A Standalone Soliton Microcomb Prototype

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Abstract: We built a standalone prototype for generating soliton microcombs. Our prototype supports both manual and automatic soliton generation methods, laying a good foundation for the commercial application of microcombs while maintaining professionalism.

1. Introduction

Microresonator-based dissipative Kerr solitons (DKSs) have been rapidly developed and applied in recent years. Although the soliton microcomb has a chip-scale size, a free spectral range (FSR) of sub-terahertz level, and can be heterogeneously integrated with lasers at the wafer level [1], the process of generating soliton microcombs still relies on large laboratory equipment. Soliton microcombs need to be developed into a compact standalone soliton prototype for commercial use. The prototype will be equipped with the optoelectronic devices needed to generate the soliton combs and control components including a computer while meeting the needs of various applications in terms of portability, stability, and ease of use.

Although lasers and silicon nitride microresonators have been integrated recently [1, 2], the operation of the system is still limited to the laboratory environment. The latest work about soliton prototypes is from EPFL [3], but their system still requires an external computer and monitor. We miniaturized the soliton generation system and installed it into a standalone case. The prototype only needs to be connected to an optical spectrum analyzer (OSA) to start the debugging of the soliton.

2. Prototype Design

Our prototype is approximately 495 mm long, 193 mm wide, and 350 mm high when folded (Fig. 1(a)), with a total weight of 18.26 kg. The prototype is powered by a high-quality ATX power supply and requires about 80 W to operate. The prototype shell is equipped with a screen, a foldable keyboard, a touchpad, and a built-in industrial PC to control lasers and other devices via a MATLAB program. Glued to the thermoelectric cooler and the thermistor, the silicon nitride chip is coupled to the fiber array (Fig. 1(b)). The metal paddings of the microring heater are also wire-bonded to the PCB board and the chip is finally packaged by the metal shell. The packaged chip has a coupling loss of about 3 dB per facet. The silicon nitride chip is produced by LIGENTEC, the radius of the microring is about 306 μm, and the FSR is about 75 GHz. Lasers (PPCL550) are purchased from Pure Photonics. Single-mode Erbium-doped fiber amplifier (EDFA) modules (Beogold Technology) have a maximum output power of +33 dBm, and the optical loss from the EDFA output to the chip input is about 3 dB. The bandpass filters (BPFs) for ASE noise suppression have a 0.5-dB bandwidth of 15 nm. The center wavelengths of the fiber Bragg gratings (FBGs) match the wavelengths of lasers. Each FBG has a 3-dB bandwidth of 1 nm and a reflectivity of 99.9%. The programmable optical power meter (OPM) has three channels (Ch1-Ch3), with the maximum optical power of +25 dBm and the highest sampling rate of 1 kSa/s. Cooling fans are installed in the prototype to ensure the temperature stability of the devices. The left side of the prototype is equipped with power switches of the devices and FC/APC fiber adapters for the soliton microcomb output. The MATLAB program of the prototype mainly controls the laser frequencies, the output power of the EDFAs, and the working state of the OPM.

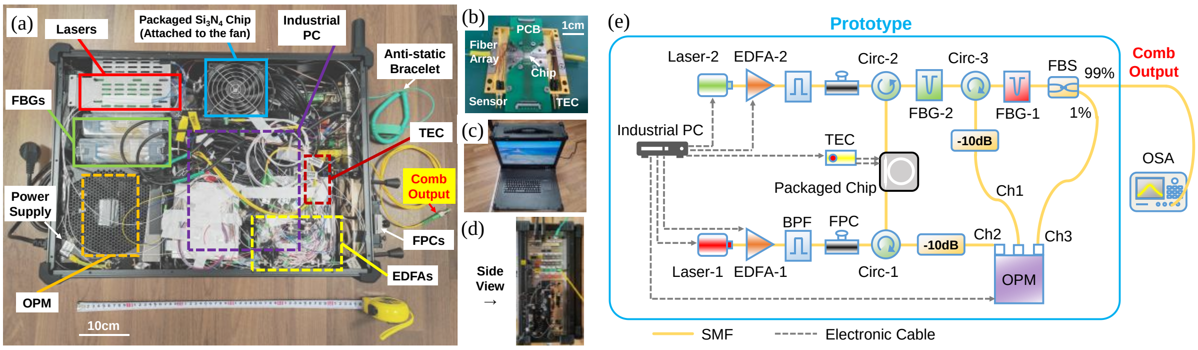

Fig. 1. Soliton microcomb prototype.

