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A high performance compact vibration sensor based on fiber Bragg grating

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A high-performance compact vibration sensor based on fiber Bragg grating (FBG) is designed. The acceleration sensitivity of the FBG vibration sensor is measured to be larger than 30 pm/g. From 10 Hz to 250 Hz, a quite flat frequency-response curve can be obtained with additional damping, which suppresses the resonance peak effectively. A phase-generated carrier (PGC) demodulation technique realized by compact reconfigurable input and output (RIO) system is applied in our sensing system.

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Hence, the mechanical parameters of the system are optimized to make that the system has a relatively higher natural frequency, and a wider frequency response range. The structure is installed and protected in a shell, which is sealed and filled with silicone oil to introduce additional damping. When \( q \) is large enough, the strain produced on FBG can be written as

\[
el = \frac{q_0}{b l q_0^3},
\]

where \( q_0 \) is acceleration amplitude. Apparently, the larger strain produced on the FBG, the higher acceleration sensitivity can be obtained. In our design, a FBG with reflection peak wavelength of 1546.9 nm and linewidth of about 0.1 nm. The FBG is pre-stretched to produce 0.1 nm wavelength shift during curing procedure. Red copper is employed for oscillator and duralumin for other parts of our sensor head. In addition, the viscosity of silicone oil is about 500 cs. This sensor head has dimension of only 70 × 40 × 15 mm

The scheme of FBG vibration sensing system is illustrated in Fig. 2. A standard accelerometer is used to quantize the acceleration of the vibration platform where the FBG sensor head is mounted. The commercial...
piezoelectric accelerometer (model: LC0109) has a sensitivity of 100 mV/g, and measuring range of 50 g. The reflection spectrum of the FBG is changed according to the vibration signal. The narrow bandwidth of only 0.1 nm of the FBG enables us to obtain high sensitivity. Then, an unbalanced Michelson interferometer with optical path difference of 5 mm will convert the shift of the frequency or wavelength into the shift of phase. A phase generated carrier algorithm is used for demodulation, which introduces a large phase shift outside the signal band to detect small phase shifts and eliminate fading caused by large environmental drifts. Here, we apply compact RIO by National Instruments to realize real-time phase-generated carrier (PGC) demodulation for FBG sensing.

The acceleration signal frequency is tuned from 10 Hz to 250 Hz. From the frequency spectrum (Fig. 3), we can see the ground noise is about 0.001 pm/√Hz, which is dependent on the system electrical noise as well as ambient noise. The acceleration sensitivity of the same FBG vibration sensor head without and with silicone oil is measured. It is about 35 pm/g and 30 pm/g without and with additional damping separately. Hence, the equivalent noise acceleration is calculated to be about 33 µg/√Hz. The frequency response of FBG vibration sensor is obtained and drawn in Fig. 4. As we can see, the curve of sensor without damping has an obvious resonance peak at around 130 Hz. Filling oil increases the damping parameter and can suppress the resonance effectively. However, it brings in little sacrifice of sensitivity.

A high-performance compact vibration sensor based on fiber Bragg grating is reported. The acceleration and frequency response are tested and compared without and with silicone oil inside the sensor head. Using PGC demodulation technique realized by compact RIO system, the acceleration sensitivity of the FBG vibration sensor is measured to be larger than 30 pm/g, and the testing results illustrate that the damping can help suppress the resonance peak effectively. The frequency response curve with damping is quite flat in the range of 10 Hz to 250 Hz.

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