Listening with Light!

Optical sensing technology, originally developed for cold-war anti-submarine warfare, is promising to be a reliable and cost-effective method of monitoring and improving reservoir performance.

Jane Whaley

As oil companies become increasingly aware of the importance of ensuring maximum productivity from their fields, they are turning to advanced technologies for help. The use of fibre-optic sensors and cables for permanent seismic reservoir monitoring is at the forefront of this.

Enhancing field recovery

"At the moment companies are recovering about 30% of total hydrocarbon in-place from each field – that's like peeling a banana, eating the top third and throwing the rest away!" says Martin Bett, Chief Executive of Stingray Geophysical. "We anticipate a push for enhanced recovery not just from oil companies themselves, but also from environmental groups and governments, as pressure mounts to develop and manage our natural resources responsibly. Governments seeing their oil and gas tax and royalty revenues dwindle with falling production will increasingly encourage and eventually require higher rates of recovery. Research into technologies supporting and enabling through-life reservoir management is therefore essential if, as an industry, we are to strive for 60% recovery or more from our reservoirs.

To achieve this, operators need to know what is happening to their producing reservoirs with cost-effective and reliable reservoir monitoring systems. New fields are likely to be smaller, more complex and more challenging to exploit, so development decisions will require information and technologies that allow operators to improve recovery and lower their risk, even as part of the initial field development capital expenditure plan. We believe that fibre-optic sensing technology is key for the widespread adoption of seismic reservoir monitoring."

Fibre-optic based systems offer a number of key advantages. There are no underwater electronics, so they are inherently more reliable, and they are smaller and lighter and therefore easier and safer to deploy in a producing field. The power requirements are considerably lower than required by electrical systems and they can easily support the large numbers of sensors needed for monitoring small changes in reservoir behaviour over time. Sensors can be left in-situ for many years, so that recurrent seismic surveys can be shot over the reservoir with a high degree of repeatability. In this way changes and developments occurring in the reservoir over months or years can be easily and continually monitored to optimise drilling and enhanced recovery programmes.

Fibre-optics

An optical fibre is a glass or plastic fibre designed to guide light along its length by confining as much light as possible in a propagating form. Due to low loss and high bandwidth properties of fibre cables they can be used over greater distances than copper cables.

Technology developed from defence research

Phil Nash, Chief Technology Officer at Stingray Geophysical, is one of the world's leading experts on fibre-optic sensing technology. "I began researching this area in the 1980's, while working on anti-submarine sensors for the UK Ministry of Defence," he explains. "The end of the Cold War meant a decline in defence research but an increasing interest in exploiting defence technology in non-defence markets. In 2002 the MoD privatised its R&D activities and the resultant company, QinetiQ, which I joined, had the freedom to exploit these technologies for more commercial applications."

"We realised that fibre-optic technology could be useful in the oil industry, with the seismic arena looking particularly promising. With industry sponsors, including BP, Chevron, ConocoPhillips and Shell, we set up a research project to investigate whether fibre-optic sensors could produce better seismic records than conventional electrical sensors. We tested this in the laboratory and onshore and then in 2004 undertook an extensive offshore test. By experimenting with different sensor and multiplexing designs we proved that we could develop an efficient, cost-effective, and reliable system supporting a large number of sensors."

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Phil Nash is Chief Technology Officer of Stingray Geophysical and one of the world's leading experts on fibre-optic technology. He originally worked for, Plessey, the UK Ministry of Defence and QinetiQ before moving into the oil industry.

Stingray Geophysical was established in early 2006 to commercialise this technology under licence from QinetiQ. The new company secured backing from a venture capital consortium lead by Energy Ventures and including Hydro Technology Ventures and Chevron Technology Ventures.

As Martin explains, "Stingray looks like a small company, but we benefit from many years and millions of dollars of investment in advanced fibre-sensing technology. Through our partners we have access to

