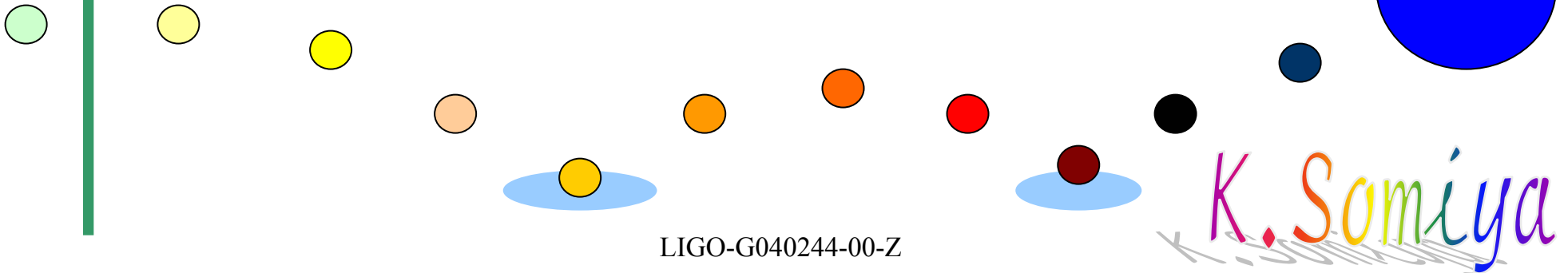


# RSE Experiment in Japan

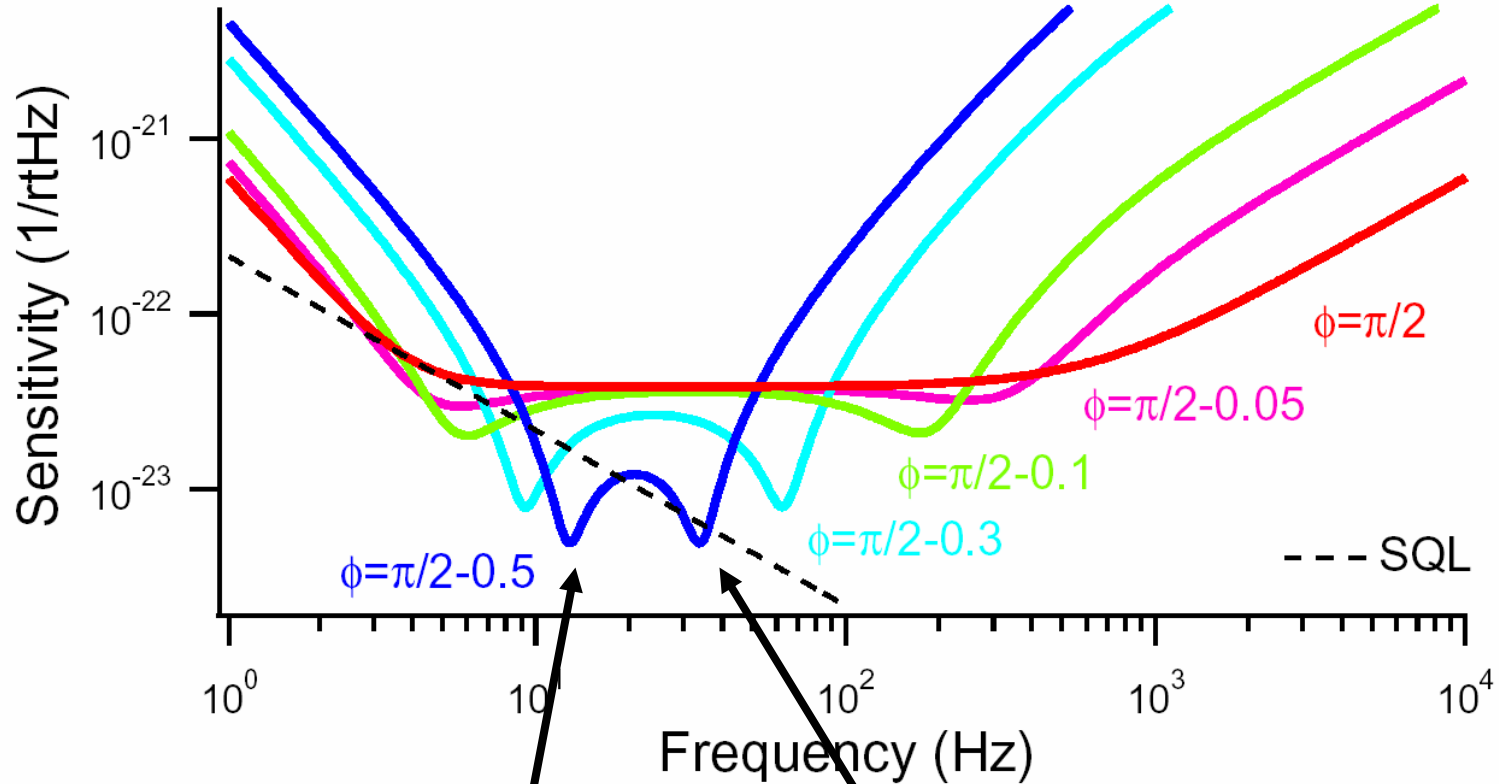
K.Somiya, O.Miyakawa,  
P.Beyersdorf, and S.Kawamura

Feb. 20<sup>th</sup> , 2004  
Aspen Meeting



# Detuned RSE Spectrum

$\phi$  : detune phase



Low freq. peak :  
**Optical Spring**

High freq. peak :  
**signal recycling peak**

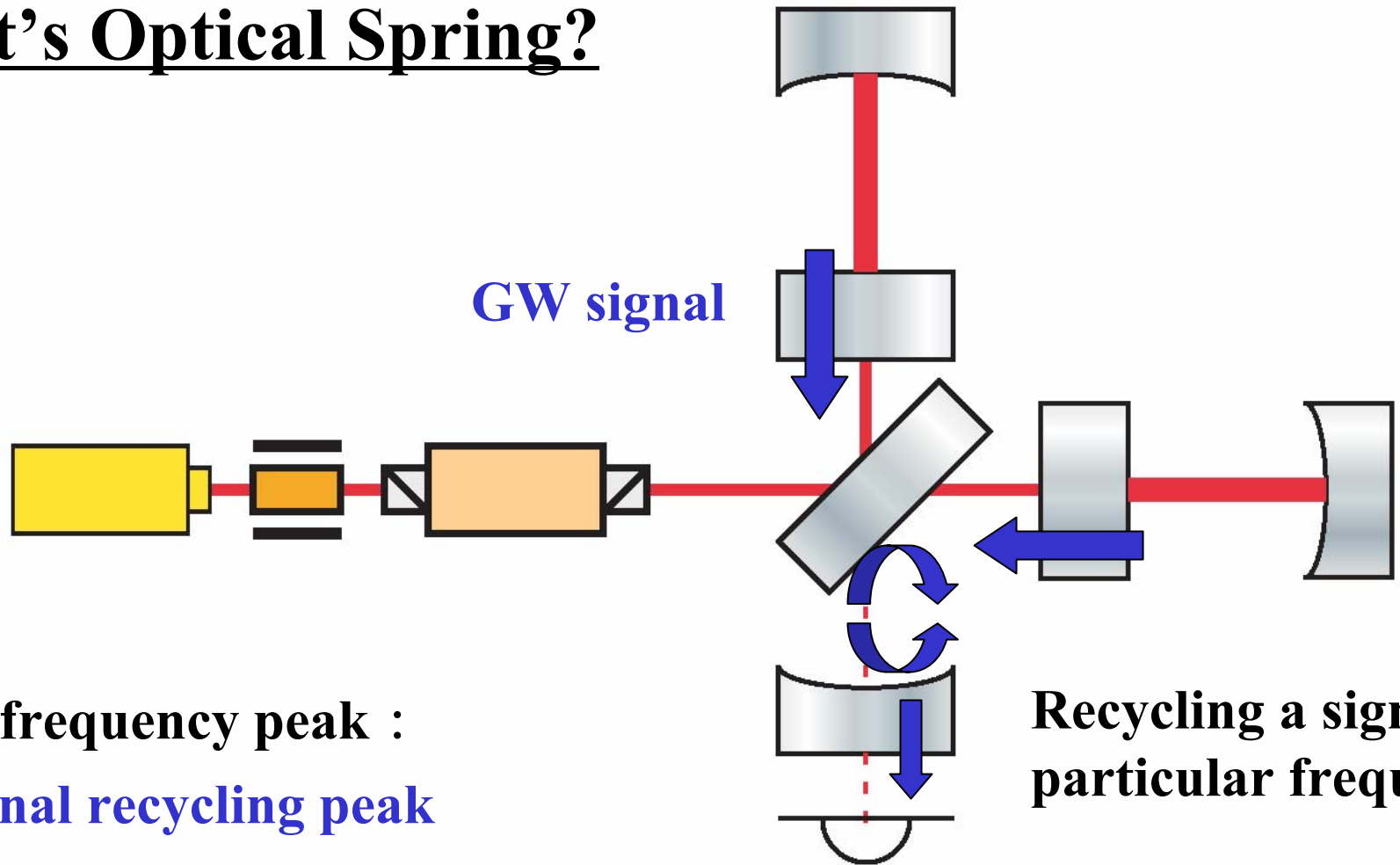
radiation pressure effect

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This has been measured.

