Evidence of a Bose glass state?

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"In nano-sized systems many physical properties are greatly altered from those of macroscopic-sized systems. Therefore, study of nano-sized systems, in general, is very important in developing fundamental physics," Keiya Shirahama tells *PhysOrg.com* via email.

Shirahama is a professor at Keio University in Tokyo, Japan. He has been working with superfluidity for 20 years, and is interested in seeing how it works on the nanoscale. Along with Keiichi Yamamoto and Yoshiyuki Shibayama, also at Keio, he says that, "our investigation has revealed a new aspect in the relationship between superfluidity and BEC." The results can be seen in *Physical Review Letters*: "Thermodynamic Evidence for Nanoscale Bose-Einstein Condensation in 4He Confined in Nanoporous Media."

Shirahama explains that, normally, superfluidity is caused when Bose-Einstein condensation (BEC) develops. Particles -- such as those in the liquid helium the Keio University team used in their experiment -- condense into a single quantum state. "It is generally believed that superfluidity and BEC occur at exactly the same temperature."

But this experiment found something different: "Our finding, however, clearly shows that in nano-sized helium superfluidity and BEC occur at different temperatures. This is quite unique," Shirahama says.

The experiment consisted of confining nano-sized helium in a nano-structure composed of porous material. When the team saw superfluidity, they wanted to verify the presence of BEC. "[D]etection of superfluidity does not mean observation of BEC, because the former is dynamical property, while the latter can only be detected by thermodynamic measurement or microscopic means such as neutron scattering. So we decided to measure heat capacity of nano-sized helium."

In order to test the heat capacity, Shirahama and his team used the adiabatic method. They isolated the liquid helium -- and the nano-porous material -- in a vacuum. "We applied some heat by making a current flow to a heater attached to the sample cell, and we measured the increase in temperature. By analyzing the time dependent data, we can obtain heat capacity." These measurements, however, were done several times in order to get a full data set.

Once this was done, Shirahama and his peers discovered that they may have found the first evidence of a Bose glass state. A Bose glass state is a mostly theoretical state in which a disorder causes the localization of BEC. "This has been of great theoretical interest since the seminal work of Professor Matthew Fisher and his coworkers at UC Santa Barbara was published in 1989," Shirahama says. "However, there have been few experimental studies...Our nano-sized helium may be a first example of such Bose glass states."

This pronouncement underscores some of the other uses that the work done at Keio University can have. Fundamentally, extensions of this work could lead to a greater understanding of both superfluidity and BEC development at the nanoscale -- and how it differs from development on larger scales.

"Another possible application of our work is to physics of the so called High-Temperature Superconductors, or HTSC. In HTSC there is a state that shows superconducting properties only in nano-length scale. It is called pseudo-gap state. Our nanoscale BEC state bears a resemblance to the pseudo-gap state in HTSC," Shirahama points out.

There are also practical applications for this work. Shirahama says that down the road the work could have bearing in developing a practical quantum interference device.