“Useful abnormality”: the benefits of abnormal rolls in optics

Scientists of Siberian Federal University and L. V. Kirensky Institute of Physics of Krasnoyarsk Research Centre (SB RAS) have studied the optical photonic structures with a scattering medium consisting of nematic liquid crystals.

During the experiment, the team investigated special abnormal rolls — complex periodic structures that occur in nematics under the impact of electroconvective helicoidal flow of fluid. It is assumed that the obtained results can be used to analyze complex structures and processes that occur in ordered systems.

‘We study structures similar to cylinders (rolls) — they resemble a well-known dish of Japanese cuisine. We were able to track the formation of such rolls and their behaviour in nematic liquid crystals. It is known that in a gradually heated liquid (for example, in water) there occurs a movement of a substance when a warm liquid rises up through one channel, and a cold liquid drops down another one. As a result, we have a closed loop formed. Nematic liquid crystals have got a set axis of symmetry, and any movement in them goes along the trajectories determined by this axis. This is how the rolls we are curious about appear. They can be relatively simple, and then this movement around the axis of symmetry is banal, which leads to the formation of rolls elongated along this axis. But sometimes there form complex spiral flows leading to the appearance of so-called abnormal (in other words, not normal) rolls. Now imagine that we put this already complex medium into an optical resonator — a structure of two parallel mirrors between which you can accumulate light,’ explained **Mikhail Krakhalyov**, one of the authors of the study, an associate professor of the Department of General Physics at Siberian Federal University, and a senior researcher at L. V. Kirensky Institute of Physics (SB RAS).

The scholar assures: in nematic crystals you can find many different forms of rolls, and they are of interest not only for specialists studying the fundamental laws of hydrodynamics or optics.

The abnormal rolls are, perhaps, the most curious: outwardly they are very similar to their “normal” brothers in terms of their form but differ significantly from them by their internal structure. This makes them an exciting object as a model of a scattering medium with a complex twisted structure.

‘Just as a car’s engine prefers running on clean gasoline, the conventional optical resonators like quiet nematic liquid crystals that are uniformly oriented and almost do not scatter light. We in our turn showed that even if you put a noisy, from the point of view of optics, environment consisting of abnormal rolls into a resonator, you can quite successfully register the parameters and characteristics that are found for classical systems with calm nematics. Moreover, due to the presence of a resonator, such system is sensitive both to the very fact of the presence of electroconvection processes and to their structure. For example, we can not only easily distinguish normal and abnormal rolls, but also having measured the optical parameters of such system, determine the parameters associated with the structure (morphology) of the rolls,’ noted **Mikhail Krakhalyov**.

But why go a complicated, at first glance, way, if you can choose the usual filler for the resonator? The answer lies in the essence of most biological fluids of plants, animals and humans — they contain light-scattering or light-absorbing elements (cells, proteins, etc.). And the analysis of such liquids, for example, by measuring the intensity of scattered light, allows determining the concentration and size of the scattering particles but does not allow concluding about their inherent structure. The evolvement of

the approaches enabling to determine more parameters of complex systems can expand the capabilities for their study and analysis.

> *'We appeal for being careful in forecasts. Still, to date, resonators with a "noisy" scattering medium (like abnormal rolls in nematic liquid crystals) are understudied yet, the same as are the methods of practical application. But judging by our experiments, such an optical system is really challenging from the point of view of the analysis of complex systems, which can lead to the creation of sensors (detectors), including for biological systems later on,'* the researcher concluded.

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