
Curriculum Vitae: **Andreas J. Heinrich**

Heinrich is a world-leading researcher in the field of quantum-coherent nanoscience with a focus on quantum spins on surfaces. He pioneered spin excitation and single-atom spin resonance spectroscopy with scanning tunneling microscopes – methods that have provided high-resolution access to the quantum states of atoms and nanostructures on surfaces. This has culminated in the demonstration of a qubit platform made of atomic spins on a surface (Science 2023) and quantum sensing with atomic-scale spatial resolution (under review 2024). Heinrich is fascinated by the world of atoms and nanostructures, built with atomic-scale precision, and educates the public on nanoscience as demonstrated by the 2013 release of the movie “A Boy and his Atom”.

A native of Germany, Heinrich received his PhD in 1998 from the University of Göttingen and then joined the research group of Dr. Donald Eigler at IBM Almaden as a postdoc. Heinrich spent 18 years in IBM Research, which uniquely positioned him to bridge the needs of industrial research and the academic world. Heinrich became a distinguished professor of Ewha Womans University in Seoul, South Korea in August 2016 and started the Center for Quantum Nanoscience (QNS) of the Institute for Basic Science (IBS) in January 2017. QNS is operating several state-of-the-art STM and AFM systems and combines this atomic-scale approach with ensemble-averaging techniques such as x-ray spectroscopy and ensemble ESR with a surface-science focus. These experimental techniques are rounded off with synthetic chemistry and a well-rounded theory team. QNS’s motto is “engineering the quantum future”. On the goal-oriented side, this implies a focus on developing new qubit platforms for quantum computation with spins on surfaces. On the exploratory side of our research agenda, we continue the decades’ long quest of exploring how the world works on the atomic length scale.

Academic Degrees

1998	PhD Physics, University of Göttingen, Germany
1994	Masters (Diplom), University of Göttingen, Germany

Employment

2017 - current	Director of Center for Quantum Nanoscience (QNS) of Institute of Basic Science (IBS)
2016 - current	Distinguished Professor at Ewha Womans University

2005 - 2016	Research Staff Member at IBM Almaden Group leader on scanning probe microscopy and magnetic nanostructures on surfaces
2001 - 2004	Researcher / Engineer at IBM Almaden
1998 - 2001	Postdoc at IBM Almaden with Dr. Donald M. Eigler
1994 - 1998	Research Assistant, University of Göttingen (Prof. Rainer G. Ulbrich and Dr. Martin Wenderoth, Supervisors)

Scientific Impact

Quantum Spins on Surfaces

In 2004, Heinrich created the field of atomic scale spectroscopy of individual magnetic atoms on surfaces and helped to grow this topic to international prominence in the following years.

Key milestones:

- Design and construction of a novel scanning tunneling microscope for temperatures below 1 Kelvin and high magnetic fields – specifically built to investigate single-atom electron loss spectroscopy on magnetic atoms. This microscope was the first of its kind in the world.
- First to achieve single atom spin-excitation spectroscopy with his STM measurement of the Zeeman splitting of individual atoms on surfaces (*Science* 2004).
- Groundbreaking achievements with spin excitation spectroscopy include the measurement of single atom magnetic anisotropy (*Science* 2007), spin-spin coupling in engineered chains (*Science* 2006), and the Kondo effect (*Nature Physics* 2008).
- Developed nanosecond scanning tunneling microscopy (STM) (*Science* 2010), an improvement in time resolution of 100,000 times.
- Demonstrated atomic-scale magnetic data storage (*Science* 2012 and *Nature* 2017), which led to world-wide coverage in scientific and general media.
- Combined spin excitation spectroscopy with ensemble averaging x-ray absorption spectroscopy (*Science* 2014).

- Developed single-atom electron spin resonance ESR-STM (*Science* 2015) which can be used as quantum sensor on clean surfaces to measure nuclear spins and neighboring atoms and molecules (*Science* 2018, *Nature Nanotechnology* 2017).
- Implemented pulsed spin resonance in ESR-STM to coherently manipulate single spins on a surface and demonstrate Ramsey and spin echo sequence to measure quantum coherence (*Science* 2019).
- Extended ESR-STM from single atoms to single molecules, enabling the much broader reach of synthetic chemistry to tailor the quantum properties of spins on surfaces (*Nature Chemistry* 2021).
- Created a new qubit platform atom by atom and successfully demonstrated the ability to control multiple qubits simultaneously, enabling the application of single-, two-, and three-qubit gates (*Science* 2023)
- Heinrich has given 28 plenary lectures and over 90 invited talks at major international conferences. He has given about 120 seminar and colloquium talks at universities and international research institutions.

Precise atom manipulation

In addition to these groundbreaking accomplishments, Heinrich has built on the pioneering achievements of Dr. D.M. Eigler in the area of precise atom manipulation on surfaces by constructing model devices for possible future applications in data storage and computation.

