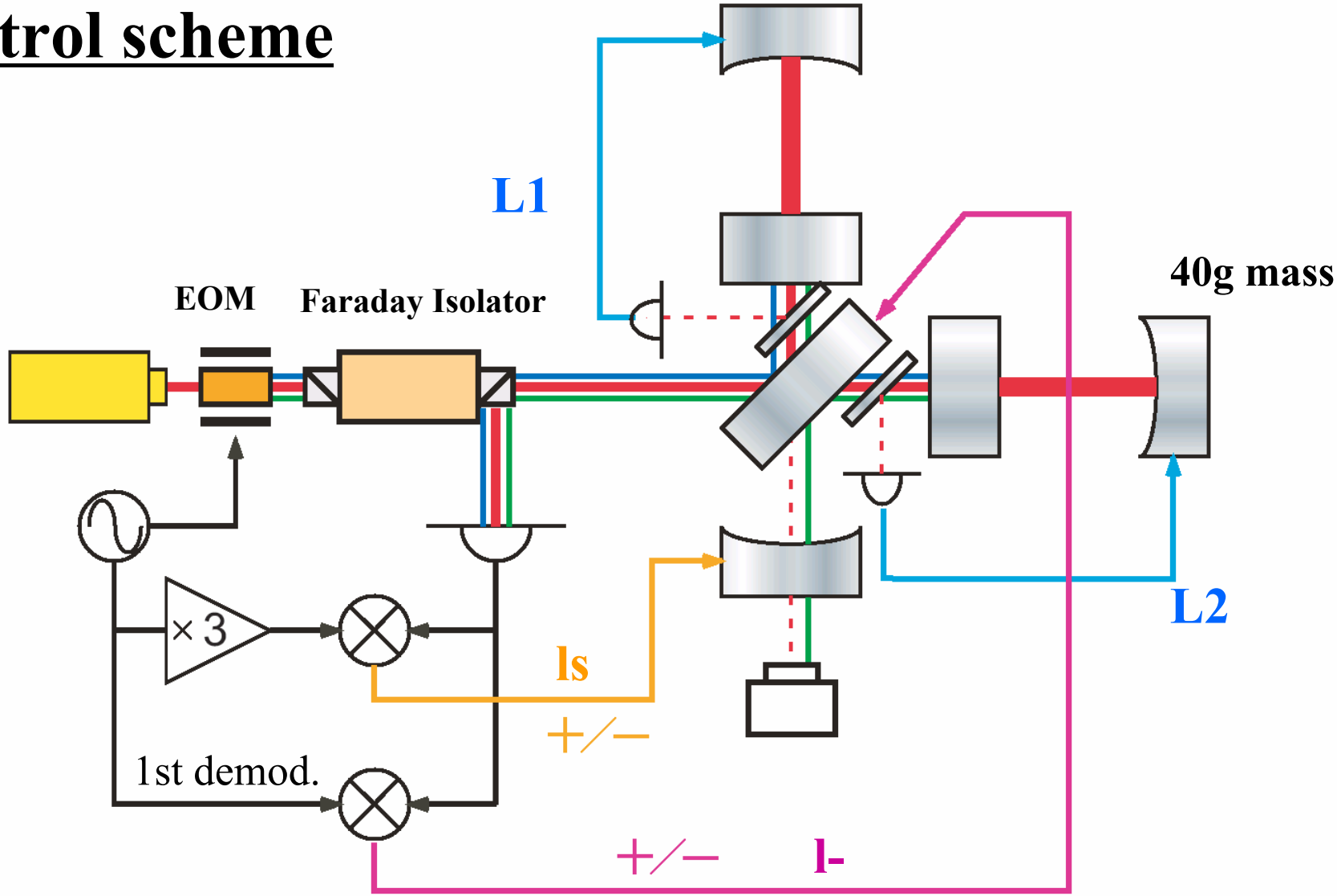
Mass and the peak frequency

F=2000, $\phi = \pi/2 - 0.4$, r=0.89



Using light masses, we can see the radiation pressure effect even with a not-high power laser.

