Atomic, molecular and optical physics

PhD, postdoc and research assistant positions

in Amsterdam and Eindhoven

The AMO groups in Amsterdam and Eindhoven offer a lively, international environment to perform cutting edge research. We offer positions on exciting and challenging experiments to explore

- Tests of fundamental physics
- Quantum simulation with trapped ions, ultracold atoms and molecules
- Quantum sensing with continuous atom lasers and superradiant clocks
- Quantum computing with new architectures

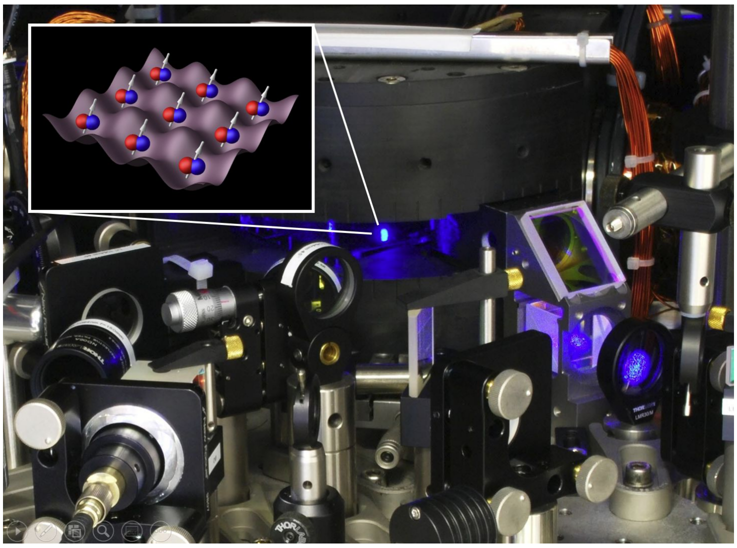
UNIVERSITY OF AMSTERDAM

PhD position

(and potentially postdoc position in summer 2021)

Quantum simulation with RbSr ground-state molecules

In this project you will create a new class of ultracold molecules and use them to perform quantum simulations [1]. So far all ultracold ground-state molecules are composed of two alkali atoms. Our target molecule, RbSr, consists of an alkali and an alkaline-earth atom. This results in a rich and barely explored molecular structure, in particular a large electric dipole moment together with a magnetic moment. These properties make RbSr an excellent candidate for quantum simulations.



After creating the molecules using unusual magnetic Feshbach resonances we discovered [2], you and the research team will transfer the molecules to their absolute ground state. This transfer requires molecular spectroscopy to choose the best transfer path and implementation of a suitable laser pulse sequence (STIRAP). Once ultracold ground state molecules are available you will research how to engineer their interactions by applying electromagnetic fields. Engineering spin-dependent interactions between our lattice confined molecules will allow us to study interesting models of quantum magnetism. A second goal will be to induce repulsive interactions between the molecules, so that they can collide with each other without undergoing chemical reactions. In this way it should be possible to create a quantum gas of molecules. In the long-run, the methods you are developing can be used to create molecules that are similar to RbSr and that might enable extremely precise measurements of the electron electric dipole moment, advancing a promising road towards the discovery of physics beyond the standard model.

You will work in a team of two PhD students, one postdoc, PIs Klaasjan van Druten and Florian Schreck, and a network of collaborators. This project is supported by a Dutch research programme on quantum simulation.

For more information please contact Florian Schreck (schreck@uva.nl) or take a look at our website www.strontiumBEC.com.

[1] John L. Bohn, Ana Maria Rey, Jun Ye, *Cold molecules: Progress in quantum engineering of chemistry and quantum matter*, Science **357**, 1002 (2017).

[2] Vincent Barbé, Alessio Ciamei, Benjamin Pasquiou, Lukas Reichsöllner, Florian Schreck, Piotr S. Żuchowski & Jeremy M. Hutson, *Observation of Feshbach resonances between alkali and closed-shell atoms*, Nature Physics 14, 881 (2018).

