# WF

**1:00 pm**
Room A1

## Fiber Devices

Alan D. Kersey, *Naval Research Laboratory, Presider*

## WF1 1:00 pm

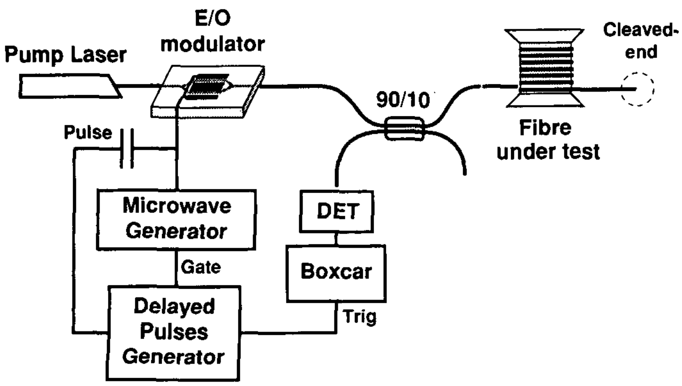
### Measurement of the distributed-Brillouin-gain spectrum in optical fibers by using a single laser source

Marc Niklès, Luc Thévenaz, Philippe A. Robert, *Metrology Laboratory, Swiss Federal Institute of Technology, CH-1015 Lausanne, Switzerland*

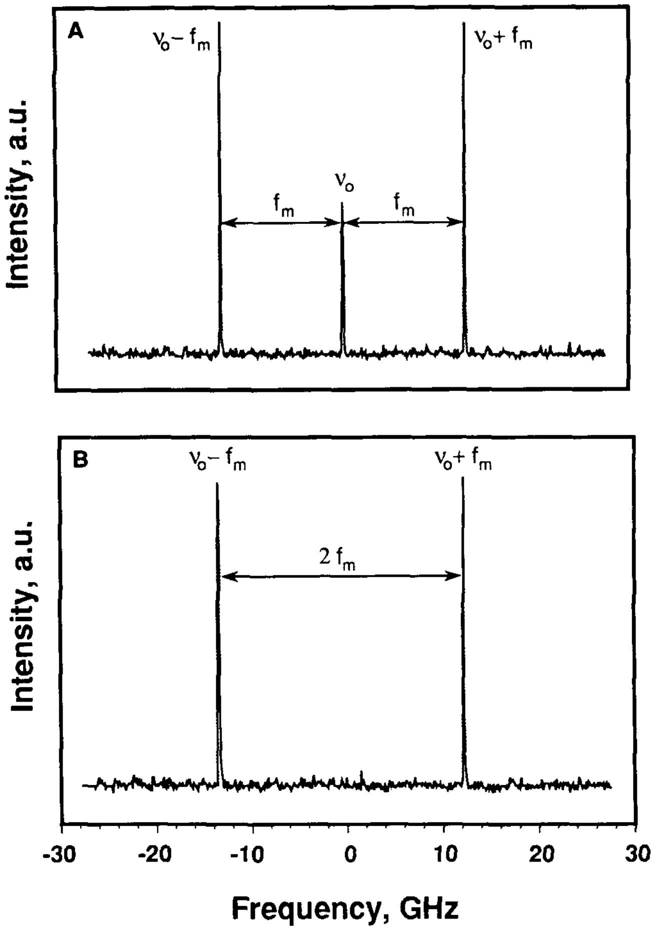
Brillouin-gain-spectrum measurement along an optical fiber has recently gained a lot of interest owing to its potential for strain monitoring in installed cables[1] and for distributed temperature sensing.[2] This measurement requires two lightwaves propagating in opposite directions through the fiber. One pumps the medium, and the other acts as probe signal and thus experiences amplification when it lies within the Brillouin-gain spectral range (12–13 GHz below the pump-light frequency near 1300 nm). Most of the methods reported to date use either two distinct laser sources,[1,2] causing problems when the fiber ends are remote, or a single laser source, at the expense of setup complexity.[3]

We present a different method that has the following advantages: (1) few optical elements are required, (2) a single laser source is used, and (3) a single fiber end is accessed. A schematic diagram of the experimental setup is shown in Fig. 1. The operation of this setup relies on two features. First, the pump and probe signals are pulses that both propagate back and forth through the fiber by using a reflection at the far end. The pump pulse provides gain to the probe signal during its forward propagation, whereas the probe pulse is amplified on the way back, so that the amplification actually occurs only at the crossing point of the pulses. A reflection of only a few percent is necessary at the fiber far end, and the Fresnel reflection is actually sufficient.

