Exploratory Workshop - Rydberg Physics with Two-Electron Systems

February 23 - 25, 2015
Center for Optical Quantum Technologies
University of Hamburg

Schedule

Monday 23/2

8:30 am *Registration*

8:50 am *Welcome and introduction to the workshop*

9:00 am A. Glätzle
Frustrated magnetism with alkali Rydberg atoms

9:45 am A.M. Rey
Synchronization of radiating dipoles

11:00 am M. Jones
Two-electron effects in cold Rydberg gases

11:45 am I. Lesanovsky
Long-range interacting many-body systems with alkaline-earth-metal atoms

12:30 pm *Lunch*

2:30 pm D. Peter
Topological flat bands with Chern number C=2 by dipolar exchange interactions

3:15 pm B. Dunning
Strontium Rydberg atoms: Opportunities and challenges

4:30 pm B. Sanders
Quantum simulation of micro and macro frustrated quantum magnetism

5:30 pm *Lab tours*

Tuesday 24/2

9:00 am C. Greene
Perturbed two-electron Rydberg spectra and their implications

9:45 am T. Gallagher
Bound and autoionizing Rydberg states of alkaline earth atoms

11:00 am J. Burgdörfer

High-n Rydberg wavepackets in quasi-two electron atoms

11:45 am S. Scheel
Rydberg excitons in cuprous oxide – Rydberg physics with giant artificial atoms

12:30 pm *Lunch*

2:30 pm F. Schreck
New tricks with ultracold strontium: Laser cooling to BEC & Ultracold RbSr molecules

3:15 pm M. Saffman
Laser cooling, Rydberg spectroscopy and coherent trapping of Holmium atoms

4:30 pm Tom Killian
Ultralong-range molecules and EIT in strontium ultracold Rydberg gases

6:15 pm *Departure for conference dinner*

Wednesday 25/2

9:00 am T. Pfau
A single charge in a Bose-Einstein condensate: from two to few to many-body physics

9:45 am H. R. Sadeghpour
These Rydberg molecules are fluffy, but they carry a biggg stick

11:00 am P. Pillet
Two examples of three-body physics with Rydberg atoms in Förster dipole-dipole coupling and in Coulomb coupling

11:45 am T. Pohl
Rydberg-excitation of two-electron triplet states

12:30 pm *Departure*

Monday 23/2

8:30 am - 8:50 am ***Registration***

8:50 am - 9:00 am ***Welcome and introduction to the workshop***

9:00 am - 9:45 am

A. Glätzle

Institute for Theoretical Physics, University of Innsbruck

Frustrated magnetism with alkali Rydberg atoms

We show how a broad class of lattice spin-1/2 models can be realized with cold alkali atoms stored in optical or magnetic trap arrays. The effective spin-1/2 is represented by a pair of atomic (hyperfine) ground states, and spin-spin interactions are obtained by weakly laser admixing van der Waals interactions between Rydberg states.
The strengths of the diagonal “zz” spin interactions as well as the “flip-flop”, and "flip-flip" and "flop-flop" interactions can be tuned by exploiting quantum interference, thus realizing different spin symmetries.
In particular, we exploit the strong angular dependence of van der Waals interactions between high angular momentum Rydberg states. Together with the possibility of designing step-like potentials we can implement Abelian gauge theories in a series of geometries, which could be demonstrated within state of the art experiments.
The resulting energy scales of interactions compare well with typical temperatures and decoherence time-scales, making the exploration of exotic forms of quantum magnetism, including emergent gauge theories, compass models and quantum spin ice models, accessible within state-of-the-art experiments.

[1] A. Glätzle, M. Dalmonte, R. Nath, I. Rousochatzakis, R. Mössner, P. Zoller, Quantum Spin Ice and dimer models with Rydberg atoms, Phys. Rev. X 4, 041037 (2014)

[2] A. Glätzle, M. Dalmonte, R. Nath, C. Gross, I. Bloch, P. Zoller, Frustrated Quantum Magnetism with Laser-Dressed Rydberg Atoms, arXiv:1410.3388

[3] B. Vermersch, M. Punk, A. Glätzle, C. Gross, P. Zoller, Dynamical preparation of laser-excited anisotropic Rydberg crystals in 2D optical lattices, New J. Phys. in press, arXiv:1408.0662

