Toward Suppression Of Radiation Pressure Noise In Resonant Cavities With Suspended Small Mirrors

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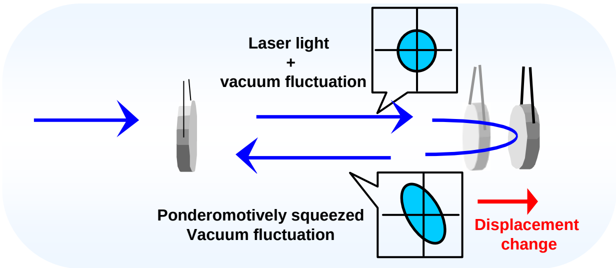
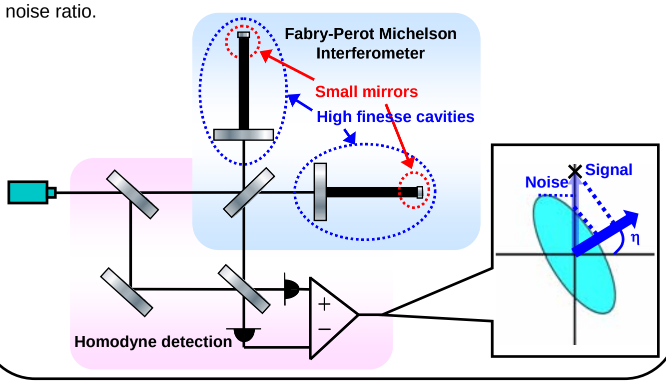
◆ Motivation

The sensitivity of future gravitational-wave detectors will be limited by radiation pressure noise and shot noise in most frequency bands. Neither radiation pressure noise nor quantum effects produced by the radiation pressure have been observed yet. Therefore our motivation is the observation of radiation pressure noise and suppression of it by ponderomotive squeezing. When laser light and a vacuum fluctuation are injected into a cavity with a suspended mirror, the vacuum fluctuation is ponderomotively squeezed by the back action of the suspended mirror on the light.



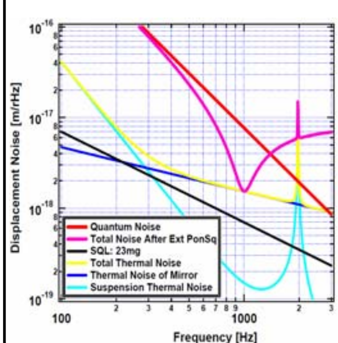
◆ Optical Layout

The radiation pressure noise of a high finesse cavity is increased by decreasing the mass of the mirror. In our experiment a Fabry-Perot Michelson interferometer with a homodyne detection scheme will be build with high finesse cavities containing suspended small mirrors. The reason for the homodyne scheme is to adjust the homodyne phase for the best signal to noise ratio.



◆ Noise Budget

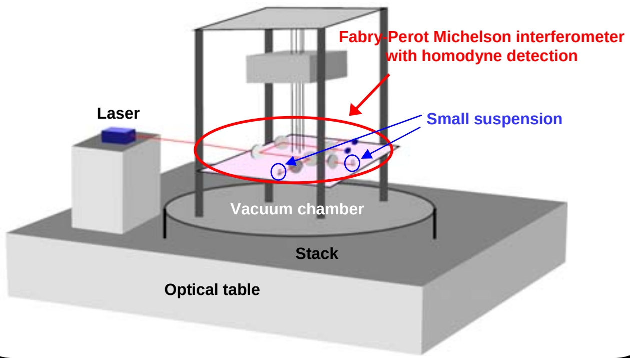
To see the radiation pressure noise, the sensitivity of 8*10-18 m/rHz at 1 kHz is required with Fabry-Perot cavities of a finesse of 8000 containing suspended mirrors of 23 mg. To achieve this sensitivity, the other noise levels like mirror thermal noise, suspension thermal noise, seismic noise and laser frequency noise should be suppressed below 1×10-18 m/rHz at 1 kHz. For the mirror thermal noise, the Q-factor of the mirrors of 10^5 is expected. For the suspension thermal noise, the mirrors are suspended by silica fiber with lengths of 1 cm and thickness of 10 µm. The seismic noise has to be isolated more than 100 dB. The laser frequency noise should be isolated more than 60 dB.



Laser Power	200 mW
Finesse	8000
Weight of end mirror	23 mg
Diameter of end mirror	3 mm
Thickness of end mirror	1.5 mm
Q factor of end mirror	10^5
Coating loss	4×10^{-4}
Length of silica fiber	1 cm
Thickness of silica fiber	10 µm

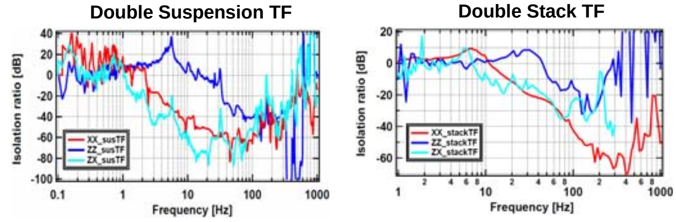
◆ Experimental Setup

For seismic isolation, the whole interferometer is suspended as a double pendulum with an eddy-current damping system located on three double stacks as shown in the drawing below. A Fabry-Perot Michelson interferometer with homodyne detection is built on the suspended bread board. To see the radiation pressure noise and suppress it using ponderomotive squeezing, two mirrors of 23 mg are suspended and the other mirrors and beam splitters are fixed on the suspended bread board.

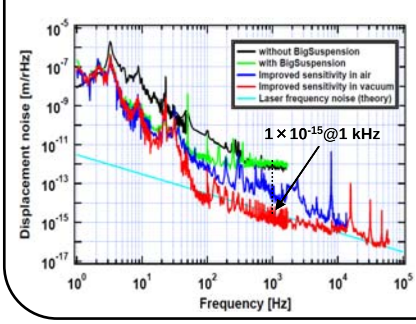


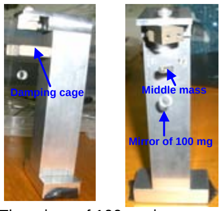
◆ Current Status

From the measurements of the transfer function of the seismic isolation systems, the isolation of 100 dB at 1 kHz could be expected. Here the horizontal to horizontal and vertical to horizontal isolations of the double stack are -23 dB at 45 Hz and -22 dB at 51 Hz, and -83 dB at 45 Hz and -87 dB at 51 Hz, respectively.



With this seismic isolation system a preliminary setup consisting of one Fabry-Perot cavity of a finesse of 800 with a suspended mirror of 100 mg has been locked. The current best sensitivity is 1×10-15 m/rHz at 1 kHz. The sensitivity above 100 Hz seems to be limited by laser frequency noise at the moment.



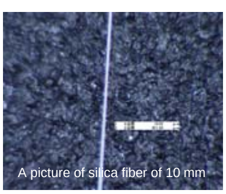


The mirror of 100 mg is suspended by tungsten wire of 10 µm as a double pendulum. The weight of the middle mass is about 100 mg.

◆ Summary & Future Plan

The current sensitivity above 100 Hz seems to be limited by laser frequency noise. To achieve the sensitivity goal, the noise reduction of 60 dB is needed. Therefore a reference cavity with a finesse of 50000 will be introduced, and CMRR of 1/100 would be achieved.

Moreover, the current suspension systems with mirrors of 100 mg will be changed to mirrors of 23 mg, suspended by silica fiber of 10 µm with a length of 1 cm.



A picture of silica fiber of 10 mm

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