Dean's Representative for Scientific Communication: press.contact@fuw.edu.pl Pasteura 5, 02-093 Warsaw tel. +48 22 5532935 fax +48 22 5532999 email: dziekfiz@fuw.edu.pl www.fuw.edu.pl

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Measuring a Single Molecule Without Disturbing Its State

Researchers at the University of Innsbruck, in collaboration with Dr Marcin Gronowski and Professor Michał Tomza from the Faculty of Physics at the University of Warsaw, have published a paper in Nature describing an innovative method for studying individual molecular ions. They demonstrated that the absorption of a single photon by a single polyatomic $CaOH^+$ ion can be detected using precise quantum techniques.

The researchers developed an approach in which the signal produced by the absorbed photon is not observed directly. Instead, it is detected through the extremely subtle recoil imparted to the $CaOH^+$ molecule. This effect is then amplified using a nonclassical motional state of two ions confined in the same trap, the so-called Schrödinger cat state. Such a state is a quantum superposition of two distinct states of motion and is exceptionally sensitive to even the smallest disturbances. The information about photon absorption is subsequently mapped onto a change in the state of the second ion, an atomic Ca^+ ion, which acts as a highly sensitive detector. The resulting signal is then read out using laser-induced fluorescence. The authors emphasize that this is the first application of this method to detecting the absorption of a single photon by a molecular ion.

The experiment was designed and carried out by Professor Philipp Schindler's group in Innsbruck, while the researchers from the University of Warsaw developed a detailed theoretical description of the properties of the molecular ion. This description was essential for analysing and interpreting the experimental results. The method was used to investigate the O–H bond-stretching vibrations of individual $CaOH^+$ ions excited by femtosecond pulses in the mid-infrared spectral range.

The published results represent an important step towards nondestructive measurements of complex polyatomic molecules and more advanced control of their quantum states. They open up new possibilities for both precision molecular spectroscopy and the development of molecule-based quantum technologies.

Faculty of Physics at the University of Warsaw

Physics and astronomy at the University of Warsaw appeared in 1816 as part of the then Faculty of Philosophy. In 1825, the Astronomical Observatory was established. Currently, the Faculty of Physics at the University of Warsaw consists of the following institutes: Experimental Physics, Theoretical Physics, Geophysics and the Department of Mathematical Methods in Physics. The research covers almost all areas of modern physics on scales from quantum to cosmological. The Faculty's research and teaching staff consists of over 250 academic teachers. About 1350 students and over 150 doctoral students study at the Faculty of Physics UW. The University of Warsaw is among the 200 best universities in the world,

educating in the field of physics according to Shanghai's Global Ranking of Academic Subjects.

SCIENTIFIC PUBLICATION:

Z. Wu, T. Duka, M. Isaza-Monsalve, M. Kautzky, V. Svarc, A. Turci, R. Nardi, M. Gronowski, M. Tomza, B. J. Furey, P. Schindler, "Infrared absorption spectroscopy of a single polyatomic molecular ion", Nature (2026), https://www.nature.com/articles/s41586-026-10915-8

CONTACT:

Prof. dr. hab. Michał Tomza
Faculty of Physics, University of Warsaw
phone +48 22 55 32 972
email: michal.tomza@fuw.edu.pl

GRAPHIC MATERIALS:

FUW260904b_fot01.jpg
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From left: researchers from the Faculty of Physics, University of Warsaw: Prof. Michał Tomza and Dr Marcin Gronowski. Photo: Patrycja Chuchała/UW

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