Physicists predict new state of matter

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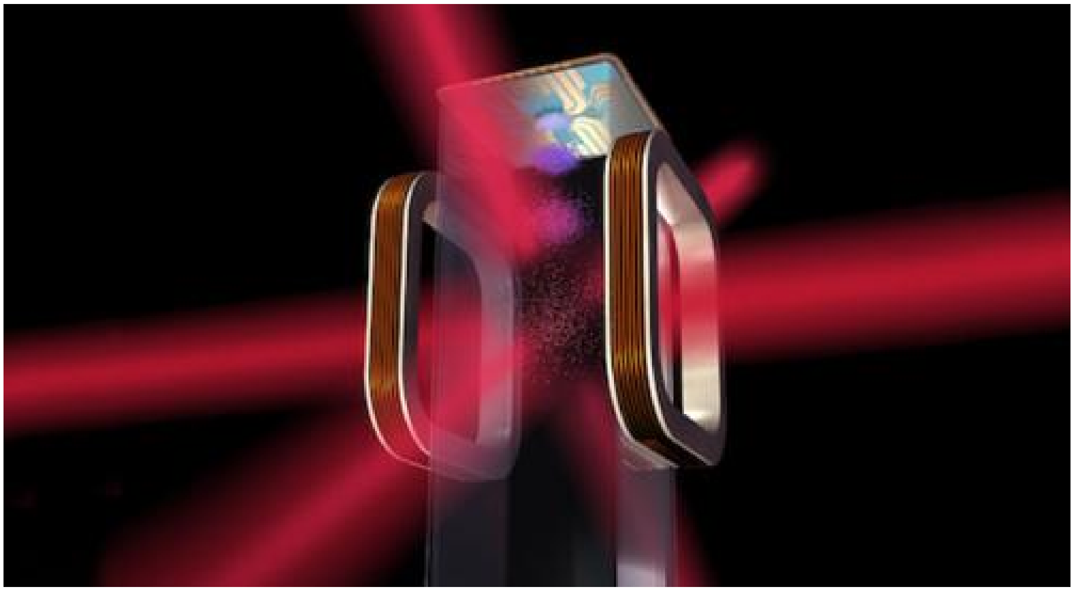

Credit: Moscow Institute of Physics and Technology

A researcher with the Department of Electrodynamics of Complex Systems and Nanophotonics, Alexander Rozhkov, has presented theoretical calculations which indicate the possible existence of fermionic matter in apreviously unknown state – in the form ofaone-dimensional liquid, which cannot be described within the framework of existing models. Details are contained in Rozhkov's article in the journal *Physical Review Letters*.

Rozhkov explained that the one-dimensional liquid state of matter is not necessarily one that can be observed with the naked eye on a macroscopic scale. The term "liquid" should be understood broadly, he said; it applies to models describing multi-particle systems with inter-particle interaction. Such models can be described as quite ordinary objects such as electrons in conductors and more sophisticated objects,such as nanotubes, nanowires or graphene sheets.

"Currently there are two general models of fermionic matter, namely fermionic liquid (for three- and two-dimensional spaces) and Tomonaga-Luttinger liquid (for one-dimensional space)," Rozhkov said. "I showed that it is possible to produce yet another state of one-dimensional matter adjusting certain interactions. This state is similar to both of these models, but cannot be reduced to either. I suggested calling it aquasi-fermionic liquid."

As follows from the proposed name, the newly found matter consists of fermions, which are particles with half-integer spin. (Spin is the quantum characteristic of a particle, while half-integer is an integer plus one-half.) According to the laws of quantum mechanics, the behavior of substances consisting of fermions differs from that of matter consisting of bosons, which are particles with integer spin.

The difference between Bose and fermionic liquids can be illustrated with the example of liquid helium: the atom of a helium-4 isotope has a Bose nucleus, and forms of Bose liquid that undergoes Bose condensation at temperatures below 2.17 Kelvin. A Bose-condensed liquid exhibits superfluidity, for example, it can flow through any crack without meeting any resistance. Helium-3 has a fermion nucleus, and therefore forms afermionic liquid. To turn helium-3 into a superfluid one needs to cool it to 0.0025 Kelvin.

Rozhkov also noted that at low temperatures and in high magnetic fields, fermions begin to behave as if they had no spin, which simplifies their modeling, allowing a researcher to maintain sufficient accuracy.

Preliminary estimates show that the new one-dimensional liquid statecan be obtained using atoms cooled to very low temperatures in magnetic traps. However, it is still too early to consider the practical application of such a system, according to Rozhkov.

"In almost any contemporary paper, both theoretical and experimental, researchers describe the practical application of their discovery, but at this stage I would not hopetoo much for any practical application," Rozhkov said. "I found an exotic mutant different from anything currently known. And whether this can be applied in practice remains to be seen. At this moment I don't think so," said Rozhkov.

Rozhkov added that the group of researchers he works with is also looking into other low-dimensional and multi-particle systems. For example, new results were recently obtained on the possible anti-ferromagnetism in two-layer graphene-AA, and a new description for quantum dots of superconducting material was drafted.

Provided by Moscow Institute of Physics and Technology

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