Active Vibration Isolation using a Suspension Point Interferometer

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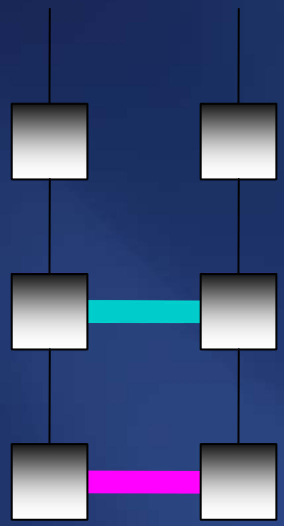
Introduction

Suspension Point Interferometer (SPI)



Active vibration isolation method

using a laser interferometer itself

Originally proposed by Prof. R. Drever

Low Freq., Improve Stability, Cryogenic Interferometer

Prototype Experiments

SPI	-40dB in noise spectrum below 3Hz limited by vertical vibration
VSPI	-40dB in transfer function measurement

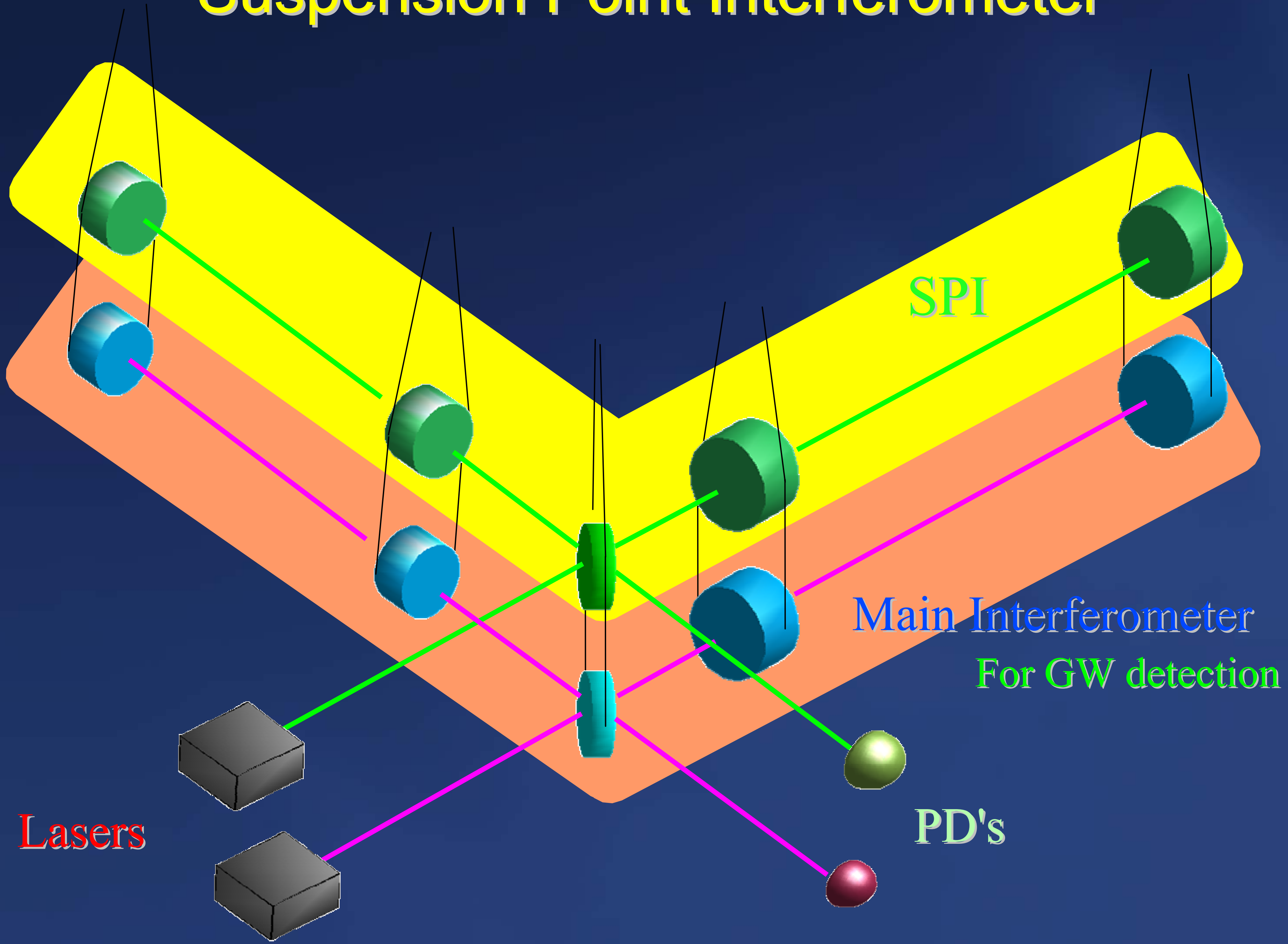
Current experiment: Combination of SPI and VSPI

Development Status

Contents

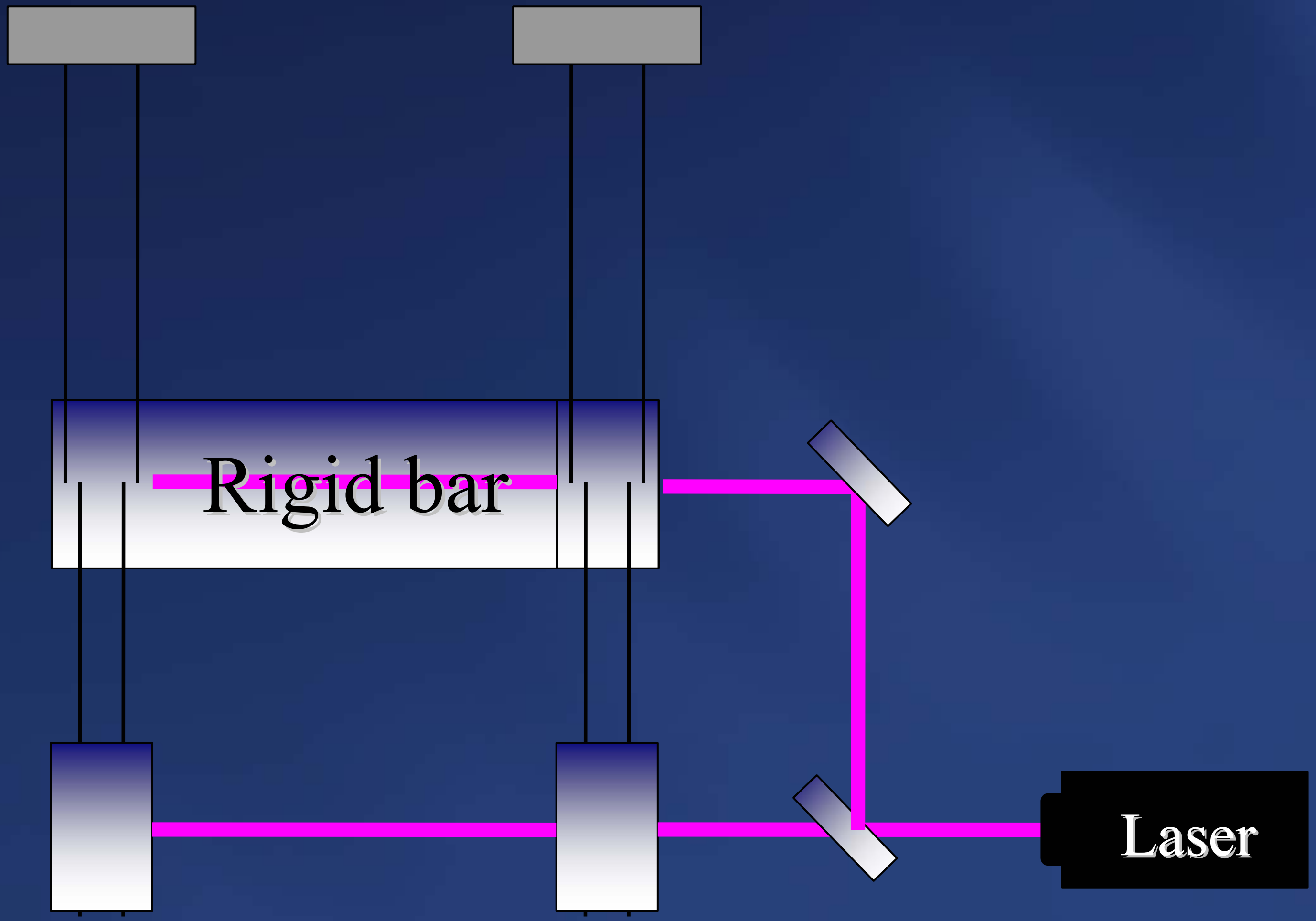
- SPI
  - Principle
  - Advantages, Applications
  - Proto-Type Experiment
- VSPI
  - Principle
  - Proto-Type Experiment
- SPI+VSPI
  - Overview
  - Experimental apparatus
  - Development Status, Future plans
- Summary

