WHITE PAPER

Polymer Optical Fiber Ultrasound Sensor (POFUS)

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1 Introduction

Conventional ultrasound sensors rely on single element piezo-electric transducers (PZT) or micromachined PZT arrays. Although the PZTs have a higher detection sensitivity compared to their counterparts, their opaque nature, bulky size, complexities moving to higher operating frequencies, susceptibility to harsh environments and EMI, limits the use of PZTs for a wide range of applications.

SHUTE Sensing Solutions proudly introduces development of a Polymer Optical Ultrasound Sensor (POFUS), which uses the strain-induced spectral shift of the Fiber Bragg Grating (FBG) sensor to measure the incoming ultrasound waves. The POFUS from SHUTE will not only hold the typical advantages of optical fiber sensors over conventional sensors, like, reduced size, immunity to EMI, but also offer additional advantages like high-frequency operation, ease of multiplexing and bio compatibility, making it a promising ultrasound sensor for diverse applications ranging from industrial to medical imaging. The fact that the POFUS is embedded into a very thin biocompatible fiber and its acoustic impedances matching the human body, makes it ideal for intravascular and endoscopic applications in the body.

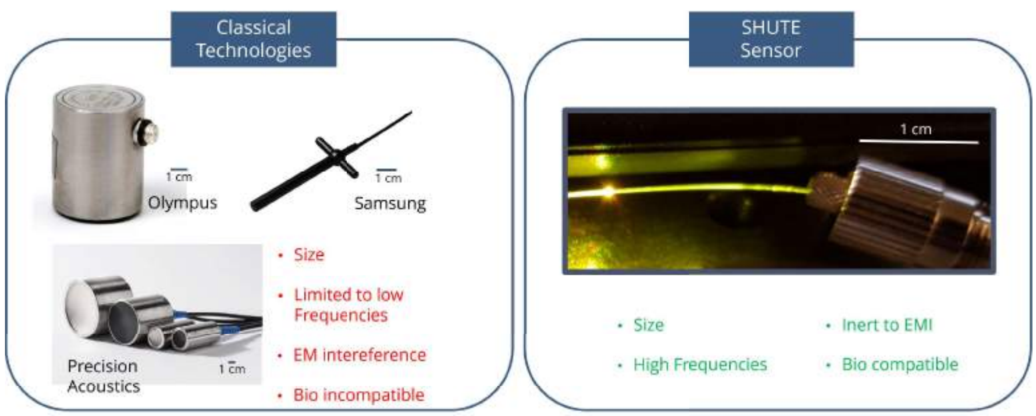

Figure 1: Comparison of classical ultrasound sensors and SHUTE sensors

2 Fiber Bragg Grating as sensors

The POF sensors are based on Fiber Bragg Gratings (FBGs). The main principle is that as ultrasound waves passes through the FBG it causes the material to expand and contract. This mechanical elongation of the FBG shifts its wavelength depending on the frequency and pressure amplitude. The wavelength shift is detected by a photodetector which converts it into an electrical signal for further analysis.

SHUTE Sensing solutions

3 POFUS

The Polymer Optical Fiber Ultrasound Sensor (POFUS) uses the strain-induced spectral shift of the FBG sensor to detect the intensity of the incoming ultrasound waves, see Figure 2. At SHUTE we have developed a novel low-cost interrogation system that is able to detect ultrasound waves up to 5 MHz as well as acoustic sound waves. The POFUS has the advantage of small size probe that can be used for scanning in multiple in-vivo environments. Our POFUS testing setup consists of a light source, photodetector, piezo-electric ultrasound transducer, and FBG sensor. The FBG sensor is mounted in the center of a metallic hole plate and immersed into a water tank, as observed in Figure 3. Furthermore, the ultrasound transducer is immersed in the water tank and pointed towards the FBG sensor. The angle of incidence between the transducer and sensor can be measured and changed manually, see Figure 4.