Let's see this effect!!

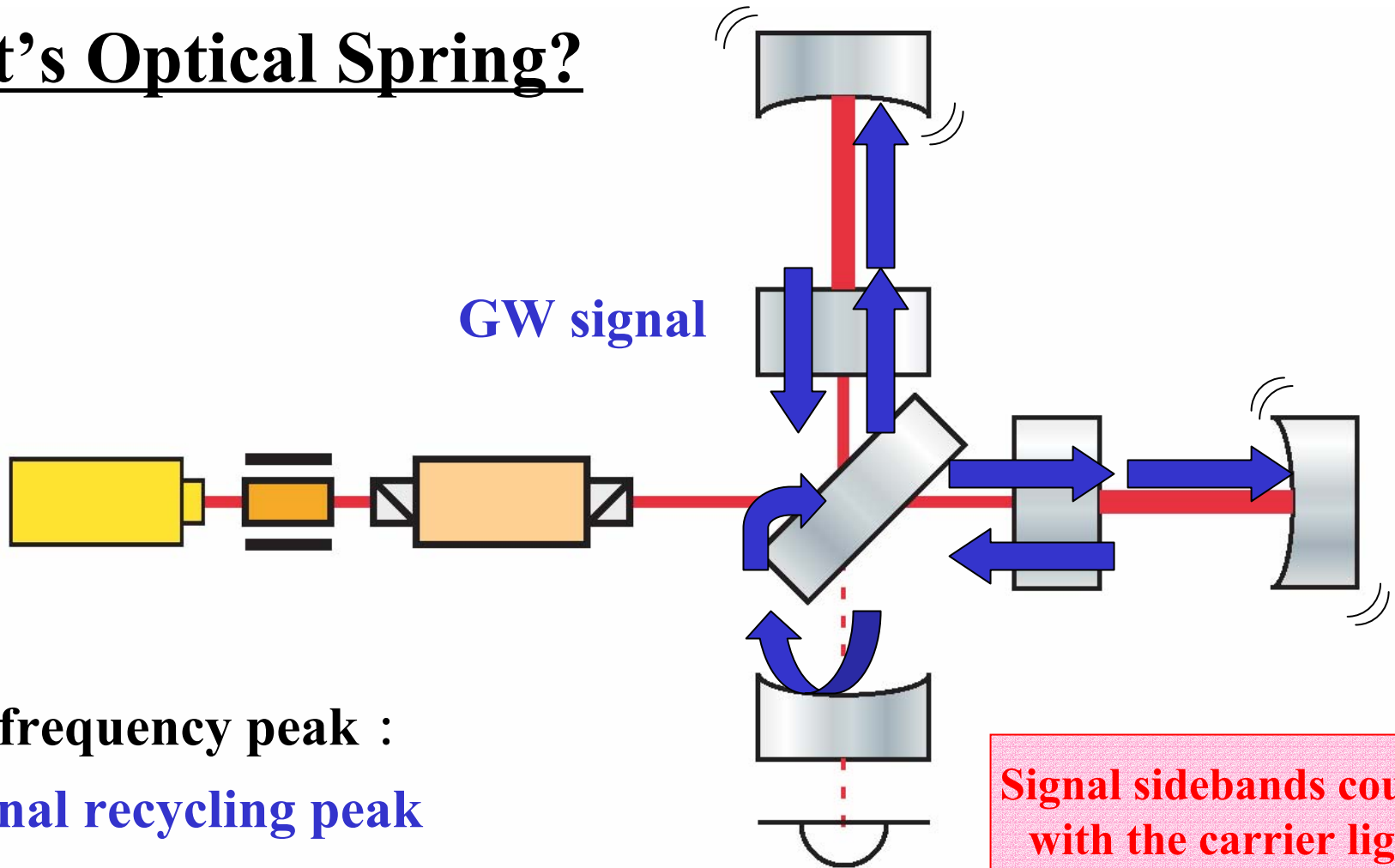
# What's Optical Spring?



