Development of a New Broadband Optical Seismometer

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The mainstay observatory-class seismometers used by global networks for the past two decades are no longer manufactured and there is no other commercially available product of sufficient quality on the market today. For such quality instruments, the development risk is high, the development time long, and the market small and apparently not sufficient to provide commercial viability.

To meet the instrumentation requirements of global seismology, we have designed and built a prototype sensor that uses optical fiber interferometry to record the motion of an inertial mass. The use of optical fiber interferometry rather than traditional electronic displacement transducers affords significant advantages. Features of this broadband optical seismometer include:

- A linear, high-resolution displacement sensor;
- Displacement measurement referenced to the wavelength of light, providing continuous calibration;
- Increased dynamic range;
- Increased bandwidth;
- No electronics in the sensor — only optical fiber connection to the seismometer — eliminating heat from electronics in the sensor package and noise pickup from connecting electrical cables;
- Smaller package — our design will be applicable to both vault and borehole installations and should be relatively easy to manufacture.

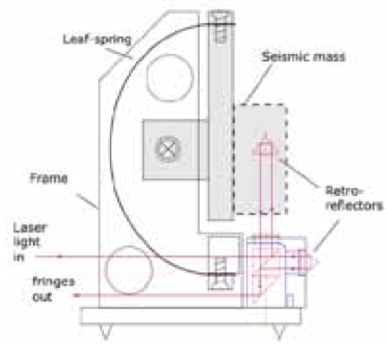

Figure 1. Schematic of vertical-component optical seismometer. The two fringe signals are input to a fast A/D converter (105 sps). An algorithm on the digital signal processor (DSP) continually updates the parameters of an ellipse that characterizes the fringe pattern while instantaneously computing the optical phase (i.e., the mass displacement), yielding a real-time, high-precision fringe resolver. The DSP circumvents the need for an analog data recorder, providing digital data logging with an equivalent dynamic range of about 30 bits.

We have developed an optical displacement transducer that promises to lead to a greatly improved seismometer. The use of optical fiber interferometry in place of electronics adds other important benefits, including immunity to noise pickup, simplification of remote deployment (in a borehole, for example), the elimination of a heat source in the seismometer—an important cause of noise in the best existing systems, and the elimination of components that can be damaged in electrical storms (a problem in many field settings).

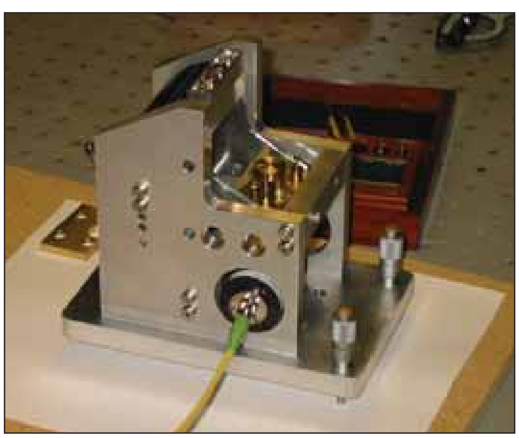

Figure 2. Prototype Vertical Optical Seismometer. This unit has a mass of 360 grams and a free period of a few seconds. The spring is a single strip of "NiSpan-C", a trade name for a particular alloy of iron-nickel with small amounts of chromium and titanium.

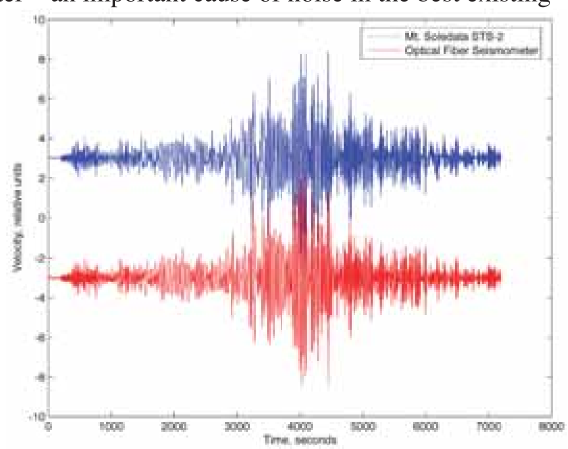

Figure 3. The 2004 Sumatra earthquake provided an opportunity to test our algorithm for converting mass displacement to ground displacement based on the spring-mass mechanical characteristics. This is a challenge because the new sensor does not rely on force-feedback as do conventional sensors. The good agreement between the record from the prototype optical sensor (red) and a conventional sensor (blue) indicates that the processing is correct (although much further work is needed).