Suspension Point Interferometer



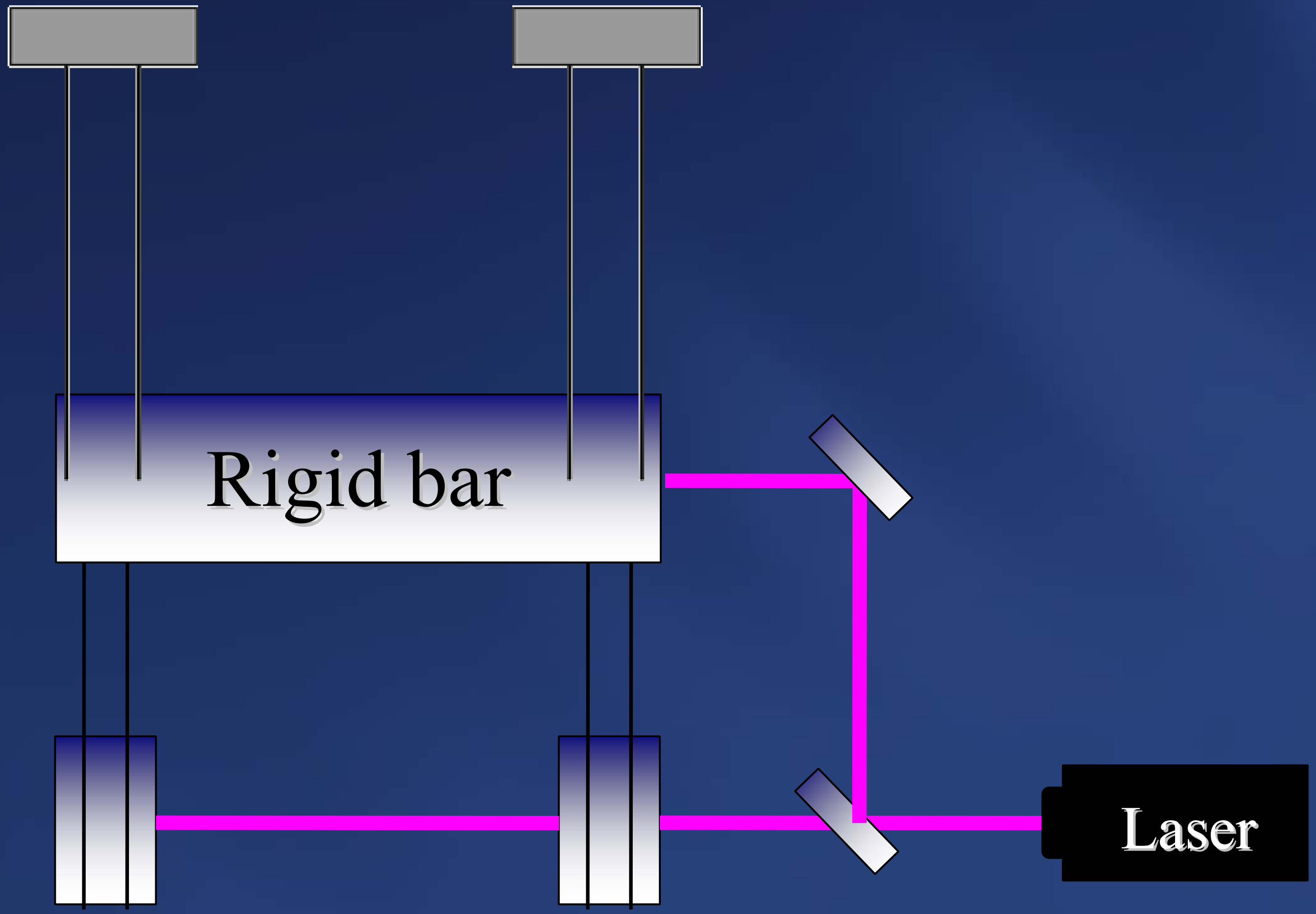
Working principle of SPI

Lock SPI



Working principle of SPI

Vibration is suppressed



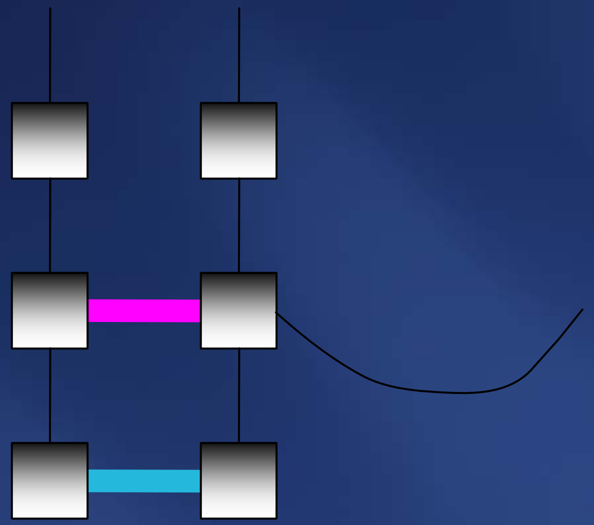
Advantages and Applications

Interferometer = Ultra Low Noise Sensor

High performance active vibration isolation system

Seismic vibration

Cryogenic Interferometer



Vibration isolation of heat links

Reduction of RMS motion

Stabilization

Easy lock acquisition

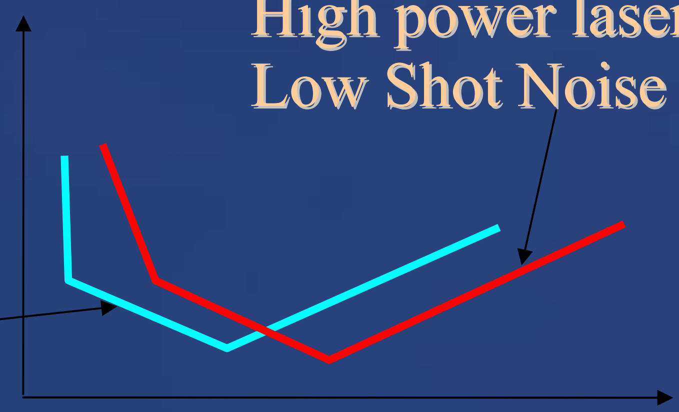
Actuator noise reduction

Two Interferometers

Coincidence Analysis

Dual Band

SPI
High power laser
