MEMS Accelerometer with Remote Optical Readout for Power Generator Monitoring

M. Tormen, B. Timotijevic, Y. Pétremand, M. Lützelschwab, D. Bayat, O. Dubochet

A MEMS-based accelerometer with a remote optical readout is presented. Advantages are simplified electronics, high rejection of the common mode signal and high measurement linearity, low production cost for the accelerometer chip, low cost and high yield for the system assembly.

Miniaturized accelerometers with a remote optical readout are required devices for the continuous monitoring of vibrations inside power generators. In turbo and hydro generators, end-winding vibrations are present during operation, causing undesirable out-of-service repairs in the long run. Continuous monitoring of these vibrations is, therefore, mandatory. The high electromagnetic fields in the generators impose the use of devices immune to electromagnetic interferences.

A MEMS accelerometer with a remote optical readout has been developed. Solutions have been proposed in the past [1, 2, 3]. The advantages, compared to state-of-the-art devices for such applications, are the following: simplified electronics when compared to wavelength or phase-based measurement systems; high rejection of the common mode signal and high measurement linearity thanks to a differential intensity signal approach; a low cost MEMS chip given the reduced number of fabrication steps and the number of chips per wafer (more than 400 on a 6” wafer); a low cost and high yield system assembly thanks to a simple and robust assembly process; low barriers to market-entry, since the reduced package volume is compatible with the already allocated space in turbo generators. For electromagnetic immunity, no metal is present in the sensor head.

Fabrication of the MEMS chip (Figure 1) starts from a 6 inch SOI (Silicon-On-Insulator) wafer. It is composed of a seismic mass, suspended through springs, with opened regions to introduce a damping gel, and of a 2-facet mirror, moving with the seismic mass, redirecting the optical signal from an input fiber into two output fibers. In order to reduce the system dimensions, the two output fibers were placed at 70 deg. with respect to the input fiber.

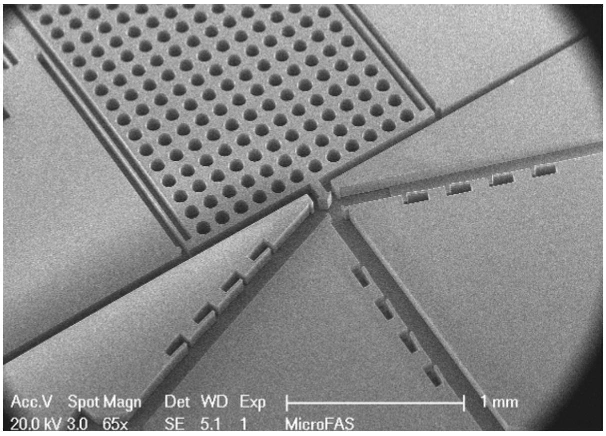

Figure 1: SEM picture of the fabricated device.

The package provides a solid base for the interface between the MEMS device and the optical fibers. In terms of possible materials for the package, metal parts are excluded because of the strong electromagnetic fields present in the generators; moreover, temperatures of up to 155 °C and a hydrogen rich atmosphere (5 bars) represent further constraints in the choice of the package material. PEEK was chosen as the package material because of its physical and chemical properties as well as its adequate machinability. The optical fibers are completely molded in UV curable adhesive, thereby providing an effective strain relief. The output fibers are placed at an angle of 70 deg. with respect to the central input fiber. The fiber alignment is done using a six axis alignment stage with an arbitrary pivot point. For mechanical protection, a glass lid is added to the package at a final step. Figure 2 shows the fully assembled device with connectorized fibers.

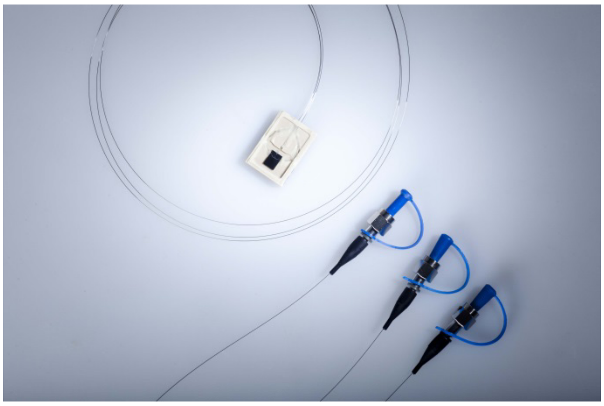

Figure 2: Fully assembled and connectorized optical accelerometer sensor.

The first resonance frequency is designed to be above 1 kHz, and squeeze air film damping was introduced to flatten even further the frequency response in the range of interest (10 Hz-400 Hz). Roughly 30 prototypes have been tested at this stage.

In conclusion, a MEMS-based accelerometer with a remote optical readout has been developed. Advantages of the present solution are the high rejection of the common mode signal thanks to a differential intensity signal approach, low cost for the MEMS chip given the number of chips per wafer, low cost and high yield system assembly thanks to a simple and robust assembly process.

[1] B. Guldimann, “Micromachined fiber optic accelerometer based on intensity modulation”, PhD thesis, University of Neuchâtel, 2001

[2] Y.-G. Lee, *et al.*, "Performance of a single reflective grating-based fiber optic accelerometer”, Meas. Sci. Technol. 23 045101, 2012

[3] Z.-Z. Yang, *et al.*, "High sensitivity fiber optic accelerometer based on folding F-P cavity", Proc. SPIE 8914, International Symposium on Photoelectronic Detection and Imaging 2013: Fiber Optic Sensors and Optical Coherence Tomography, 891411, 29 August 2013