**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.**

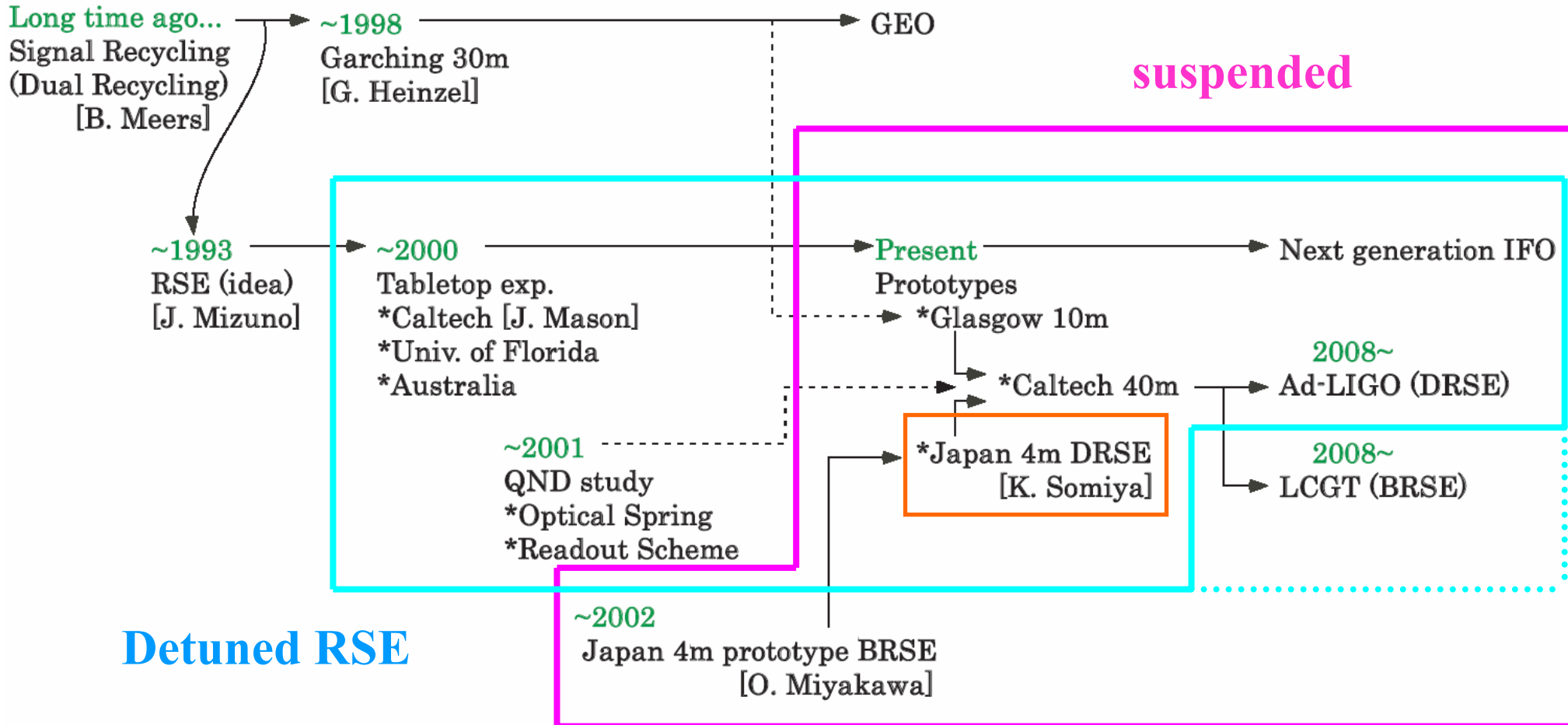
LIGO-G040244-00-Z

**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?

Suspended on **pendulum**



Free mass



**Radiation pressure effect** observable

# Japan 4m RSE



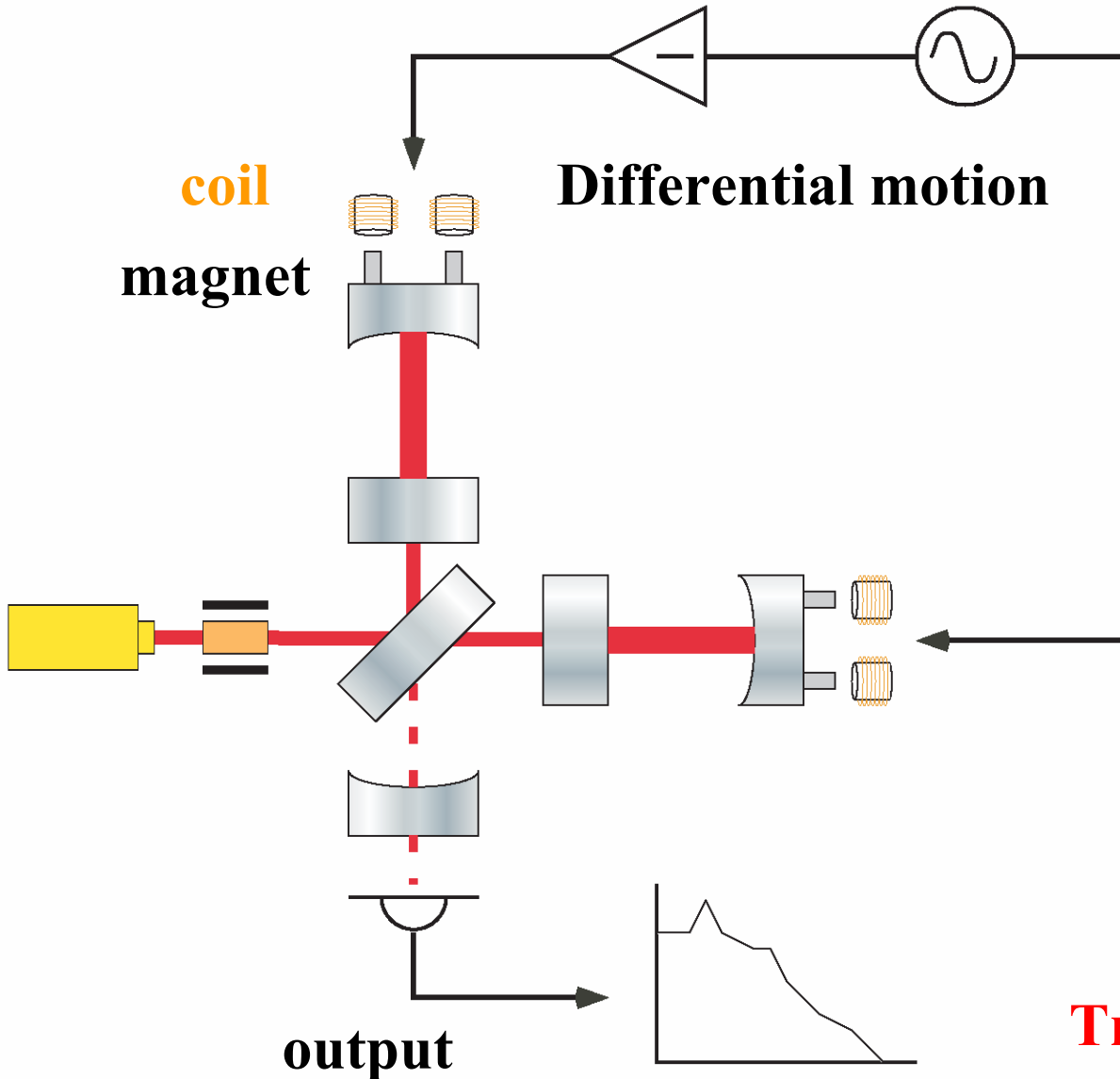
Detuned RSE  
Prototype interferometer

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



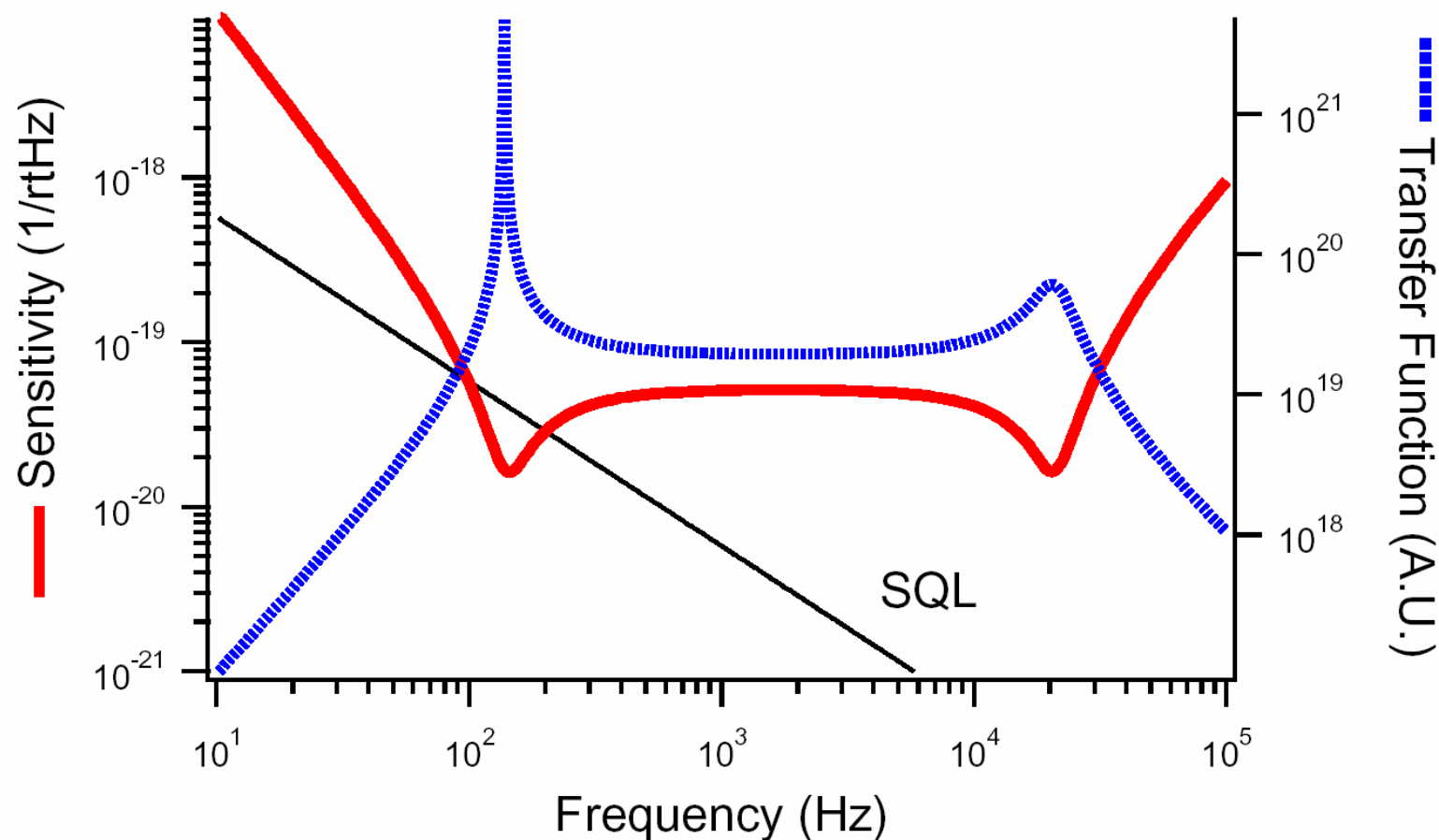
Output shows response to gravitational-wave signals



