The third category decided in the sixth edition of the awards

Haider, Rose and Urban share the Frontiers of Knowledge Award for inventing the subatomic precision microscope, which opens up new development avenues in nanoscience

- When others had given up on the goal of achieving subatomic precision, the three formed a team, secured funding and, within a decade, had solved the problem and designed a working prototype
- The image obtained through aberration-corrected transmission electron microscopy makes it possible to observe in detail the behaviors of atoms and correlate them with the physical properties of materials
- Several hundred of these microscopes are now in use round the world in materials, nanoelectronic and molecular biology research

Madrid, January 21 2014.- The BBVA Foundation Frontiers of Knowledge Award in the Basic Sciences category goes in this sixth edition to German physicists **Maximilian Haider**, **Harald Rose** and **Knut Urban** for "greatly enhancing the resolving power of electron microscopy by developing aberration-corrected electron optics, a breakthrough enabling subatomic precision."

The three researchers took on an obstacle – the low resolution of electron microscopy – that was barring the way to progress in nanotechnology and was also viewed as largely insurmountable. In fact, state agencies decided to suspend official funding of the field, just as the new laureates were joining forces to find a solution. In less than a decade, they not only had a theoretical solution but also a prototype microscope.

Their technique is the only one capable of exploring materials in the range of one picometer, equal to one hundredth of the diameter of a hydrogen atom – a trillionth of a meter. This enables the motions of each atom and its interactions to be imaged with a hitherto undreamt-of precision.

The nomination was put forward by Achim Bachem, Chairman of the Board of Research Center Jülich and Vice President of the Helmholtz Association of

German National Research Centers. In his view, the laureates' contribution "arrives at a time where the developing nanosciences, in particular physics and chemistry as well as the related nanotechnologies, are calling for high-resolution instrumentation for research, synthesis and validation of technologies."

Imaging atoms to predict properties

Haider, Rose and Urban's microscope fulfils one of physicists' most cherished ambitions: to determine, from the imaging of atoms, which behavior corresponds to a particular property, like conductivity or hardness. And then by emulating this behavior, to achieve the property in question. This, in turn, will facilitate the design of custom-made materials, opening up multiple new applications in electronics and biomedicine.

In the words of the jury's citation, *aberration-corrected transmission electron microscopy* – the name of Haider, Rose and Urban's technique – "in now a key technique in many areas of fundamental and applied science," enabling scientists to "study the consequences of subtle atomic shifts in the properties of materials, and dynamics of interactions at specific atomic sites."

It is now being used in the study of materials like graphene, in new chip miniaturization techniques and in molecular biology, among other fields.

Proof of its importance is the speed with which it has been taken up by the scientific community. Haider, Rose and Urban secured the funding for their work in 1991 and had a prototype going by 1997. In 1998, they published the first captured images in *Nature,* and in 2001 unveiled the technique at a scientific meeting in San Francisco. As early as 2003, the first commercial microscopes had reached the lab, and now there are hundreds deployed around the world – two of them in Spain – despite a price that can run to four million dollars.

The jury stressed how sheer tenacity had got the three men to their goal: "A little over two decades ago, the resolution of the electron microscope used to explore materials (…) appeared to have reached its limits, and, having given up hope, the community's attention shifted elsewhere. The persistence of Maximilian Haider, Harald Rose and Knut Urban over the next decade led to the understanding, development and deployment of aberration-corrected techniques in electron optics."

They also explain in their citation how the three worked together as a team. Rose came up with a novel optical concept that solved the underlying problem, derived from the image distortion caused by lenses – a phenomenon known as spherical aberration; Haider constructed the prototype of an aberration-corrected transmission electron microscope; and Urban developed this prototype into a working platform for the physics of materials.

"A real shock"

In phone conversations yesterday evening, the three laureates declared themselves both grateful and surprised. "I am so happy. I really didn't think we were going to win it," remarked Haider. "It's a really nice feeling," added Urban.

Haider, the founder of a company that commercializes aberration-corrected transmission electron microscopes, stressed that understanding the atomic structure of materials is the first step to improving them, so we can create, for instance, "memory chips for mobile phones."