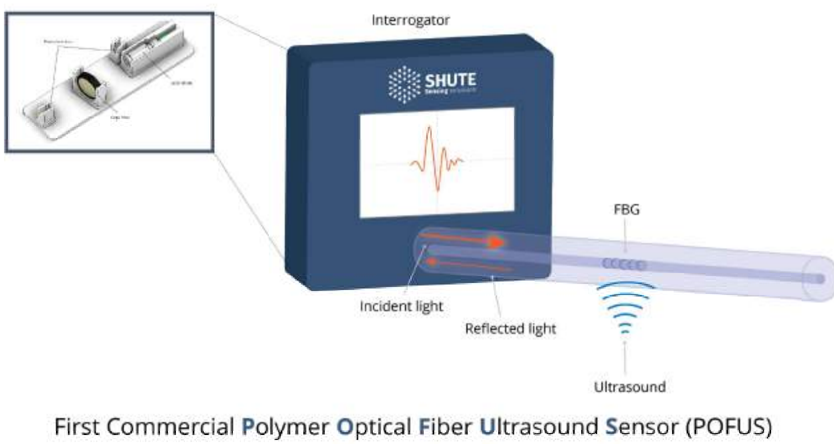

Figure 2: Illustration of our POFUS system

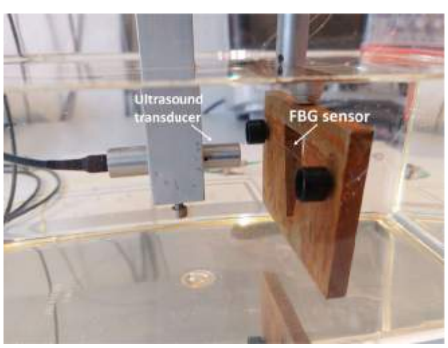

Figure 3: FBG sensor and transducer in water tank

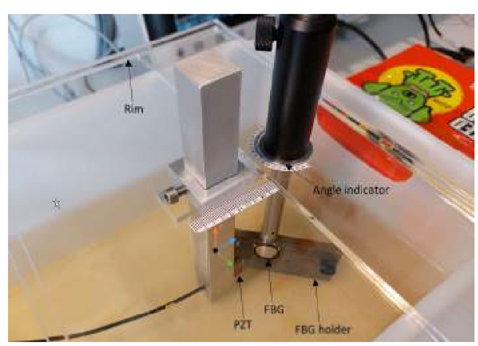

Figure 4: Rotations stage for ultrasound measurements

The ultrasound transducer delivers frequencies of 1 MHz and 5 MHz. The response of the FBG sensor to 1 MHz ultrasound frequency can be seen in Figure 5. As illustrated, the amplitude response is measured by its peak-to-peak voltage ($V_{pk\text{-}pk}$) and the corresponding frequency response showed a clear peak centered at 1 MHz. The response of the FBG sensor to 5 MHz ultrasound frequency can be seen in Figure 6. As illustrated, the amplitude response has $V_{pk\text{-}pk}$ of approximately 22 mV, and frequency bandwidth of approximately 1.3 to 3 MHz.

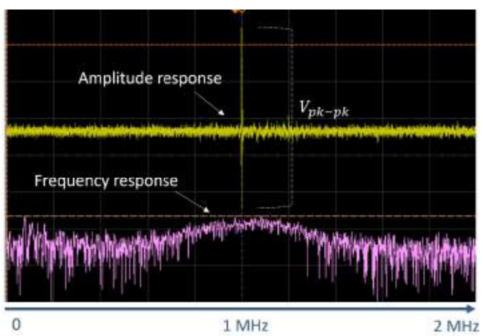

Figure 5: Response of FBG sensor to 1 MHz ultrasound frequency

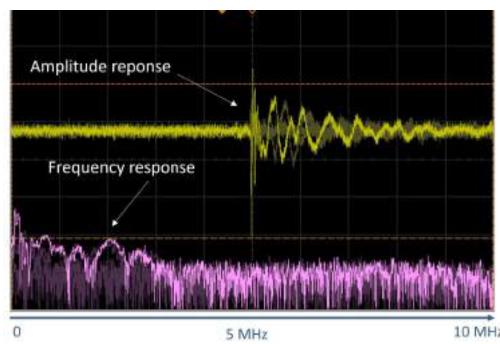

Figure 6: Response of FBG sensor to 5 MHz ultrasound frequency

4 Acoustic detection

At SHUTE we have also developed an acoustic emission detection system (optical microphone) consisting of a FBG sensor, interrogator and PC. The interrogator consists of a light source, coupler and a photodetector. Light goes through the fiber and the reflected light from the FBG sensing point is measured using a photodetector which is further processed by a PC, see Figure 7. Sound waves or frequencies can be detected by the FBG sensing point due to a wavelength shift caused by an elongation of the grating, just as with the POFUS. The induced spectral shift is measured by the photodetector as intensity amplitude variation, which recreates the sound pulse. Our sensor is attached to a membrane to better detect incoming sound waves and the mechanical design is illustrated in Figure 8. Acoustic emission frequencies up to 20 kHz are detected using our FBG sensor, however detection of higher frequencies is feasible.

The detected acoustic waves from the FBG sensor are converted into a spectrogram, which is a visual representation of the frequencies that make up the sound, see Figure 9. The recorded sound waves can then be played back and listened to.

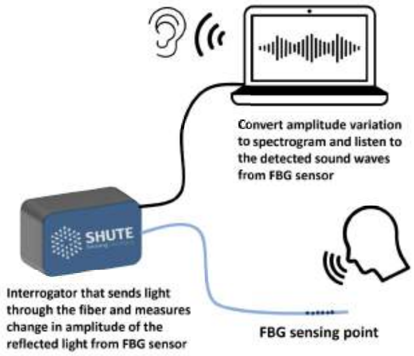

Figure 7: Schematics for detection of audio signals

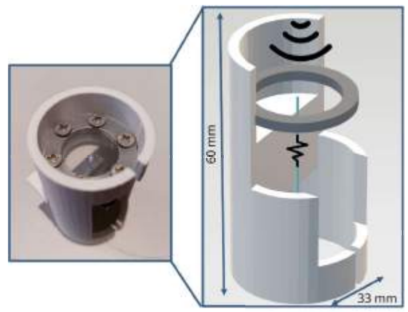

Figure 8: Small size probe fiber sensor attached to the membrane to detect incoming sound waves

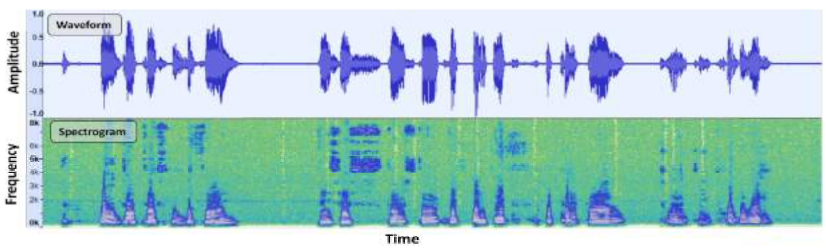

Figure 9: Detected audio signals showing both as waveform and spectrogram

5 Conclusion

Our POFUS sensor is a compact and cost-efficient opto-electronic system capable of detecting audio signals as well as ultrasound frequencies up to 5 MHz. In addition, the mechanical design of our membrane could successfully detect incoming sound waves and then be played back and listened to.

6 Contact

For further information about the technology and how it applies to your potential use case, please contact :

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