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Beth Potier
UNH Media Relations

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Contact: Beth Potier
603-862-1566
UNH Media Relations

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Editors and reporters: Bogdan Diaconescu is available at bogdan@einstein.unh.edu or by cell: 603-978-2664. Karsten Pohl is available at karsten.pohl@unh.edu or by cell in Germany: 011-49-170-653-3654.

DURHAM, N.H. – New research led by University of New Hampshire physicists has proved the existence of a new type of electron wave on metal surfaces: the acoustic surface plasmon, which will have implications for developments in nano-optics, high-temperature superconductors, and the fundamental understanding of chemical reactions on surfaces. The research, led by Bogdan Diaconescu and Karsten Pohl of UNH, is published in the July 5 issue of the journal "Nature."

"The existence of this wave means that the electrons on the surfaces of copper, iron, beryllium and other metals behave like water on a lake's surface," says Pohl, associate professor of physics at UNH. "When a stone is thrown into a lake, waves spread radially in all directions. A similar wave can be created by the electrons on a metal surface when they are disturbed, for instance, by light."

Acoustic surface plasmons have long been predicted on merely theoretical grounds, their existence has been extraordinarily difficult to prove experimentally. "Just one year ago, another group of scientists concluded that these waves do not exist," says Diaconescu, a postdoctoral research associate in the Condensed Matter Group of the physics department at UNH. "These researchers have probably not been able to find the acoustic plasmon because the experiments require extreme precision and great patience. One attempt after the other did not show anything if, for example, the surface was not prepared well enough or the detectors were not adjusted precisely enough."

The new experiment that found the acoustic surface plasmon used an extremely precise electron gun, which shoots slow electrons on a specially prepared surface of a beryllium crystal. When the electrons are reflected back from the electron lake on the surface of the metal, some of them lose an amount of energy that corresponds to the excitation of an acoustic plasmon wave. This energy loss could be measured with a detector that was placed in an ultra-high vacuum chamber, together with the beryllium sample. The energy loss is small but corresponds exactly to the theoretical prediction.

Research on metal surfaces is important for the development of new industrial catalysts and for the cleaning the exhaust of factories and cars. As the new plasmons are very likely to play a role in chemical reactions on metal surfaces, theoretical and experimental research will have to take them into account as a new phenomenon in the future. In addition, there are several promising perspectives in nano-microscopy and optical signal processing when the new plasmons are excited directly with light diffracted off very small nano-features. The researchers estimate that, depending on their energy, the waves spread down to a few nanometers (one millionth of a millimeter), and die out after a few femtoseconds (one millionth of a billionth of a second) after they have been created, thus witnessing very fast chemical processes at the atomic scale.

Another potential application is using the waves to carry optical signals along nanometer-wide channels for up to few micrometers and as such allowing the integration of optical signal propagation and processing devices on nanometer-length scales. And one of the most interesting but still very speculative applications of the plasmons relates to high temperature superconductivity. It is known today that the superconductivity happens in two-dimensional sheets in the material, which give rise to the special electron pairs which can move without resistance through the conductor. How this happens precisely is unclear but acoustic plasmons could be part of the explanation. If this is the case, it is a great advantage that it is now possible to study the new acoustic plasmons on surfaces, where they is much easier to probe them than inside the material.

Diaconescu and Pohl received funding for this research from the National Science Foundation.

To download the paper, "Low-energy acoustic plasmons at metal surfaces," click here: http://unh.edu/news/docs/plasmons.pdf

An image is available to download here:
http://davinci.unh.edu/~bogdan/docu/ASP_Be(0001)/ASP-and-SP_Be0001.tif
Description: When a small charge is placed close to a metal surface, standing electron waves are created. These are shown in the lower part of the figure. Another type of waves, called plasmons, are created when the charge is slightly jiggled. These plasmons, which need a rather high energy to be excited, have been known for a long time and are present on the surfaces of all metals. Bogdan Diaconescu and Karsten Pohl with their colleagues have now proved the existence of a new type of plasmon, called "acoustic," which can be excited with any energy (wavelength) and which can therefore be compared to water waves in a lake. The new type of wave is superimposed on the standing waves and is shown in the upper part of the figure.