Monday 23/2

9:45 am - 10:30 am

A.M. Rey
Physics Department, JILA, NIST and University of Colorado, Boulder

Synchronization of radiating dipoles

Collective ensembles of damped-driven oscillators are ubiquitous in the physical and natural sciences and have an important role in many technological applications. One of the most fascinating behaviors that they exhibit is the phenomenon of synchronization, which describes the spontaneous locking of all of the oscillators to a common phase. Although there has been significant progress in the study of synchronization in classical systems, many open questions remain in the effort to develop a comparable understanding of the same phenomena in the quantum realm. In this talk I will present some progress in that direction and show that macroscopic quantum synchronization can be seen to spontaneously emerge in radiating dipolar quantum systems with frozen motional degrees of freedom. I will also discuss preliminary steps at JILA towards the observation of these predictions in Sr atoms.

10:30 am - 11:00 am ***Coffee***

11:00 am - 11:45 am

M. Jones
Department of Physics, Durham University

Two-electron effects in cold Rydberg gases

If cold Rydberg gases are dominated by the long-range behaviour associated with the Rydberg electron - what can a second electron add? At Durham we have studied this theoretically and experimentally over the last 8 years. We find that the second electron can modify the nature of the long-range interaction, though this effect is small. More importantly, the second electron enables efficient detection through autoionization and greater flexibility for optical trapping. More recently, we have used the narrow intercombination lines that are a feature of the spectra of two-electron atoms to create very cold dense atomic samples in which we have observed interaction effects including evidence of blockade. Exciting to the Rydberg state using these narrow lines opens exciting new directions for metrology and many-body physics.

11:45 am - 12:30 pm

I. Lesanovsky
School of Physics & Astronomy, The University of Nottingham

Long-range interacting many-body systems with alkaline-earth-metal atoms

Alkaline-earth-metal atoms can exhibit long-range dipolar interactions, which are generated via the coherent exchange of photons on transition of the triplet manifold. In the case of bosonic strontium this transition has a wavelength of 2.6 μm and a dipole moment of 4.03 D. Moreover, there exists a magic wavelength permitting the creation of magic optical lattices. These ingredients enable the realization and study of mixtures of hard-core lattice bosons featuring long-range hopping, with tunable disorder and anisotropy. We discuss the underlying many-body master equation, investigate the dynamics of excitation transport, and analyze spectroscopic signatures stemming from coherent long-range interactions and collective dissipation. Our results show that lattice gases of alkaline-earth-metal atoms permit the creation of long-lived collective atomic states and constitute a simple and versatile platform for the exploration of many-body systems with long-range interactions.

12:30 pm - 2:30 pm ***Lunch***

2:30 pm - 3:15 pm

D. Peter
Institute for Theoretical Physics III, University of Stuttgart

Topological flat bands with Chern number C=2 by dipolar exchange interactions

We demonstrate the realization of topological band structures by exploiting the intrinsic spin-orbit coupling of dipolar interactions in combination with broken time-reversal symmetry. The system is based on Rydberg atoms or polar molecules which are pinned on a 2D lattice. Then, the dynamics of the rotational excitations follows a hopping Hamiltonian which is determined by the dipolar exchange interactions. We find topological bands with Chern number C=2 on the square lattice, while a very rich structure of different topological bands appears on the honeycomb lattice. We show that the system is robust against missing molecules. For certain parameters we obtain flat bands, providing a promising candidate for the realization of bosonic fractional Chern insulators.

