Symposium SAMOP Dissertation Prize 2023 (SYAD)

jointly organized by all divisions of the section AMOP

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The divisions of the section AMOP award a PhD prize 2023. 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 2021 or 2022. 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 E415)

Invited Talks

SYAD 1.1	Mon	14:30–15:00	E415	**Quantum gas magnifier for sub-lattice resolved imaging of 3D quantum systems** — •Luca Asteria
SYAD 1.2	Mon	15:00–15:30	E415	**From femtoseconds to femtometers – controlling quantum dynamics in molecules with ultrafast lasers** — •Patrick Rupprecht
SYAD 1.3	Mon	15:30–16:00	E415	**Particle Delocalization in Many-Body Localized Phases** — •Maximilian Kiefer-Emmanouilidis
SYAD 1.4	Mon	16:00–16:30	E415	**Feshbach resonances in a hybrid atom-ion system** — •Pascal Weckesser

Sessions

SYAD 1.1–1.4	Mon	14:30–16:30	E415	**SAMOP Dissertation Prize Symposium (SYAD)**

SYAD 1: SAMOP Dissertation Prize Symposium (SYAD)

Time: Monday 14:30–16:30 Location: E415

Invited Talk SYAD 1.1 Mon 14:30 E415
Quantum gas magnifier for sub-lattice resolved imaging of 3D quantum systems — •Luca Asteria — Institut für Laserphysik, Hamburg University, Hamburg — The Hamburg Centre for Ultrafast Imaging, Hamburg

Ultracold atoms in optical lattices are promising platforms for studies of fundamental physics and quantum simulation of many body physics. An in-situ detection of the atomic density distribution within the lattice however is challenging due to diffraction limits within the optical detection.

Here we demonstrate a new detection technique, based on a magnification of the pure density distribution prior to the optical detection which allows large scale images of the lattice system with sub-lattice spacing resolution. The protocol is based on a T/4 evolution in a harmonic trap and subsequent time of flight which magnifies the initial atomic density distribution up to a factor of 90. We get thus an effective resolution as small as 80μm, which even allows the observation of the motion of the atoms within the lattice sites, a promising step towards the real-space study of systems with orbital degrees of freedom.

Furthermore, we demonstrate how similar matter wave protocols could be used to access spatial coherence properties at the microscopic range level. This paves the way for quantum simulations of new types of materials and various applications in quantum technologies.

Invited Talk SYAD 1.2 Mon 15:00 E415
From femtoseconds to femtometers – controlling quantum dynamics in molecules with ultrafast lasers — •Patrick Rupprecht — Max-Planck-Institut für Kernphysik

Core-level absorption spectroscopy has proven to be a powerful tool to gain a deeper understanding of ultrafast quantum dynamics in atoms, molecules, and solid-state materials. Especially the capability of x-ray transient absorption spectroscopy (XTAS) to elucidate dynamics in neutral molecules on the atto- and femtosecond time scales stands out.

In my talk, I will present a novel source for few-cycle, center-wavelength-tunable ($\lambda_c = 1 - 2\,\mu m$) laser pulses in combination with a flexible transient absorption setup at the *Max Planck Institute for Nuclear Physics*. These experimental capabilities are utilized to control the quantum-mechanical part of the electron–electron interaction, the exchange energy, for the first time by perturbing gaseous SF_6 molecules with infrared pulses of variable intensity of up to 2×10^{14} W/cm^2. In a second experiment, time-resolved x-ray absorption spectroscopy is used to elucidate vibrational molecular dynamics in the perturbative limit with an unprecedented spatial precision of 14 fm. These XTAS studies pave the way for new ultrafast chemical control schemes as well as precision metrology on molecular bonds.

Invited Talk SYAD 1.3 Mon 15:30 E415
Particle Delocalization in Many-Body Localized Phases — •Maximilian Kiefer-Emmanouilidis — Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Kaiserslautern, Germany — Deutsches Forschungszentrum für Künstliche Intelligenz, Kaiserslautern, Germany — University of Manitoba, Winnipeg, Canada

Can a generic isolated quantum many-body system avoid thermalization? Textbook thermodynamics say no, at least for any generic interacting system. In 2006 Basko et al. argued to the contrary and described the phenomenon known today as many-body localization (MBL), where in highly disordered materials interacting electrons may localize in space, thus withstanding thermalization. In this talk I present evidence gathered during my dissertation which fundamentally questions the current picture of the MBL phase. I show that even in the paradigmatic model of MBL, where the von Neumann entanglement entropy grows $S \sim \ln t$ particles can spread subdiffusively. In my dissertation I studied the contribution to a systems entanglement entropy which stems from particle-number fluctuations. This quantity known as the number entropy S_N describes the entanglement generated by particles moving between partitioning cuts and is easily accessible in setups of ultracold atoms utilizing a quantum gas microscope. In a system that exhibits MBL, particles should travel only short distances, and thus S_N should be bounded after a quench. I have shown numerically that the number entropy grows proportional to the entanglement entropy, $S_N \sim \ln S \sim \ln\ln t$, and is therefore unbounded if S is unbounded. This questions the existence of the MBL phase.

Invited Talk SYAD 1.4 Mon 16:00 E415
Feshbach resonances in a hybrid atom-ion system — •Pascal Weckesser — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Straße 3, 79104 Freiburg, Germany

In the past decade, hybrid atom-ion systems have emerged as a new platform featuring long-range interactions. Cooling the system close to the quantum limit allows the investigation of novel quantum phenomena, such as charged mesoscopic molecules, as well as the study of quantum chemistry and quantum simulation. Reaching the ultracold regime, however, is a challenging task, as intrinsic heating effects of conventional radiofrequency (rf) traps limit most experiments to the millikelvin regime, where atom-ion interactions remain classical.

In my talk, I will discuss two pathways to overcome this limitation and present the first observation of Feshbach resonances between atoms and ions. We minimize the intrinsic heating rates by choosing a system with large mass imbalance - ^{6}Li atoms and $^{138}Ba^+$ ions. Additionally, we can optically trap the ions allowing us to operate in complete absence of detrimental rf fields. As a result, we cool the system to the s- and p-wave scattering regime and find 11 resonances by magnetic-field dependent ion loss spectroscopy. We further demonstrate the tunability of the resonances by controlling the ion's sympathetic cooling rate. These results pave the way towards studying complex many-body systems, such as charged polarons in the strong coupling regime or the coherent formation of molecular ions.