New Folder Name Mode Cleaner and Autoalignment

Mode Cleaner and Autoalignment Suspension, Control, and Isolation

AA, DHS, 6 August 1991

General description of the suspension design

The goal is to make a versatile suspension system for a hanging optical element. It will be first used in linear and triangular cavities and for input, output, and test optics. It will be designed in consultation with the LIGO ICD team to make it consistent with the design philosophy used there. It will not be specifically a design to be used in the LIGO interferometer, but efforts will be made to follow LIGO constraints when available to give data to help the LIGO design. The current beamsplitter suspension is used as the point of departure for the design.

The system will support an optical element (mirror, beamsplitter, isolator, etc.) on a pendulum of length 30 cm (1 Hz) so that the optic beam height (center of suspended element) is at a standard height of 12.45 cm. A single wire sling is proposed (practically necessary, given the small thickness of the substrates that will be used in the Mode Cleaner and Autoalignment tasks).

The structures supporting the pendulum and the OSEMS will be rigid and simple, with a small 'footprint' to allow close spacing of suspensions. The design is planned to be used with a bottom attachment (built up, above the stack).

OSEMs are used for damping; four around circumference on back, one on side; there will be a provision for vertical OSEM (above or below optic element); their position will be adjustable.

Initial alignment; Remote control

When first installed, the mirror must be aligned with the optic axis. The mirror angles must be close enough to the final angles to allow the system to be brought into perfect alignment using forces from the OSEM coils. In addition, the OSEMs must be aligned with the mirror to reduce coupling of ground motion to the mirror and to center the sensor in its limited dynamic range; alignment to <0.1 mm is required along the optical axis. These initial alignments are performed by making manual mechanical adjustments, After this initial alignment, only drift in the stacks (height, position, rotations) or stretching of the suspension wire will misalign the mirror w.r.t. (with respect to) the optic axis or the OSEM w.r.t. the mirror. We propose to correct these misalignments at the source, and to leave the mirror suspension point and the OSEMs fixed with respect to each other.

The stretching of the suspension wire is probably negligible: A vertical resonance frequency of the mirror of 10 Hz (which is typical) is due to a total wire elongation of 2.5 mm. The drift in this length over reasonable (i.e., 1 year) time periods is expected to be much less than the total elongation; if it is less than 10% of the total elongation, we expect less than 0.25 mm of stretch in the wire. This is an insignificant change in the height of the mirror, so no remote control over the height of the mirror w.r.t. the OSEMs is necessary.

We are left with drift in the stack. The biggest term will be the vertical downward drift. For LIGO, this will be specified as less than 1 cm/year (and will be less for the proposed mode cleaner stacks). The change in the optical axis due to this drift is unimportant (due to the long radius of curvature of our cavity mirrors), but for prototypes the expected drift is not negligible when compared with the mirror surfaces. In addition, other optical components which may be suspended (isolators, modulators) have smaller usable apertures. It appears important to remotely correct (i.e., with motors and screws) for this motion.

Tilts of the stack top plate will be due to differential drift in the stack 'table legs'. We can estimate this differential drift to be of the order of 10% of the total drift, leading to tilts of the order of 1 mm/year over a 1 m diameter table top (10^{-3} rad). Given the pendulum length of 30 cm, this causes the mirror to move about 0.3 mm w.r.t. the optical axis and w.r.t. the OSEMS; this exceeds the centering requirement for the OSEMS. Thus remote control of the tilts is necessary.

Translations of the stack top plate can be estimated to be a small fraction of the vertical drift, since there are no direct horizontal forces if the mass loading on the stack top plate is uniform. We estimate that no remote control over this motion is necessary.

Rotations of the stack top plate are like translations: There are no direct forces which should cause this drift, and so we estimate that it will be a small angle compared with the tilts ($\approx$10%). This 10^{-4} rad rotation affects both the mirror and the OSEMs. Forces from the OSEMS can bring this back into alignment, requiring 5μm motions of the vanes and magnets w.r.t. the OSEMs. We conclude that no rotation of the stack top plate is required.

Mirror Support and Adjustment

The mirror will be suspended from a single loop of thin wire, the upper ends of which will be clamped to an aluminum rod with square cross section, called a suspension block (Fig. 1). The suspension block will be supported by a structure attached to the top mass of the seismic isolation stack. A 5/8" aluminum support plate, atop four 1" aluminum rods, is anticipated to be sufficiently rigid for supporting the suspension block. Before the design of the structure is finalized, we propose to build a simple prototype to measure its mechanical transfer function. This will be combined with the ground noise, the isolation stack transfer function, and the pendulum transfer function to preduct the influence of the resonances on the mirror motion.