Key milestones:

- Development of a technique to control the motion of CO molecules on surfaces. Application of such processes to perform arbitrary logic operations via mechanical computations (*Science* 2002).
- Construction of a state-of-the-art low-temperature atomic force microscope in close collaboration with Professor Franz Giessibl (Regensburg) with atomic resolution. This work sparked an increasing interest in low-temperature AFM with atoms and small molecules in the following decade.
- Published a fundamentally new technique for measuring the atomic forces that act on atoms and molecules on surfaces. Applied this technique to measure the force it takes to move atoms and molecules on surfaces (*Science* 2008).
- Construction of complex nanostructures for atomic-scale magnetic data storage (see above, *Science* 2012).

- Creation of the World's smallest movie 'A Boy and His Atom' with about 10,000 precise atom moves (YouTube 2013).

Recognition

Awards and plenary lectures

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| 2023 | Physics of Magnetism 2023 (PM'23), Poland:
'Towards quantum computing with spins on surfaces' |
| 2023 | Humboldt Research Award by the Humboldt Foundation, Germany:
'The pioneer of the field of quantum spins on surfaces' |
| 2022 | 22nd International Vacuum Congress (IVC-22), Japan:
'Electron Spin Resonance of Individual Spins on a Surface' |
| 2021 | Plenary lecture at Karl Friedrich Bonhoeffer Award Lecture at Max
Planck Institute for Biophysical Chemistry, Göttingen, Germany:
'Quantum Spins on Surfaces' |
| 2021 | Plenary lecture at ElecMol20 Conference, virtual:
'Electron Spin Resonance of Individual Atomic and Molecular Spins on
a Surface' |
| 2021 | Plenary lecture at the 9th International Symposium on Surface
Science (ISSS-9), virtual:
Investigating the Quantum Magnetism of Atoms on Surfaces with
Scanning Tunneling Microscopy |
| 2021 | Keynote speech at Swiss Nano Convention 2021, virtual:
'Quantum Spins on Surfaces: The Scanning Probe Approach' |
| 2021 | International fellowship of the Japan Society of Vacuum and Surface
Science (JVSS) |
| 2020 | The Heinrich Rohrer Medal (Grand Medal) by the Japan Society of
Vacuum and Surface Science, Japan:
'Ground-breaking development of scanning tunneling microscope
methods to study the spin properties of magnetic atoms on surfaces' |
| 2019 | Plenary lecture at The 11th International Conference on Advanced
Materials and Devices (ICAMD 2019), Jeju, Korea:
'Quantum Nanoscience: Atoms on Surfaces' |

