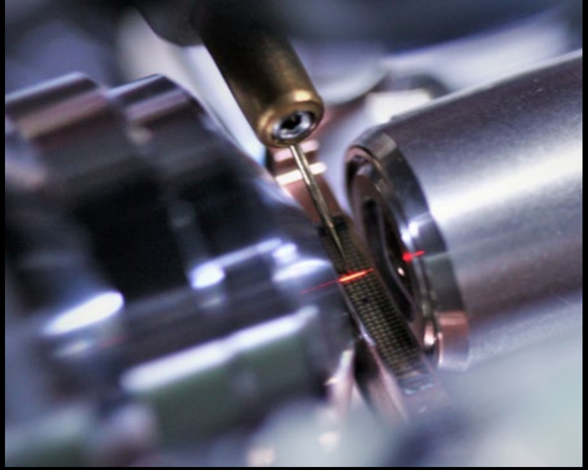
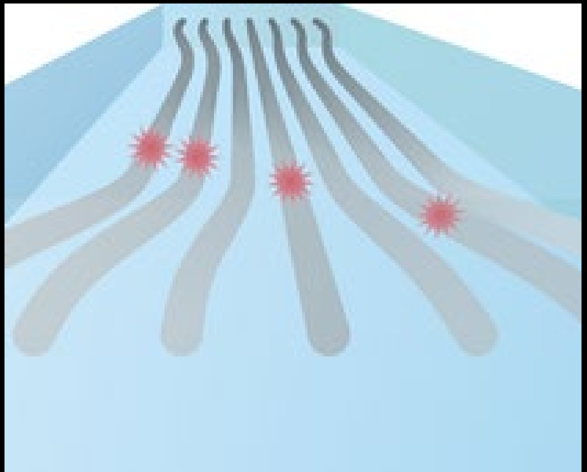
Photonics Group

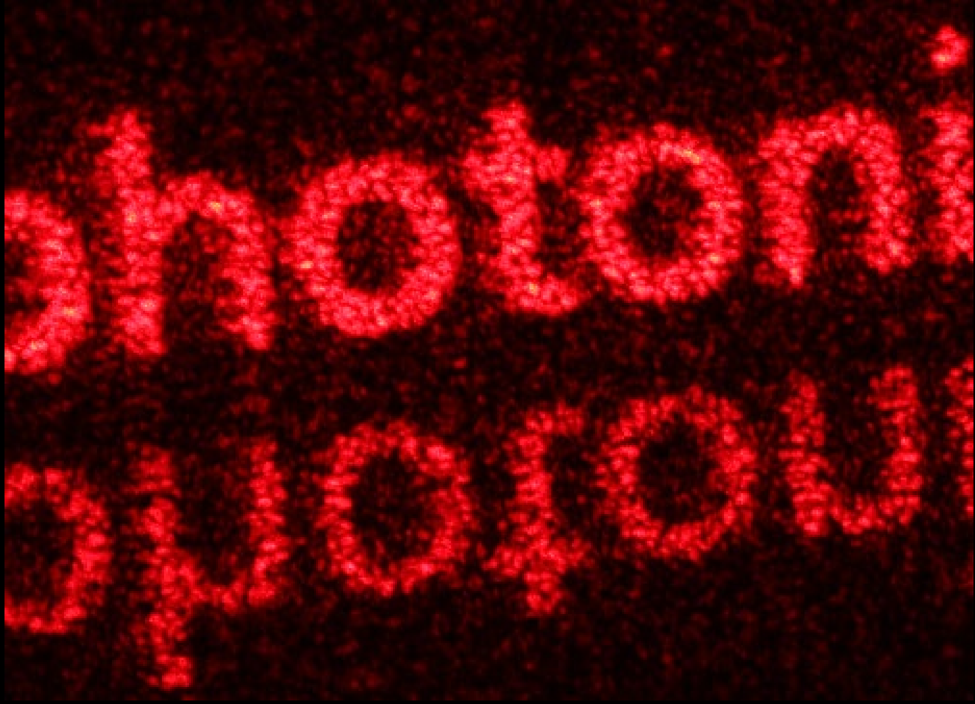
Prof. Gregor Weihs

Thesis topics 2024

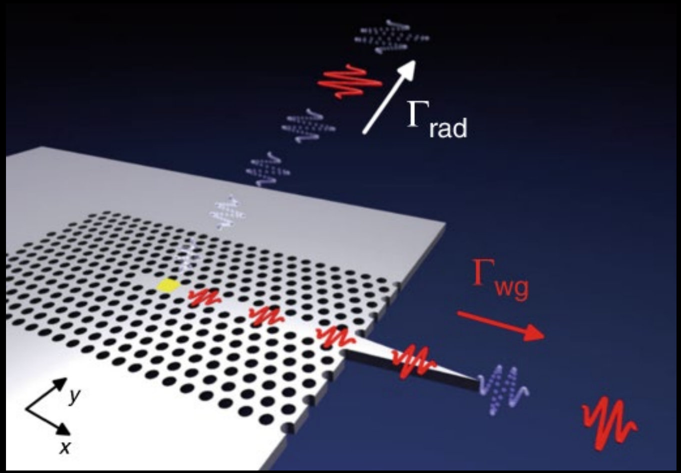
Vikas Remesh, 17.01.2024

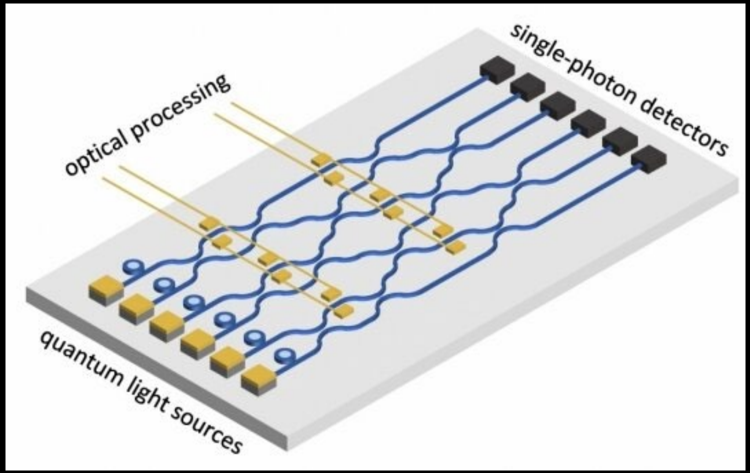


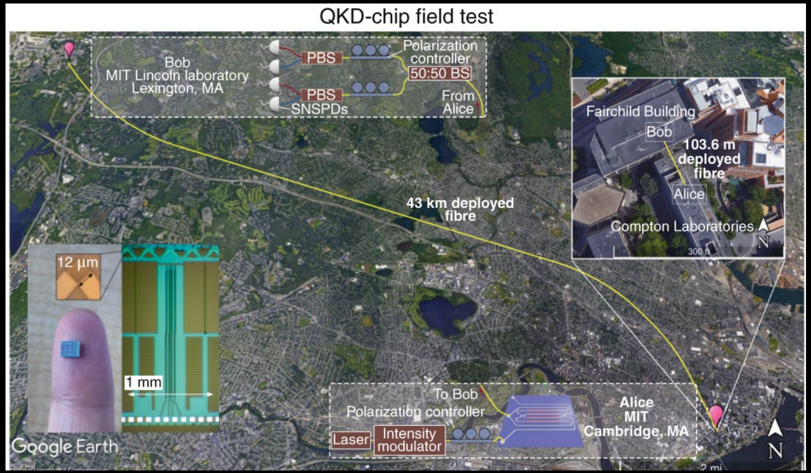




Develop quantum photonic architectures for fundamental and technological applications







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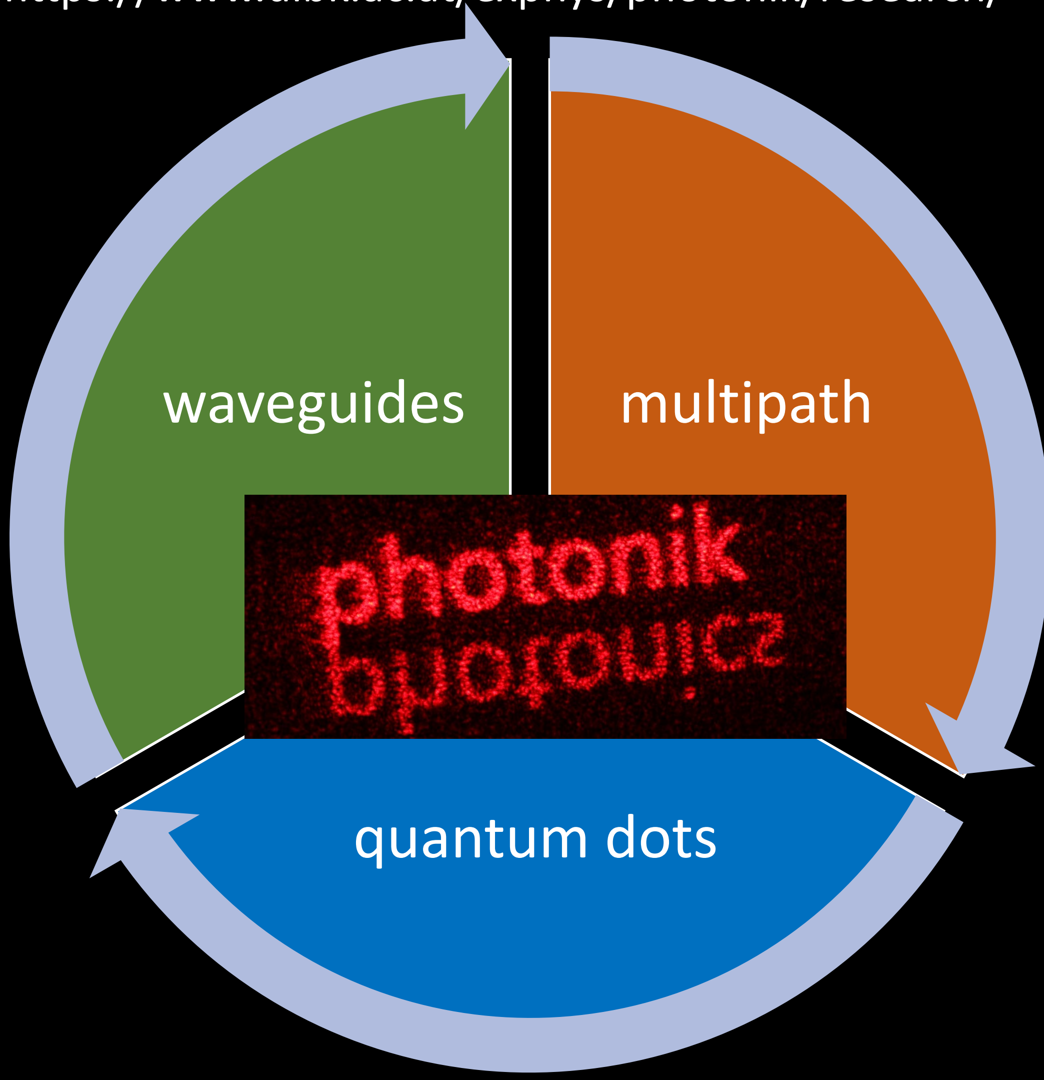
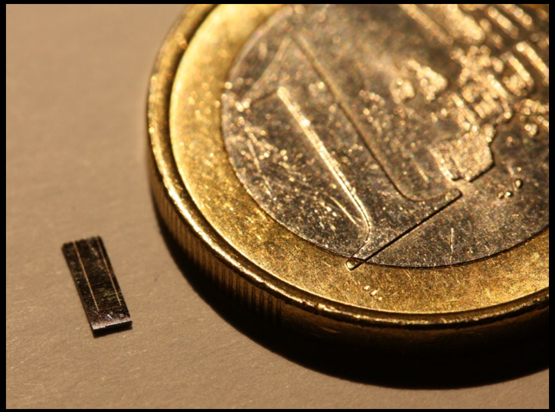


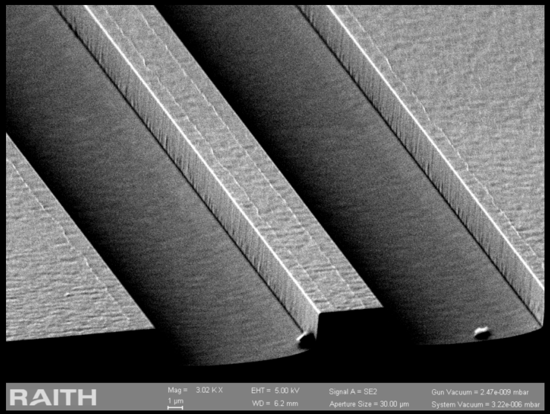
MSc thesis topics

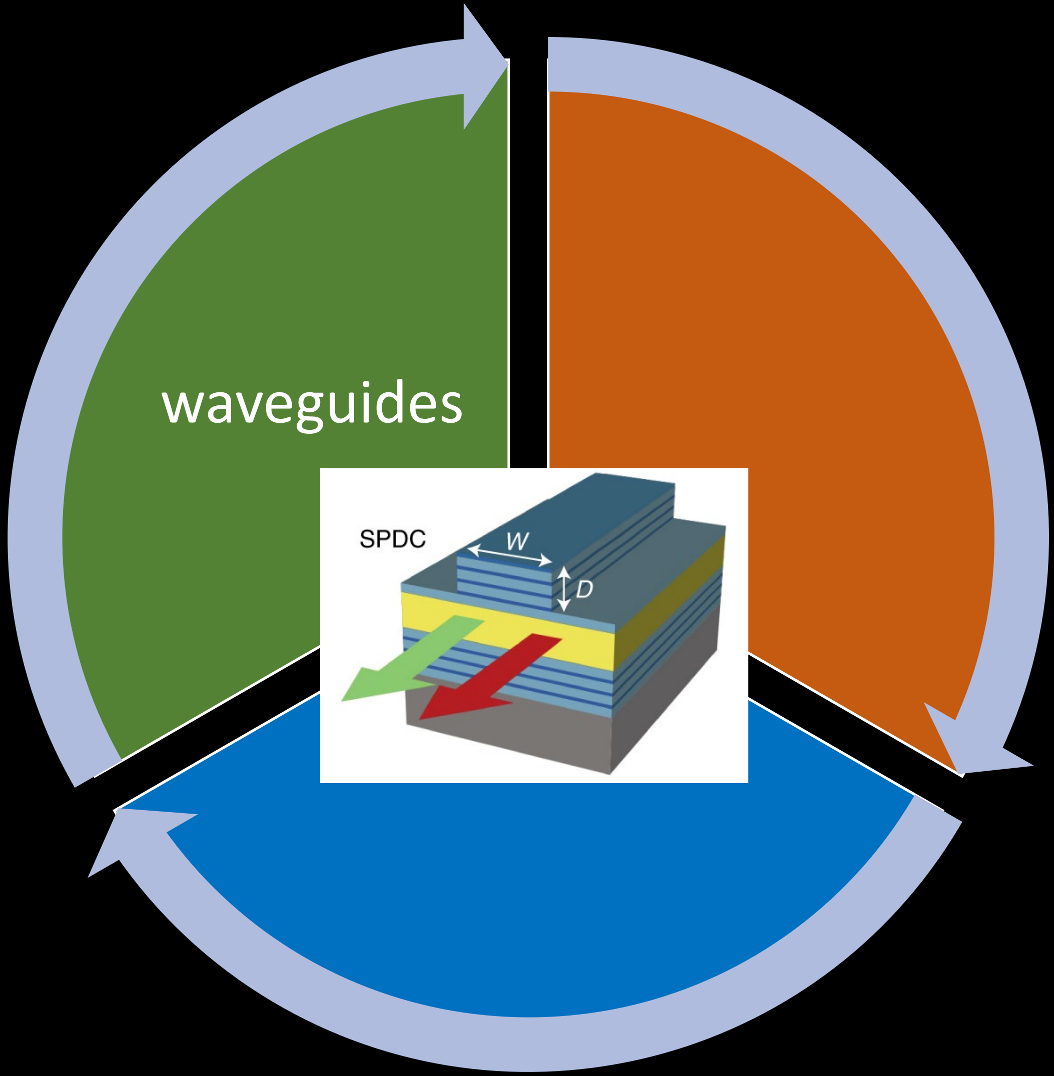
BSc thesis topics

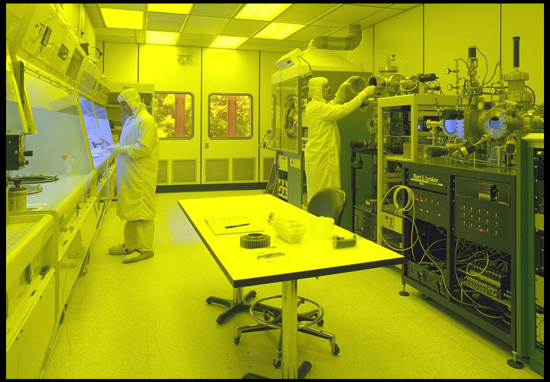
Develop on-chip quantum light sources for quantum technology applications

Stefan Frick









Nanofabrication +
Optics laboratory

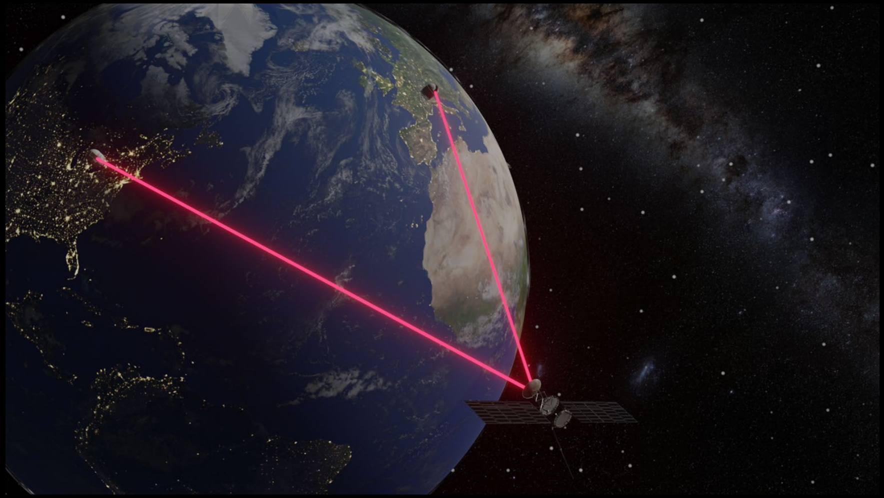
Thesis topic/ waveguides team

Stefan Frick

Simulating secure key rates in a satellite based QKD

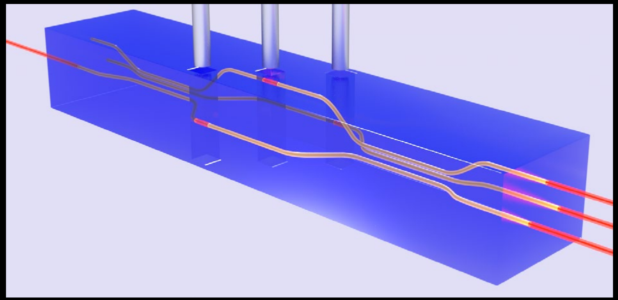
- Ground station: *Hafelekar*
- Satellite: *QEYSSat (Canada)*

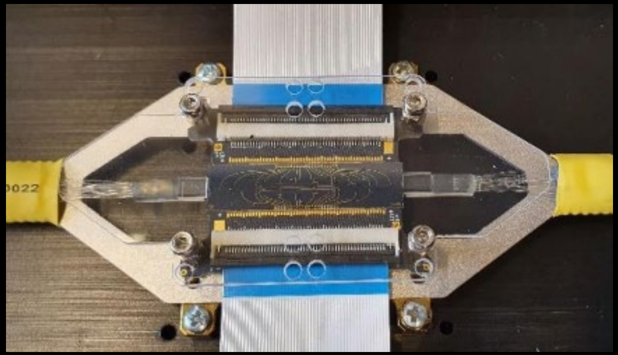
Task: Numerically simulate the accessible key rate throughout the year