Fine adjustment of the initial mirror height (via the wire length) will be carried out by use of guitar string tuning screw-type devices, temporarily attached to the suspension block. Once the wires are adjusted, they will be clamped to the suspension block and trimmed, and the tuning devices will be removed.

Horizontal position and angle adjustment will rely on sliding the suspension block across the support plate. Fine adjustment will be provided by horizontal screws. Once adjusted, the suspension block will be clamped to the support plate. The fine adjustment screws can be either temporary or permanent fixtures.

Mirror control

Active mirror control in translation along the beam and in the tilt degrees of freedom, as well as damping at the pendulum frequency, will be done with 4 OSEMs of existing design, possibly modified for enhanced vacuum compatibility. The OSEMs will be arranged in a square pattern (Fig. 1). Experience with similar arrangements has shown that the sideways motion needs to be damped, so that a 5th, lateral OSEM, is required (not shown in Fig. 1).

For maximum flexibility, the OSEM configuration, and the frame that supports the OSEMs, called the OSEM 'cage', will be designed to accommodate mirrors with diameters between 3" and 4", and with various thickness. To that end, the following features seem desirable:

- The 4 front OSEMs will be held by arms that can slide and tilt (Fig. 2). The adjustment range should be within a radius of 1/2". For each specific mirror size and OSEM pattern, a jig will be needed, in order to set the OSEM heads with adequate precision.
- The side OSEM axis will be strictly horizontal. The holder for this OSEM will slide up and down (range TBD) for adjustment.
- The length of horizontal elements of the OSEM cage can be customized, in order to accommodate mirrors with given size.
- The earthquake stops will be fork-like elements, that are attached to the OSEM cage, and can slide and tilt, similar to the OSEM head holders (Fig. 3).

The horizontal element at the bottom of the OSEM cage will be wider than the vertical elements, for better stability and ease of clamping. The horizontal element at the top of the OSEM cage could be modified to allow a vertical OSEM to be used.

Seismic Isolation

The two experiments (Mode Cleaner, Autoalignment) have different seismic isolation requirements. Initially, the Autoalignment experiment will use the existing MIT 5 m vacuum system optical tables as the suspension system mounting surface. When the LIGO prototype stacks are completed, the suspension system will be mounted on them.

Seismic isolation for the Mode Cleaner experiment will be provided by a three-layer stack (Fig.4). A full scale model, using silicone rubber springs and 20 kg aluminum disks, has been tested and found to perform slightly better than the stacks currently used in the 40 m prototype.

The silicone rubber springs, now in use in the 40 m prototype, have unknown, possibly high outgassing rates. A series of outgassing tests, with this rubber, as well as with an allegedly better type of silicone rubber, are in progress.

The top plate of the stack will be adjustable in height and the two tilts, which will allow to compensate for various drifts (sagging) of the rubber springs. It is desirable to have the adjustments motorized.

