A highly stable and 2.4×10^9 quality factor packaged microrod resonator

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Abstract: We demonstrate a highly stable and ultrahigh quality factor of 2.4×10^9 packaged microrod resonator in which Kerr optical frequency combs are generated to realize data transmission at total rate up to 100 Gb/s.

1. Introduction

Whispering gallery mode (WGM) microresonators have become a frontier research hotspot by virtue of high quality (Q) factor and small mode volume. Recent years, microresonators have witnessed wide applications in sensing [1], nonlinear optics [2], microwave photonics [3] and optical communications [4]. Particularly, parametric oscillation effect in microresonators is an excellent way to generate optical frequency combs (OFCs), which have attracted great interests in optical communication. However, microresonator has strict environmental requirements and difficulty to maintain stable operation for long periods of time. Moreover, it requires three-dimensional nano-positioning systems for precision coupling. All of these have limited the application and development of microresonator frequency combs.

Here, we demonstrate a packaged microrod resonator with an ultrahigh-Q of 2.4×10^9. In addition, this resonator exhibits the superior long-term stability achieved by fine temperature adjustment via a thermoelectric cooler (TEC). The OFCs are generated in this resonator based on parametric oscillation effect with a pumping threshold as low as 266 μW. As a proof-of-principle experiment, back-to-back data transmission of Non-Return-to-Zero On-Off-Keying (NRZ OOK) with rate up to 100 Gb/s is demonstrated using the OFCs. The proposed ultrahigh-Q packaged microrod resonator provides a promising platform for the optical communications, metrology and sensing.

2. Experimental Results

Fig. 1(a) shows the packaged silica microrod resonator, which is fabricated on an automated laboratory platform within one minute by precise control of the automated procedures. As shown in Fig. 1(b), the Q of the microrod

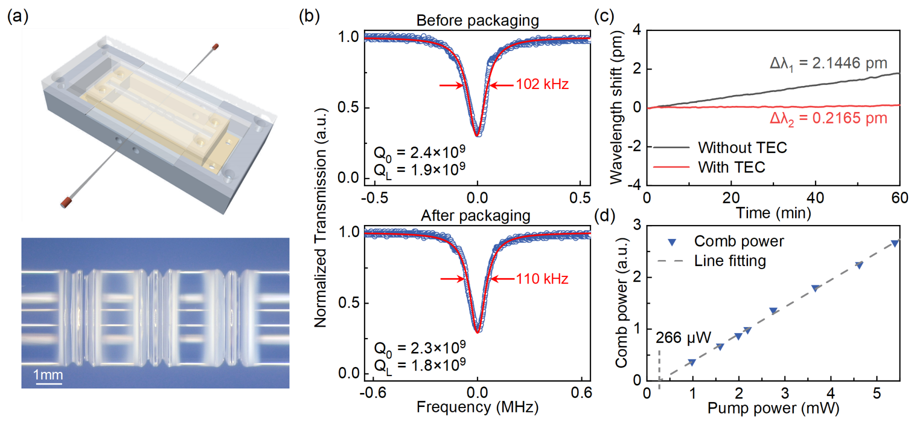

Fig. 1. (a) Top: schematic diagram of the packaged microrod resonator; bottom: optical imaging of the microrod resonator. (b) Measured greater than 2 billion Q of the microrod resonator before and after packaging. (c) The stability of the packaged microrod resonator over 1 hour without and with TEC. (d) Parametric oscillation power versus pump power showing an oscillation threshold of 266 μW.

resonator can reach up to 2.4×10^9, and the Q can be still maintained at as high as 2.3×10^9 after packaging with TEC. Fig. 1(c) shows the mode stability of the packaged microrod resonator tested over 60 minutes. It is observed that the mode stability is improved by a factor of nearly 10 times by utilization of the TEC. Experimentally, the threshold power of parametric oscillation is characterized by measuring the optical sideband power at different pump powers, as displayed in Fig. 1(d). The threshold power can be obtained by linear fitting extrapolation to 266 μW [5]. A lower threshold power can be achieved by optimizing the preparation process of the microrod resonator and improving the coupling conditions during the packaging process, implying that the packaged microrod resonator can be applied in the low-power scenarios.

As a proof-of-principle experiment, a two-channel WDM back-to-back data transmission experiment is implemented based on the OFCs generated in the packaged microrod resonator, and the spectrum of the OFCs is shown in Fig. 2(a). To evaluate the data transmission performance, the transmitted data signal quality versus receiver input power at three different channels is depicted in Fig. 2(b). A data stream of 25 Gb/s and 50 Gb/s is modulated at these three light carriers, where carrier (0) is used as the reference light. It can be observed that carrier (-1) has a better data signal transmission performance compared with that of carrier (+1). In addition, the data signal quality factor of each channel is measured, and the eye diagrams and the corresponding optical-carrier-to-noise-ratio (OCNR) of each comb line is plotted in Fig. 2(c). It's observed the data transmission shows better signal quality by utilization of a carrier with higher OCNR. With the rate of 25 Gb/s, the signal quality of carrier (-1) and (+1) is measured to be 14.2 and 8.3 respectively. Within the error range allowed by the forward error correction algorithm, the data transmission over the two channels can be considered reliable and error-free. The amplifier spontaneous emission noise inhomogeneity of the erbium-doped fiber amplifier makes the OCNR of carrier (-1) larger and therefore the transmitted data signal quality is better.

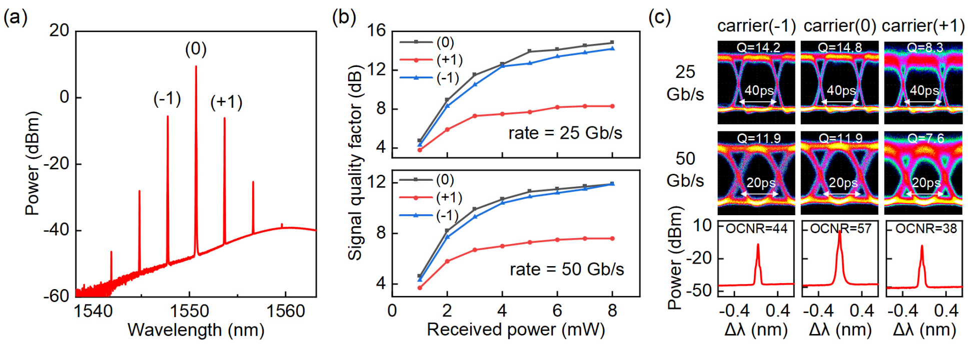

Fig. 2. (a) Spectrum of Kerr OFC generated in the packaged microrod resonator. (b) Measured signal quality factors as change of received power at different channel with the data rate of 25 Gb/s (top) and 50 Gb/s (bottom). (c) Eye diagrams and the corresponding OCNRs for each channel.

3. Conclusion

In conclusion, we have demonstrated a packaged microrod resonator with high stability and ultrahigh-Q greater than two billion. Data transmission of NRZ OOK with rate up to 100 Gb/s by utilization of the Kerr OFCs generated in this resonator is experimentally verified, exhibiting the feasibility of this packaged OFCs for optical communication. Moreover, this packaged microrod resonator shows advantages of high portability, great robustness and low power consumption, and it has wide applications in high-speed communication, metrology and sensing.

4. Acknowledgements

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