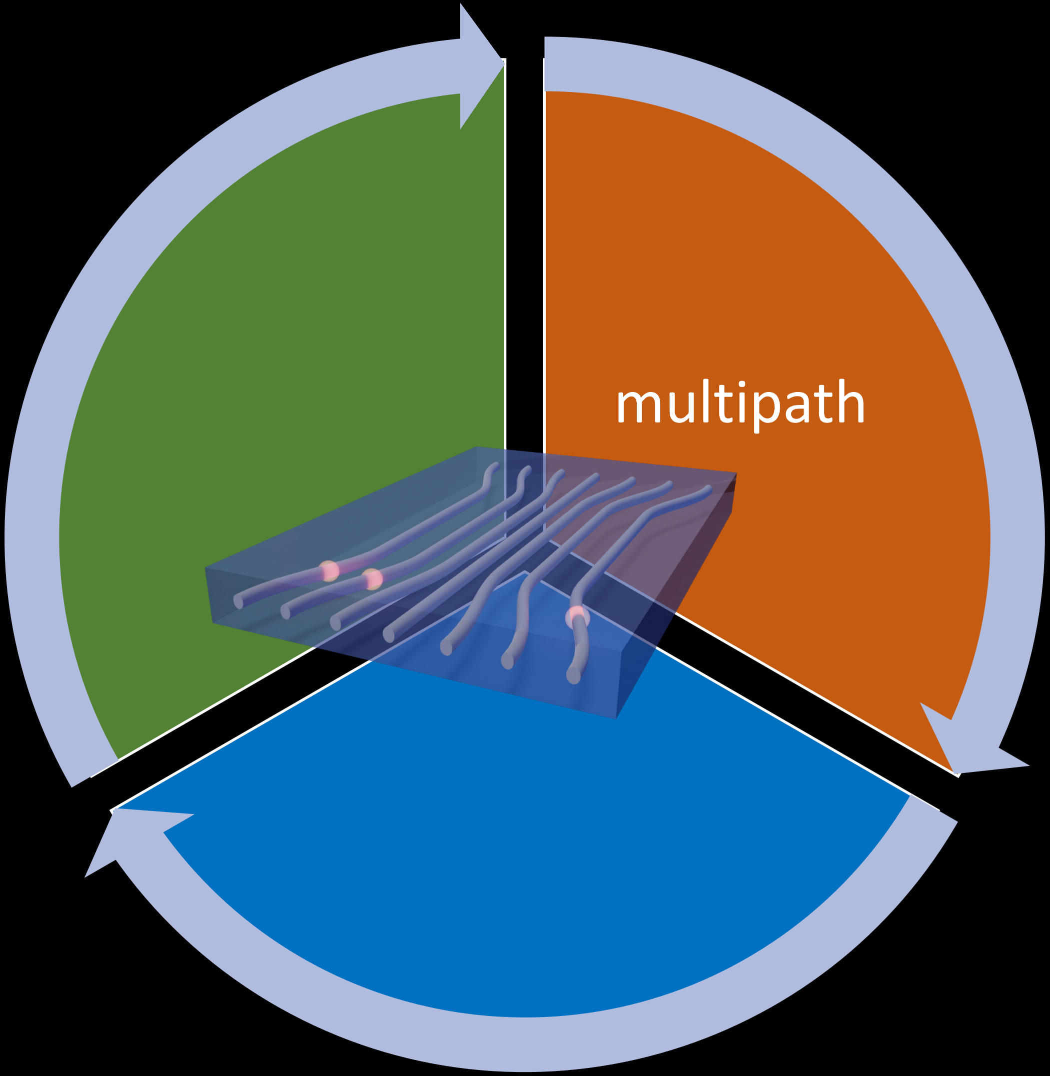


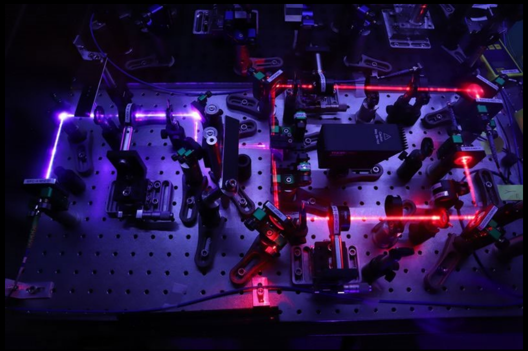
Testing foundations of quantum mechanics via interference effects

Robert Keil

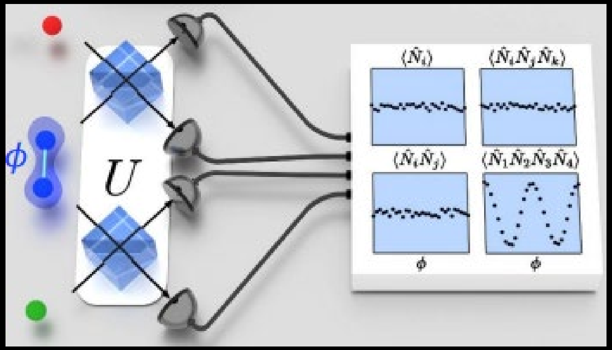








Optics laboratory +
theoretical analysis



Topic/ multipath team

Dr. Robert Keil

RK1 Anpassung von Einzelphotonenspektren durch elektro-optische Modulation (vergeben)

In Quantennetzwerken sollen unterschiedliche Komponenten, wie Quantenprozessoren, -speicher oder Einzelphotonenquellen verbunden werden um komplexe Aufgaben der Quanteninformationsverarbeitung zu erfüllen. Da eine Vielzahl unterschiedlicher Technologien für diese Aufgaben in Frage kommen, ist zu erwarten, dass diese Netzwerke aus unterschiedlichen physikalischen Systemen bestehen, die jeweils Photonen mit unterschiedlichen spektralen Eigenschaften emittieren oder absorbieren. Um eine effiziente Übertragung innerhalb des Netzwerks sicherzustellen, ist es daher erforderlich die Spektren der Photonen umzuwandeln. Insbesondere die Umwandlung der spektralen Bandbreite stellt dabei eine besondere Herausforderung dar. Hierfür hat sich in den letzten Jahren die elektro-optische Manipulation der Photonen durch ein so-genannte *time lens* als geeignetes Mittel herausgestellt [1, 2].

In dieser Bachelorarbeit soll das Konzept der *time lens* aus der Literatur erarbeitet und mit anderen Methoden der spektralen Manipulation verglichen werden. Anschließend soll mittels numerischer Simulation die mit realistischen Parametern erreichbare spektrale Erweiterung von Einzelphotonen aus Halbleiterquantenpunkten [3] bestimmt werden. Diese Simulationen unterstützen ein im Aufbau befindliches Experiment der AG Photonik.

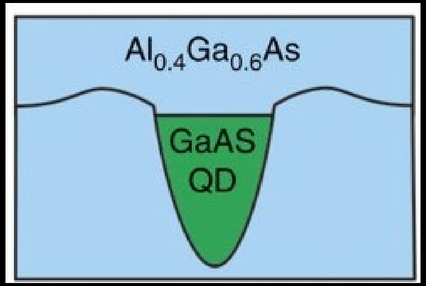
1) M. Karpiński, M. Jachura, L. J. Wright, B. J. Smith, *Bandwidth manipulation of quantum light by an electro-optic time lens*, Nature Photon. **11**, 53 (2017), [link]

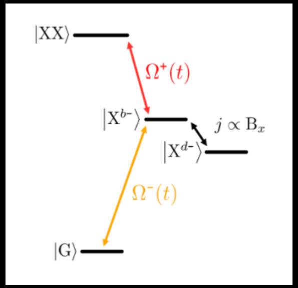
2) F. Sośnicki, M. Mikołajczyk, A. Golestani, M. Karpiński, *Interface between picosecond and nanosecond quantum light pulses*, Nat. Photon. **17**, 761 (2023), [link]

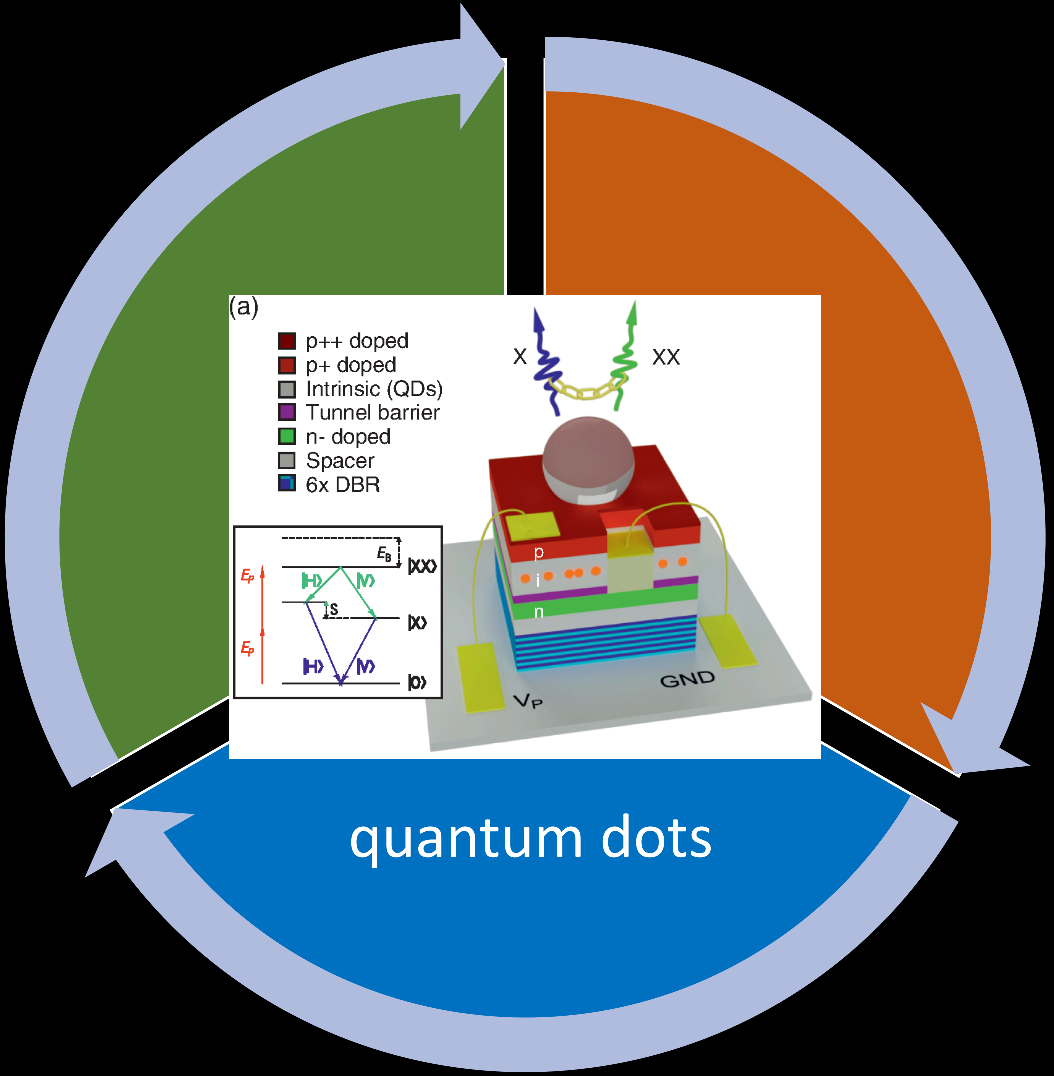
3) Y. Arakawa, M. J. Holmes, *Progress in quantum-dot single photon sources for quantum information technologies: A broad spectrum overview*, Appl. Phys. Rev. **7**, 021309 (2020), [link]

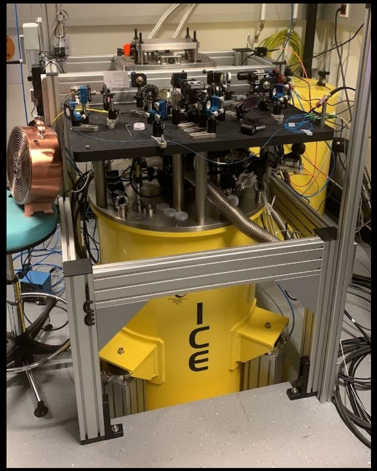
Controlled generation of quantum light states from quantum dots

Vikas Remesh

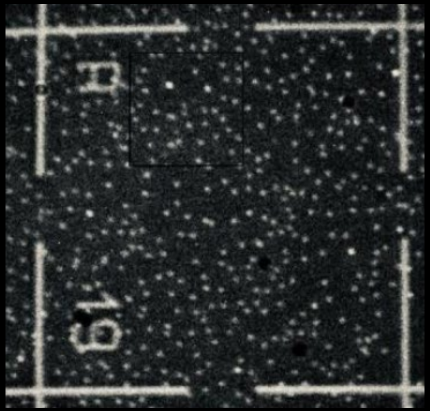


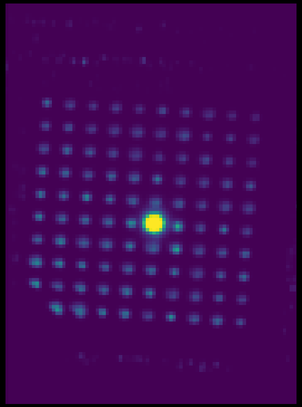


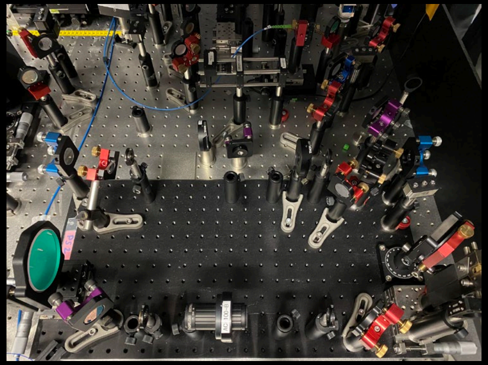




Optics laboratory +
theoretical analysis



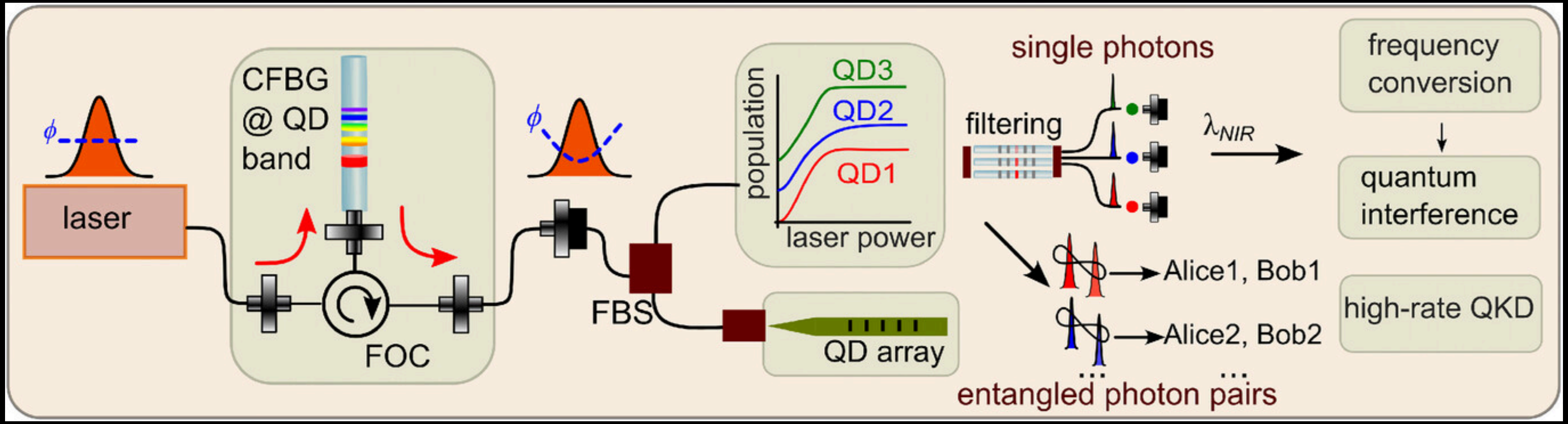




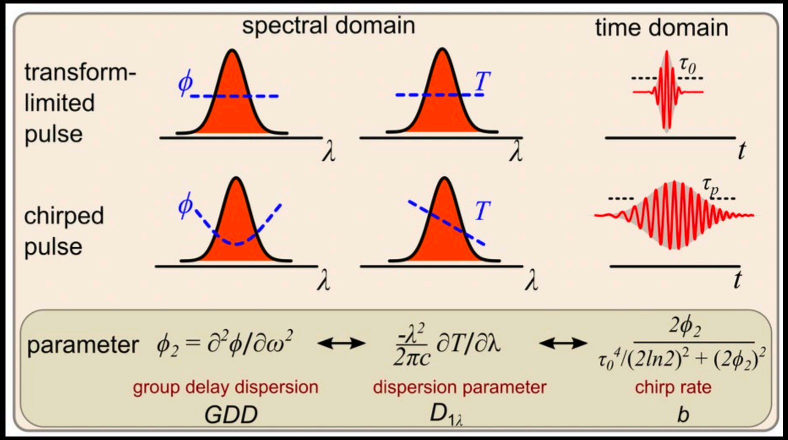
Thesis topic/ quantum dots team

Vikas Remesh

Chirped pulse excitation of quantum dots

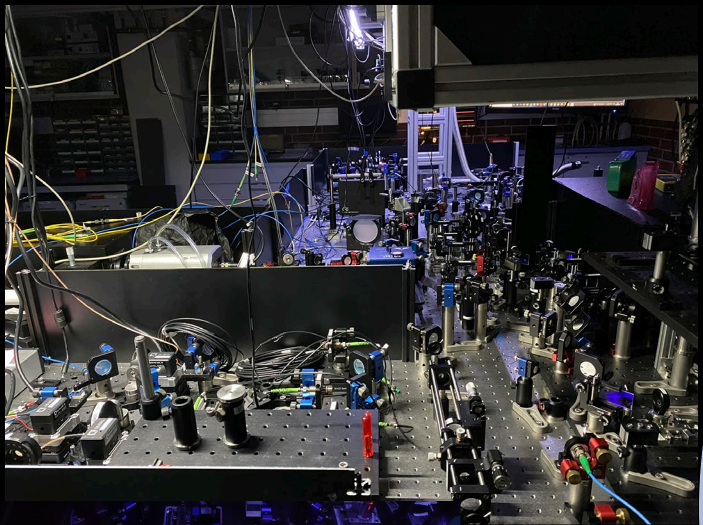


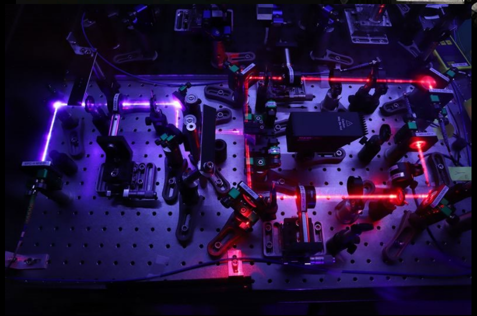
Task: *Characterization of chirped pulses via time-of-arrival method*

