Attempting to unlock the secrets of superfluidity

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Ever since superfluidity was discovered in liquid helium, scientists have been searching for its causes, and exploring the different phases of matter in which superflow might exist (gases, liquids and solids).

"The property most closely associated with superfluidity is Bose-Einstein condensation," Henry Glyde tells PhysOrg.com. Superfluidity in solid helium was reported in 2004. "BEC has been observed in liquids and gases, and the question now is: Does it exist in solids? We wanted to look for BEC in this third phase of matter."

Glyde is a scientist at the University of Delaware, but the team on the project to discover Bose-Einstein condensation (BEC) in solid helium-4 consists of scientists from the National Physical Laboratory in Teddington and ISIS at the Rutherford Appleton Laboratory in the United Kingdom, as well as the NIST Center for Neutron Research in Gaithersburg, Maryland, and at the University of Maryland in College Park. The U.S. Department of Energy also plays a major role in providing funding for this research. Diallo, Pearce, Azuah, Kirichek, Taylor and Glyde had their findings published in a Physical Review Letters piece titled "Bose-Einstein Condensation in Solid 4He."

"BEC is a phenomena in which a large fraction of bosons in a system condense in a single quantum state," explains Glyde. "With most BEC, you get superfluidity. This is when there is flow without resistance. We know this exists in gases and liquids. This superfluidity is very useful in many applications, including superconducting. Finding BEC in a solid could answer questions about how superfluidity works, and help us learn more about BEC."

"This work could potentially have impacts on other areas of science," Glyde explains. "If we can understand the origin of the BEC phenomenon, and of superfluidity, we can help clarify the whole connection between superfluidity, superconductivity and BEC. This is especially important in superconductivity, where we have a number of high temperature superconductors, and there is no consensus on how it arises." Glyde pauses before continuing: "Clearly, BEC is playing a role, and when we know what that is, there is the potential for very wide application."

Some of the applications of BEC itself are creating highly coherent beams of atoms that could be used to create precise atomic circuitry. Applications that can arise from understanding the role that BEC plays in superfluidity include electrical wires that carry currents that do not lose energy to resistance and creating very powerful magnets. "Once we understand the mechanism, how it works, than we can begin to tailor it to applications and materials to get the properties we want," enthuses Glyde.

Glyde says that in 2004, Kim and Chan found that superflow does indeed exist in solid helium. "The next step was to measure it for Bose-Einstein condensation," Glyde says. "We wanted to see if BEC was also present in solid helium." The experiment used neutron scattering to measure the solid helium and then Glyde and his coauthors searched the measurement for BEC clues.

And the results? "We did not see any BEC in solid helium," Glyde admits. "But this experiment did set a sort of limit. We didn't use the highest resolution possible." Glyde explains that when higher resolution is used in neutron scattering, fewer counting statistics are available. "We didn’t know what we would see in this first experiment. But we did get a good signal, and we set a precision level.”

This means that further experiments are planned for solid helium. “We plan to increase the resolution, as well as try the experiment at a lower temperature and use a larger solid,” Glyde explains. He also says that BEC might be connected with a defect in the material. Therefore, a future experiment with solid helium will also include a way to enhance defects in the solid.

“We’ve seen BEC in liquid helium using this instrument and made the connection with superfluidity,” Glyde insists. “Now we’re doing it with solid helium. This technique should work on this last phase of matter. And at the increased level, if there’s something there to see, we’ll see it.”

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