Low Shot Noise



Main Interferometer
Low power laser
Low Radiation Pressure

Theoretical performance

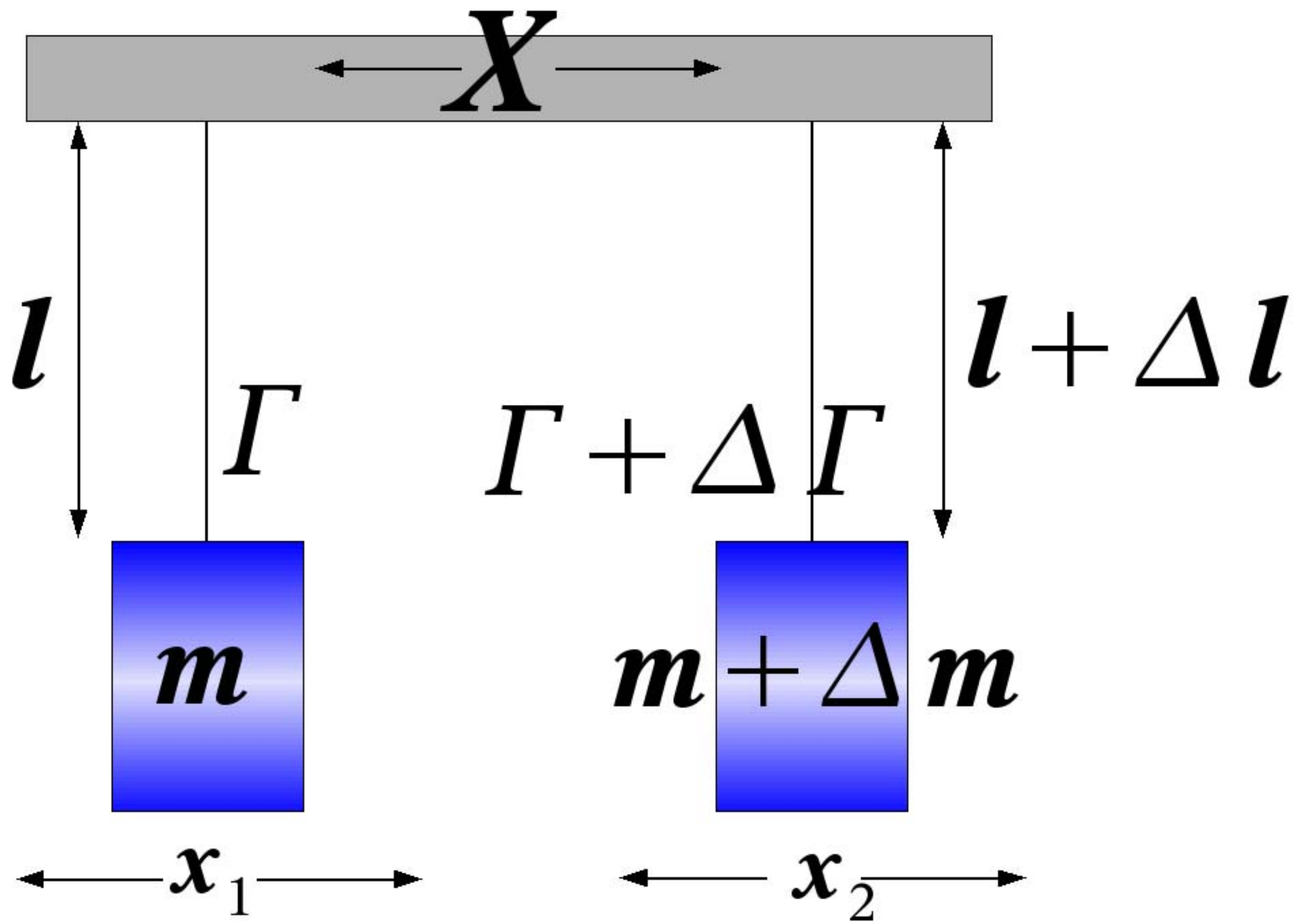
Main factors

Control Gain

CMRR

Coupling from other degrees of freedom

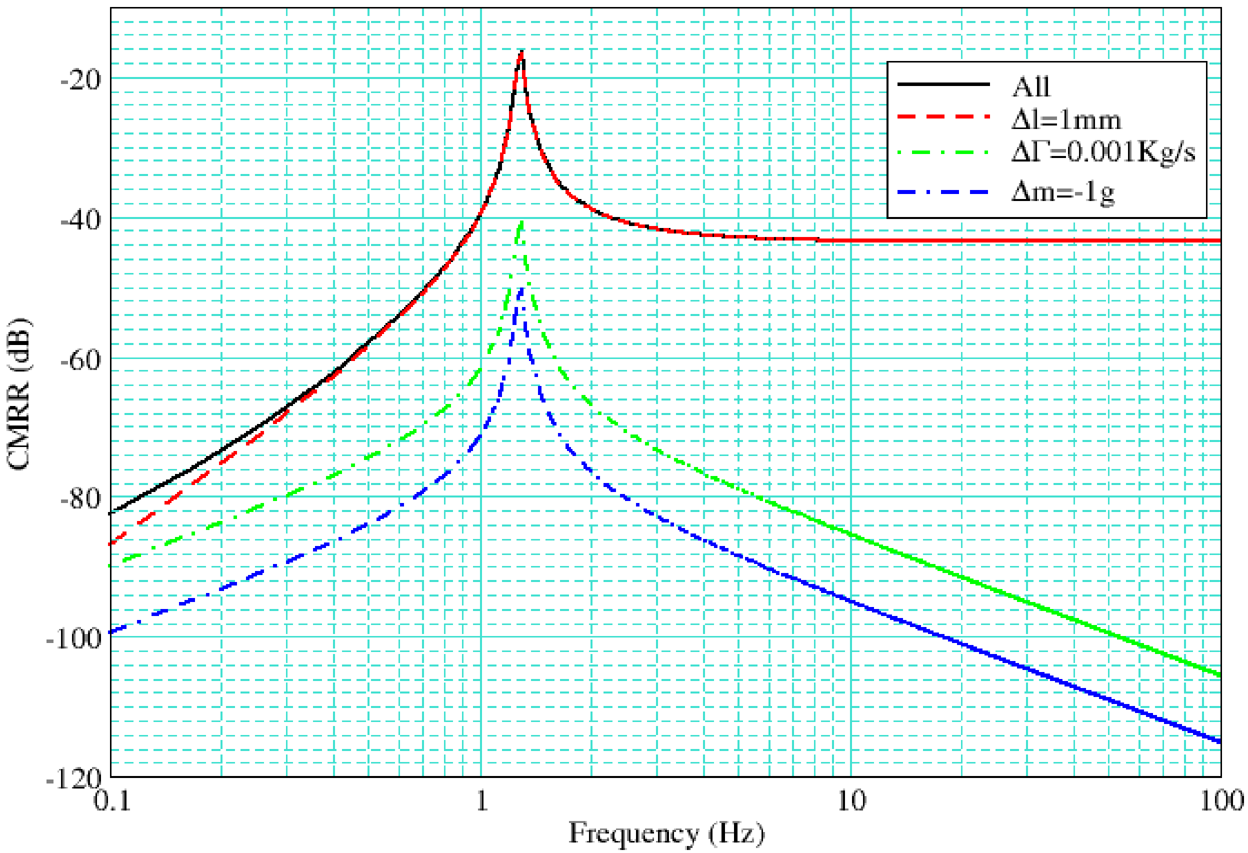
Asymmetry in the suspension



$$H_1(\omega) = \frac{x_1}{X} \qquad H_2(\omega) = \frac{x_2}{X}$$

$$\mathrm{CMRR} \equiv 2\left|\frac{H_1 - H_2}{H_1 + H_2}\right|$$

$$\simeq |H_1(\omega)|\sqrt{\left(\frac{\Delta l}{g}\right)^2 \omega^4 + \left(\frac{l\Gamma}{mg}\right)^2 \left(\frac{\Delta l}{l} + \frac{\Delta \Gamma}{\Gamma} - \frac{\Delta m}{m}\right)^2 \omega^2}$$



