Symposium SAMOP Dissertation Prize 2022 (SYAD)

jointly organized by all divisions of the section AMOP

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The divisions of the section AMOP award a PhD prize 2022. The prize acknowledges outstanding research from a PhD work and its excellent written and oral presentation. Eligible for nomination were outstanding PhD theses from the research fields of AMOP completed in 2020 or 2021. Based on the nominations, a jury formed by representatives of the AMOP research areas selected four finalists for the award. The finalists are invited to present their research in this dissertation prize symposium. Right after the symposium, the awardee will be selected by the prize committee.

Overview of Invited Talks and Sessions

(Lecture hall Audimax)

Invited Talks

SYAD 1.1	Tue	14:00–14:30	Audimax	**New insights into the Fermi-Hubbard model in and out-of equilibrium** — •Annabelle Bohrdt
SYAD 1.2	Tue	14:30–15:00	Audimax	**Searches for New Physics with Yb^{+} Optical Clocks** — •Richard Lange
SYAD 1.3	Tue	15:00–15:30	Audimax	**Machine Learning Methodologies for Quantum Information** — •Hendrik Poulsen Nautrup
SYAD 1.4	Tue	15:30–16:00	Audimax	**Precision Mass Measurement of the Deuteron's Atomic Mass** — •Sascha Rau

Sessions

SYAD 1.1–1.4	Tue	14:00–16:00	Audimax	**SAMOP Dissertation Prize Symposium**

SYAD 1: SAMOP Dissertation Prize Symposium

Time: Tuesday 14:00–16:00 Location: Audimax

Invited Talk SYAD 1.1 Tue 14:00 Audimax

New insights into the Fermi-Hubbard model in and out-of equilibrium — •Annabelle Bohrdt — Harvard University, Cambridge MA, USA

Understanding the phase diagram of the two-dimensional Fermi-Hubbard model – and by extension, high temperature superconductivity in the cuprate materials – poses one of the biggest challenges in condensed matter physics. In this talk, I will show how the recent advances in experiments with cold atoms in optical lattices, naturally suited for quantum simulation of the Fermi-Hubbard model, offer a completely new perspective on this decades old problem. I will present a microscopic description of a single hole in a quantum antiferromagnet – a first and crucial step to unravel the underlying physics of the enigmatic Hubbard model. In particular, I will discuss numerical as well as experimental results for the interplay of spin and charge degrees of freedom in the dynamics of a single hole. As an outlook, I will demonstrate how the understanding of a single hole yields insights into the finite doping regime and a mechanism for pairing at unprecedentedly high temperatures.

Invited Talk SYAD 1.2 Tue 14:30 Audimax

Searches for New Physics with Yb^+ Optical Clocks — •Richard Lange — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany

The most advanced atomic clocks are based on laser-cooled trapped atoms or ions and employ forbidden optical transitions as the reference. $^{171}Yb^+$ provides two such transitions, an electric quadrupole (E2) and an electric octupole (E3) transition, that are particularly well suited to search for physics beyond the Standard Model.

In my talk, I will describe how a comparison of two Yb^+(E3) clocks with 4×10^{-18} uncertainty is used to improve limits on a violation of Lorentz symmetry for electrons by about two orders of magnitude. I will also present a long-term comparison of the E3 and E2 transition frequencies that tightens the limit on temporal variations of the fine structure constant α by more than a factor of 20 to below 10^{-18}/yr. The excited state of the E3 transition features an exceptionally long lifetime which we measure with a new method to 1.58(8) years. Finally, novel interrogation methods enable the suppression of clock shifts, for instance by excitation of the ion in the dark center of Laguerre-Gaussian modes. By introducing these techniques and an advanced experimental setup, I will show how the performance of Yb^+ optical clocks is improved in the quest to unveil new physics.

Invited Talk SYAD 1.3 Tue 15:00 Audimax

Machine Learning Methodologies for Quantum Information — •Hendrik Poulsen Nautrup — Institute for Theoretical Physics, University of Innsbruck, 6020 Innsbruck, Austria

Machine learning technologies already permeate our everyday life. In the wake of this rapid progress, we naturally expect machine learning to consolidate its impact on basic research as well. However, with the attention largely on big data and problem solving, machine learning has fallen short of this expectation.

In my talk, I will present three complementary approaches to facilitate the mutual development of machine learning and basic quantum information science. Specifically, I am not only interested in machine learning as a numerical tool to solve complex problems, but also to establish machine learning methodologies as general-purpose tools for scientific research. In this way, we will see how researchers can learn from artificial intelligence (AI), how researchers have to adapt their methods to integrate AI, and how quantum information can facilitate the development of AI for research.

Invited Talk SYAD 1.4 Tue 15:30 Audimax

Precision Mass Measurement of the Deuteron's Atomic Mass — •Sascha Rau — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

The rest masses of many light nuclei, e.g. the proton, deuteron, triton and helion are of great importance for testing our current understanding of physics as well as in metrology. One example are comparisons of rotational and vibrational spectra in HD^+ molecular ions with theory, which can be used to test 3-body QED calculations [1]. There, the masses of the involved particles are required as input parameters. Recently discussed discrepancies in measurements of these masses, carried out at different mass spectrometers and termed light ion mass puzzle, strongly call for investigation through independent measurements.

In my talk, I will present a mass measurement of the deuteron's atomic mass [2] carried out at LIONTRAP, a high-precision spectrometer dedicated to light ions. There, a newly implemented superconducting magnetic field-shaping coil enabled overcoming the leading systematic uncertainty for light ion mass measurements. This enabled us to reach a precision of $\delta m/m = 8.5 \times 10^{-12}$, the most precise measurement in atomic mass units so far. The observed $5\,\sigma$ discrepancy to the previous best measurement does not only reduce the light ion mass puzzle significantly, but is also confirmed by a series of systematic checks, including a direct measurement of the HD^+ mass and comparisons with HD^+ spectroscopy.

[1] M. Germann *et al.*, Phys. Rev. Reas. **3**, L022028 (2021)
[2] S. Rau *et al.*, Nature **585**, 43-47 (2020)