All-fiber femtosecond Cherenkov laser at visible wavelengths

Fiber-optic Cherenkov radiation (CR), also known as dispersive wave generation or non-solitonic radiation, is produced in small-core photonic crystal fibers (PCF) when a soliton perturbed by fiber higher-order dispersion co-propagates with a dispersive wave fulfilling a certain phase-matching condition [1]. The resonant ultrafast wave conversion via the fiber-optic CR mechanism is instrumental for applications in biophotonics such as bio-imaging and microscopy [2]. In this work, we demonstrate a highly-stable all-fiber, fully monolithic CR system based on an Yb-fiber femtosecond laser, producing electrically tunable femtosecond CR output in the visible (VIS) spectral range of 580-630 nm, with the 3 dB spectral bandwidth not exceeding 36 nm, with average power in the milliwatt range. Relative intensity noise (RIN) of this laser, affecting the sensitivity of bio-imaging and microscopy systems, is found to be as low as -103 dBc/Hz. This is 2 orders of magnitudes lower noise as compared to spectrally-sliced supercontinuum, which is the current standard of ultrafast fiber-optic generation at visible wavelength.

The layout of the laser system is shown in Fig. 1(a). The system consists of two parts: an all-fiber self-stabilized Yb-doped femtosecond laser [3,4] operating at 1035 nm central wavelength and 26.7 MHz repetition rate used as the pump source; and a spliced-on small-core nonlinear PCF NL-3.0-850 (NKT Photonics A/S) with zero-dispersion wavelength around 850 nm, used for Cherenkov wave conversion [5]. Bridge fibers are used in the CR link to enhance the conversion efficiency. Fig. 1(b) shows the far-field saturated visible images of the CR emitted from the laser system, generated as the pump power increases in the range 150 mW - 300 mW.

The emitted CR spectra corresponding to different average output powers are shown in Fig. 1(c). When the average emitted CR power is increasing from 0.46 mW to 4.2 mW, the central wavelength is shifting from 630 nm to 580 nm, and the 3 dB bandwidth of the spectrum increases from 14 nm to 36 nm. The physical mechanism of wavelength tunability with changing the pump power is related to different linear and nonlinear compression conditions for weaker and stronger pump laser pulses in the hollow-core pulse compressor and CR stages of the laser (Fig. 1(a)). Fig. 1 (d) shows the autocorrelation (AC) of the CR with the output power of 1.7 mW. The FWHM of the AC trace for the generated CR pulse is 160 fs. The FWHM of the AC of the input pump pulse at 1035 nm is 832 fs. The CR pulse is more than 5 times shorter than the pump pulse, as a result of the nonlinear pump pulse compression in the CR fiber link. We are currently working on achieving an even broader electrical tunability of the CR output, ideally covering the significant part of the visible spectral range.