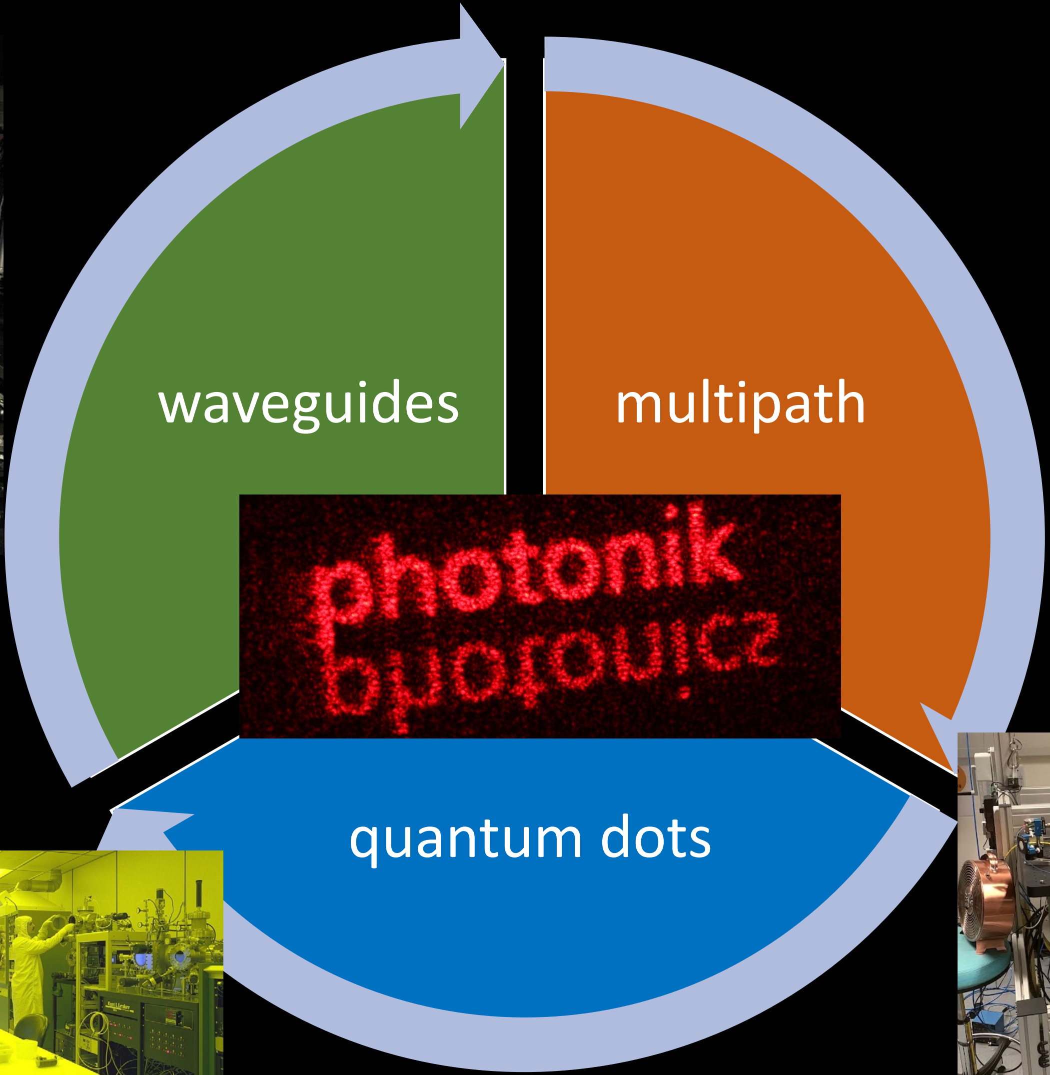


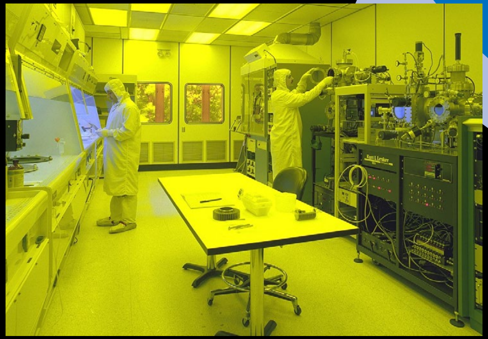
- *What is the sensitivity limit of this method?*
- *What is the highest precision we can achieve?*
- *How does this method perform in comparison to other methods?*

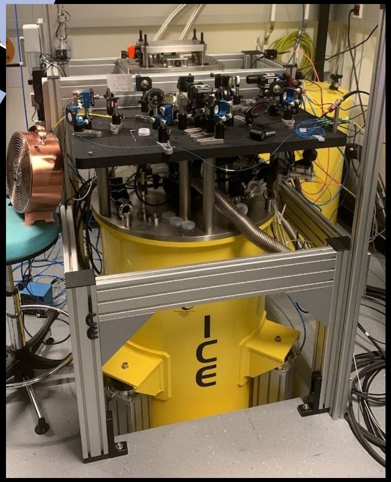
https://www.uibk.ac.at/exphys/photonik/research/







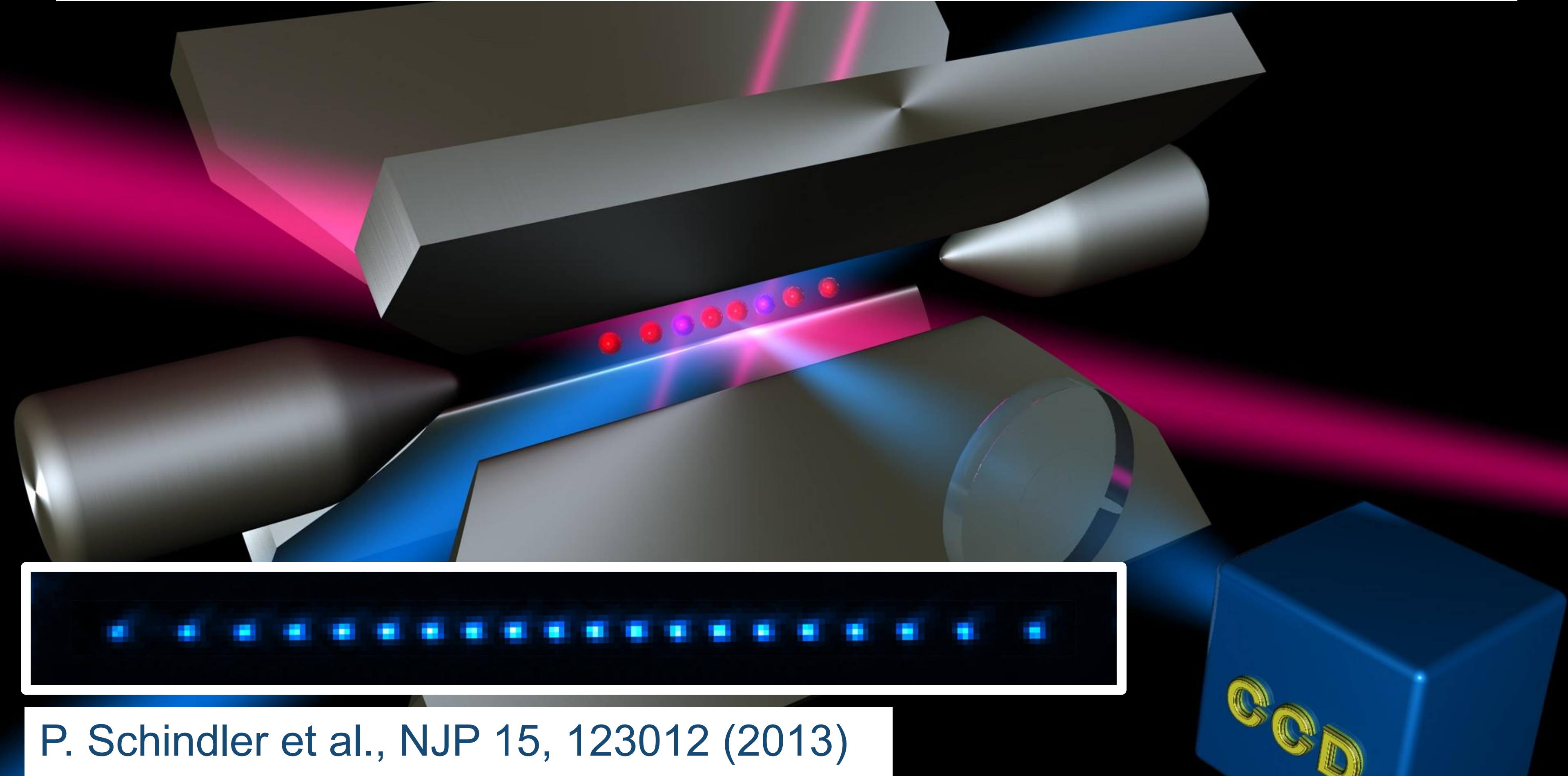




MSc thesis topics

BSc thesis topics

Quantum information processing with trapped ions



P. Schindler et al., NJP 15, 123012 (2013)

Quantum information processing with trapped ions

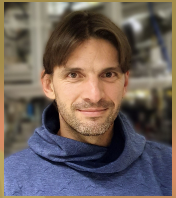
Quantum engineering

- Develop a robust quantum hardware platform
- Reduce errors in ion-trap quantum computers
- Implement quantum algorithms

Thomas Monz

Molecular quantum technologies and scalable systems

- Control single molecular ions
- Encode quantum information in single molecules
- Develop scalable quantum computing architectures



Philipp Schindler

High dimensional quantum systems

- Encode information more efficiently in multiple levels
- Develop quantum algorithms for qudit systems
- Simulate physics using quantum computers

Martin Ringbauer

Quantum information processing with trapped ions

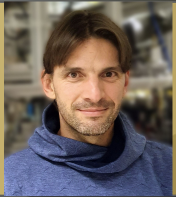
Bachelor topics:

- Optische Integration in Quantentechnologien, Nature **586**, 533–537 & 538-542 (2020)
- Kontrollmethoden für bessere Atomuhren, Phys. Rev. X **11**, 041049 (2021)
- Mit mehr Redundanz zu besserer Fehlerkorrektur, Nature **614**, pages 676–681 (2023)
- Quantenlogik mit molekularen Ionen, Nature **581,** 273–277 (2020)
- Quantenzufallsgenerator, Nature **540**, 213-219 (2016)
- Quantensimulation für die Teilchenphysik, Nature **534**, 516-519 (2016)
- Quantensimulation von chemischen Prozessen, Nature Chemistry **15**, 1503 (2023)

Masters topics:

- High-fidelity entangling gate operations with trapped ions
- Encoding quantum information in a single molecule
- Noise characterization and modeling of quantum logic gates

Thomas
Monz



Philipp
Schindler

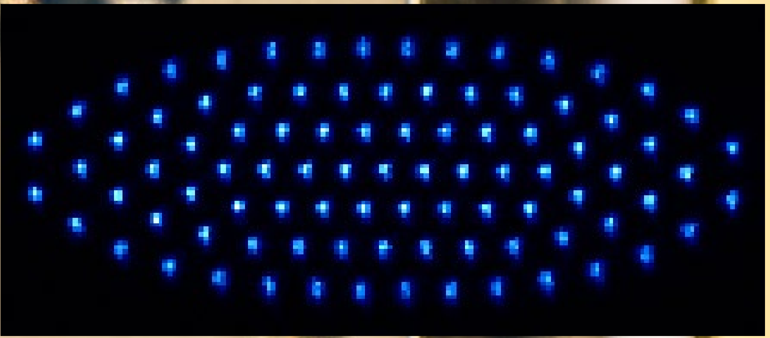
Martin
Ringbauer

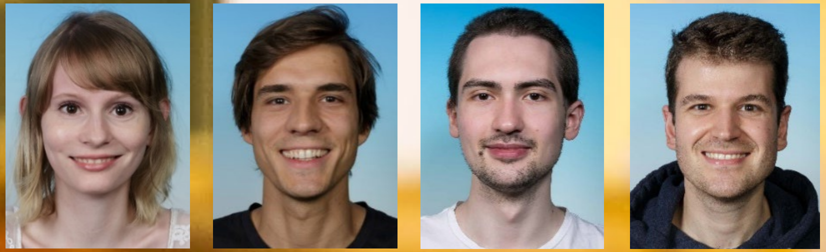
Quantum simulation and spectroscopy with trapped-ion crystals

universität innsbruck
Institut für Experimentalphysik

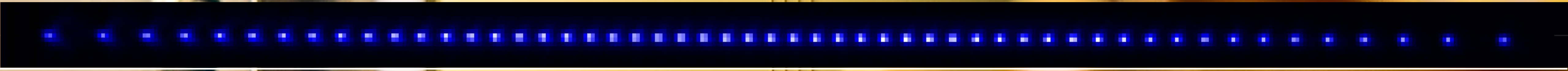
Goal: Investigating quantum-many body physics using tool from quantum information processing methods

Approach: Creation of an engineered quantum system with with up to 100 qubits and single-particle coherent control



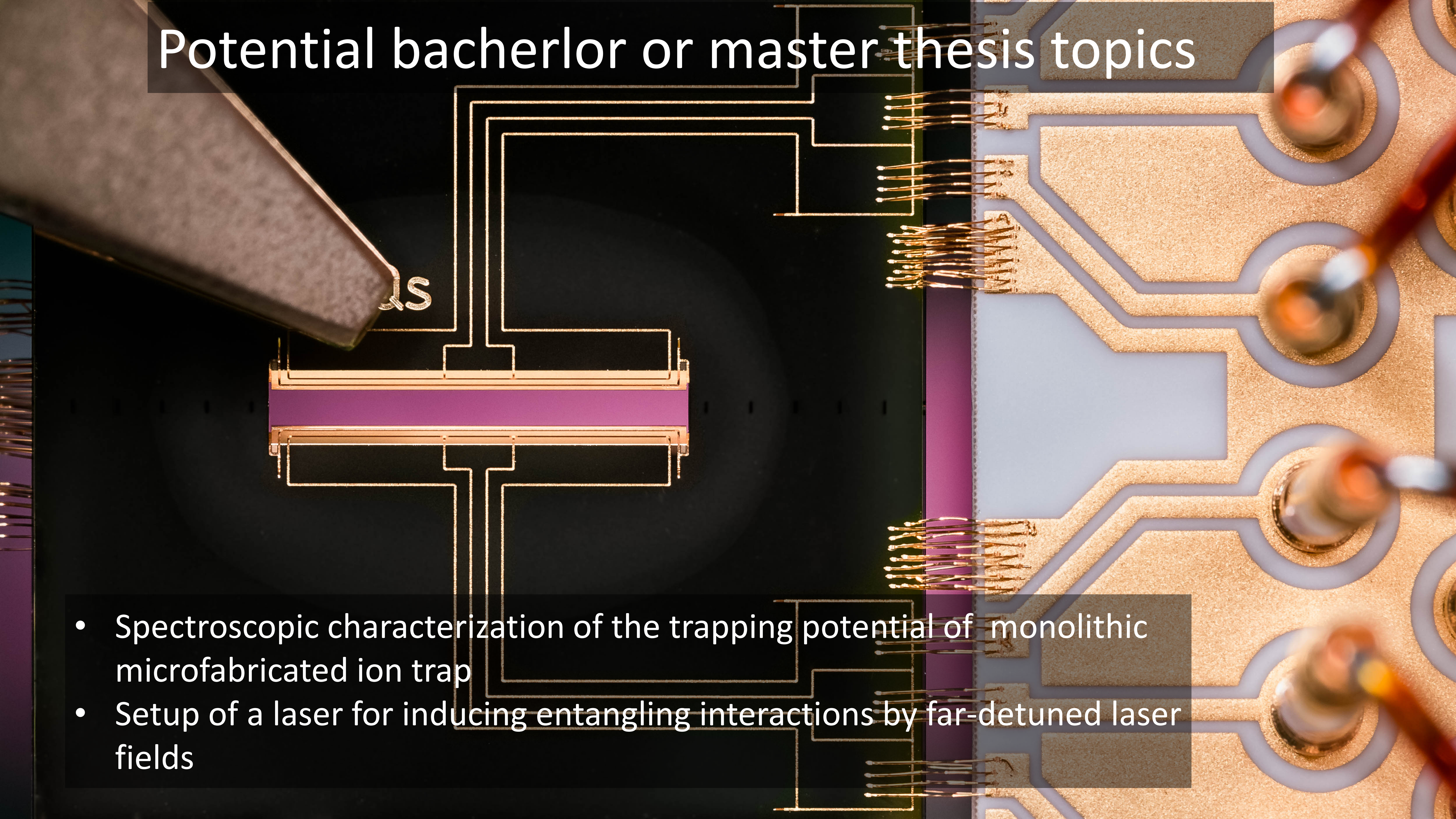


Helene Hainzer | Dominik Kiesenhofer | Artem Zhdanov | Matthias Bock



Christian Roos
Institute for Experimental Physics, University of Innsbruck, Austria

Potential bacherlor or master thesis topics



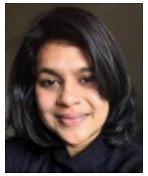
- Spectroscopic characterization of the trapping potential of monolithic microfabricated ion trap
- Setup of a laser for inducing entangling interactions by far-detuned laser fields

Our team and research questions

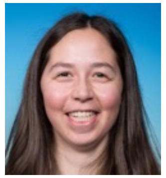
Distributed Quantum Systems

Lanyon (PI) | Schupp (PhD) → AQT | Koong (P.doc) → Oxford | Winkler (PhD) | Canteri (PhD) | Krutianskii (P.doc) | Meraner (PhD) → Bernard-gruppe | Bate (PhD) | Krcmarsky (PhD) | Stroinski (Master) | Helgert (Master)

Wintermayer (PhD)



Kodakkat (Postdoc)



Runggaldier (Master)

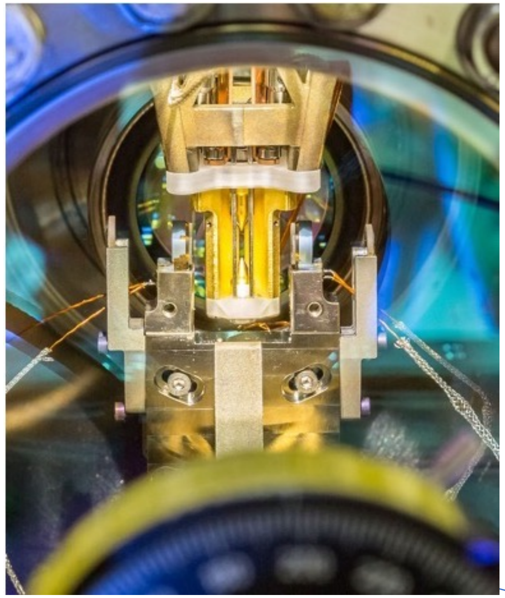
1. *How can entanglement be distributed, stored & grown between remote locations?*
2. *What are the most promising applications of distributed entanglement & how can we realize them?*

ben.lanyon@uibk.ac.at

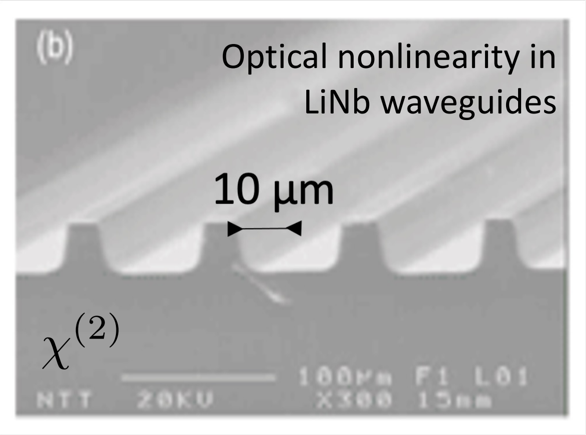
Our experimental platforms

Distributed Quantum Systems

Ion-trap with optical cavities

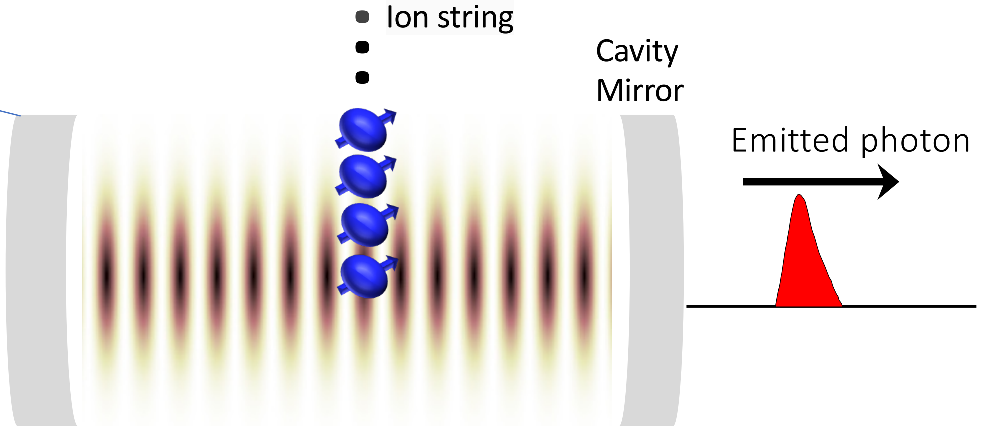


Telecom photon conversion



Off-campus fiber network

Transportable quantum node



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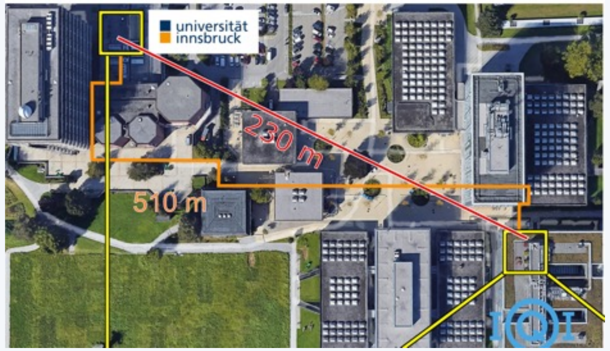
Distributed Quantum Systems

Some recent results

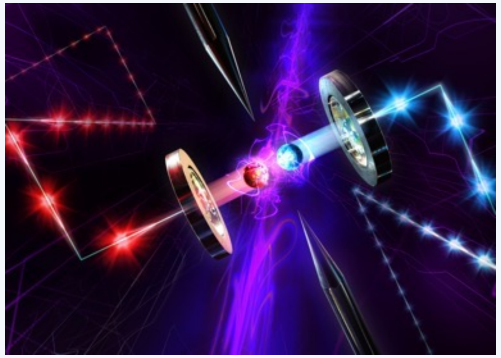
Entanglement of ions over 230 meters



Krutyanski & Galli *et al*, Phys. Rev. Lett. **2023**

Editor's choice
See article "Trapped ions go the distance":

A quantum repeater node



Krutyanski *et al*, Phys. Rev. Lett. **2023**

Editor's choice
See article "quantum repeater goes the distance":

physicsworld
TOP 10
BREAKTHROUGH
2023

ben.lanyon@uibk.ac.at

Available student positions

Distributed Quantum Systems

Bachelor thesis title “Generation of multipartite ‘GHZ-type’ entanglement in trapped ions”

The ‘Greenberger-Horne-Zeilinger’ state is an example of a form of entanglement that can be shared amongst multiple particle, such as photons or atoms. This thesis will first explore the theory of multi-particle entanglement, then focus on an experiment in which GHZ states were made in Innsbruck with up to 14 atoms. Finally, we'll look at how these states offer increased sensitivity to certain fields and can therefore serve as future quantum-enhanced sensors.

