Optics 11 @ Physics with Industry 2020

High sensitivity universal fiber optic hydrophone

1. Company information

Optics11 is a high-tech company focusing on development of cutting-edge sensing solutions based on fiber optics. Our mission is to provide affordable high accuracy and high reliability fiber optic systems to tackle most challenging applications in industry. Optics11 has currently 45 employees working on R&D, sensors and interrogators manufacturing, sales and marketing. Among current and past R&D activities one can mention: all-optical acoustic emission (AE) monitoring system, state-of-the-art FBG sensing platform and all-optical seismic monitoring system. In all those cases Optics11 developed both the transducer as well as the interrogator unit. We work worldwide strongly focusing our sales on EMEA region and US.

2. Problem

Since many years people are exploring underwater secrets of seas and oceans. The common denominator for most of those efforts is an extremely high operational cost. As an example, a single day of geo surveying vessel operation can cost millions of dollars. A mid-size vessel can tow up to few thousands of electrical hydrophones spread along multiple strings called streamers. A singe streamer has a diameter of about 10-20cm and length of even few kilometers. Making those streamers smaller and lightweight would lead to a significant reduction of operational cost and therefore facilitate seabed exploration efforts. Moreover, such a reduction in dimensions and weight would be also beneficial for other applications such as oceanography or underwater surveillance.

In order to reduce the diameter of a seismic streamer one can consider replacing the existing electrical hydrophones with its fibre optic equivalents. Optical fibers are light in comparison to electric wires and can carry a lot of information. In principle a single streamer may contain only one 125µm fiber able to address hundreds of sensors. However, such an approach comes with a challenge. In order to provide high fidelity signal in all conditions, fibre optic hydrophones have to maintain high sensitivity (meaning - being able to detect minute pressure variations in order of millipascals) independent of the extreme static pressure (imposed by operational depth of the streamer – typically between 100kPa-1MPa). This becomes even more challenging in case of semi- static pressure changes coming from depth variation during towing operation.

A typical fibre optic hydrophone manufactured by Optics11 is shown on Fig.1. It consists of a cylindrical support structure carrying a fiber mandrel and a core encapsulated inside. The strain transferred to the fiber during ambient pressure variation (acoustic wave passing through the hydrophone) can be recorded using interferometric methods. This can be done with an extreme resolution reaching femtostrains. Even though the number makes a great impression, the overall performance of the hydrophone strongly depends on the mechanical properties of support structure, core material and strain transfer. That is where we think is the key to build a universal hydrophone that could be characterized by high sensitivity independent of static pressure variation.

Just to give an example, in order to boost the sensitivity, one could consider using core material that is extremely compliant (low bulk modulus), for example air. That would provide very high transfer function coefficient. However, such a hydrophone would be crushed and destroyed by static pressure at greater depths. Covering both aspects at the same time is the scope of our challenge.

The typical frequency range of our hydrophones are within 100Hz to 5kHz, it does not need to be flat in response, however more a bandwidth of interest.

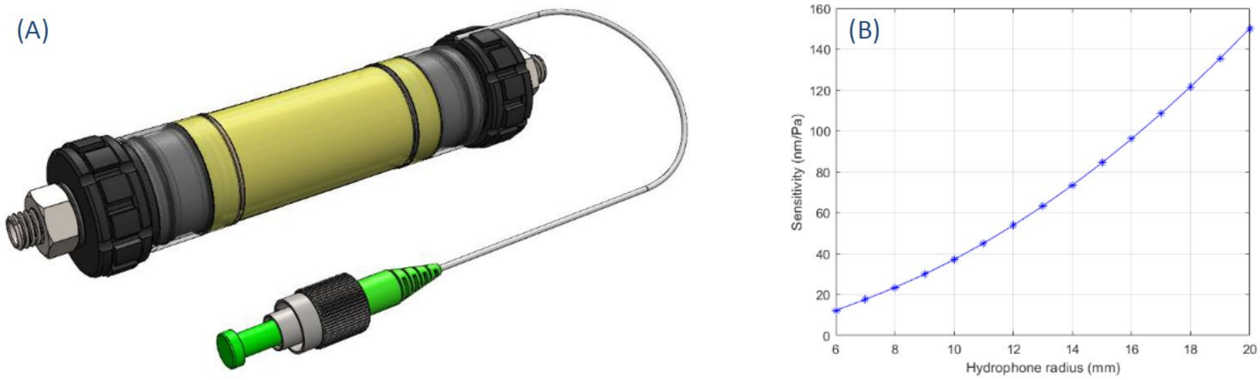

Figure 1 Visualization of a fiber optic hydrophone having diameter of Ø25mm and 110mm in length (A). The fiber stretched by pressure variation is wound in the central part of the yellow cylinder; Plot showing an example of reduction in hydrophone sensitivity as a function of radius for given core material (B).

We would like to further evaluate the core design that would lead towards a fiber optic hydrophone that can be characterized by (even outside boundaries imposed by current design):

- improved sensitivity
- no significant change in sensitivity with static pressure variation (up to 30 bar)
- small dimensions, especially diameter
- no significant memory effects coming from multiple static pressure cycles
- reasonable manufacturing costs and effort; stable quality over time

The challenge can be tackled by experimental physicists, mechanical engineers and material scientists.

Just to mention few possible directions, one can think of a static pressure compensation mechanism (bellows or thixotropic fluids), negative stiffness springs or use of smart materials (composite materials, negative Poisson's ratio).