(a) The internal view of the prototype; (b) The packaged silicon nitride chip; (c) The appearance of the prototype; (d) The left side view of the prototype; (e) The schematic diagram of the optical path. Circ: circulator, FBS: fiber beam splitter, -10dB: 10 dB optical attenuator, TEC: temperature controller, SMF: single mode fiber. Laser-1: pump laser, Laser-2: auxiliary laser.

3. Soliton Microcomb Generation

The optical path of soliton generation based on the dual-pump method is shown in Fig. 1(e). Our prototype is compatible with the automated soliton generation method we previously proposed in Ref. [4]. After power-up, the MATLAB program is run to initialize and warm up the lasers, EDFAs, and turn on the OPM for optical power monitoring. FBG-1 and FBG-2 are used to reflect the laser from pump laser (Laser-1) and auxiliary laser (Laser-2), respectively. The three channels of the OPM measure the optical power remaining after the pump laser (Ch1) and the auxiliary laser (Ch2) have passed through the chip, as well as the soliton power (Ch3) after removing the pump and auxiliary power.

The pump laser and auxiliary laser can be continuously tuned around wavelengths preset around resonant peaks in the range of ±30 GHz. After being amplified by the EDFAs, the laser beams pass through the BPFs and the FPCs successively. By monitoring the change of optical power in Ch1 and Ch2, we can manually adjust the polarization to the maximum or minimum state to ensure the pump light and the auxiliary light propagate in orthogonal mode and thus reduce the influence of the auxiliary light on the soliton. Initially, the pump laser is fixed, and the auxiliary laser can be tuned to a wide range in the direction of increasing wavelength to find the location of the resonant peak and to keep the wavelength in the blue detuning region of the resonant peak. After finding the crossing point of the auxiliary laser to the red detuning region, we adjust its wavelength to stop before the crossing point. Next, the pump laser is tuned extensively to find the position of the soliton step. When the pump wavelength enters the red detuning region, multiple solitons are formed and the number of solitons decreases as the detuning increases. Whenever the number of solitons switches, the power changes significantly, forming the soliton step as shown in Fig. 2(a). The number of solitons decreases as the detuning increases and finally enters the single-soliton state. The final single-soliton spectrum we obtained is shown in Fig. 2(b) whose envelope exhibits a typical sech^2 shape. The wavelengths of the pump and auxiliary laser are 1551.93 nm (30 dBm) and 1555.24 nm (32.8 dBm), respectively.

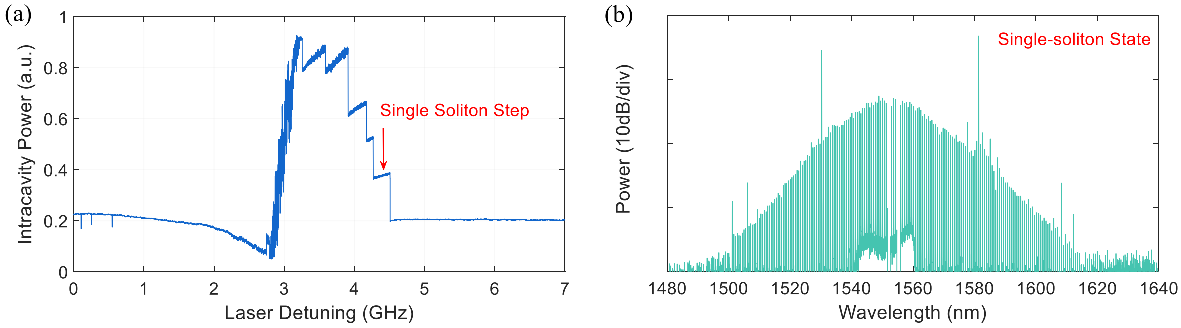

Fig. 2. (a) Intracavity power as a function of the laser detuning recorded by the OPM. The different steps designate transitions between different soliton states. (b) The optical spectrum of the single-soliton state generated by our prototype. The two gaps around 1552 nm and 1555 nm in the spectrum are caused by the FBGs.

The MATLAB program is used to adjust the laser frequency, power, and monitor the output power and temperature in real-time. Without changing the hardware connection, users can also choose automatic soliton generation programs [4] to meet different needs. The single soliton was stabilized for a maximum of 30 minutes, and heaters on the microring can be further applied in the stabilization procedure to extend the single soliton step.

4. Conclusion

We have successfully miniaturized the soliton microcomb generation and control system and installed all the required devices into a 19.5-inch case. Our prototype supports both manual and automatic soliton microcomb generation methods, laying a good foundation for the commercial application of microcombs while maintaining professionalism. And the prototype can be further modified to enhance the stability of the single soliton.

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5. References

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