

# **Curriculum Vitae Rainer Blatt**

Institute of Experimental Physics  
University of Innsbruck and  
Institute of Quantum Optics and Quantum Information  
Austrian Academy of Science

Rainer Blatt (born 8 September 1952) is a German-Austrian experimental physicist. His research centers on the areas of quantum optics and quantum information. He and his team were the first to teleport atoms, to create a „quantum byte“ and a universal quantum simulator.



**BIOGRAPHY** Rainer Blatt graduated in physics from the University of Mainz in 1979. He finished his doctorate in 1981 and worked as research assistant in the team of Günter Werth. In 1982 Blatt received a research grant of the Deutsche Forschungsgemeinschaft (DFG) to go to the Joint Institute for Laboratory Astrophysics (JILA), Boulder, and work with John L. Hall (Nobel Prize winner 2005) for a year. In 1983 he went on to the Freie Universität Berlin, and in the following year joined the working group of Peter E. Toschek at the University of Hamburg. After another stay in the US, Rainer Blatt applied to qualify as a professor by receiving the "venia docendi" in experimental physics in 1988. In the period from 1989 until 1994 he worked as a Heisenberg research fellow at the University of Hamburg and returned several times to JILA in Boulder. In 1994 he was appointed professor of physics at the University of Göttingen and in the following year he was offered a chair in experimental physics at the University of Innsbruck. Since 2003 Blatt has also held the position of Scientific Director at the Institute for Quantum Optics and Quantum Information (IQOQI) of the Austrian Academy of Sciences (ÖAW). Rainer Blatt is married, with three children.

**RESEARCH** Experimental physicist Rainer Blatt has carried out trail-blazing experiments in the fields of precision spectroscopy, quantum metrology and quantum information processing. He works with atoms caught in ion traps, which he manipulates using laser beams. This work is based on joint work with, and suggestions made in the mid-1990s by theorists Ignacio Cirac and Peter Zoller. In 2003 Blatt's group was able to realize for the first time the proposed Cirac-Zoller entangling operation and in 2004, Blatt's working group succeeded for the first time in transferring the quantum information of one atom in a totally controlled manner onto another atom (teleportation). The science journal Nature reported the experiment and gave it pride of place on the cover. Two years later, Rainer Blatt's working group already managed to entangle up to eight atoms in a controlled manner. The creation of this first "quantum byte" (qubyte) was a further step on the way towards a quantum computer. 2011 the team managed to push this record to 14 entangled atoms and since 2018 they routinely work with 20 fully controlled ion qubits. Since 2011 Blatt's group has taken important steps towards successful quantum error correction and succeeded in encoding a logical qubit with seven physical qubits. Since then the group has also realized a universal quantum simulator, performed open systems quantum simulations and for the first time demonstrated a quantum simulation of a lattice gauge theory. Currently, Blatt's team routinely operates with two quantum computers, working towards the implementation of scalable quantum computation and quantum simulation. He is also known for his support of young scientists. Several of his assistants have received prestigious awards and have since been appointed professorships at universities abroad.

**AWARDS** Rainer Blatt has received numerous awards for his achievements in the fields of quantum optics and metrology. He received the International Quantum Communication Award 2016 for his pioneering experiments on quantum information processing. In 2015 he was awarded the John Stewart Bell Prize for Research on Fundamental Issues in Quantum Mechanics and Their Applications, and in 2014 the "Tiroler Landespreis for Science" by the Tyrolean Government. The Australian Academy of Science announced him as the 2013 Frew Fellow. In 2013 he also received the "Humboldt-Forschungspreis". In 2012 the German Physical Society awarded him the "Stern-Gerlach-Medal", in 2011 he was awarded the Science Award for Outstanding Achievements of the Stiftung Südtiroler Sparkasse. Together with Ignacio Cirac he won the Carl Zeiss Research Award (2009). In 2008 he received an „ERC Advanced Grant“ by the European Research Council and the Kardinal Innitzer Award. In 2007 Rainer Blatt and his European project partners were nominated by the European Commission for the Descartes Prize. In 2006 he received the Schrödinger Prize of the Austrian Academy of Sciences. Since 2008 Rainer Blatt is full member of the Austrian Academy of Sciences.

