Scientists reconstruct full state of a quantum liquid

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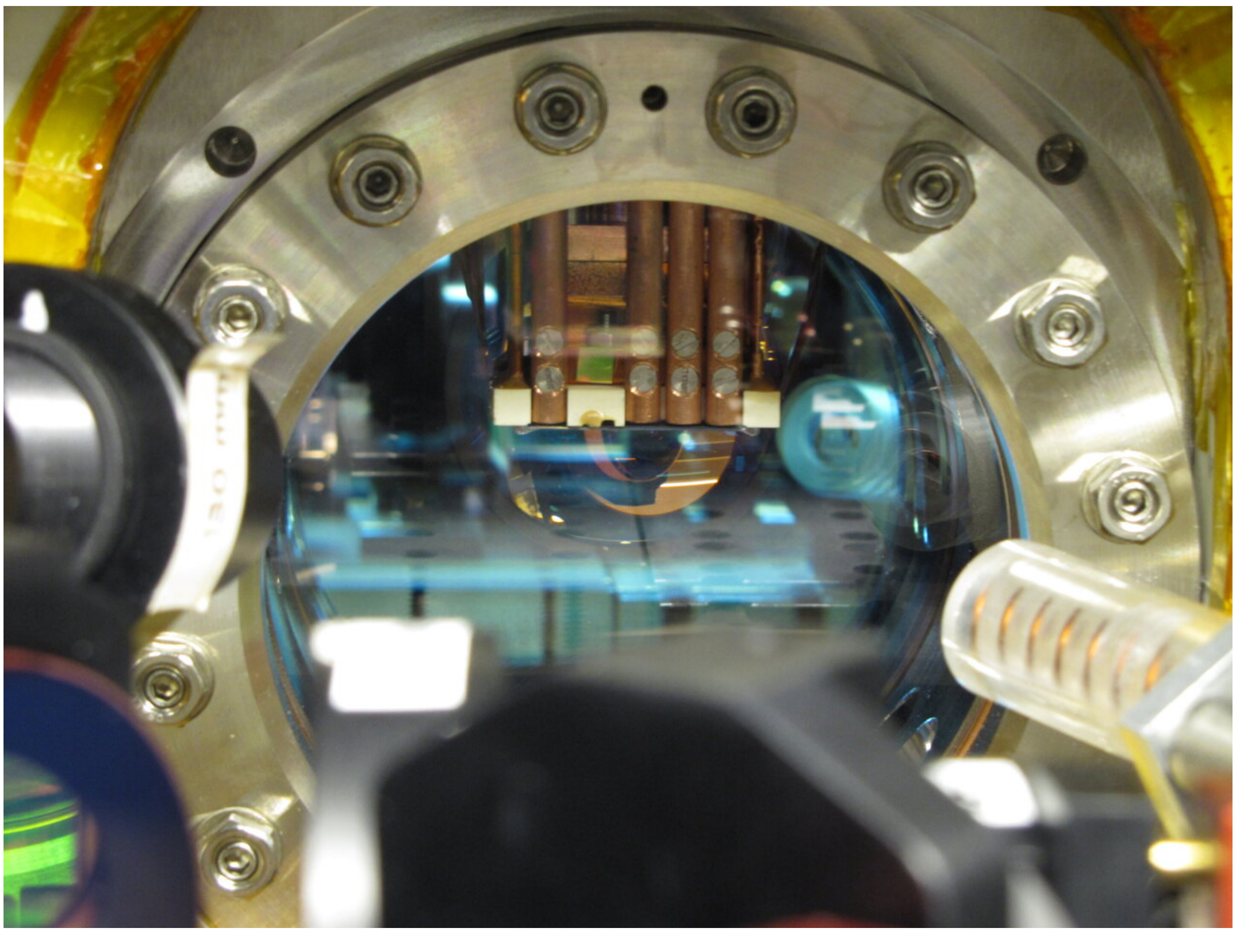

In the heart of the experimental setup sits the Atomchip in a vacuum chamber in Schmiedmayer lab at the Atominstitut of TU Wien in Vienna. Credit: Thomas Schweigler

A team of physicists has illuminated certain properties of quantum systems by observing how their fluctuations spread over time. The research offers an intricate understanding of a complex phenomenon that is foundational to quantum computing—a method that can perform certain calculations significantly more efficiently than conventional computing.

"In an era of quantum computing it's vital to generate a precise characterization of the systems we are building," explains Dries Sels, an assistant professor in New York University's Department of Physics and an author of the paper, which is published in the journal *Nature Physics*. "This work reconstructs the full state of a quantum liquid, consistent with the predictions of a quantum field theory—similar to those that describe the fundamental particles in our universe."

Sels adds that the breakthrough offers promise for technological advancement.

"Quantum computing relies on the ability to generate entanglement between different subsystems, and that's exactly what we can probe with our method," he notes. "The ability to do such precise characterization could also lead to better quantum sensors—another application area of quantum technologies."

The research team, which included scientists from Vienna University of Technology, ETH Zurich, Free University of Berlin, and the Max-Planck Institute of Quantum Optics, performed a tomography of a quantum system—the reconstruction of a specific quantum state with the aim of seeking experimental evidence of a theory.

The studied quantum system consisted of ultracold atoms—slow-moving atoms that make the movement easier to analyze because of their near-zero temperature—trapped on an atom chip.

In their work, the scientists created two "copies" of this quantum system—cigar-shaped clouds of atoms that evolve over time without influencing each other. At different stages of this process, the team performed a series of experiments that revealed the two copies' correlations.

"By constructing an entire history of these correlations, we can infer what is the initial quantum state of the system and extract its properties," explains Sels. "Initially, we have a very strongly coupled quantum liquid, which we split into two so that it evolves as two independent liquids, and then we recombine it to reveal the ripples that are in the liquid.

"It's like watching the ripples in a pond after throwing a rock in it and inferring the properties of the rock, such as its size, shape, and weight."

More information: Mohammadamin Tajik, Verification of the area law of mutual information in a quantum field simulator, *Nature Physics* (2023). DOI: 10.1038/s41567-023-02027-1.
www.nature.com/articles/s41567-023-02027-1

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