3:15 pm - 4:00 pm

B. Dunning
Physics & Astronomy, Rice University

Strontium Rydberg atoms: Opportunities and challenges

Strontium Rydberg atoms provide an opportunity to study many different aspects of Rydberg physics. Strontium is attractive for several reasons. Its even isotopes have no ground state hyperfine structure which results in particularly simple excitation spectra and the required excitation wavelengths are well matched to diode laser systems. The core ion is optically active which permits the fluorescence imaging of (high- l) Rydberg states and the monitoring of the evolution of atomic l-state distributions in cold Rydberg gases. Core excitation also provides an opportunity to create strongly-correlated quasi-stable two-electron-excited "planetary atoms". Creation of Rydberg atoms with well-defined initial positions/separations, coupled with their subsequent excitation to very-high-n states using a carefully-tailored series of short electric field pulses, promises to allow detailed study of strongly-coupled Rydberg atom pairs and, with periodic external driving, the potential formation of quasi-stable "molecular" Rydberg states. Introduction of a controlled admixture of Rydberg character into the ground state wave function by Rydberg dressing can be used to control the atom-atom interactions in a cold Rydberg gas or BEC. Such interactions can be tuned by varying the Rabi frequency and overall detuning and, depending as to the choice of isotope and dressing state, can be either attractive or repulsive. However, measurements involving dressing with the 333S1 state using an optical dipole trap show that, even when well detuned from resonance, such dressing can lead to a rapid decrease in the ground state atom population in the trap. This decrease is attributed to Rydberg atom excitation which can lead to direct escape from the trap and/or to the population of very-long-lived metastable states. The data suggest a reaction model in which initial excitation of a Rydberg atom triggers the rapid growth of a local Rydberg atom cluster leading to enhanced Rydberg excitation rates.

Research undertaken in collaboration with X. Zhang, B. DeSalvo, J. Aman, T.C. Killian, S. Yoshida, and J. Burgdorfer

4:00 pm - 4:30 pm ***Coffee***

Monday 23/2

4:30 pm -5:15 pm

B. Sanders
Physics and Astronomy, University of Calgary

Quantum simulation of micro and macro frustrated quantum magnetism

We propose a scheme for simulation frustrated quantum magnetism such that the microscopic states of the constituent effective particles and the macroscopic susceptibility can be measured conjointly.

5:30 pm ***Lab tours***

9:00 am - 9:45 am

C. Greene
Department of Physics and Astronomy, Purdue University

Perturbed two-electron Rydberg spectra and their implications

One of the most dramatic differences between the spectroscopy of an atom with two valence electrons versus an atom with just one is the existence of level perturbations due to doubly excited states. This rearranges the density of states and oscillator strength distribution in the alkaline earth atoms in a fundamental manner and changes the regular Rydberg series characteristic of the alkali atoms into a lumpier and more richly complex nature. Some of the implications of this qualitatively different pattern of energy levels will be addressed, with a focus on the implications for Rydberg molecules.

9:45 am - 10:30 am

T. Gallagher
Department of Physics, University of Virginia

Bound and autoionizing Rydberg states of alkaline earth atoms

The Rydberg states of alkaline earth atoms are particularly interesting because their ionic cores can be optically excited with a laser. The ability to excite the ionic core can provide a way to manipulate the Rydberg atom. In addition, the core itself is interesting both for clocks and quantum information applications, and the Rydberg electron provides a subtle probe of the ion's properties. The optical excitation of the core of an alkaline earth Rydberg atom to a doubly excited will be described. Typically the ionic core absorbs one or more photons while the Rydberg electron is a spectator. Not surprisingly, the process is often termed isolated core excitation. Generally, but not always, the result is autoionization, and the Rydberg electron is ejected. A classical description of autoionization leads naturally to the conditions under which the Rydberg electron remains bound. Simple techniques based on the polarizability of the core and the Stark effect can be used to determine which states will autoionize, rather than decay radiatively. Finally, microwave spectroscopy of the bound high ℓ states provides a means to determine the polarizability of the ion core, which, due to the black body radiation shift, is a crucial property of an ion used in an optical clock.

10:30 am - 11:00 am ***Coffee***

11:00 am - 11:45 am

J. Burgdörfer
Institute for Theoretical Physics, Vienna University of Technology

High-n Rydberg wavepackets in quasi-two electron atoms

Exploring the dynamics of Rydberg wavepackets beyond the quasi-one electron limit has remained a challenge, both experimentally and theoretically. Recent advances in the three-photon excitation of strontium, a quasi-two electron systems, to high Rydberg states ($n \geq 300$) with number densities sufficient to explore both intraatomic and interatomic electron-electron interaction [1] promises to open up the possibility to study correlated dynamics at the classical-quantum border. The interatomic coupling may reach a strength to realize dipole blockade on an almost macroscopic scale (≈ 0.1 mm). We will present quantum and classical simulations to elucidate the excitation and propagation of high-n Rydberg wavepackets driven by ultrashort pulses.