SEISMIC ISOLATION

AA, 22 July 1991

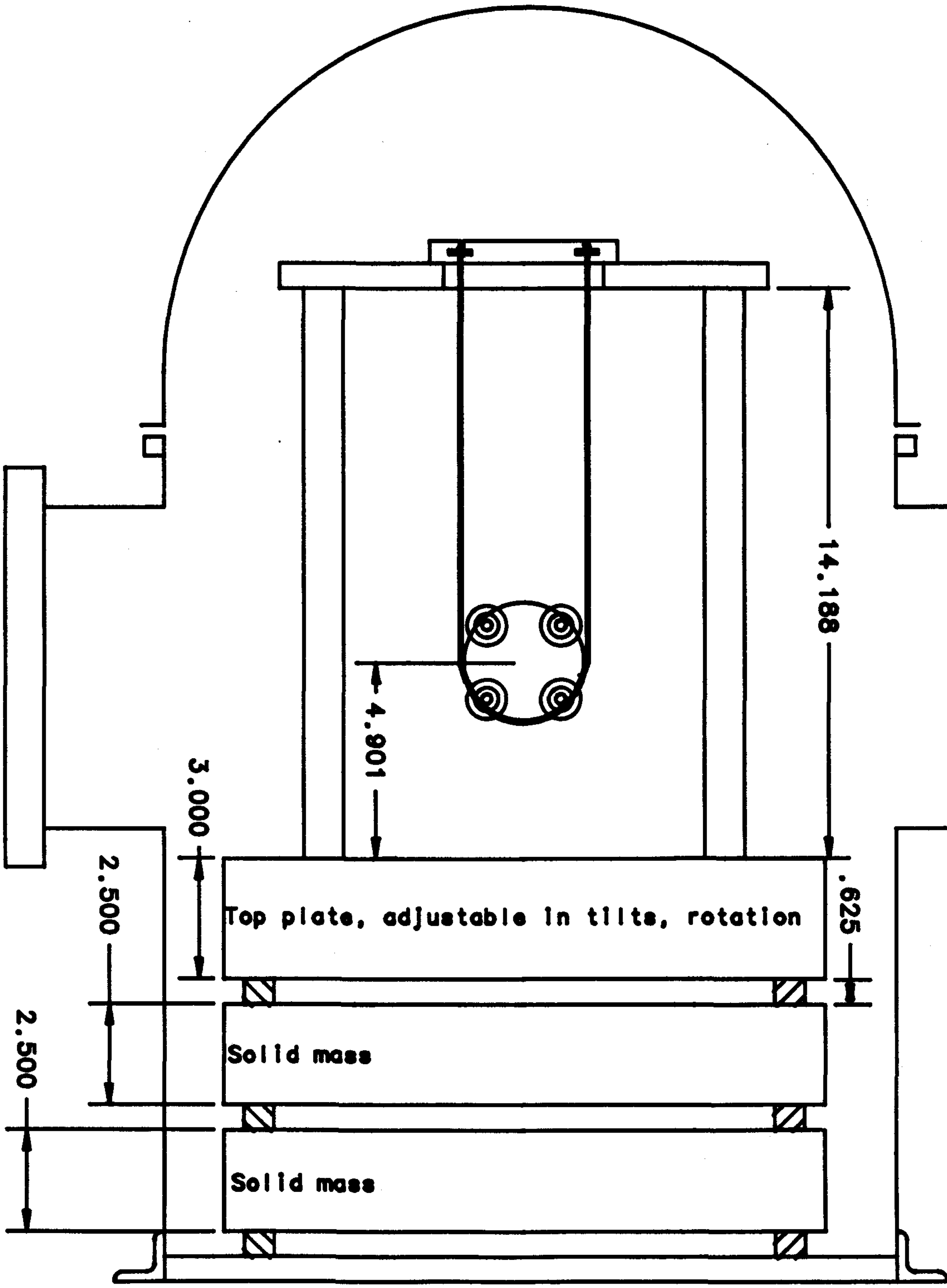

Fig. 1

OSEM CAGE CONCEPT: FRONTAL VIEW

22JULY 1991

