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Photonic molecule microcombs at 50 GHz repetition rate

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Abstract: We present a microcomb in a photonic molecule with 50 GHz repetition rate. The comb attains $> 50\%$ power conversion efficiency and displays a quiet point of operation in repetition rate with decreased phase noise.

1. Introduction

Microcombs have found a myriad of applications, from coherent communications to RF photonics [1]. For some of these fields, power conversion efficiency and repetition rates <100 GHz are essential. However, attaining these two characteristics simultaneously is extremely challenging. Bright soliton microcombs operating at < 50 GHz repetition rates have been reported in ultra-high-Q silicon nitride (Si_3N_4) microresonators [2,3], but the conversion efficiency remains in the order of a few percent. In the normal dispersion regime, microcombs with low repetition rate have been reported in single cavities [4,5]. The work in [5] constitutes a notable exception, as it demonstrates a 50 GHz dark-pulse Kerr comb with 34 % conversion efficiency. However, dark-pulse Kerr combs in single cavities with normal dispersion rely on fortuitous linear coupling between transverse modes to initiate the microcomb from a continuous-wave laser pump [6, 7]. Reliable, turn-key operation of normal dispersion microcombs with high conversion efficiency can be attained in photonic molecules [8–10] (an arrangement of linearly coupled cavities). Here, we demonstrate, for the first time to our knowledge, the operation of a photonic molecule microcomb at 50 GHz. The comb is generated by pumping a mode-crossing induced by coupling between cavities, resulting in 51% conversion efficiency and a stable repetition rate enabled by the existence of a quiet point [11]. This work paves the way for the realization of practical transmitters in coherent communications with high spectral efficiency [12, 13].

2. Photonic molecule microcomb

Our photonic molecule is composed by two coupled cavities with microheaters placed on top of both cavities, see Fig. 1 (a). The microcomb is generated in the main cavity with a radius of 455.56 μm while the auxiliary cavity is 47.39 μm, corresponding to 49.97 GHz and 480.4 GHz FSRs. The cross-section of the waveguide of each resonator has a height of 600 nm and a width of 1600 nm, which in turn allows to operate in the normal dispersion. The GVD value measured near the pump wavelength is 92.4 ps^2/km. A tunable external cavity diode laser with a wavelength at 1555.26 nm is used as a pump source. The light is coupled to the chip using lens fibers, the measured coupling losses are 2 dB per facet. We apply 480 mW to the heater on top of the auxiliary cavity to tune the location of the mode crossing.

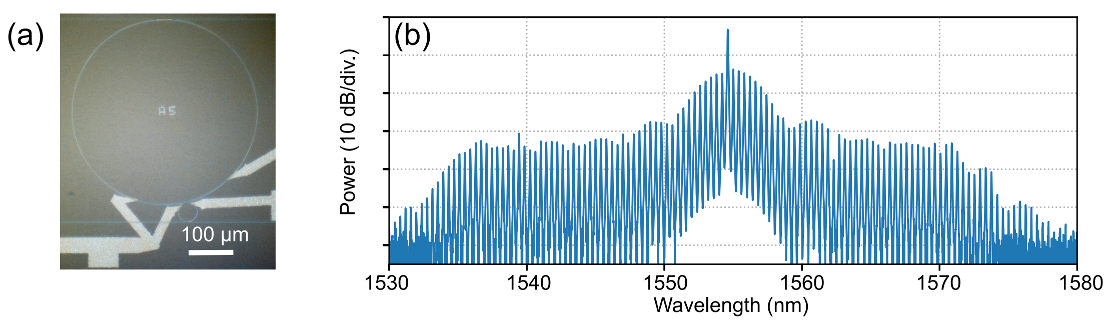

Fig. 1. Generation of a microcomb with 50 GHz repetition rate. (a) Picture of the photonic molecule with microheaters placed in both cavities. (b) Optical spectrum of the generated microcomb.

To initiate the comb, we tune the laser from the blue side to the main cavity resonance. The frequency comb spectrum is shown in Fig. 1 (b). The microcomb is generated with 17 mW of optical power on chip and covers ∼ 40 nm in bandwidth. We investigated the power conversion efficiency (ratio between the output power without the pump divided by the input pump power) and measured a 51 % efficiency of the generated comb. By increasing the input power, the bandwidth of the comb increases at the expense of the conversion efficiency. The repetition rate of the microcomb was measured by direct photodetection using a high bandwidth PIN photodetector. The output electrical signal with a frequency of 49.975 GHz is recorded using an electrical spectrum analyzer, Fig. 2 (a). Figure 2 (b) shows the change of soliton repetition frequency with pump frequency (measured with a wavemeter and referred to an arbitrary origin). We observed the presence of a quiet point operation, that is a point of enhanced repetition rate stability [11] arising from the resilience of the repetition rate to changes in pump frequency. Fig. 2 (c) presents the phase noise power spectral density (PSD) of the repetition frequency for two detuning configurations. The blue trace corresponds to the PSD phase noise for the quiet point of operation, resulting in a decrease in phase noise, most notably between 1 kHz and 1 MHz offset frequencies.

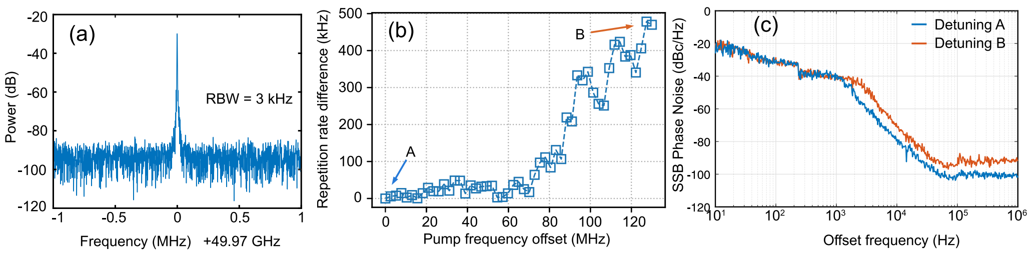

Fig. 2. Characterization of the microcomb repetition rate. (a) Radio frequency beat note of the repetition rate. (b) Repetition rate frequencies versus pump frequency detuning. (c) Single sideband (SSB) phase noise of the 50 GHz photo-detected signal at two detuning values.

In conclusion, we demonstrate a 50 GHz repetition rate microcomb with 50% conversion efficiency based on a normal dispersion photonic molecule. These results are valuable in applications such as optical coherent communication and RF photonics because of the high optical power and compatibility with the bandwidth of conventional electronics.

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