Control scheme



- 4 degrees of freedom
- Third Harmonics Demodulation for ls

Signal Extraction Matrix

9-180MHz (High-Freq method)

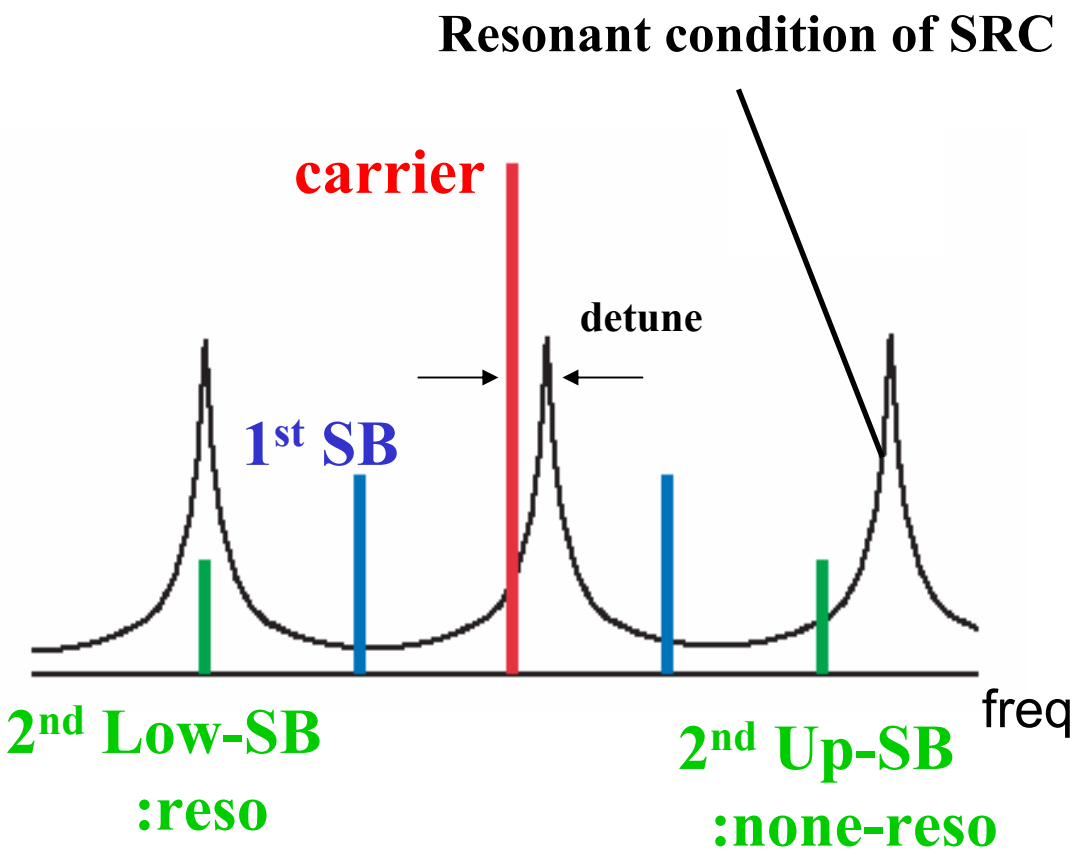
	Port	Demod.	L_+	L_-	ℓ_+	ℓ_-	ℓ_s	norm.
L_+	SP	f_1	**1**	0.000	-0.001	0.000	0.000	1890
L_-	AP	f_2	0	**1**	0	0.001	0	-1500
ℓ_+	SP	$f_2 - f_1$	-0.006	-0.001	**1**	-0.006	-0.444	19.5
ℓ_-	AP	DDM	0.00	0.00	-0.12	**1**	0.02	0.242
ℓ_s	PO	$f_2 - f_1$	-0.002	0.000	0.036	0.024	**1**	245

15-35MHz (Low-Freq method)

	Port	Demod.	L_+	L_-	ℓ_+	ℓ_-	ℓ_s	norm.
L_+	SP	f_1	**1**	0.000	-0.000	0.000	-0.000	12600
L_-	AP	f_2	0	**1**	0	0.001	0	894
ℓ_+	SP	DDM	0.000	-0.001	**1**	0.495	0.698	2.81
ℓ_-	AP	DDM	-0.000	0.002	-0.009	**1**	-0.015	-0.622
ℓ_s	PO	DDM	0.002	-0.002	0.033	-0.894	**1**	15.1

We can also use Low-freq method with 15-30MHz if no PR (simple!).

Control scheme of Detuned RSE ~ one-side SB lock

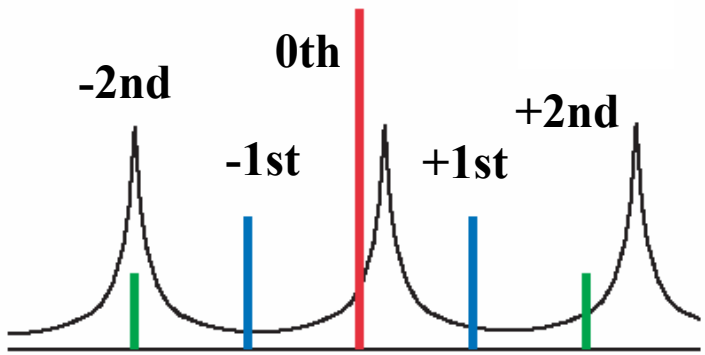


SRC is controlled with
third harmonics demodulation scheme.

