The design and construction are described of an experimental strainmeter. This observes changes in the number of waves of light standing in a one-kilometer gap between points on the earth's surface. Strain is observed over a frequency range of zero to several hundred hertz, to an accuracy of an arbitrarily-small fraction of a wave-length of light. Frequency-dependent phase and amplitude distortion are absent. As the read-out is of the nature of a servo device, dynamic range limitations are not encountered.

The prototype instrument is located in a region affected by the world rift system.

Location:

A segment of the world rift system, the East Pacific Rise, traverses the western part of the North American continent. It has been suggested [1] that at the latitude of Oregon, Washington and British Columbia the crest of the Rise traverses the Willamette Valley-Puget Sound-Georgia Strait axis, figure 1. The migration of the crest to this locale, together with the development of vulcanicity along the line of the High Cascades, has been related [2] to a decline in activity suffered by the Juan de Fuca Ridge five million years B.P.

If the tectonic system described, or one similar, is operative in the Pacific Northwest it is likely that western Washington and British Columbia are suffering relaxational spread of the continental crust towards the adjoining ocean basin [3]. To discover whether the deformation system suggested or an alternative is present, and as part of an instrument development program, the writers are engaged in the construction of a laser-operated extensometer designed to monitor strain imposition in a ground sample having a dimension of one kilometer. Due to the fact that the extensometer described below is capable of the distortionless recording of oscillatory strains of all frequencies, as well as secular extension, it acts also as a seismograph.
Earth strain measurements through the use of a laser:

It is to be expected that strain measured in a sample of ground having a scale of decimeters is not representative of regional conditions, due to the presence of elastic discontinuities such as joints and fractures. This expectation is borne out by experience in Japan [4], where it has been found necessary to construct water-tube tilt-meters of a few tens of meters in scale rather than rely upon the output of tripod-supported horizontal pendulums. For this reason, and to obtain advantages in detecting low-frequency seismic waves, we have laid emphasis upon measuring the strain change in ground samples having a scale of hundreds of meters. A compact instrument, the tetrahedral or Kelvin seismograph [5], not discussed here, is planned for the purpose of observing waves of all propagation modes and frequencies.

The use of lasers for earth strain measurement was suggested some time ago (6, 7, 8). Two systems different in principle have been used, One system [8] uses two lasers mounted at a right angle. The mirrors that form the laser cavities are fastened to the rock. This system measures the strain difference between the two perpendicular arms. Limitations are imposed by the ambiguity of the readout signal. Since part of the laser cavity is in the air the atmospheric pressure fluctuations change the laser frequency. Compensation can conceivably be achieved by making the air gap in both lasers equal. As may be seen from what follows, the requirements are strict.

The number of wavelengths in the laser cavity is

\[ N = \frac{\lambda_1 n_1}{\lambda_0} + \frac{\lambda_2 n_2}{\lambda_0} + \frac{\lambda_3 n_3}{\lambda_0} \]

where \( \lambda_0 \) is the laser wavelength in vacuum, \( \lambda_1 \) is the geometrical length of the air gap and \( n_1 \) is the index of refraction of air. The subscripts 2 and 3 denote the corresponding quantities inside the discharge tube and the glass windows

\[ N \lambda_0 = \lambda_1 n_1 + \lambda_2 n_2 + \lambda_3 n_3 \]

The changes of the index of refraction (pressure) and the geometrical cavity length (temperature) change the laser wavelength:

\[ N \Delta \lambda = \lambda_1 \Delta n_1 + \lambda_2 \Delta n_2 + n_1 \Delta \lambda_1 + n_2 \Delta \lambda_2 \]

The changes in the windows are, in comparison, negligible.

For constant temperature and unchanging density in the discharge tube the wavelength change is

\[ \Delta \lambda = \frac{\lambda_1}{N} \Delta n_1 \]