**Transfer function measurement**



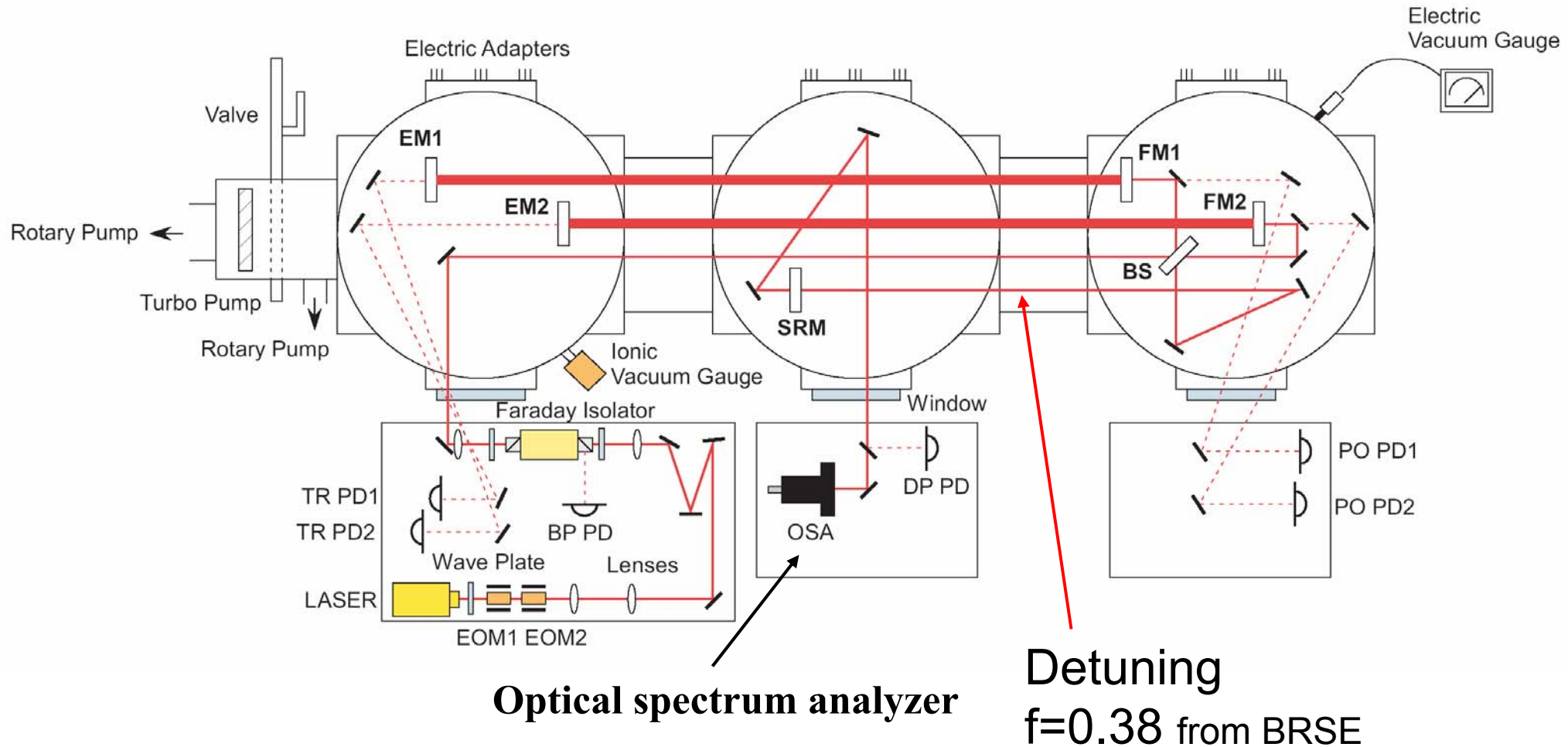
# Quantum noise and transfer function



**Peak appears at the frequency of the QND dip.**

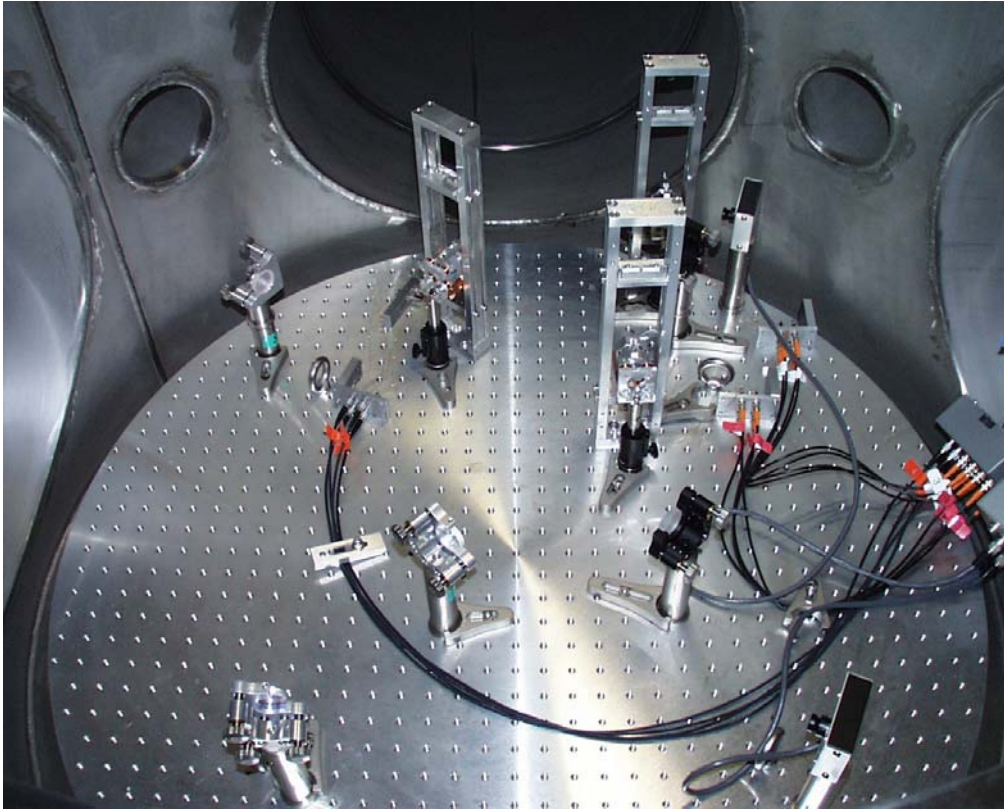
→ **We can see this peak in our interferometer.**

