VIENNA GRADUATE CONFERENCE ON COMPLEX QUANTUM SYSTEMS

2019

28-30 October / Ceremonial Hall
University of Vienna

BOOK OF ABSTRACTS

INVITED SPEAKERS

CoQuS ComplexQuantumSystems
universität wien
TU WIEN
FWF Der Wissenschaftsfonds.
VCQ Vienna Center for Quantum Science and Technology
IQOQI Vienna
IST AUSTRIA Institute of Science and Technology

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International guest speakers

Jens Eisert, FU Berlin

Monday, 28 October 2019, 09.00

"Towards closing the loopholes of showing a quantum advantage"

Quantum devices promise the efficient solution of problems out of reach for classical computers. However, before reaching the ultimate goal of realizing full fault tolerant quantum computers, one has to unambiguously show the possibility of a quantum advantage. In this talk, we will discuss prospects of achieving a complexity-theoretic quantum advantage that both lives up to mathematically rigorous standards and is experimentally practically feasible. On a mathematical technical level, we will see how proof techniques of anti-concentration bounds, of black-box verification and of average-case complexity come into play. On a physical level, we will elaborate on how such schemes may be realized with realistic near-term quantum devices.

Ronald Hanson, TU Delft

Monday, 28 October 2019, 10.45

"Quantum networks of diamond spins"

Entanglement – the property that particles can share a single quantum state - is arguably the most counterintuitive yet potentially most powerful element in quantum theory. The non-local features of quantum theory are highlighted by the conflict between entanglement and local causality discovered by John Bell. Decades of Bell inequality tests, culminating in a series of loophole-free tests in 2015, have confirmed the non-locality of nature [1].
Future quantum networks [2] may harness these unique features of entanglement in a range of exciting applications, such as quantum computation and simulation, secure communication, enhanced metrology for astronomy and time-keeping as well as fundamental investigations. To fulfill these promises, a strong worldwide effort is ongoing to gain precise control over the full quantum dynamics of multi-particle nodes and to wire them up using quantum-photonic channels.
Here I will present recent and ongoing work with the specific target of realizing the first multi-node network wired by quantum entanglement, including first primitive network experiments [3,4] using diamond-based quantum network nodes.

[1] For a popular account of these experiments, see e.g. Ronald Hanson and Krister Shalm, Scientific American 319, 58-65 (2018).
[2] Quantum internet: A vision for the road ahead, S Wehner, D Elkouss, R Hanson, Science 362 (6412), eaam9288 (2018).
[3] N. Kalb et al., Science 356, 928 (2017).
[4] P.C. Humphreys et al., Nature 558, 268 (2018).

Renato Renner, ETH Zürich

Tuesday, 29 October 2019, 09.00

“Quantum Information Theoretic Paradoxes”

Whether quantum theory accurately describes nature on larger scales is still an open question, for experimental tests are mostly limited to small systems. Fortunately, theorists still have a powerful tool available to approach this question: thought experiments. While such experiments, as their name suggests, are infeasible (at least with current technology), we can use them to test whether our currently available physical theories provide consistent predictions. Thought experiments often involve an information-theoretic component. Examples include the paradox around Maxwell’s demon and the black hole information paradox. In my talk, I will focus on a recently proposed information-theoretic thought experiment, whose purpose is to test whether quantum theory is consistent when applied to complex systems.

Ana Maria Rey, University of Colorado

Tuesday, 29 October 2019, 10.45

“Enhanced metrology using quantum-correlated matter”

One of the most important tasks in modern quantum science is to coherently control and entangle many-body systems, and to subsequently use these systems to realize useful quantum devices such as quantum-enhanced sensors. However, many-body entangled states are difficult to prepare and preserve since internal dynamics and external noise rapidly degrade any useful entanglement. In this talk I will introduce a protocol that counterintuitively exploits inhomogeneities, a typical source of dephasing in a many-body system, in combination with interactions to generate metrologically useful and robust many-body entangled states. I will explain how to apply these ideas to state-of-the-art 3D optical lattice clocks and by carefully combining the nominally undesirable effects of inter-atomic interactions and spin-orbit coupling, one can engineer a spin squeezing process that generates metrologically useful entangled states. Moreover, I will explain how harnessing the interplay between spin- orbit coupling and interactions can lead to the generation of cluster states and cat states opening a path for the use of 3D optical lattice clocks as a platform for one way quantum computation.

