New Folder Name Beam Alignment

Beam Alignment and Orientation Control in LIGO Interferometers: Outline of a Proposed System, and steps to its design.

R.W.P. Drever 2/8/90

1. Proposed System.

Functions.

The system is designed to monitor and control the following:–

(a) Orientations of test masses, mirrors and other components, in pitch and yaw;

(b) Directions of interferometer beams relative to lines joining the effective centers of certain of these components;

(c) Positions of interferometer beams relative to the effective centers of certain of these components, and the positions of the centers of certain others of these components relative to the beams, in directions transverse to the beam axes.

The system is designed to facilitate a start-up of an interferometer from complete switch-off to full operation without allowing the main beams to strike other than the correct components. It is capable of operating both in a manually-trimmed mode, and, in its full form, in a completely automatic self-optimizing mode. This is achieved using a hierarchal arrangement of three different types of sensing systems to give high final precision (better than 0.1 microradian in angle) along with adequate dynamic range for start-up.

Operating Modes:

1. Acquisition mode.
2. Operating — manual adjustment mode.
3. Operating — self optimizing mode.

The control of mirrors and components in each mode is as follows:–

Mode 1.

(a) Coarse sensing and control relative to seismically isolated optical baseplates is obtained using signals from sets of three or five position sensors/thrusters for each component.

(b) Second stage orientation control is achieved using "offset local pilot beams" whose directions are defined by sets of spaced reference points which are stable relative to the foundations of each building. (Angular drift less than 1 microradian per day).

Mode 2.

The main control is by offset local pilot beams, with a fine trim obtained by sensing the positions of the main interferometer beams relative to the effective centers of the test masses at each end of the kilometer arms, together with an additional manual fine adjustment when necessary.

Mode 3.

The main mirrors are controlled by autoalignment systems using sensors which monitor the gradients in optical phase difference over the wavefronts of interfering beam components, together with signals from beam centering units which monitor the beam positions relative to the centers of the test masses. Other optical components are controlled by wavefront matching and beam centering systems.

2. Outline of Main Conceptual Design and Development Work Required. (With tentative estimates of manpower and time required)

A. For Modes 1 and 2 only — the absolute minimal system (possibly barely adequate)

1. Overall systems design
2. Concepts for optics for local offset beams and sensors.
3. Engineering design of stable mounts for pilot lasers, reference quadrant photodiodes, and offset prism units with capability of controlling beams within the vacuum envelope without disturbing vacuum.
4. Electronic units for Mode 1 and 2 operation

B. For Mode 3 Operation.

1. Autoalignment units — Sensing heads — design of quadrant diode wavefront phase sensing systems

   Autoalignment Electronics — engineered version of prototype design

2. (a) Beam centering units. Development of tracking quadrant photodiode system which locks to test masses.

   (b) Alternative Techniques for beam centering sensors:

   Development of TV camera technology with fast digital image processing or use of special camera with random access to individual pixels and fast computer control.

This would be a bigger development effort, but could lead to a more flexible and sophisticated system. If 10 MHz bandwidth were achievable, application to autoalignment could be possible.