Amplifier Enhances Ringdown Spectroscopy. Hitz, B. and Stewart, G.

In recent years, investigators have adapted the principles of ringdown spectroscopy (see sidebar, facing page) to fiber optic configurations by placing high reflectors on each end of a fiber and observing the ringdown time of an injected pulse. But a major drawback is the difficulty of creating a low-loss, high-Q resonator in an optical fiber.

Because the insertion of an open-path sample cell introduces unacceptable loss, fiber optic ringdown spectroscopy has been restricted to an interaction between the evanescent field and the sample. The weakness of this interaction has limited the utility of the technique. Recently, researchers at the University of Strathclyde in Glasgow, UK, added an erbium-doped fiber amplifier to a fiber optic ringdown loop and found that the amplifier's gain can offset cavity losses.

They used an approximately 60-m-long loop that included 5 to 10 m of erbium-doped fiber pumped by a 980-nm diode laser (Figure 1).

In initial experiments with the amplifier gain set below the lasing threshold for the loop, they injected an ~200-ns, 1532.8-nm pulse from a distributed feedback laser into the loop and observed ringdown times as long as 10 µs (Figure 2). This is roughly an improvement of an order of magnitude over previous results with passive fiber optic ringdown cavities.

It is very difficult to generate reliable data with such a system, however, because random fluctuations in the gain can overwhelm the meaningful signal. But in an oscillating laser, the saturated gain is clamped to its threshold value. Taking advantage of this, the researchers increased the gain until the loop reached threshold and the gain became firmly clamped. Then they injected the ringdown pulse and observed ringdown times without error from fluctuating gain.

It is important to realize that an injected pulse will ring down in a resonator, even though the resonator is oscillating. One might be forgiven for thinking that, because the resonator is oscillating -- its net gain is unity -- the injected pulse would circulate indefinitely. However, there is a very small part of the total laser power that is due not to stimulated emission, but to spontaneous emission. The injected pulse, whose amplitude is much smaller than that of the circulating laser power, is amplified only by stimulated emission, and, hence, its net gain is slightly less than unity for each round trip. It rings down.

With the loop gain clamped, the researchers observed ringdown times as long as 200 µs, although they note that repeatability of these long times was difficult. A ringdown time of 200 µs corresponds to a net loss of 0.004 dB in the 38-m loop. This means that the injected pulse makes approximately 1100 passes through the loop, so that the effective length of the 5-cm sample cell is 55 m.

They could set the exact lasing frequency of the loop by adjusting the bandpass filter. When the laser frequency was not the same as -- or nearly the same as -- the injected pulse's frequency, shorter ringdown times were observed because the bandpass filter attenuated the pulse. The longest ringdown times occurred when the laser was tuned to the same frequency as the injected pulse so that both passed through the filter with minimum loss.

But, in that case, the injected pulse disturbed the population inversion enough to initiate relaxation oscillations, which had to be subtracted from the signal to obtain usable data.

Figure 1. A pulse injected from the distributed feedback laser (lower left) "rings down" as it passes repeatedly around the loop. An erbium-doped fiber amplifier (top) offsets losses in the micro-optic sample cell and elsewhere in the loop.

Figure 2. A ringdown time of approximately 10 µs is obtained when the gain in the loop is below lasing threshold.