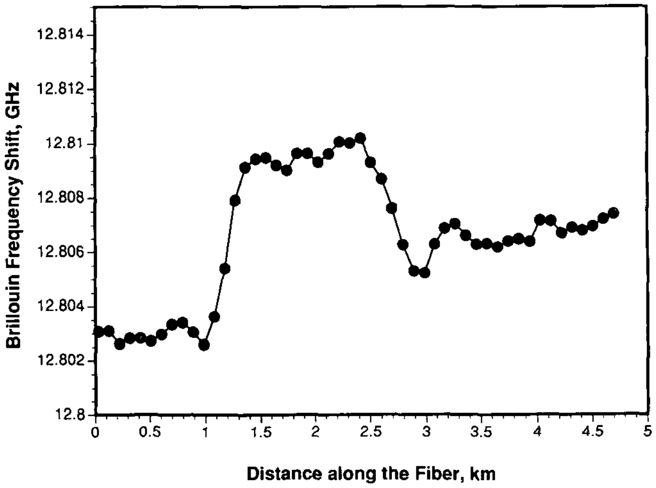
The second and more important feature is the use of a guided-wave intensity modulator for pulsing the cw laser light to form the pump signal and for generating the probe signal.



**WF1 Fig. 1.** Schematic diagram of the experimental setup.



**WF1 Fig. 2.** Fabry–Perot scan of the modulator output spectrum for two different dc bias settings. In addition to the incident frequency (carrier) used as a pump signal, two sidebands generated by the microwave drive signal are observed. The lower sideband is used as a probe signal. The dc level modifies only the transmitted carrier level, reduced to zero in B, and does not change the intensity of the sidebands.



**WF1 Fig. 3.** Measurement of the maximum Brillouin-gain frequency along three spliced single-mode fibers with the same nominal characteristics. The high-frequency resolution obtained with this setup makes the three fibers clearly distinguishable.

The frequency shift of the laser light is achieved by simply applying microwave signal at the Brillouin-shift frequency on the modulator electrodes. This creates sidebands in the laser spectrum, so that the first lower sideband lies in the Brillouin-amplification spectral range and can be thus identified with the probe signal. The upper sideband is an idle signal that just causes an intensity offset. Therefore the probe optical frequency can be easily scanned by just varying the microwave signal frequency and can be pulsed simply by gating the microwave-generator output. The dc bias setting on the intensity modulator does not change the sidebands' amplitude and just determines the amount of transmitted amplitude of the fundamental frequency, as shown in Fig. 2. This feature is used for pulse shaping the pump signal.

Since this technique uses a single laser and a modulator for the generation of the pump and probe signals, it ensures an inherent stability of their frequency difference. Measurements of the maximum Brillouin-gain frequency are therefore performed with excellent resolution by using this technique, as shown in Fig. 3. Three distinct fibers may be easily distinguished within a line, even though they were identically manufactured. The measured standard deviation in the determination of the Brillouin-shift frequency is 300 kHz. The best spatial resolution obtained to date is 150 m, given by the minimum pulse width leaving a sufficient gain. The results from this technique are steadily improving along with system optimization.

1. T. Horiguchi, T. Kurashima, and M. Tateda, IEEE Photon. Technol. Lett. **2,** 352 (1990).
2. X. Bao, D. J. Webb, and D. A. Jackson, Opt. Lett. **18,** 552 (1993).
3. K. Shimizu, T. Horiguchi, Y. Koyamada, and T. Kurashima, Opt. Lett. **18,** 185 (1993).