

A 420 MHz Cr:forsterite femtosecond ring laser and its use for continuum generation in the 1-2 micron range

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Abstract: We present a Cr:forsterite ring laser producing 30 fs pulses at a 420 MHz repetition rate. The output is broadened in highly nonlinear fiber yielding spectra covering 1050-2200 nm.

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We have developed a chromium-doped forsterite femtosecond ring laser that generates 30 fs pulses at a 420 MHz repetition rate with ~ 500 mW of average power. To our knowledge, this is the first ring configuration as well as the highest repetition rate yet reported for a femtosecond Cr:forsterite laser. The compact solid-state design and broad spectral output make this laser attractive for applications in the important 1.3-1.6 μm regime. Additional spectral broadening of the laser output in highly nonlinear optical fibers leads to supercontinuum generation, with the broadest spectra extending across an octave. The underlying optical frequency comb can be linked to existing optical frequency standards, thereby establishing a broad array of precisely known frequencies across the near infrared spectrum.

Because of its importance for fiber-based communications [1], the 1.3-1.6 μm regime is a natural direction in which to spread the new tools of femtosecond-laser-based frequency metrology [2-4]. Towards this end, we have developed a high repetition rate, broadband Cr:forsterite femtosecond laser. Our laser consists of a compact, prismless 6-mirror ring cavity similar to earlier work with Ti:sapphire [5]. The repetition rate in this present configuration is 420 MHz, yet we believe it could readily be increased to 1 GHz. The pump is a 10 W Ytterbium fiber laser operating at 1075 nm. Intra-cavity dispersion compensation is provided by a combination of chirped and GTI (Gires-Tournois interferometer) mirrors. For the optimal dispersion compensation, we obtain a FWHM spectral width of 59 nm. This spectrum is shown as curve (iv) in Fig. 1(a). External compression with chirped mirrors provides 30 fs pulses. The average power is 480 mW, implying a pulse energy of 1.1 nJ.

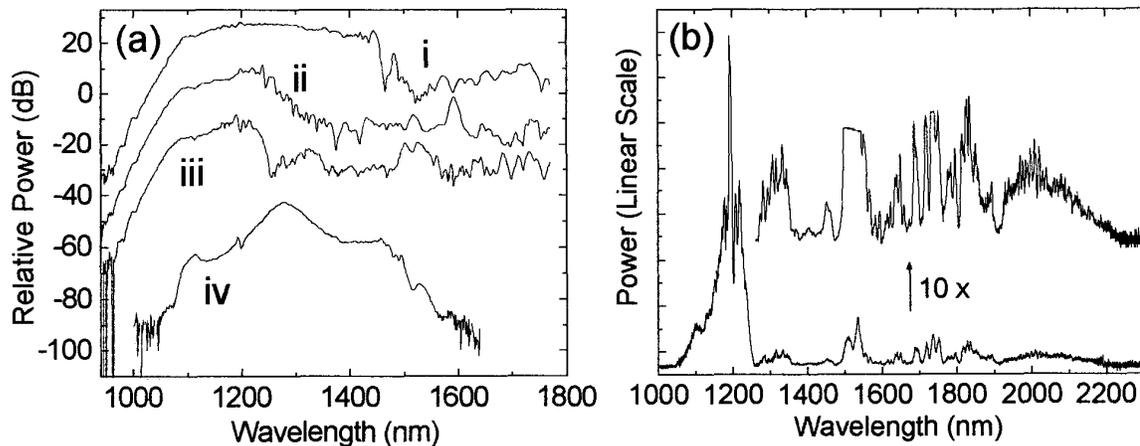


Fig. 1: (a) Spectra from the ring Cr:forsterite laser with and without broadening in HNLF as recorded with an optical spectrum analyzer. (i) and (ii) show the spectrum broadened in two different pieces of HNLF; (iii) shows the spectrum after hybrid dispersion-decreasing HNLF; (iv) shows the output spectrum of the laser. (b) Spectrum after hybrid dispersion-decreasing HNLF on a linear scale recorded using a monochromator with sensitivity out to 2200 nm. The inset is a 10x magnification of the selected portion of the spectrum.

To further broaden the spectrum we sent these laser pulses through various germanium doped, dispersion shifted, highly nonlinear fibers (HNLF) originally designed for use at 1.5 μm [6-8]. We have experimented with individual 10 m pieces of HNLF as well as hybrid fibers that are created by splicing together pieces of HNLF with different group velocity dispersion (GVD). The results of our fiber broadening experiments are also shown in Fig 1. Curves (i) and (ii) of Fig. 1(a) show the spectra after 260 mW was coupled into HNLF with calculated GVD of -13.4 and -11.8 ps/(nm-km) at 1280 nm, respectively. Trace (iii) was obtained when 180 mW was coupled into a 6 m dispersion-decreasing hybrid fiber, consisting of four 1.5 m sections of HNLF having GVD at 1280 nm of -10.8, -11.8, -13.4, and -14.4 ps/(nm-km), respectively. The continuum spectra of Fig. 1(a) are clipped at 1770 nm, so we also made measurements with a monochromator and an IR detector. The result for the 6 m long hybrid fiber is shown in Fig. 1(b). This spectrum spans an octave ranging from 1080 to 2160 nm. With such a broad spectrum, it should be feasible to measure the carrier-envelope offset frequency of the associated frequency-domain comb directly via the self-referencing technique [4].

In order to provide an absolute reference for the frequency-domain comb, a portion of the light near 1314 nm has been frequency doubled and we have observed a strong heterodyne beat between an individual mode of the frequency-doubled comb and the 657 nm stabilized diode laser of the calcium optical frequency standard. By controlling the cavity length of the Cr:forsterite laser, we can phase lock this beat to a radio frequency reference. Further details of phase-locking of the Cr:forsterite frequency comb to the calcium standard will be provided.

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