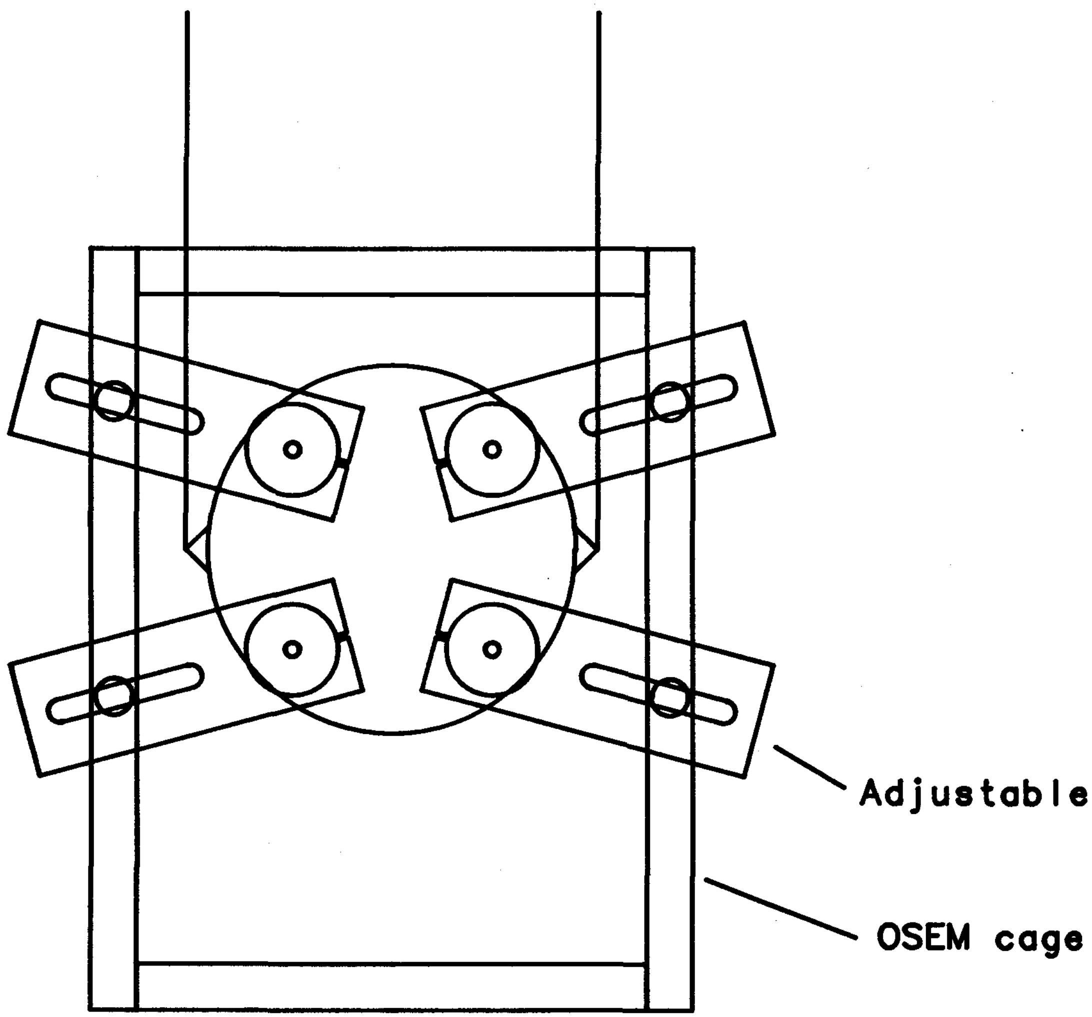

Fig. 2

OSEM CAGE CONCEPT: TOP VIEW

24 JULY 1991

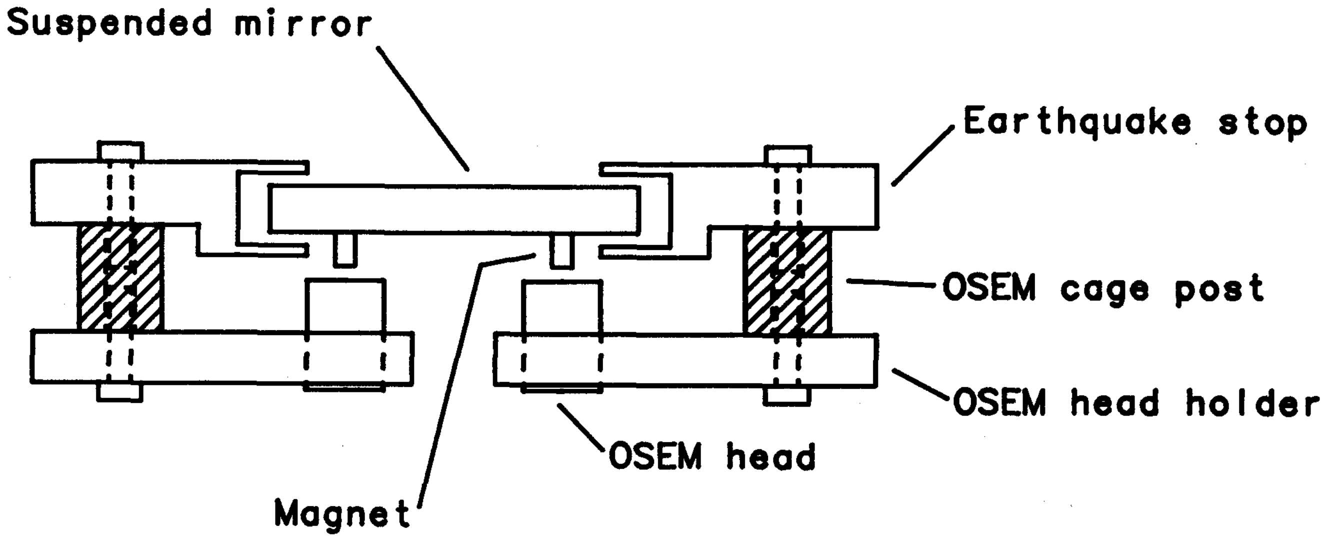

Fig. 3