$\rightarrow \dfrac{\Delta l}{l}$

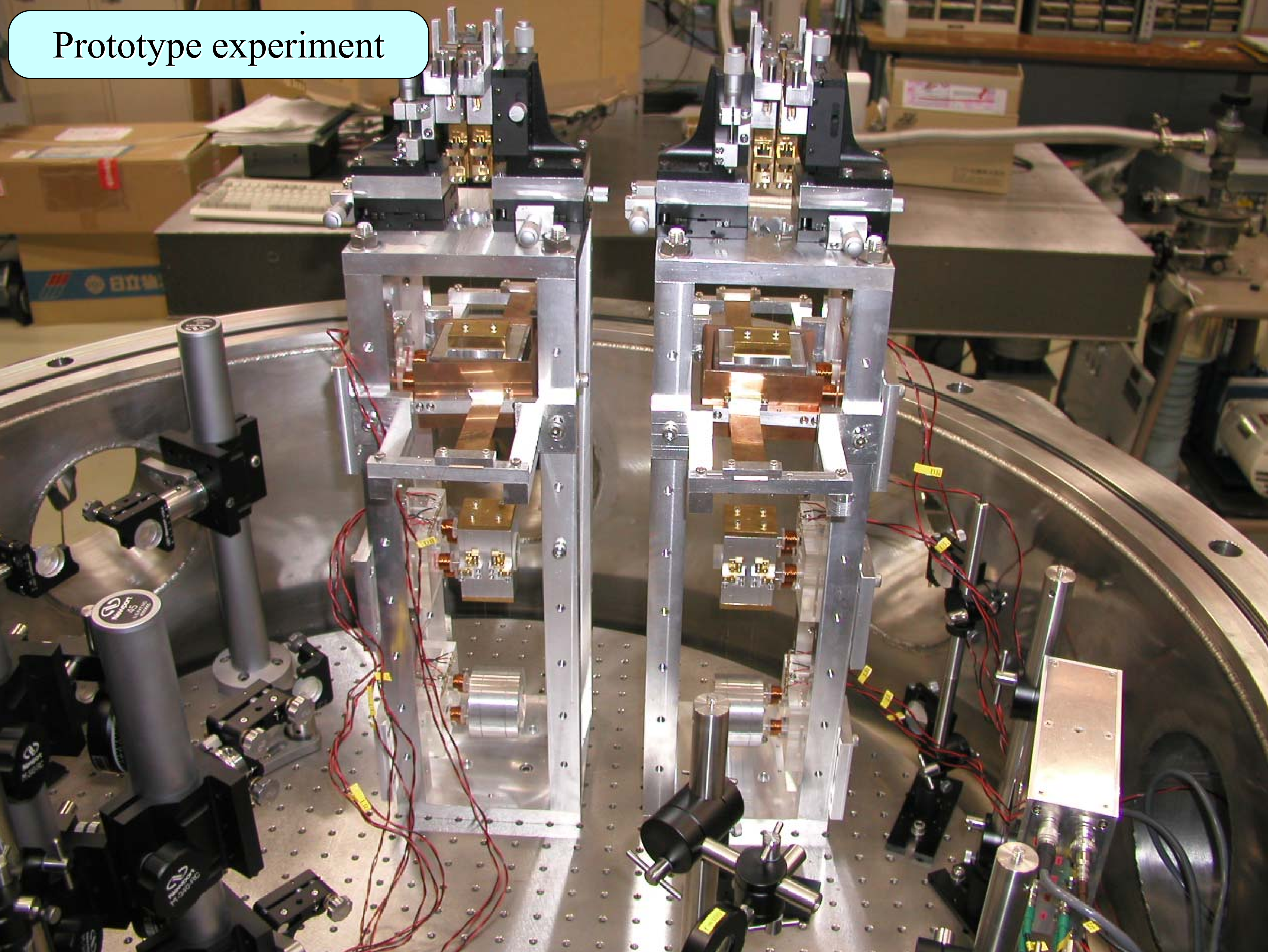
at high frequencies

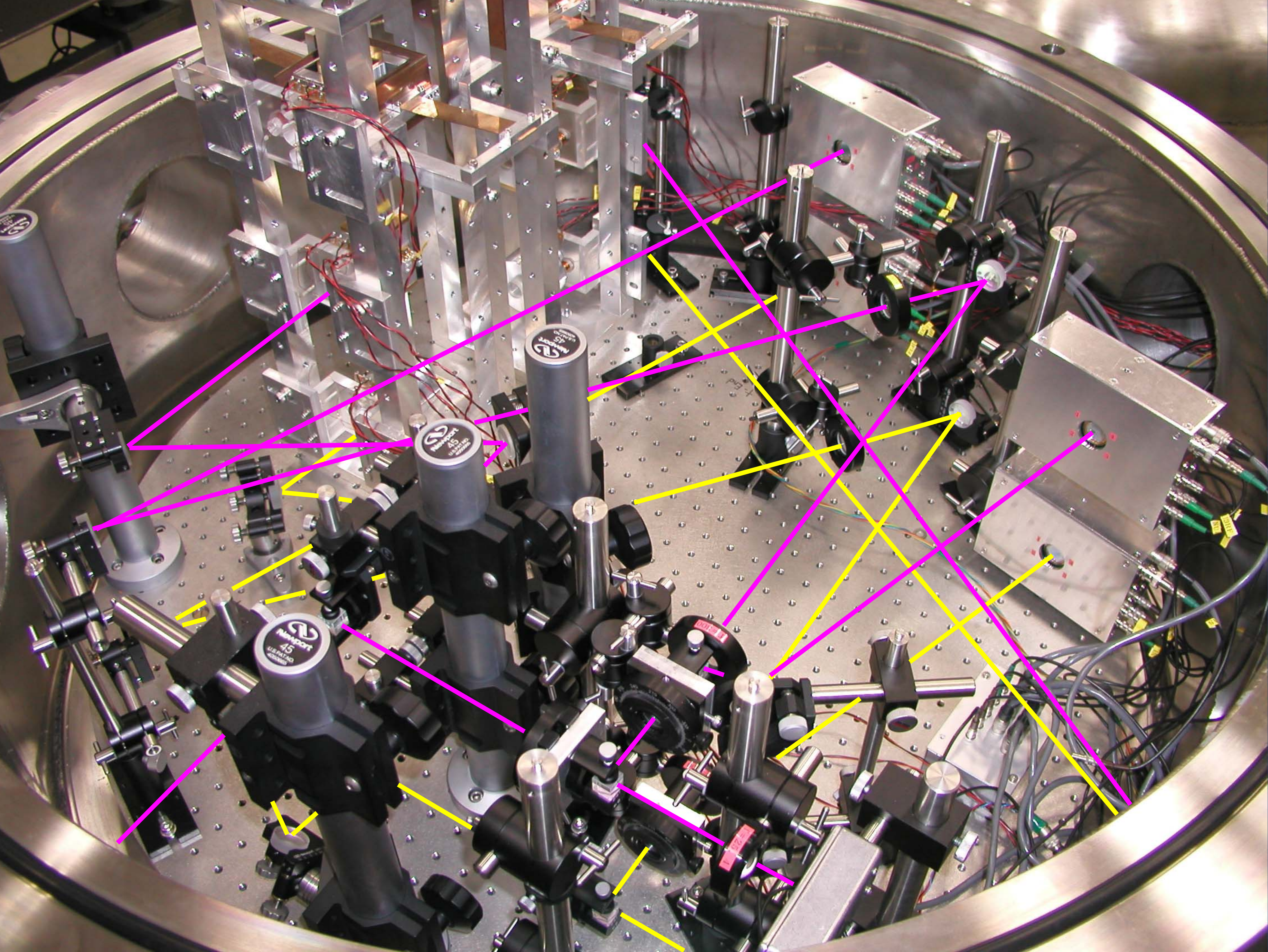
$m = 200\,\mathrm{g}$

$l = 150\,\mathrm{mm}$

$\Gamma = 0.1\,\mathrm{Kg/s}$

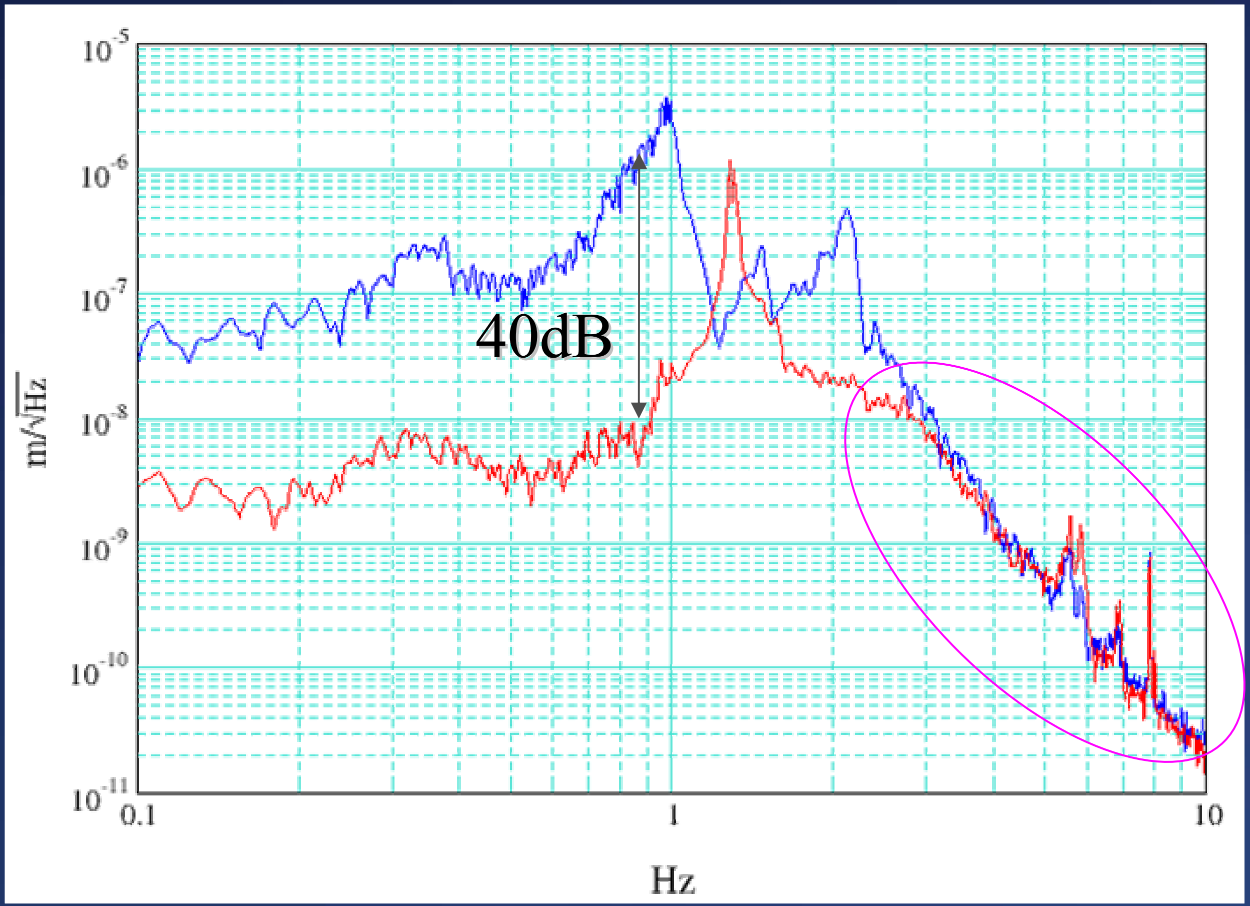
Prototype experiment