Shift the FSR little from $2f_m$

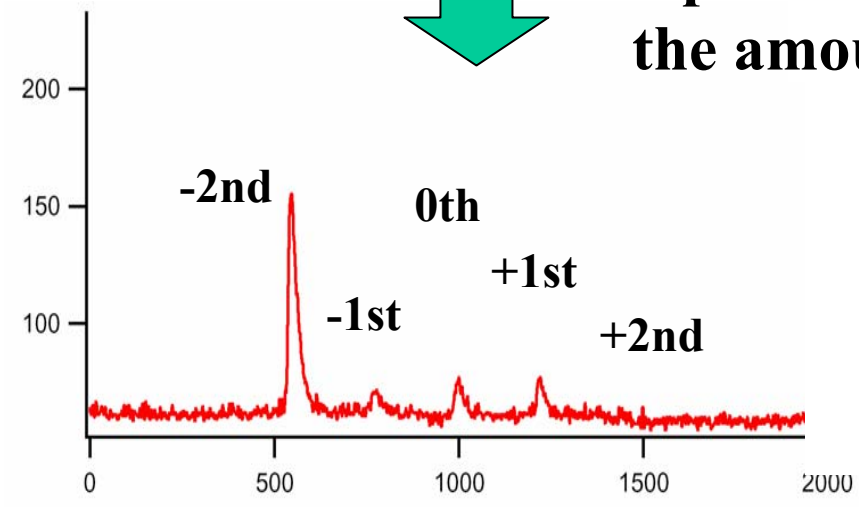
Detune

Ascertain with OSA



One-side SB lock

Experimental result



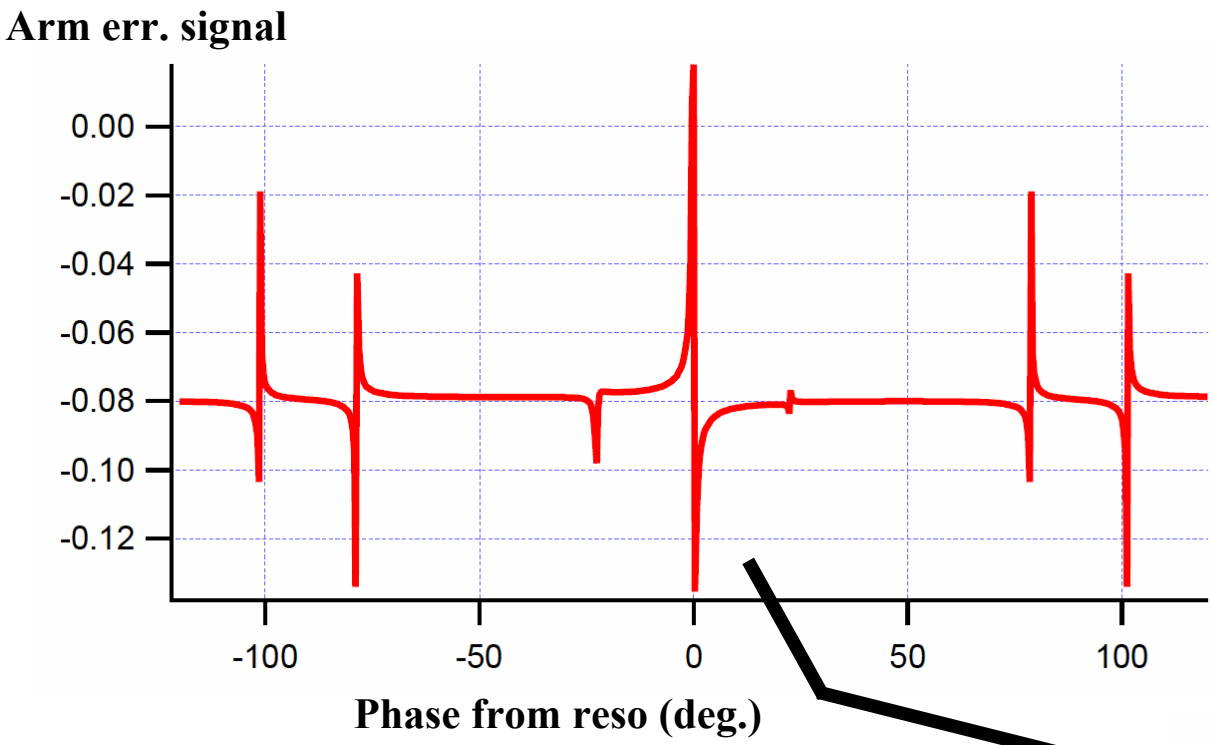
Optical Spectrum Analyzer at DP shows the amount of each optical components

Unbalance between U/L SB

↓

Detune!!

