First workshop coming on distributed optical fibre sensing for reservoir and production monitoring

EAGE is to hold a first Workshop on Fibre Optic Sensing for Reservoir and Production Monitoring on 9-11 March 2020 in Amsterdam, The Netherlands. Co-chair of the event Mahmoud Farhadiroushan, co-founder, Silixa, explains why interest is growing in the E&P oil and gas industry.

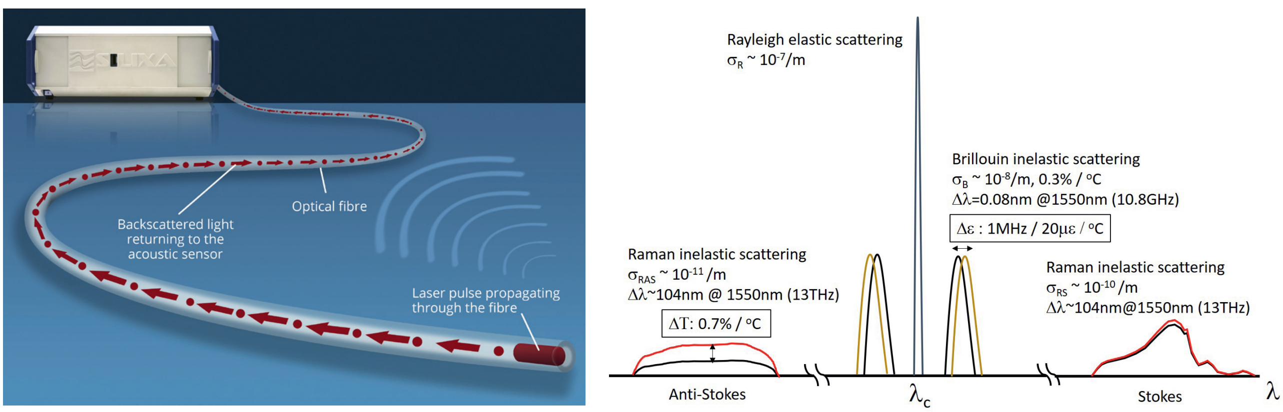

Figure 1 (a) Distributed Optical Fibre Sensor based on Optical Time Domain Reflectometry (OTDR), (b) Rayleigh, Brillouin and Raman backscatter spectrum.

Distributed optical sensors can provide wide coverage for monitoring dynamic fluid movements along the wellbore and for acquiring high resolution seismic images deep down in the reservoir. The optical fibre acts as a dense array of sensors with a wide aperture to monitor the temperature, strain and acoustic energy distributions. Multiple fibres can be housed within a cable and deployed in different configurations to offer novel methods to acquire data continuously downhole.

Measurement principle

The principle operation of the majority of distributed optical fibre sensors is based on Optical Time Domain Reflectometry (OTDR). As indicated in Figure 1, a tiny fraction of the incident light is backscattered towards the optoelectronic interrogator unit as a laser pulse travels through the fibre.

The distributed temperature sensor (DTS) utilizes the very weak inelastic Raman backscatter light resulting from interaction of the incident light pulse with molecular lattice thermal vibrations energy along the fibre. A resolution of down to 0.01°C with sub-metre spatial resolution can be achieved over 10 km of fibre. The DTS can be used for production profiling by characterizing the heating and/or cooling effects resulting from the inflow/outflow temperature variations at different depths along the wellbore.

The distributed strain sensor (DSS) uses the inelastic Brillouin backscatter light where the incident light interacts with acoustic phonon energy in the fibre. The frequency of the Brillouin backscatter light varies with strain and temperature. Compensating for the temperature effect, the strain profile can be measured along the fibre. The DSS can provide a resolution of several mirostrain ($\mu\varepsilon$) with spatial resolution of several metres. One application is subsidence monitoring where the fibre is installed behind the casing and cemented to the formation.

