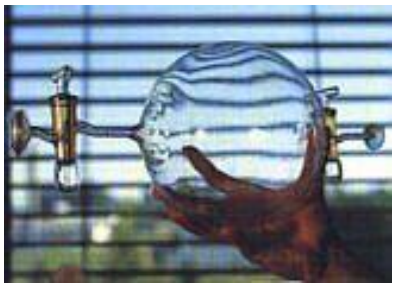
Körber European Science Prize 1998

Magnetic Resonance Tomography with Helium-3

Werner Heil, Michèle Leduc, Ernst W. Otten, Manfred Thelen

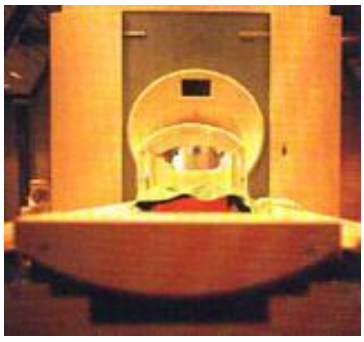
A special variant of the noble gas helium, developed by physicists in the course of fundamental research, helps to ray the lung better than usual and to detect diseases of the respiratory organ earlier.



Helium-3 – a substance which is invisible to the human eye, but has special qualities
(Photo: Friedrun Reinhold)

Images of a breathing lung seen for the first time in such detail, showing normal organ functions and pathological disorders alike. Images that show how air circulates through the bronchi of the lung and from there into finer and finer branches. Images which, most importantly, do not have any of the adverse effects of X-rays or radioactivity and on which pathological changes in the lungs can be identified sooner than ever before. A kind of “magic substance" has made this possible – a very special variant of the noble gas helium which a patient can inhale and which can then be visualized on a magnetic resonance tomogram. For all practical purposes, it provides us with a kind “fingerprint of events" in the lung. The procedure is the result of the extraordinary collaboration of two completely different branches of science, which received the Körber European Science Prize 1998. It all started 10 years ago...

In the fall of 1987, the experimental physicists Professor Ernst W. Otten and Dr. Werner Heil of the University of Mainz Physics Institute went to the Kastler Brossel Laboratory of the École Supérieure in Paris for a semester to work with their colleague Professor Michèle Leduc. Ms. Leduc, a laser specialist, had developed a high-powered laser with a specific wavelength. The two physicists from Mainz were interested in the apparatus and wanted to learn how to produce large amounts of a new substance which they needed for their basic studies in physics, a special form of the noble gas helium, using the laser. The gar was to help the physicists study atomic nuclear structure experimentally.



A conventional MRI scanner was modified for imaging with polarized helium
(Photo: Friedrun Reinhold)

After hydrogen, helium has the simplest structure of the chemical elements. It consists of a positively charged nucleus, around which two negatively charged electrons rotate – similar to the way the planets orbit our sun. The nucleus of normal helium, in turn, consists of two protons – each with a positive charge – and two neutrons, which are electrically neutral. Otten and Heil, however, work with a variant of helium – known as an isotope – which lacks one neutron.

Werner Heil, Ernst W. Otten, Manfred Thelen und Michèle Leduc (from left) (Photo: Friedrun Reinhold)

This variant is called helium-3, i.e., it only has three particles in the nucleus. Imagine the building blocks of an atom to be spheres which revolve around their axis like the planets. The revolving of the parts of an atom is known as “spin" in physics. As Professor Otten explained, the two protons in helium spin in opposite directions, which neutralizes them both. A neutron has spin, too, paired with a magnetic dipole, just as the earth does as it rotates. Since there is only one neutron in helium-3, its spin and magnetic dipole are not neutralized, and hence can be directed, i.e., polarized. It is precisely this effect that was important for the physicists. Using polarized light from Professor Leduc’s special laser, they were able to coordinate the neutrons in helium-3, i.e., to polarize the spin.

Such a gas opens completely new experimental possibilities in physics. Professor Otten: “We bombard the polarized nucleus with electrons using an accelerator. These are deflected from the electromagnetic field of the polarized neutrons, which makes it possible to gain information about the structure of the neutron. Practically speaking, it’s a kind of microscope for atomic particles."

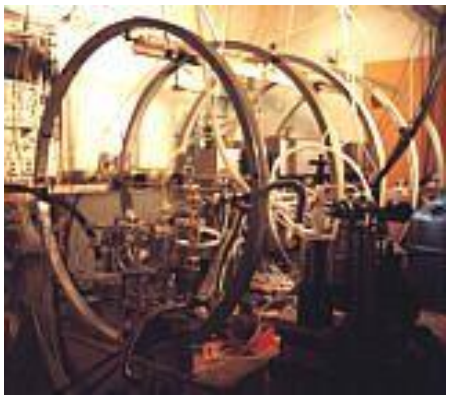
While Otten and Heil, who returned to Mainz in the summer of 1988, were tinkering with techniques for producing spin-polarized helium, the radiologist Professor Manfred Thelen and his co-workers in Mainz were examining patients with conventional magnetic resonance imaging techniques.

Neither of the teams anticipated yet that in just a few years they would be combining their special knowledge into a new procedure. The turning point in the development came when Professor Otten read a publication in the journal Nature in 1994. In this article, American scientists reported on an experiment in which they introduced spin-polarized gas – xenon, in this case – into the lung of a dead mouse so as to visualize the organ. Otten drew the conclusion: “We could reproduce that in the human lung." Shortly thereafter Manfred Thelen’s telephone rang and Ernst Otten was on the line. The physicist reported that he had a substance with highly polarized nuclear spin and asked Thelen if he had any use for it.

Monitors visualize what the MRI scanner registers
(Photo: Friedrun Reinhold)

Thelen recognized the enormous clinical potential immediately. A substance whose nuclei are already polarized and hence do not need to be magnetized in the tomograph would be far superior to water molecules. He enthusiastically agreed to a collaboration and after only 2 months the

technique was employed for the first time. “The results were overwhelming," enthuses Thelen. “For the first time we were able to see respiratory gas distribution in the trachea and lung." At the beginning of 1996 the technique became established in Mainz.



Five coils generate a magnetic field in which helium-3 is polarized with the infrared laser
(Photo: Friedrun Reinhold)

The prize money from the Körber Foundation to the amount of 700,000 DM will be used to further develop the project methodologically and medically. Thelen envisions numerous useful applications for magnetic resonance imaging with helium. For example, the technique can be used for the early diagnosis of many lung diseases, such as chronic obstructive pulmonary disorders (COPD), bronchial asthma, or mucoviscidosis. At the same time the efficacy of treatment and medication can be monitored. If surgery is required for lung tumors or emphysema, the technique can be applied to study the organ’s function beforehand and to decide which parts of the organ could be removed without affecting respiration to too great a degree. And in many cases disorders in respiratory distribution can be recognized before any signs or symptoms have become manifest. Therefore, treatment measures can be initiated before any irrevocable damage has been incurred in the lung.

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