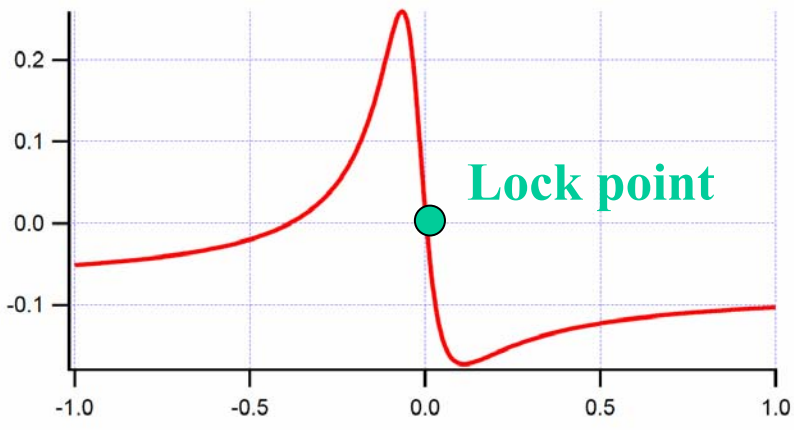
What happens with detuning? ~ ex. Arm cavity lock



Offset when none-reso.

No offset when reso.

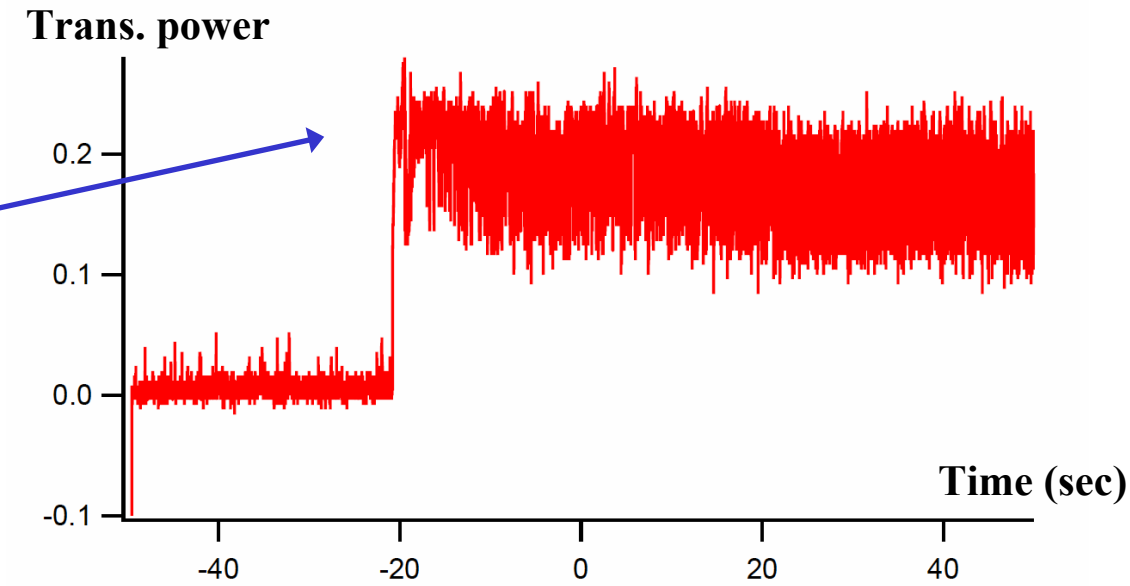
