# Researchers discover photonic snake states, a new instrument for unveiling the secrets of light

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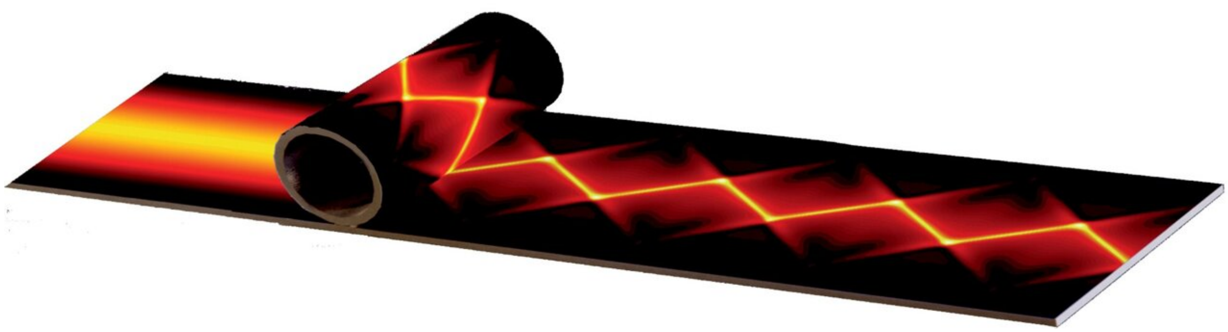

Photonic micro-cylinder in the photonic snake generation regime. Credit: UPV

Light, with its countless colors, is one of the wonders of nature. To truly understand what we see, it is essential to know the precise colors of the light with which we perceive our world. We achieve this by means of optical rules called frequency combs, the first realization of which won the Nobel Prize in Physics in 2005.

Optical rulers are used to measure not only colors but also times, distances and other essential magnitudes; hence their importance in science and technological applications. They are the tools that allow us to enter the realm of light and reveal its deepest secrets.

This is precisely what a recent study led by the Universitat Politècnica de València (UPV), with the participation of researchers from the Universitat Politècnica de Catalunya—Barcelona Tech (UPC) and the Institute of Photonic Sciences (ICFO), has made possible. In their work, published in the scientific research journal *Nature Photonics*, they have discovered the "Photonic snake states," a new instrument for unraveling the secrets of light.

This study has attracted the attention of the international scientific community and opens up unprecedented perspectives in the formation of frequency combs: it predicts the existence of two-dimensional optical rules, more complex than the one-dimensional ones used so far and offering unprecedented versatility in a wide range of applications.

## Applications in communications, spectroscopy, or computing

Frequency combs have a wide range of applications, particularly in the field of communications. According to the authors of the study, these combs allow large amounts of information to be transmitted through optical fibers in a very efficient way since, by having well-defined frequencies, multiple light signals can be sent simultaneously and easily separated when they are received.

Another area where frequency combs have proven to be very useful is spectroscopy. The ability to obtain optical spectra with unprecedented accuracy and resolution makes it easier the identification of different substances. This has direct applications in fields such as chemistry, biology and medicine, where accurate detection of molecules and characterization of materials is essential.

In the case of metrology, the science of measurement, these structures are used as a reference to define standards thanks to their ability to generate stable and known frequencies. This allows exact measurements of fundamental quantities, such as time or length, relevant to most scientific fields.

Finally, frequency combs have also found promising applications in quantum computing, where light particles (or photons) play a key role. In particular, frequency combs can be used to generate single photons with specific properties, which is crucial for the development of these technologies.

## The future of optical rules

A fundamental problem that must be analyzed to succeed in these proposals is the instabilities that appear when trying to construct these optical rules, which prevents the generation of versatile light forms. As Professor Pedro Fernández de Córdoba, researcher at the UPV's IUMPA and co-author of this work, points out, "It should be noted that our team has obtained, from a theoretical point of view, the conditions for the light structure to be stable, finding zigzag-shaped configurations that we have called Photonic Snakes. The stability of these light states is a crucial aspect of future applications."

This paper has also shown that it is possible to create a two-dimensional arrangement of individually accessible, synchronized optical rules. This discovery provides a large collection of rules generated in a single device and controlled by a single laser light source. In fact, as Prof. Carles Milián, who led this research, says, "The potential impact of this breakthrough is extraordinary, as it could enable the development of broadband, reconfigurable, monolithic multicomb devices. These devices would provide different frequency combs on demand and in real-time, significantly expanding existing applications."

Finally, this study is based on rigorous and very complete theoretical models, which have considered all the known effects that could appear in future experiments on the formation of two-dimensional frequency combs and have been simulated using powerful theoretical and numerical tools. In fact, as Professor J. Alberto Conejero, Director of UPV's Department of Applied Mathematics and co-author of this work, points out, "this research has built a very precise model that includes all the phenomena that can influence the formation of these structures. It will function as a guide for future experiments, with the consequent economic impact of knowing in advance the experimental parameters with which stable light snakes can be generated."

This discovery marks a milestone in the physics of these structures and paves the way for an "exciting future of advanced optical devices," Salim B. Ivars (Universitat Politècnica de Catalunya), Yaroslav V. Kartashov and Lluís Torner (ICFO) have also contributed to the work. According to the latter, "this important discovery is remarkable for being unexpected and surprising, and has been possible thanks to the intuition and leadership of Professor Milián."

The UPV, UPC, and ICFO team says this finding will further stimulate research in this field and lead to revolutionary new applications and technologies. "Thanks to these advances, we are one step closer to unraveling the mysteries of light and harnessing its full potential for the benefit of our society," they conclude.

**More information:** Salim B. Ivars et al, Photonic snake states in two-dimensional frequency combs, *Nature Photonics* (2023). DOI: 10.1038/s41566-023-01220-1

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