Scientists develop new method of high-precision optical measurement

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An international collaborative of scientists has devised a method to control the number of optical solitons in microresonators, which underlie modern photonics. Photonics is a dynamically developing field of modern physics. Microresonators are basic structural elements of photonics, an integral part of almost all sophisticated optical and microwave devices. In fact, resonators are circular light traps. Microresonators are currently used for laser stabilization and optical filters.

In their research, the results of which are published in *Nature Physics*, the scientists have addressed the problem of stable optical pulse generation in resonators—in other words, to ensure that every pulse (soliton) put into it persists for a long period of time. The second experimental aim was to reduce the number of soliton pulses moving in a resonator to one. At the same time, the outgoing emission spectrum has the appearance of a super-stable optical frequency comb, which could be used as a high-precision ruler for optical spectra.

Grigory Lichachev, a doctoral student at the Faculty of Physics, said, "Pulses should live for a long period of time, and it should be only one, not several pulses. When there is only one pulse, it has the clearest spectrum, known as a comb, which has many applications, for instance, in spectroscopy."

The scientists studied two optical resonators on a chip base only one micron thick. The first one was made out of optical crystal, magnesium fluoride (MgF2); the second one out of silicon nitride (Si3N4).

A laser was introduced light into the resonator, and the properties of its pulses were measured at output with the help of spectrometer.

The experiment demonstrated a method that forms one pulse, which propagates around in a resonator. Physicists observed a regular spectral comb, which is the distinguishing characteristic of a soliton. Moreover, the article shows a new and very effective method worked out by scientists to observe solitons in real-time. This was achieved by the addition of weak phase modulation to the input signal and further response registration to this disturbance. Such an approach opens up new possibilities for maintaining and stabilizing combs.

The technique worked out by the scientists actuates an unknown large number of solitons in a resonator and then sequentially reduces this number to a single pulse. The scientists emphasize that the reduction of extra solitons sequentially becomes possible only due to the change of laser frequency used for actuating the resonator.

The optical frequency comb is the foundation of the laser-based precision spectroscopy technique, which was awarded the Nobel Prize for Physics in 2005. Applications include astronomy and high-precision sensors, for instance, to measure the spectrum of an unknown substance. Using two identical optical solitons and overlapping their optical frequency combs, scientists could measure optical frequencies, which could not be measured directly because of their size.

Potential applications of this method include the measurement of gas composition using spectroscopy in the mid-infrared range. By directing two optical solitons to the experimental gas through a common optical fiber, scientists could observe notches, connected with specific absorption lines, in the spectrum output.

Usage of two solitons allows scientists to measure frequencies in radio waves beyond the optical range. If it takes seconds to measure frequencies in an optical spectrometer, then in the microwave range, the measurement time is nanoseconds.

More information: H. Guo et al, Universal dynamics and deterministic switching of dissipative Kerr solitons in optical microresonators, *Nature Physics* (2016). DOI: 10.1038/nphys3893

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