UNIVERSITY OF AMSTERDAM

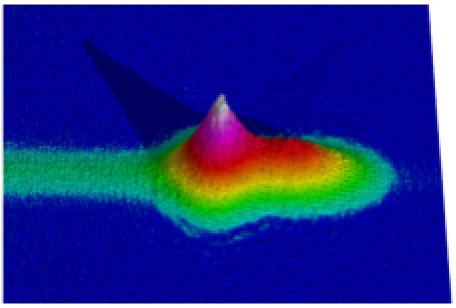
PhD position

(and potentially postdoc position in summer 2021)

Continuous atom laser

In this project you will try to produce the first continuous atom laser [1]. Analogous to the optical laser, an atom laser is a beam of atoms described by a coherent matter-wave. Such a beam could be the ultimate source for an atom interferometer. Ultracold-atom interferometers are widely used for state-of-the-art precision measurements, with applications for inertial navigation (acceleration and rotation sensors) and for gravimetry and gravity gradiometry (mineral exploration, groundwater monitoring). They are also at the forefront of fundamental research endeavours such as testing Einstein's equivalence principle, measuring the fine structure constant, detecting dark matter, and probing gravitational waves in a bandwidth not accessed by optical interferometers.

However, so far only short atom laser pulses have been created by outcoupling condensed atoms from a Bose-Einstein condensate (BEC). Once all atoms have been outcoupled, after 0.1s or so, the atom laser stops and the next laser pulse requires the creation of a new BEC, which is a lengthy process (it takes many seconds). The continual interruptions and the low duty cycle have limited atom lasers on many fronts and blocked them from reaching their potential for precision measurement. In this project we want to overcome these limitations.



Our group's Bose-Einstein condensate in steady-state, the first of its kind [2].

Our unique breakthrough is that we are able to create continuous-wave BECs, BECs in flow equilibrium between loss of atoms and addition of fresh atoms by a mechanism that can preserve coherence. In this way we can sustain a BEC in steady-state for as long as we desire, which provides us with an ideal source for a continuous atom laser [2].

Your first research avenue will be to study the properties of this driven-dissipative BEC together with the research team. You will then implement a mechanism to outcouple atoms from the steady-state BEC, with the goal to produce the first continuous atom laser beam. If successful we'll explore its potential for ultracold-atom interferometry.

You will work in a team with one other PhD student, and PIs Benjamin Pasquiou and Florian Schreck. The work will be executed within the European Quantum Flagship project iqClock, the European Innovative Training Network MoSaiQC and a Dutch National Science Agenda project.

For more information please contact Florian Schreck (schreck@uva.nl) or take a look at our website www.strontiumBEC.com.

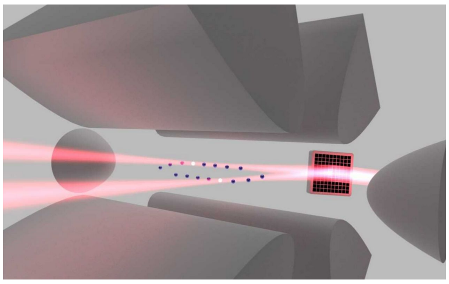
[1] N. Robins et al., *Atom lasers: Production, properties and prospects for precision inertial measurement*, Phys. Rep. **529**, 265 (2013).

[2] Chen et al., *An ultracold Bose-Einstein condensate in steady state*, arXiv:2012.07605 (2020).

Combined theory - experimental PhD position

Trapped ions in optical tweezers

Trapped ions form one of the most accurate quantum computers that we have available. Two-qubit quantum gates have been demonstrated with errors below 0.1% [1,2] and quantum simulators containing up to 53 ions [3] have been reported.



Precision quantum gates between ions are mediated by soundwaves in the ion crystal. In our experiment, we aim to implement a new way to control the interactions between the qubits allowing direct engineering of the soundwaves that mediate the interactions between the ion-qubits. The scheme uses optical tweezers that will be generated with spatial light-modulators. By pinning appropriate ions in the crystal, we can engineer the soundwave spectrum such that the resulting qubit interactions match the ones desired [4]. The scheme can be used both for quantum computation [5] and for quantum simulation in 2-dimensional ion crystals [6].