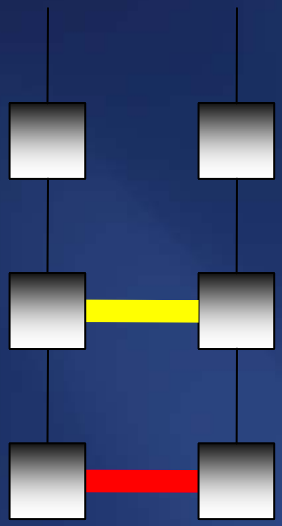

Newport
45
Newport
45
Newport
45

Results from the proto-type experiment

Triple pendulum Fabry-Perot Cavity



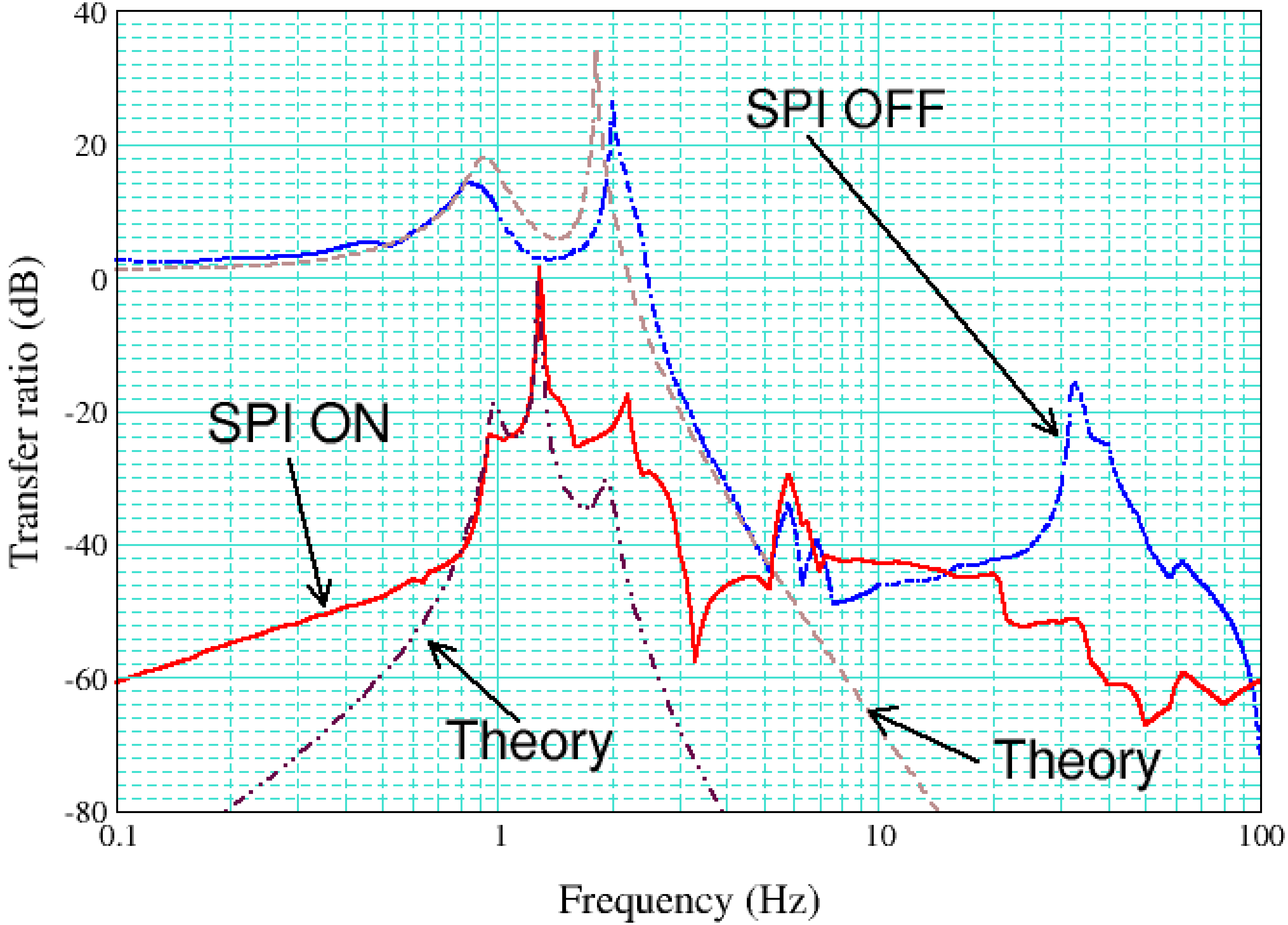
Vertical vibration



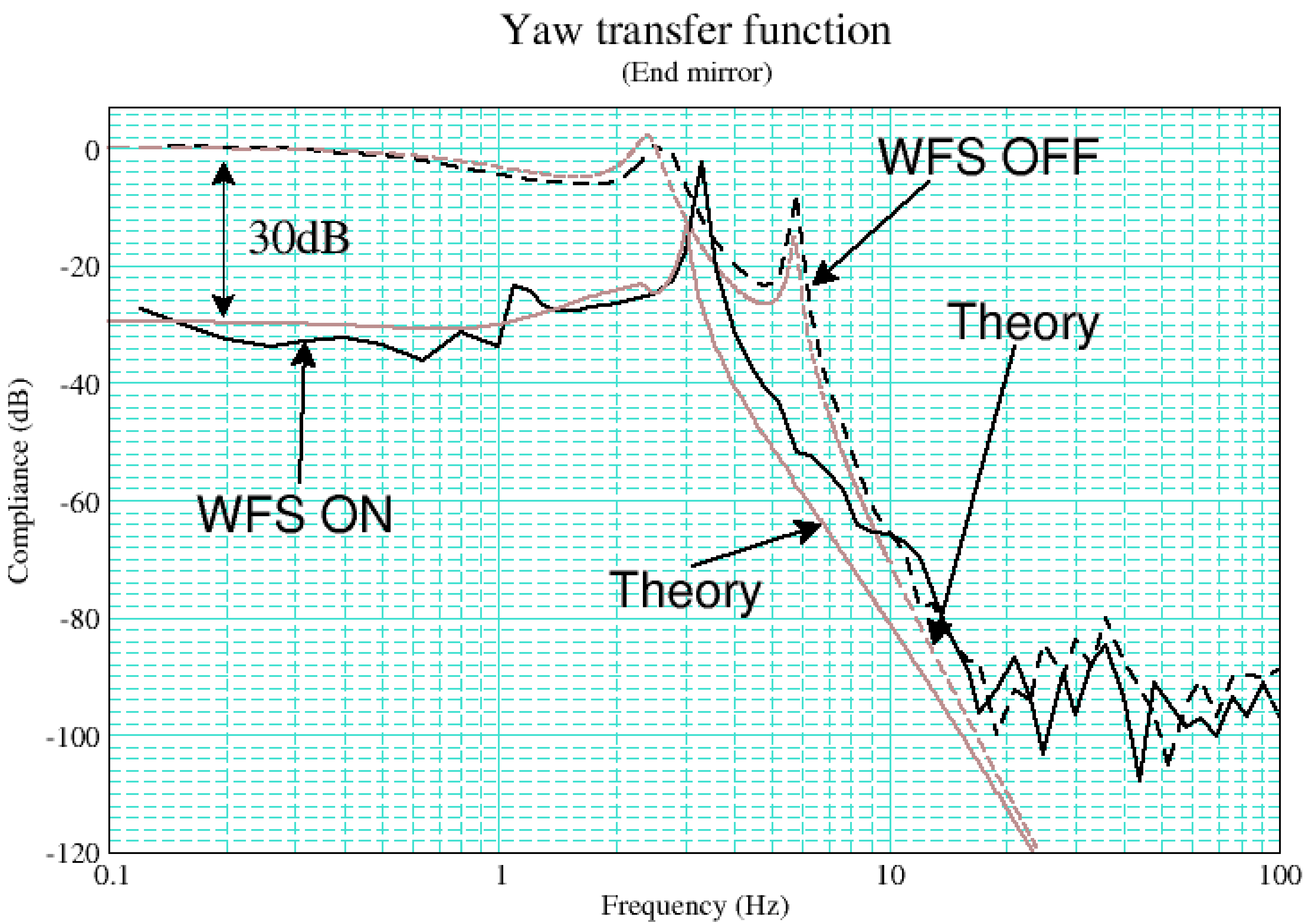
Vertical vibration is dominant above 3Hz