## PERSONAL DATA SHEET

**PERSONAL DETAILS** Otto Rainer Blatt, born 8 September 1952 in Idar-Oberstein, Germany, married, three children, German and Austrian citizenship

**EDUCATION** 1959-1963 Primary school in Idar-Oberstein, Germany  
1963-1971 High school in Idar-Oberstein, Germany  
1971-1973 Military service in Germany  
1973-1979 Studies of physics at Univ. of Mainz, Diploma degree 1979  
1979-1981 Dissertation in physics at Univ. of Mainz, Doctoral degree 1981

**ACADEMIC EDUCATION AND POSITIONS HELD** 1981-1982 Univ. of Mainz (w/ Prof. G. Werth), Research Associate  
1982-1983 Joint Institute of Laboratory Astrophysics (JILA), Boulder, CO, USA, Research fellowship of the Deutsche Forschungsgemeinschaft (DFG) (Dr. J. L. Hall)  
1983-1984 Freie Universität Berlin (w/ Prof. E. Matthias), Research Associate  
1984-1987 University of Hamburg (w/ Prof. P. Toschek), Research Associate  
1988 Habilitation thesis, Hamburg, Privatdozent at University of Hamburg  
1989-1994 University of Hamburg, Heisenberg fellow  
1991-1994 JILA, Boulder, CO, USA, several research visits  
1994-1995 University of Göttingen, Professor of Physics at 3. Physikalisches Institut  
since 1995 University of Innsbruck, Full Professor of Physics  
2000-2013 Director of Institute of Experimental Physics, University of Innsbruck  
since 2000 CEO of Institut für Quanteninformaton Ges.m.b.H, Innsbruck  
since 2001 member of the academic senate of University of Innsbruck  
since 2003 Scientific Director of the newly founded Institute for Quantum Optics and Quantum Information (IQOQI) of the Austrian Academy of Sciences; from 2003-2009 and since 2015 he also has been Managing Director of the IQOQI  
2003-2008 corresponding member of the Austrian Academy of Sciences  
since 2008 full member of the Austrian Academy of Sciences

**AWARDS AND OFFERS** 1989 Heisenberg fellowship award of Deutsche Forschungsgemeinschaft (DFG)  
1995 Offer to become Full Professor of Physics at University of Jena (declined)  
1997 Innovations-Preis by Tiroler Sparkasse  
2006 Schrödinger-Preis of the Austrian Academy of Sciences  
2007 Descartes prize finalist award for QGATES consortium  
2008 ERC Advanced Investigator Grant  
2008 Karl Innitzer Award  
2009 Carl Zeiss Research Award (with Ignacio Cirac)  
2011 Stiftung Südtiroler Sparkasse Science Award  
2012 Stern Gerlach Medal, German Physical Society  
2013 Order of merit by the Region of Tyrol  
2013 Alexander von Humboldt Research Award of the Humboldt Foundation  
2013 2013 Frew Fellow, Australian Academy of Science  
2014 Tiroler Landespreis für Wissenschaft (Science award of the state of Tyrol)  
2015 John Stewart Bell Prize  
2016 Quantum Communication Award

## PROFESSIONAL ACTIVITIES

1997-2003 coopted board member of QEOD of the EPS  
1999 chairman of ICOLS99, International Conference on Laser Spectroscopy  
1999-2003 editorial board member of Journal Phys. B: „Quantum and Semiclassical Optics“  
2000 chairman of IQEC, Nice, International Quantum Electronics Conference  
since 2003 regular board member of the QEOD of the EPS  
2003-2009 board member of the ICQE, International Council of Quantum Electronics  
since 2004 associate editor of “Quantum Information and Computation”  
since 2004 editorial board member of “Quantum Information Processing”  
since 2005 editorial board member of “Applied Physics B (Lasers and Optics)”  
2005-2006 member and chairman (2006) of the Schawlow prize committee of APS  
2006 chairman of 20th ICAP, International Conference on Atomic Physics Memberships  
since 1979 member of the Deutsche Physikalische Gesellschaft (DPG)  
since 1982 member of the American Physical Society (APS), fellow 2003  
since 1996 member of the Austrian Physical Society (ÖPG)  
since 1998 member of the European Physical Society (EPS)  
since 2000 member of the Institute of Physics (IOP, chartered physicist)  
since 2001 member of the Optical Society of America (OSA)  
2004-2010 board member, Quantum Information Processing Interdisciplinary Research Collaboration (QIP IRC), Oxford  
2006-2018 member (and chairman) of the Scientific Advisory Board MPQ, Garching  
since 2009 speaker FWF SFB project F40  
since 2009 member of the Austrian Science Board  
since 2011 member of the Scientific Advisory Committee, ARC Centre of Excellence for Engineered Quantum Systems, Australia  
since 2012 Member of the Council for the Lindau Nobel Laureate Meetings

