Femtosecond OPO pumped by a high power ytterbium rod-type fiber laser mode locked at harmonic repetition rates

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Given their interest in multiple, most notably in spectroscopy, high-speed optical sampling, optical frequency comb, super-continuum generation, and others, high repetition rate (HRR) femtosecond lasers have attracted a lot of attention in the last decade. In rare-earth-doped fiber, the HRR can be achieved by controlling the nonlinear polarization rotation in long and heavily doped erbium or ytterbium fibers. However, it is usually difficult to tune the central wavelength of oscillators by providing pulses at an HRR. Further extension in the IR can be achieved through pumping an optical parametric oscillator (OPO) by amplifying the output of an HRR laser system. Compared with SHG and SFG, OPOs generate pulses that can be tuned on a broad spectral range, with limited pulse-to-pulse energy fluctuations and almost a TEM_{00} beam profile. Hence, one of the simplest and efficient ways to generate tunable HRR femtosecond pulses on a broad spectral range is to pump an OPO with a high-power laser oscillator, where one can adjust the PRR. We perform an experiment using an ytterbium rod-type fiber that provides more than 4.5W output power and tens of nJ per pulses, in which the PRR is controlled by nonlinear polarization rotation. The pulses delivered by this laser are further used to pump an OPO. The OPO is shown to work without any further adjustments. The femtosecond signal pulse delivered by this singly resonant OPO is tunable from 1450nm to 1700nm.

The setup is sketched in Fig. 1. The ring cavity is designed around a 0.75m long large-mode-area (LMA) double-clad ytterbium rod-type fiber. A 4nm interference filter centered at 1040nm with transmission limits the spectral bandwidth of the laser. A nonlinear and partially transmitting mirror is built by combining a quarter-wave plate (QWP) and half-wave plates (HWP1, HWP2) with an optical isolator, which takes advantage of nonlinear polarization evolution (NPE) within the LMA fiber. The pulses yielded by the laser are sent through a pair of chirped mirrors that compensate for the chirp induced by the propagation of the laser pulse in the amplifying fiber. The linear cavity of the OPO is singly resonant for the signal pulse. The OPO is built around a 3mm long MgO-PPLN and two plane and two concave mirrors with a radius curvature of 10cm. The cavity length for synchronous pumping at the 108MHz first repetition rate of the fiber laser is 1.39m.

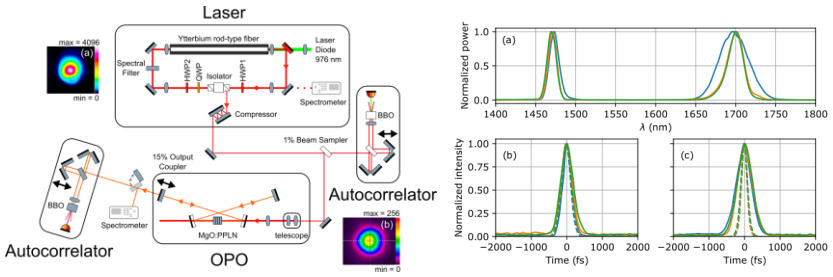

Fig. 1. (Left) Set-up of the femtosecond large-mode-area fiber laser and the linear optical parametric oscillator. QWP, quarter-wave plate; HWP, half-wave plate; MgO:PPLN, Magnesium doped periodically polarized lithium niobate. a-b) spatial profile of the beam delivered by the laser and OPO, respectively. (Right) Spectra and autocorrelation traces of the signal pulse delivered by the OPO. The curves are in green for the fundamental, in orange for the $2f_0$ and in blue for the $3f_0$ PRR. (a) 1470nm and 1695nm spectrum. FWHM for 1470nm is 14.0nm, 13.0nm and 13.0nm; FWHM for 1695 nm is 44.0nm, 24.0nm and 22.0nm. (b) Autocorrelation trace for the 1470nm spectrum. Measured durations (plain line) are 290fs, 360fs and 420fs; Fourier-limited durations (dot line) are 277fs, 347fs and 322fs for the 108MHz, 216MHz and 324MHz respectively. (c) Autocorrelation trace for the 1695 nm spectrum. Measured durations (plain line) are 490fs, 480fs and 500fs; Fourier-limited durations (dot line) are 181 fs, 190 fs and 212 fs for the 108 MHz, 216 MHz and 324 MHz PRR, respectively.

In conclusion, we have reported on an LMA rod-type ytterbium-doped all-normal dispersion fiber laser that can yield more than 4.5W output power and tens of nJ femtosecond pulses at up to 540 MHz. The control of the pulse repetition rate is based on NPR in a laser cavity. The compressed pulses delivered by this laser source are, without further amplification, used to pump an OPO. The femtosecond pulses delivered by this OPO were found to be tunable from 1400nm to 1700nm, and the average output power was higher than 1watt. More details about side mode suppression ratio, slope efficiency, RF spectra, spectra and AC traces at different repetition rates will be presented.