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RESEARCH TRAINING GROUP

DYNAMICS OF CONTROLLED ATOMIC AND MOLECULAR SYSTEMS

BOOK OF ABSTRACTS

Kick-Off Meeting 2022

RTG DynCAM

Dynamics of Controlled Atomic and Molecular Systems

May 19 & 20, 2022

Le Petit Kohlberg
Lucelle, France

Imprint

RTG 2717 / Dynamics of Controlled Atomic and Molecular Systems

Spokesperson: Frank Stienkemeier

Coordination: Simone Ortolf

Institute of Physics

University of Freiburg

Hermann-Herder-Straße 3

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General Information

Duration

Thursday, May 19, 2022, 8:00 a.m. – Friday, May 20, 2022, 9:00 p.m.

Accommodation

Hotel Restaurant
Le Petit Kohlberg
Lieu de Petit Kohlberg
68480 Lucelle
Alsace, France
https://www.petitkohlberg.com/en/

Travel information

BY BUS

We will travel together to Lucelle by coach. Start is on Thursday at 8:00 am at the Institute of Physics, Hermann-Herder-Str. 3. We will return to Freiburg on Friday around 5:30 pm.

BY CAR

Travelling along the A35 autoroute, take the "St Louis/Hésingue" exit. Head towards Hésingue, Folgensbourg, Ferrette, Winkel. Between Winkel and Lucelle, at "Les Verreries", take a left turn for Le Petit Kohlberg.

Meals & Drinks

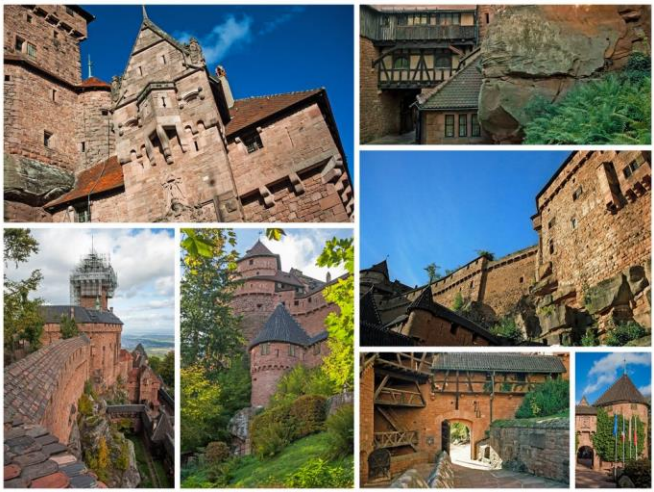
Meals and drinks during the scientific program are included.

Final Dinner, May 20

At the end of the kick-off meeting, our final dinner will take place at the "Paradies Restaurant" in Freiburg. We will meet there at 7 pm.
Address: Mathildenstr. 26-28, 79106 Freiburg

Excursion

On Friday we will start our journey home to Freiburg at 11 am. On the way back we will stop at the castle *Haut-Koenigsbourg* near Orschwiller in Alsace. The impressive 12th century fortress was conquered and destroyed several times until the 17th century. At the beginning of the 20th century, the castle was reconstructed and made accessible to the public.



Program

Thursday, May 19, 2022

8:00 a.m.	**Departure** Institute of Physics, Hermann-Herder-Str. 3
10:00 a.m.	**Arrival** Hotel Le Petit Kohlberg, Lucelle
10:30 a.m.	**Coffee Break 1** Hotel Le Petit Kohlberg
11:00 a.m.	**Welcome & Talk 1 - Pascal Weckesser** Seminar room, Frank Stienkemeier / Chair: Tobias Schätz
12:00 p.m.	**Lunch** Hotel Le Petit Kohlberg, Restaurant
2:00 p.m.	**Talk 2 – Stefan Willitsch** Seminar Room, Chair: Katrin Erath
3:00 p.m.	**Talk 3 – Christoph Bostedt** Seminar room, Chair: Giuseppe Sansone
4:00 p.m.	**Coffee Break 2** Hotel Le Petit Kohlberg
4:30 p.m.	**Scientific Speed Dating** Seminar room, Sebastian Hartweg
7:00 p.m.	**Dinner** Hotel Le Petit Kohlberg, Restaurant