## RESEARCH FUNDING

1982-1983 DFG research fellowship  
1989-1994 DFG Heisenberg fellowship  
1989-1995 multiple DFG projects on quantum optics and quantum information  
1996-1999 multiple FWF projects on quantum optics with trapped ions  
1996-2003 two EU network projects on quantum information processing  
1999-2008 funding within FWF SFB project F15: “Control and measurement of coherent quantum systems”  
since 2000 funding through Institut für Quanteninformation GmbH, Tirol, Austria  
2000-2007 multiple EU network projects on quantum based information processing  
2003-2009 two ARO (US) projects on scalable quantum information processing  
2005-2009 EU IP project SCALA: “Scalable quantum computing with light and atoms”  
2005-2007 EU ERA-pilot QIST: “Structuring European Research Area within QI ...”  
2005-2006 Accion Integrada: “Quantum feedback with single ions”  
2006-2009 EU STREP project MICROTRAP: “Development of pan-European technology ...”  
2006-2009 EU NoE QUROPE: QIPC NoE  
2008-2017 funding within FWF SFB project F40: “Foundations and Applications of Quantum Science”  
since 2010 EU network AQUOTE: „Atomic Quantum Technologies“  
since 2010 ARO (US) project: „Multi-qubit coherent operations with trapped ions“  
since 2011 FWF project: „Single Photon Interactions (SINPHONIA)“  
since 2013 FWF project: „Complex Quantum Simulations (COMQUATS)“  
since 2013 Commercial Applications for RF-Arrays of Traps (CARAT)  
since 2013 Quantum Simulations in Arbitrary Ion Lattices (Q-Sail)  
since 2013 Quantum Engineered stats for optical clocks and atomic sensors  
since 2013 Simulations and Interfaces with Quantum Systems (SIQS)  
since 2014 Certified Topological quantum computation (CETO)  
since 2016 Encoded Qubit Alive (eQual)

## SCIENTIFIC PROFILE

After graduating in 1981 at the University of Mainz, Rainer Blatt joined the group of Dr. John L. Hall (Nobel-laureate of 2005) in 1982 where he started a project on the cooling of a beam of Sodium atoms. At that time this was a very hot topic, since first atomic beam cooling results were presented just in 1981 by the group of W. Phillips (Nobel laureate of 1998). Together with W. Ertmer (now Hannover) Blatt was successful in achieving atomic beam cooling with a frequency chirp technique that for the first time allowed them to stop atoms out of a beam. After returning to Germany he started to work at the University of Hamburg (w/ P. Toschek and W. Neuhauser) with single trapped ions and they were among the first to see quantum jumps in single atoms, a technique now routinely used in quantum information processing and for metrology purposes. With this work he did his Habilitation thesis in 1988 and continued there as a Heisenberg fellow, using the freedom that comes with this fellowship to further work with single trapped  $Ba^+$  and  $Yb^+$  ions on fundamental quantum optics experiments and for an implementation of a frequency standard.

Throughout his work, Rainer Blatt has learned from the very best experimentalists and thus has always tried to tackle hard experimental problems that seemed almost impossible at first. While experiments with single trapped ions take quite some time to be mastered, they provide some of the cleanest and most fundamental subjects for basic research, which has never ceased to fascinate him. Thus, when the discussions about quantum computers started around 1994, Blatt had the luck and the opportunity to work with his longstanding colleague P. Zoller (at that time with CU, Boulder, CO) and I. Cirac (then in Madrid, Innsbruck and Boulder) who proposed trapped ions for quantum computation and immediately started their quantum computer project at his new position at the University of Göttingen, Germany. Therefore, they were among the first to start implementing experiments toward quantum information processing with trapped ions, ideas initially developed by P. Zoller and I. Cirac.

