FURTHER READING

Real-time distributed strain sensing by BOCDR:
www.youtube.com/watch?v=vZ3SoIt7TWE

Page 754, 'Low-cost Brillouin optical correlation-domain reflectometry involving merely one fibre amplifier', Y. Mizuno, G. Han, K. Noda, H. Lee and K. Nakamura.

Optical reflectometry implemented using only one fibre amplifier for distributed strain sensing

reflect on this

Researchers from the Tokyo Institute of Technology, Japan, have shown that in Brillouin optical correlation-domain reflectometry (BOCDR), implemented using three erbium-doped fibre amplifiers (EDFAs), the one EDFA in the Stokes path plays the greatest role in enhancing the signal to noise ratio (SNR) of the measurement.

Structural healthcare

Age degradation and seismic damage to civil infrastructure poses a serious problem for society. One promising technology for monitoring the condition of these structures is optical fibre sensing. By embedding long optical fibres into a structure, strain and temperature distributions along the fibres can be detected. Among the various types of optical fibre sensors available, distributed strain and temperature sensors based on Brillouin scattering have received considerable attention due to their high sensitivity and stability. One such sensor is the group's advanced technology, called "BOCDR", which operates based on the correlation control of continuous light waves.

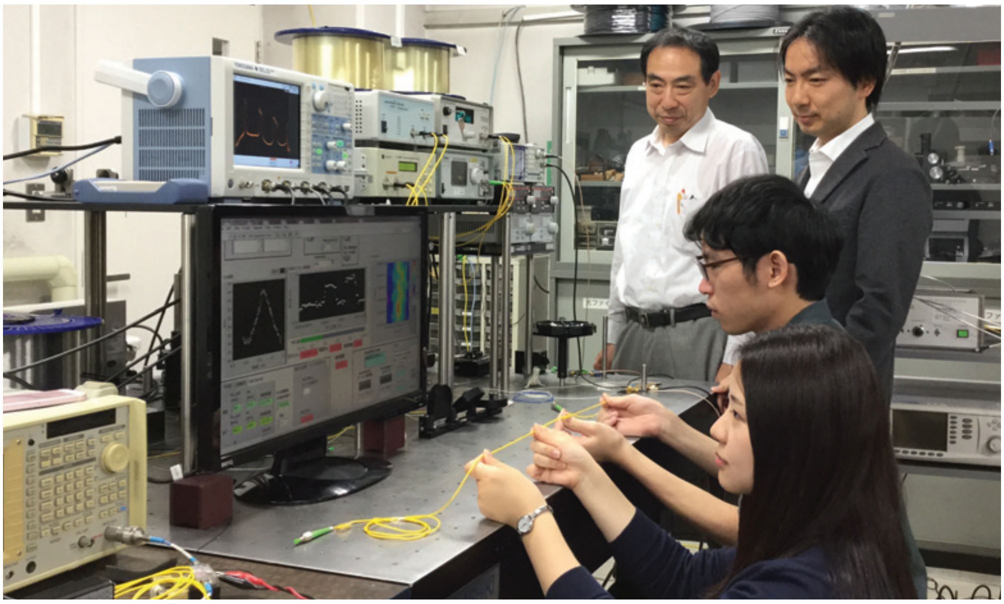
Co-author Doctor Mizuno describes BOCDR: "It is known to be an intrinsically one-end-access distributed sensing technique with high spatial resolution. This means that millimetre-long strains can be detected by injecting light into only one end of a sensing fibre. Another advantage of BOCDR is its so-called random accessibility, with which we can measure strain or temperature at any point (or points) along the sensing fibre at high speed. In addition, we have recently succeeded in increasing its sampling rate to >100 kHz and demonstrated one-end-access real-time distributed measurement for the first time to the best of our knowledge."

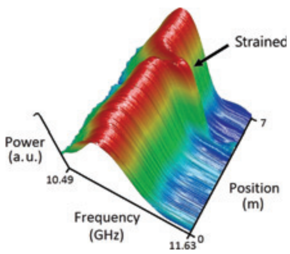
Illuminating

The major drawbacks of conventional BOCDR include its relatively high cost and large system size, which limit the range of practical applications with reduced portability. In their Letter, to tackle this issue, they work to minimise the number of high-cost, large-scale optical amplifiers conventionally employed in the system. As a result of comprehensive evaluation, they showed that the use of merely one amplifier, which plays the most significant role in enhancing the SNR of the system, is sufficient to perform distributed strain measurement. In addition to this, it was noted that the light source does not need to be a high-power laser; a cost-effective standard laser can be used. These results are beneficial from the viewpoints of size and cost and will boost the practicality of BOCDR.

Real-time distributed Brillouin sensing has also been demonstrated by Brillouin optical time-domain analysis (BOTDA) and Brillouin optical correlation-domain analysis (BOCDA). Although these techniques have much higher SNRs, two light beams need to be injected into both ends of a sensing fibre. Note that the two-end-access nature is not beneficial to users, not only because the degree of freedom in deploying the fibre is reduced but also because the measurement can no longer be continued if the fibre has one breakage point. In contrast, though the SNR is lower, BOCDR is more user-friendly with its one-end accessibility, which can mitigate such shortcomings.

The team's work has made it possible for the first time to achieve one-end-access real-time distributed measurement at considerably low cost. This proves the feasibility, and will lead to the eventual implementation, of practical distributed vibration sensing.





TOP: Ms. Heeyoung Lee (first, from front), Mr. Kohei Noda (second), Asst. Prof. Yosuke Mizuno (third), and Prof. Kentaro Nakamura (fourth) measuring strain distribution by BOCDR at Tokyo Institute of Technology. A relevant video is available online.
BOTTOM: Example of Brillouin gain spectrum distribution measured when strain was locally applied.

Just the one

BOCDR is a one-end-access system, which means that extremely weak spontaneous Brillouin scattering needs to be exploited, leading to a low SNR in general. Note that two-end-access systems allow the use of stimulated Brillouin scattering, which is much stronger. To improve the SNR in BOCDR, three or more optical amplifiers have been used in conventional systems, resulting in relatively large system size and high cost. In this work, by carefully investigating the role of each amplifier, implementing BOCDR utilising only one amplifier was achieved.

The proposed low-cost BOCDR can be used as a health monitoring technique for various structures, such as buildings, tunnels, bridges, dams, levees, windmill blades, and aircraft wings. It also has potential applications in robotics, acting as artificial "nerves" for detecting touch, distortion, and temperature change. Therefore, this work will impact research in many different topics ranging from optical sensing to robotic, medical, environmental, architectural, and civil engineering fields.

Future sensing

Other large-scale and/or high-cost devices used in the system are an electrical spectrum analyser (ESA) and a high-speed photodetector (PD), which are used to observe Brillouin gain spectra for strain and temperature measurement. To reduce the size and cost of the system further, the group are planning to replace these devices with a voltage-controlled oscillator, an electrical notch filter, and a low-speed PD. They are hopeful that the ESA-free configuration of BOCDR will also enhance the operating speed of the system.

Doctor Mizuno outlines his expectations for the near future: "We expect that distributed optical fibre sensors will be practically used in society to provide safe and secure environments all over the world. As for technological progress, performance of distributed sensors, such as spatial resolution, measurement range, sampling rate, accuracy, and cost will be drastically improved beyond our anticipation. Some physical parameters that have not been measured accurately in a distributed manner, including acidity, acoustic impedance, and radioactive concentration, will be possible. Complete discrimination of multiple parameters, not only strain and temperature but also many other combinations, will also be feasible."

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