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Dr. Knut Urban
JARA & Peter Gruenberg Institute

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"Pushing the Frontiers - Insight into Transmission Electron Microscopy"

The realization of aberration-corrected electron optics provides the instrumental basis for atomic resolution electron microscopy. But, in contrast to common believe, optical resolution is just one of the pre-requisites of atomic resolution work. The world of atoms is that of quantum physics, and there the term 'image' looses its conventional meaning. The electron waves sent through a crystal in order to provide us with information on the object are subject to quantum-mechanical interaction with the atom potential as described by a Schrödinger form of the Dirac equation for relativistic electrons. The resulting complex wave function at the exit plane of the specimen does not lent itself to an intuitive interpretation. And this holds true even more so, when the additional quite complex phase and amplitude shift behavior of an electron lens are taken into account in addition. In order to understand the images and to push the frontiers of electron microscopy to picometer precision it is unavoidable that the highly non-linear quantum-mechanical imaging process is inverted on a computer. This procedure is hampered by the fact that in quantum-physical dimensions such important imaging parameters as sample thickness or sample tilt are unknown (there is no meter rule in atomic dimensions). The key is therefore an iterative matching of the experimental images on the basis that atomic coordinates and imaging parameters are treated as free parameters. This lecture prepared for a non-specialized public will put this basis of atomic resolution electron microscopy into the right perspective and will elaborate on a number of illustrative examples of recent experimental work [2].

[1] Urban, K. (2009). Is science prepared for atomic resolution electron microscopy? Nature Materials 8, 261-262.

[2] Jia, C. L., Urban, K., Alexe, M., Hesse, D. & Vrejoiu, I. (2011). Direct Observation of Continuous Electric Dipole Rotation in Flux-Closure Domains in Ferroelectric $Pb(Zr,Ti)O_3$, Science 331, 1420-1423.

Professor Knut Urban studied physics at the Technical University of Stuttgart where he also received his Doctor degree in natural sciences 1972. He was a staff scientist at the Max Planck Institute for Metal Research in Stuttgart from 1972 till 1986 when he became Professor for General Materials Properties at the University of Erlangen-Nuremberg. In 1987 he took over a Chair for Experimental Physics at RWTH Aachen University, and he became Director at the Institute for Solid State Research at the Research Center Juelich. In 2004 he founded the Ernst Ruska Centre for Microscopy and Spectroscopy with Electrons at Juelich as an international user center in the field of advanced electron optics.

He retired from his position at Juelich in August 2010. And took over an appointment as JARA Senior (Distinguished) Professor at RWTH Aachen University. He spent extended times as Guest Professor at Bhabha Research Centre, Mumbai/India, at Saclay Research Centre in Paris/France and at Tohoku University Sendai/Japan. Currently he is also affiliated as a Professor to Tsinghua University, Beijing, and Jiaotong University, Xi'an, China.

His research interests range from ultra-high resolution electron optics to the physics of complex alloys, dielectrics, oxide superconductors and Josephson-effect based Terahertz spectroscopy. Together with Max Haider and Harald Rose he developed during the nineties aberration-corrected electron optics and on this basis atomic-resolution electron microscopy.

From 2004 to 2006 he was President of the German Physical Society. Among his awards are the 2007 Karl-Heinz Beckurts Prize for Innovation, the 2007 Von Hippel Award of MRS and the 2008 Honda Prize for Ecotechnology. In 2011 he was awarded the Wolf Prize in Physics.