In this combined theory/experimental PhD project you will work in a team that develops this new quantum computation platform. Your project will center on investigation of the role of interaction range, connectivity, and dimensionality in transport and entanglement dynamics in quantum many-body systems both theoretically and experimentally. The project will consist of several interrelated sub-projects that aim to answer the following questions:

1. What is the functional form of equilibration in systems with long-range vs short-range interactions?
2. What is the appropriate controlled approximation that captures the transport dynamics in higher dimensional systems?
3. What is the most experimentally accessible way to create flexible connectivity and create patterns of interest?

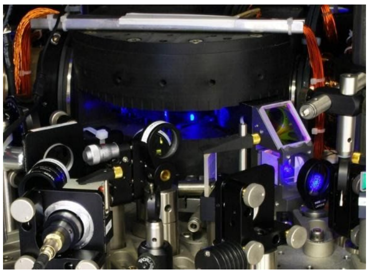
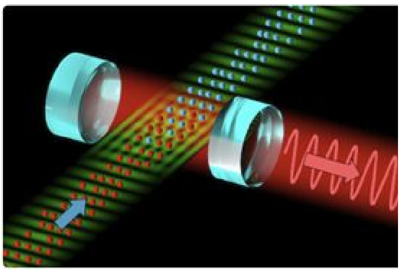
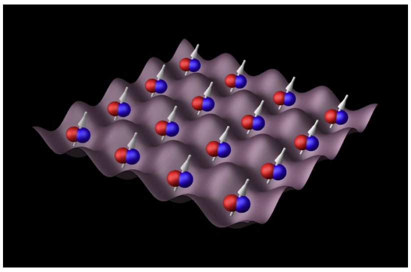
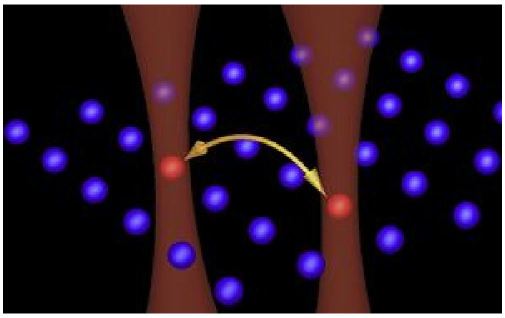
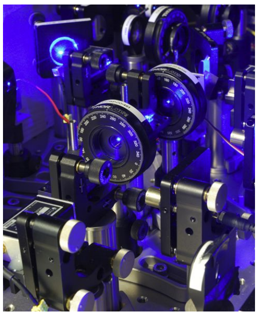
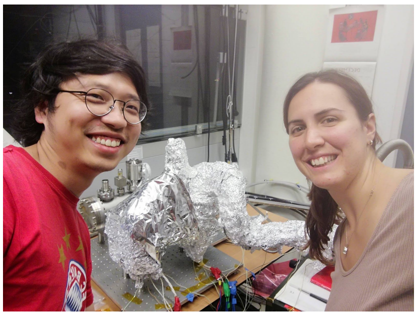
Once we have characterized the behavior of our models theoretically, you will shift your attention to implementing them on the quantum simulation platform. The work will involve setting up optics, lasers and electronics as well as programming.

For more information please contact Arghavan Safavi (a.safavinaini@uva.nl) or Rene Gerritsma (r.gerritsma@uva.nl) take a look at our website www.hyqs.nl.

[1] C. J. Ballance et al., Phys. Rev. Lett. 117, 060504 (2016).
[2] J. P. Gaebler et al., Phys. Rev. Lett. 117, 060505 (2016).
[3] Zhang et al., Nature 551, 601 (2017).
[4] Lauprêtre et al., Phys. Rev. A 99, 031401(R) (2019).
[5] S. E. Rasmussen et al., Phys. Rev. A 101, 022308 (2020).
[6] R. Nath et al., New J. Phys. 17, 065018 (2015).

