Technique characterizes phases of superfluids changing to supersolids and back

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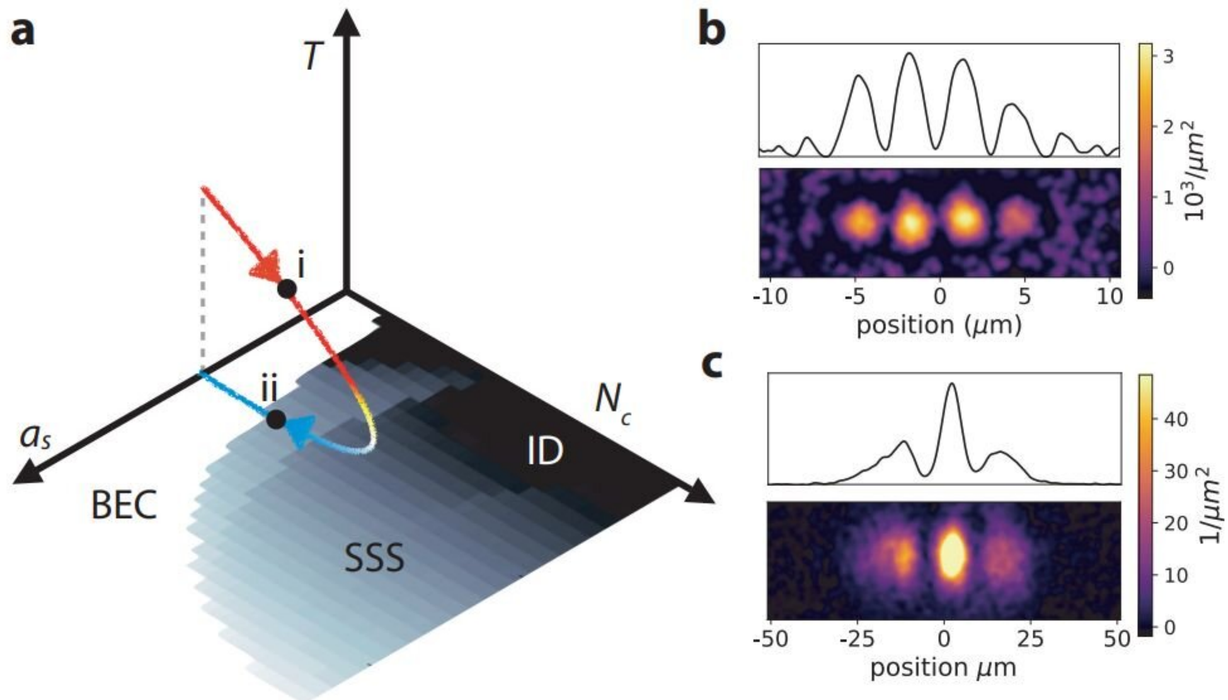

Evaporation trajectory through the finitetemperature phase diagram. Credit: arXiv:2101.06975 [cond-mat.quant-gas]

A team of researchers from the Institute for Quantum Optics and Quantum Information and the University of Innsbruck, has developed a technique for characterizing the phases a superfluid undergoes as it changes to a supersolid and then back again. The group has written a paper describing their technique and have uploaded it to the arXiv preprint server.

Supersolids are materials with characteristics of both solids and liquids—they have spatial ordering, but they also flow. They were first theorized back in 1957, and in more recent times, have been demonstrated with experiments involving converting superfluids to supersolids via Bose-Einstein condensates. And while such experiments have proven useful, they have not allowed researchers to characterize the phases a superfluid goes through as it changes to a supersolid. In this new effort, the researchers took another approach.

The researchers used evaporative cooling. This involved trapping dysprosium atoms in a cloud using lasers, which also formed an optical barrier. Importantly, the atoms in the cloud could escape if they had high enough energy. As they did so, the temperature of the cloud decreased, eventually reaching several hundred degrees Kelvin. The researchers then lowered the height of the barrier, which lowered the temperature in the cloud even more until the atoms left in the cloud formed a supersolid.

To characterize the phase changes, the researchers used both Faraday phase-contrast imaging and time-of-flight imaging. To gain a clear perspective on what was happing, the researchers had to run their experiment repeatedly while varying the rate at which the barrier was lowered. Using the two techniques, the researchers were able to measure the phase change modulation at a timescale of 150 ms. And in so doing, they were also able to see that density modulations associated with a solid phase came first in the process. Then, 40 ms later, characteristics of a superfluid became evident just prior to the cloud forming a supersolid.

The technique also allowed the researchers to characterize the phases involved as the superfluid reverted back to a superfluid. They found it started with restoration of continuous translational symmetry, which brought the system back to a superfluid and then back to a simple cloud. They noted that the superfluid phase lasted longer than the first phase, showing that the processes were not happening at the same time.

More information: Maximilian Sohmen et al, Birth, Life, and Death of a Dipolar Supersolid, *Physical Review Letters* (2021). DOI: 10.1103/PhysRevLett.126.233401 . On *Arxiv*: arxiv.org/abs/2101.06975