# Setup of Japan 4m prototype RSE

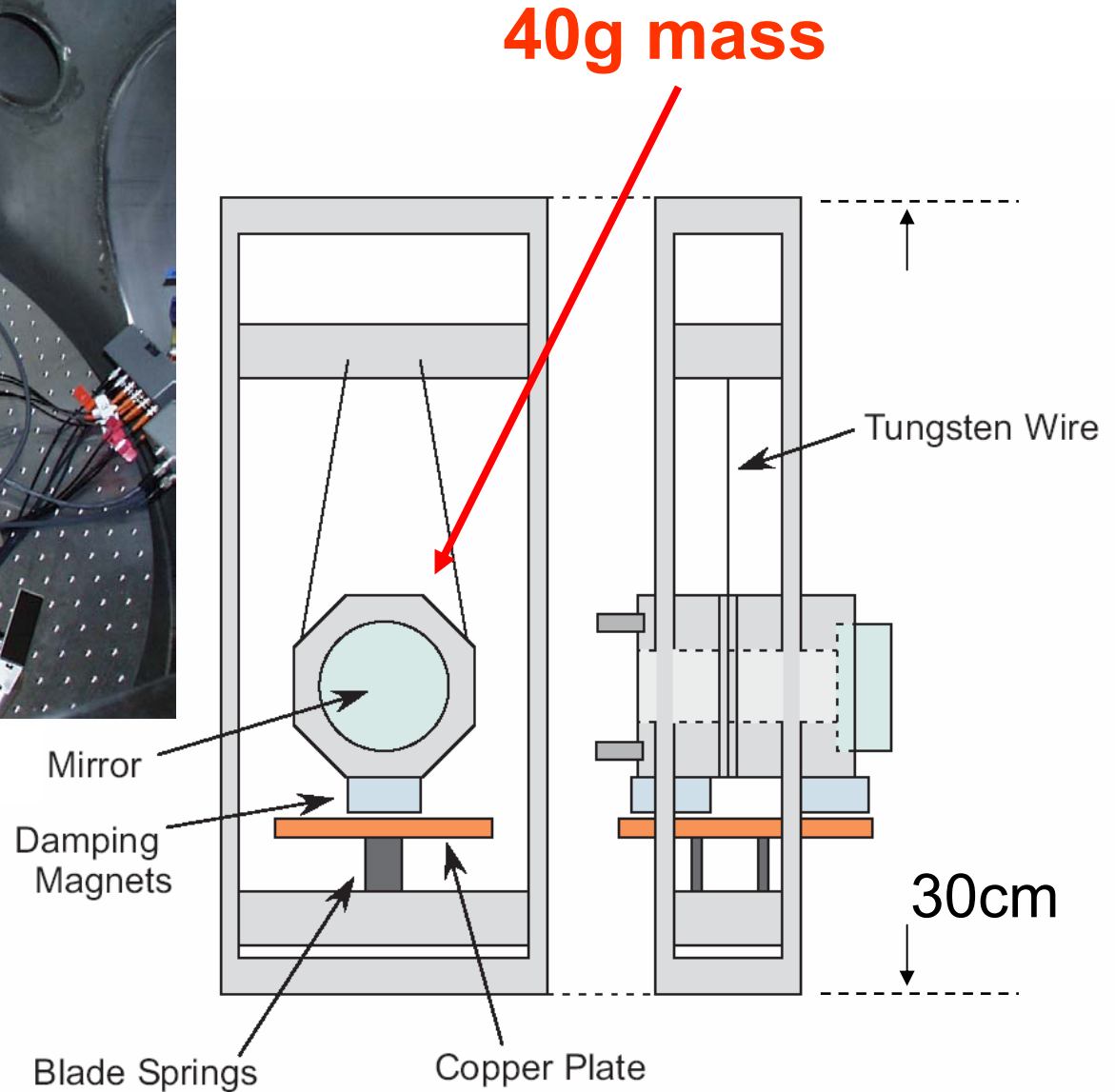


Laser: 500mW, arm finesse: 2000,  $R_{RSE} : 80\%$

# Setup of Japan 4m prototype RSE

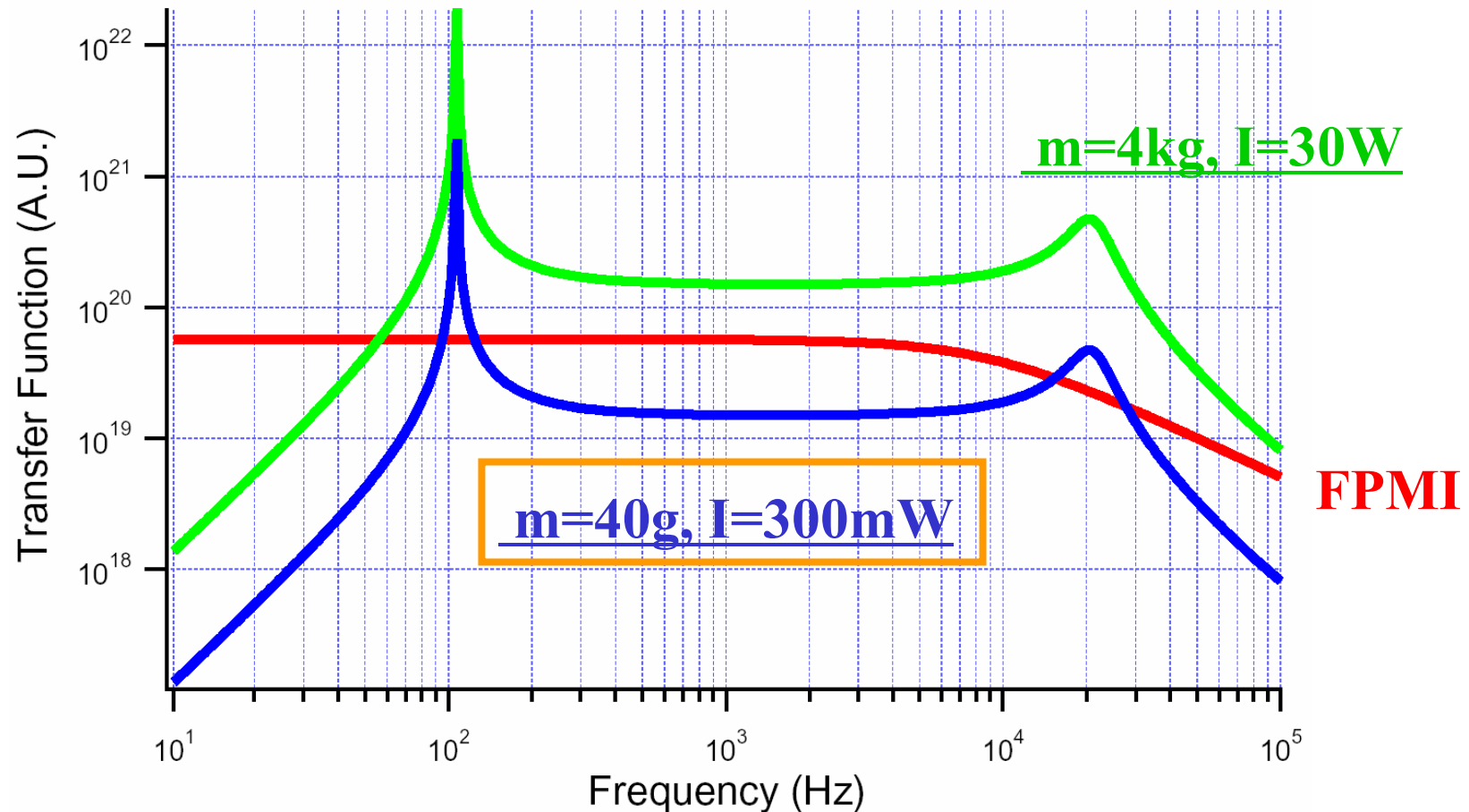


Diameter of  
the vacuum chamber: 1m



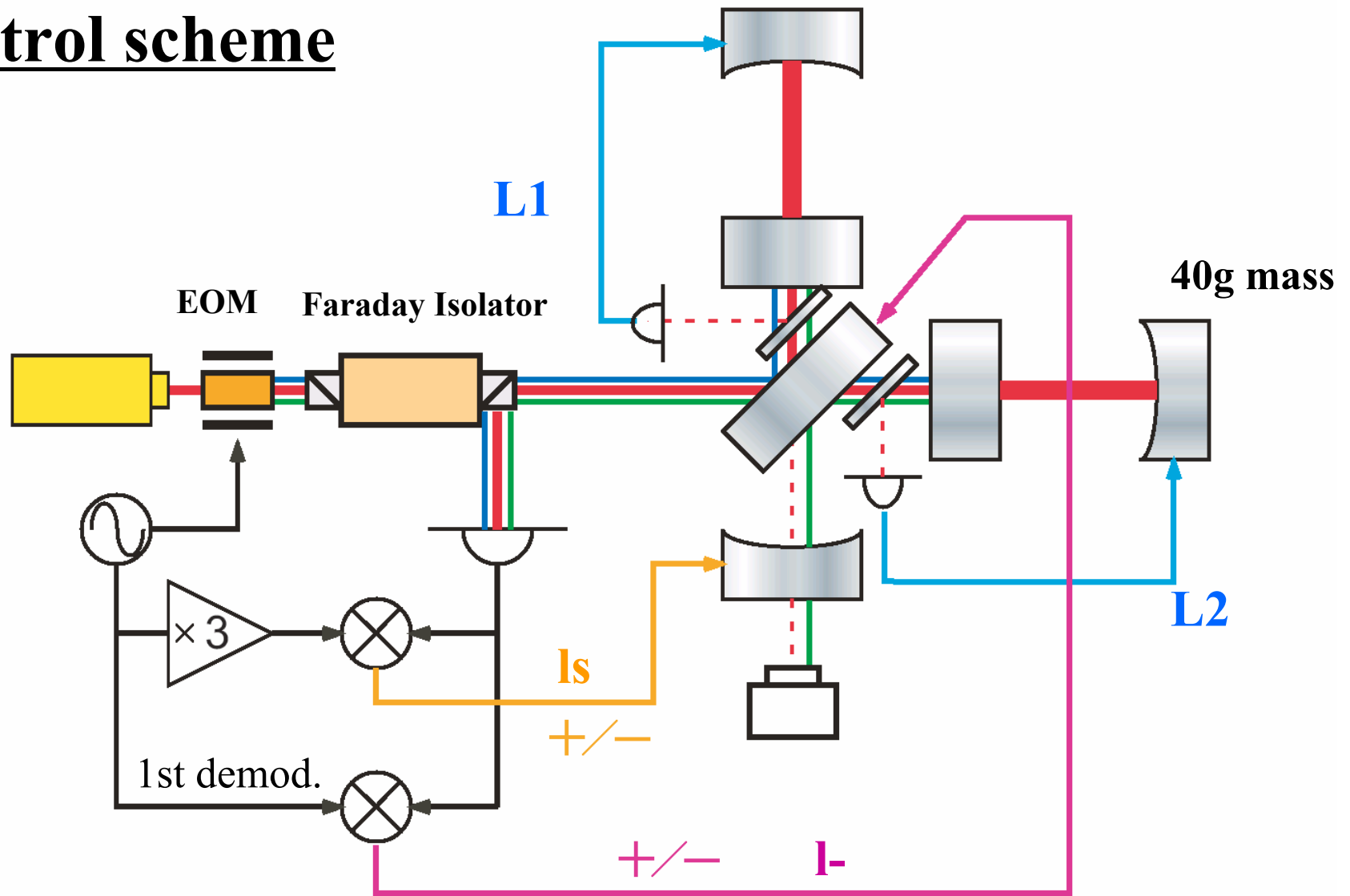
# Mass and the peak frequency

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



**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  $I_s$

# Signal Extraction Matrix

**9-180MHz (High-Freq method)**

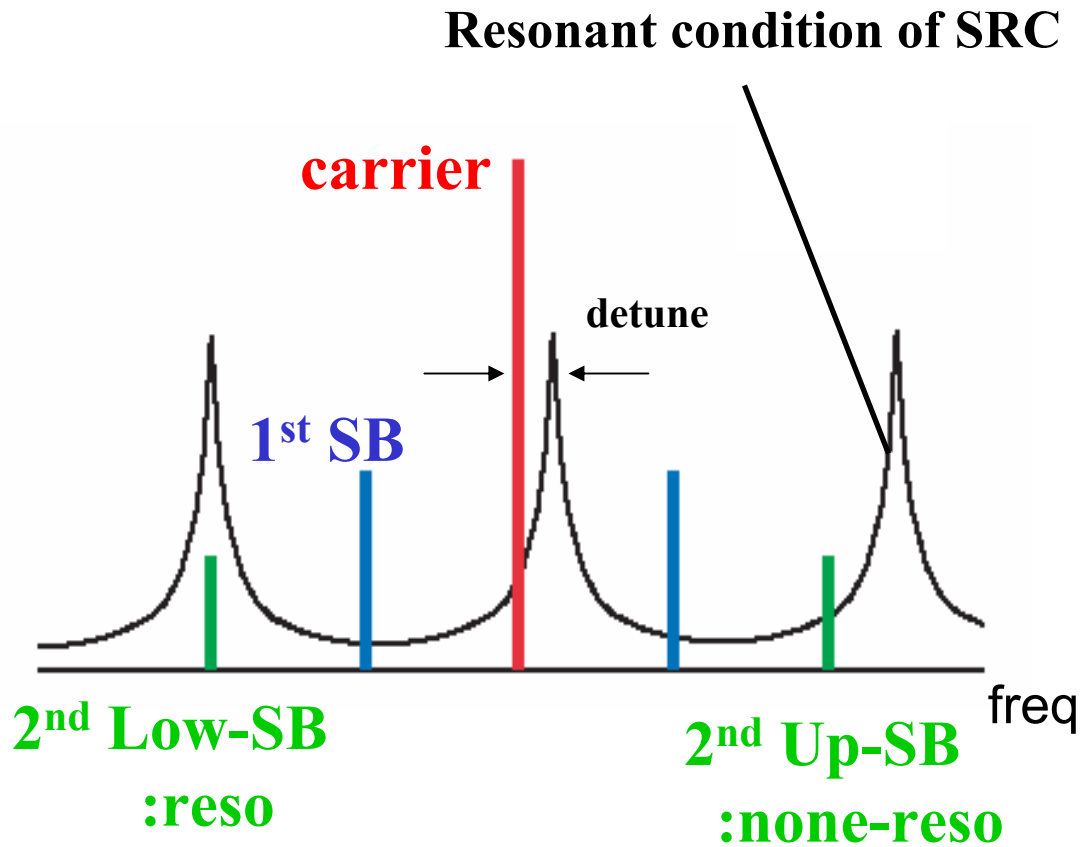
	Port	Demod.	$L_+$	$L_-$	$l_+$	$l_-$	$l_s$	norm.
$L_+$	SP	$f_1$	<b>1</b>	0.000	-0.001	0.000	0.000	1890
$L_-$	AP	$f_2$	0	<b>1</b>	0	0.001	0	-1500
$l_+$	SP	$f_2 - f_1$	-0.006	-0.001	<b>1</b>	-0.006	-0.444	19.5
$l_-$	AP	DDM	0.00	0.00	-0.12	<b>1</b>	0.02	0.242
$l_s$	PO	$f_2 - f_1$	-0.002	0.000	0.036	0.024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