UNIVERSITY OF AMSTERDAM

Permanent research assistant position in the Quantum Gases and Quantum Information Group

We offer a research assistant position at the level of a postdoc that is permanent. Our group comprises six research teams exploring physics with ultracold atoms and ions:

- Ultracold RbSr ground state molecules
- Continuous atom laser
- Quantum simulation and computation with Rydberg coupled Sr atoms
- Superradiant clocks
- Yb ion - Li atom mixtures
- Quantum simulation with 2D ion crystals

You will contribute to several of these experiments in a coordinating role. In practice you will join one of these teams and contribute to reaching a specific goal, in a role similar to the one of a postdoc. Once this goal is reached, you will switch teams, giving you the opportunity to learn about and contribute to different types of experiments. In this way you can assure that know-how is maintained within the group and strengthen the know-how exchange between teams.

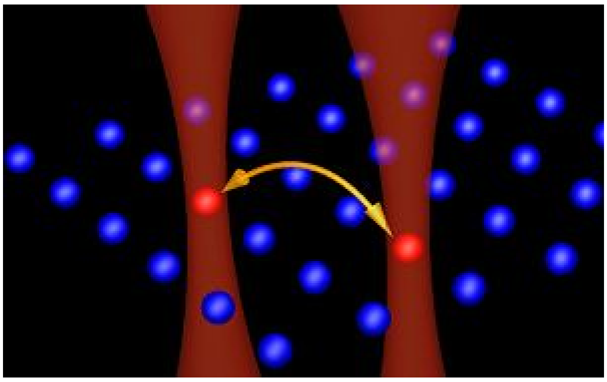
Your role will also be to help organize the group, e.g. keeping infrastructure alive (vacuum equipment, soldering stations,...) and educate PhDs on its usage, help training master students and PhDs, provide lab safety training, coordinate purchases, etc.

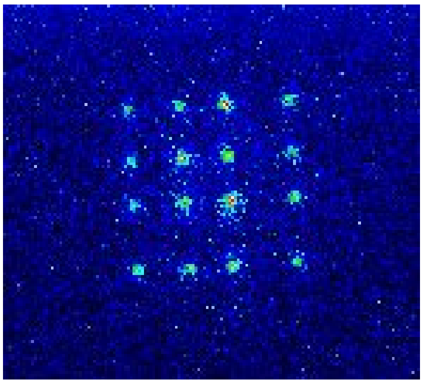
Furthermore you will contribute with a small percentage of your time to the institute's needs, such as aiding in organizing lab spaces, coordinating with the research assistants of the soft and hard condensed matter groups, helping with public outreach, etc.

A PhD in experimental AMO physics is required. For more information please contact Florian Schreck (schreck@uva.nl) or take a look at our websites www.strontiumBEC.com and hyqs.nl.

PhD and postdoc positions

Quantum simulation and computing with Rydberg coupled Sr atoms





Quantum computers and simulators can solve problems that are utterly out of reach for traditional computers. We are building two quantum computers/simulators based on arrays of strontium atoms held in optical tweezers [1], one at the Eindhoven University of Technology and one at the University of Amsterdam. Quantum bits are encoded in the internal states of these atoms and quantum calculations are carried out by shining laser beams onto the atoms in a well-orchestrated way. Quantum computers based on neutral atoms profit from the fact that the atoms are naturally identical and that it is quite easy to scale the computer to hundreds of quantum bits. Our quantum computer is based on strontium atoms, an alkaline-earth element that is also commonly used to build some of the best clocks in the world. Exploiting clock technology from our European Quantum Flagship project iqClock and supported by QuantumDelta NL and the Quantum Software Consortium we intend to build quantum computers that can demonstrate algorithms developed by QuSoft or solve quantum chemistry problems. In Amsterdam we can currently trap strontium atoms in an array of 16 tweezers (see picture) and we are extending our machine with the lasers necessary to implement one- and two-qubit gates. In Eindhoven we started building a second apparatus, with the ambition of connecting it to the quantum computing cloud platform Quantum Inspire in 2024.