zoom

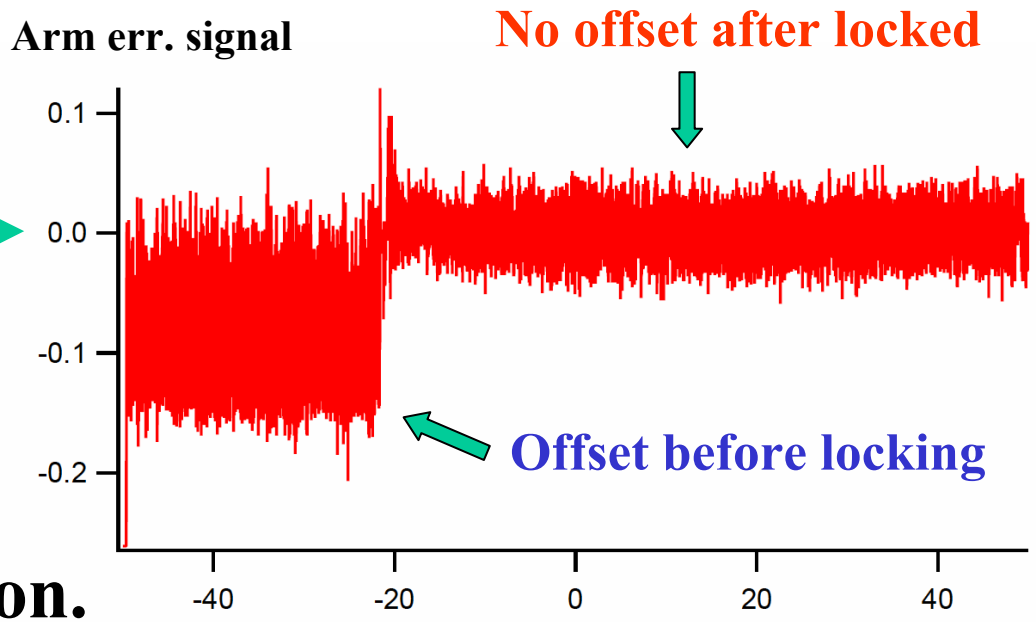


We can observe this at experiment.

Offset before locking

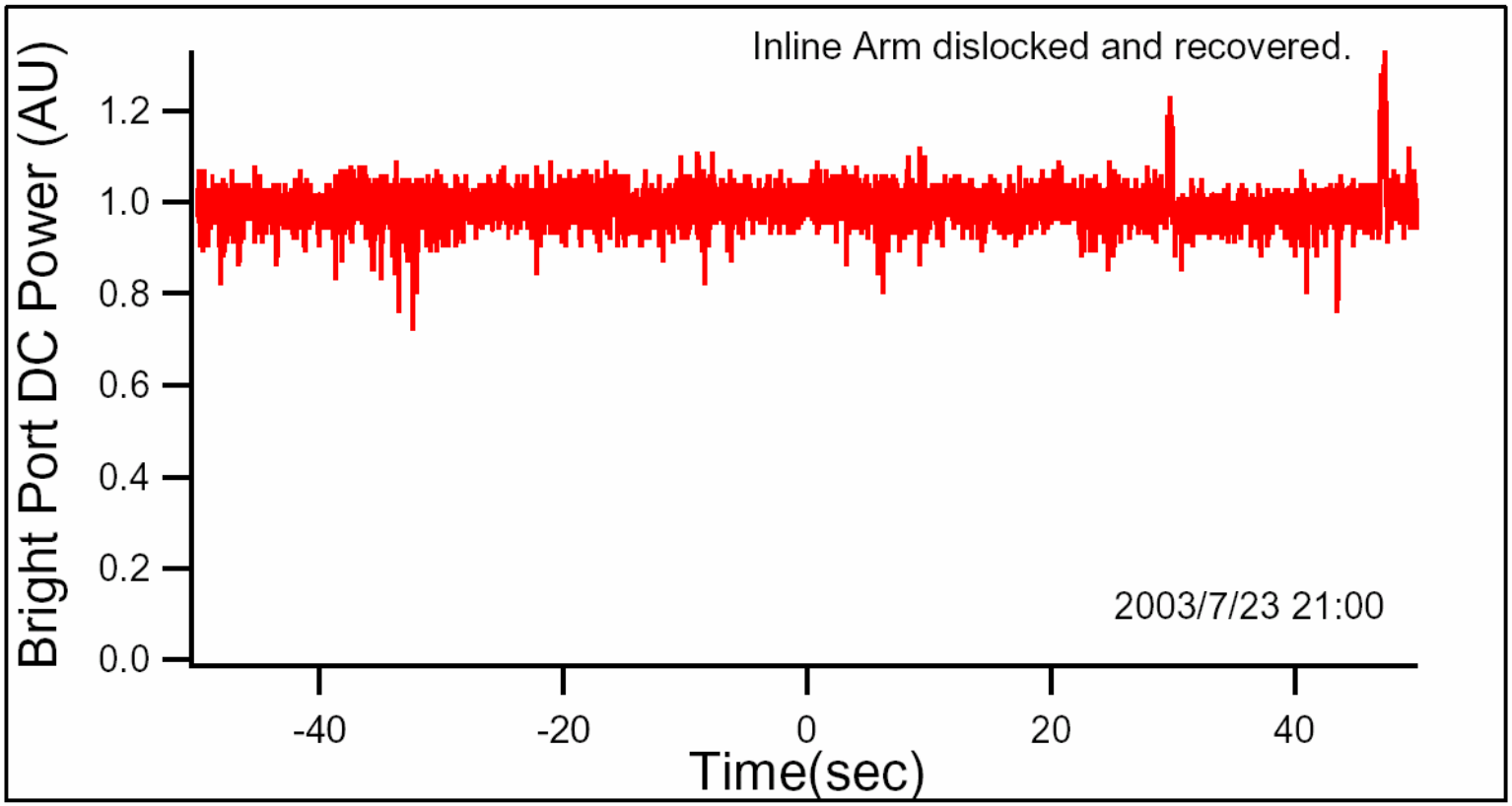
Maximized at the resonance.