**15-35MHz (Low-Freq method)**

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



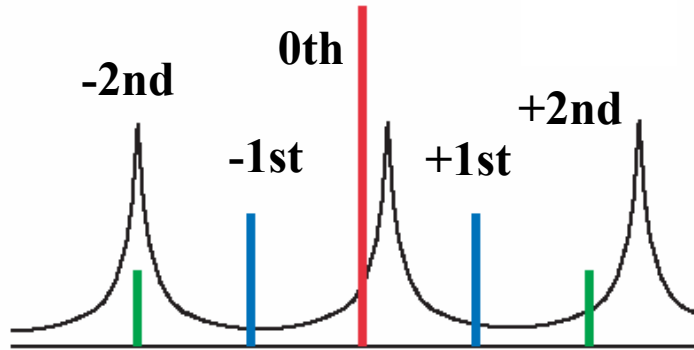
SRC is controlled with  
third harmonics demodulation scheme.

Shift the FSR little from  $2f_m$



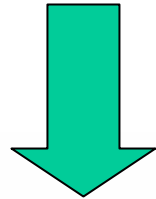
**Detune**

# Ascertain with OSA

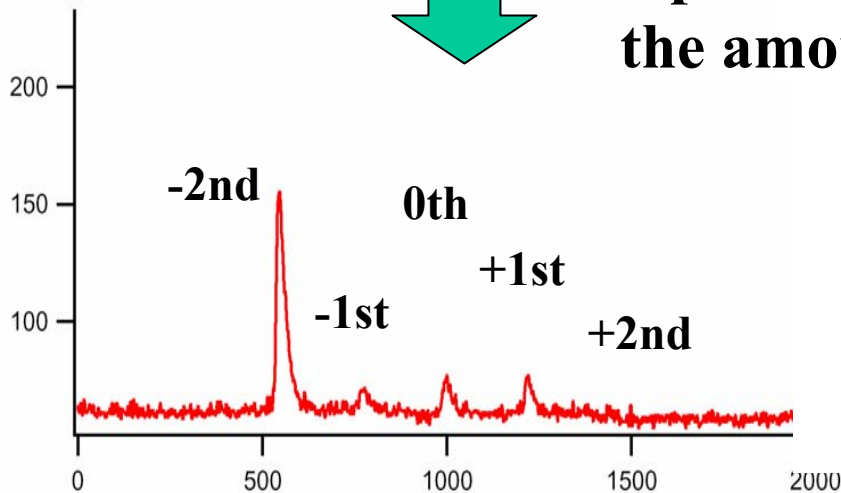


**One-side SB lock**

**Experimental result**



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



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**Unbalance between U/L SB**

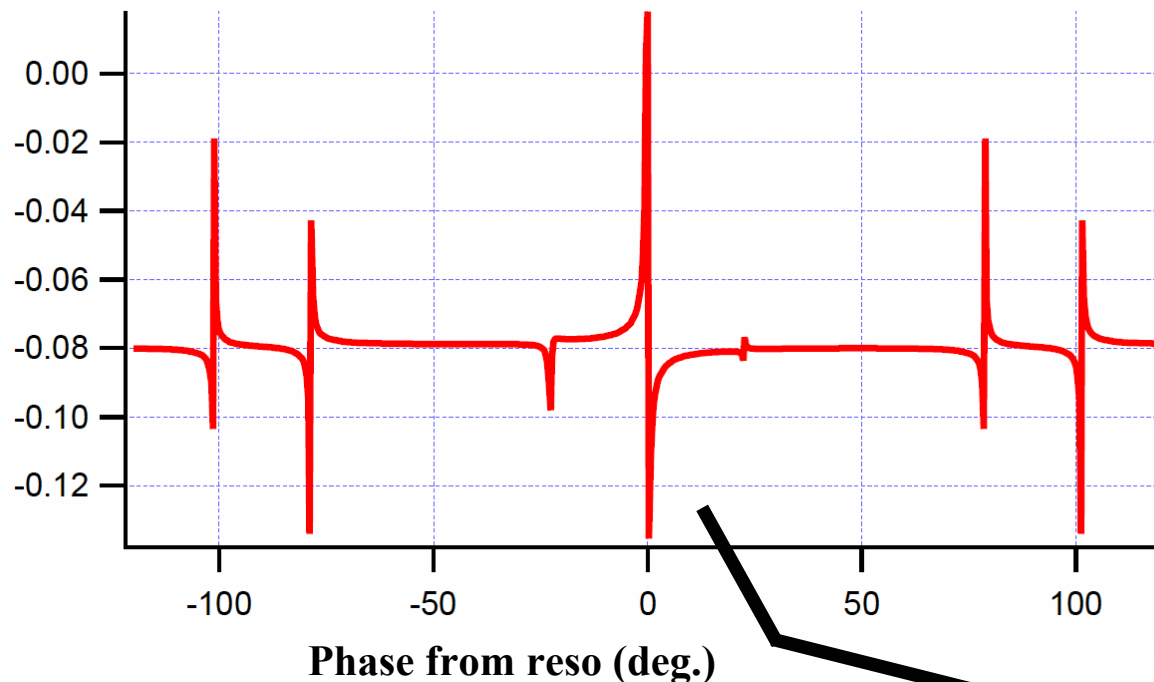


**Detune!!**



# What happens with detuning? ~ ex. Arm cavity lock

Arm err. signal

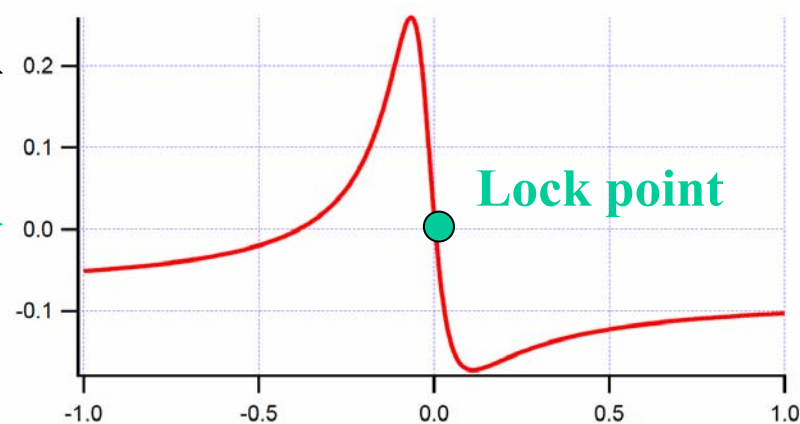


← Offset when none-reso.

No offset when reso.

zoom

zero →

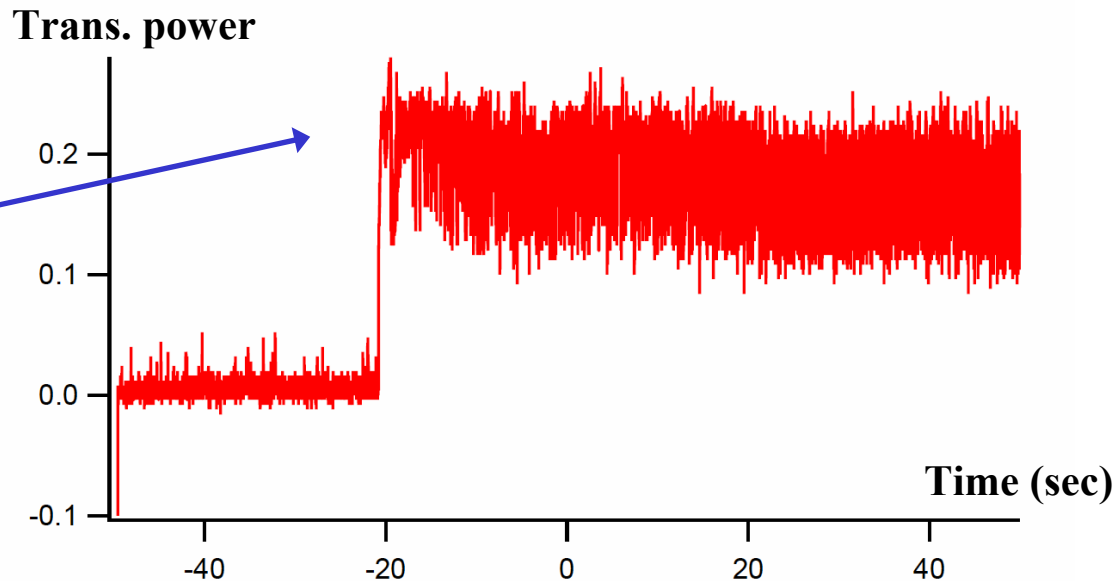


We can observe this at experiment.