Ian Walmsley, Imperial College London

Tuesday, 29 October 2019, 19.00

”From fleas to qubits: how optics shapes physics”

Light has had a huge influence on the development of physics, and continues to help us push the frontiers of knowledge. From fundamental phenomena that yield new understanding about the world, to instruments and methods that provide enabling technologies for discovery from gravitational waves to sub-cellular biodynamics, optics continues to inform and to shape the world. I will explore why this is the case, from both a historical perspective and looking to the future.

Vladan Vuletić, MIT

Wednesday, 30 October 2019, 09.00

"Spin squeezing in optical-clock atoms"

Entangled states of many particles can be used to overcome limits on measurements performed with ensembles of independent atoms (standard quantum limit). A particularly simple form of entanglement is spin squeezing, where the quantum noise for the variable of interest, e.g., the phase of an atomic clock, is redistributed into another variable. Spin squeezing can be generated by coupling the atomic ensemble to an optical cavity. We report the first sizeable spin squeezing in an optical-clock atom, ytterbium. The squeezing is generated in the electronic ground state, but can be transferred onto the clock transition via an ultrastable laser. I will also discuss prospects and limitations for spin squeezing in clocks and other precision experiments.

Andreas Wallraff, ETH Zürich

Wednesday, 30 October 2019, 10.45

"Superconducting Circuits for Quantum Information Processing"

Superconducting circuits are a prime contender both for realizing universal quantum computation in fault-tolerant processors and for solving noisy intermediate-scale quantum (NISQ) problems without error correction. Superconducting circuits also play an important role in state of the art quantum optics experiments and provide interfaces in hybrid systems when combined with semiconductor quantum dots, color centers or mechanical oscillators. In this talk, I will introduce the operation of superconducting circuits in the quantum regime and put quantum information processing with superconducting circuits into perspective. As one of two examples of our own research, I will present an experiment in the area of fault tolerant quantum computing in which we stabilize the entanglement of a pair of superconducting qubits using parity detection and real-time feedback [1]. In quantum-error-correction codes, measuring multi-qubit parity operators and subsequently conditioning operations on the observed error syndrome is quintessential. We perform experiments in a multiplexed device architecture [2], which enables fast, high fidelity, single-shot qubit read-out [3], unconditional reset [4], and high fidelity single and two-qubit gates. As a second example, I will present the realization of a deterministic state transfer and entanglement generation protocol aimed at extending monolithic chip-based architectures for quantum information processing in a modular approach. Our all-microwave protocol exchanges time-symmetric itinerant single photons between individually packaged chips connected by transmission lines to achieve on demand state transfer and remote entanglement [5]. We foresee that sharing information coherently between physically separated chips in a network of quantum computing modules is essential for realizing a viable extensible quantum information processing architecture.

[1] C. Kraglund Andersen et al., npj Quantum Information 5, 69 (2019)
[2] J. Heinsoo et al., Phys. Rev. Applied 10, 034040 (2018)
[3] T. Walter et al., Phys. Rev. Applied 7, 054020 (2017)
[4] P. Magnard et al., Phys. Rev. Lett. 121, 060502 (2018)
[5] P. Kurpiers et al., Nature 558, 264-267 (2018)

CoQuS Alumni

Borivoje Dakić, Universität Wien

Monday, 28 October 2019, 09.45

"Verification and characterization of large-scale quantum systems"

An important prerequisite for real applications of quantum technologies is reliable verification, i.e. the ability to accurately benchmark the functionality of quantum devices. While practical solutions for small-sized quantum systems exist, there are two major difficulties to be addressed when dealing with quantum systems of realistic sizes: a) the issue of finite (low) measurement statistics, b) high memory and computational costs needed for classical post-processing. In this talk, I will present recent developments in probabilistic verification and characterization of large-scale quantum systems in the context of entanglement verification [1,2] and quantum state tomography [3]. These findings bring novel insights into quantum information processing, ranging from foundational to practical.

