Abstract. 620 fs pulses have been generated at 1.3 μm by a Praseodymium-doped fluoride fibre laser. Temporal self stabilisation at frequencies up to 440 MHz has been observed.

Praseodymium (Pr3+) doped fluoride fibre has been shown to act as an amplifier providing gain at 1.3 μm, the second low loss window in Silica fibre. Pr3+ doped into a fluoride glass host exhibits high gain over a range of ~50 nm and this broad bandwidth has the potential to support femtosecond pulses.

One problem with Pr3+ doped single mode fibres is that they tend to be highly normally dispersive at 1.3 μm, making it difficult to exploit the soliton-like pulse compression effects that lead to ultrashort pulses in similar erbium-doped fibre systems. The shortest pulse duration from a Pr3+ fibre laser reported until now is 1.6 ps with a time-bandwidth product of 0.85 from a “Figure-of-Eight” laser (FB) cavity configuration whose overall dispersion was normal. We have built a FB, with anomalous overall dispersion which generates almost transform-limited pulses as short as 620 fs.

The total length of the optimised laser cavity was 166 m, including a 7 m length of Pr3+ doped fibre. The dopant concentration was 2000 ppm and the laser was pumped by up to 1 W from a Ti:Al2O3 laser tuned to 1.03 μm. The splices between the fluoride and Silica fibres were mechanical and had a measured loss of 0.4 dB each. The anomalous dispersive fibre in the NALM had a minimum dispersion at 1.27 μm and an estimated dispersion of ~45 ps/nm/km at 1.3 μm.

Figure 1 shows the autocorrelation (with spectrum inset) of 620 fs pulses generated by the laser. The time-bandwidth product was calculated to be ~0.50, but it was noticed that the measured pulse duration changed slightly if the polarisation of the input light to the autocorrelator was rotated. It was found that the laser output could be resolved into two orthogonally polarised components with slightly different pulse durations and spectra, as has recently been observed in a similar erbium-based system2. The time-bandwidth product calculated using the appropriate spectral component is 0.32, close to the transform limit for such2 pulses.

In general this laser exhibited the usual temporal output of FBs consisting of bunches of randomly spaced short pulses periodic at the round trip time of the cavity. It also displayed a novel mode of mode-locked operation, however, in which the random stream of pulses would self-organise over a period of a few seconds into a well defined pulse train at harmonics of the round trip frequency, as has recently
been observed in a ytterbium-ceria doped fibre ring laser. This was observed both at low harmonics (up to 7th, ~5 MHz) and high harmonics of the cavity, with a maximum repetition rate of 437 MHz, corresponding to the 617th harmonic. These different repetition rates were selected by adjustment of the two polarisation controllers and once established exhibited long term stability. In the case of the low harmonic stabilisation the pulses were generally found to have a square envelope and were ~2 ns long, the exact duration being proportional to the pump power. It was also possible to generate pulses <1 ps in this case. For the higher harmonics, however, the pulses were always in the femtosecond regime.

In addition to the temporal output regimes described above, it was also possible by adjusting the fibre strainers to generate bursts of femtosecond pulses at repetition rates of up to 200 GHz with the number of pulses present in the burst dependent on the pump power. This effect is attributed to spectral beating caused by birefringence in the NALM.

References