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# Offset before locking

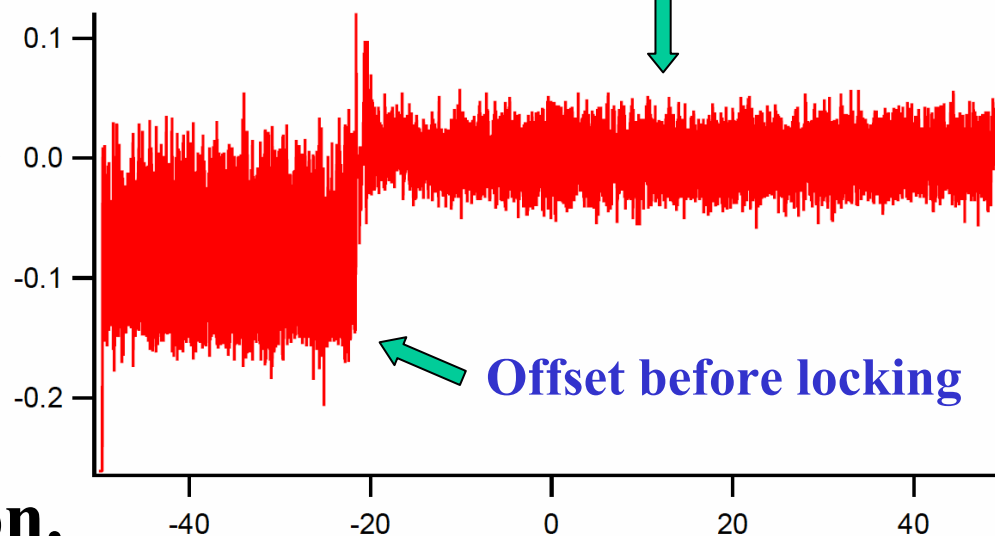
Maximized at the resonance.



Arm err. signal

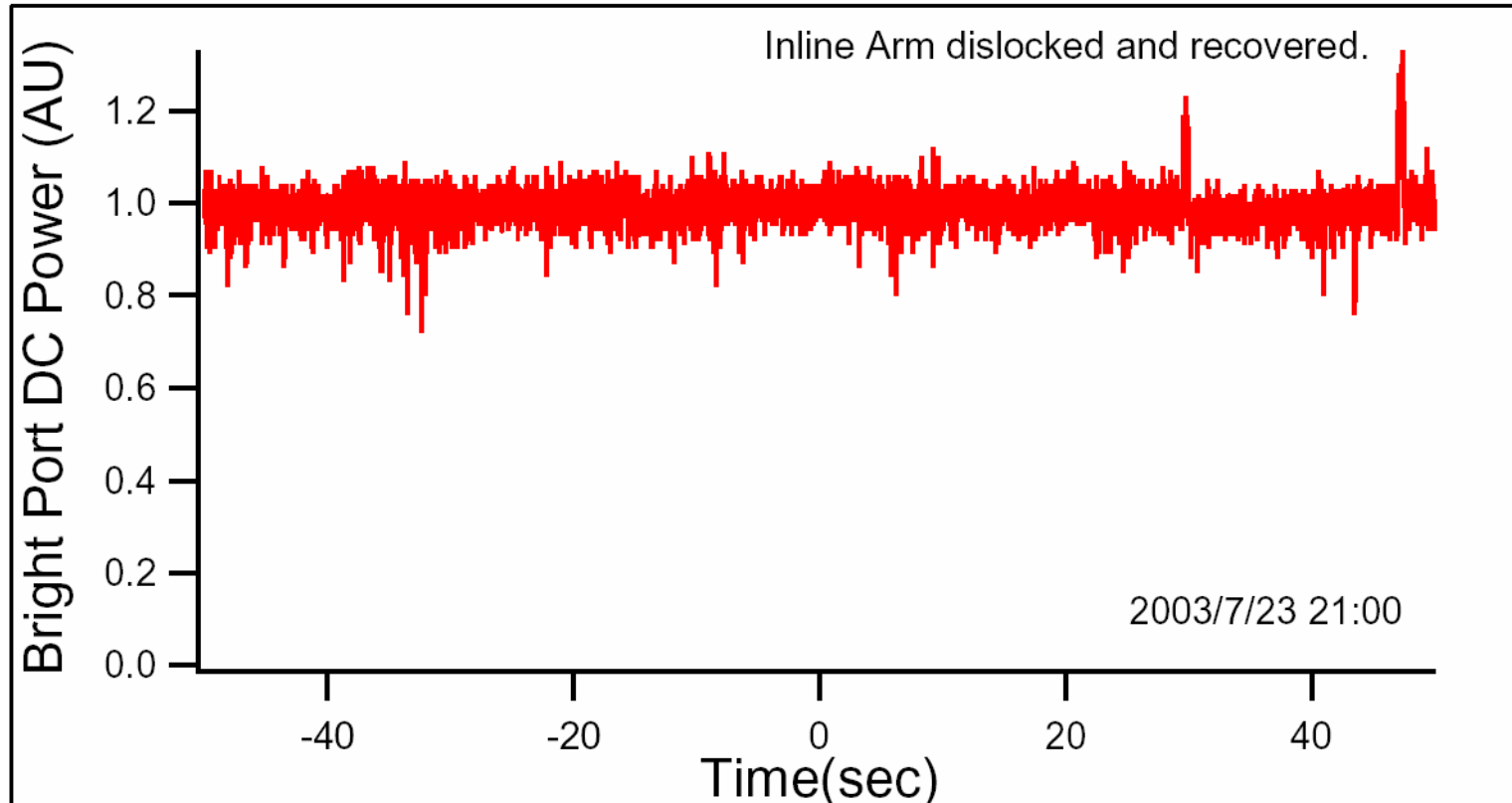
No offset after locked

zero →



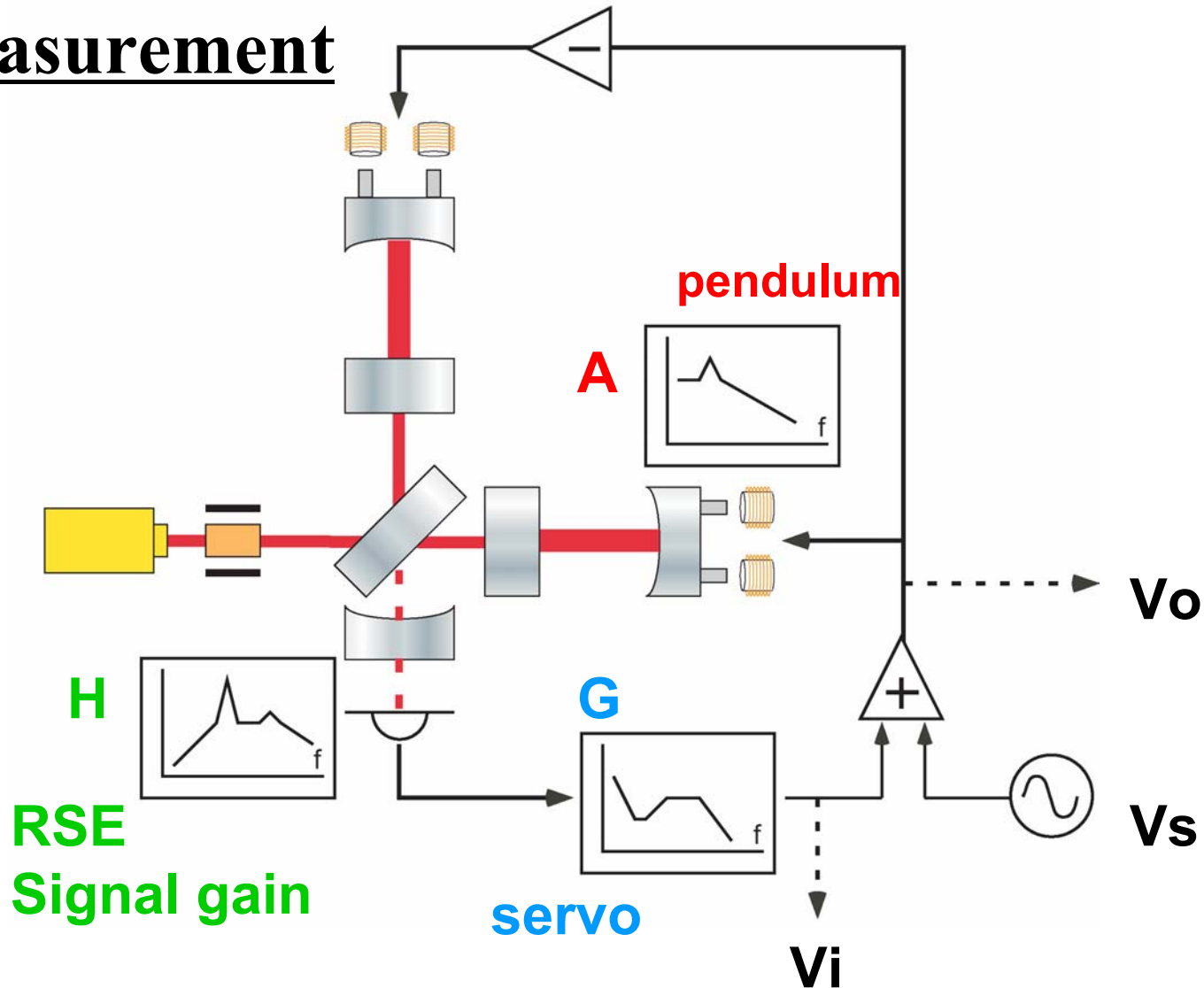
This happens only if SRC is locked at detuned condition.

