**New Folder Name** Investigation of Noise

"An Investigation of Noise from the Test Mass Damping System in the Mark II 40 m Interferometer," by S. Kawamura, 1 February 1994

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# AN INVESTIGATION OF NOISE FROM THE TEST MASS DAMPING SYSTEM IN THE MARK II 40M INTERFEROMETER

S. KAWAMURA, 1 February 1994

Abstract

An experimental study to predict noise from the test mass orientation damping controller and the pendulum damping controller in the Mark II 40m interferometer was performed. The predicted noise was found to be more than 20dB below the current best interferometer noise above 100Hz and 220Hz, respectively.

## I. ORIENTATION DAMPING CONTROLLER NOISE

The displacement noise caused by the test mass orientation damping controller (ODC; See Fig. 1) was predicted by (1) measuring the feedback voltage applied to the ODC coil, (2) obtaining the transfer function from this coil voltage to mirror angle, and (3) converting the mirror angle into mirror displacement with assumed beam spot position (for the resonant green light) of d=1mm using the linear model (S.Kawamura and M.E.Zucker, "Mirror Orientation Noise in a Fabry-Perot Interferometer Gravitational Wave Detector", Applied Optics, 1994, in press).

The ODC coil monitor voltage, which is applied to the coil and a series resistance, was measured (instead of the coil voltage itself) through high pass filters/amplifiers to make it possible to measure the noise spectrum with high sensitivity up to 200Hz (logbook[1] #30, p.87W). The coil monitor spectrum for tilt and yaw for each test mass was dominated by the input noise below 100Hz and showed about 4nV/rHz around 200Hz (#30, p.87W; p.89Y; p.92W; p.94W).

The transfer function from the coil monitor voltage to the output of the XY-decoder was measured by injecting a swept sine into the test input of the ODC coil driver (#30, p.86Y; p.88W; p.90Y; p.91Y; p.93Y). In the vicinity of each resonance, the transfer function showed $f^{-2}$ frequency dependence below the resonance and $f^{-4}$ above them. The list of the resonant frequencies are shown in Table 1.

The calibration from the XY-decoder output to mirror angle was obtained by inserting five 1mm-glass slides with an angle of 45° in the global beam before the quadrant diode and the lens (if any) and monitoring the voltage change at the XY-decoder output, while holding the mass under the local control (#30, p.82W — p.83Y).

The ODC noise for each degree of freedom was predicted using the "linear optical lever model" and assuming a beam spot position of d=1mm (#30, p.95Y). The quadrature sum of these noises is shown in Fig.2 (#30, p.96W), along with the best displacement spectrum of Mark II (#31, p.41W; Nov. 21, 93). The figure also shows that different masses and axes are dominant in different frequency ranges. The predicted noise is found to be responsible

[1] Citations refer to the 40m interferometer logbook series

for some of the current (best) displacement noise below 40Hz and to be more than 20dB below it above 100Hz.

It was also verified that the interferometer noise was not improved except below 40Hz by reducing the orientation control gain by a factor of 10 for all the masses and axes (#31, p.53Y). This result indicates that the prediction is reasonable and nothing inexplicable is going on.

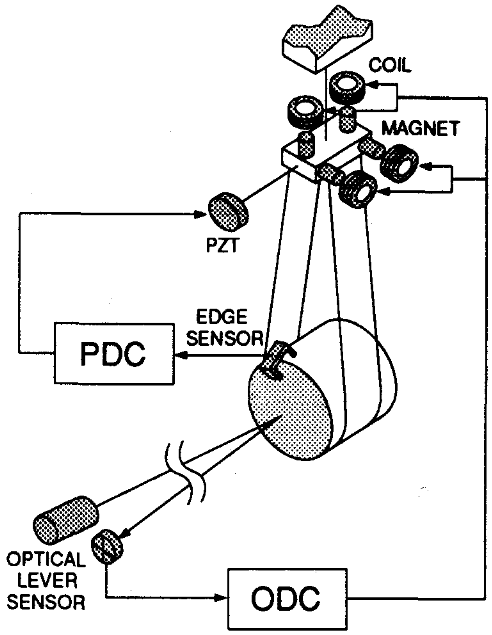


Fig. 1 Schematic of the test mass damping system. (ODC denotes orientation damping controller; PDC denotes pendulum damping controller.)

Table 1 Resonant frequencies in the orientation system

| Test Mass | | Resonant Frequencies (Hz) |
|---|---|---|
| EV | X | 31.1 |
| | Y | 79.1 |
| EE | X | 22.1 |
| | Y | 109.3 |
| SV | X | 31.4 |
| | Y | 80.9 |
| SE | X | 21.9 |
| | Y | 108.6 |

## II. PENDULUM DAMPING CONTROLLER NOISE

The displacement noise caused by the pendulum damping controller (PDC; See Fig.1) was predicted by (1) measuring the PDC feedback voltage applied to the PZT and (2) obtaining the transfer function from this PZT voltage to mirror displacement.

