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Cracking the code of supersolid light – and what it means for future quantum tech

EU-funded researchers have brought supersolid light to life in the lab and are now exploring how this strange new state of matter could power real-world technologies.

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Can light ever be a solid? It turns out that, in the microscopic world of the quantum realm, maybe it can.

In a recent groundbreaking EU-funded study published in Nature, a team of researchers succeeded in creating supersolid light – a strange, hybrid state of matter that combines the structure of a solid with the frictionless flow of a superfluid.

From theory to application

Now, their focus is shifting from theory to application as they explore how this discovery could pave the way for advances in quantum computing and photonic technologies, including the optical neural networks that power AI.

Daniele Sanvitto, a prominent physicist specialising in light-matter interactions, led the research at Italy's National Research Council (CNR).

"We actually found a supersolid phase in a state that combines light and matter," said Sanvitto, who is the director of research at the Institute of Nanotechnology (CNR NANOTEC) in Lecce, Italy, and is coordinating a four-year EU-funded research initiative called Q-ONE.

Combining the expertise of scientists from leading research institutes in Italy, Austria and the USA, the team managed to create a state of light and matter that was simultaneously a crystal-like solid but also flowed like a liquid.

This discovery was achieved by harnessing a hybrid particle known as an exciton-polariton, which combines properties of light (photon) and matter (exciton). With its help, the researchers are opening new scientific frontiers with potential applications that stretch far beyond the lab, in Europe and beyond.

This major breakthrough in quantum physics also comes at a timely juncture. On 16 May we celebrate the International Day of Light, the anniversary of the first use of a laser in 1960 by the American physicist Theodore Maiman.

Q-ONE's research into supersolids shows how far this field of research has come since then.

Supersolid light

Most of us are familiar with the regular states of matter – solid, liquid and gas. But there are other exotic states that can be created too, such as superfluids, liquids that flow without resistance. Supersolids are another exotic state.

"If a superfluid gets some ordered structure in space, like a crystal, then it's called supersolid," said Sanvitto. "It looks like a solid, but at the same time it can move, in principle, without friction."

Eight years ago, Sanvitto and his team showed that light could flow like a fluid inside a semiconductor. Now, they have taken that research further by creating an ordered structure made from unusual light-matter particles.

These are formed when photons – particles of light – strongly interact with electronic excitations in a semiconductor, creating hybrid entities known as exciton-polaritons.

Because they combine properties of both light and matter, they open up new possibilities for manipulating light in ways not previously possible.

Supersolids – materials that behave both like a solid and a superfluid at the same time – have until now only been observed for ultra-cold atomic gases. But that is starting to change.

"We're the first to show that supersolids can also form in solid state devices that do not require ultra-cold temperatures," said Sanvitto.

This breakthrough makes it possible to explore real-world applications without the need for the complex and ultra-cold lab setups used for atomic condensates. This will potentially pave the way for new technologies in computing, sensing and more.

"It's exciting because it means we can explore entirely new physical phenomena in a semiconductor chip."

Quantum states

The Q-ONE researchers want to create and identify different quantum states of matter using polariton quantum neural networks.

"Our goal in the Q-ONE research is to harness the strong nonlinear properties of polaritons to build an artificial neural network that can not only identify but eventually create quantum states of light," said Sanvitto.

The Q-ONE research team is not the only group exploring the intersection of quantum states and AI. Since 2010, Professor Barbara Piętka, a physicist at the University of Warsaw, has also been leading a research group focused on exciton-polaritons.

Piętka is currently coordinating a four-year research project called PolArt, supported by the European Innovation Council. Her team is working closely with Sanvitto's team at the CNR in Italy, as well as with other leading researchers in the field from France, Italy, Poland and Singapore.

Neural networks

Their work is specifically looking at ways to use exciton-polaritons with artificial neural networks.

"Exciton-polaritons are our building block," said Piętka. "We are using these particles, known as quasiparticles, to construct big neural networks."

According to Piętka, much of what they are doing has been made possible by work such as Sanvitto's, which has shown that exciton-polaritons can be used to construct advanced neural computation networks – computer networks that mimic the structure and function of the human brain and nervous system.

One possibility explored by the PolArt team is to integrate them onto chips using crystals made from a material called perovskite. Compared to conventional computer chips that emulate neural networks, the polariton-based approach consumes significantly less energy and offers faster processing speeds.

"We can perform a single operation using just a few photons," said Piętka.

Bigger, faster, better

Piętka and her team are working to scale up their polariton-based neural networks to handle increasingly complex tasks.

"We are building progressively larger networks that enable us to tackle more sophisticated challenges," she explains.

This approach could eventually power faster, more efficient large language models. These advanced AI models have been designed perform well while using fewer resources and are becoming increasingly embedded in our daily lives.

"The bigger the network, the more advanced the task it can perform," said Piętka.

Leading role

According to Sanvitto, Europe is currently at the forefront of research into exciton-polaritons.

"The competition is intense – especially with China investing heavily in science – but Europe is leading much of this field at the moment," he said.

Piętka agrees, noting that research into polariton neural networks remains largely concentrated in Europe.

However, this leadership, thanks in part to funding from the EU, especially through the European Research Council and the European Innovation Council, is at risk of fading unless we increase investments in science.

"It's crucial for Europe to continue investing in this research and more generally in fundamental science to stay ahead," said Sanvitto.

Both teams have more work ahead – and high hopes. "The ultimate goal is to develop a network that processes data with maximum speed and efficiency," said Piętka.

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