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Femtosecond-Driven Up-Conversion in a Radially Poled LiNbO₃ Microresonator

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Nowadays, there are plenty of different techniques developed for the generation of Optical Frequency Combs (OFCs), but Mode Locked Laser (MLL) OFC is still the most commonly used and commercially available one [1]. Although MLLs are capable of producing very high-peak power OFCs with femtosecond pulse durations, it is sometimes challenging to apply them directly for a number of reasons. First, MLLs typically produce OFCs with repetition frequencies (f_r) below 1 GHz, so additional filtering of the unwanted modes is required for the applications in telecommunications, astrocombs etc. Second, many spectral regions – namely mid-infrared, visible and ultraviolet – are difficult to access by MLLs, which implies the use of external parametric up- and down-conversion. One promising platform for such spectral transfer is high Q-factor optical microresonators based on second order ($\chi^{(2)}$) nonlinear crystals, since not only do they provide the desired spectral transfer, but also open up opportunities for the miniaturization of the system. In addition, such microresonators support whispering gallery modes that possess very low mode volumes, making it possible to enhance nonlinear $\chi^{(2)}$ processes. This is a significant advantage over the already existing bulk analogs.

Fig. 1 Optical spectra of the pump (A, C, E) and SH (B, D) and a microphotograph of the scattered SH (F); see the comments in the figure for details

Interestingly, femtosecond-pumped up- and down-conversion in $\chi^{(2)}$ optical microresonators have only recently been demonstrated [2]. In the work of Herr et al., pumping of LiNbO₃ microresonator with the pump repetition frequency fraction of 1/2 was used (i.e. f_r of the OFC is half of the microresonator's Free Spectral Range (FSR): 10.5 GHz vs. 21 GHz). In contrast, our work is devoted to a more extreme case of parametric up-conversion in a similar microresonator where the f_r -fraction is 1/60 (250 MHz vs. 15 GHz). Furthermore, we use very short pump pulses of 80 fs at the telecom wavelength 1560 nm with an average power up to 500 mW (25 W peak power) and produce the second harmonic (SH) as well as third and fourth optical harmonics of the pump. Fig. 1 demonstrates high-resolution (105 MHz) Fourier-Transform spectra of the initial pump and the pump transmitted through the microresonator (A), the generated SH frequency comb (B) as well as zoomed spectra of the pump and SH (C, D, E) (see comments in Fig. 1 for details). We reveal an interesting operating regime where a single resonance mode of the microresonator simultaneously supports a number of pump comb modes (see Fig. 1(C)), leading to a favorable insensitivity of the system to pump comb offset frequency and f_r .

References

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