[1] Ye, S. et al., 2014 Phys. Rev. A 90, 013401 (2014)

11:45 am - 12:30 pm

S. Scheel
Institute of Physics, University of Rostock

Rydberg excitons in cuprous oxide - Rydberg physics with giant artificial atoms

Excitons in semiconductors are bound states of an electron in the conduction band and the corresponding hole in the valence band whose binding energy closely follows the Rydberg series. In a recent experiment, excitons with a principal quantum number up to n=25 have been observed in the semiconductor cuprous oxide Cu2O [1]. Due to their relatively low Rydberg energy of 92meV, and therefore large exciton Bohr radii of more than 1nm, already wavefunctions with n=25 extend over a radial distance of more than 2 microns. The vastly enhanced van der Waals interaction results in strong Rydberg blockade which manifests itself in a sharp quenching of absorption with increasing pump power.

In this talk, after a brief summary of the original experiment, I will introduce the concept of quantum defects in excitons that is mainly due to the nonparabolicity of the valence bands. As the valence bands are split due to spin-orbit and magnetic interactions [2], their mutual coupling distorts the band dispersion that can be re-interpreted as a modification of the Coulomb interaction at short distances. Recent precision measurements in electric fields support this view.

I will further discuss the possibility of producing exciton states in crossed electric and magnetic fields with giant dipole moments, first anticipated more than 20 years ago [3].

[1] T.Kazimierczuk, D.Fröhlich, S.Scheel, H.Stolz, and M.Bayer, Nature 514, 343 (2014).

[2] K.Suzuki and J.C.Hensel, Phys. Rev. B 9, 4184 (1974).

[3] P.Schmelcher, Phys. Rev. B 48, 14462 (1993).

12:30 pm - 2:30 pm ***Lunch***

2:30 pm - 3:15 pm

F. Schreck
Institute of Physics, University of Amsterdam

New tricks with ultracold strontium: Laser cooling to BEC & Ultracold RbSr molecules

I will present two research lines that we are currently pursuing with ultracold strontium. In the first research line, we have cooled a gas of strontium to quantum degeneracy using laser cooling as the only cooling method. We are currently developing a setup in which we hope to exploit this technique to build a perpetual atom laser, which has many applications in precision measurement.

In the second line of research, we are working towards ultracold RbSr ground-state molecules, which are open-shell polar molecules, having a large electronic dipole moment and an unpaired electron. Compared to the already existing ultracold closed-shell polar molecules, RbSr molecules provide us with a larger parameter space for interaction control and the study of many-body physics. As first steps towards these molecules, we have created a quantum gas mixture of Rb and Sr, performed RbSr molecular spectroscopy, and established a new molecule association method.

3:15 pm - 4:00 pm

M. Saffman
Department of Physics, University of Wisconsin-Madison

Laser cooling, Rydberg spectroscopy and coherent trapping of Holmium atoms

We present progress towards using the large ground hyperfine manifold of neutral Holmium for collective encoding of a quantum register. Holmium atoms have been laser cooled and magneto-optically trapped using the strong 410.5 nm transition[1]. Using trapped atoms we have measured the quantum defects of the 4f^11 6sns and 4f^11 6snd series using MOT depletion spectroscopy[2]. The Rydberg series are well described by the Rydberg-Ritz formula, apart from a strong perturbation of the ns series at n=51. Current work directed towards long coherence time trapping of multiple qubits, and measurements of the Rydberg interaction strength and lifetimes will be described. Work supported by the NSF.

1. J. Miao, J. Hostetter, G. Stratis, and M. Saffman, Phys. Rev. A 89, 041401(R) (2014).

2. J. Hostetter, J. D. Pritchard, J. E. Lawler, and M. Saffman, "Measurement of Holmium Rydberg series through MOT depletion spectroscopy", to be submitted (2014).

