The 'molecular octopus': A little brother of 'Schroedinger's cat'

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For the first time – as presented in *Nature Communications* - the quantum behaviour of molecules consisting of more than 400 atoms was demonstrated by quantum physicists based at the University of Vienna in collaboration with chemists from Basel and Delaware.

The international and interdisciplinary team of scientists thus sets a new record in the verification of the quantum properties of nanoparticles. In addition, an important aspect of the famous thought experiment known as 'Schroedinger's cat' is probed. However, due to the particular shape of the chosen molecules the reported experiment could be more fittingly called 'molecular octopus'.

'Schroedinger's cat': simultaneously dead and alive?

Since the beginning of the 20th century, quantum mechanics has been a pillar of modern physics. Still, some of its predictions seem to disagree with our common sense and the observations in our everyday life. This contradiction was brought to the fore 80 years ago by the Austrian physicist Erwin Schroedinger; he wondered whether it was possible to realize states of extreme superposition such as, for example, that of a cat which is simultaneously dead and alive. This experiment has not been realized with actual cats for good reasons. Nevertheless, the successful experiments by Gerlich et al. show that it is possible to reproduce important aspects of this thought experiment with large organic molecules.

'Superposition' demonstrated for larger and larger molecules

In quantum physics, the propagation of massive particles is described by means of matter waves. In a certain sense, this means that the particles loose their classical property of a well-defined position and their quantum wave function can extend simultaneously over a large area. Formally, this state resembles that of a cat that is at the same time dead and alive. In quantum physics this is called a 'superposition'.

Markus Arndt and his team at the University of Vienna tackle the question, up to which degree of complexity the amazing laws of quantum physics still apply. To this end, they investigate the quantum behaviour of molecules of increasing size, in particular their superposition at various positions in an interferometer. The high instability of most organic complexes, however, poses a major challenge in the process.

Tailor-made molecules solve the problem of instability

Many molecules break apart during the preparation of the thermal particle beam. Therefore, a close collaboration with chemists from Switzerland and the United States was crucial for the success of the recent experiments. The team of Marcel Mayor at the University of Basel and Paul J. Fagan from Central Research and Development of DuPont in Wilmington, DE, accomplished the synthesis of massive molecule complexes, which can survive the critical evaporation process.

A new record

The use of specifically synthesized organic molecules consisting of complexes of up to 430 atoms enabled the researchers to demonstrate the quantum wave nature in mass and size regimes that hitherto had been experimentally inaccessible.

These particles are comparable in size, mass and complexity to Insulin molecules and exhibit many features of classical objects. Nevertheless, in the current experiment the tailor-made molecules can exist in a superposition of clearly distinguishable positions and therefore – similar to 'Schroedinger's cat' – in a state that is excluded in classical physics.

More information: Quantum interference of large organic molecules: Stefan Gerlich, Sandra Eibenberger, Mathias Tomandl, Stefan Nimmrichter, Klaus Hornberger, Paul J. Fagan, Jens Tüxen, Marcel Mayor und Markus Arndt. *Nature Communications*, April 5, 2011, doi: 10.1038/ncomms1263

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