Program

Friday, May 20, 2022

8:00 a.m.	**Breakfast** Hotel Le Petit Kohlberg, Restaurant
9:00 a.m.	**Talk 4 – Andreas Wituschek** Seminar Room, Chair: Lukas Bruder
10:00 a.m.	**Concluding Remarks – Frank Stienkemeier** Seminar room, Chair: Frank Stienkemeier
11:00 a.m.	**Departure & Drive to Castle**
12:30 p.m.	**Hiking, Lunch Boxes & Tour of the Castle** **Castle Haut-Koenigsbourg** Orschwiller, Alsace, France
4:00 p.m.	**Return to Freiburg**
5:30 p.m. / 6:00 p.m.	**Arrival** Institute of Physics, Hermann-Herder-Str. 3
7:00 p.m.	**Final Dinner at Paradies Restaurant** Paradies, Mathildenstr. 26-28, Freiburg

Abstracts

Switching a monolayer atomic mirror using a single Rydberg atom

Pascal Weckesser

Institute Quantum Many-Body Systems Division, Max-Planck Institute of Quantum Optics, Garching (Munich), Germany

Understanding and tuning light-matter interactions is essential for numerous applications in quantum science. Recently, a new avenue of light-matter interaction has been realized by exploiting the rich interplay of individual photons with structured subwavelength arrays of quantum emitters stored in a two-dimensional (2d) square optical lattice. These monolayers feature intriguing optical properties, including large cross-sections, a cooperative subradient response as well as directionality of the emitted light, turning the array into an efficient mirror.

In this talk, I present our recent findings, where we control the optical response of such an atomic mirror using a single ancilla atom excited to a Rydberg state. We deterministically prepare the ancilla at the center of the array using the single-site resolution of our quantum gas microscope. Driving Rabi oscillations on the ancilla atom, we demonstrate coherent control over the transmission and reflection. Finally, increasing the mirror size directly reveals the spatial area around the ancilla atom where the switching is effective. Our results pave the way towards novel quantum metasurfaces and the creation of controlled atom-photon entanglement.

Quantum technologies for trapped molecular ions

Stefan Willitsch

University of Basel, Switzerland

Molecules are quantum systems of prime significance in a variety of contexts ranging from physics over chemistry to biology. In spite of their importance, the development of quantum technologies for molecules has remained a long-standing challenge due to their complex quantum structures. Trapped molecular ions are particular attractive in this context as it is possible to observe, manipulate and control single isolated molecules under precisely controlled conditions. We will give an overview of the current state-of-the-art in the field of molecular-ion quantum technologies and highlight some salient applications. We will focus on recently developed quantum-non-demolition techniques for the non-destructive detection of the internal quantum states of single trapped molecular ions [1,2,3]. These approaches offer new perspectives not only for the detection, but also for the preparation and the manipulation of molecular quantum states on the single-particle level with a sensitivity several orders of magnitude higher compared to previous schemes. We will discuss applications of these techniques in the realms of precision molecular spectroscopy and quantum science [4].

[1] Z. Meir, G. Hegi, K. Najafian, M. Sinhal and S. Willitsch, "State-selective coherent motional excitation as a new approach for the manipulation, spectroscopy and state-to-state chemistry of single molecular ions", *Faraday Discuss.* 217 (2019), 561

[2] M. Sinhal, Z. Meir, K. Najafian, G. Hegi and S. Willitsch, "Quantum non-demolition state detection and spectroscopy of single trapped molecules", *Science* 367 (2020), 1213

[3] K. Najafian, Z. Meir, M. Sinhal and S. Willitsch, "Identification of molecular quantum states using phase-sensitive forces", *Nat. Commun.* 11 (2020), 4470

[4] K. Najafian, Z. Meir and S. Willitsch, "From megahertz to terahertz qubits encoded in molecular ions: theoretical analysis of dipole-forbidden spectroscopic transitions in N_2^+", *Phys. Chem. Chem. Phys.* 22 (2020), 23083

The new Maloja endstation at SwissFEL – opportunities from ultrafast spectroscopy to single-shot imaging

Christoph Bostedt

Laboratory for Femtochemistry, Paul Scherrer Institute, Villigen (Switzerland)

LUXS Laboratory for Ultrafast X-Ray Sciences, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne (Switzerland)

X-ray free-electron lasers (XFEL), such as the Swiss Free-Electron Laser at PSI, deliver extremely intense, coherent x-ray flashes with femtosecond pulse length. The unprecedented brightness of these x-ray lasers opens the door for imaging transient states of matter and non-linear spectroscopy approaches for core-level states.