[1] A. Dimić and B. Dakić, Single-copy entanglement detection, njp Quantum Information 4, 11 (2018)
[2] Saggio et al, Experimental few-copy multipartite entanglement detection, Nature Physics 15, 935–940, 2019
[3] J. Morris and B. Dakić, Selective Quantum State Tomography, arXiv:1909.05880, 2019

Stefan Nimmrichter, MPI Erlangen

Monday, 28 October 2019, 11.30

"Quantum dynamics of randomly probed systems: from quantum thermometry to classical gravity"

The study of open quantum systems subjected to random repeated probing by external degrees of freedom has wide-ranging applications in quantum foundations and thermodynamics. The respective theoretical framework can be used to assess equilibration and energy exchange with thermal or engineered non-thermal reservoirs, or to model processes driven by random measurements and feedback operations.
For example, one can measure the temperature of a thermal reservoir by locally probing it with a constant stream of identically prepared quantum systems. The interplay between thermalisation and repeated probing leads to a build-up of quantum correlations between subsequent probes and to temperature sensitivity beyond a conventional thermometer.
In the field of quantum foundations, coarse-grained master equation models for random measurement-feedback channels can be used to describe Newtonian gravity as a fundamentally classical interaction. This alternative to a yet to be finalised quantum theory of gravity can be tested in matter-wave interferometry and levitated optomechanics experiments.

Sandra Eibenberger-Arias, Fritz-Haber-Institut der MPG

Tuesday, 29 October 2019, 09.45

"Spectroscopy and control of cold, chiral molecules in the gas-phase"

Chiral molecules are important in nature and exist in one of two mirror-image versions (enantiomers), that cannot be transformed into each other by mere rotation or translation. They are of high importance in many biological and chemical reactions, also in the human body. Even though most physical properties of enantiomers are identical – which makes them intrinsically difficult to separate – their handedness often determines their functionality. There is a plethora of scientific methods to study chirality, however, chiral analysis, particularly for complex samples, is still challenging.

I will present the recently developed enantiomer-specific state transfer method [1], where tailored microwave fields are used to enantiomer-selectively populate or depopulate a chosen rotational state. Three mutually orthogonally polarized, resonant, phase-controlled microwave pulses are used to drive connected rotational transitions, resulting in controlled, enantiomer-specific population transfer. The technique builds on microwave three wave mixing [2], a recently established method for detecting chiral molecules enantiomer-specifically using microwave spectroscopy.

I will present the experimental implementation of the enantiomer-specific state transfer method and I will discuss further outlook on its applications for fundamental physics studies as well as for physical chemistry.

[1] S. Eibenberger, J. Doyle, & D. Patterson, Enantiomer-Specific State Transfer of Chiral Molecules. Phys Rev Lett 118, 123002, (2017).

[2] D. Patterson, M. Schnell, J. M. Doyle, Enantiomer-specific detection of chiral molecules via microwave spectroscopy. Nature 497, 475-477 (2013)

Tim Langen, Universität Stuttgart

Tuesday, 29 October 2019, 11.30

"Dipolar gases - from magnetic atoms to molecules"

Over the last two decades ultracold quantum gases have become a versatile tool in many fields of physics ranging from quantum simulation to non-linear optics and precision measurements. Their particular appeal stems from the precise tunability of nearly all relevant parameters, including the strength of interactions between the particles in the gas. However, the character of these interactions is typically limited to be isotropic and short-ranged. If the particles, on the other hand, feature magnetic or electric dipole moments, interactions can become anisotropic and long-ranged. In this talk I will discuss how this subtle change has recently lead to the discovery of a wealth of new phenomena, including novel states of matter, self-bound quantum liquids, or the emergence of quantum chaos [1].

