Proposal for Use of the 40 m Interferometer to Accelerate Investigations of High-Frequency Noise in Magnetic Test-Mass Suspensions.

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(a) Introduction.

The development and investigation at Caltech of magnetic suspensions for interferometer test masses can be regarded as having two main objectives:
(1) the extension of interferometer performance to lower frequencies, and
(2) the reduction of suspension and internal test-mass noise.

It was recognized from the start that effective work on the first objective could be carried out more quickly than on the second, since a relatively simple interferometer system can be made to give useful information about low-frequency operation, while it takes considerably more time and effort to build up the higher-performance test system required for full noise investigations. Work in both areas is proceeding well, as planned.

The idea proposed here has arisen in part because our current work has suggested a new possibility of using paramagnetic materials as test masses which might be suspended magnetically without attaching conventional magnets. This has led us to consider ways of bringing forward some of our previously planned noise measurements of magnetically suspended masses. These measurements may become more important than we had previously thought.

We now suggest that it may be possible to carry out some of these measurements by using the LIGO 40 m interferometer in a special non-exclusive way. This may allow some very low-noise measurements of small levitated masses without necessarily compromising other possible uses, such as investigations of unanticipated interferometer problems which may be encountered at the LIGO sites. Such a limited but potentially important application of the 40 m prototype looks like becoming more practicable in the near future as experienced personnel who have been using the interferometer move to the full-size interferometers at Hanford and Livingston.

In recent work with the 40 m interferometer it appears that achievement of low noise has not been as important an objective as the practical development of recombining, power recycling, and locking systems, and it seems likely that the present noise performance is some way from its ultimate. We suggest now a minor and reversible addition to make possible the lower-noise but limited measurements we propose even if the interferometer is not at present optimized for noise performance. Some other properties of the interferometer are very convenient, particularly the fact that it still operates with green light, which has real advantages for work which we are planning in the near future.

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(b) Outline of what is proposed.

It is suggested that the interferometer is kept operating as normal, but a removable deflecting beam-splitter is added in front of the power recycling mirror. This is arranged to deflect a part of the input light out through an existing view-port into a separate vacuum enclosure which contains a pair of the magnetic test masses under investigation, set up to form a short Fabry-Perot cavity (perhaps 0.4 m long) with a reflection-locking photodiode.

The main 40-m system would be operated as usual (at slightly reduced light levels), and the output from the photodiode monitoring the small auxiliary cavity would allow measurement of relative displacement noise between the two levitated test masses. The potential displacement sensitivity could be better than that of the main interferometer by a factor which might approach the ratio of the main 40-m arm length to the length of the small cavity, which might lie in the range ten to one hundred, although diminished to some extent by power and other limitations. As the pair of magnetic suspensions sets a minimum separation between the test masses the fact that the final laser stabilization is achieved by reference to a quiet 40 meter-long cavity between suspended mirrors is an important advantage, not yet available elsewhere, for this particular application. Thus exceptionally sensitive low-noise measurements may be practicable even if the main system is some way from its ultimate performance.

(c) Important practical aspects.

(1) The auxiliary vacuum chamber containing the small test system would be isolated from the main vacuum system by an optical window, and would be pumped separately, so there would be no danger of contamination of the main system. This would allow much more rapid tests which might involve magnets of various kinds, and other special materials, which could be time consuming to vacuum-qualify for the main interferometer.

(2) The main interferometer could revert to normal operation at any time. If the loss of light at the pick-off mirror was significant, it could be arranged that this mirror is relatively easily removable from the beamline when necessary, perhaps with a remotely controlled mirror that could be moved without breaking vacuum.

(3) The time-frame when we envisage that use of the interferometer in this way could be most valuable may start a few months from now. This might well be around the time when other LIGO uses may diminish. It should be remarked that this suggested use of the 40 m LIGO interferometer would not replace most of the longer-term research for which we are setting up the test interferometer in the synchrotron building, but it could make it practicable to carry out some important and possibly urgent measurements much sooner.

(4) An ongoing use of the type suggested here could be valuable for LIGO in keeping the 40 m in operating condition with minimal manpower effort. If manpower shortage did lead to the complete shutdown of the instrument, there could be a danger that some of the special expertise required for satisfactory operation and repair of this complex and demanding experimental apparatus might be dissipated, and it might take a long time to get it back into proper operation again later when required.

(5) The possible advances in test-mass noise which this use of the 40 m prototype might facilitate could prove extremely significant for improving the eventual sensitivity of the LIGO interferometers themselves.

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