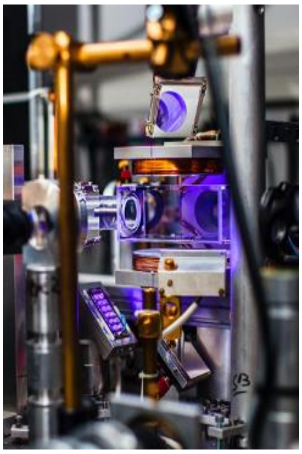
Scientific highlight

In 2020, CCQ reached a major scientific milestone by observing the dynamical emergence of quasiparticles for the first time in a Bosonic quantum environment. This was made possible by the close collaboration between three of the Center's research groups and marks a vital enabling step for future research in CCQ.

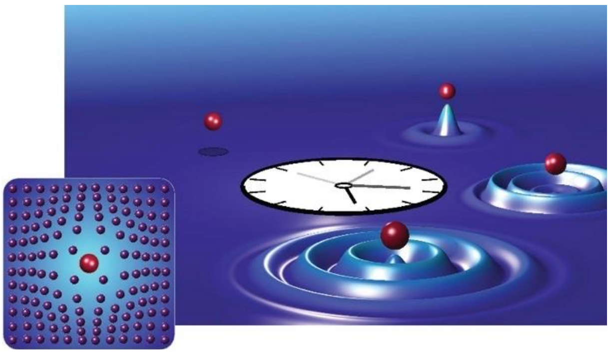


Picture of a part of the Aarhus experiment, where atoms are initially trapped and cooled. (Lars Kruse/AU foto)

Many different particles exist in nature, from elementary particles such as electrons and protons, to compound objects like atoms or molecules that make up the building blocks of matter. But there can also be quasiparticles, which consist of many particles and even contain excitations in collections of trillions of atoms. This bizarre idea has become one of the most fruitful and widely applied concepts in science, as it offers intuitive insights into the inner workings of complex systems. While traces of such quasiparticles have been found in many experiments, observing the process of how they come into existence is difficult in conventional materials and remained an elusive goal.

This has now been accomplished in CCQ. The experiments, reported in a recent issue of Nature Physics*, are based on an exotic state of matter, known as a Bose-Einstein condensate. It can be formed by using laser light and magnetic fields to cool atoms down to extremely low temperatures that are a million times colder than interstellar space. Changing the quantum state of only a few atoms in the condensate, triggers the formation of a special kind of quasiparticle, a so-called Bose polaron. It is known to emerge in more common materials when an electron moves through a crystal of atoms, making the Bose polaron one of the most prominent and fundamental quasiparticles in nature. It can determine the conductivity of a material and is believed to play a vital role for such striking effects, as superconductivity and giant magnetoresistance, which have become indispensable to modern technology.

While most materials only allow for indirect observations of such polarons, the CCQ experiment now makes it possible to deliberately create these quasiparticles and observe their dynamics in real time. This permits to simulate the intricate process of quasiparticle formation, which is not possible on any available computer to date, but can now be done using the ultracold quantum gas as an analogue platform. Indeed, such a quantum simulator has already revealed surprises and sharpened our understanding of quasiparticles tremendously.



An atom can evolve into a quasiparticle by generating excitations in a quantum gas. This process resembles the motion of an electron through a solid as it deforms the underlying crystal. (CCQ, AU.)

Being able to initiate and probe the quantum dynamics of individual quasiparticles represents an important step for CCQ. Based on this achievement, the Center can now explore possibilities beyond the mere experimental observation and aim to manipulate quasiparticles by coupling laser light to individual atoms in a large quantum environment. Realizing and exploring such capabilities may reveal new ways in which the properties of a material may someday be controlled and engineered in a similar fashion.

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* M. Skou *et al.*, *Non-equilibrium quantum dynamics and formation of the Bose polaron*, Nature Phys. (2021). https://doi.org/10.1038/s41567-021-01184-5