Transfer function measurements

Transfer functions from the damping mass to the main interferometer

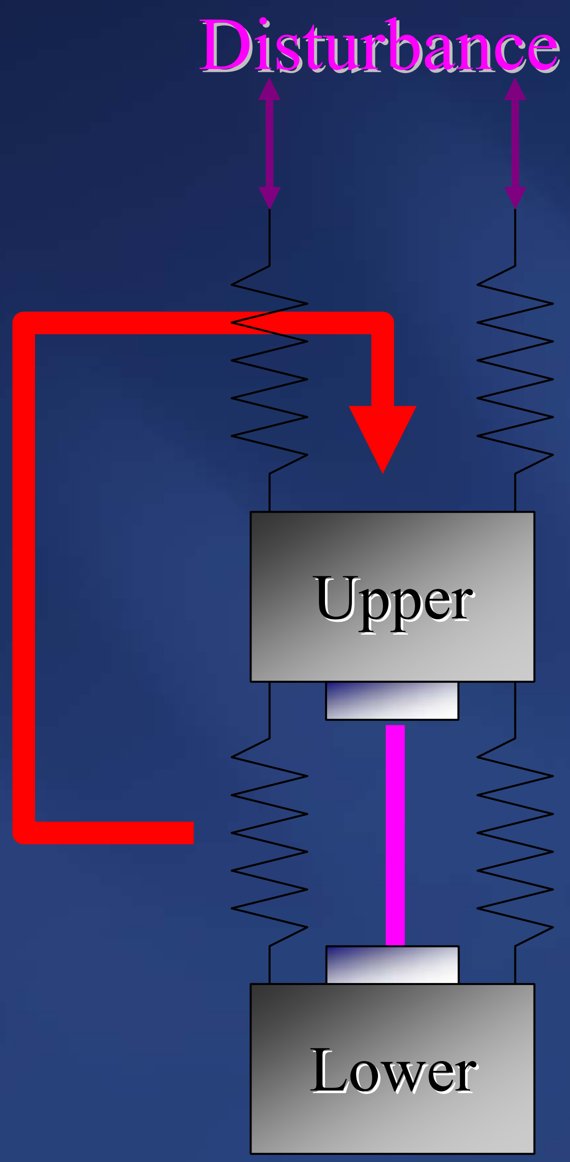


WFS test



Yaw transfer function
(End mirror)
0
-20
-40
-60
-80
-100
-120
Compliance (dB)
0.1
1
10
100
Frequency (Hz)
30dB
WFS OFF
WFS ON
Theory
Theory

Vertical Suspension Point Interferometer



Goal

Stop the lower mass in the inertial frame

Assumption

External disturbances are only introduced from the suspension points

Reference

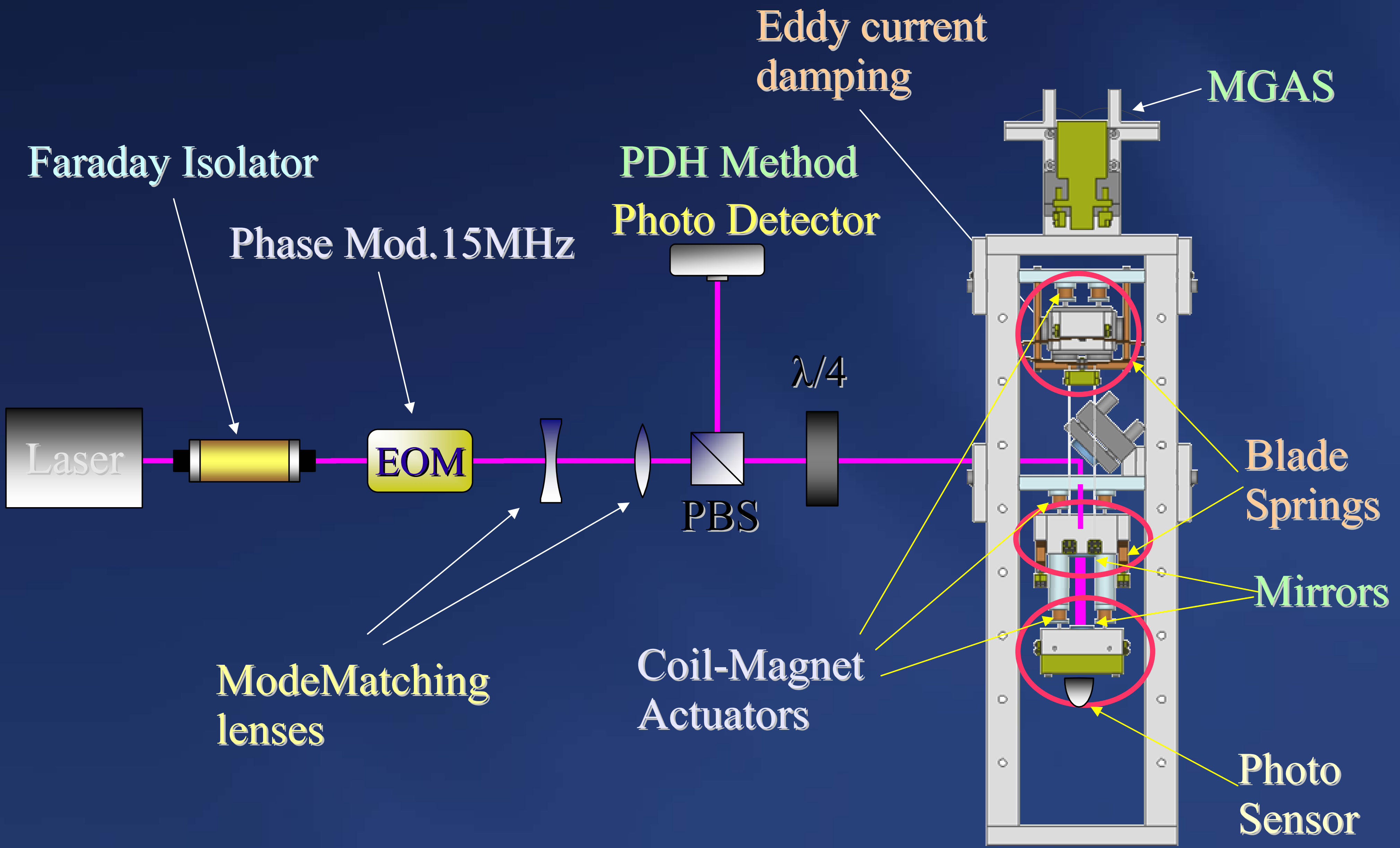
Lower mass= More sticky to the inertial frame

