# Dr. Axel U. J. Lode

**Personal details:**
Dr. Axel U. J. Lode
Pronouns: he/him

**Contact**
email: axel.lode@physik.
uni-freiburg.de
web:
http://ultracold.org/axel

Condensed Matter Theory
Institute of Physics
University of Freiburg
79104 Freiburg
Germany

## Junior group leader for ultracold atomic systems

**Mission statement**  My aim is to contribute to the pivotal contemporary technological advances in the field of quantum science, technology, and engineering. To this end, driven by curiosity for fundamental quantum physics and the concepts behind many-body dynamics, I strive to develop, apply, teach, and provide reliable and directly applicable computational and machine learning tools for modeling quantum states, quantum devices, and analog quantum simulators made of ultracold atoms as well as their readout in quantum measurements.

## Education

**2009–2013: Ph.D. in physics**
- Thesis: *Tunneling Dynamics in Open Ultracold Bosonic Systems*
- Group: Theoretical Chemistry, Heidelberg University, Germany
- Supervisor: Prof. Lorenz S. Cederbaum
- Date of defense: 3rd of June, 2013
- Grade: Magna cum laude (Very good)

**2002–2008: Diploma in physics**
- Thesis: *Exact Dynamics of Few-Boson-Systems decaying by Tunneling through a Barrier*
- Group: Theoretical Chemistry, Heidelberg University, Germany
- Supervisor: Prof. Lorenz S. Cederbaum

## Employment record

**since 10/2019: Junior group leader**
- Project: *Numerical Models for Many-Body Physics and Single-Shot Images*
- Host group/institution: Prof. Michael Thoss, Theoretical Condensed Matter Physics Group, Institute of Physics, University of Freiburg, Germany
- Supervision of Master's students
- PhD student Miriam Büttner (since 03/2020)

**01/2019–09/2019: Principal Investigator**
- Project: *Numerical Models for Many-Body Physics and Single-Shot Images*
- Host group/institution: Prof. Jörg Schmiedmayer, Prof. Norbert J. Mauser, Wolfgang Pauli Institute and Atominstitut, Vienna University (of Technology), Vienna, Austria

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## 7/2017–12/2018: Senior Postdoc at the Wolfgang Pauli Institute and Atominstitut, Vienna University (of Technology), Austria

- Research: *Numerical modeling of Schrödinger dynamics in direct collaboration with experimental cold-atom setup*
- Supervision of Bachelor student
- Advisors: Prof. Jörg Schmiedmayer, Prof. Norbert J. Mauser

## 9/2014–10/2014, 8/2015–9/2015: Research and teaching visits

- Lecture: *A Layman's Guide to the Multiconfigurational Time-Dependent Hartree for Bosons*
- Research: *Many-body physics and quantum turbulence*
- Hosts/Institution: Prof. Vanderlei S. Bagnato and Dr. Marios C. Tsatsos, Group of Optics, University of São Paulo, São Carlos, Brazil.

## 11/2013–6/2017: Condensed Matter Theory & Quantum Computing Group, University of Basel, Switzerland

- Research: *Development and applications of software for many-body dynamics of ultracold bosons*
- Supervision of a Masters project work and a Masters thesis
- Advisor: Prof. Christoph Bruder

## 4/2012–7/2012: Research visit

- Research: *Benchmarking of the MCTDHB package*
- Funding: Minerva Short Term Research Grant
- Host/Institutions: Prof. Ofir E. Alon, Haifa University and Technion, Haifa, Israel.

# Awards and Scholarships

## 08/2014: Springer Thesis Prize for Ph.D. Thesis

- Publication of Ph.D. Thesis as book in the Springer Theses series (see list of publications)
- Awarding institution: Springer International Publishing
- EUR 0.5k

## 6/2013: DAAD-funded "RISE" fellows

- funding of a three-month research visit of Storm E. Weiner from UC, Berkeley and Tomos Wells from Imperial College, London
- research fellowship resulted in three publications

## 4/2012: Minerva Short Term Research Grant

- Funding for a three-month research visit to Prof. Ofir E. Alon, Haifa, Israel
- Awarding institution: Minerva foundation of the Max Planck Society

## 12/2011: Dr. Sophie-Bernthsen Award for Diploma Thesis

- Awarding institution: Heidelberg University, Heidelberg, Germany
- EUR 0.6k

## 12/2008: Ph.D. Scholarship

- International Graduiertenkolleg 710, Complex Processes: Modeling, Simulation and Optimization
- Awarding institution: Interdisciplinary Center for Scientific Computing, Heidelberg University, Heidelberg, Germany

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## Grants

### since 1/2019: Standalone grant from the Austrian Science Fund (FWF)

- ○ Project title: *Numerical models for many-body physics and single-shot images*
- ○ Amount: EUR 390k

### since 6/2013: Grant for computation time

- ○ Project title: *The multiconfigurational time-dependent Hartree for indistinguishable particles high-performance computation project*
- ○ Host/Institution: national German supercomputing center in Stuttgart (HLRS)
- ○ Amount: EUR ∼100k per year (renewed several times since 2013)

## Research Interests

- ○ Quantum many-body dynamics
- ○ Quantum optics, AMO physics
- ○ Quantum simulation – emulating condensed matter with AMO physics
- ○ Numerical and machine learning methods
- ○ Software development, optimization, and parallelization