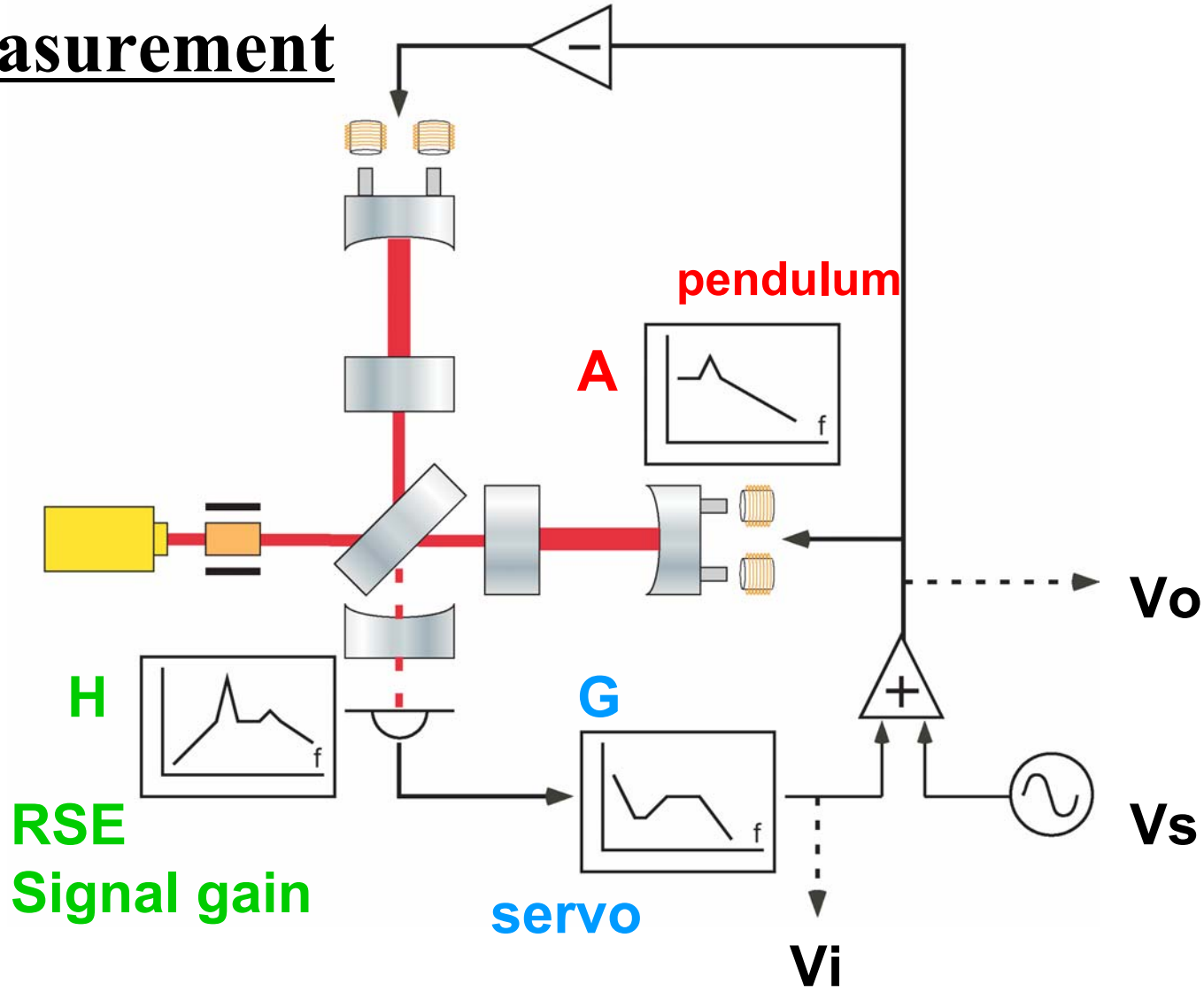
This happens only if SRC is locked at detuned condition.

