Optical cavity-less 40-GHz picosecond pulse generator in the visible wavelength range

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High-repetition-rate optical frequency-comb sources emitting picosecond pulses play important roles in various scientific researches and industrial applications. Such ultrafast pulse sources are mostly generated in optical cavities or microresonators. By means of the wavelength-conversion techniques, it is possible to transfer the cavity-based near-IR robust and compact sources to the mid-IR or to the visible wavelength regions [1-2], for which there is an increasing demand, for biophotonics and other applications. Here we demonstrate the generation of high-repetition-rate picosecond pulses in the visible wavelength range by using a fully optical cavity-less configuration. First, we developed a tunable C-band picosecond pulse generator whose high-repetition-rate is also tunable from 20 to 40 GHz. This near-IR optical cavity-less system makes use of high reliability components developed for telecommunications [3]. Next, it was used to directly pump a nonlinear periodically poled ridge $LiNbO_3$ (PPLN) waveguide fabricated on silicon substrate [4]. This highly efficient $\chi^{(2)}$-type nonlinear material, which performs ultrafast-response of second harmonic generation (SHG), will offer us the opportunities to develop fiber-coupled frequency doubling modules for fiber-integrated picosecond pulse sources in the visible. Figure 1(a) presents the experimental setup, where the generation of stable 40-GHz pulse trains is obtained through the nonlinear compression of an initial beat-signal in a cavity-less optical-fiber-based device. The initial sinusoidal beating is generated by using a commercial $LiNbO_3$ intensity modulator driven by a half repetition-rate external RF clock and then amplified by means of Er-doped fiber amplifier. Moreover, we imposed a RF phase modulation to suppress Brillouin backscattering into the 2.2-km-long compression fiber. High-quality 6-ps Gaussian pulses at a repetition rate of 40 GHz are then obtained with an average power of 400 mW at the fiber output as shown in Fig. 1(c1-1). The corresponding spectrum is reported in Fig. 1(b1) with a FWHM bandwidth about 100 GHz. This pulse source is then injected into the fundamental mode of our PPLN waveguide by means of a lensed fiber. The center wavelength and state of polarization of the near-IR pulse train is set to match the optimum SHG conversion of the PPLN waveguide whose temperature is stabilized near room temperature. The 20mm long SHG waveguide gives a normalized conversion coefficient of 40%/W. After beam collimation at the waveguide output, an optical prism and an optical diaphragm are used to efficiently filter out the SHG signal and reject the residual pump and spectra generated by other nonlinear processes. The SHG signal is then collected into a multimode fiber and analyzed by means of an optical spectrum analyzer (~15 GHz resolution) and our 45-GHz photodiode – oscilloscope system. As shown in Fig. 1(b2), the SHG spectrum exhibits a 40-GHz frequency-comb profile centered at ~771 nm whose bandwidth is ~100 GHz. The SHG average power is measured to be about 30 mW. The temporal profile of our 40-GHz pulse train converted into the visible is shown in Fig. 1(c2) and exhibits a 40-GHz sinusoidal waveform due to the limitations of our detection system. The same behaviour and pulse duration is obtained when applying the same detection device to the measurement of our initial near-IR picosecond pulse train (see Fig. 1(c1-2)).

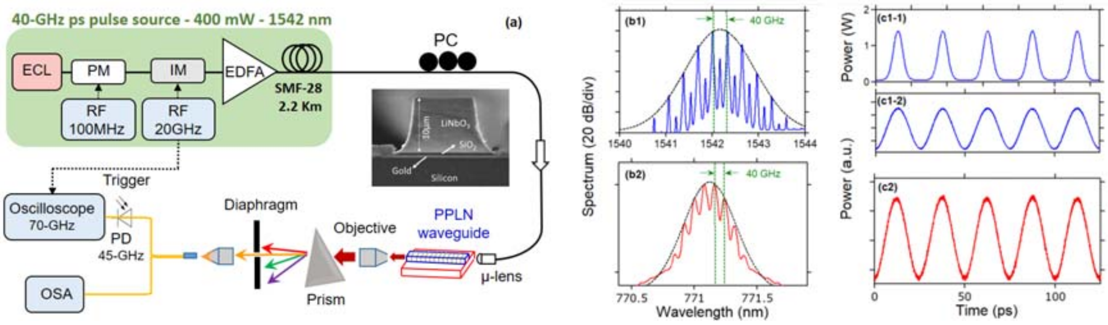

Fig. 1 (a) Experimental setup. ECL: External Cavity Laser; PM: Phase Modulator; IM: Intensity Modulator; EDFA: Erbium Doped Fiber Amplifier; SMF: Single Mode Fiber; PC: Polarization Controller; OSA: Optical Spectral Analyzer; PD: Photodiode. (b) Measured power spectra of our 40-GHz near-IR plse source (b1) and our SHG-based visible pulse source (b2). Dashed-dark curves are the Gaussian fits. (c) Measured intensity profiles of our 40-GHz near-IR pulse (c1-1,c1-2) and SHG-converted pulse train (c2). [c1-1 (FWHM ~ 6 ps) measured by an optical sampling oscilloscope with 1-ps resolution, c1-2 (FWHM ~ 11 ps) and c2 (FWHM ~ 11 ps) measured by 45-GHz PD + Oscilloscope].

References

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