Researchers achieve broadest microcomb spectral span on record

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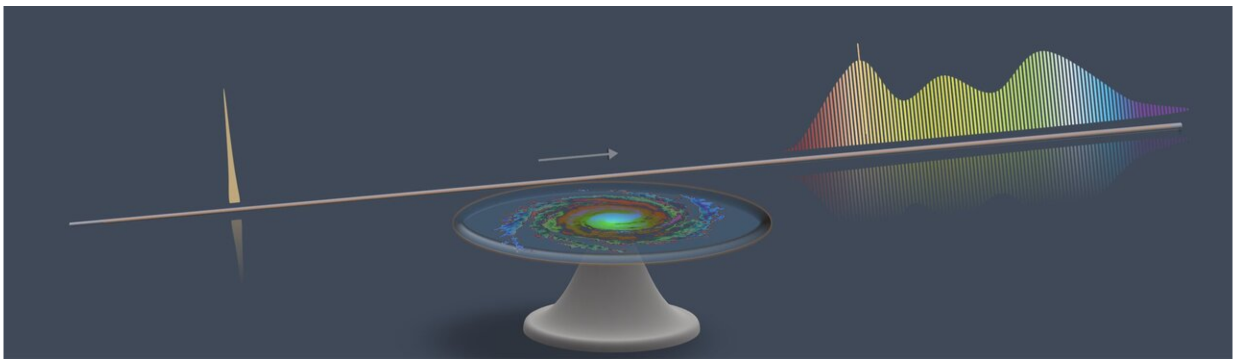

The nonlinear microresonator converts a single wavelength pump coming in from the left into a rainbow of frequency combs. The combs exit to the waveguide with the help of chaotic motion in the deformed microresonator. Credit: Xu Yi

Xu Yi, assistant professor of electrical and computer engineering at the University of Virginia, collaborated with Yun-Feng Xiao's group from Peking University and researchers at Caltech to achieve the broadest recorded spectral span in a microcomb.

Their peer-reviewed paper, "Chaos-assisted two-octave-spanning microcombs," was published May 11, 2020, in *Nature Communications*, a multidisciplinary journal dedicated to publishing high-quality research in all areas of the biological, health, physical, chemical and Earth sciences.

Yi and Xiao co-supervised this work and are the corresponding authors. Co-authors include Hao-Jing Chen, Qing-Xin Ji,Qi-Tao Cao, Qihuang Gong at Peking University, and Heming Wang and Qi-Fan Yang at Caltech. Yi's group is sponsored by the U.S. National Science Foundation. Xiao's group is funded by National Natural Science Foundation of China and National Key Research and Development Program of China.

The team applied chaos theory to a specific type of photonic device called a microresonator-based frequency comb, or microcomb. The microcomb efficiently converts photons from single to multiple wavelengths. The researchers demonstrated the broadest (i.e., most colorful) microcomb spectral span ever recorded. As photons accumulate and their motion intensifies, the frequency comb generates light in the ultraviolet to infrared spectrum.

"It's like turning a monochrome magic lantern into a technicolor film projector," Yi said. The broad spectrum of light generated from the photons increases its usefulness in spectroscopy, optical clocks and astronomy calibration to search for exoplanets.

The microcomb works by connecting two interdependent elements: a microresonator, which is a ring-shaped micrometer-scale structure that envelopes the photons and generates the frequency comb, and an output bus-waveguide. The waveguide regulates the light emission: only matched speed light can exit from the resonator to the waveguide. As Xiao explained, "It's similar to finding an exit ramp from a highway; no matter how fast you drive, the exit always has a speed limit."

The research team figured out a smart way to help more photons catch their exit. Their solution is to deform the microresonator in a way that creates chaotic light motion inside the ring. "This chaotic motion scrambles the speed of light at all available wavelengths," said co-author and Peking University research team member Hao-Jing Chen. When the speed in the resonator matches that of the output bus-waveguide at a specific moment, the light will exit the resonator and flow through the waveguide.

The team's adoption of chaos theory is an outgrowth of their previous study on chaos-assisted broadband momentum transformation in deformed microcavity, which was published in *Science* in 2017 (*Science* 358, 344-347).

This research builds on UVA Engineering's strengths in photonics. The Charles L. Brown Department of Electrical and Computer Engineering has a solid foundation in semiconductor materials and device physics that extends to advanced optoelectronic devices. Yi's microphotonics lab conducts research on high-quality integrated photonic resonators, with a dual focus on microresonator-based optical frequency combs and continuous-variable-based photonic quantum computing.

"The introduction of chaos and cavity deformation not only provides a new mechanism, but also an additional degree of freedom in designing photonic devices," Yi said. "This could accelerate optics and photonics research in quantum computing and other applications that are vital to future economic growth and sustainability."

Nature Communications published this research on May 11, 2020.

More information: Hao-Jing Chen et al, Chaos-assisted two-octave-spanning microcombs, *Nature Communications* (2020). DOI: 10.1038/s41467-020-15914-5

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