RSE Lock （L_1, L_2, l-, ls）



World's first lock of DRSE with suspended mirrors

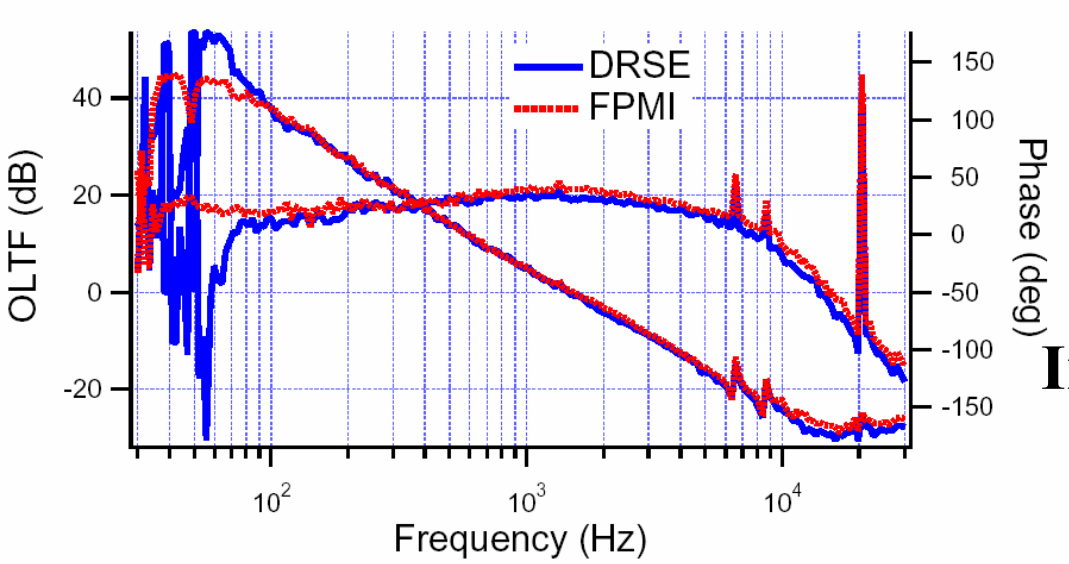
TF measurement

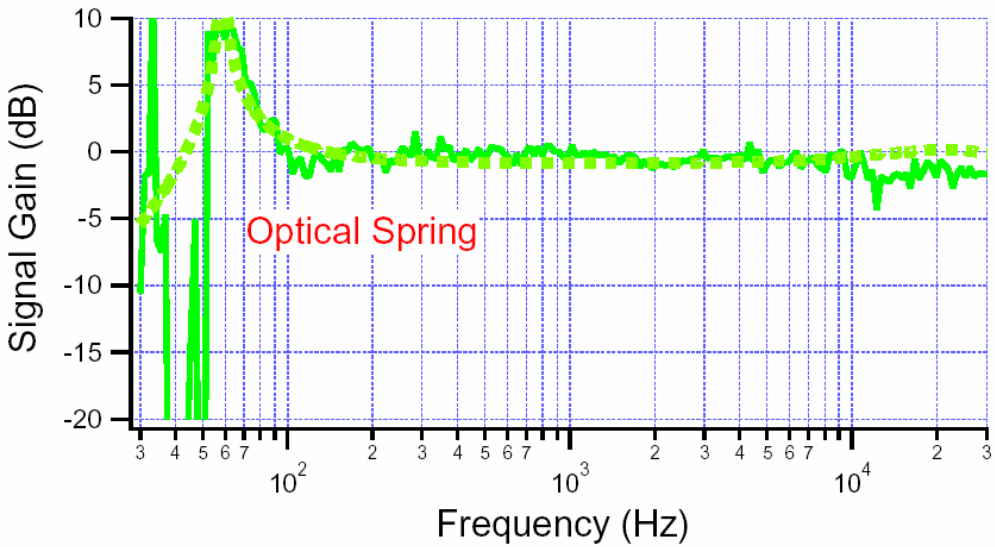


Vi/Vo=AGH includes pendulum, servo, and RSE.

⟶ measure FPMI and RSE then take the ratio.