You’ll learn about the basics of the field of quantum information science and how to generate entanglement between individual atoms. The thesis can be written in either German or English

Master theses:

Master topics are available on request.
Previous master students: Helen Hainzer, Marco Canteri, Armin Winkler
Current master students: Johannes Helgert, Tabea Stroinski, Tatjana Runggaldier

ben.lanyon@uibk.ac.at

universität
innsbruck

Vorstellung der AG Northup & Abschlussarbeitsthemen 2024

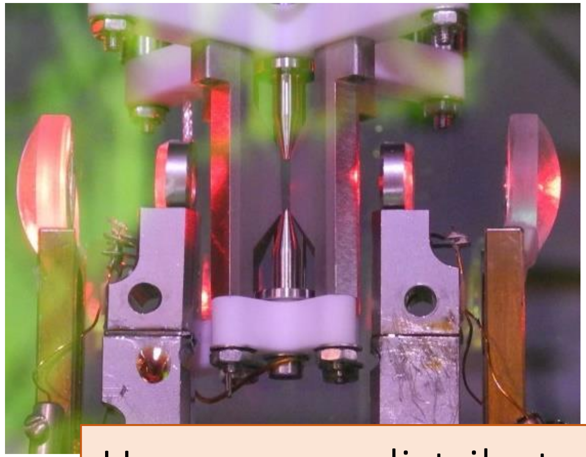
Tracy Northup, Institute for Experimental Physics

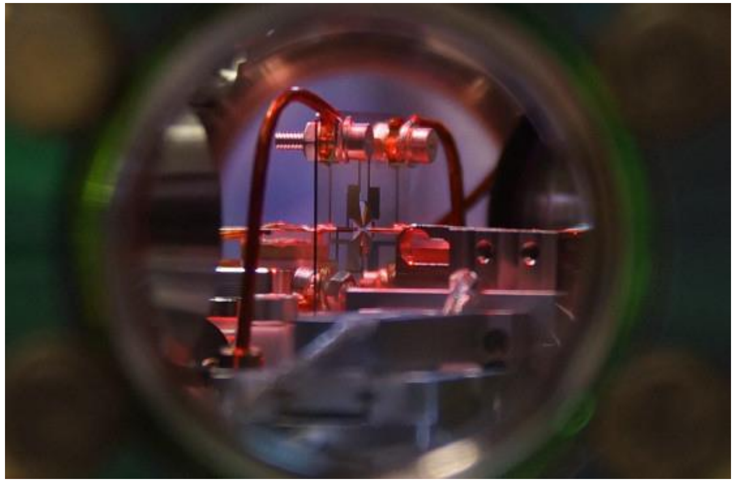
QUANTUM INTERFACES GROUP

Quantum Interfaces Group

- two postdocs, nine PhD students, two master's students
- quantum interfaces:
  how can we transfer quantum states between atoms (ions), photons, & phonons?

trapped ions coupled to optical cavities for quantum networks

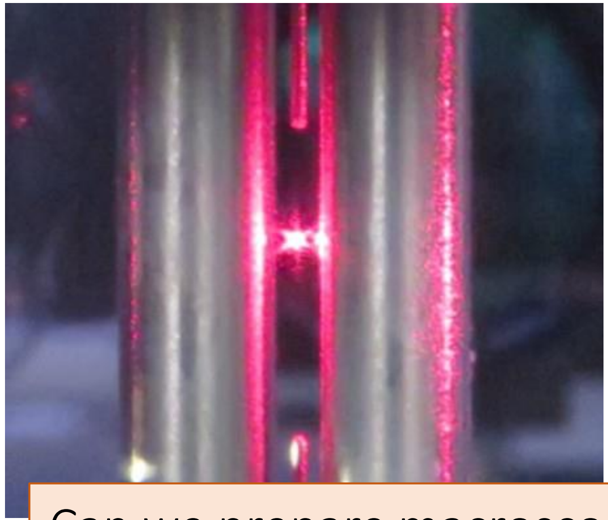




How can we distribute quantum entanglement over long distances?

QUANTUM iNTERFACES GROUP

levitated nanoparticles: towards quantum states of motion



Can we prepare macroscopic quantum superpositions?

Recent bachelor’s thesis topics

- “The attosecond optical clock network,” Matthias Dallio
- “Quantum approximate optimization algorithm with a trapped ion quantum simulator,” Pavel Filippov
- “Quantenlogik-Spektroskopie von hochgeladenen Ionen,” Hannah Beckmann
- “Expanding the observable volume of the universe: application of squeezed light in the LIGO detector,” Regina Wieser

Bachelor's thesis topics 2024

- "Quantum networks with neutral atom processing nodes"
  Arrays of individually controlled neutral atoms are a promising platform for future quantum networks. How will such networks operate? What are the latest developments in this research field?

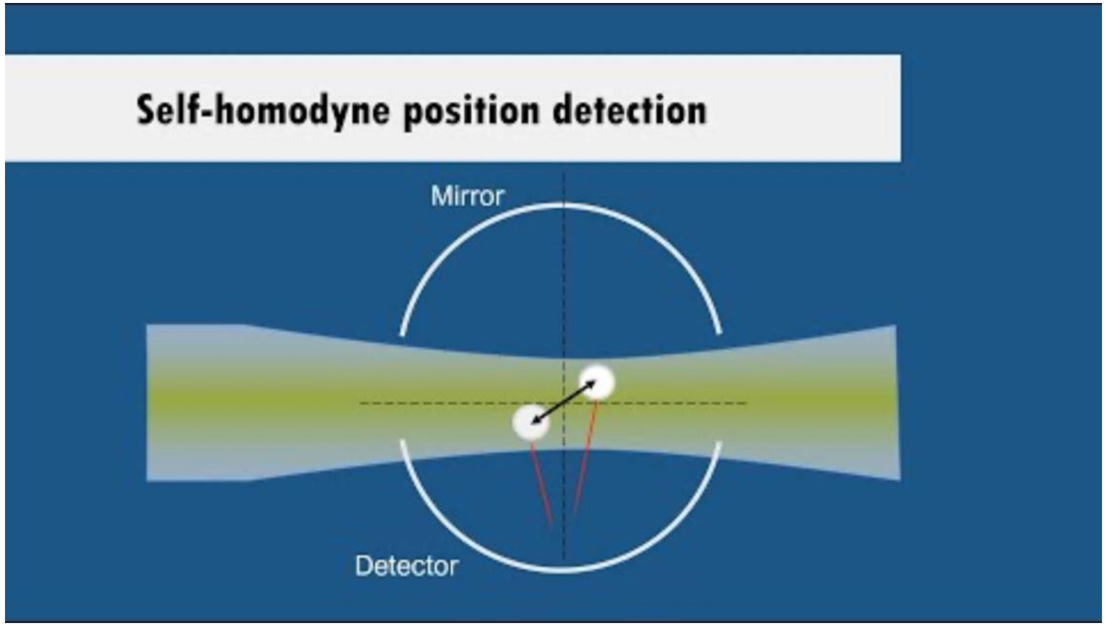
- "Mechanical quantum sensing in the search for dark matter"
  How can mechanical systems (such as levitated nanoparticles) be used to search for dark matter? Is this a realistic approach? What are the strengths of such systems for these searches?

Recent master's thesis topics

- "A new control system for a quantum network node," Riccardo Conzatti
- "Towards absorption of single photons for an ion-cavity interface," Luca Mastrangelo

Recent master's thesis topics

- "A new control system for a quantum network node," Riccardo Conzatti
- "Towards absorption of single photons for an ion-cavity interface," Luca Mastrangelo
- "Self-homodyne position detection of a levitated silica nanoparticle," Katharina Heidegger
  ÖPG Student Prize 2023!



Link

Dipolar Quantum Gases

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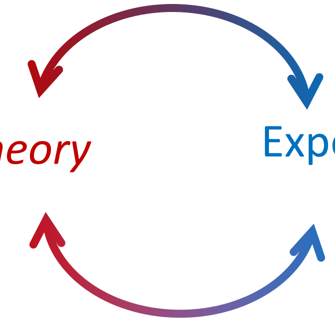
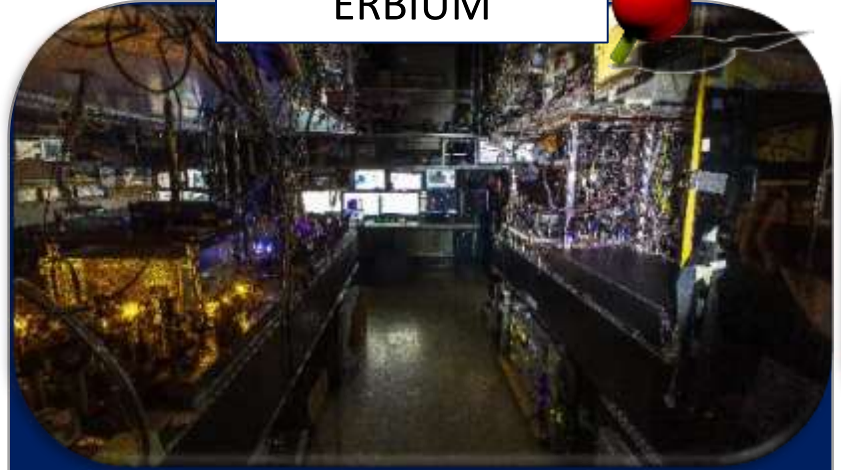
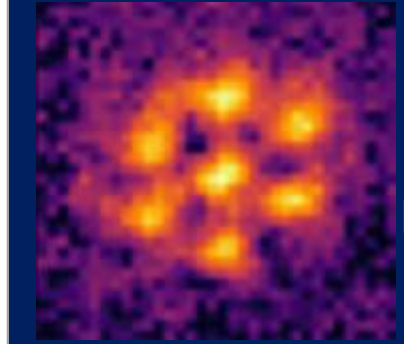
Institute for Experimental Physics and IQOQI



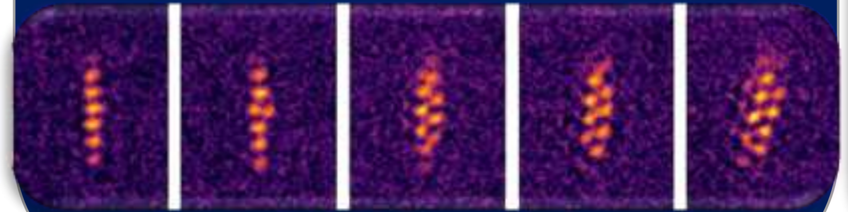
3 LABS and a THEORY TEAM

ERBIUM

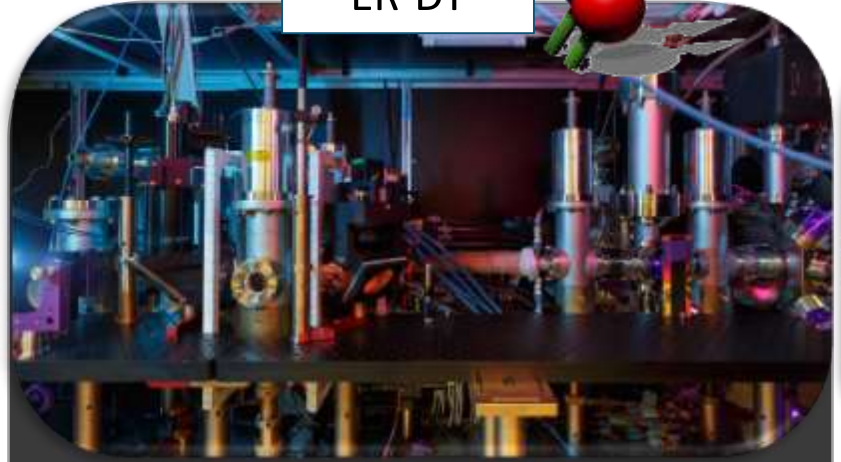


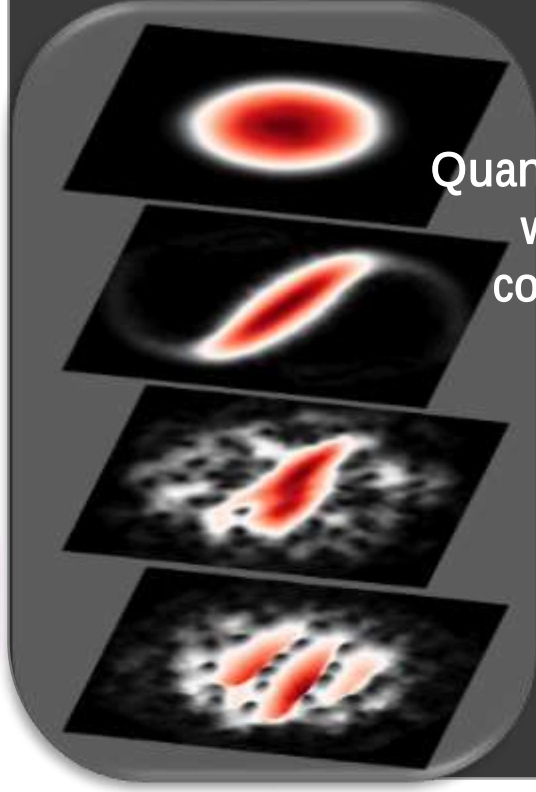


The discover of Supersolidity and Bloch Oscillations



ER-DY

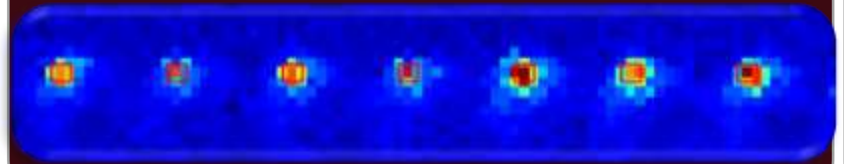




Quantum Vortices with high connectivity

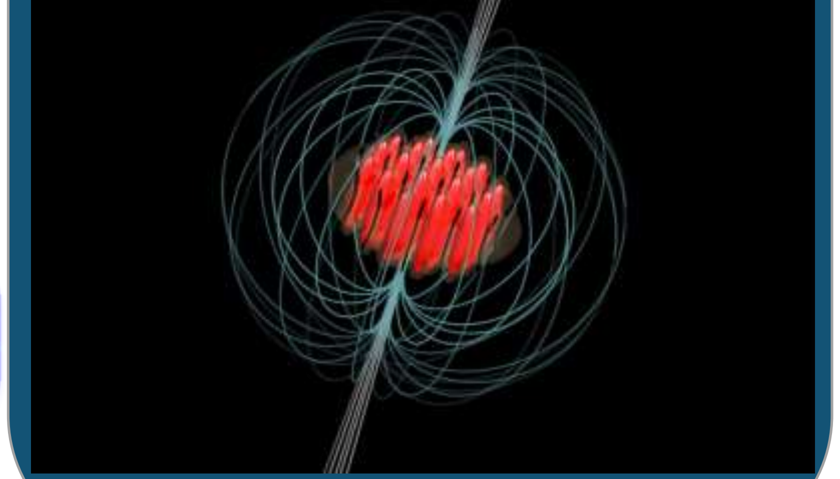
T-REQS

Single atomic magnet in an array of tweezers for quantum info



Theory

Simulation of the behavior of dipolar quantum gases



Dipolar Quantum Gases

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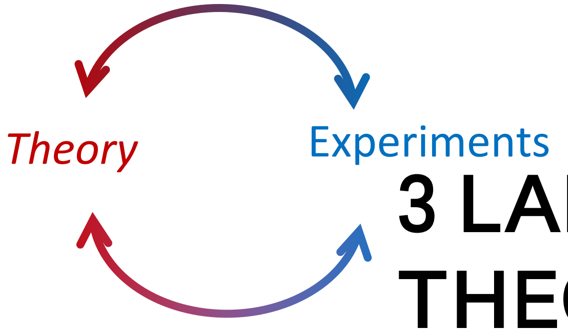
Institute for Experimental Physics and IQOQI