The phase coherent Distributed Acoustic Sensor (DAS) is based on digital detection of elastic Rayleigh backscatter resulting from small built-in inhomogeneous variations of the refractive index along the fibre. The DAS measures the dynamic strain perturbations down to sub nano-strain ($n\varepsilon$) along the fibre which are induced by acoustic vibration energy. The system can be used as a continuous dense array of acoustic sensors with a wide aperture. The DAS system has a wide range of applications for inwell monitor-

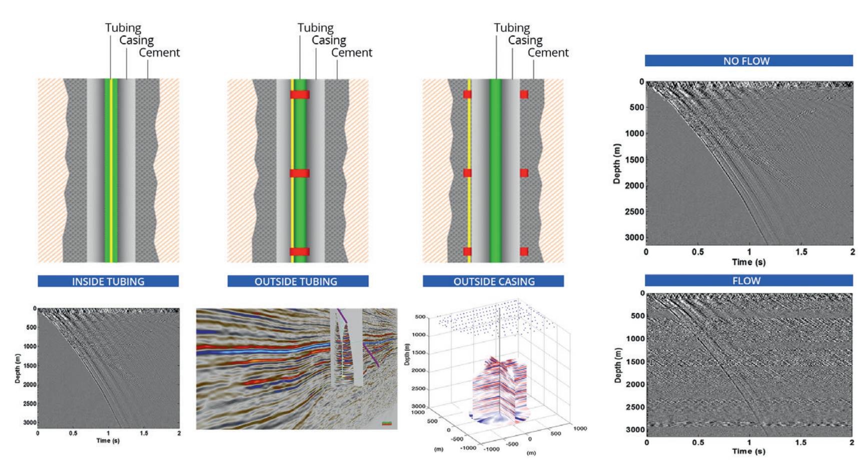

Figure 2 Examples of the sensing cable deployment and seismic data acquisitions for different well conditions.

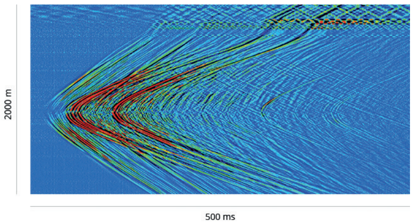

Figure 3 Microseismic events recoded over a wide detection aperture of the precision Engineered Acoustic Sensor (EAS).

ing including production profiling, sand and leak detection, as well as active and passive seismic data acquisition.

Installations methods

The small diameter, rugged fibre optic sensing cable can be deployed in different configurations as indicated in Figure 2. The flowing well conditions may be adjusted while recording the data simultaneously to characterize the well production profile and/or acquire seismic data. The fibre can be used to listen to the flow noise across the perforated zones, and the acoustic energy and the spectra response may be used to characterize the flowing conditions. In addition, using a phase array processing technique, we can determine the speed of sound in up-going and down-going directions. The fluid properties may be determined from the average speed of sound, and the fluid velocity may be calculated by determining the doppler shift experienced between up-going and down-going sound waves.

The optical fibre can withstand high temperatures and permanent installation offers many practical benefits for continuous production monitoring, passive seismic and seismic acquisition on-demand. Distributed Acoustic Sensing can provide higher resolution 3D VSP images near the wellbore than ocean bottom seismic, enabling better placement of infill wells, side-tracks or new perforations. Since the fibre is permanently installed low-cost, regular, repeat seismic acquisition is possible and time-lapse VSP seismic images can reveal changes within the reservoir.

Precision Engineered Acoustic Sensor (EAS)

The DAS systems usually utilize single-mode fibres. However, more recently, precision an Engineered Acoustic Sensor (EAS) utilizing a sensing fibre with bright scatter centres has been demonstrated to provide significantly improvements in sensitivity by 100x (20 dB). Figure 3 shows the capturing of multiple microseismicw events over the wide aperture of the engineered fibre extending all the way to the surface.

We encourage you to contribute to the technical programme of the *First EAGE Workshop on Fibre Optic Sensing for Reservoir and Production Monitoring*. The deadline to submit extended abstracts is 8 December 2019. For more information on the submission topics and guidelines, please check out the event website via our calendar of events: events.eage.org.

Figure 4 Long-offset subsea wells monitoring using Engineered Acoustic Sensor (EAS).

The EAS also provides a new platform for acquiring high resolution seismic images in deep water subsea wells. As indicated in Figure 4, the downhole engineered fibre can be connected to existing fibres in the umbilical (up to 30 km) and the optoelectronics interrogator unit can be installed on a topside facility.

In addition, using optical amplification techniques (controlling light with light), the operating range can be extended to long-offset subsea wells over 100 km.

Conclusion

Distributed fibre optic sensing technology provides a new powerful tool for continuous high-resolution mapping of the subsurface.