Microwave-Rate Soliton Microcombs on a Monolithic $LiNbO_3$ Platform

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Abstract:

We report microwave-rate soliton microcombs on a chip-scale lithium niobate platform.

Summary of Research:

Coherent microwaves play an important role in many applications, such as wireless communication, radar, imaging, and clocks. Among various approaches, soliton microcombs exhibit great potential for coherent microwave generation due to their good coherence properties in combination with chip-scale design. So far, radio-frequency-rate and microwave-rate soliton microcombs were produced only in silica and silicon nitride platforms [1-4]. Here we report microwave-rate soliton microcombs produced on a chip-scale lithium niobate platform, with repetition rate down to 13.5 GHz.

The devices are fabricated on the 610 nm Z-cut lithium niobate (LN) on insulator wafer. The etching thickness is about 420 nm and the waveguide width of the ring resonator is about 2.2 µm (Figure 1(a) insets). The group velocity dispersion is about -0.037 ps^2/m for the fundamental TE mode family, which is suitable for the soliton generation.

To tune the microwave frequency, we integrate an electro-optic modulator directly onto the comb resonator, as shown in Figure 1(a). Lithium niobate exhibits strong electro-optic Pockels effect, which is ideal for this purpose. For the z-cut comb resonator, we utilize the r_{31} EO term of lithium niobate to tune the quasi-TE comb modes of the resonator. The electrodes are deposited along the ring resonator waveguide with an electrode-waveguide spacing of about 4 µm so as to maintain the high optical Q of the resonator as well as good electro-optic tuning efficiency.

The repetition rate of the soliton microcombs, corresponding to the frequency of the microwave, is determined by the resonator size. By changing the radius of the ring resonator from 100 µm to 1500 µm, we are able to produce soliton microcombs with rep rate from 200 GHz to 13.5 GHz, as shown in Figure 1(b),(c),(d), and (g). As an example, Figure 1(d) and (g) show the spectra of the detected microwave at 19.8 and 13.5 GHz, respectively, which exhibit a signal-to-noise ratio of above 70 dB. The corresponding phase noise spectra are shown in Figure 1(f) and (i), respectively. For the 19.8 GHz signal (Figure 1(e)), the phase noise is about -40 dBc/Hz at 1 kHz, reaches -110 dBc/Hz at 10 kHz, and finally goes below -130 dBc/Hz at 3 MHz. The phase noise for the 13.5 GHz signal (Figure 1(h)) exhibits a similar phase noise level. The low phase noise indicates the high coherence of LN solitons, which is crucial for their applications in microwave photonics.

References:

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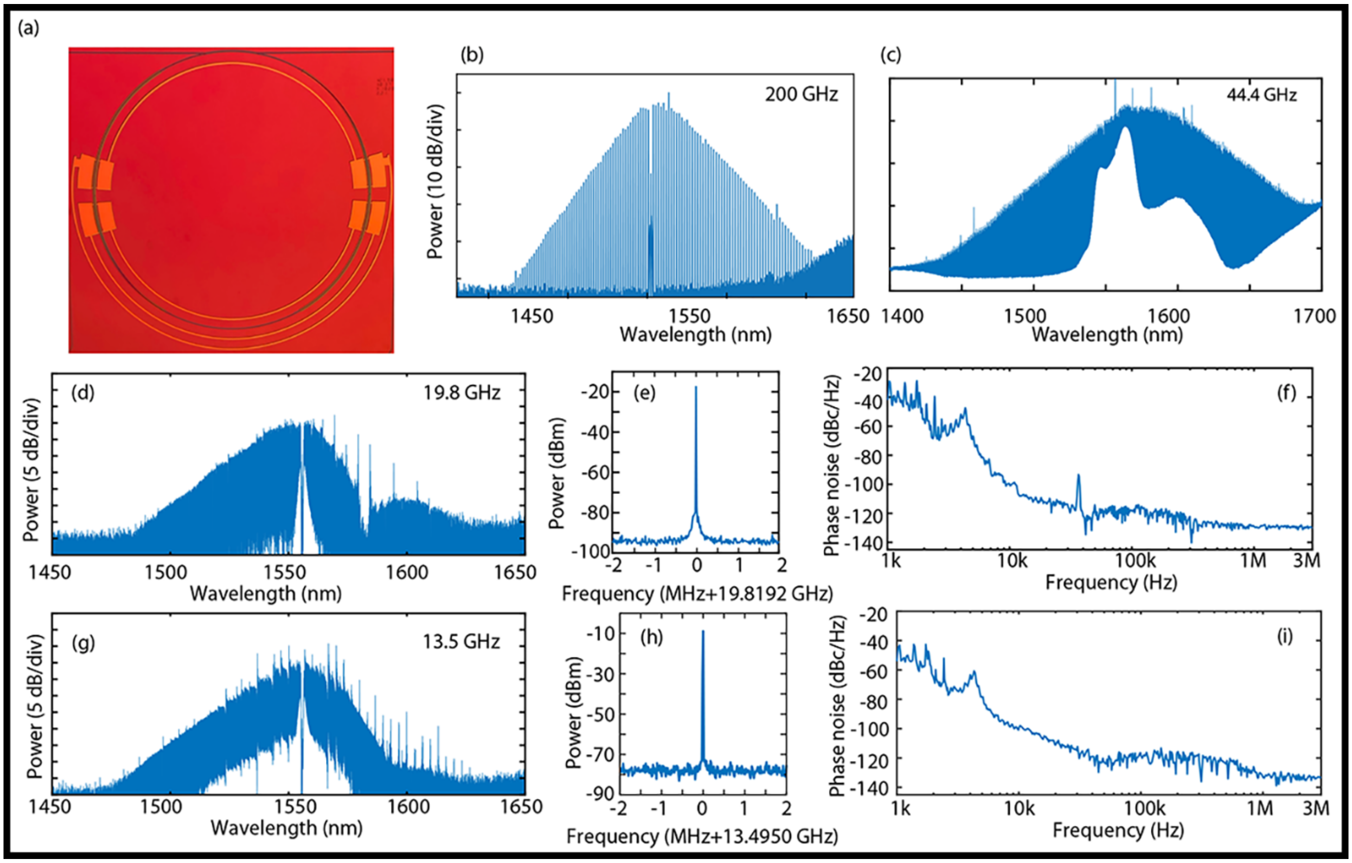

Figure 1: (a) Image of a ring resonator integrated with electrodes. Soliton spectra for LN ring resonators with radii of about 100 µm (b), 450 µm (c), 1020 µm (d), and 1500 µm (g). (e) ((h)) RF signal generated from soliton microcombs in (d) ((g)), and the RBW is 200 Hz. (f) ((i)) Measured phase noise of the RF signal in (e) ((h)).