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Improved laser performance of Tm^{3+} and Pr^{3+}-doped ZBLAN fibres

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In this paper we present the performance of TM^{3+} and Pr^{3+}-doped ZBLAN fibre lasers at blue, green, and red wavelengths, both pumped efficiently with the output of Yb^{3+}-doped silica fibre lasers.[1]

Laser output at 480 nm has been produced by three-step upconversion in Tm: ZBLAN fibre[2] of infrared light in the 1100-nm to 1140-nm region, generated from Yb:silica fibre. A 90-m length of Yb^{3+}-doped silica fibre ([Yb] ~200 ppm, ~0.17NA, 3.25 μm core diameter) was pumped at 1047 nm and fibre gratings were used to obtain output at 1100, 1112, 1128, or 1141 nm, with a slope efficiency of 57% with respect to absorbed power. The Tm^{3+}-doped ZBLAN fibre (from Le Verre Fluoré) had a concentration of ~1000 ppm wt, NA ~0.21, and cutoff wavelength ~800 nm. Laser performance has been investigated for pumping at each wavelength, and, as predicted by blue fluorescence measurements made with OPO,[3] pumping at 1141 nm produced the best results. This was an output power of 23 mW at 480 nm in a single transverse mode from a cavity consisting of one highly reflecting mirror and a 37% transmitting output coupler. The lasing threshold occurred for 100 mW of incident power, and the slope efficiency was 10% with respect to incident power. In a separate experiment, thresholds as low as 11.3 mW of launched power in a cavity formed by two high reflecting mirrors butted on to 0.6 m of fibre.

In the case of the Pr^{3+}-doped ZBLAN laser, two wavelengths required for upconversion pumping (840 and 1020 nm) have also been obtained from an Yb^{3+}-doped silica laser. The Yb fibre ([Yb] ~200 ppm, ~0.17NA, 3.0 μm core diameter) was pumped at 840 nm with the output of a Ti:sapphire laser, and fibre gratings were spliced to each end of a 6 m length of fibre to force oscillation to occur at 1020 nm. This length of fibre was chosen so that roughly equal amounts of the two pump wavelengths required for the upconversion process (laser output at 1020 nm and unabsorbed pump at 840 nm) were obtained. The Pr^{3+}-doped fibres used in this work were fabricated at British Telecom Laboratories. Most of the results achieved to date have used a fibre with [Pr] ~480 ppm wt, fibre diameter 3.25 μm, and NA ~0.2. Laser output at 491, 520, and 635 nm has been investigated and the best results obtained to date are 55 mW at 635 nm, 18 mW at 520 nm, and 6 mW at 491 nm. Each of these powers was achieved for 380 mW pump power from the Yb^{3+}-doped silica laser incident on the launch objective. Very recently, work has commenced using a fibre with higher NA ([Pr] ~1000 ppm wt, cutoff wavelength ~800 nm, and NA ~0.39), which could in principle result in a factor of 3.8 reduction in laser thresholds; preliminary results are encouraging, with a factor of 2 demonstrated so far. Latest results with this fibre will be presented.

In conclusion, it has been shown that the Yb^{3+}-doped silica laser, which in principle can be pumped with diodes at 840 nm and 975 nm, provides a convenient and efficient means of obtaining the pump wavelengths required for upconversion in both Tm^{3+} and Pr^{3+}ZBLAN fibre from which significant powers at 480, 493, 520, and 635 nm can be achieved.

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