New method extracts neutrons from superfluid helium

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"There are many applications for ultracold neutrons in fundamental physics," Oliver Zimmer tells *PhysOrg.com*. "And we will find even more applications with a stronger source of ultracold neutrons." Zimmer, a scientist at the Institut Laue Langevin in Grenoble, France, thinks that he and his colleagues may have found a way to tap a better source for ultracold neutrons by extracting them from superfluid helium.

"Right now," Zimmer explains, "the best source provides not more than 50 neutrons per cubic centimeter. When we extract them from superfluid helium, we could get a factor 100 more."

Zimmer led a team of scientists from the physics faculty of the Technical University Munich in Germany, the Laboratory of Nuclear Problems in Russia, the ILL in Grenoble, the Munich research reactor FRM II and the Paul Scherrer Institut in Switzerland in creating a prototype that shows how neutron extraction from superfluid helium works. Their findings are published in *Physical Review Letters* in a piece titled, "Superfluid-Helium Converter for Accumulation and Extraction of Ultracold Neutrons."

"Extracting the neutrons from the superfluid is particularly important for a neutron lifetime measurement because when left in the helium, it can be absorbed by impurities, or get additional energy by scattering, even at a low temperature," Zimmer says. He explains that extraction solves these problems, and it makes the use of ultracold neutrons also more versatile. "More possibilities for broader application of these neutrons open up when you don’t have to do experiments in the superfluid helium.”

The international team is building on an idea that was first suggested 30 years ago. However, a first attempt 20 years ago to extract ultracold neutrons accumulated in helium didn’t work because the scientists involved were using “windows” to try and extract the neutrons horizontally.

Instead, Zimmer and his colleagues switched the direction. “With the windows,” he explains, “the neutrons had to pass through a series of foils to get out. We use a vertical extraction, so the neutrons don’t have to pass through any material. In the earlier experiments, the neutrons were probably being eaten away by absorption in the foil material and by leakage through gaps in the neutron guide.”

Most of the present uses for ultracold neutrons are to do with fundamental physics. Zimmer points out that even though everyday applications with ultracold neutrons are a long way off, experiments with this neutral particle advance the understanding in many areas, including “the synthesis of chemical elements in the early universe during the first minutes after the big bang, or the question why there is so much matter found in the universe but practically no anti-matter. Experiments on the neutron lifetime and the search for the electric dipole moment of the neutron are crucial for this.” He continues, expounding via email: “And when we have a stronger source for these neutrons, we will probably find more applications for ultracold neutrons because their present low number is severely limiting the counting statistical accuracy in any experiment.”

Zimmer insists that this ultracold neutron extraction method adds the missing piece to creating a source for experimental purposes: “First, scientists discovered that this high rate of production in ultracold neutrons is possible. Next, they found that these neutrons can accumulate for a long time, allowing you to get a higher density of them." He emphasizes: "These things have been done in helium. The last missing part is to get the neutrons out of the helium, and our prototype has shown we can do this."

How close are ultracold neutrons to being extracted from superfluid helium for cutting edge experimental purposes? According to Zimmer, not far off. "Our second apparatus currently being constructed will already serve as a facility for this. As a first application, I think within the next two years, we will carry out a compelling neutron lifetime experiment."

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