W1.1 1 kW Pulsed Fibre Laser For Time Division Multiplexed Sensor Systems

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Summary

Q-switching of fibre lasers is an attractive means of converting the relatively low CW power of pump laser diodes into short, high intensity pulses for use in time-resolved sensor systems. Peak powers of 100W at 1.06μm with 15ns duration have previously been reported[1] based on the use of Nd-doped alumino-silicate fibre as the gain medium. We report here the attainment of much higher powers in short pulses in a module specifically designed for high-resolution distributed sensor applications.

A multi-component neodymium-doped phosphate glass fibre is used as the amplifying element. The core material was Schott LG750 (1 wt% Nd^{3+}) which was fabricated into a single-mode fibre using a rod-in-tube manufacturing technique described elsewhere[2]. Fibres fabricated with LG750 (a phosphate glass) as the core material have the advantage of higher emission cross-sections than those of silica-based fibres. In bulk form the emission cross-section[3] of LG750 is 4.10^{-20} cm^2 compared with Nd-doped silica fibres which have emission cross sections around 1.10^{-20} cm^2 [4]. This gives rise to higher gain in terms of dB/mW. A further advantage of the phosphate glass fibre is its high content of Nd^{3+} which permits very short fibre lasers to be constructed, an essential if short Q-switched pulses are required. High round trip gain combined with a short cavity gives rise to rapid power build up even when relatively large values of output coupling are used. The combination of rapid power build-up and relatively large output coupling enables short pulses to be obtained.

Fig. 1 shows the laser configuration. A 25mm length of fibre was potted in a silica capilliary using conventional epoxy. The ends of the capilliary were polished orthogonal to the optical axis and a dichroic dielectric coating was applied to one end of the capilliary. The coating was >99% reflection at 1.054μm with >90% transmission at 810nm. A 1mm glass slide was bonded to the other capilliary end in order to displace the 4% Fresnel reflection from the waveguide end in order to prevent premature oscillation of the high gain laser. An intra-cavity lens was used to collimate the fibre output onto a 30% reflection mirror which provided the laser output and round-trip feedback. A compact electro-optic integrated Q-switch was used to modulate the cavity loss. The overall cavity length (10cm) was dominated by the length of the Q-switching element. A 100mW single-stripe laser diode operating at 812nm was used as the pump source and was coupled into the fibre using conventional launch optics.

Fig. 2 shows the variation of output power and pulse duration (at sub 1kHz repetition rate) with the laser diode output power. Although it was not possible to determine the efficiency of coupling into the highly-doped fibre directly, measurements on a similar un-doped fibre indicated that up to 50% launch efficiency was possible. A peak power of 1.06 ± 0.05kW with 2ns duration was obtained. It is interesting to note that the pulse duration is only 2.5 times the cavity round trip period. The deviation of the power characteristic from an expected straight line at the higher pump powers is attributed to bleaching of the pump absorption of the fibre at these higher pump powers. This implies that a higher-still Nd^{3+} concentration in the fibre is desirable. Inset in fig. 2 is an oscilloscope trace of the output pulse shape at maximum pump power recorded with a high speed InGaAs photodetector.

Fig 3. Shows the variation of peak power and pulse duration as a function of repetition frequency at maximum pump power. Above 1kHz, lower-power, longer-duration pulses are observed as expected for a medium with a upper-level lifetime of $\approx 300\mu s$. This is due to the inability of the population inversion to reach its maximum equilibrium value in the time between Q-switch trigger pulses.

In summary, we have obtained 1.1kW peak power pulses with 2ns duration from a laser-diode pumped Nd-doped fibre laser. This is the highest power obtained to date from a diode-pumped fibre laser source. The laser is compact, robust and potentially inexpensive. Further increases in peak power are possible by shortening the cavity and the laser is potentially tunable. We believe this makes it ideal for a number of time-multiplexed sensor applications, particularly those based on OTDR, such as the Raman distributed fibre temperature sensor.