Measurement results





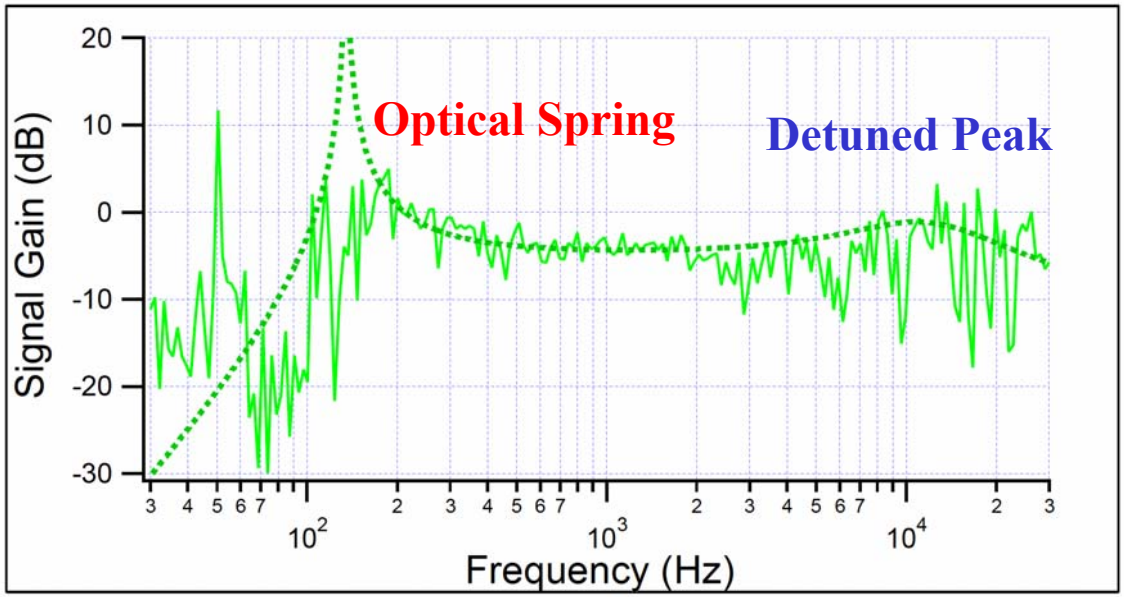
Includes pendulum and servos

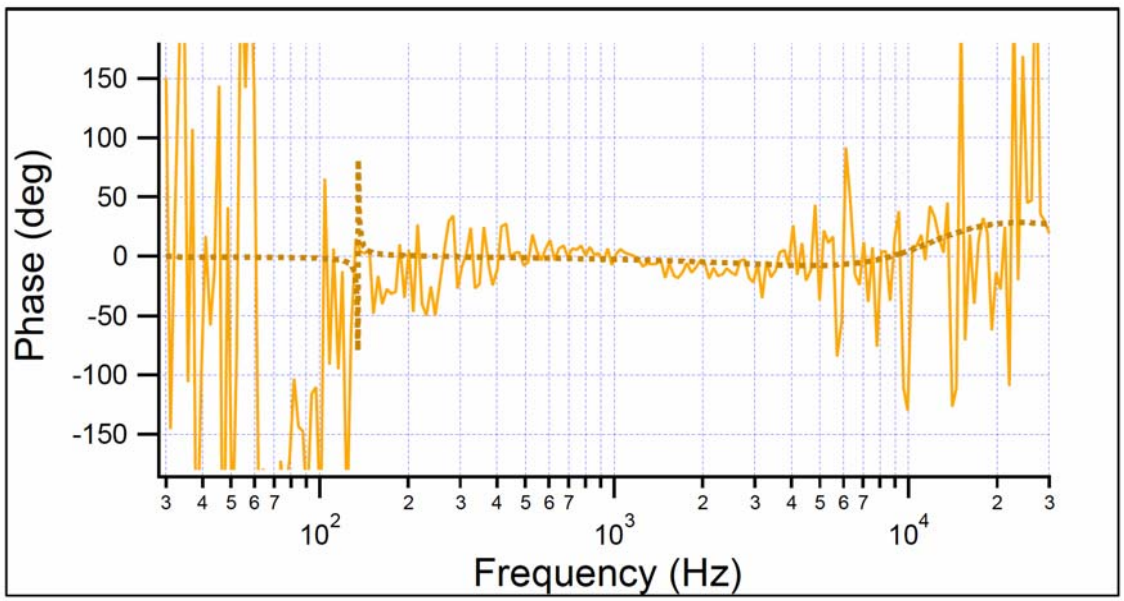
The ratio shows the signal gain.

Optical Spring is hopefully measured!!

I=350mW, F=1000, ρ=0.4, ϕ=π/2-0.6

We were able to see the other peak at the beginning.





- Measured 2 months earlier.
- Precision level was lower.
- Finesse was higher.

I=350mW, F=2000, ρ=0.5, ϕ=π/2-0.6

Conclusion

- We have locked Detuned RSE with suspended mirrors.
- We can hopefully say the optical spring is observed.

To be improved

- Precise measurement with high finesse cavities.
- The peak can be at higher freq. with a different detune phase.
- Offset problem of l- signal.

What to do

- Change the mirrors and retry in Japan
- Do it in Caltech 40m

QND comes closer and closer