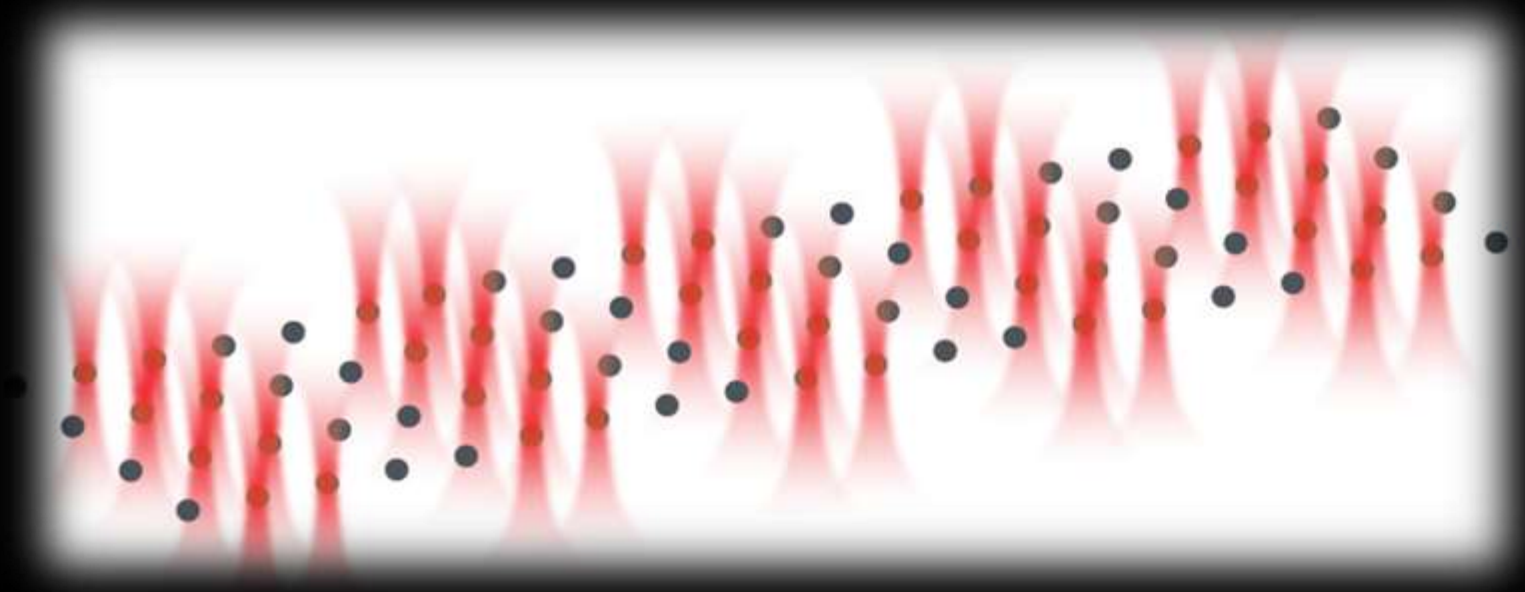


3 LABS and a
THEORY TEAM

Bachelor Project

1. Quantum computing with neutral atoms in optical tweezers

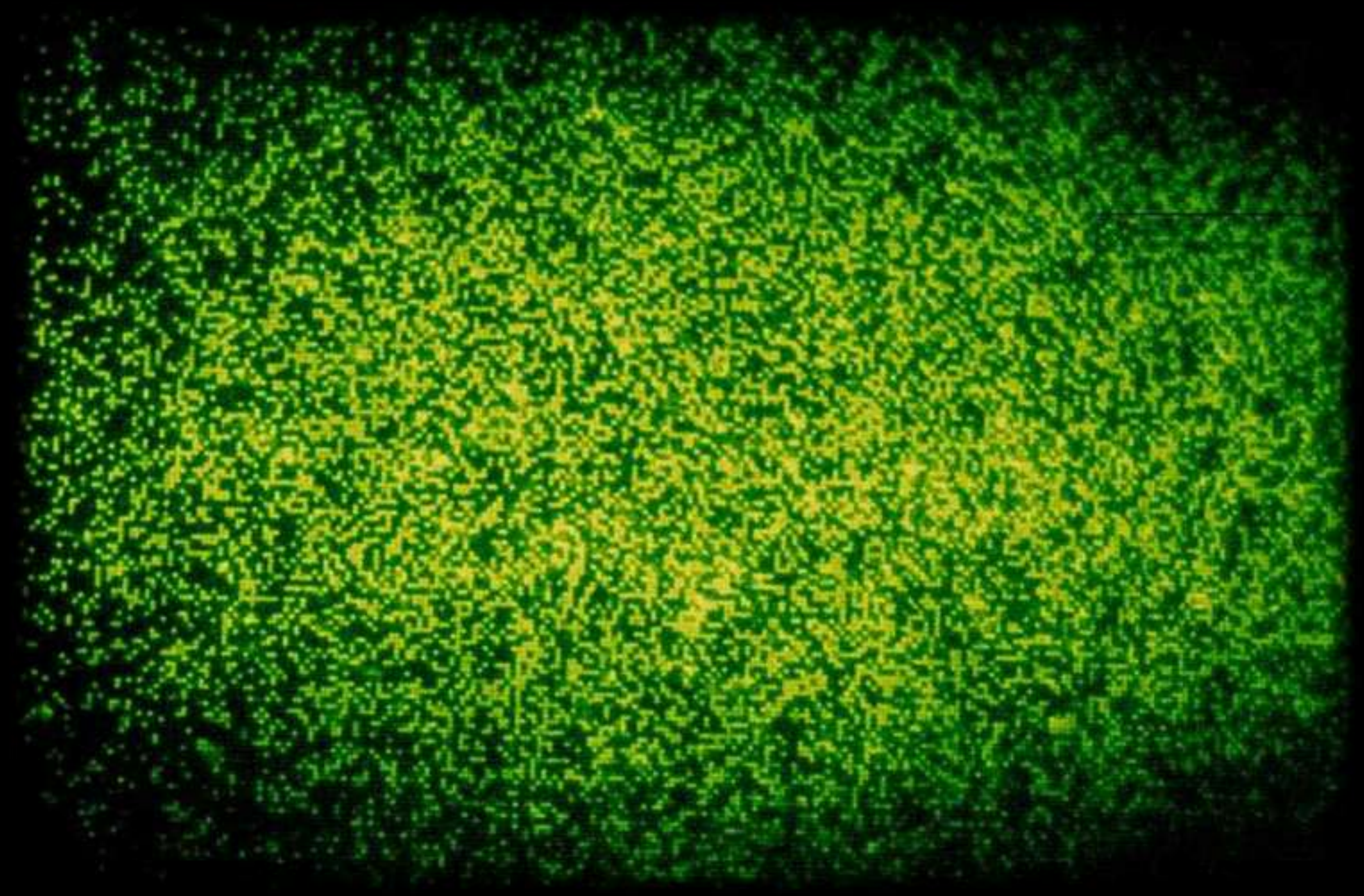
Quantum computing aims at solving computational problems that are intractable for classical processors, exploiting the quantum nature of atoms and of artificial systems with a similar internal energy structure. This project focuses on a specific platform, neutral atoms trapped in optical tweezers, and explores the implementation of qubits up to the state of the art achieved by recent experiments.



You will learn:

- What the building blocks of a quantum computer are, such as qubits, qubit gates, entangling gates and readout protocols.
- How sets of atoms can be trapped and controlled in single-atom traps arranged in arbitrary geometries.
- How the performance of a quantum computer can be quantified and benchmarked.

Bachelor Project



2. Observation methods in quantum gas experiments: from absorption to ultra-fast fluorescence

Keystone of progress in quantum gas experiments, observation methods extensively rely on the various atom-light interaction properties: a coherent source of light propagating through an atomic gas accumulates intensity and phase variations, and atoms scatter photons as being excited. Cutting-edge techniques are now developed to satisfy requirements of most advanced experiments, exceeding resolution limits and detecting single photons. The Bachelorarbeit will work out the basic principles of imaging techniques in quantum gas experiments: absorption, fluorescence, and phase contrast imaging. The Bachelorarbeit will also set-up and test the production of µs light pulses for the implementation of a novel ultra-fast imaging technique.

You will learn:

- How atom-light interactions are used for imaging purposes.
- How to image single atoms and what are the limits of resolution
- How to set up electronics in the laboratory for fast generation and control of optical pulses

Bachelor Project

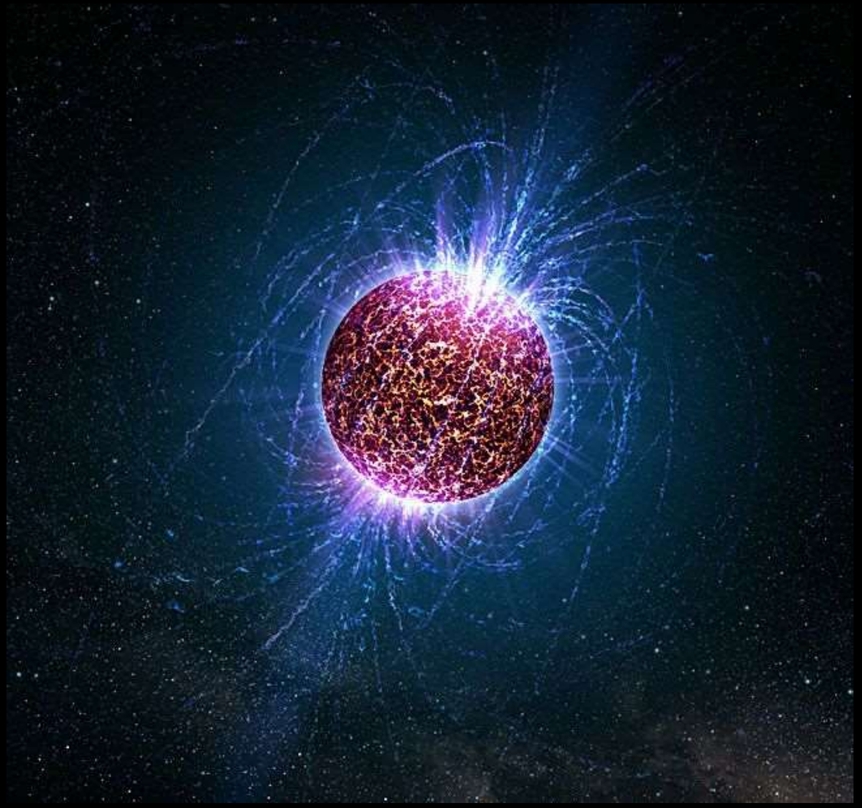
3. Glitches: from neutron stars to ultracold dipolar gases

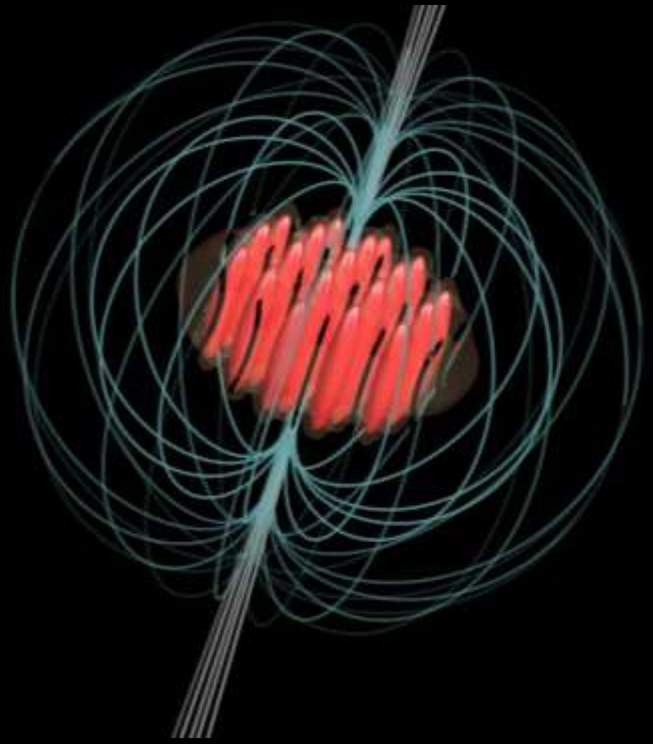
A particular flavor of neutron stars rapidly rotate in such a way that we can observe a pulsating flash of light each time the magnetic field poles point directly at Earth. Known as “pulsars”, the frequency of this flash is almost perfectly periodic, slowing down due to radiation emission. Once every few years, however, the star speeds up, in a process known as a glitch.

The reason for a glitch is unknown, but expected to be related to the partly superfluid nature of neutron stars. The project aims to explore the links between pulsar glitches and glitches in dipolar supersolid states.

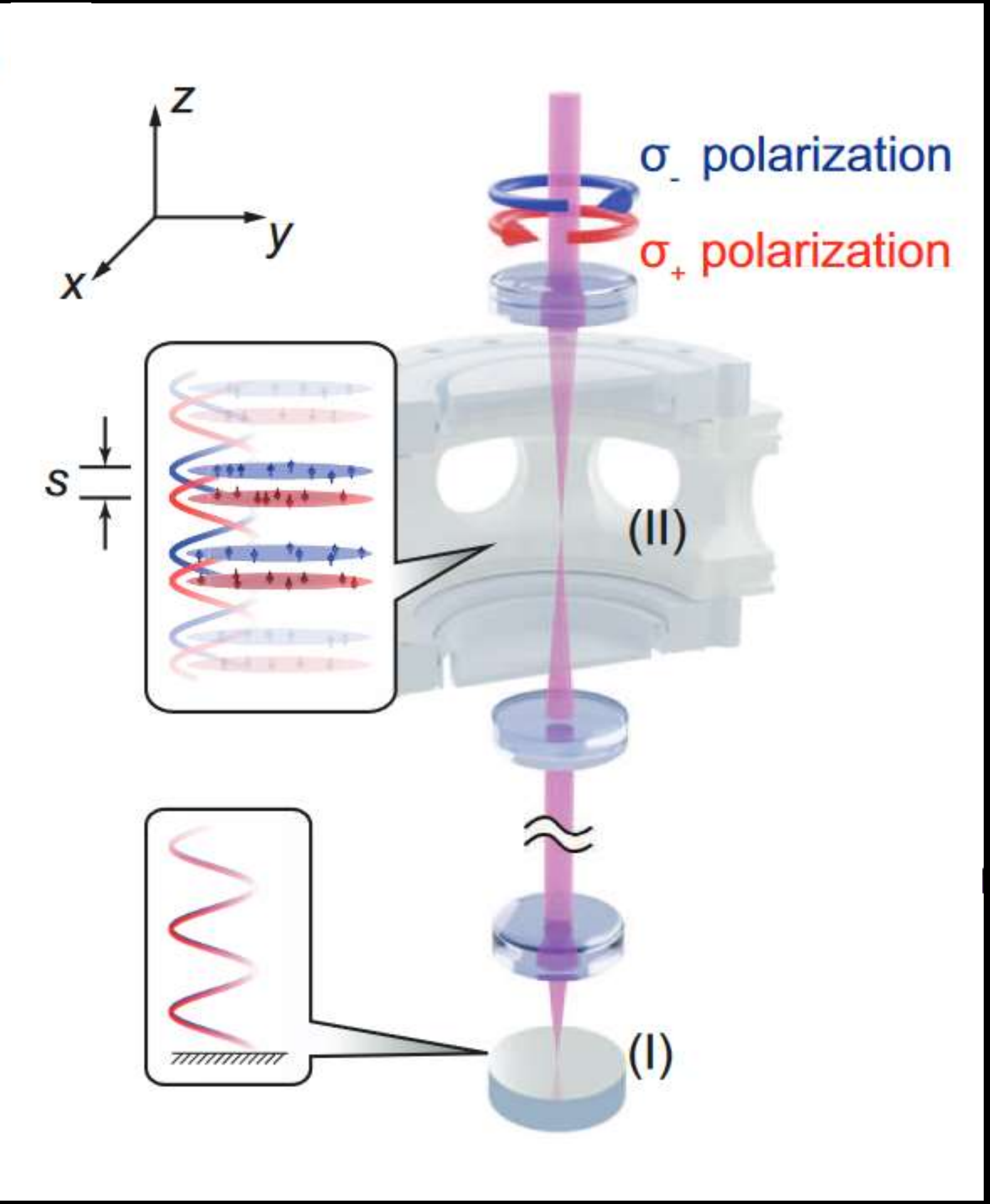
You will learn:

- How neutron stars form and why we believe their interiors are partly superfluid and supersolid.
- How using ultracold dipolar atoms we can create the supersolid phase here on Earth.
- How to numerically simulate the glitch mechanism using ultracold dipolar supersolids.





Bachelor Project



4. Sub-wavelength optical potentials for ultracold atom quantum simulators

Quantum simulation in ultracold systems aims to address problems that surpass the capabilities of classical computers by flexibly tuning the Hamiltonian of particles. These opportunities are further enhanced when atoms are confined within periodic potential configurations created by laser fields, known as optical lattices. One of the main challenges in such setups is to reduce the spacing between lattice sites relative to the laser wavelength, in order to enhance interactions between the atoms, thereby expanding the scope of quantum simulation applications. This project is dedicated to exploring the feasibility of implementing optical lattice potentials smaller than the wavelength within our erbium platform, building upon the state-of-the-art progress achieved in recent experiments.

You will learn how to:

- Trap and cool atoms using laser beams
- Design optical lattice geometries for building quantum simulators
- Utilize tools from the atomic physics and optics fields to implement non-conventional sub-wavelength optical lattices

Contact Us

francesca.ferlaino@uibk.ac.at

manfred.mark@uibk.ac.at

Bachelor Projects

1. Quantum computing with neutral atoms in optical tweezers
2. Observation methods in quantum gas experiments: from absorption to ultra-fast fluorescence
3. Glitches: from neutron stars to ultracold dipolar gases
4. Sub-wavelength optical potentials for ultracold atom quantum simulators

Master Projects

1. Algorithms and software development for optical tweezers manipulation
2. Design of protocols for the implementation of qudits in neutral atoms in optical tweezers
3. Glitches: from neutron stars to ultracold dipolar gases
4. Spin manipulation in optical lattices
5. Quantum gas microscope for strongly dipolar atoms

Master Project

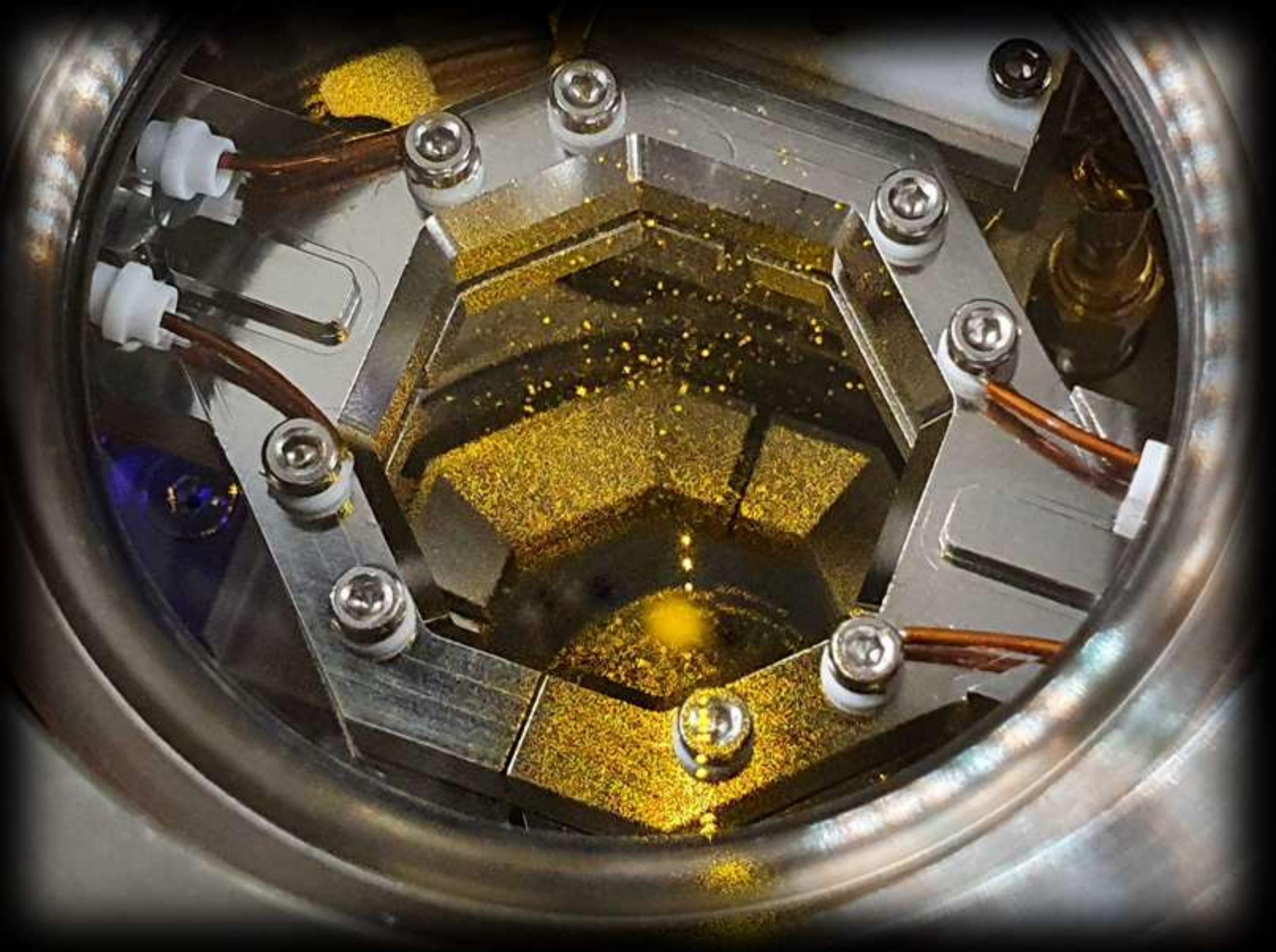
1. Algorithms and software development for optical tweezers manipulation

Tightly focused beams of light, known as optical tweezers, have fast become a leading method for trapping and moving single atoms, with broad applications in particular in the fields of quantum computing and simulation. In this project, you will develop a control software to automatically re-arrange the positions of a set of optical traps to achieve arbitrary geometries of ordered arrays of atoms .

