Creating frequency combs in microresonators

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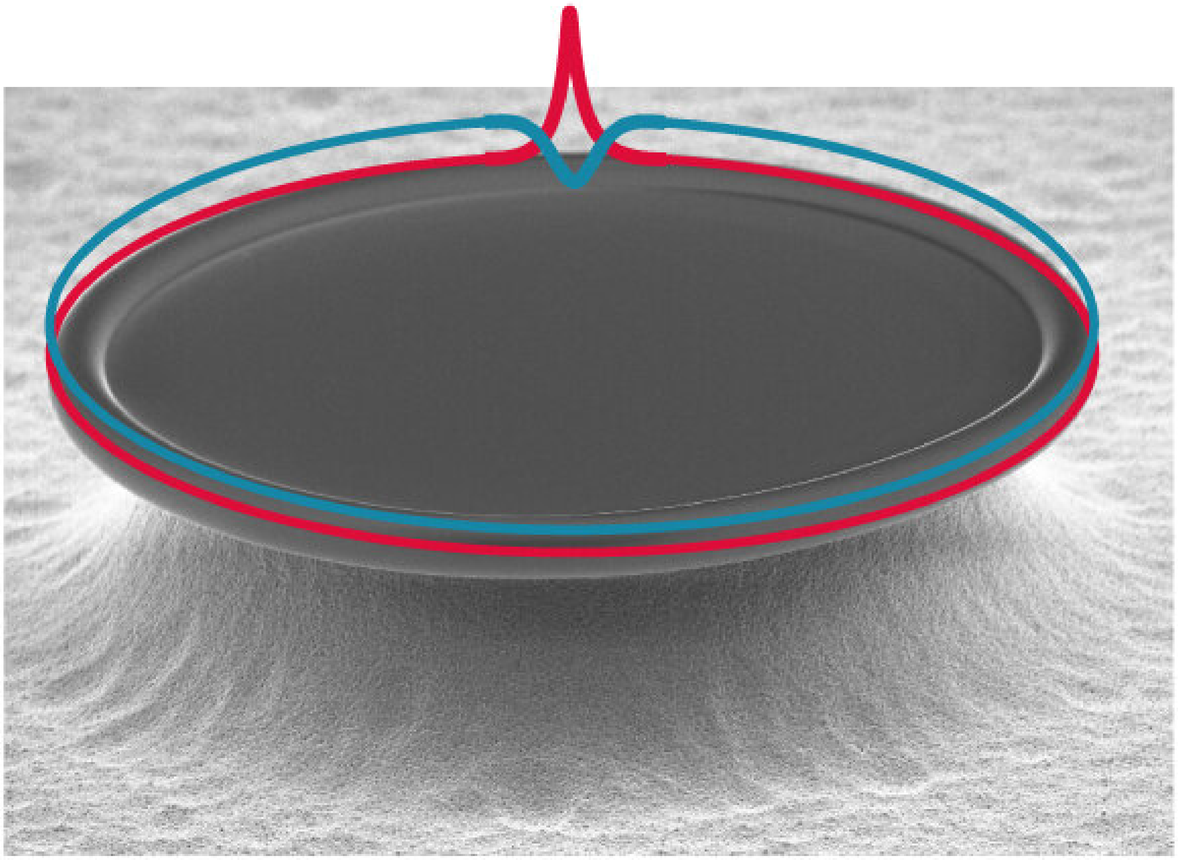
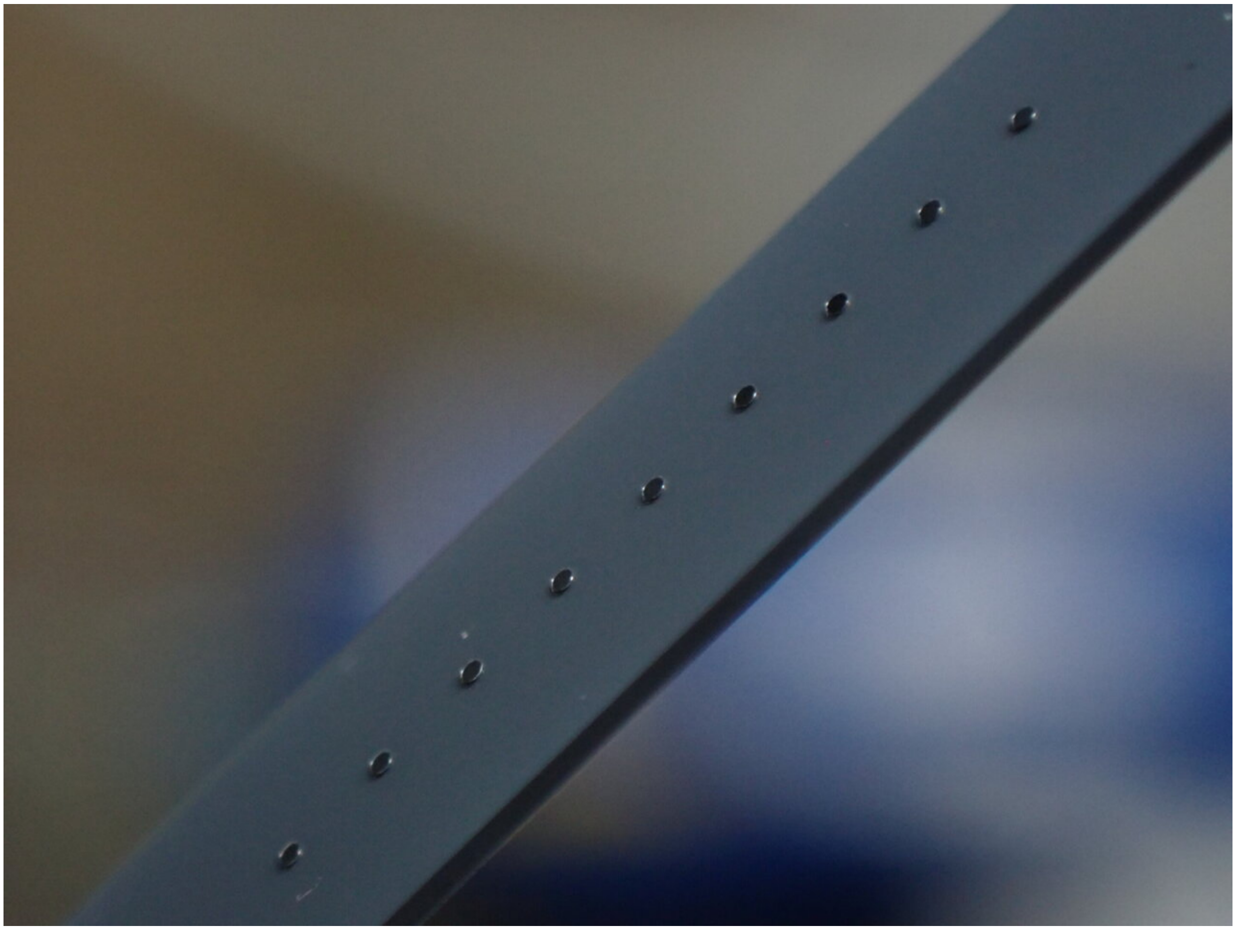


