Self-Starting Lithium Niobate Soliton Microcombs

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Primary CNF Tools Used: JEOL 9500, Yes Asher, AJA, DISCO dicing saw

Abstract:

We report soliton generation in a high-*Q* lithium niobate resonator. The photorefractive effect enables self-starting mode locking and is able to produce stable single solitons on demand that feature reversible switching between soliton states.

Summary of Research:

The recent demonstration of soliton mode locking in microresonators [1] represents a major turning point in the subject of frequency microcombs and many material systems and cavity geometries are being explored for various applications [2]. In this work soliton generation in a high-*Q* lithium niobate (LN) resonator is observed for the first time. Moreover, on account of the intriguing properties of lithium niobate the soliton mode locked system is able to self-start. Specifically, soliton microcombs must be pumped at a frequency that is red detuned relative to a cavity resonance [2], but this regime is also unstable due to a thermo-optical nonlinearity [3]. As a result special techniques for pumping and triggering solitons have been developed [2]. Here the photorefractive property of LN is shown to allow stable operation and pumping on the red-detuned side of resonance. As a result, self-starting mode locking of soliton microcombs is demonstrated by a simple and reversible pump tuning process.

LN features a strong photorefractive effect, which causes an intensity-dependent decrease of refractive index [4]. Moreover, LN exhibits a negligible thermo-optic coefficient for the ordinary polarized light (around room temperature) [5], leading to a suppressed thermo-optic nonlinearity. The combination of these two effects results in a net decrease of refractive index with increased optical intensity. This behavior is opposite to that induced by thermo-optic and/or optical Kerr nonlinearities in conventional Kerr soliton microresonators [2]. The optical Kerr effect from the soliton shifts the resonance towards the red, while the photorefractive effect significantly shifts the resonance towards the blue. As a result, the soliton formation regime resides directly within the laser detuning regime that is self-stabilized by the photorefractive effect, thereby enabling self-starting soliton mode locking.

To show this capability, we used a LN microresonator (shown as Figure 1), which has a radius of 100 mm. The group velocity dispersion of the device is engineered to be slightly anomalous. The device was patterned by electron-beam lithography (JEOL 9500).

To produce Kerr combs, a pump power of 33 mW is coupled onto the chip. When the pump frequency is scanned into a cavity resonance from long wavelength, the average intracavity power readily shows clear discrete steps (Figure 2). Figure 3 shows the spectrum measured for the single soliton at the first power step, which exhibits a smooth hyperbolic sech-shaped spectral envelope.

References:

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[5] L Moretti, M. Lodice, F. G. D. Corte, and I. Rendina, "Temperature dependence of the thermo-optic coefficient of lithium niobate, from 300 to 515 K in the visible and infrared regions," J. Appl. Phys. 98, 036101 (2005).

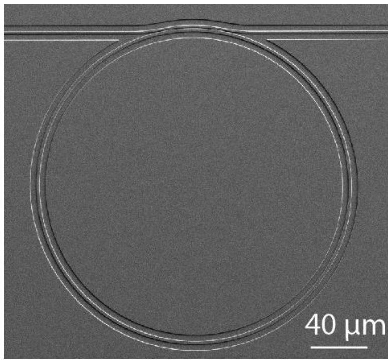

Figure 1: Scanning electron microscope image of a LN microring resonator.

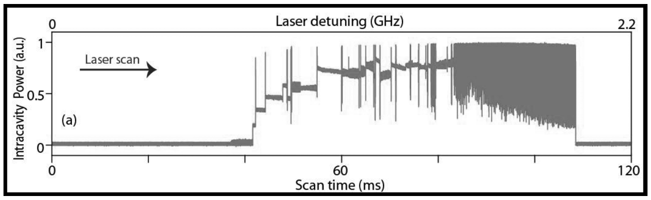

Figure 2: Intracavity power as a function of time when the laser is scanned from red to blue (long to short wavelength).

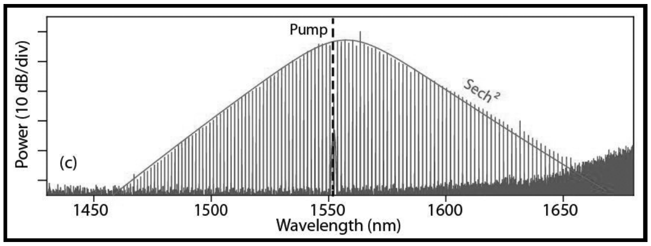

Figure 3: Optical spectrum of the single soliton state.