You will:

- Programmatically interface with advanced instrumentation.
- Design and implement efficient algorithms for tweezer fast manipulation.
- Develop high-performance code in a low-level programming language

Master Project



2. Design of protocols for the implementation of qudits in neutral atoms in optical tweezers

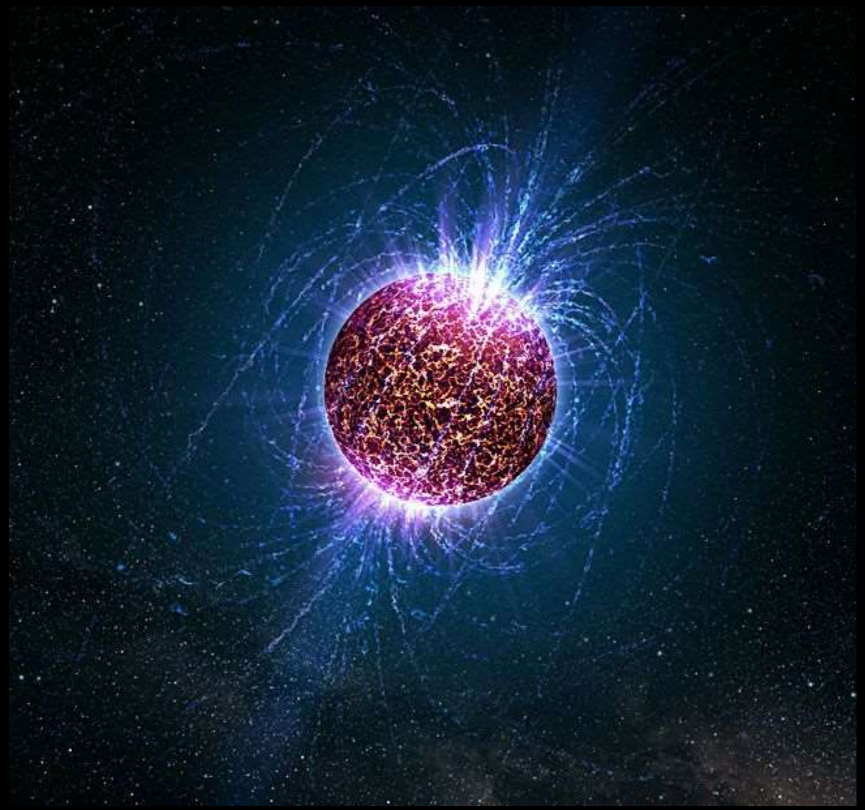
Quantum computing is a quickly developing technology exploiting the properties of quantum states to solve computational problems that are intractable for classical processors. This project aims at designing and implementing experimental protocols for the initialization, manipulation and entanglement of quantum bits of information in a high-dimensional space (qudits), using the vast state space offered by erbium atoms trapped in optical tweezers.

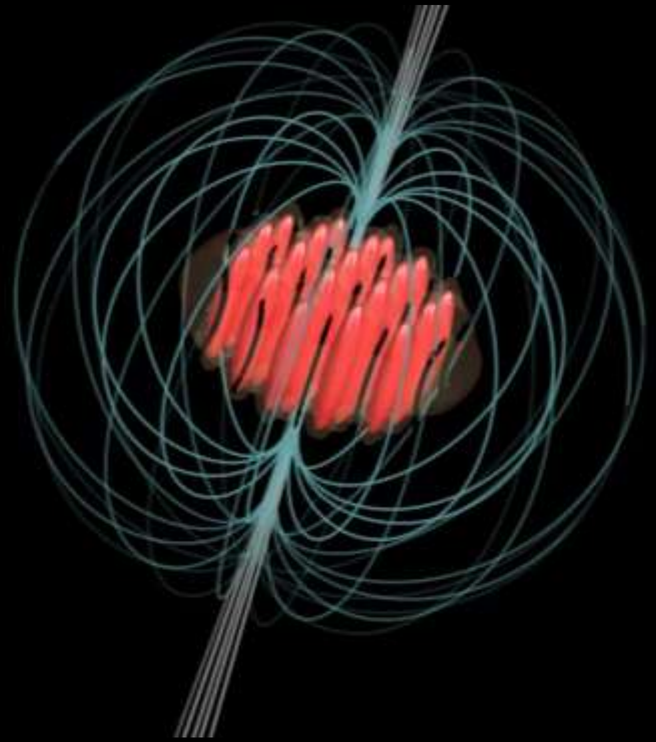
You will learn:

- How atoms can be manipulated with laser light to encode and process quantum information.
- How to design protocols for the initialization of qudits and implementation of single and multi-qudits gates.
- How to set up electronics in the laboratory for fast generation and control of optical pulses

Master Project

3. Glitches: from neutron stars to ultracold dipolar gases





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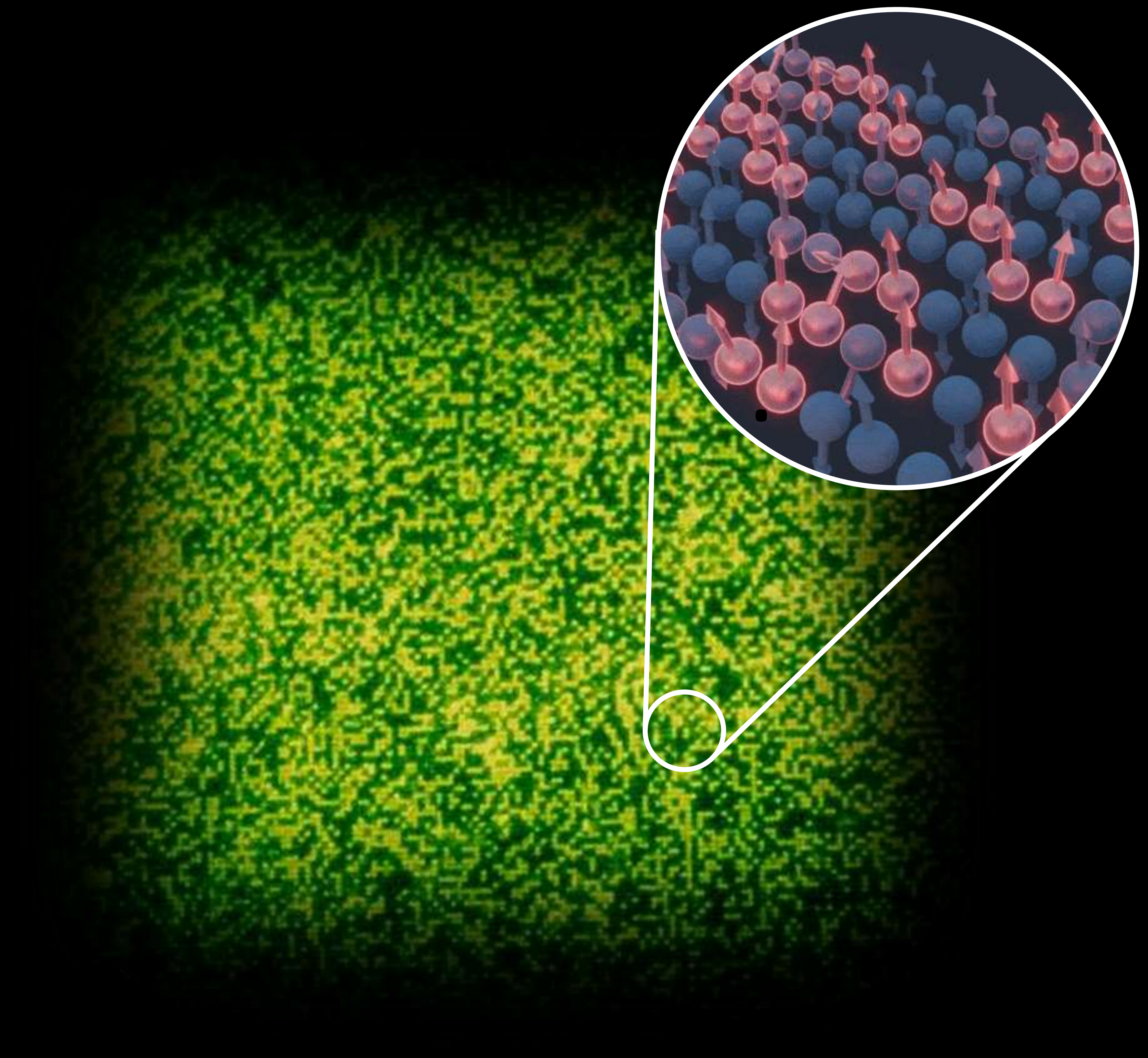
The reason for a glitch is unknown, but expected to be related to the partly superfluid nature of neutron stars. This project aims to tie our understanding of pulsar glitches and glitches in dipolar supersolid states.

You will learn:

- How to perform numerical simulations with the extended Gross-Pitaevskii equation, emulating neutron star dynamics.
- Physics of quantum vortices in a dipolar supersolid.
- How to use High Performance Computers (supercomputers)



Master Project

4. Spin manipulation in optical lattices

Ultracold atoms offer an exceptional platform for quantum simulation, enabling flexible control over many-body interactions. In this regard, the optical manipulation of spin states and their interactions in erbium experiments paves the way for the simulation of many exotic phases of condensed matter. This project focuses on manipulating and imaging the spins of atoms at the single-site level within optical lattice systems. This achievement will represent a major step towards realizing unconventional states of matter within our ultracold atom platform.

You will learn how to:

- Manipulate atoms using light
- Engineer laser beams using light modulation tools
- Build a stable optical setup for atomic lattices applications

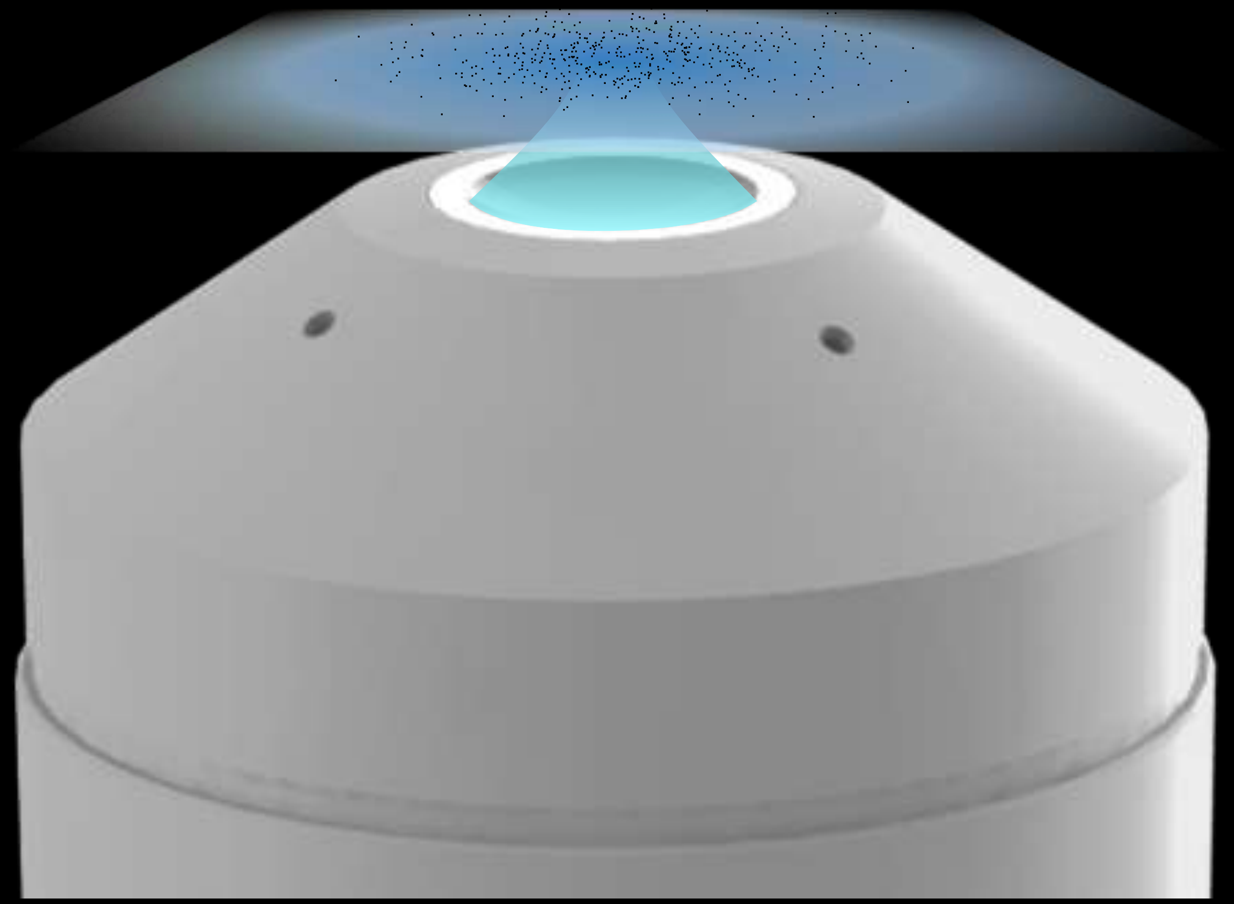
Master Project

5. Quantum gas microscope for strongly dipolar atoms

With the recent technological progress in observation and detection methods, the next generation of quantum gas experiments opens a new venue for the study of interacting quantum systems in unexplored regimes with acquired sub-wavelength spatial resolution and single photon sensitivity. The student will participate to the implementation of the various systems required for the realization of an ensemble of strongly dipolar atoms in optical lattices in a quantum gas microscope experiment.

You will learn:

- Lattice physics with dipolar atoms
- How to build and implement various optical traps, from opto-mechanics to electronics and computer control
- Fluorescence imaging with a quantum gas microscope



Strongly Correlated Quantum Matter Group

AG Nägerl

www.quantummatter.at

17th January 2024, Innsbruck

universität innsbruck

FOR 2247

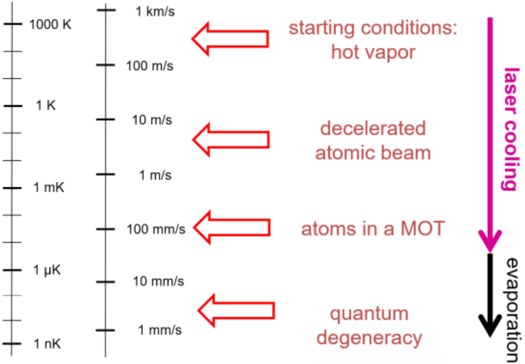
FWF Der Wissenschaftsfonds.

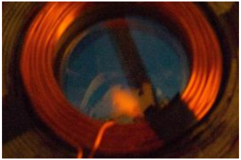
erc

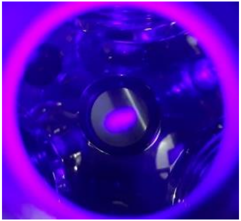
Atoms, Light, and Molecules
Innsbruck Physics Research Center

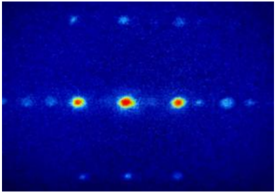
Ultracold atoms

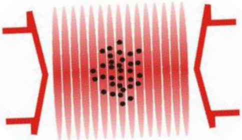
temperature regimes



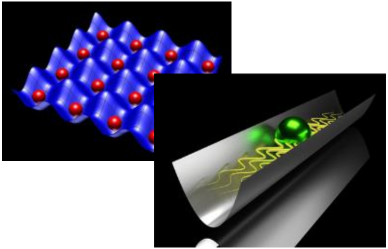








Research Highlights



- Quantum simulation
- Many-body quantum dynamics
- Novel quantum phases of matter
- Dipolar quantum gases
- Quantum gas microscopy
- High-precision laser spectroscopy

Observation of many-body dynamical localization, Y. Gou et al. arxiv 2312.13880 (2023).

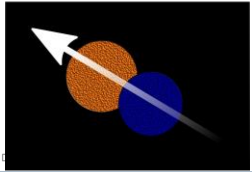
Bose-Einstein condensation of non-ground-state caesium atoms, M. Horvat et al. arxiv 2310.12025 (2023).

Cooling bosons by dimensional reduction, Y. Guo, H. Yao et al. arxiv 2308.04144 (2023) accepted in Nature physics.

Experimental Observation of the 2D-1D Dimensional Crossover in Strongly Interacting Ultracold Bosons Y. Guo, H. Yao et al. arxiv 2308.00411 (2023) accepted in Science Advances.

An association sequence suitable for producing ground-state RbCs molecules in optical lattices, A. Das et al. SciPost Phys. (2023).

Observation of confinement-induced resonances in a 3D lattice, D. Capecchi et al. Phys. Rev. Lett. (2023).