4:00 pm - 4:30 pm ***Coffee***

4:30 pm - 5:15 pm

T. Killian
Physics & Astronomy, Rice University

Ultralong-range molecules and EIT in strontium ultracold Rydberg gases

Alkaline-earth metal atoms are attracting increased attention for studies of ultracold Rydberg gases because of new opportunities created by strong core transitions accessible with visible light and the presence of excited triplet states. Core transitions can be used for flexible optical trapping and optical imaging of Rydberg atoms, and triplet levels appear promising for creating stronger optical coupling of ground and Rydberg levels with reduced light scattering. Compared to an alkali metal atom, the existence of both singlet and triplet Rydberg levels creates additional choices of configurations of excited states and associated Rydberg-Rydberg interactions.

We have created and characterized ultralong-range Sr2 molecules formed from one ground-state 5*s*2 1*S*0 atom and one atom in a 5*sns* 3*S*1 Rydberg state for n ranging between 29 and 36. I will describe recent experiments conducted at Rice University in which we take advantage of these opportunities with ultracold strontium gases.
Molecules are created in a trapped ultracold atomic gas using two-photon excitation, near resonance with the 5*s*5*p* 3*P*1 intermediate state. Combined with numerical calculation of the molecular potentials and wavefunctions, this allows us to extract values for the effective *s*-wave and *p*-wave scattering lengths describing collisions between an electron and a ground-state Sr atom.
We have also studied phenomena associated with electromagnetically induced transparency in the 5*s*2 1*S*0-5*s*5*p* 3*P*1-5*sns* 3*S*1 ladder system. Well-resolved Autler-Townes doublets are visible in the atom-loss signal when a strong 320 nm pump laser on resonance with the 5*s*5*p* 3*P*1-5*sns* 3*S*1 transition and a weak 689 nm probe laser near resonance with the 5*s*2 1*S*0-5*s*5*p* 3*P*1 are applied. The configuration of both lasers on resonance appears promising for Rydberg dressing experiments, and we will discuss our progress towards this goal.

6:15 pm ***Departure for conference dinner***

9:00 am - 9:45 am

T. Pfau
5th Institute of Physics, University of Stuttgart

A single charge in a Bose-Einstein condensate: from two to few to many-body physics

Electrons attract polarizable atoms via a 1/r^4 potential. For slow electrons the scattering from that potential is purely s-wave and can be described by a Fermi pseudopotential. To study this interaction Rydberg electrons are well suited as they are slow and trapped by the charged nucleus. In the environment of a high pressure discharge Amaldi and Segre, already in 1934 observed a lineshift proportional to the scattering length [1].
At ultracold temperatures and Rydberg states with medium size principle quantum numbers *n*, one or two ground state atoms can be trapped in the meanfield potential created by the Rydberg electron, leading to so called ultra-long range Rydberg molecules [2].
At higher Rydberg states the spatial extent of the Rydberg electron orbit is increasing. For principal quantum numbers *n* in the range of 100-200 and typical BEC densities, up to several ten thousand ground state atoms are located inside one Rydberg atom, We excite a single Rydberg electron in the BEC, the orbital size of which becomes comparable to the size of the BEC. We study the coupling between the electron and phonons in the BEC [3].
We also observe evidence for ultracold charge transfer processes for a single ion which is shielded by a Rydberg electron. Also reactive processes due to few-body Langevin dynamics involving a single ion can be studied.
As an outlook, the trapping of a full condensate inside a Rydberg atom of high principal quantum number and the imaging of the Rydberg electron's wave function by its impact onto the surrounding ultracold cloud seem to be within reach [4].

[1] E. Amaldi and E. Segre, Nature **133**, 141 (1934)

[2] C. H. Greene, et al., PRL **85,** 2458 (2000); V. Bendkowsky et al., Nature **458**, 1005 (2009)

[3] J . B. Balewski, et al., Nature **502**, 664 (2013)

[4] T. Karpiuk, et al., arXiv:1402.6875

Wednesday 25/2

9:45 am - 10:30 am

H.R. Sadeghpour

ITAMP Harvard Smithsonian Center for Astrophysics

These Rydberg molecules are fluffy, but they carry a biggg stick

There's now sufficient and convincing evidence that ultra long-range (and ultracold) Rydberg molecules, consisting of one ground state atom and one Rydberg state atom, exist. Several groups have formed them in different Rydberg states and some of their properties have been documented. Studies with two-electron atoms are beginning to show the emergence of such molecular states. In this talk, I will describe the mechanism for how these homonuclear molecules can sport permanent electric dipole moments- sometimes extraordinarily large dipole moments. We know that formation of permanent dipole moments requires some sort of symmetry breaking, but homonuclear molecules do not break parity or charge symmetry. Something must give. If time permits, I will get into some few- and many-body aspects of these molecular states.

