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Prospects for 1.3μm amplifiers

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Abstract
Current status and future prospects for a practical 1.3μm fibre amplifier are reviewed.

Summary
The optical amplifier became a realistic prospect for telecommunications after the demonstration of the erbium doped fibre amplifier (EDFA), operating at 1.5μm, in 1987 [1]. Subsequent demonstrations of the diode-pumped device [2] led to the first commercial products in 1990 and installation of optically amplified systems followed in 1993. However much of the installed base of fibre is designed for 1.3μm operation and thus the early success of the EDFA spurred the search for a 1.3μm fibre amplifier. First efforts focused on neodymium (Nd^{3+}) and a diode pumped device exhibiting 10dB gain for 50mW of pump power was demonstrated in a ZBLAN fibre in 1991 [3]. However the performance of Nd^{3+} is limited in several respects, the most important of which, signal excited state absorption (ESA) limits the operating wavelength to more than 1.32μm, longer than ideal for zero dispersion in telecoms systems. Further the performance is fundamentally limited by the low branching ratio of the 1.3μm transition relative to competing transitions such as the 1.06μm emission. Techniques to completely suppress the build up of amplified spontaneous emission at 1.06μm have been proposed [4] but, as yet none have been demonstrated.

An alternative 1.3μm system has been demonstrated more recently [5] and gain of 23dB for 124mW of pump power has been achieved from a Pr^{3+} doped ZBLAN-based fibre amplifier (PDFA) module pumped by a single laser diode [6]. Unfortunately the Pr^{3+} system also suffers a major drawback, the gain achieved at 1.3μm is limited due to a high non-radiative decay rate from the metastable level to an intermediate which dominates over the 1.3μm emission even in a low phonon energy system such as those based on fluorides. Nevertheless many would argue that the level of performance already achieved, particularly for the Nd:YLF pumped power amplifier, is adequate with the 250mW (24dBm) output obtained for 1.8W of pump (an 18% slope efficiency) [7] approaching the performance of commercial erbium:ytterbium 1.5μm power amplifiers.

Despite the acceptable power amplifier performance barriers to widespread application remain. Efficiency of line amplifiers, longevity of fibre and compatibility with installed fibre remain in question. In particular the fibre is not robust to water, mechanically weak and the long term power handling capability is in doubt. At the installation level fusion splicing between ZBLAN and silica fibre remains a major drawback.

The problem of efficiency is being addressed with the identification and development of new host glasses, namely mixed halides such as CdF_2:$CdCl_2$ [8,9] and sulphides such as Ga_2S_3:La_2S_3 [10,11] and GeS_2. The lattice vibration (phonon) energy of these glasses is significantly lower than that of ZBLAN ($\sim$400cm^{-1} cf 580cm^{-1}) reducing nonradiative effects. As a result, spectroscopic analysis of Pr^{3+} in these glasses has revealed increased lifetimes of 325μs for the mixed halide and 290μs for GLS compared with 110μs for ZBLAN. In addition the radiative quantum efficiency was correspondingly increased to 12% and 53% in the new glasses from $\sim$4% in ZBLAN.

Unfortunately the improved efficiency of the mixed halide has been achieved at the expense of stability, being highly hygroscopic and with a melting point of only 305°C. Unless the composition can be modified or a technique for hermetically sealing the fibre developed this structure does not present a viable alternative.

Alternatively the Ga_2S_3:La_2S_3 system is a much more promising host. The glass has a higher melting point than ZBLAN ($\sim$455°C cf $\sim$860°C) and is not hygroscopic. In addition defined compositions are less prone to crystallization than ZBLAN. A potential drawback with Ga_2S_3:La_2S_3 based glasses is their longer wavelength Urbach edge and thus subsequently increased loss at the pump wavelength. This is potentially a serious problem for Pr^{3+} in which the maximum concentration for efficient operation is limited to $\sim$500ppm. However, intrinsic losses of $<$0.1dB/m at the pump wavelengths are predicted for the latest glasses and since single-mode chalcogenide fibres with losses less than 1dB/m at 1.5μm have already been drawn [12], a 1.3μm GLS amplifier appears a realistic possibility. Unfortunately the Pr^{3+} amplifier will only work in a non-silica glass thus the amplifier fibre is always going to be incompatible with the transmission fibre and techniques for connecting will have to be employed. Mode matching and reflections are an additional problem for GLS due to the high refractive index ($\sim$2.5), but are not considered unsolvable.

In conclusion many opportunities exist for the development of a practical 1.3μm amplifier however many obstacles remain to be overcome before the device will find widespread application. Unfortunately, unlike the EDFA, which was based on established silica fabrication technology, the 1.3μm amplifier is based on new materials technology and thus development is likely to be slower.

References

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