In the first part of the talk, I will introduce a series of experiments with ultracold dysprosium atoms, which feature the strongest magnetic dipole moment in the periodic table. Such gases can form exotic droplets that are - counterintuitively - stabilized by quantum fluctuations [2]. These droplets are a 100 million times less dense than liquid helium droplets, but exhibit similar liquid-like properties. Moreover, the gases can self-organize to form a supersolid state of matter [3,4]. Such a supersolid is a paradoxical state in which atoms assume a rigid periodic pattern, as in a crystal, and yet flow without friction, as in a superfluid.

In the second part of the talk, I will briefly present our ongoing effort to directly laser cool electrically dipolar molecules into the quantum regime. Laser cooling of even the simplest molecules had long been considered impossible due to their complex vibrational and rotational level structure. However, quasi-closed transitions suitable for laser cooling have recently been identified in many molecules [5,6]. With typical electric dipole moments of several Debye, such molecules exhibit dipolar interactions that can be orders of magnitude stronger than in magnetically dipolar atoms. Moreover, ultracold molecules will offer unique experimental possibilities for precision measurements and cold chemistry.

[1] T. Langen and M.J. Mark: Ultrakalt magnetisiert, Physik Journal 17, 35 (2018).
[2] M. Schmitt et al.: Self-bound droplets of a dilute magnetic quantum liquid, Nature 539, 259 (2016).
[3] F. Boettcher et al.: Transient supersolid properties in an array of dipolar quantum droplets, Phys. Rev. X 9, 011051 (2019).
[4] M. Guo et al.: The low-energy Goldstone mode in a trapped dipolar supersolid, arxiv:1906.04633 (2019).
[5] M. Tarbutt: Laser cooling of molecules, Contemp. Phys. (2019).
[6] R. Albrecht et al.: Optical cycling of a cold barium monofluoride beam enabled by magnetic fields, arxiv:1906.08798 (2019).

Simon Gröblacher, TU Delft

Wednesday, 30 October 2019, 09.45

"Microwave to optics conversion using mechanical oscillators"

Conversion between signals in the microwave and optical domains is of great interest, particularly for connecting future superconducting quantum computers into a global quantum network. The idea is to transduce microwaves that are usually lost after a mere few centimeters into an optical signal which does allow transmission of quantum information over tens or even hundreds of kilometers. Here we would like to discuss two recent important steps in realizing such a practical device by demonstrating coherent conversion between GHz signals and the optical telecom band with minimal thermal background noise, while also exploring a new and low-loss piezoelectric material for this process.

Marissa Giustina, Google Corp.

Wednesday, 30 October 2019, 11.30

"Building Google's Quantum Computer"

The Google AI Quantum team develops quantum information processing hardware based on superconducting circuit qubits, which have shown promise in small-scale demonstrations as a good candidate system for building a large-scale universal quantum computer. However, to realize such a large-scale system, significant development work is necessary both to improve qubit performance and to build infrastructure capable of supporting orders of magnitude more qubits. This presentation introduces Google's quantum computing effort from a hardware perspective, including a discussion of some unique challenges inherent to quantum hardware, snapshots of the technology we have been developing, and some recent results.

CoQuS Students

Manuel Erhard, Universität Wien

Monday, 28 October 2019, 14.45

"Teleporting High-Dimensional Quantum States"

Quantum teleportation allows a "disembodied" transmission of unknown quantum states between distant quantum systems. Until recently, all teleportation experiments were limited to a two-dimensional subspace of quantized multiple levels of the quantum systems. In this talk, I will discuss a new scheme for teleportation of higher-dimensional photonic quantum states and the experimental demonstration of teleporting a photonic qutrit. Our results from measurements over a complete set of 12 qutrit states in mutually unbiased bases yield a teleportation fidelity of 0.75(1). This result is well above both the optimal single-copy qutrit state-estimation limit of 1/2 and maximal qubit-qutrit overlap of 2/3, thus confirming a genuine and nonclassical three-dimensional teleportation. Our work paves the way for advanced quantum technologies in higher dimensions, since teleportation plays a central role in quantum repeaters and quantum networks.