Aid to modelling the subsurface

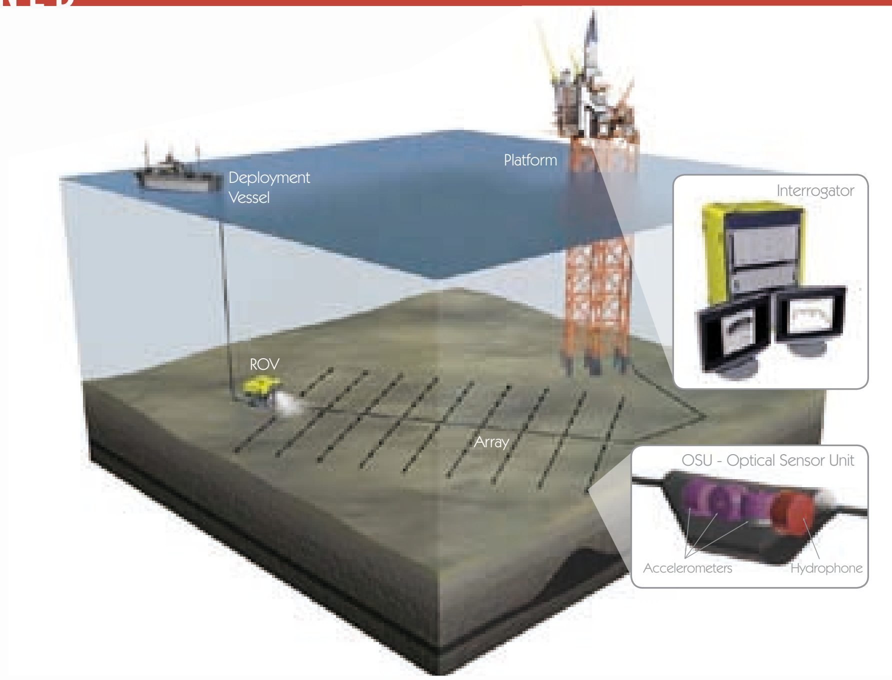
Optoplan, part-owned by the Norwegian geophysical company Wavefield Inseis, has been working with fibre-optic sensing systems for oil and gas applications since 1985. They recently developed a permanent fibre-optic seabed system, called Optowave, based on downhole optical seismic technology, as Hilde Nakstad, Development Manager for Subsea Systems, explains.

"Our Optowave system is based on Fibre Bragg Grating (FBG) technology," she says. "A FBG is a wavelength selective reflection imprinted in the core of the fibre. By using FBGs, all sensors in a single 4C seismic station can be made from one continuous length of fibre. Alternative fibre-optic technologies are based on the use of couplers and wavelength division multiplexers, which adds cost and complexity to the station and in particular to the manufacturing process. With all sensors made from a continuous length of fibre the need for optical fibre splicing is significantly reduced and packaging of bulky optical components is eliminated, enabling a cost-effective manufacturing process.

"In addition to the advantages of our subsea optical fibre system," Hilde adds, "the Optowave interrogation system is founded on an innovative demodulation method that increases the number of sensors which can be read on a single fibre. Compared to conventional interrogation techniques, this method also significantly improves the performance with respect to crosstalk and noise."

Hilde concludes that "a permanently installed system, leading to enhanced repeatability from survey to survey, significantly aids oil companies in modelling the subsurface and in understanding the effect of production on geology, thus maximizing the oil recovery rate from the reservoir in a very cost-effective manner."

Hilde Nakstad is Development Manager, Subsea Systems, at Optoplan AS, the company that pioneered fibre-optic sensing in the oil and gas industry.



Each optical sensing unit contains 3 fibre-optic accelerometers and a hydrophone. Light pulsed down the fibres is reflected off mirrors at either end of each sensor, enabling the measurement of small changes in the length of the fibre as seismic waves from an acoustic seismic source reflecting off subsurface structures cause the fibre to stretch and relax. The system is deployed permanently on the seafloor, allowing highly accurate repeat surveys to be undertaken for the cost of a single seismic vessel.

the scientists, engineers and modern laboratories and test facilities in QinetiQ, while Atlas Elektronik, our manufacturing partner, has a 15,000m2 manufacturing plant and a proven track-record of building fibre-optic cables and sensors for various applications. Our deployment partner, Bergen Oilfield Services, has wide experience in deploying ocean bottom seabed arrays in many environments. Stingray therefore has access to a vast range of capabilities and expertise, allowing us to compete on better than equal terms with our competitors because all our resources are singularly focused on developing Fosar, our fibre-optic seismic reservoir monitoring solution."

Seismic on demand

"The beauty of fibre-optic systems like Fosar is that there are no electronics in the water, making the systems inherently reliable, as the telecommunications industry has already discovered," Phil continues. "We are able to communicate with hundreds of sensors over a few optical fibres using an armoured cable less than 13mm in diameter and more than 12km in length. Our arrays can be laid out in configurations to suit seabed conditions and subsea infrastructure. Multiple configurations are possible using commercial off-the-shelf connectors for seabed assembly or future array extensions."

Permanent seabed sensing systems have a number of major advantages over more conventional technologies. The position of each sensor is known with great accuracy, which improves repeatability, and the signal to noise ratio is much better than that obtained using towed seismic. The accelerometers acquire shear wave data, which can be used in applications such as fracture characterisation, lithology determination and imaging below gas. For permanent seabed applications fibre-optic sensing systems use less power and are more reliable than standard technologies, making the system much more cost-effective over the life of a field.

Stingray have tested prototype systems both in the laboratory and on the seafloor. "A great deal of work has gone into developing this system, as seismic applications demand greater fidelity and sensitivity than other uses," Phil explains. "We have now developed a system that is more economic, efficient and reliable than anything else available."

"The seismic market boomed during 2006, and the shortfall in available seismic vessels is continuing in 2007. With no spare capacity in the towed streamer market, a system like Fosar providing 'seismic on demand' is key, for both geophysicists and asset managers, in order to assess and prolong field life."

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