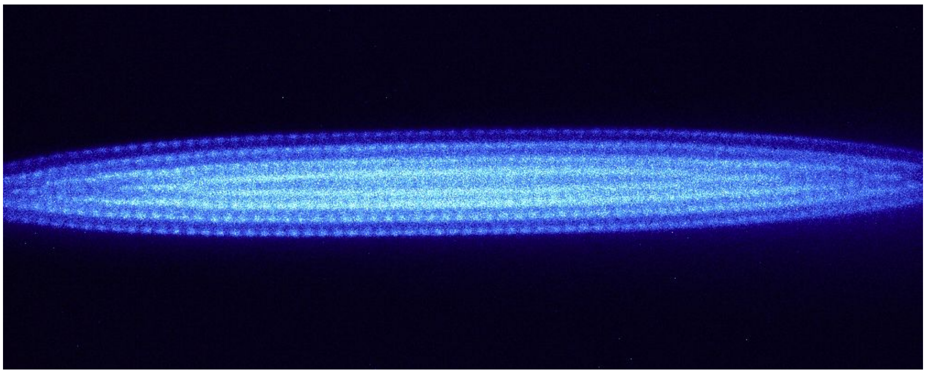
Currently PhD and postdoc positions are available in Eindhoven and in the near future we expect a PhD position to become available in Amsterdam.

For more information please contact Florian Schreck (schreck@uva.nl) and Servaas Kokkelmans (s.kokkelmans@tue.nl) or take a look at our website www.strontiumBEC.com and the Eindhoven Coherence and Quantum Technologies group.

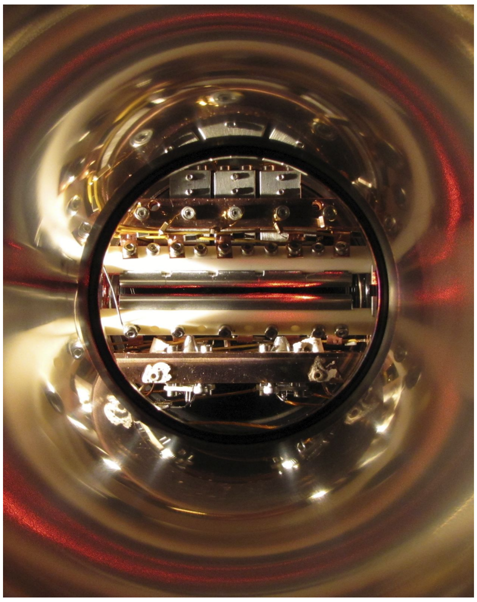
[1] M. Morgado, S. Whitlock, *Quantum simulation and computing with Rydberg-interacting qubits*, arXiv:2011.03031 (2020).

Postdoc position

Determination of the proton-electron mass ratio and search for physics beyond the Standard Model in the HD^+ molecular ion



There is a postdoc job opening in the research group of Quantum Metrology and Laser Applications (QMLA) at LaserLaB, Vrije Universiteit Amsterdam. The very international QMLA group consists of some 20 strongly collaborating senior and junior scientists, and focuses on precision measurements of atomic and molecular systems using advanced laser techniques as well as techniques to cool the motion of atoms and molecules. For this they use the joint infrastructure at LaserLaB, with a variety of lasers ranging from ultrastable to ultrafast, connected to atomic clocks and frequency comb lasers. The goals are to test fundamental theories of physics (like Quantum Electrodynamics), to determine fundamental constants (like the proton-electron mass ratio), and to search for physics beyond the Standard Model, such as fifth forces and extra dimensions; see for example Physics beyond the Standard Model from hydrogen spectroscopy J. Mol. Spectr. 320 (2016) 1.



The research will be carried out in an existing ion-trap setup using ultrastable lasers and radiofrequency fields. As a postdoc you will be responsible for the ongoing upgrade of the experiment and its control system, the development of new spectroscopic detection techniques, numerical modelling, acquisition of data and analysis, and interpretation of data in the context of fundamental physical laws.

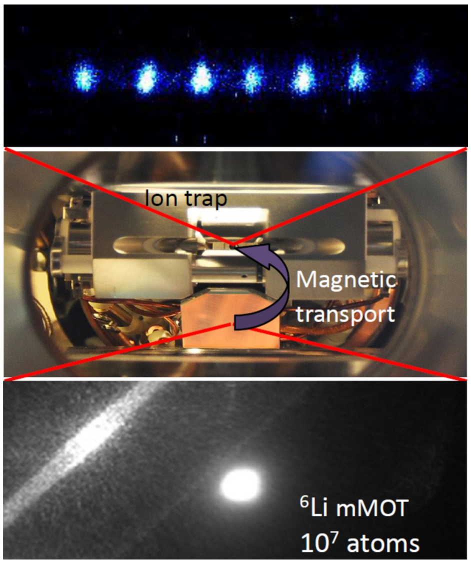
See also: Proton-Electron Mass Ratio from Laser Spectroscopy of HD^+ at the Part-Per-Trillion Level, Science **369**, 1238 (2020)

Contact person: Dr. Jeroen Koelemeij, j.c.j.koelemeij@vu.nl.