Fabry-Perot Interferometer

Relative motion between the upper and lower mass

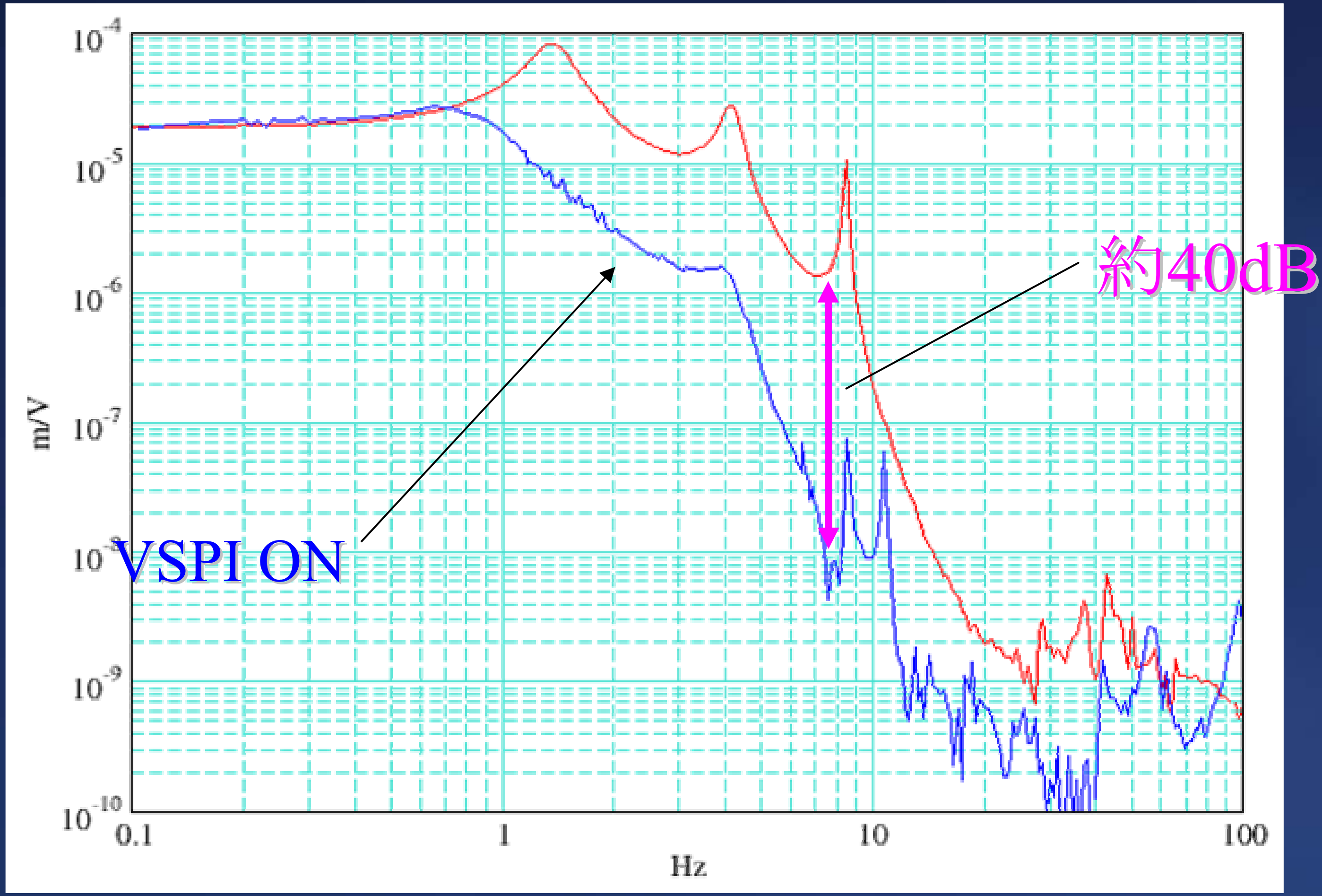
→ Cancel the disturbance

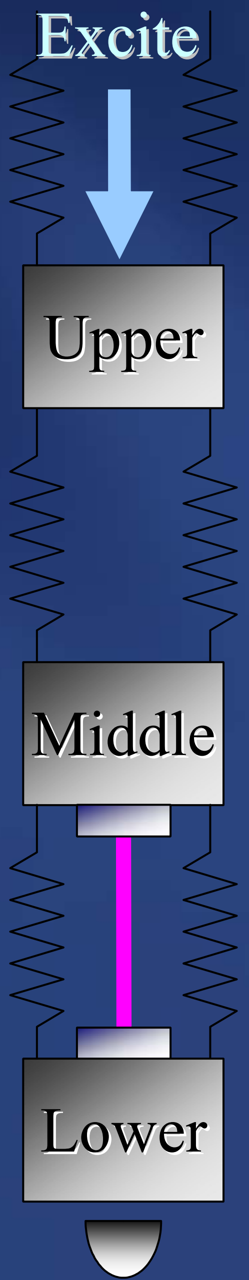
VSPI Experiment



Results of the VSPI experiment

Excitation Voltage → Displacement of the lower mass





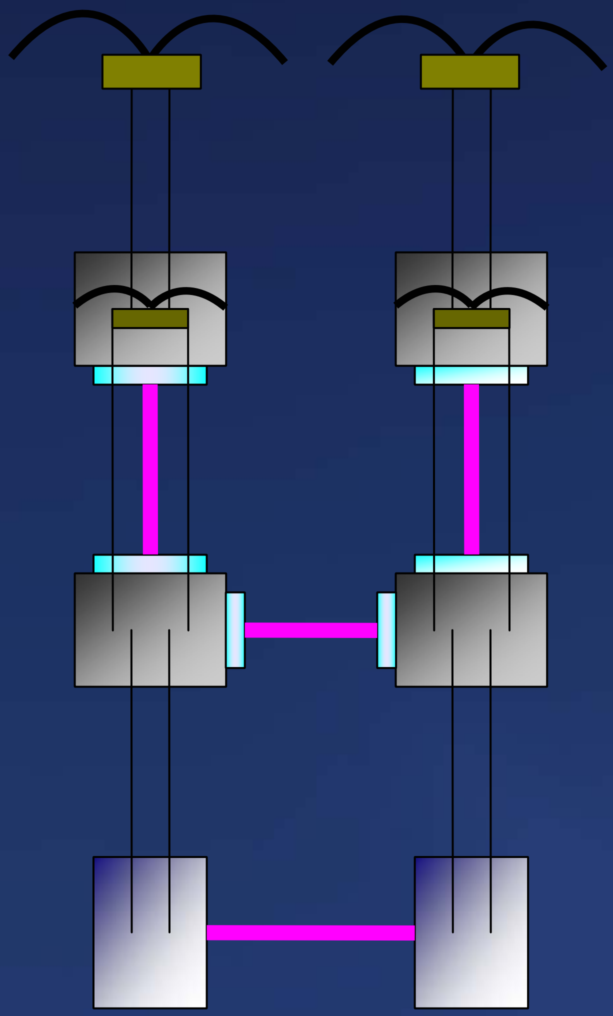
Working fine up to 10Hz

Next Step

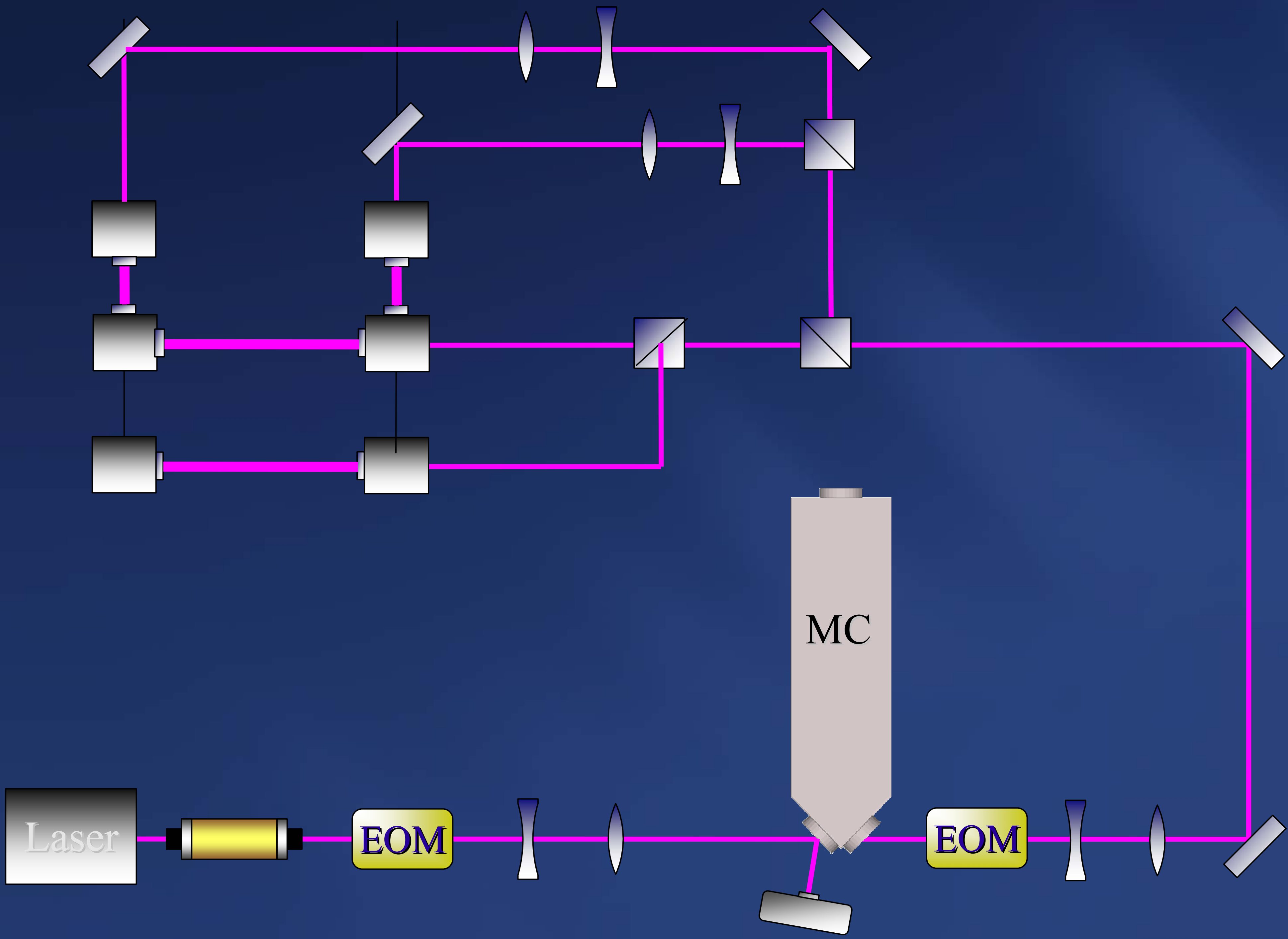
Combination of SPI and VSPI

Aim: Achieve good vibration isolation performance above the resonant freq. of the pendulum.