I will first report about the current developments at SwissFEL and an introduction to the new Maloja endstation for atomic, molecular and non-linear (AMO) science as well as ultrafast chemistry. The Maloja endstation is matched to the advanced operational modes of the Athos soft x-ray branch of SwissFEL. The Athos undulator section features an innovative design with small chicanes, enabling novel and advanced XFEL operation modes. Specifically, the potential to generate ultrashort pulses from a few femtoseconds down to hundreds of attoseconds, high-power operation with up to mJ pulse energy, or two-color X-ray pump-probe schemes. The capabilities of the Athos undulator line together with the Maloja endstation open new exciting opportunities for the field of AMO science or ultrafast chemistry and I will show a few early examples.

I will finish with selected ultrafast imaging examples enabled by XFEL sources. Single-shot imaging of individual superfluid helium nanodroplets allows the unambiguous identification of quantum vortices. Ultrafast scattering of highly excited nanoplasmas carries information about their transient electronic states. The combination of optical with x-ray lasers allows the investigation of dynamically evolving systems with femtosecond time and nanometer spatial resolution.

EUV Photolithography at ZEISS - My First Experience in Industry

Andreas Wituschek

ZEISS Semiconductor Manufacturing Technology, Oberkochen, Germany

We present Moore's law describes the doubling of transistor density in integrated circuits (ICs) about every two years. The latest miniaturization of ICs has been facilitated by extreme ultraviolet (EUV) optical lithography. The technologically highly sophisticated development and manufacturing of EUV lithography optics is done by Zeiss.

In my talk I will present the basics of optical lithography and describe the challenges posed by ever smaller structures. I will provide an overview of EUV optics manufacturing technologies and processes at Zeiss. In addition, I will describe typical tasks of a scientist in a high-tech company and share my own experiences of starting a job in industry after graduation from university.

List of Participants

Invited Speakers

Christoph Bostedt, Laboratory for Femtochemistry, Paul Scherrer Institute, Forschungsstrasse 111, 5232 Villigen (Switzerland).

Pascal Weckesser, Quantum Many-Body Systems Division, Max-Planck Institute of Quantum Optics, Hans Kopfermann Str. 1, 85748 Garching b. München.

Stefan Willitsch, Department of Chemistry, University Basel, Klingelbergstrasse 80, 4056 Basel (Switzerland)

Andreas Wituschek, ZEISS Semiconductor Manufacturing Technology, Rudolf-Eber-Str. 2, 73447 Oberkochen.

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Katrin Erath[1, 3]

Tobias Lau[1, 2]

Bernd von Issendorff[1]

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RK Kathir[1]

Samuel Kellerer[1]

Friedemann Landmesser[1]

Yilin Li[1]

Ioannis Makos[1]

Barbara Merzuk[1]

Moritz Michelbach[1],

Hanan Mir[3]

Arne Morlok[1]

Aaron Ngai[1]

Fabian Richter[1]

Kevin Schwarz[1]

Anja Seegebrecht[1]

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[2] Helmholtz-Zentrum Berlin für Materialien und Energie, Hahn-Meitner-Platz 1, 14109 Berlin

[3] Fraunhofer Institut für Solare Energiesysteme ISE, Heidenhofstr. 2, 79110 Freiburg.

Notes

Notes

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RTG DynCAM Kick-Off Meeting

(19. & 20.05.2022)

	Thursday, 19.05.2022	Friday, 20.05.2022
08:00	**Departure IoP**	Breakfast
08:30	Drive to Lucelle, France	
09:00		**Andreas WITUSCHEK**
09:30		
10:00		**Concluding Remarks**
10:30	Arrival & Coffee Break	
11:00	**Pascal WECKESSER**	Drive from Hotel to Castle
11:30		
12:00	Lunch Break	
12:30		
13:00		Hiking, Lunch and Tour of the Castle
13:30		
14:00	**Stefan WILLITSCH**	
14:30		
15:00	**Christoph BOSTEDT**	
15:30		
16:00	Coffee Break	
16:30	**Scientific Speed Dating**	Return to Freiburg
17:00		
17:30		
18:00		
18:30		
19:00	Dinner at Hotel	Final Dinner at Paradies Restaurant, Freiburg
19:30		
20:00		