He also explained the advantages of his technique over tunneling microscopy, which can also image materials at the atomic level, albeit with lower resolution: "Tunneling microscopy allows you to see the atoms in a sample, but only on the surface. We, however, can also have a look through the object. We can see the positions of atoms and observe and measure them with a precision of around 50 picometers. This means we can observe how materials interact on the atomic scale, and deduce their macroscopic properties from their microscopic characteristics."

The new electron microscopes are also useful in biology, to examine viruses for example. And they win out over conventional electron microscopes in being less aggressive with the biological samples.

Asked why they decided to persevere where many of their colleagues had given up, both Haider and Urban say they were convinced at the time that the problem could be cracked. The three scientists, based at different institutions and exploring different directions within materials science, coincided at a conference in 1989 where Rose presented his theoretical approach. "Within five minutes I had an idea for a solution, but it took me another twenty years to catch up with these five minutes," Rose recalls.

"And the idea was a good one," remarks colleague Urban, himself by that time a reputed scientist. The three decided to collaborate and apply for a public grant, unaware that U.S. agencies had just decided to call off the search for a higher-resolution electron microscope. But Rose, who admits to a stubborn streak, was convinced that the goal could be achieved, in that "there was no physical law to prevent it." Determined to press on in the face of rejection, Haider, Rose and Urban approached the Volkswagen Foundation, which, as Urban explains, funds research "that is not necessarily all that close to practical developments."

Urban admits that this was a risky career move, given the dimensions of the challenge; "But if you don't take risks, you don't discover new things!." And he points out the paradox that a project that struggled to find funding "has produced industrial results extremely fast." Adamant that it is the science only that interests him, his name does not figure on many of the patents protecting the technique, though he is "totally on board" with basic research leading to industrial developments. "When I began working with Rose and Haider, all the equipment

purchased by my laboratory came from Japan. European manufacturers had abandoned the sector, because there were no new products, no innovation."

Bio notes

Maximilian Haider was born in 1950 in Freistadt (Austria) and trained in optics before going on to complete a degree course in physics. After obtaining his PhD from the University of Darmstadt (Germany) in 1987, he worked as Head of the Electron Microscopy Group at the European Molecular Biology Laboratory in Heidelberg from 1989 to 1996. One year later, he founded CEOS, a company now specializing in the manufacture of aberration-corrected electron microscopes. From 2007 to 2010, he collaborated on the U.S. Energy Department's TEAM project, contributing additional research on the spherical and chromatic correction of optical aberrations. A professor at Karlsruhe Institute of Technology since 2008, he has authored 110 papers during his research career and has 22 patents to his name.

Harald Rose was born in Bremen (Germany) in 1935 and obtained his PhD on physics from the Technical University of Darmstadt, where he would return as a professor on two occasions: from 1971 to 1975 and 1980 to 2000. A theoretical physicist, he has spent part of his research and teaching career in the United States, where he worked in a series of centers including the Institute of Applied Physics at Cornell University and the national laboratories of Oak Ridge (Tennessee), Argonne (Illinois) and Lawrence Berkeley (California). Appointed senior professor at the University of Ulm in 2009, his scientific production spans around 200 papers and 110 patents.

Knut Urban was born in Stuttgart (Germany) in 1941, and earned his BS and PhD in physics from his hometown university. For 14 years (1972-1986), he headed the High-Voltage Electron Microscopy Group at the Max-Planck-Institute for Metals Research. Today he holds the Chair for Experimental Physics at RWTH Aachen University and is also a research fellow on the JARA project, a joint initiative of this university and the Research Center Jülich, one of the Europe's largest interdisciplinary research centers, where he also led the Institute of Solid State Research and founded the Ernst Ruska Centre (ER-C) for Microscopy and Spectroscopy with Electrons. His research work has also materialized in eight patents and some 390 scientific papers.

The BBVA Foundation Frontiers of Knowledge Awards

The BBVA Foundation promotes, funds and disseminates world-class scientific research and artistic creation, in the conviction that science, culture and knowledge in its broadest sense hold the key to a better future for people. The Foundation designs and implements its programs in partnership with leading scientific and cultural organizations in Spain and abroad, seeking to identify and

prioritize those projects with the power to move forward the frontiers of the known world.

