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Fiber optics in geophysics. Distributed acoustic sensing (DAS)

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Optical fibers have been developed to transmit information over long distances with extremely high transmission speeds and traffic-carrying capacity. Ideally, the use of total internal reflection allows light pulses to be transmitted without loss over any distance. As light travels through an optical fiber, however, it undergoes reflection, scattering, absorption, and radiation outward. Because of these effects, every 50 km, there is an optic repeater, powered by an electrical cable laid along with the optic fiber. Some of these effects (Raman scattering, Brillouin scattering and Rayleigh scattering) are used for distributed measurements.

Optical fibers are widely used in geophysics [1]. Let us introduce such a classification.

1. Fiber optic data lines.

2. Optical sensors of mechanical movements [2] with further data transmission via optical fiber; in some cases it allows to completely abandon electronic components inside the sensor.

3. Sensors without mechanical elements that use the optical fiber as a sensing element, for example fiber optic gyroscopes [3].

4. Seismic sensors sited along the fiber optic cable. A prominent example is Smart cable [4]. SMART cables are a marriage of standard fiber optic telecommunication cables with deep-sea scientific sensors ineide repeaters. SMART cable sensors “piggyback” along the power and communications infrastructure of a million kilometers of undersea fiber optic cable.

5. Interferometric and polarization-based systems [5], where the entire long-distance fiber optic cable acts as a sensor.

6. Quasi-distributed measurements are made using special engineered optical cables [6] designed to improve the signal-to-noise ratio (SNR) or to increase the distance over which fiber-optic sensors operate. Most often, fibers which are used for these purposes, are made with Bragg gratings written into them at certain intervals [7].

7. Distributed measurements, which are made using much cheaper standard fibers. In geophysical research, Distributed Temperature Sensors (DTS) and Distributed Acoustic Sensors (DAS) are used, which can be presented in a form of a virtual strain meters installed along the cable [8].

The DAS, which are in our point of view of special interest, can be organized along the cables that are already placed and therefore are cheap and easy to deploy. They provide unprecedented measurement density, and have a wide frequency range.

References.

[1] G. Rajan, Optical Fiber Sensors: Advanced Techniques and Applications, Boca Raton, Fla.: CRC Press, 2017.

[2] T. Chang, Z. Wang, Y. Yang, Y. Zhang, Z. Zheng, L. Cheng, and H.-L. Cui, Opt. Express. 28 (2020) 6102.

[3] K.V. Kislov and V.V. Gravirov, Seismic Instruments. 57(2) (2021) 187.

[4] Güralp successfully deploys worlds first ‘SMART cable'. Retrieved March 8, 2024, from https://www.guralp.com/about-us/news-and-events/guralp-successfully-deploys-worlds-first-smart-cable

[5] G. Marra, D.M. Fairweather, V. Kamalov, P. Gaynor, M. Cantono, S. Mulholland, B. Baptie, J.C. Castellanos, G. Vagenas, J.O. Gaudron, J. Kronjäger, I.R. Hill, M. Schioppo, I. Barbeito Edreira, K.A. Burrows, C. Clivati, D. Calonico and A. Curtis, Science 376 (2022) 874.

[6] T. Lee, M. Beresna, A. Masoudi and G. Brambilla, Journal of Lightwave Technology 41 (2023) 4051

[7] O.V. Butov, K.A. Tomyshev, I.A. Nechepurenko, A.V. Dorofeenko, S.A. Nikitov, Physics –Uspekhi 65(12) (2022) 1290.

[8] K.V. Kislov and V.V. Gravirov, Seismic Instruments. 58(5) (2022) 485.