Taking pictures with protons

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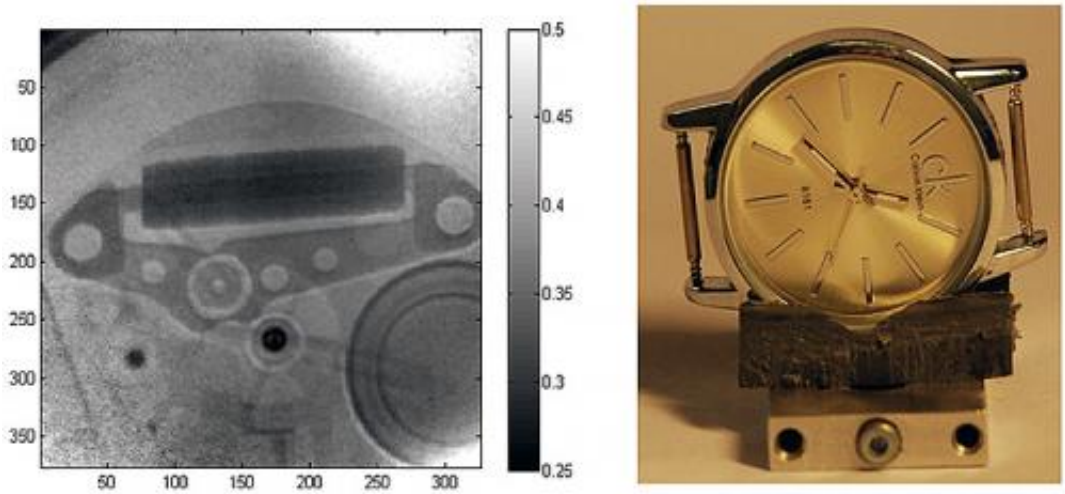

A wristwatch was one of the first items imaged by the new proton radiography system. At left, the inner workings of the mechanism are visible.

A new facility for using protons to take microscopic images has been commissioned at the ring accelerator of the GSI Helmholtzzentrum für Schwerionenforschung GmbH (Helmholtz Centre for Heavy Ion Research) in Darmstadt, Germany.

The proton microscope was developed by an international collaboration consisting of Los Alamos National Laboratory, GSI, the Technical

University Darmstadt, and the Institute for Theoretical and Experimental Physics, Russia.

Protons, like neutrons, are the building blocks of atomic nuclei. Similar to x-rays, they can be used to radiograph objects, generating images of them. Protons are able to penetrate hot dense matter that can't be examined with light or x-rays. This technology, also known as "proton radiography," was originally invented at Los Alamos National Laboratory in the 1990s, but has been adopted around the world. In the future, the technique will be used at an accelerator currently under construction in Darmstadt called the Facility for Antiproton and Ion Research (FAIR) and at the proposed Matter and Radiation In Extremes (MaRIE) facility at Los Alamos.

In their first experiments, researchers used a proton beam accelerated to an energy of 4.5 gigaelectronvolts (more than 98 percent of the speed of light) by the GSI accelerator facility. A special setup of four quadrupole magnets served as optics to magnify objects with the beam. Initially, they radiographed different items like sets of wires with varying sizes and a wristwatch.

Scientists have succeeded in resolving objects and structures down to a size of 30 micrometers or one thousandth of an inch. The GSI facility, called the Proton Microscope for FAIR, or PRIOR, achieved resolutions comparable to existing facilities in the U.S. or Russia. Scientists plan to improve this to a value of up to 10 micrometers in experiments this year. Another goal is the recording of image sequences of moving objects. In experiments scheduled for July 2014 thin wires will be explosively evaporated by a strong electrical discharge, and this "plasma explosion" will be examined with the proton beam.

The study of plasma is of particular interest to scientists because plasma is found in stars or gas planets like Jupiter. This state of matter can be

generated in the laboratory with lasers or strong electrical discharges for short intervals of time. Because protons can penetrate plasmas, they offer unique possibilities to measure the properties of plasma with instruments like PRIOR.

"Combining the experience of this international collaboration has proven to be very productive," said Frank Merrill of the Laboratory's Neutron Science and Technology group and a collaborator on the project. "By joining the enhancements gained from increased proton energy with the gains from proton microscope imaging lenses, a new and remarkable proton radiography capability has been developed."

"Next to the research on events in space, the technique also has very practical applications", said Dmitry Varentsov from GSI's department Plasma Physics and Detectors. "For example one could radiograph running engines or diagnose and treat tumors with it. We want to explore all these opportunities."

The proton microscope will also play an important role at the FAIR accelerator facility. GSI will serve as injector for FAIR. The new FAIR accelerators will provide protons with even higher energies improving the possibilities for experiments. After the completion of FAIR the PRIOR setup will be moved to the new facility. The development of this technique is being extended to the use of electrons and will be utilized for applications at MaRIE.

Provided by Los Alamos National Laboratory