Esteban Castro Ruiz, Universität Wien

Monday, 28 October 2019, 15.00

"Time reference frames and gravitating quantum clocks"

I will present a framework for quantum mechanics in the presence of superpositions of massive quantum objects, which lead to an indefinite spacetime metric. The framework is based on the "timeless" approach to quantum mechanics, in which time evolution is recovered in the form of correlations between a quantum system and a clock. After briefly introducing the main ideas of the timeless framework, I will explain how one can use these ideas to arrive at the concept of quantum temporal reference frames. I will then explain how this concept is useful for treating situations involving gravitating quantum systems, and how some notions we are used to in cases where the spacetime metric is fixed are generalised to the case where we have a "superposition of metrics." In particular, I will argue that the temporal localisability of events becomes a relative notion in the absence of a well defined metric. Nevertheless, even if the metric is indefinite, for every event there exists a (quantum) temporal reference frame in which the dynamical description of that event reduces to the usual description we know from ordinary quantum mechanics. The price to pay is that, if the metric is indefinite, other events will generally look "smeared out" in time according to that reference frame.

Philipp Rieser, Universität Wien

Monday, 28 October 2019, 15.45

"Quantum-Assisted Molecule Metrology"

The wave nature of molecules is a perfect example of the peculiarities of quantum physics. Molecular quantum optics deals with phenomena related to this wave nature and in particular the interaction of molecules with light. Modern molecule interferometry can further test the notions of macroscopicity and the speculative limits of the linearity of quantum physics by observing quantum effects in massive particles and more recently also biologically relevant molecules. Intrinsically, molecule interferometers generate nanoscale fringes in the density distribution of molecular beams which can be shifted by external perturbations and be read with nanometre accuracy. This high sensitivity to beam shifts and wave dephasing can in turn be used to extract a variety of interesting molecular electronic properties. Molecular matter-wave experiments hence open a wide field of research at the interdisciplinary interface between quantum optics and chemical physics. Complex many-body systems further offer a vast variety of electric, magnetic and optical properties that render quantum decoherence interesting and may be technologically useful for future applications.

Valeria Saggio, Universität Wien

Monday, 28 October 2019, 16.00

"Experimental few-copy multipartite entanglement detection"

The reliable verification of quantum entanglement is an essential task to scale up quantum technologies. Recently, because of technological developments which allow for the experimental realization of quantum devices with increasing complexity, an entanglement verification method that is both reliable and resource-efficient is urgently needed. Although progressively more efficient techniques have been developed, most of these focus solely on minimizing the number of measurement settings. Additionally, in each measurement setting these methods still require many copies of the same quantum state, i.e. many detection events. Recently, a single-shot probabilistic method was proposed [1], wherein it was shown that even a single detection event can be sufficient to verify if a state exhibits entanglement. In our work [2], we extend this theoretical approach by showing that any entanglement witness can be translated into this probabilistic framework. In this way, entanglement detection can be easily carried out in a resource efficient way, meaning that any witness operator can be used to reliably certify the presence of entanglement by using only a very low number of copies of the quantum system. To benchmark our theoretical findings, we report the experimental entanglement verification in a photonic six-qubit cluster state generated using three single-photon sources at telecommunication wavelength. We find that the presence of entanglement can be certified with at least 99.74% by using only 20 copies of the state. Additionally, we show that genuine six-qubit entanglement is verified with at least 99% confidence by using 112 copies of state. This novel method entails a significant reduction of resources and provides an easy tool to certify the presence of entanglement in largescale systems, promising a great impact in future experiments where an efficient and resource saving approach will be essential for entanglement verification problems in multi-qubit states.