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- 2019 Plenary lecture at the 2019 China National Electron Microscopy Conference of the Chinese Academy of Sciences, Hefei, China: 'Quantum Nanoscience: Spins on Surfaces'
- 2019 Invited talk at the Seoul Forum 2019, Seoul, Korea: 'From Quantum Nanoscience to 'The Boy and His Atom''
- 2018 100 Excellent National R&D Performance in 2018 and Ministerial Citation from the Ministry of Science and ICT, Republic of Korea
- 2018 Plenary lecture at the European Magnetic Resonance Meeting (EUROMAR 2018), Nantes, France: 'The Quantum Science of Atoms on Surfaces – Single Spin Electron Spin Resonance'
- 2018 Foresight Institute 2018 Feynman Prize – Experimental
For advances in manipulating atoms and small molecules on surfaces and employing them for data storage and computation.
- 2018 Keithley Award for Advances in Measurement Science from the American Physical Society:
For the design and construction of a series of highly sophisticated scanning probe instruments, including the development of inelastic electron tunneling spectroscopy at the single atom and single spin limit, that provided many breakthroughs in the science of measurement.
- 2017 Awarded directorship of the Center for Quantum Nanoscience as part of the Institute for Basic Science. This award provides significant long-term funding for basic science research.
- 2017 Plenary lecture at the 50th Annual International Meeting of the ESR Spectroscopy Group of the Royal Society of Chemistry, Oxford, United Kingdom: 'Electron Spin Resonance of single atoms on a surface'
- 2017 Plenary lecture at Korean Physical Society Fall Meeting, Gyeongju, Korea: 'The Quantum Properties of Magnetic Atoms on Surfaces'
- 2016 Distinguished Fellowship under the Chinese Academy of Science President's International Fellowship Initiative
- 2015 Fellow of the American Association for the Advancement of Science: For the development of scanning tunneling microscope methods to study individual magnetic atoms by spin-excitation spectroscopy and nanosecond pump-probe techniques.
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- 2015 Plenary lecture at the International Vacuum Science Congress 20 (IVC-20) and ICN+T 2016, Busan, Korea:
'Electron Spin Resonance of single atoms on a surface'
- 2014 Outstanding Technical Achievement Award, IBM:
For the creation of the scientific movie 'A Boy and his Atom' and the resulting public engagement with IBM basic science research.
- 2014 Plenary lecture at Dutch Physical Society Meeting, Veldhoven, The Netherlands:
'A Brief History of Atom Manipulation'.
- 2012 Fellow of the American Physical Society:
For the development of spin excitation spectroscopy and nanosecond STM.
- 2012 Plenary lecture at International Conference on Nanoscale Science and Technology (ICNT 2012), Paris, France:
'Quantum or Classic: An atomic-scale perspective on magnetism on surfaces'.
- 2011 Best of IBM Award (top 100 annual contributors out of 430,000 employees):
For Atomic Scale Manipulation and Chemistry on Surfaces.
- 2011 Corporate Award, IBM:
For Atomic Scale Manipulation and Chemistry on Surfaces.
- 2011 Plenary lecture at German Physical Society Meeting, Dresden, Germany:
'Probing the energetics and dynamics of individual atomic spins on surfaces'.
- 2010 Outstanding Technical Achievement Award, IBM:
For the development of a technique for measuring atomic forces during the manipulation of atoms on surfaces.
- 2010 Plenary lecture at International Vacuum Congress (IVC 18), Beijing, China:
'Nanosecond STM and quantum tunneling of magnetization'.
- 2009 Zhong-Guan Cun Forum at Institute of Physics, Chinese Academy of Sciences:
'An atomic-scale look at magnetic nanostructures on surfaces'.
- 2007 Outstanding Innovation Award, IBM:
For the development of a scanning tunneling microscope for the
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- investigation and atomic-scale construction of magnetic nanostructures.
- 2006 Plenary lecture at California Section of the American Physical Society, Long Beach, CA, USA:
'Magnetism Revisited on the Atomic Scale'.
- 2003 Research Division Award, IBM:
For the development of molecule cascades, a novel concept for information processing on the atomic scale.
- 2005 Plenary lecture at International Conference on Scanning Probe Microscopy and Related Techniques (SPM'13), Sapporo, Japan:
'Inelastic STM spectroscopy at Low Temperatures'.
- 2005 Plenary lecture at 32nd Annual Meeting of Canadian Microscopy Society, Hamilton, Canada:
'Scanning Tunneling Microscopy'.
- 2003 Plenary lecture at International Conference on Scanning Probe Microscopy and Related Techniques (SPM'12), Eindhoven, The Netherlands:
'Molecule Cascades: Concepts and Applications'.
- 2003 Plenary lecture at Spring Meeting of German Physical Society, Dresden, Germany:
'The STM as a Hand in the Nanoworld'.
- 1998 Feodor Lynen scholarship, the Alexander von Humboldt-Foundation, Germany:
Funded postdoctoral research at IBM.

List of Organized Workshops and Conferences

- 2023 The 2nd IBS Conference on Quantum Nanoscience, Seoul, Korea
- 2019 The 1st IBS Conference on Quantum Nanoscience, Seoul, Korea
- 2019 Quantum Spins at the Nanoscale – Recent Theoretical Advances, Seoul, Korea
- 2018 Workshop on Advanced Scanning Probe Microscopy(ASPM II)
2017, Busan, Korea
- 2017 Workshop on Advanced Scanning Probe Microscopy(ASPM I)
2017, Gyeonggi-Do, Korea
- 2016 Workshop on Experimental Physics, Seoul, Korea

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| 2016 | Theory Workshop on Solid State Physics, Seoul, Korea |
| 2009 | Winter Conference at the Aspen Center for Physics 'Unifying themes in condensed matter', Aspen, CO, USA |

Organizing committees of national and international conferences

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| 2019 - present | International Organizing Committee of the 9th International Symposium on Surface Science(ISSS-9) by the Japan Society of Vacuum and Surface Science (JVSS), Takamatsu, Japan |
| 2018 | Organizing Committee of the Second Spins on Surfaces(SoS II) Workshop, San Sebastian, Spain |

Scientific Advisory Boards

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| 2023 | Scientific Advisory Board of University of Basel, Basel, Switzerland |
| 2012 - 2020 | Scientific Advisory Board of Max Planck Institute for Solid State Research, Stuttgart, Germany. |
| 2014 - 2016 | Scientific Advisory Board of Center for Low-dimensional electronic materials (CALDES) of Institute of Basic Science (IBS), Pohang, Republic of Korea. |

Membership of Scientific Societies

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| 2017 - present | Membership of the Korean Physical Society |
| 1993 - present | Membership of the German Physical Society |
| 1999 - present | Membership of the American Physical Society |
| 2001 - present | Membership of the American Association for the Advancement of Science (AAAS) |