## Teaching

- ○ 1 Bachelor's thesis supervision
- ○ 2 Master's theses' supervision (1 ongoing)
- ○ 1 PhD student supervision (ongoing)
- ○ 18 researchers coached in usage of developed software
- ○ 130+ registered users of developed open-source software
- ○ 4 tutorials
- ○ 2 teaching assistances (1 ongoing)
- ○ 1 journal club (started 1/2021)
- ○ 2 lectures (3rd upcoming)

## (Co-)Organization of Events

### 5/2018; 4/2018; 11/2017; 3/2017: (Co-)organization of several mini-symposia

- ○ Titles (in reverse chronological order):
  - ○ *MCTDH-X: Many-body physics of interacting atoms in cavities and fermions with spin*
  - ○ *Multiconfigurational time-dependent Hartree methods for multi-species and multi-component many-body systems*
  - ○ *Many-body excitation spectra: Linear response of the multiconfigurational time-dependent Hartree method for indistinguishable particles*
  - ○ *MultiConfiguration TimeDependent Hartree Boson (MCTDHB)*
- ○ Host/Institution: Wolfgang Pauli Institute, University of Vienna, Vienna, Austria

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**12/2019: Organization of mini-symposium**
○ Title: *Machine learning and many-body physics*
○ Host/Institution: University of Freiburg, Freiburg, Germany

## Software

### Lead developer
○ *MCTDH-X: the multiconfigurational time-dependent Hartree for indistinguishable particles software*, see http://ultracold.org
○ *UNIQORN: the universal neural-network interface for quantum observable readout from $N$-body wavefunctions*, see https://gitlab.com/UNIQORN and http://ultracold.org

### Contributor
○ *OpenMCTDHB package*, see http://OpenMCTDHB.uni-hd.de
○ *MCTDHB package*, see http://mctdhb.org

## Ten Key Publications

○ *Detecting One-Dimensional Dipolar Bosonic Crystal Orders via Full Distribution Functions*,
B. Chatterjee, J. Schmiedmayer, C. Lévêque, and **A. U. J. Lode**,
DOI: https://doi.org/10.1103/PhysRevLett.125.093602,
Phys. Rev. Lett. **125**, 093602 (2020).
○ *Colloquium: Multiconfigurational time-dependent Hartree approaches for indistinguishable particles: Wave-packet dynamics of many-body systems*,
**A. U. J. Lode**, C. Camille Lévêque, L. B. Madsen, A. I. Streltsov, O. E. Alon,
DOI: https://doi.org/10.1103/RevModPhys.92.011001,
Rev. Mod. Phys. **92**, 011001 (2020).
○ *MCTDH-X: The multiconfigurational time-dependent Hartree method for indistinguishable particles software*,
R. Lin, P. Molignini, L. Papariello, M. C. Tsatsos, C. Lévêque, S. E. Weiner, E. Fasshauer, R. Chitra, and **A. U. J. Lode**,
DOI: https://doi.org/10.1088/2058-9565/ab788b,
Quantum Sci. Technol. **5**, 024004 (2020).
○ *Pathway to chaos through hierarchical superfluidity in a cavity-BEC system*,
R. Lin, P. Molignini, **A. U. J. Lode**, and R. Chitra,
DOI: https://doi.org/10.1103/PhysRevA.101.061602,
Phys. Rev. A **101**, 061602(R) (2020).
○ *Parametric Excitation of a Bose-Einstein Condensate: From Faraday Waves to Granulation*,
J. H. V. Nguyen, M. C. Tsatsos, D. Luo, **A. U. J. Lode**, G. D. Telles, V. S. Bagnato, and R. G. Hulet,
DOI: https://doi.org/10.1103/PhysRevX.9.011052,
Phys. Rev. X **9**, 011052 (2019).
○ *Fragmented superradiance: Correlations in a Bose-Einstein Condensate in an Optical Cavity beyond the Dicke Model*,
**A. U. J. Lode** and Christoph Bruder,
DOI: https://doi.org/10.1103/PhysRevLett.118.013603,
Phys. Rev. Lett. **118**, 013603 (2017).

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○ *The multiconfigurational time-dependent Hartree method for bosons with internal degrees of freedom: Theory and composite fragmentation of multi-component Bose-Einstein condensates*,
**A. U. J. Lode**,
DOI: https://doi.org/10.1103/PhysRevA.93.063601,
Phys. Rev. A **93**, 063601 (2016).

○ *The multiconfigurational time-dependent Hartree for fermions: Implementation, exactness and application to few-fermion tunneling to open space*,
E. Fasshauer and **A. U. J. Lode**,
DOI: https://doi.org/10.1103/PhysRevA.93.033635,
Phys. Rev. A **93**, 033635 (2016).

○ *How an interacting many-body system tunnels through a potential barrier to open space*,
**A. U. J. Lode**, A. I. Streltsov, K. Sakmann, O. E. Alon, and L. S. Cederbaum,
DOI: https://doi.org/10.1073/pnas.1201345109,
Proc. Natl. Acad. Sci. USA **109**, 13521 (2012).

○ *Numerically exact quantum dynamics of bosons with time-dependent interactions of harmonic type*,
**A. U. J. Lode**, K. Sakmann, O. E. Alon, L. S. Cederbaum, and A. I. Streltsov,
DOI: https://doi.org/10.1103/PhysRevA.86.063606,
Phys. Rev. A **86**, 063606 (2012).