$$10^{-16}\,\mathrm{m}/\sqrt{\mathrm{Hz}}\ @\ 10\,\mathrm{Hz}$$

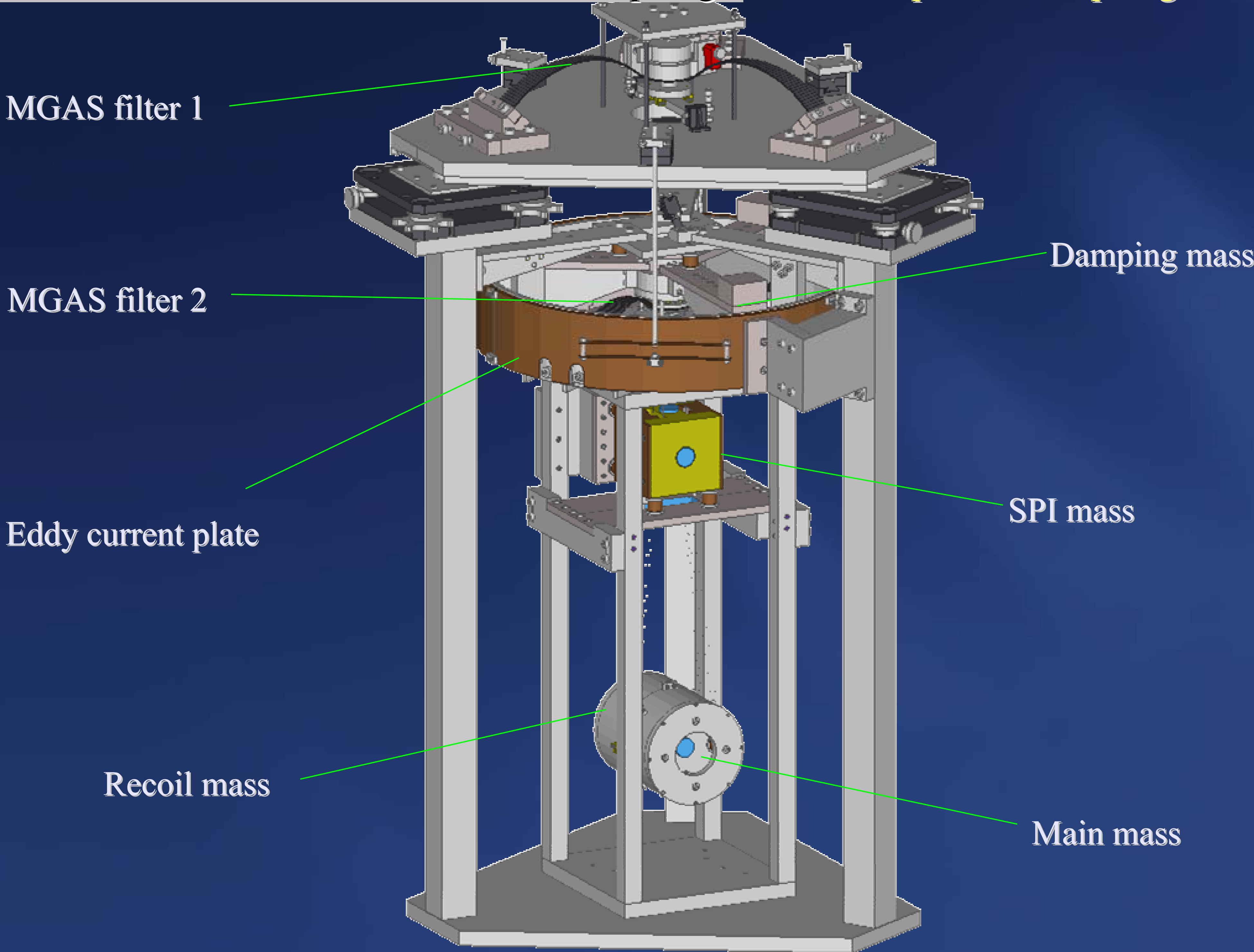


Overview of experimental setup



MGAS=Monolithic Geometric Anti Spring

Low freq. vertical spring

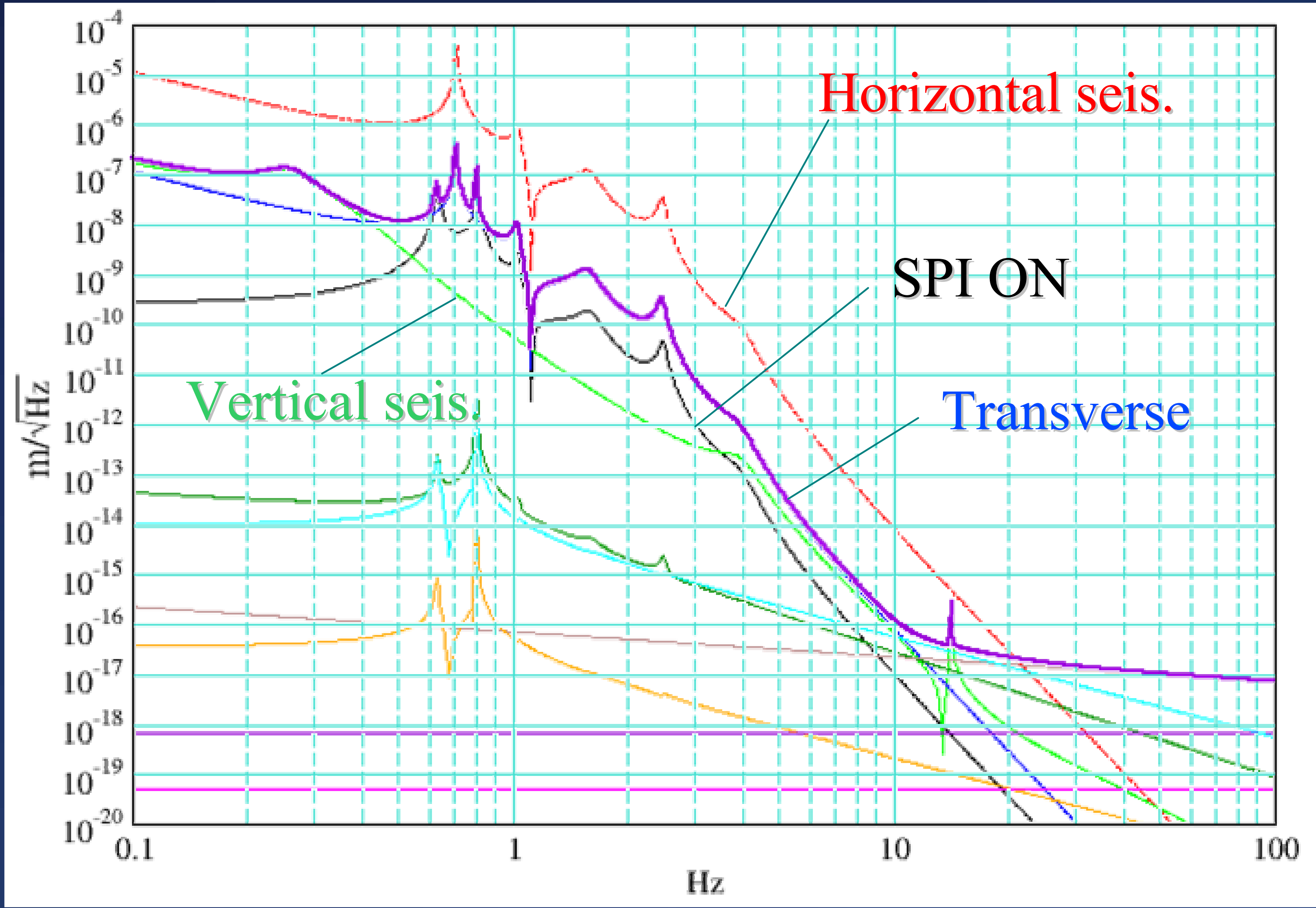


Noise Budget

Last stage:40cm pendulum
Other stages: 20cm

V-H Coupling 1%
Asymmetry 1%

Wire Q=1000
Mirror Q=10000



100mW at input
Finesse = 500

Vacuum 10^{-3} torr

Development Status

Vacuum Chamber: done

Suspension design: done

MGAS test: done

Optical components: done

Waiting for the suspension parts to arrive

To Do

Test the suspension system

Electric circuits

Assemble the whole system

Noise hunting

Summary

SPI, VSPI

High performance active vibration isolation scheme

Next generation detectors

Prototype experiments

Good results below the resonant freq. of the pendulums

Limited by vertical vibration

Next experiment

SPI + MGASF + VSPI

better vertical vibration isolation

Test and assembly of the suspension is going on