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A practical, low-noise, stretched pulse Yb^{3+} doped fiber laser

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Abstract: We report on the development of what we believe to be a practical and highly-stable stretched pulse laser based on Yb^{3+} doped silica fiber. The laser generates high quality, 60 pJ pulses of <110fs duration at a repetition rate of ~54 MHz.

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Yb^{3+} doped silica fibers represent an attractive medium for the generation and amplification of ultrashort pulses. We demonstrated the first short pulse Yb^{3+} silica fiber oscillator in 1996 [1]. Although good self-starting performance was obtained and <100fs pulses were generated, the cavity was of a complex design, incorporating an optical circulator arrangement and an intracavity prism based dispersion compensator. Moreover, it was pumped with a Ti:Sapphire laser. Here we report the development of a far more practical and stable diode-pumped system, that we consider will prove highly attractive for a wide range of scientific and industrial applications.

A schematic of our cavity is shown in Fig.1. As previously, mode-locked operation is based upon the stretched pulse principle [2] employing nonlinear polarisation rotation as a fast saturable absorber [3]. The cavity contains a grating-based intracavity dispersion compensator, ~1.0m of high-concentration, moderately birefringent Yb^{3+} doped fiber, a 976/1050 nm WDM coupler, two polarisers and associated waveplates for intracavity polarisation control. A suitably optimised SESAM device is also incorporated to facilitate reliable self-start mode-locking [4]. The laser is pumped with a telecommunications-qualified, grating-stabilised, 976 nm semiconductor pump diode. The laser output is extracted from PBS2, at which point in the cavity the pulses have a negative linear chirp, and so the pulse needs to be compressed external to the cavity- in this instance by propagation within a short length of single-mode fiber.

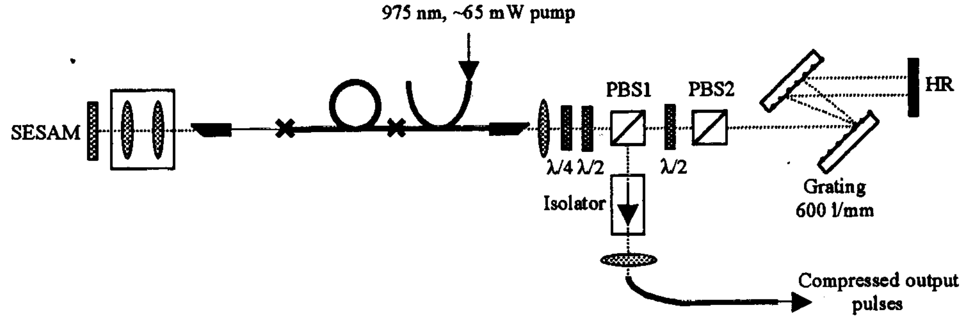


Fig. 1. Experimental configuration. PBS, porization beam splitter; DDL, dispersive delay line; HR, high reflectivity mirror.

With the wave-plates correctly set relative to the birefringence axes of the fiber, and the grating adjusted for an optimum level of dispersion compensation, highly reliable and stable, self-start, stretched-pulse mode locking could be achieved for pump powers as low as 62 mW. In Fig.2 we plot the RF spectrum at the cavity's fundamental frequency (53.7 MHz) which highlights the low amplitude noise (<0.05%, limited by measurement resolution). Note that the most stable operation, and shortest pulse durations were achieved with a small, net normal group velocity dispersion within the cavity.

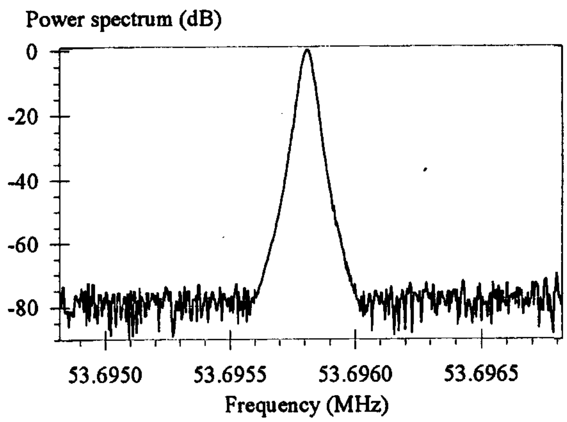
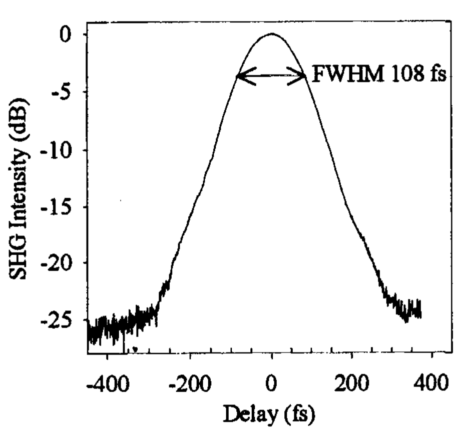


Fig. 2. RF spectrum at the cavity round trip frequency highlighting the low amplitude noise of the laser.

In Fig.3 we plot the autocorrelation and optical spectrum of the shortest pulses obtained from the system. These pulses have an estimated half-width of 108 fs (assuming a Gaussian pulse shape), and spectral bandwidth of 18.6 nm. The pulse spectrum is centered at 1056 nm. Both the autocorrelation and spectrum are seen to be extremely clean over the available dynamic range of the measurement equipment. The corresponding time bandwidth product of the pulses is ~0.54, typical for this type of laser. The maximum average output power of the laser in this instance was 3 mW, corresponding to ~60 pJ pulse energy. At much higher powers multiple pulse generation within the cavity is observed.



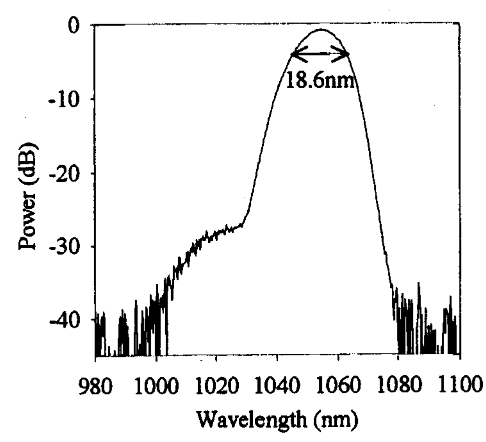


Fig. 3. Autocorrelation trace and spectrum of the shortest pulses obtained from the cavity.

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