Pre-announcement: Potential opening of PhD position

Trapped ions in a Fermi sea

An impurity interacting with a quantum bath is a nontrivial many-body model system with broad relevance to condensed matter. These systems could shed light on the fuzzy boundary between classical and quantum physics and may prove to be of fundamental importance when considering the practical applicability of quantum technology such as quantum computers. This is because a clear understanding of quantum systems coupled to increasingly complex (quantum) environments will be indispensable for building quantum technologies where such couplings are unavoidable.



You will use a single trapped Yb^+ ion as impurity, immersed in a bath of Li atoms. We have recently shown that this system can reach the quantum regime of interacting atoms and ions which opens up a host of new possibilities. You will study the coupling of the spin of a single ion, or its quantized motion in the harmonic potential, to a quantum bath of Li atoms that are as cold as 100 nK. Using tools developed in ultracold atomic physics, we can change the bath from a weakly interacting degenerate Fermi gas, via a strongly interacting gas at unitarity, to a Bose-Einstein condensate of weakly bound Li_2 molecules. Finally we will answer an intriguing question: Do Feshbach resonances exist between atoms and ions in analogy to neutral systems? Now that we have produced a mixture of atoms and ions that is cold enough for quantum effects to dominate, we can answer this question.

Once we have understood the quantum physics of the single impurity-bath system, we can use it in a number of applications. One obvious extension is to increase the number of impurities and immerse a crystal of trapped ions into the atomic cloud. Now, the harmonic oscillators take the form of soundwaves that can couple to the atomic bath. Since the atoms are fermions, the system resembles a natural crystalline solid and could therefore be used as a quantum simulator of such solids. Finally, the cold atoms could be used to keep the ion crystal very cold. Ion crystals are presently the most accurate prototype quantum computers available and the atomic gas may allow to cool (and therefore improve) the system further.

For more information about the status of this project, please contact Rene Gerritsma (r.gerritsma@uva.nl) take a look at our website www.hyqs.nl.

References

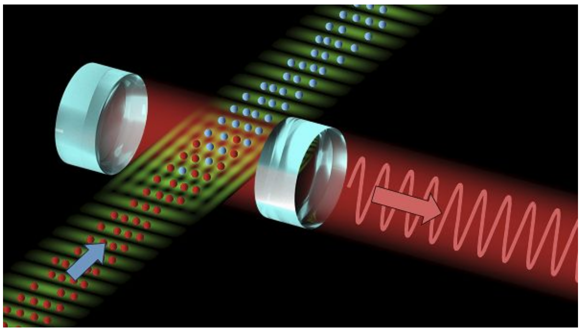
T. Feldker et al., Nature Physics 16, 413–416 (2020).

N. V. Ewald et al., Phys. Rev. Lett. 122, 253401 (2019).

University of Amsterdam

Pre-announcement: Potential opening of PhD and postdoc positions in summer 2021

Superradiant Sr clock



In this project you will develop a new type of optical clock: a continuously operating superradiant clock. Optical clocks exploit mHz linewidth transitions of atoms as frequency references and can achieve an accuracy that corresponds to going one second wrong over the lifetime of the universe. Conventional clocks operate by stabilizing a laser on the atomic clock transition and reading out the laser frequency by using an optical frequency comb. The interrogated atoms have to be extremely cold in order for the Doppler effect not to distort the measurement. Preparing a sample of atoms at ultracold temperatures takes time. To bridge that time the clock laser is short-term stabilized on a cavity.

