Towards pump-efficient 1.311μm fibre amplifiers

D N Payne, R I Laming and D W Hewak
Optoelectronics Research Centre
University of Southampton
S017 1BJ, UK

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, the installed base of fibre is designed for 1. 3 μm 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, performance of Nd^{3+} in ZBLAN 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. Current research shows that alternative fluoride glasses can allow operation down to ~1310nm, which appears to be adequate for most installed systems which have a dispersion zero around 1315nm. Care must also be taken to suppress the large amplified spontaneous emission which results from the more-favoured 1.06μm transition [4].

More recently [5], a gain of 23dB for 124mW gain coefficient 0.16dB/mW of pump power has been achieved from Pr^{3+} doped ZBLAN-based fibre amplifier (PDFA) module pumped by a laser diodes. Unfortunately, the pump efficiency in the Pr^{3+} system is limited owing to a high non-radiative decay rate from the metastable to an intermediate level which dominates the 1.3μm emission even in a low phonon-energy glass such as that based on fluorides. Nevertheless, at least for a power amplifier, many would argue that the level of performance already achieved is adequate with a 250mW (24dBm) output obtained for 1.8W of pump from a Nd:YLF laser (an 18% slope efficiency) [7]. This approaches the performance of commercial erbium:ytterbium 1.5μm power amplifiers, but is a long way from EDFA line and pre-amplifier performance.

The problem of pump efficiency is being addressed with the identification and development of new host glasses, namely mixed-halides such as CdF_2:$CdCl_2$[7] and sulphides such as Ga_2S_3:La_2S_3 and GeS_2.The lattice vibration (phonon) energy of these glasses is significantly lower than that of ZBLAN (~400cm^{-1} cf 580cm^{-1}), which reduces phonon-mediated, 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% respectively in the new glasses (c.f. ~4% in ZBLAN). Unfortunately, the improved efficiency of the mixed halide has been achieved at the expense of stability, being hygroscopic and with a melting point of only 305°C.

The Ga_2S_3:La_2S_3 system is a much more promising host. The glass has a higher melting point than ZBLAN (A cf B) 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, which leads to 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 ~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 1μm have already been drawn[11], a 1.3μm GLS amplifier appears a realistic possibility.

In conclusion, many opportunities exist for the development of a practical 1.3μm amplifier, although many obstacles remain to be overcome before the device will find widespread application. The key to pump-efficient operation is the continued development of new low-phonon energy glasses, with chalcogenides looking most promising.

References

1. Mears et al. Electron. Lett., 23, 1987. p. 1026.
2. Nakazawa et al. Appl. Phys. Lett., 54, 1989. p. 295
3. Miyajima et al, Proc. Opt. Amp. and their Appl., Snowmass, 1991, p. 16.
4. Pedersen et al, Proc. Opt. Amp. and their Apl., Santa Fe, 1992, p. 16.
5. Ohishi et al, Proc. OFC'91, San Diego, 1991. PD 2.
6. Yamada et al. Proc. Opt. Amp. and their Appl., Yokohama, 1993, . 240.
7. Whitley et al, BT Technol. J., 11 (2). 1993.
8. Newhouse et al, Proc. Opt. Amp. and their Appl., Santa Fe, 12, PD 16.
9. Samson et al. Proc. Opt. and their Appl., Yokohama, 1993, p. 240.
10. Becker et al. Proc. Opt. Amp. and their Appl., Santa Fe, 1992, PD 5.
11. Hewak et al, Electron. Lett., 29, 1993, p. 237.
12. Asobe et al, Electron. Lett., 29, 1993, p. 1966.