Visualisation of coupled dark and bright light pulses (blue and red respectively) in a microresonator, which has a diameter of 235 micrometer. Credit: Max-Planck-Institute for the Science of Light

For the first time, scientists were able to create ultrashort dark and bright light pulses that are linked together in tiny glass rings called microresonators. Each of the flashes consist of many different, precisely defined colors: a frequency comb. The combination of the pulses increases the color range of the emitted light from the microresonators. This new light source helps to make more precise sensors to trace for example lowest quantities of explosives at an airport or for distance sensors in autonomous cars to detect obstacles on a street.

It sounds like magic: Laser light of only one color produce a rainbow of many different colors. Scientists are able to produce this strange effect in microresonators, small disks made of glass. If they send a pulsed laser beam into these structures, ultrashort packets of light waves are running in its interior in circles. And start to send out light of different, evenly spaced frequencies like the teeth of a comb. The invention of the optical frequency comb was awarded with the Nobel Prize in Physics in 2005.

Now, researcher from the Max-Planck-Institute for the Science of Light (MPL) in Erlangen and the Imperial College London were able to produce for the first time an even stranger effect: By directing two Laser beams of slightly different infrared light at the outer rim of the microresonator they got two wave packets, called solitons: one bright and one dark, which run in circles. A dark pulse means having a constant light signal that goes dark for a very short time. Both dark and bright light pulses only last for $1/10^{13}$th of a second.



Several Microresonators, which are produced on silicon wafers. Credit: Max-Planck-Institute for the Science of Light

Microresonators can be easily manufactured in large quantities

Both were coupled and trapped together inside the resonators. This pair produced a frequency comb in the infrared spectrum with two peaks of hundreds of precisely defined frequencies. "Therefore, we can use more frequencies to transport information through a glass fiber", explains Pascal Del'Haye, head of the independent research group Microphotonics at the MPL, one possible application of the effect in telecommunication. He and his colleagues have recently published their results in *Physical Review Letters*.

The broadened frequency combs can also be used in spectroscopy, another application for microresonators that can be produced in high numbers with similar techniques like computer chips. They can then be integrated into sensors which are searching for explosives at an airport or measuring air quality. Tiny microresonator based frequency comb sources for satellite-based measurements are currently also investigated in a collaboration between Airbus and the Max Planck Institute. Another application might be in Lidar systems. They are for example the eyes in autonomous cars and help them to detect pedestrians on the street.

More information: Shuangyou Zhang et al, Dark-Bright Soliton Bound States in a Microresonator, *Physical Review Letters* (2022). DOI: 10.1103/PhysRevLett.128.033901

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