interview

Alumina aplenty

Brillouin scattering threatens to limit continued power-scaling for many fibre applications, but sapphire-derived all-glass fibres with large concentrations of alumina may help to eliminate this problem. *Nature Photonics* spoke to Peter Dragic and John Ballato to learn more.

Why use alumina-doped fibres?

Alumina is used ubiquitously as an additive to silica in fibre lasers and amplifiers. Alumina tends to be a good solvent for rare-earth elements and allows for high dopant concentrations. Pure alumina (crystalline sapphire) fibres are traditionally made using methods such as laser-heated pedestal growth, which is a slower manufacturing process than those employed for making conventional optical fibres. In addition, pure alumina fibres are used largely for thermomechanical applications, which require high strength at high temperature. There have been some optical uses of sapphire fibres, mostly for the transmission of infrared light in biomedical applications, as they guide light reasonably well at such wavelengths.

Our work was motivated by the realization that high-alumina-content all-glass fibres could have extraordinary Brillouin scattering properties. We also have a very good model for predicting how materials mix and give rise to measured Brillouin properties. The problem was that high-alumina-content glasses crystallize easily, which makes conventional high-speed and commercially accepted volume manufacturing methods — fibre drawing — very difficult.

How did you make your fibre?

The original idea of using sapphire as a precursor for a high-alumina-content fibre came a few years ago but was set aside because sapphire melts at 2,050 °C, which is above the temperature at which silica is drawn. This is important because we employ a 'molten core' technique, as is also done when making crystalline semiconductor-core optical fibres. The core material is chosen such that it is a fluid at the temperature where the cladding glass softens and draws into fibre. This molten core moves with the cladding during the drawing process and eventually solidifies as the fibre cools. If the cooling rate is fast enough, the core melt solidifies into an amorphous phase, as it does in our high-alumina-content all-glass core. Our work is different because we used a sufficiently thick cladding tube to force a higher draw temperature — high enough to melt sapphire and thus permit its use for making a high-alumina-content all-glass optical fibre.

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Peter Dragic (pictured), Thomas Hawkins, Paul Foy, Stephanie Morris and John Ballato have developed a process to fabricate all-glass optical fibres derived from sapphire with alumina concentrations of up to 55 mol%, which is considerably higher than possible through previous techniques. The Brillouin gain coefficient of the resulting fibre is 100 times lower than that of typical commercial fibres, which will be advantageous for high-energy applications.

How does alumina change the fibre's properties?

Alumina has a refractive index larger than that of silica, which makes it amenable for use as an optical waveguide. Interestingly, alumina has other properties that give rise to the Brillouin characteristics we observed in our work. In particular, alumina has a much larger acoustic velocity, density and acoustic damping than silica, and all of these properties are imprinted on the resulting fibre. Combining these three characteristics reduces the Brillouin gain coefficient, which was one of our main aims. However, when alumina is added to silica, something very interesting happens with the photoelastic constant: the negative and positive constants of the alumina and silica components, respectively, give rise to a composition wherein the net photoelastic constant is balanced to near-zero value, which also brings the gain coefficient towards zero. This is an amazing condition, especially given that it requires a balancing act between materials, much like that accomplished with zero-stress and zero-thermo-optic-coefficient glasses.

Alumina also has another feature that is rare among most common fibre dopants: unlike materials such as silica or germania, its acoustic velocity decreases with increasing temperature. This allowed us to demonstrate another compositionally tuned fibre: one in which the Brillouin scattering frequency is independent of temperature (that is, a Brillouin athermal fibre).

What about losses and single-mode operation?

When alumina is used in high concentrations as the core-forming material, the core becomes optically multimode. In fact, our values of Δn, which is a measure of the difference in refractive index between the core and cladding, were as high as 0.1. To reduce this value, we are now looking into the use of pedestal layers and alternative cladding materials that have higher refractive indices.

Our fibres also currently exhibit rather large background losses, which we attribute to the precursor sapphire crystal. Although 0.2 dB m^{-1} loss is not bad for a first effort, it is not good enough for many applications. Loss is therefore one of the first things we will attempt to improve. We've already shown that optical losses can be greatly reduced in YAG (yttrium aluminium garnet)-derived fibres with improved precursor quality, so we are confident that we can achieve rapid improvements in transmission losses. Furthermore, unlike with YAG, there aren't really standardized procedures for doping rare-earth materials into sapphire, so we are now looking at potential doping processes.

INTERVIEW BY DAVID PILE

Peter Dragic and colleagues have an Article on sapphire-derived all-glass optical fibres on page 627 of this issue.