Acknowledgements

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References

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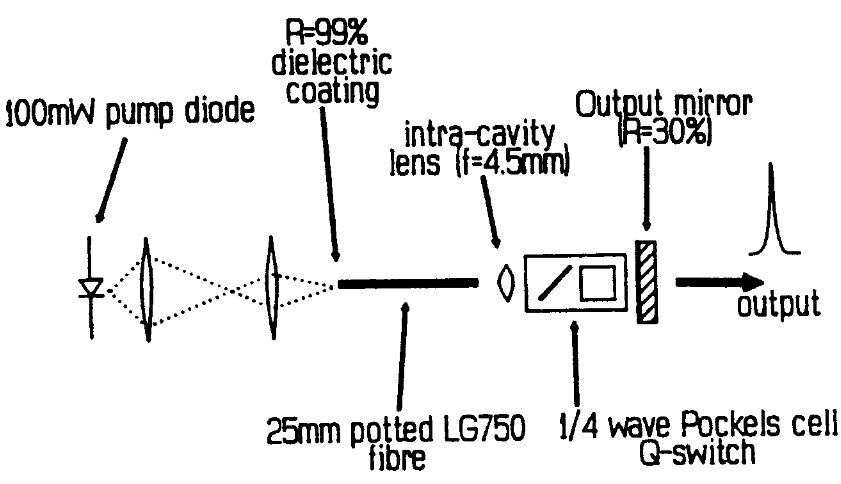

Fig. 1 Q-switched fibre laser configuration. Cavity length 10cm.

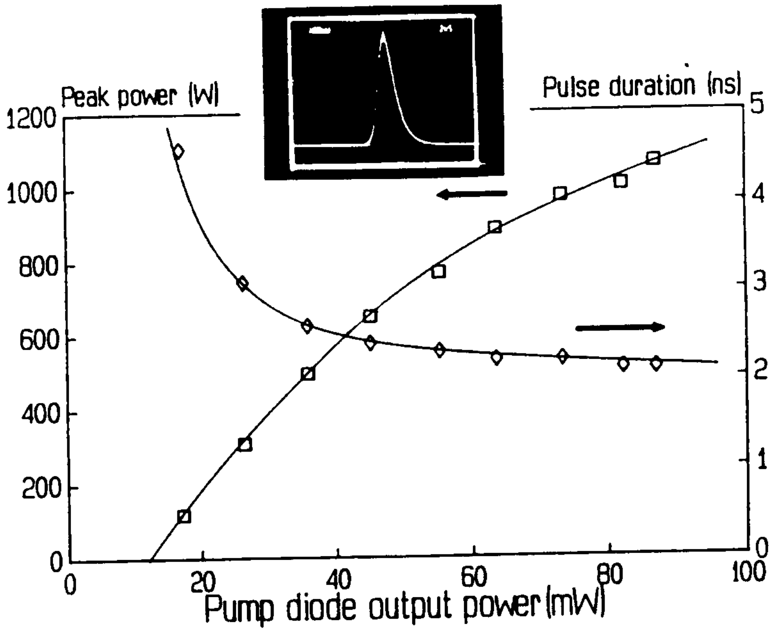

Fig. 2 Q-switched pulse peak power and duration variation with laser diode output power. Repetition frequency < 1kHz. Inset is the pulse shape at maximum pump power (87mW).

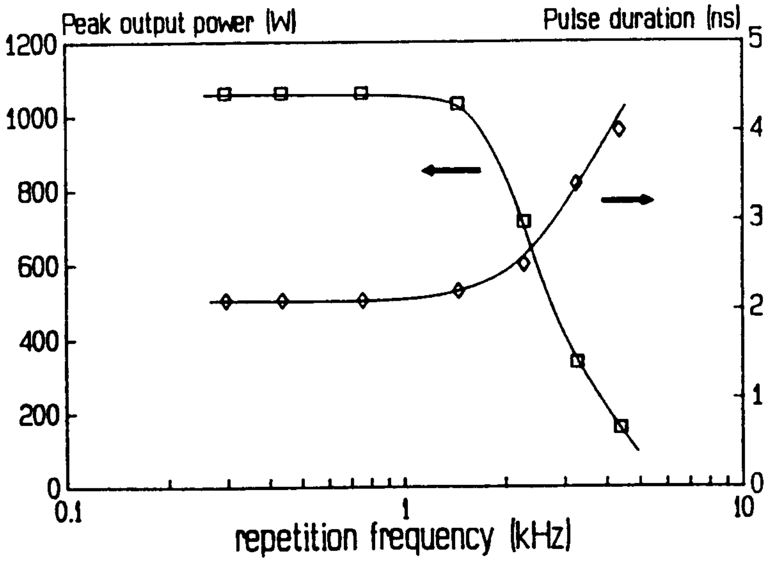

Fig. 3 Q-switched pulse peak power and duration variation with repetition frequency. Pump power 87mW.