10:30 pm - 11:00 am ***Coffee***

11:00 am - 11:45 am

P. Pillet

Laboratoire Aimé Cotton, CNRS, University Paris-Sud

Two examples of three-body physics with Rydberg atoms in Förster dipole-dipole coupling and in Coulomb coupling

Rydberg atoms offer opportunities to isolate three-body effects from the two-body ones and to characterize the particle-correlations. Two different couplings between particles are considered: the dipole-dipole interaction and the Coulomb interaction.

In a cold gas of Rydberg atoms in mutual dipole-dipole or Förster coupling, we intend to separate few-body from the two-body processes [J. H. Gurian et al., PRL108, 023005 (2012)]. An example of Förster resonance is for Cs atom: np+np → ns+(n+1)s, where the exchange of internal energy between the two atoms is reached in resonance by adding a weak static electric field, F0, which Stark-shifts the energy of the p-states, leading to a substantial transfer of population towards the s states.

Wednesday 25/2

Three-body Förster resonances can also be observed with a reaction: 3 x np → ns + (n+1)s + np'. The resonance occurs for a value of the static electric field different from the one associated to the two-body process, $F_1 \neq F_0$. The two-body Förster coupling is out of resonance, and the missing exchanged internal energy between two Rydberg atoms is compensated by the change of level by a third atom, p → p' [1]. Such a three-body process presents a Borromean character, where the three-body processes become the elementary coupling in absence of two-body ones.

An atom, with two highly excited electrons, or double-Rydberg helium-like atom corresponds to the old, but still not fully understood, Coulomb three-body problem in atomic physics. The double-Rydberg atoms spectroscopically labelled as $n_1l_1n_2l_2$, lying close of the double ionization limit, can be associated to those of the helium atom, in the same way Rydberg atoms are compared to the hydrogen atom. But here the approach is much less straightforward and fruitful, because the three-body system – the doubly charged ionic core and the two excited electrons – is not a separable and solvable problem. A configuration with different excitation of both electrons, n1<<n2, can be "separated" as an atomic Rydberg electron, n2, and an ionic Rydberg electron, n1; due to the different sizes and to the different periods of both electronic orbits. The physics of such double-Rydberg atoms has been investigated by low-resolution (10 GHz) laser spectroscopy, with the so-called isolated-core excitation (ICE), in which the inner electron of the ionic core is excited while the previously Rydberg excited far-outer one is considered as a spectator [W.E. Cooke et al., PRL 40, 178 (1978)]. For low angular momenta, both electrons collide and the doubly excited atom autoionizes, giving one electron + one ion. To avoid the autoionization process, high angular momenta, l_2, have to be considered [R.R. Jones et al., PRA 38, 2846 (1988), L Pruvost et al., J. Phys. B24, 4723 (1991)]. For such a "separable" system, n1<<n2, the di-electronic correlation of double-Rydberg states has been observed: it corresponds to the strong polarization of the inner excited electron, n1, by the field created by the outer one, n2 [P.Camus et al., PRL 62, 2365 (1989)]. Double-Rydberg states are no longer observed when the polarization becomes large enough to mix the n1 and the n1+1 manifolds of the inner electron.

[1] Borromean three-body FRET in frozen Rydberg gases, R. Faoro, B. Pelle, A. Zuliani, P. Cheinet, E. Arimondo, and P. Pillet (submitted)

11:45 am - 12:30 pm

T. Pohl
Max Planck Institute for the Physics of Complex Systems

Rydberg-excitation of two-electron triplet states

The utility of the strong interactions between Rydberg states has been demonstrated in various experiments with cold alkaline atoms. This talk will explore the potential of combining such long-lived Rydberg states with long-lived low-lying states of two-electron atoms.

On the one hand, we will demonstrate that off-resonant Rydberg excitation of two-electron atoms yields a viable approach to spin squeezing in optical lattice clocks. The resulting effective spin interactions are shown to generate substantial squeezing in large ensembles without degrading the subsequent clock interrogation.