[1] A. Dimić et al., npj Quantum Information, 4(1), 11 (2018).
[2] V. Saggio et al., Nat. Phys. doi: 10.1038/S41567-019-0550-4 (2019).

Matthias Zens, TU Wien

Tuesday, 29 October 2019, 14.45

"Cavity QED of mesoscopic spin ensembles"

Mesoscopic spin ensembles strongly coupled to a cavity offer the exciting prospect of observing complex nonclassical phenomena with features intermediate between that of single spins and of macroscopic spin ensembles. To unravel the full quantum dynamics and photon statistics of the mesoscopic spin-cavity systems, we present a time-adaptive variational renormalization group method that accurately captures the underlying Lindbladian dynamics. We demonstrate how the collective interactions in an ensemble of as many as 100 spins, arranged in a spectral frequency comb, can be harnessed to obtain a periodic pulse train of sub-Poissonian, nonclassical light [1].

[1] *„Variational Renormalization Group for Dissipative Spin-Cavity Systems: Periodic Pulses of Nonclassical Photons from Mesoscopic Spin Ensembles"*; *H. S. Dhar, M. Zens, D. O. Krimer, S. Rotter;* Phys. Rev. Lett. 121, 133601

Federica Cataldini, TU Wien

Tuesday, 29 October 2019, 15.00

"Exciting phonon modes in a one dimensional Bose Einstein condensate"

Cold atoms provide an efficient tool to study the dynamics of interacting quantum many-body systems. In one dimensional BECs intriguing phenomena have been already observed, as well as the emergence of a prethermalized state and, on longer time scales, the recurrence of coherence and long range order [1]. A major role in these processes is played by phonons, specifically the out of equilibrium properties of such systems can be described in terms of phonons' dephasing, though a full comprehension of these mechanisms is still missing. Therefore explaining them would allows us to investigate the dynamics of the system at his roots.

In the talk I will present recent results where we are able to excite the lowest phonon modes individually. We work with a 87Rb BEC prepared in a box trap, and the protocol we implement consists in driving the system in resonance with one of the modes' frequency. Our observables are the density fluctuations, that we capture via absorption imaging after a short time of flight. Doing so we can monitor the growth of the mode during the driving and his behaviour during the subsequent free evolution.

[1] Rauer et al., Science 360, 307 (2018)

Moritz Wenclawiak, TU Wien

Tuesday, 29 October 2019, 15.45

"Superradiant meta-atoms and ultrastrong light-matter coupling"

In this contribution, we study the effects arising when using a metamaterial surface featuring a dense array of superradiant cavities for experiments in the ultrastrong coupling regime. The meta-atoms interact with intersubband transitions in semiconductor heterostructures. We show that the radiative cavity loss can be substantially increased by the meta-atom arrangement. Contrary to expectations, this does not always lead to the expected transition to the weakly coupled Purcell regime. In fact, it is still possible to observe intersubband polaritons as a feature of the strong coupling between the meta-atoms and the quantum well transition. As a consequence, the usual assumption of non-interacting elements has to be revised when dealing with ensembles of strongly coupled systems.

Adarsh Prasad, TU Wien

Tuesday, 29 October 2019, 16.00

"Strongly Correlated Photon Transport in a Waveguide with Weakly Coupled Emitters"

We experimentally show correlated photon transport through an optical waveguide that contains an ensemble of weakly coupled quantum emitters. We observe that the photon statistics of the transmitted light can be continuously changed from anti-bunched light to bunched light by solely changing the number of emitters. This effect arises due to an interplay of the nonlinear optical response of the emitters, linear optical losses, and interference between the transmitted and the forward-scattered two-photon states. We use laser-cooled atoms confined in a nanofiber-based optical dipole trap and analyze the transmission through the fiber with single-photon counters. The recorded second-order time-correlation function is in agreement with its theoretical prediction and reaches values as low as g2(0) ~ 0.5.

