Photonic Applications of Sulphide Glass Optical Fibres

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Optical fibres drawn from sulphide-based glasses have been studied now for almost two decades. Initial work began in the 1970's where fibres from glasses based on arsenic sulphide or germanium sulphide rapidly found application as infrared waveguides, providing transmission to beyond 5 microns. A flurry of activity began when the possibility of an ultra-low loss, less than $10^{-2}$ dB/km, waveguide was postulated in infrared materials operating at their intrinsic loss minimum. Unfortunately, this low loss was never realized and with the invention of the optical fibre amplifier operating at 1550 nm, an ultra-low loss waveguide became in some ways redundant. However, use of these fibres as passive infrared waveguides continued, for applications as diverse as remote sensing, laser surgery and power delivery for laser machining (1).

In the early 1990's, the demonstration of an optical fibre amplifier for the 1300 nm telecommunications window, motivated again the application of non-silica optical fibres. First, a fluoride fibre device showed amplification with pump efficiencies of only a few percent. In 1993, Becker (2) demonstrated what was probably the first active application of a sulphide glass. Measurements on bulk samples of rare-earth doped gallium lanthanum glass showed the possibility of pump efficiencies of over 60%. This lead to a widespread activity to demonstrate a low-loss sulphide glass optical fibre and an 1300 nm optical fibre amplifier.

As research into gallium lanthanum sulphide and other sulphide-based glasses accelerated, it was gradually realized that the very properties which silica glass fibres lack for active applications can be found with the sulphides. Sulphide glasses, by virtue of their high refractive index provide high radiative rates for rare-earth transitions, boosting the efficiency of fibre lasers and amplifiers and the low energies of the atoms which from the glass ensure low non-radiative rates, minimizes the loss of pump energy via vibrations or heating of the glass. The high linear refractive index indicates high non-linear indices, with gallium lanthanum sulphide glass now identified as having the largest non-resonant nonlinearity reported to date (3). Already, this non-linearity has been exploited through a low-power all optical high speed switch in relatively high loss arsenic sulphide based fibres (4). Like silica, sulphide glasses are photosensitive, but with enhanced photosensitivity which can be exploited, not with high power excimer lasers operating in the ultraviolet, but with a simple low power He-Ne laser at 633 nm. In the past year, Bragg gratings have been achieved with reflectivities > 90% at wavelengths around 1550 nm (5).

While silica glass may now be the ultimate passive waveguide, an active application such as the erbium-doped fibre amplifier is the exception rather than the rule. In this paper, applications of sulphide fibres for active applications will be reviewed. Recent progress in several applications, including the 1.3 micron amplifier, photonic switching and work extending into the infrared will be reported and the prospects for a future generation of sulphide-fibre based devices examined.

References