Here we want to improve and simplify the clock by creating a laser from direct emission of light on the clock transition. Since the transition is so narrow an atom will spontaneously emit a photon only every minute or so, which doesn't give us enough photons to do anything with. To enhance emission we use superradiance. By making it impossible to know which atom in an ensemble emitted a photon, the ensemble will enter a superposition state that is more likely to emit another photon, creating an avalanche effect and usually resulting in a 'superradiant' flash of light [1]. The main challenge of this project is to prolong this flash to eternity by feeding new atoms into the superradiantly lasing ensemble without disturbing it. This challenge can be solved using techniques that we have developed over the last years, allowing us to create Sr atomic beams with unprecedented brilliance and even steady-state quantum gases [2,3]. Once we have obtained superradiant lasing on the mHz transition a wide range of research topics can be addressed, ranging from the study of many-body effects in driven-interacting systems, over cavity coupled spin-lattice models, to cavity-cooling of a stream of atoms to quantum degeneracy, forming an atom laser.

You will work in a team of several PhD students and postdocs guided by Florian Schreck, and an extensive network of collaborators. The work will be executed with our partners from the European Quantum Flagship project iqClock and the European Innovative Training Network MoSaiQC.

For more information please contact Florian Schreck (schreck@uva.nl) or take a look at our website www.strontiumBEC.com.

[1] Matthew A. Norcia, Matthew N. Winchester, Julia R. K. Cline and James K. Thompson, *Superradiance on the millihertz linewidth strontium clock transition*, Science Advances 2, e1601231 (2016).

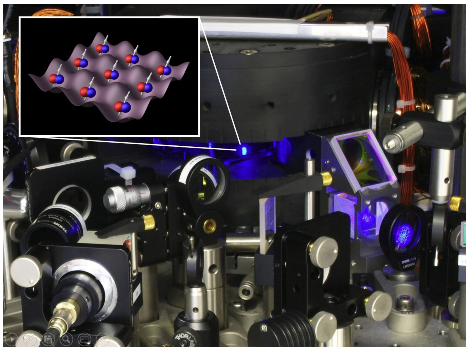
[2] Chen et al., *Continuous guided strontium beam with high phase-space density*, arXiv:1907.02793 (2019).

[3] Chen et al., *An ultracold Bose-Einstein condensate in steady state*, arXiv:2012.07605 (2020).

Appendix

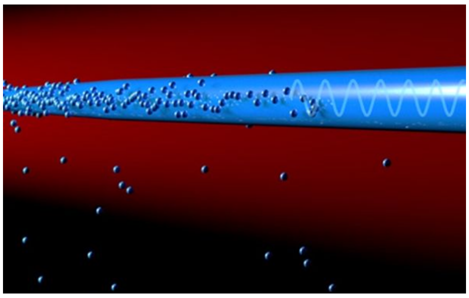
If your institute has a billboard for job advertisements, we would be thankful if you could print out the following pages and attach them there.

PhD position on quantum simulation with RbSr ground-state molecules



In this project you will create a new class of ultracold ground-state molecules, specifically RbSr, and use them to perform quantum simulations. RbSr ground-state molecules have a large electric dipole moment and a magnetic moment. These properties enable the tuning of anisotropic long-range interactions between the molecules by applying electric and magnetic fields. After creating the molecules using unusual magnetic Feshbach resonances we discovered, you, together with the research team, induce long-range, spin-dependent interactions to explore quantum magnetism. A second research avenue is to induce repulsive interactions between the molecules, so that they can collide with each other without undergoing chemical reactions. In this way it should be possible to create a quantum gas of molecules.

PhD position on the creation of a continuous atom laser



In this project you will try to create the first continuous atom laser. So far, atom lasers have only been produced as pulses of matter-wave, which greatly limits their applications despite having great potential for ultracold-atom interferometry. We have recently demonstrated a Bose-Einstein condensate (BEC) of a unique kind: a continuous-wave BEC, that can last for as long as desired. After studying the coherence and stability of this driven-dissipative BEC, you will implement a mechanism to coherently transfer atoms from the BEC into the beam of an atom laser. This would constitute the first continuous atom laser, which you will then assess for use in state-of-the-art precision measurements.