This work gained momentum with the new position at University of Innsbruck in 1995 where now P. Zoller and (in 1996) I. Cirac worked as the inventors of the ion trap quantum computer. While such experiments are quite demanding, together with a number of highly talented students and assistants they took on that challenge and developed the technology steadily in the 1990s, and achieved milestones as the side-band cooling (1999) and first quantum operations (2001-2002). Together with their colleagues P. Zoller, I. Cirac and A. Zeilinger (until 1999, then R. Grimm since 2000), they were able to create an environment and an atmosphere that enabled them to attract and inspire students, postdocs and visitors and in essence put Innsbruck on the quantum map. The hard experimental work paid off and ever since our quantum information group belongs to the finest and most experienced groups worldwide. Together with their competing group of David Wineland at NIST, Boulder, CO, they have been able to lead quantum information science with trapped ions worldwide.

Most remarkable milestones throughout the last years where the first implementation of the Deutsch-Jozsa algorithm, of the Cirac-Zoller gate operation (2003), teleportation of the state of an atom (2004), the creation of W and GHZ states on demand (2004), the first creation of a quantum byte (2005), the application of entanglement for precision quantum metrology (2006), a Mølmer-Sørensen-type gate operation entangling ions with a fidelity of 99% (2008), the realization of the quantum Toffoli gate and the state-independent experimental test of quantum contextuality (2009), the quantum simulation of the Dirac equation (2010), the creation of trapped-ion antennae for the transmission of quantum information, 14-qubit entanglement, repetitive quantum error correction, and the realization of an universal digital quantum simulator with trapped ions (2011), the construction of an efficient and tunable interface for quantum networks (2012), the simulation of quasiparticles and of a topologically encoded 7-qubit quantum register (2014), the first quantum simulation of lattice gauge theories and the realization of an efficient implementation of Shor's algorithm in an ion-trap based quantum computer (2016), observation of entangled states of a fully controlled 20-qubit system and quantum chemistry calculations on a trapped-ion quantum simulator (2018).

## SCIENTIFIC PROFILE

All this led the Austrian Academy of Sciences to consider the joint application to establish an Academy Institute dedicated to doing research in the area of Quantum Optics and Quantum Information. Eventually, this institute was founded in November 2003 and a new building was planned and set up in record time. Most of the scientific planning for the building, the laboratories and the experimental work plan was done by Blatt and his colleague R. Grimm. They were able to get the required financial support from the federal and local governments and the city of Innsbruck. Thus, in 2005 the new laboratories were ready and since then they have been able to attract even more visitors, guests and long-term researchers to Innsbruck and to collaborate with them. All in all, in the field of quantum optics and quantum information, there are more than 100 scientists working at the university and the academy institute who, of course, collaborate very closely. Innsbruck has become a world-wide centre for quantum optics and in particular, for quantum information research.

Throughout the last years, about 30 PhD students and more than 40 diploma students have graduated from Blatt's group. He has had the pleasure to attract more than 30 postdocs in the past years and most important, some of the finest young scientists became assistants in his group where they have the chance to work similar to an assistant professor, leading sub-projects and supervising their own students. Already seven of the first assistants have accomplished their Habilitation work and hold now professorships in Germany, the US and in Spain. Aside from several awards for PhD students, two of his former assistants received the prestigious Rudolf-Kaiser prize (about 25 k€ each) for their work. Three of the assistants have received an ERC Starting Grant (1.5 M€ each), one has received an ERC Advanced Grant, six assistants have won the prestigious START award of the Austrian Federal Ministry for Education and Culture (1.2 M€ each).

The scientific work of the entire group is highly appreciated and they receive routinely more than twenty invitations to international meetings every year. In 2006, Blatt was awarded the highest Austrian research prize, the Erwin-Schrödinger award of the Austrian Academy of Sciences, for quantum information research. Aside from the research activities, he teaches at the University of Innsbruck, mostly introductory courses on atomic physics, quantum physics as well as solid state physics and advanced courses on experimental quantum optics. Moreover, Blatt is involved in giving talks for the broader public, especially for teachers and high school students and together with his colleagues they are strongly interested in disseminating quantum information. For this, P. Zoller and R. Blatt are supported by the association of Tyrolean industrialists who finance a company (Institute for Quantum Information Ges.m.b.H.). With this support, they can hire staff and students, invite guests and quite generally foster the connections between university and industry. On the European stage, the IQOQI serves as centre for European Research Area (ERA) and other networking activities; they were especially involved in the formulation of the European "roadmap" towards Quantum Information Processing and Communication (QIPC) and a vital part of the €1 billion flagship initiative on quantum technologies (QT), which aims at putting Europe at the forefront of the second quantum revolution, bringing transformative advances to science, industry and society. Rainer Blatt is a member of the Commission Expert Group on QT.