The PZT voltage was measured through high pass filters/amplifiers to make it possible to measure the noise spectrum with high sensitivity up to 500Hz (#30, p.57W). The obtained spectrum for each test mass showed 100nV/rHz around 500Hz (#30, p.57W — p.58Y); it leaves room for significant improvement.

The transfer function from the PZT voltage to the mirror displacement was obtained by injecting a swept sine into the PDC servo loop between the line driver and the high voltage amplifier, and measuring the transfer function from the monitor output of the high voltage amplifier (1/72 of the PZT voltage) to the interferometer output (#30, p.64W; p69W; p70W; p71W). The obtained transfer functions for EV and SV mass showed approximately $f^{-2}$ frequency dependence and those for EE and SE mass showed additional resonances at 56Hz and 198Hz, respectively, above which the frequency dependence becomes approximately $f^{-4}$. In addition all the transfer functions are somewhat contaminated by the tilt resonances of the orientation control.

The dependence of the PDC transfer function on the beam spot position on the SE mirror was investigated (#31, p.93). It was found that the tilt resonant peak in the transfer function depends on beam spot position; the further the beam spot is from the center, the bigger the peak is. For the SE mass, the tilt peak can be about 30dB higher with a beam spot position of d=2mm than it is for a centered beam spot.

The PDC noise for each mass was predicted using the transfer function for a centered beam spot (#31, p.93WR). The quadrature sum of these noises is shown in Fig. 3 (#31,p.93WR), along with the best displacement spectrum of Mark II. Furthermore it is expected that the predicted PDC noise will have additional resonant peaks of the orientation tilt motion which depends on how far the beam spot is from the center. Fig. 3 also shows that SE mass is dominant in the predicted PDC noise over most frequencies. The result indicates that the PDC noise is more than 20dB below the current best displacement noise above 220Hz.

It was also verified that the interferometer noise was not improved except at 109Hz and at 198Hz by disabling the PDC for SE and SV (#32, p.22W). This result indicates that the prediction is reasonable.

## III. CONCLUSIONS

The predicted noise from the orientation damping controller and the pendulum damping controller was found to be more than 20dB below the current interferometer noise above 100Hz and 220Hz, respectively. Further improvement in noise performance of the test mass damping controllers will be attempted in the near future when the interferometer noise due to other sources is reduced to this level.