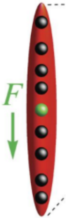


Group structure

4 labs

Cs III

Investigation of quantum dynamics in highly interacting quantum wires



RbCs

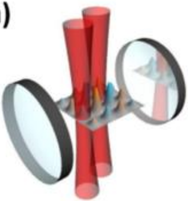
Creation/manipulation of dipolar molecules in optical lattices

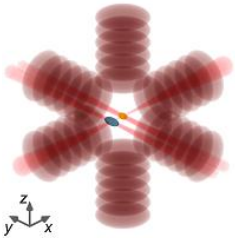
KCs

Creation of dipolar molecules under quantum microscope

Cavyt (under construction)

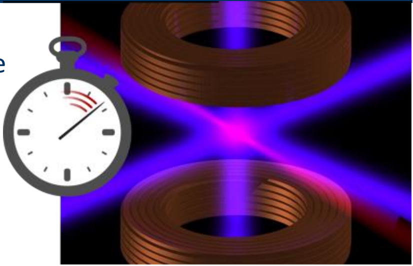
Yb atoms in tweezer arrays, coupled via photon exchange





LevT-Rev
Student setup

Bachelor projects



- Realization of laser system for molecule association
- Realization of magnetic coils setup
- Characterization of electrodes setup
- Upgrades for the LevT-Rev setup and demenstration setup
- Novel imaging setup for the Cs III experiment

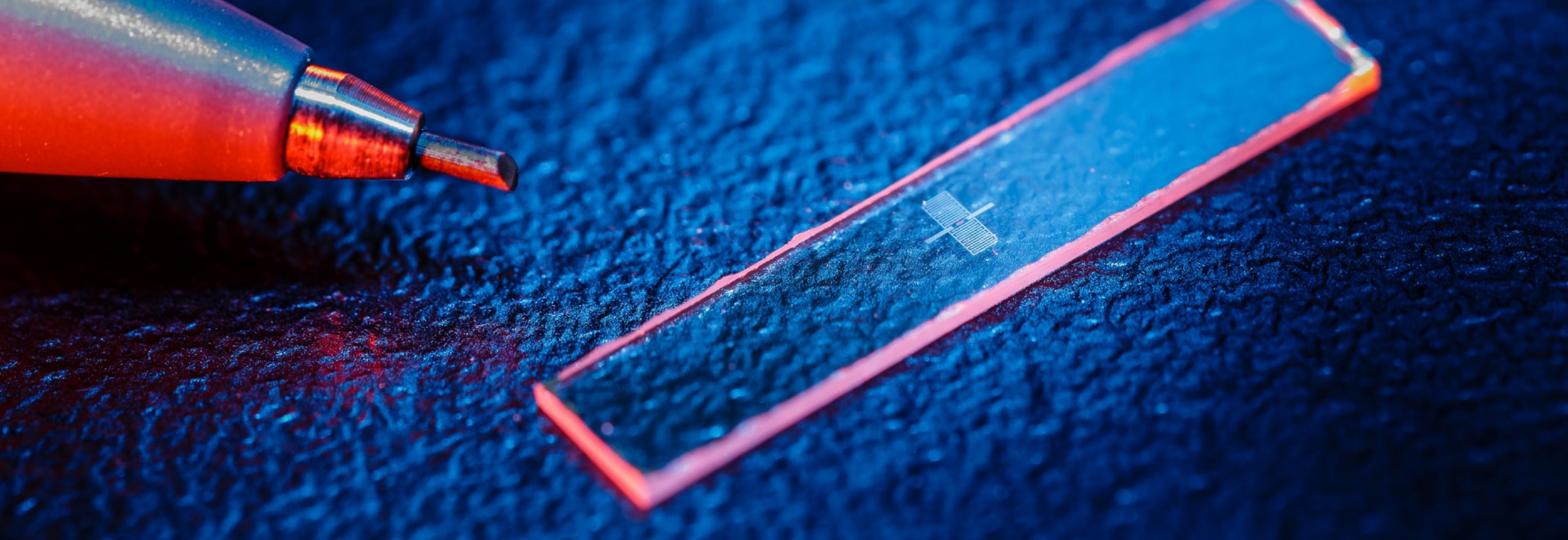
Example

Set-up for atom number stabilization

Test of photodiode for atom fluorescence detection Preparation of the reading and triggering electronics Calibration of the photodiode signal on the atoms

Quantum Circuits Group

AG Kirchmair

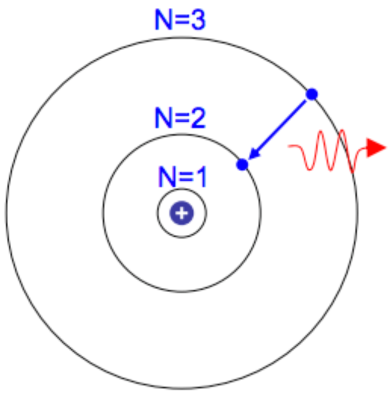


Master & Bachelor Topic presentations

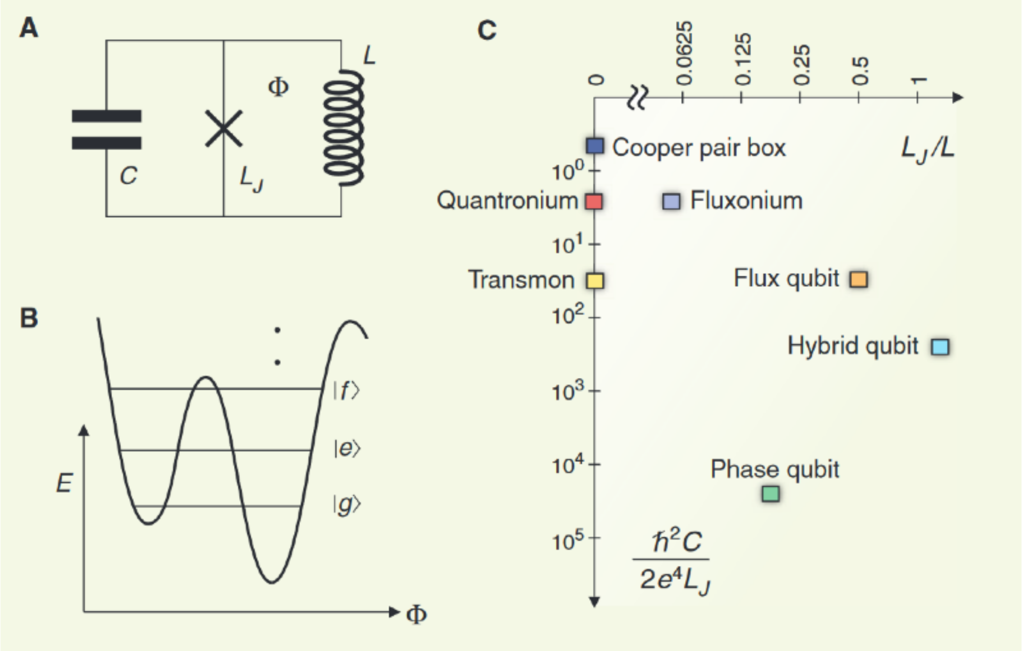
17.01.2024

Encoding of quantum bits (qubits)

Natural atom



Artificial atom



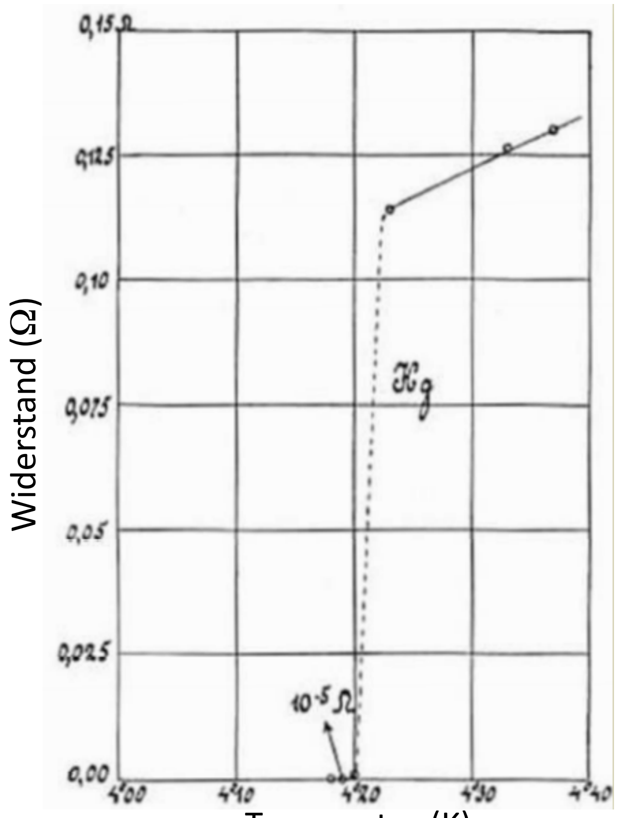
What we like about artificial atoms

- on chip
- fully controllable
- tunable
- strong coupling
- can explore regimes that are not found in natural atoms
- good candidates for new quantum technologies

Applications in

- Quantum computing, information processing
- Quantum optics
- Quantum sensors
- Metrology

