

## Press release

**Keep confidential until Feb. 18, 2004, 18:00 London time (BST)**

Vienna, February 13, 2004

### How quantum waves turn classical

#### Macromolecules lose their quantum delocalization with increasing temperature

In its upcoming issue the science journal *Nature* will publish the article:

***Decoherence of matter waves by thermal emission of radiation***

Lucia Hackermüller, Klaus Hornberger, Björn Brezger, Anton Zeilinger and Markus Arndt,  
*Nature* 427 (2004), p. 711.

This contribution shows experimentally how the thermal radiation emanating from a particle renders its quantum behavior unobservable with increasing temperature.

Since the beginnings of quantum theory 100 years ago physicists struggle to understand the interpretation of this theory and its limits of applicability. On the one hand quantum physics describes the behavior of electrons, atoms and molecules with incredible accuracy. On the other hand, this theory leads to predictions about the behavior of everyday objects that are incompatible with our conception of reality and our everyday experience.

In particular, using a special experimental arrangement called an interferometer one can make massive molecules *delocalize* in free flight. The resulting superposition of positional states is often succinctly depicted by saying that the particle is "instantaneously located at remotely separated points in space". In the Vienna experiments this separation is more than 1000 times greater than the extension of the molecule, which is about one nanometer (the millionth part of a millimeter). Although quantum theory is believed to be valid on all scales, such delocalization has never been observed with a macroscopic object – a person just cannot walk at the same time through two doors that are separated by 1000 meters.

Many physicists are searching for the reasons why the weirdness of quantum physics cannot be observed in our everyday world. The Viennese group around Anton Zeilinger and Markus Arndt has been studying this transition from the quantum world to our "classical" everyday physics since a number of years, by doing interference experiments with objects of increasing mass and complexity.

In the present work the physicists investigated the localizing influence of *heat radiation* – the electromagnetic waves (from the visible and the infrared spectrum) emanating from any warm complex object. The experiment used  $C_{70}$  fullerenes – carbon molecules which are sufficiently stable so that they can store much heat and radiate it continuously while flying through the interferometer.

Using intensive laser beams the researchers were able to heat up the molecules in free flight and in a controlled fashion. They observed that at temperatures below  $700^{\circ}\text{C}$  the fullerenes behaved like quanta showing a pronounced delocalization. At higher temperatures the visibility of quantum phenomena decreased continuously until, at temperatures above  $2800^{\circ}\text{C}$ , the molecular flight characteristics could no longer be distinguished from those of small bullets.

The explanation for this observation is provided by quantum theory itself if one accounts for the heat radiation emanating from the body. The emitted light quanta transmit information to the environment about the whereabouts of the molecule thereby localizing the particle. The formal description of the experiment is based on decoherence theory, an increasingly important concept in the context of quantum technologies. The predictions of this theory concerning the heat radiation could now be confirmed for the first time experimentally and quantitatively.

Thermal decoherence is an essential ingredient to the explanation why many effects of quantum physics remain unobservable in the everyday world. If applied to macroscopic bodies it explains why they show classical rather than quantum behavior already at room temperature. Regarding larger molecules (such as proteins or nano-crystals) it is expected that the localizing effects of heat radiation can still be suppressed sufficiently by cooling the molecules.

One may call it an ironic trait of nature that the heat radiation – whose characteristic emission spectrum initiated the quantum hypothesis more than 100 years ago – is an important mechanism that renders the quantum features of larger objects unobservable.