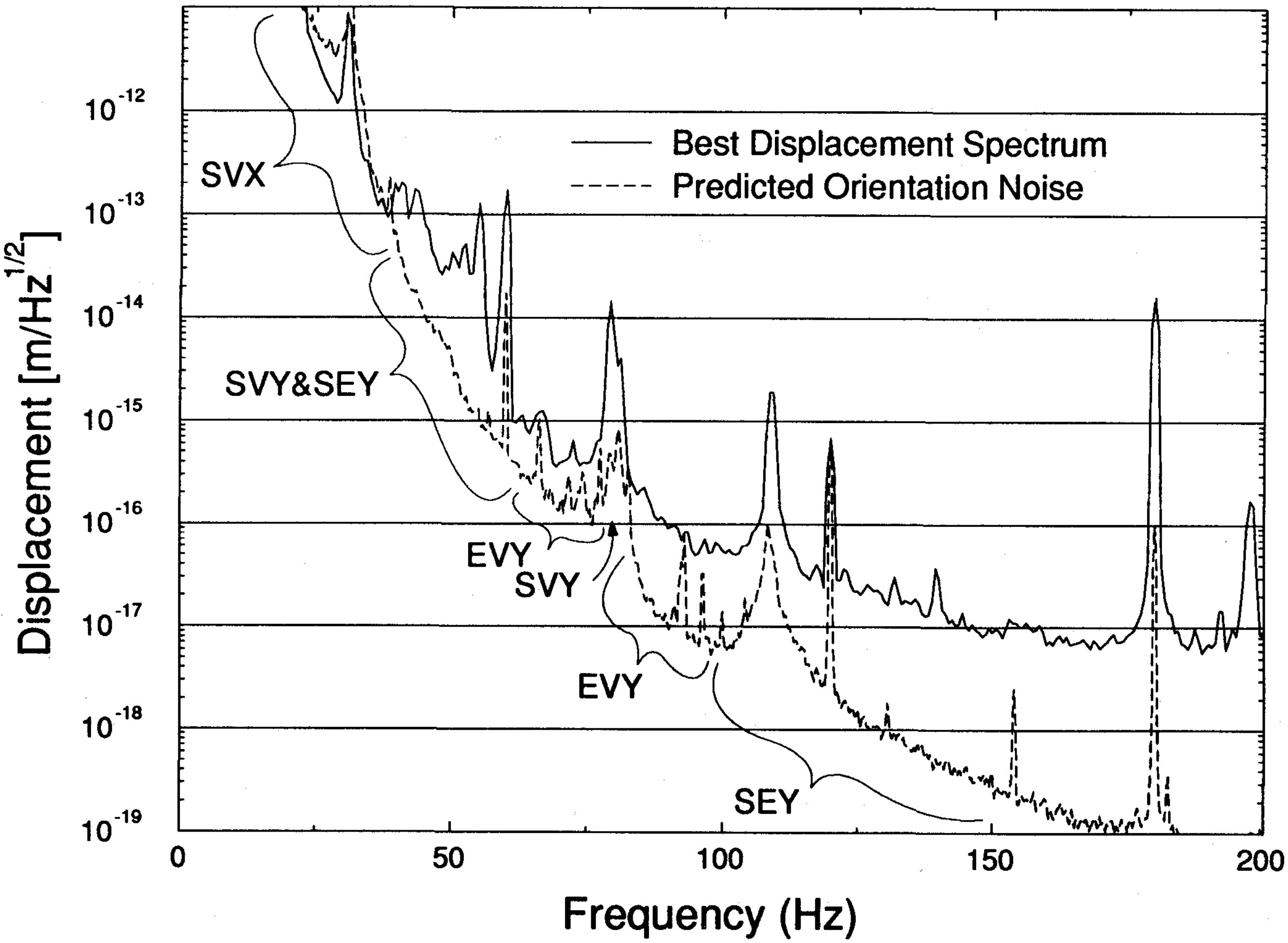


Fig. 2 Predicted orientation damping controller noise and the best displacement spectrum.

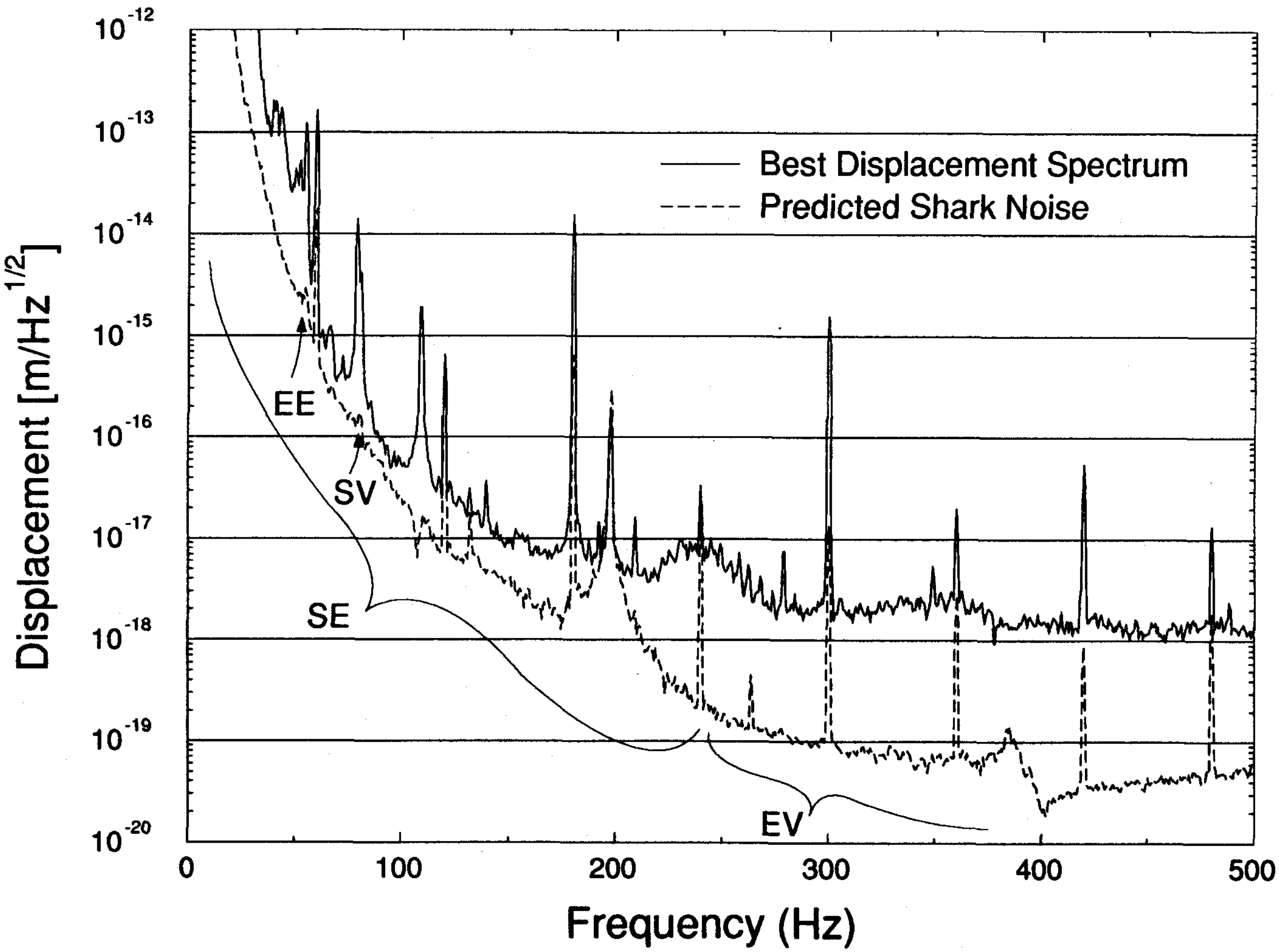


Fig. 3 Predicted pendulum damping controller noise and the best displacement spectrum.