Superconductivity



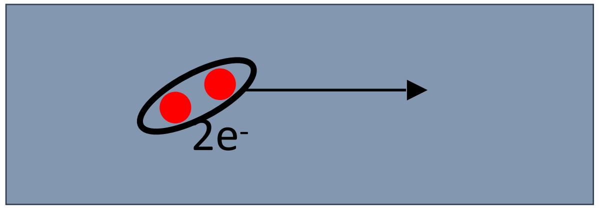
Kammerlingh Onnes, 26 Oktober, 1911

Physics Today, September 2010

More than 100 year old phenomenon

Electrons pair up to Cooper pairs

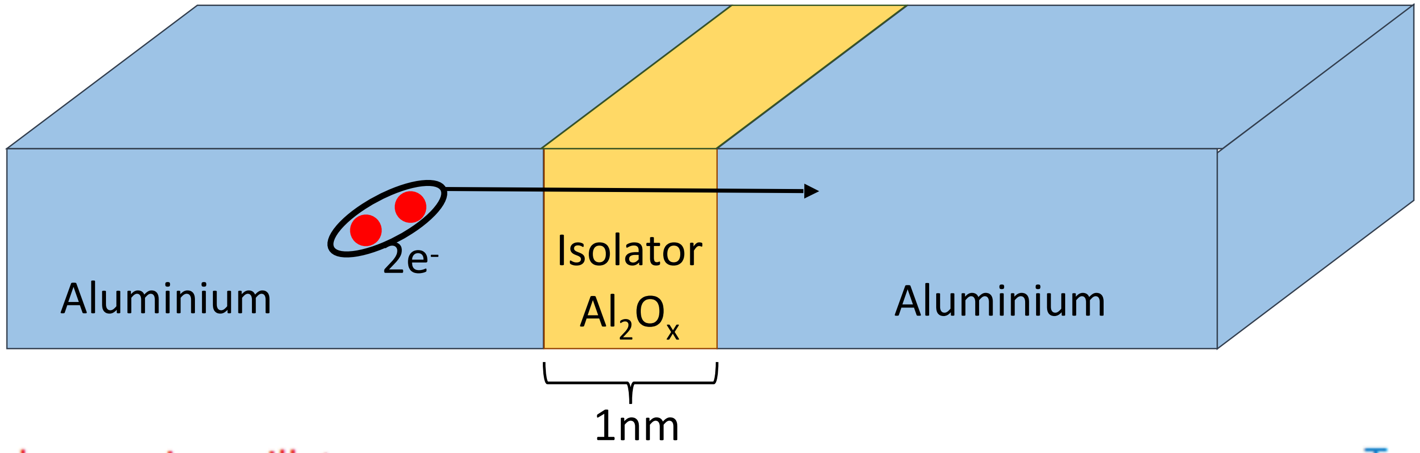
=> No resistance for current

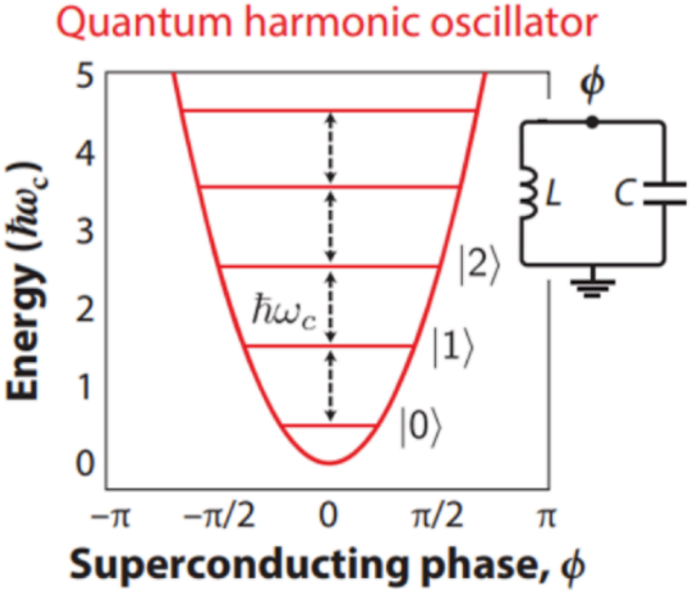


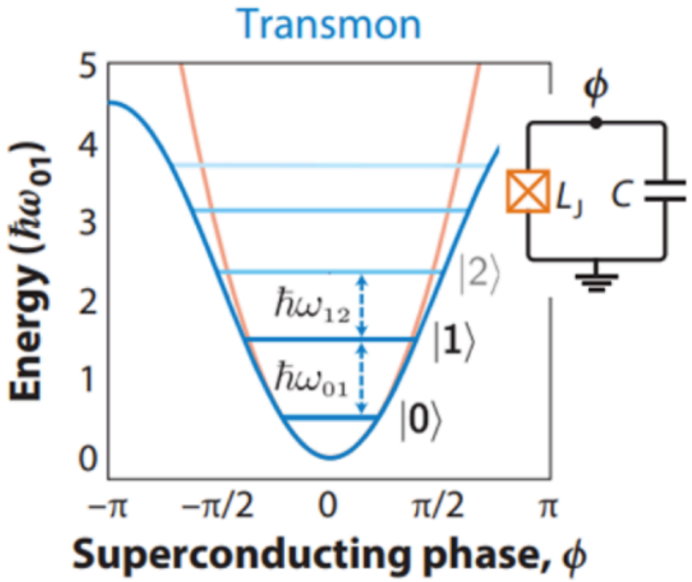
Aluminium, Niobium, Mercury …

Temperature < 1 K

Josephson Contact & Qubit Circuit

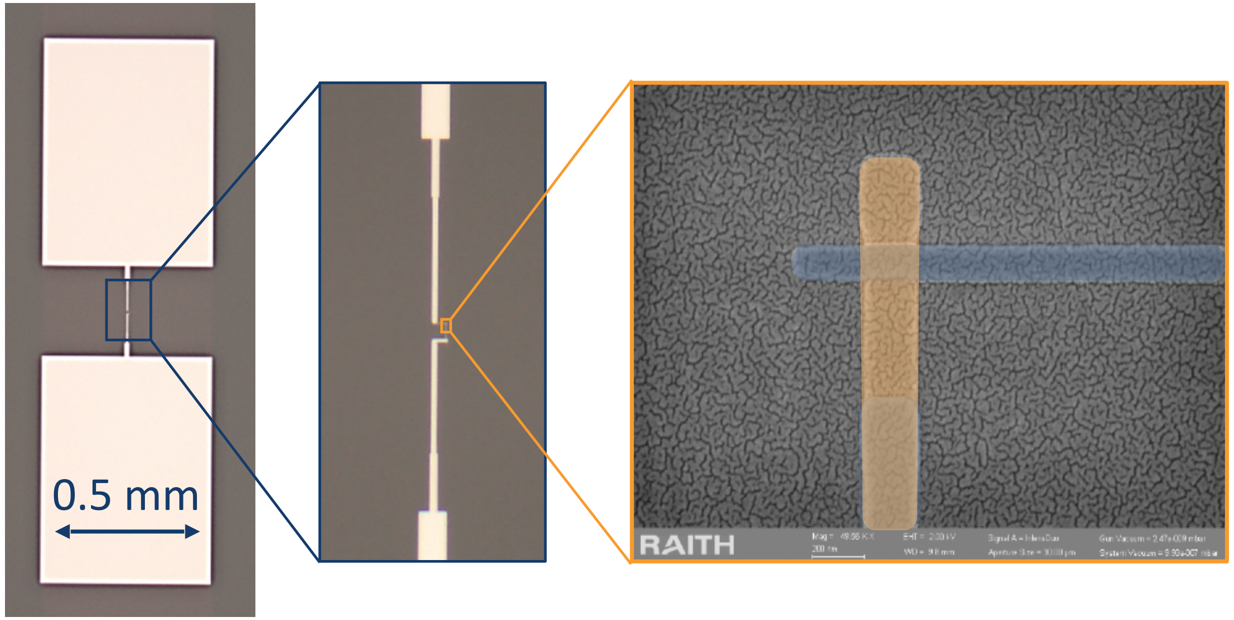






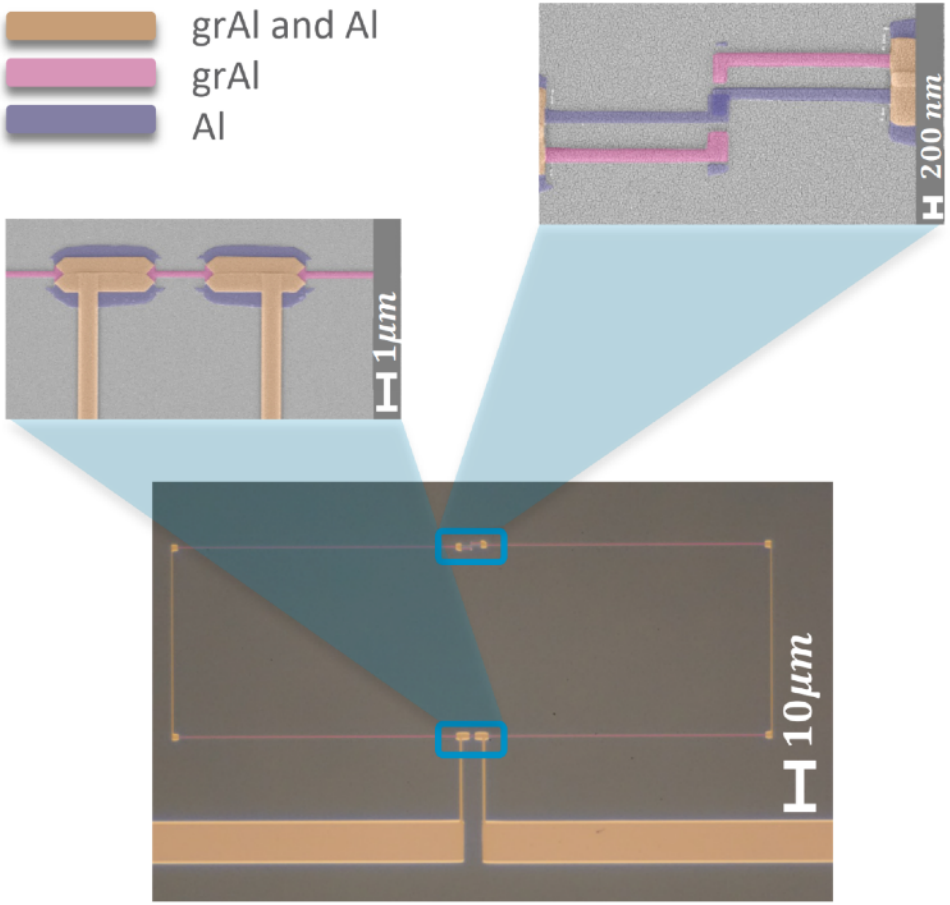
Superconducting Qubit's in Innsbruck

Transmon



Yale, MIT, IBM, Google, Saclay…

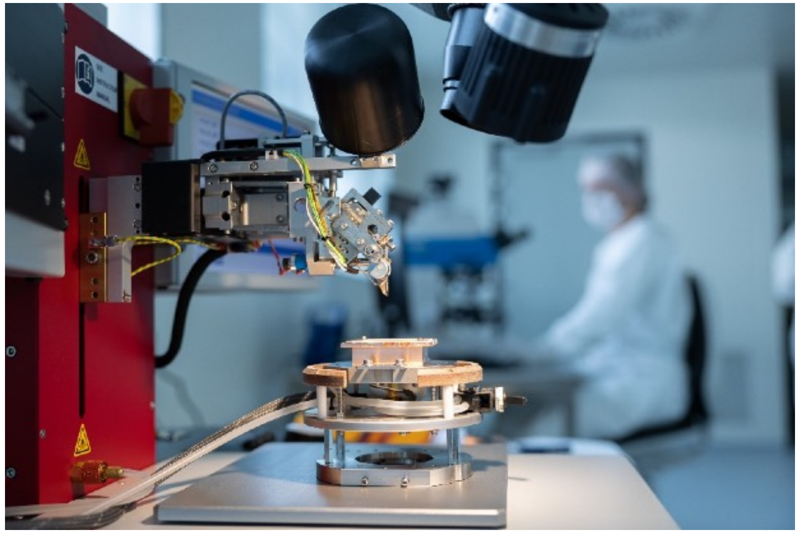
Fluxonium

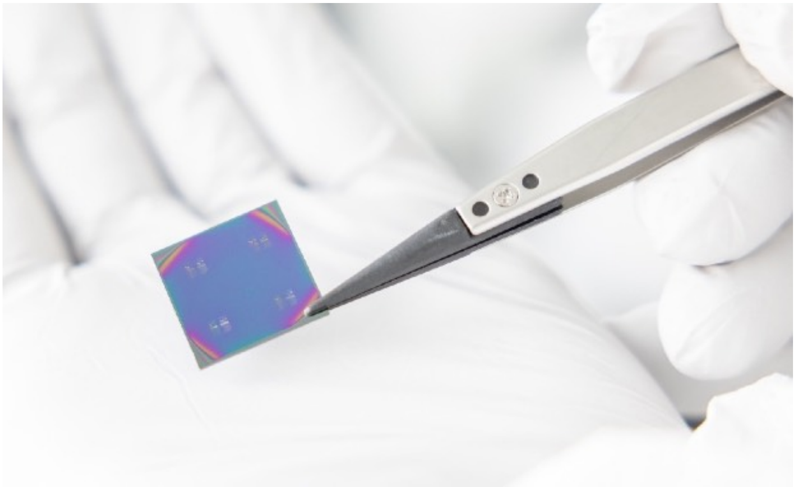


Yale, KIT, Amazon…

How do you build a qubit - cleanroom

universität innsbruck

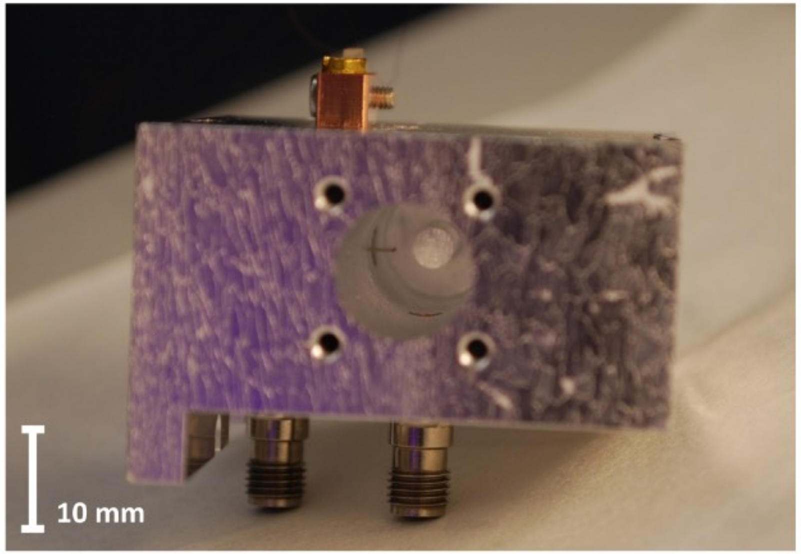


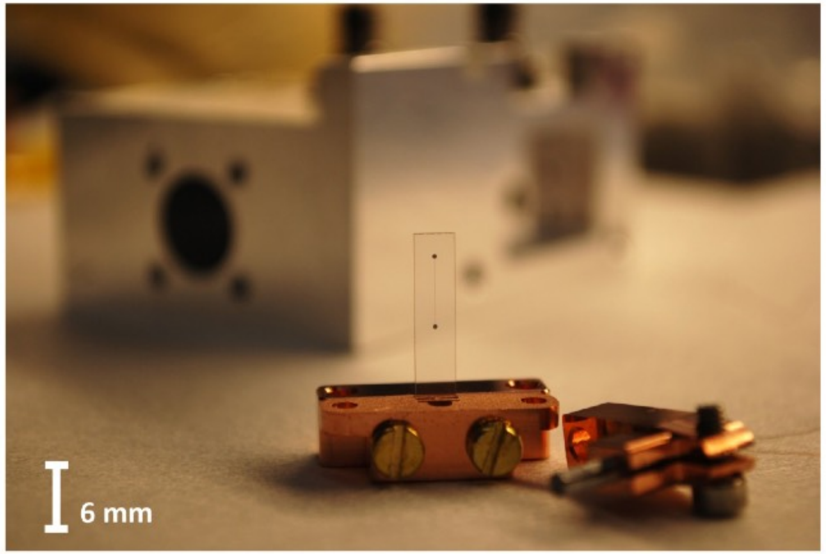


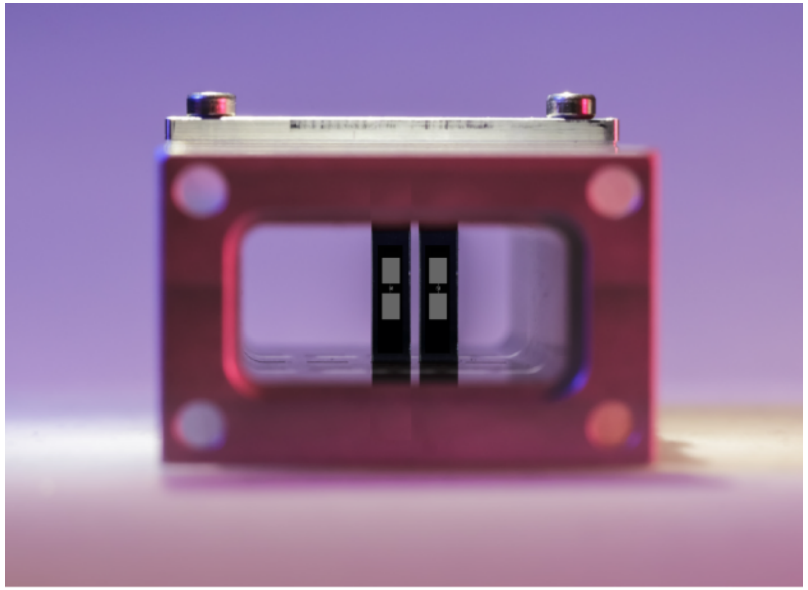
ÖAW ÖSTERREICHISCHE AKADEMIE DER WISSENSCHAFTEN

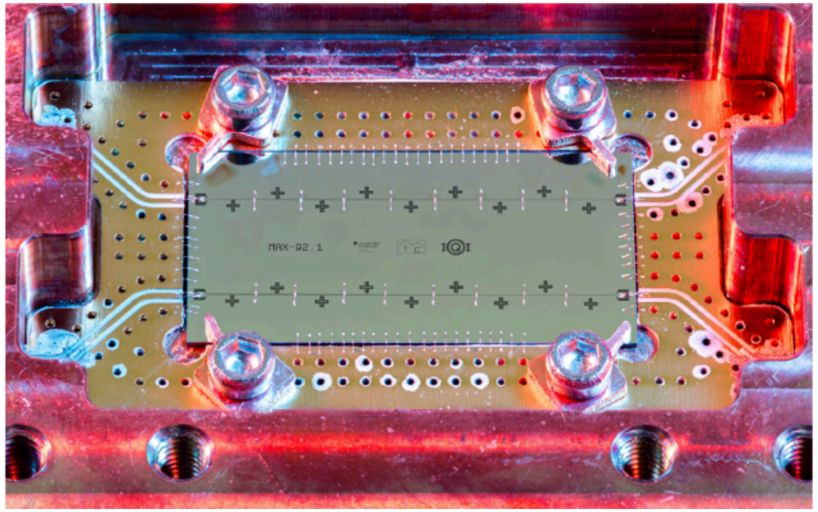
IQI

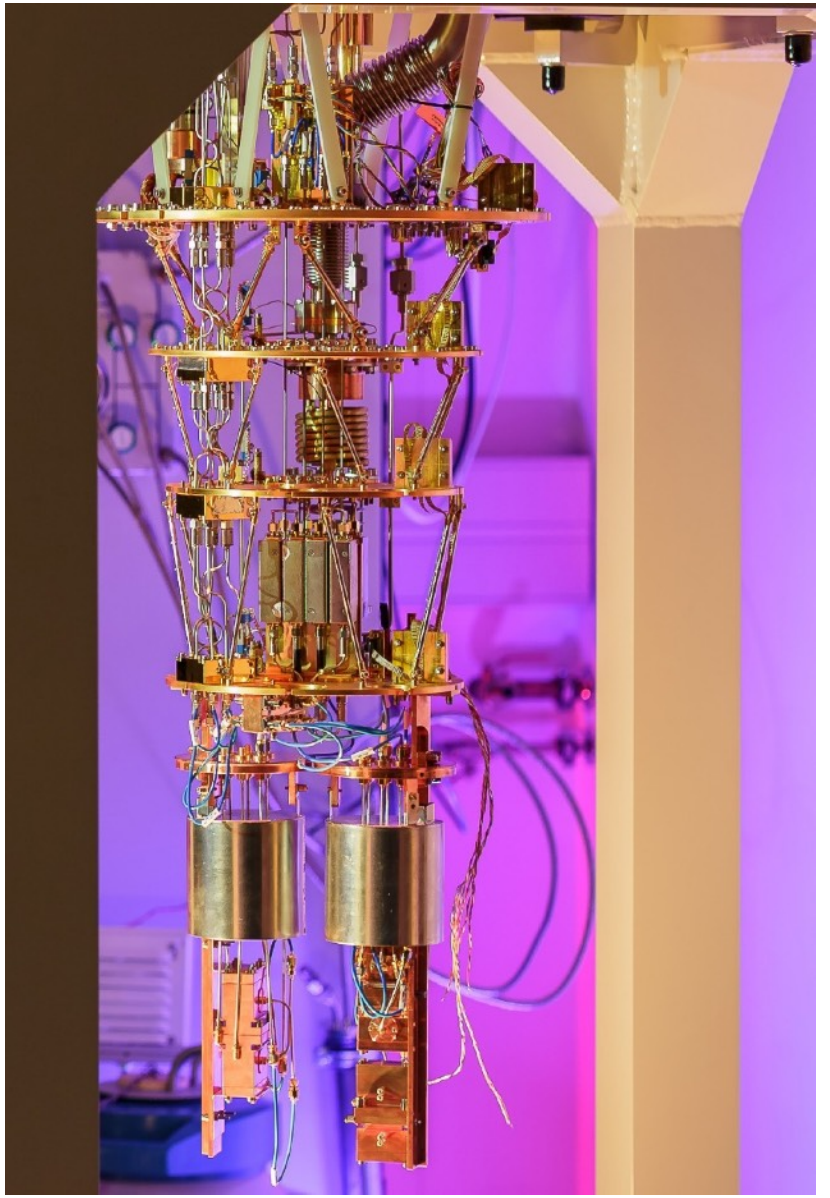
Experimental Setups & Cryostat







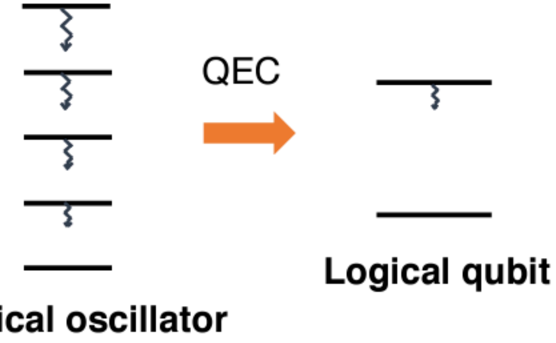


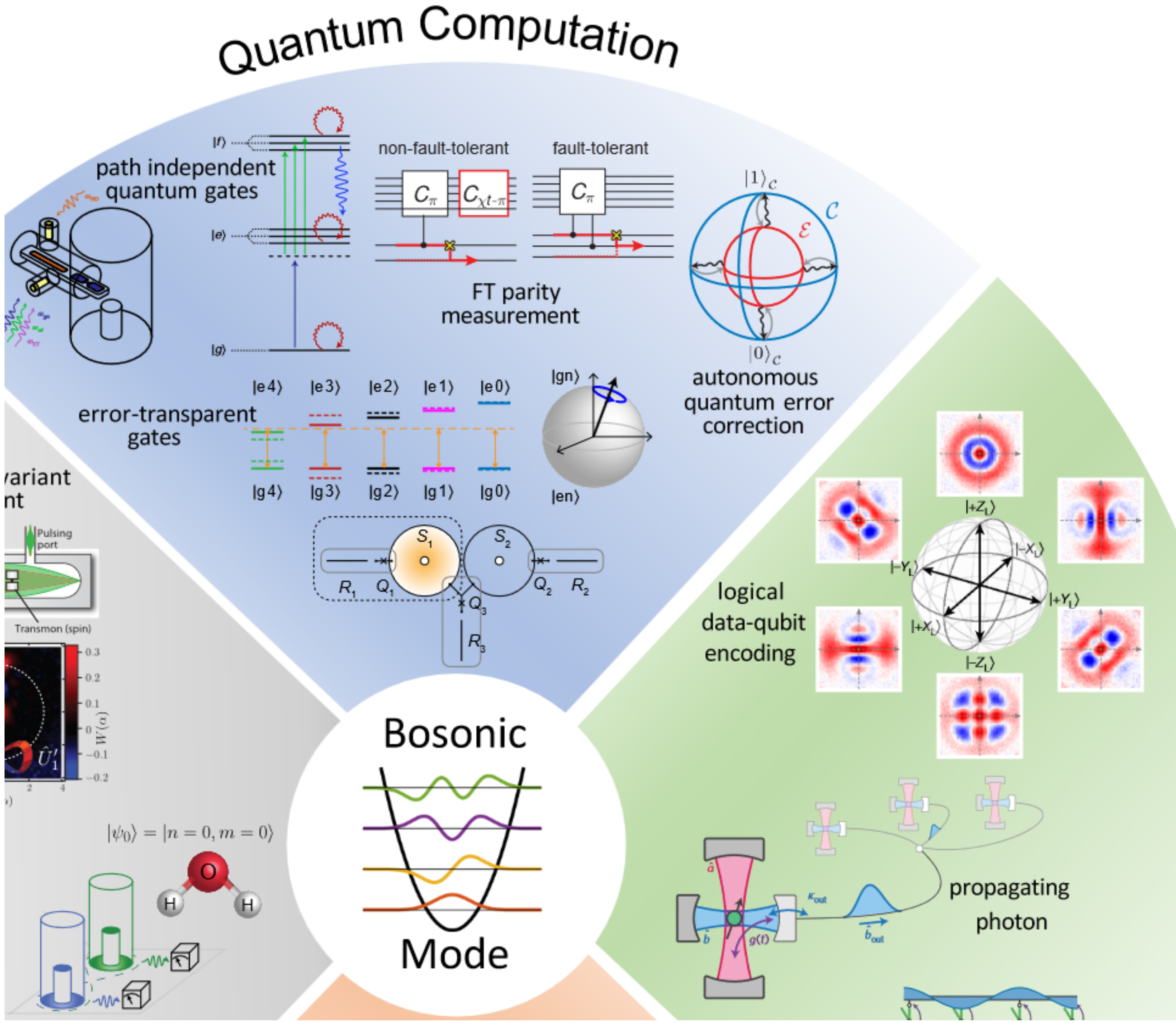


Bosonic Quantum Error Correction (QEC)

Multi-qubit QEC

Bosonic QEC

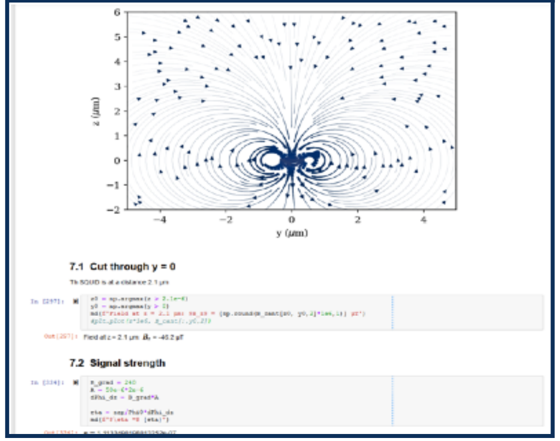




Master thesis: from Theory to Experiment

Master thesis: from Theory to Experiment

Parameter Study

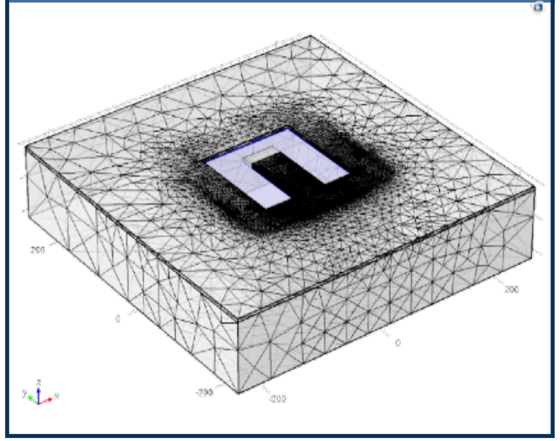


Master thesis: from Theory to Experiment

Parameter Study

- Literature research or experience about **realizable parameters**
- **Analytical calculations** and **optimization**

Simulations



Master thesis: from Theory to Experiment

universität
innsbruck

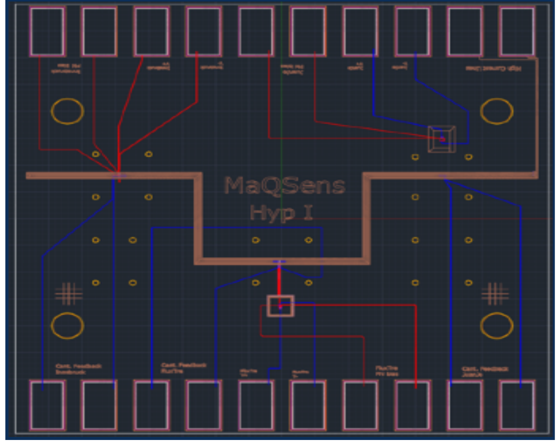
Parameter Study

- Literature research or experience about **realizable parameters**
- **Analytical calculations** and **optimization**

Simulations

- **Finite element simulations** of actual setup or simplified setup

Design



Master thesis: from Theory to Experiment

Parameter Study

- Literature research or experience about **realizable parameters**
- **Analytical calculations** and **optimization**

Simulations

- **Finite element simulations** of actual setup or simplified setup

Design

- Finalizing design and make it **compatible with fabrication process**

Sample Fabrication

Master thesis: from Theory to Experiment

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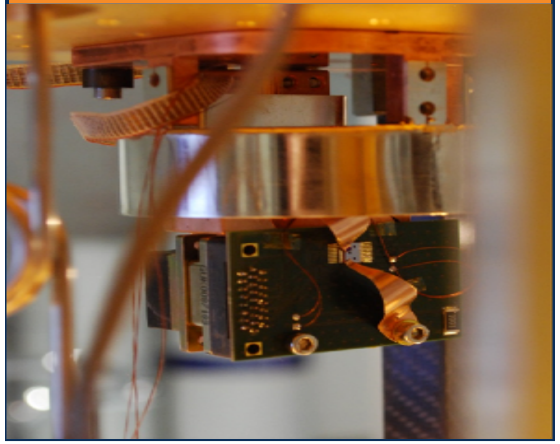

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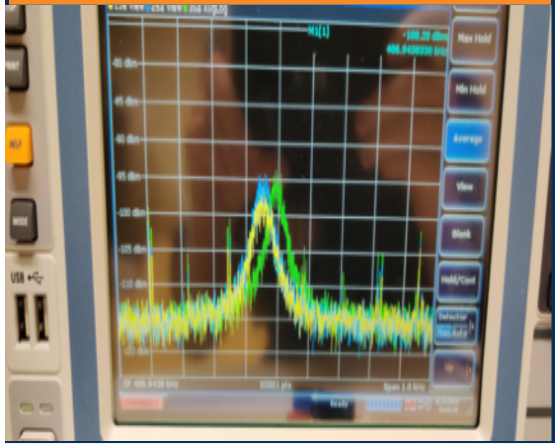

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- **Program drivers, control Systems, ….**
- **Debugging**

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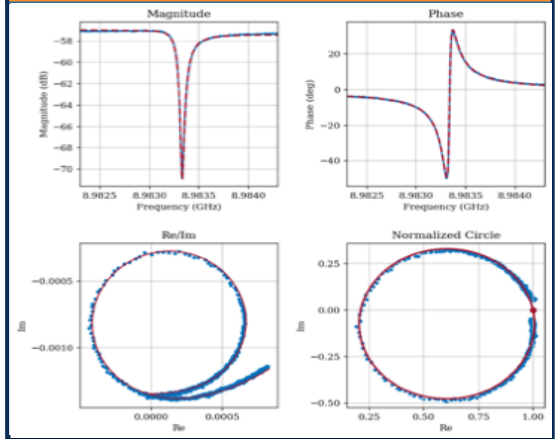

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Data Analysis

- **Understand** what's going on
- **Fit data to models** and **verify results**

Start again

- If experiment fails -> **Improve** and **start new generation**

Opportunities in 2024

- **BSc projects**
  - *Different types of superconducting qubits*
    - E.g. Transmon, fluxonium,…
    - Literature review
  - *Bosonic qubits and encoding – error correction*
    - Literature review
  - *Losses in microwave resonators*
    - *Numerical simulations*
    - *Literature review*
- **MSc projects**
  - *Come and talk to us*

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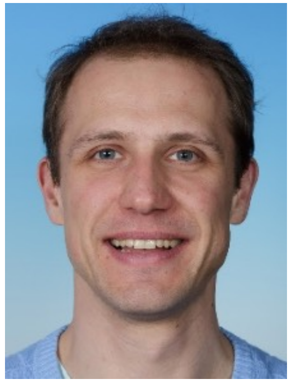

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