Georg Arnold, IST Austria

Wednesday, 30 October 2019, 14.45

"Compact and bidirectional conversion of microwave and optical signals at Millikelvin temperatures"

Superconducting circuits are promising candidates for future quantum processors. However, when it comes to long distance communication, small energy microwave signals show significant drawbacks compared to optical photons, since optical fibers offer ultra-low loss transmission and unmatched resilience to thermal noise and environmental interference. High efficiency conversion between microwaves and optical wavelengths would therefore represent a key feature to establish a long distance quantum network of superconducting processors. We will present our work on an integrated on-chip converter showing bidirectional conversion between microwave and optical photons with efficiencies around 1%. Our approach on a silicon-on-insulator platform is fully compatible with superconducting qubits.

Yuri Minoguchi, TU Wien

Wednesday, 30 October 2019, 15.00

"High Fidelity Quantum Information Processing and Simulation with Spins and Phonons in Diamond Color Centers"

We propose a scheme where interactions between negatively charged SiV Centers are mediated by high Q diamond resonator phonons. Combining the spin-phonon interaction with a continuous decoupling protocol, we show that the resulting gate is protected against dephasing. Furthermore the protection leads to an effective nearly SU(2) invariant Heisenberg interaction between spins.

Lorenzo Magrini, Universität Wien

Wednesday, 30 October 2019, 15.45

"Feedback control of a levitated nanoparticle in the quantum regime"

Strong environmental coupling and high measurement losses have for a long time prevented measurement and control of levitated dielectric particles in the quantum regime. Here we present a confocal detection scheme that allows to efficiently collect light scattered by the particle and perform displacement measurements with a resolution of $\sim 10^{-13}$ $m/\sqrt{Hz}$. A Kalman filter allows optimal state estimation and feedback cooling of the particle motion to an occupation of below 2 phonons, which is measured in the asymmetric mechanics-environment joint density of states.

Kjeld Beeks, TU Wien

Wednesday, 30 October 2019, 16.00

“Exciting the Thorium-229 isomer in a crystal”

The isomer of Th-229 is the only excited nuclear state known today that could be excited by current laser technology. Its extremely low energy (8.26 eV [1]) stems from its unique elliptical shape which creates a near degenerate ground state. Owing to its long lifetime, the Th-229m isomer could form a platform of a future nuclear optical clock. Recently, the LMU Munich experiment has observed the internal conversion de-excitation of the isomer and determined its energy [1][2]. The radiative decay has not yet been observed.
We aim to create a population of Th-229 isomers doped in a CaF2 crystal to observe the radiative decay of the isomer. Firstly, the biggest challenge of using Th-229 in a crystal is understanding the interactions between the nucleus and the crystal system. Internal conversion via crystal interaction is still an open question and defects decrease the transparency of the crystal. The suppression of both the non-radiative decay of the isomer and crystal defects are necessary for the detection of the radiative decay. We employ several methods to attempt to create a significant population of isomer nuclei in the crystal system.
To excite the Th-229 in the crystal, we grow these doped crystals and take several new approaches: firstly we apply a commercially available excimer lamp [3. The excimers show a continuous and broad emission spectrum in the VUV region, thus are able to directly excite the isomer. Secondly, we use x-rays created in the SPring8 synchrotron to resonantly excite the 2nd nuclear excited state [4]. This state directly decays to the isomer state thus creating a population of isomer nuclei in the crystal. Thirdly we dope CaF2 with Uranium-233 and use the radioactive decay of Uranium to create isomer nuclei in the crystal system [5].

[1] B. Seiferle et al., https://arxiv.org/abs/1801.05205 (2019)
[2] L. von der Wense, Nature, Volume 533 pages 47-65 (2016)
[3] J. Wieser, www.excitech.de (2019)
[4] T. Masuda et al., https://arxiv.org/abs/1902.04823 (2019)
[5] M. Schreitl et al., Phys. Rev. C. 94 014302 (2016)