On the other hand, resonant excitation via long-lived triplet states is shown to provide a new approach to strong and tuneable ground state atom interactions with coherence times that vastly exceed those of equivalent alkaline settings. Potential applications of the described schemes will also be discussed.

Directions

Center for Optical Quantum Technologies (ZOQ)
Luruper Chaussee 149, 22761 Hamburg

building 90 on the DESY/university campus, directly on your right when entering the campus through the side entrance facing Luruper Chaussee (see map below)

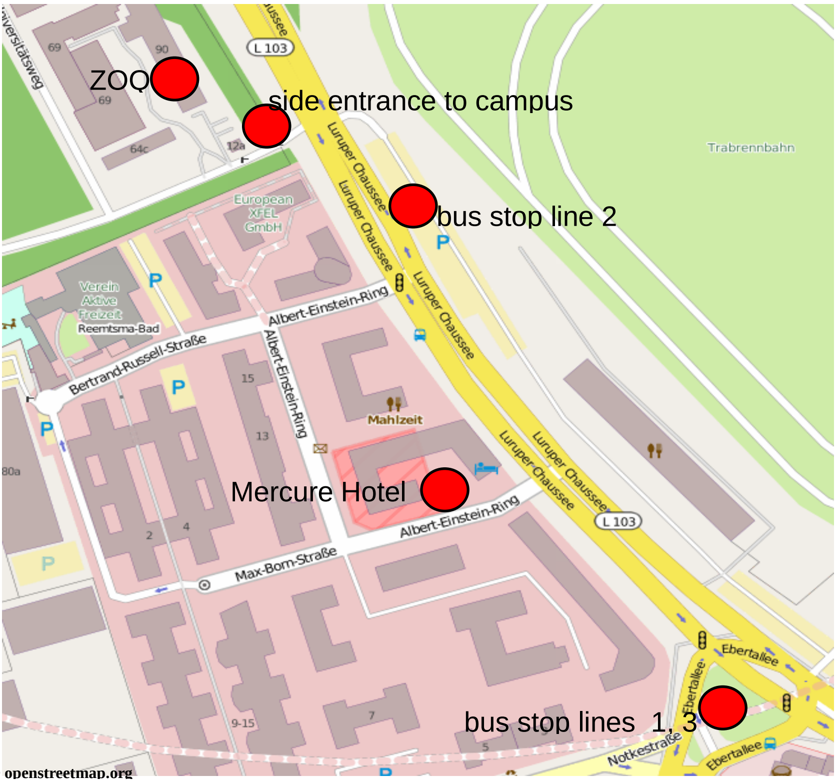
coming from the airport:

– public transport: Take the train S1 to *Othmarschen* (45 minutes), then bus 1 to *Trabrennbahn Bahrenfeld* (5 minutes). From here it is a short walk down Luruper Chaussee to the hotel and the side entrance of the campus.

– taxi: Going by taxi will take around 35 minutes.

coming from Hamburg Altona train station:

– Take bus 2 to *Luruper Chaussee/DESY* (15 minutes). The hotel and side entrance of the campus are on the opposite side of the street.



For more information on directions and the Hamburg public transport, please contact us or check www.hvv.de.

Accommodation

Mercure Hotel Hamburg am Volkspark
Albert-Einstein-Ring 2, 22761 Hamburg
H1659@accor.com, phone: (+49)40899520

DESY guest house
Notkestraße 85, 22607 Hamburg

hostel@desy.de, phone: (+49)4089982740
buildings 32/33 on the DESY campus, close to the main entrance facing Notkestraße
bus stop: *Zum Hünengrab* (bus 1)

Conference dinner

Hotel Hafen Hamburg, Restaurant Port
Seewartenstraße 9, 20459 Hamburg

Contact the organizers

Scientific organization:

Peter Schmelcher
pschmelc@physnet.uni-hamburg.de, office +49(0)4089986501

Matthias Weidemüller
weidemueller@uni-heidelberg.de, office +49(0)6221549212

Local coordination:

Anja Cordes
anja.cordes@physnet.uni-hamburg.de, office +49(0)4089986503

This workshop is organized by the Center for Optical Quantum Technologies (ZOQ, University of Hamburg) and financed by Marie Curie Initial Training COHERENCE NETWORK