Permanent research assistant in the Quantum Gases and Quantum Information group

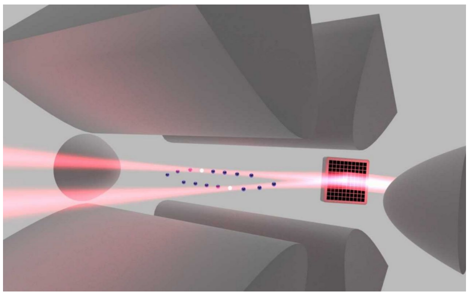
This research assistant position is a permanent position at the level of a postdoc. Our group comprises six research teams exploring physics with ultracold atoms and ions. You will join one of these teams in a role that is similar to the one of a postdoc and contribute to reaching a specific goal. Once this goal is reached, you can switch teams, giving you the opportunity to learn about and contribute to different types of experiments and the whole group the benefit of strengthened know-how exchange. Your role will also be to help organize the group (keep infrastructure alive and educate PhDs on its usage, help PhDs with organizing their work) and contribute with a small percentage of your time to the institutes needs, such as aiding in organizing lab spaces.

For more information please contact Florian Schreck (schreck@uva.nl) or take a look at our website www.strontiumBEC.com (see QR code).

February 2021

UNIVERSITY OF AMSTERDAM VU VRIJE UNIVERSITEIT AMSTERDAM TU/e EINDHOVEN UNIVERSITY OF TECHNOLOGY

Experimental and theoretical PhD on trapped ions in optical tweezers

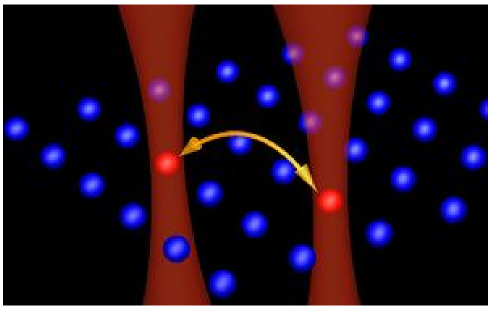


Precision quantum gates between ions are mediated by soundwaves in the ion crystal. In our experiment, we aim to implement a new way to control the interactions between the qubits allowing direct engineering of the soundwaves that mediate the interactions between the ion-qubits. You will work in a team that develops this new quantum computation platform. Your project will center on investigation of the role of interaction range, connectivity, and dimensionality in transport and entanglement dynamics in quantum many-body systems.

For more information please contact Arghavan Safavi (a.safavinaini@uva.nl) or Rene Gerritsma (r.gerritsma@uva.nl) take a look at our website hyqs.nl (see QR code).

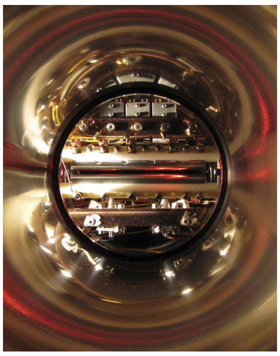
PhD and postdoc positions on quantum simulation and computing with Rydberg coupled Sr atoms

We are building two quantum computers/simulators based on arrays of strontium atoms held in optical tweezers, one at the Eindhoven University of Technology and one at the University of Amsterdam. Quantum bits are encoded in the internal states of these atoms and quantum calculations are carried out by shining laser beams onto the atoms in a well-orchestrated way. We intend to demonstrate algorithms developed by QuSoft or solve quantum chemistry problems.



For more information please contact Florian Schreck (schreck@uva.nl) and Servaas Kokkelmans (s.kokkelmans@tue.nl) or take a look at our websites (see QR codes).

Postdoc position on the determination of the proton-electron mass ratio and search for physics beyond the Standard Model in the HD^+ molecular ion



The goals of this project are to determine the proton-electron mass ratio, and to search for physics beyond the Standard Model, such as fifth forces and extra dimensions. The research will be carried out in an existing ion-trap setup using ultrastable lasers and radiofrequency fields. As a postdoc you will be responsible for the ongoing upgrade of the experiment and its control system, the development of new spectroscopic detection techniques, numerical modelling, acquisition of data and analysis, and interpretation of data in the context of fundamental physical laws.

For more information please contact Jeroen Koelemeij (j.c.j.koelemeij@vu.nl) or take a look at the website (see QR code).