# RSE Lock (L1, L2, I-, Is)



**World's first lock of DRSE with suspended mirrors**

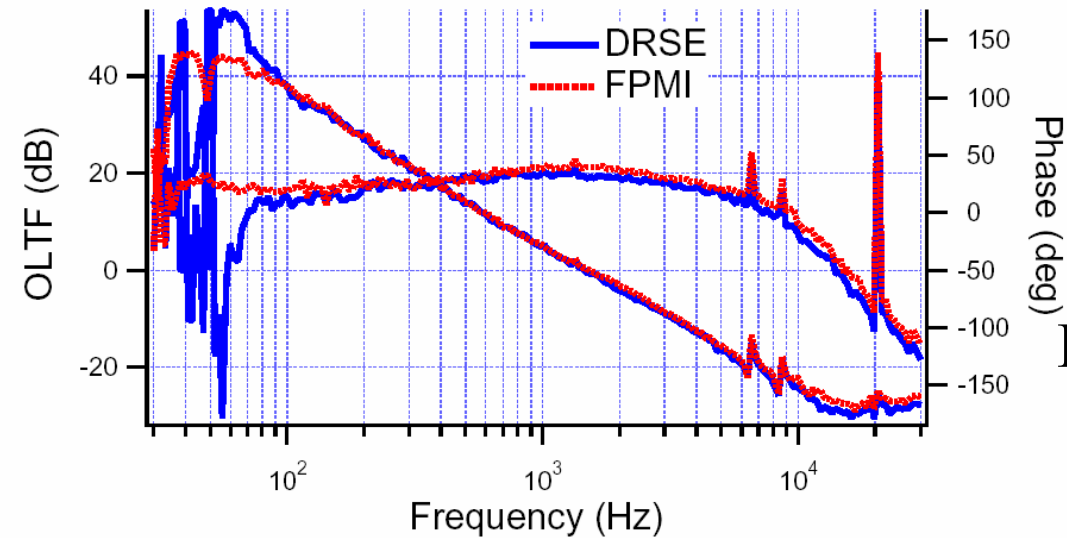
# TF measurement



$V_i/V_o = AGH$  includes **pendulum**, **servo**, and **RSE**.

→ measure FPMI and RSE then take the ratio.

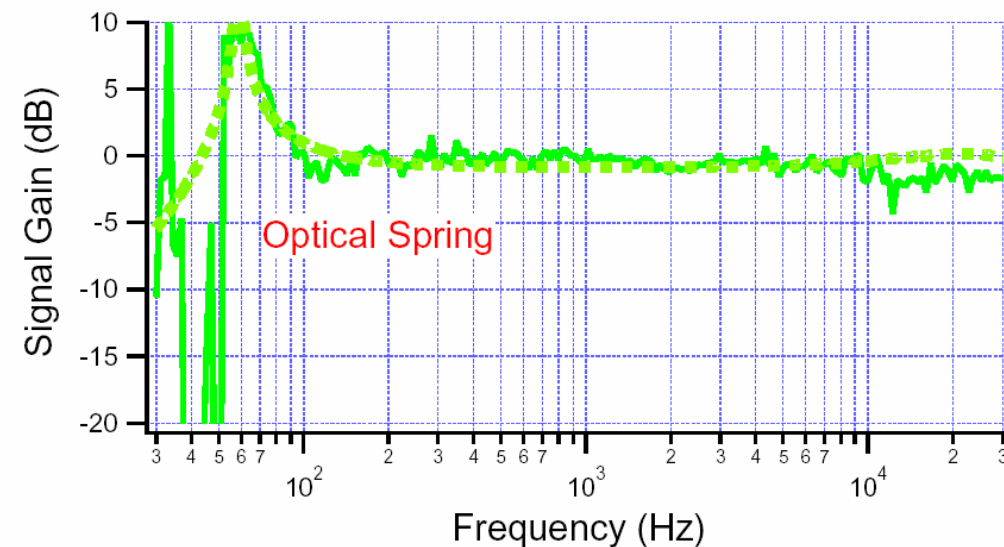
# Measurement results



Includes **pendulum** and **servos**



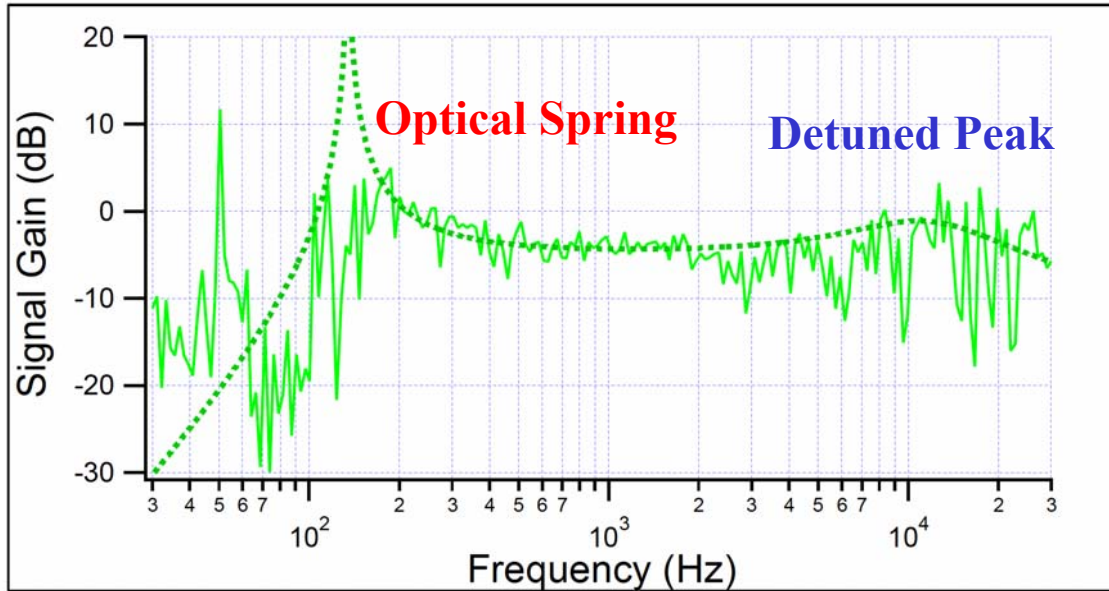
The ratio shows the signal gain.



Optical Spring is hopefully measured!!

4-00-Z  $I=350\text{mW}$ ,  $F=1000$ ,  $\rho=0.4$ ,  $\phi=\pi/2-0.6$

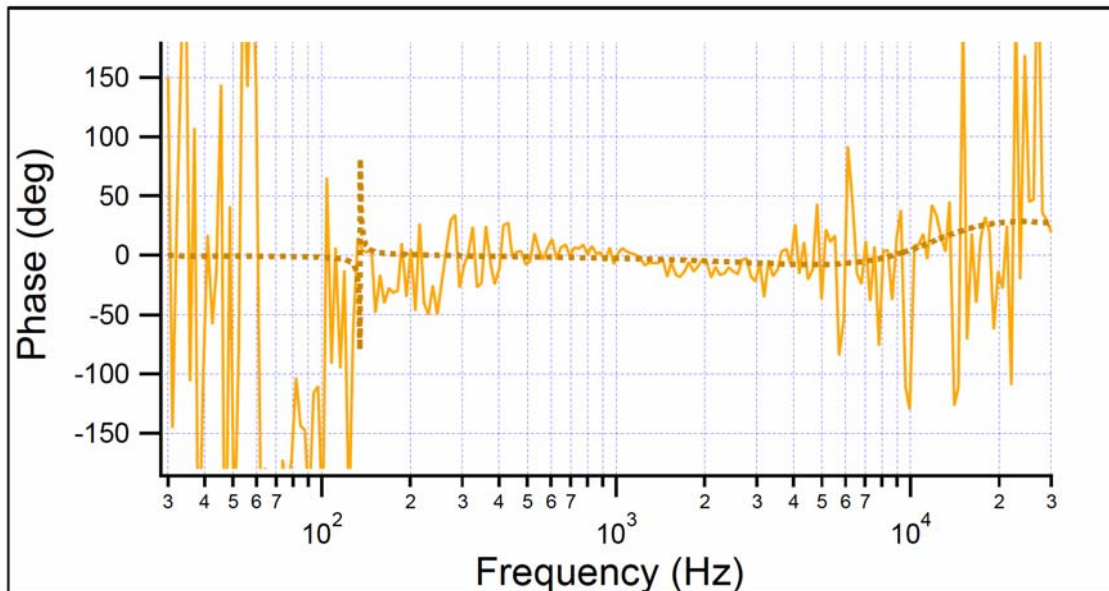
# We were able to see the other peak at the beginning.



• **Measured 2 months earlier.**

• **Precision level was lower.**

• **Finesse was higher.**



$I=350\text{mW}$ ,  $F=2000$ ,  $\rho=0.5$ ,  $\phi=\pi/2-0.6$

# 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

