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Active Feedback Stabilization of Super-efficient Microcombs

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In the past years, major scientific and technological progress has been made in the field of dissipative Kerr solitons (DKS) frequency combs on microresonators (microcombs) [1]. The generation of microcombs in Si_3N_4 microresonators exhibit broad bandwidth, high repetition rate, and low power consumption. These capabilities have opened a venue for applications within optical communication [2]. However, continuous operation and high power per comb line are needed in order to address the demands of system-level applications. Recent works have demonstrated the generation of bright solitons with unprecedented high power conversion efficiency using photonic molecules [3]. In this work, we report the continuous operation of a super-efficient DKS microcomb over 25 hours using a packaged module. The soliton state is maintained by the stabilization of thermal drifts and the on-chip optical power in the cavity. Our photonic molecule is composed of two coupled cavities with heaters placed on top. The fabricated device has been robustly packaged into a fiber-connectorized module to prevent random variations of the power coupling (Fig. 1 (a)). The experimental setup used for the feedback control is shown in Fig 1. (b). The comb is generated with 20 mW of on-chip optical power covering a bandwidth of $\sim$100 nm, see Fig. 1 (c). The power conversion efficiency of the bright soliton corresponds to 32 percent. The long-term operation is achieved by harnessing the thermal drifting of the main resonance via a feedback loop implemented on an FPGA board. The soliton power is used as a control parameter to maintain a fixed pump detuning. This indicates that the coupling between these parameters holds in the super-efficient configuration of the photonic molecule as in [4]. Fig. 1 (d) shows the spectral envelope of the microcomb with constant power over 25 hours. Since the pump laser is free-running, the active control forces the cavity to follow in order to maintain a fixed pump detuning. As a result, the frequency of the repetition rate of the microcomb drifts over 800 kHz towards higher frequencies (Fig. 1 (e)). The frequency drifting of the pump laser (Toptica CTL) was monitored over the last 5 hours of the soliton existence by beating versus a frequency comb (Menlo FC1500), see Fig. 1 (f). During the first 100 minutes of recording the resulting beat note drifts, increasing the frequency until it leaves the set span window. As the drifting continues, the beating with a neighboring line of the frequency comb is observed. The soliton power is stabilized as the photo-detected converted power remains constant (Fig. 1 (f)). Nevertheless, the drifts exhibited are very minor, and we expect increased stability by feeding back into the laser piezo-control.

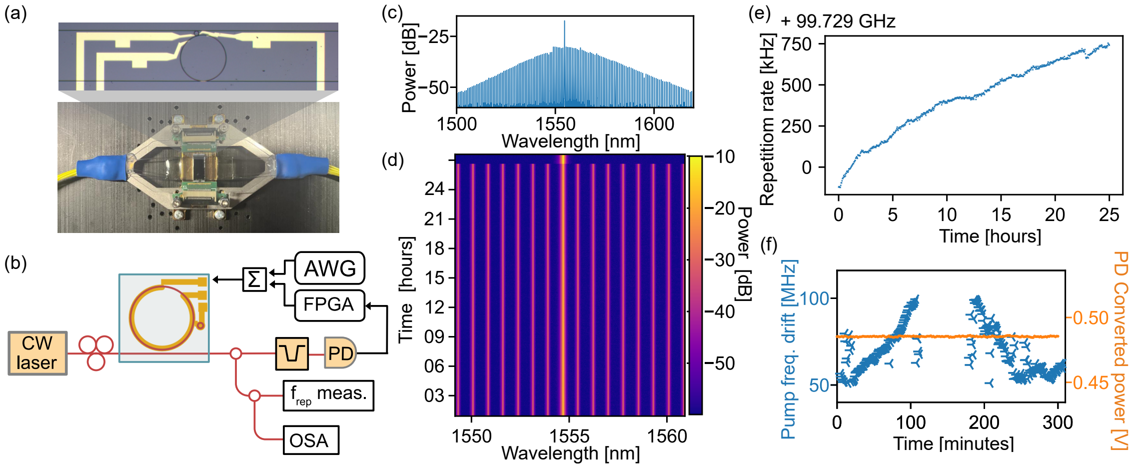

Fig. 1 Long-term operation of a bright soliton. (a) Photonic molecule packaged into a single module. (b) Experimental setup of the active thermal control. (c, d) Measured optical spectrum over 25 hours. (e) The repetition rate of the microcomb using electro-optic down-conversion. (f) Measured pump frequency drifting and photo-detected converted power of the comb.

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