The BBVA Foundation established its Frontiers of Knowledge Awards in 2008 to recognize the authors of outstanding contributions and radical advances in a broad range of scientific and technological areas congruent with the knowledge map of the late 20th and 21st centuries, and others that address central challenges, such as climate change and development cooperation, deserving of greater visibility and recognition. Their **eight categories** include classical areas like *Basic Sciences (Physics, Chemistry and Mathematics)* and *Biomedicine*, and other, more recent areas characteristic of our time, ranging from *Information and Communication Technologies*, *Ecology and Conservation Biology, Climate Change* and *Economics, Finance and Management* to *Development Cooperation* and the innovative realm of artistic creation that is *Contemporary Music*.

The **juries** in each category are made up of leading international experts in their respective fields, whose involvement endorses the rigor of the awards and has indeed been instrumental in consolidating their prestige. The BBVA Foundation is aided in the organization of the awards by the **Spanish National Research Council (CSIC)**, the country's premier multidisciplinary research organization. As well as proposing each jury chair, the CSIC is responsible for appointing the Technical Evaluation Committees that undertake an initial assessment of candidates and draw up a reasoned shortlist for the consideration of the juries.

In the Basic Sciences category, Committee members were Susana Marcos Celestino, Research Professor in the Instituto de Óptica (CSIC); Ricardo García Arganza, Research Professor in the Instituto de Ciencia de Materiales (CSIC); Fernando Rey García, Research Professor in the Instituto de Tecnología Química (CSIC-Universidad Politécnica de Valencia); Carmen García García, Research Professor in the Instituto de Física Corpuscular (CSIC); José Cernicharo Quintanilla, Research Professor in the Centro de Astrobiología (INTA-CSIC); Víctor Muñoz, Research Professor in the Centro Nacional de Biotecnología (CSIC), and Francisco Javier Rojo Marcos, scientific researcher in the Instituto de Investigaciones Químicas (CSIC-University of Seville).

Basic Sciences jury

The jury in this category was chaired by **Theodor W. Hänsch**, Director of the Division of Laser Spectroscopy at the Max Planck Institute of Quantum Optics (Germany) and 2005 Nobel Physics Laureate. The secretary was **Avelino Corma**, Research Professor in the Department of Catalysts, Instituto de Tecnología Química, CSIC-Universidad Politécnica de Valencia (Spain). Remaining members were **Ignacio Cirac,** Director of the Theory Division at the Max Planck Institute of Quantum Optics (Germany); **Trevor Hastie**, John A. Overdeck Professor of Mathematical Sciences at Stanford University (United States); **Nigel Hitchin**, Savilian Professor of Geometry at the University of Oxford (United Kingdom); **Martin Quack,** Professor of

Physical Chemistry and Head of the Molecular Kinetics and Spectroscopy Group at ETH Zurich (Switzerland); and **Sandip Tiwari**, Charles N. Mellowes Professor of Engineering at Cornell University (United States).

Laureates in previous editions

The 2012 award was shared by mathematicians **Ingrid Daubechies** (Belgium) "for her work on wavelets and her leadership in data compression, with a strong impact on technologies supporting efficient audio and video transmission" and **David Mumford** (United States), "for his contributions to algebraic geometry and to the mathematics of computer vision."

The winners in the fourth edition were Swiss astrophysicists **Michel Mayor and Didier Queloz** "for their pathbreaking development of new astronomical instruments and experimental techniques that led to the observation of planets outside the solar system."

The award in the third edition went to **Gabor A. Somorjai**, "for his pioneering experimental and conceptual contributions to the understanding of surface chemistry and catalysis at a microscopic and molecular level." In the second edition, the award was shared by **Richard Zare** of Stanford University (United States) and **Michael Fisher** of the University of Maryland (United States), for their fundamental contributions to describing the world at molecular level. Finally, the winners in the inaugural edition were physicists **Ignacio Cirac** and **Peter Zoller** for their contributions to quantum information science.

UPCOMING AWARD ANNOUNCEMENTS

CATEGORY	DATE
Biomedicine	January 28, 2014
Ecology and Conservation Biology	February 4, 2014
Contemporary Music	February 11, 2014
Economics, Finance and Management	February 18, 2014
Development Cooperation	February 25, 2014