Symposium Decoherence in the Light of Modern Experiments (SYDC)

jointly organized by
the Atomic Physics Division (A),
the Molecular Physics Division (MO), and
the Quantum Optics and Photonics Division (Q)

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Overview of Invited Talks and Sessions

(lecture room E 415)

Invited Talks

SYDC 1.1	Tu	14:00–14:30	E 415	**Environment-induced Decoherence of Quantum States: An Introduction** — •Heinz-Peter Breuer
SYDC 1.2	Tu	14:30–15:00	E 415	**Fighting Decoherence: Quantum Information Science with Trapped Ca^+ Ions** — T. Monz, K. Kim, A. Villar, P. Schindler, M. Chwalla, M. Riebe, C. F. Roos, H. Häffner, W. Hänsel, M. Hennrich, •R. Blatt
SYDC 1.3	Tu	15:00–15:30	E 415	**Decoherence phenomena in molecular systems: Localization of matter waves & stabilization of chiral configuration states** — •Klaus Hornberger
SYDC 1.4	Tu	15:30–16:00	E 415	**Decoherence of free electron waves and visualization of the transition from quantum- to classical-behaviour** — •Franz Hasselbach
SYDC 2.1	Tu	16:30–17:00	E 415	**Coherence and the loss of it in molecular photoionization** — •Uwe Hergenhahn
SYDC 2.2	Tu	17:00–17:30	E 415	**Decoherence in fermionic interferometers** — •Florian Marquardt
SYDC 2.3	Tu	17:30–18:00	E 415	**Quantum diffusion in gravitational waves backgrounds** — •Serge Reynaud, Brahim Lamine, Rémy Hervé, Astrid Lambrecht
SYDC 2.4	Tu	18:00–18:30	E 415	**Quantum coherence and decoherence in biological systems** — •Martin Plenio

Sessions

SYDC 1.1–1.4	Tu	14:00–16:00	E 415	**Decoherence in the Light of Modern Experiments I**
SYDC 2.1–2.4	Tu	16:30–18:30	E 415	**Decoherence in the Light of Modern Experiments II**

SYDC 1: Decoherence in the Light of Modern Experiments I

Time: Tuesday 14:00–16:00 Location: E 415

Invited Talk SYDC 1.1 Tu 14:00 E 415

Environment-induced Decoherence of Quantum States: An Introduction — •Heinz-Peter Breuer — Physikalisches Institut, Universität Freiburg, Hermann-Herder-Str. 3, D-79104 Freiburg, Germany

Realistic quantum mechanical systems are influenced through the coupling to an environment which contains a large number of mostly uncontrollable degrees of freedom. The interaction of an open quantum systems with its environment leads to the mechanisms of damping and dissipation, and to a strong and often rapid loss of quantum coherence. The talk gives an introduction into the theory of the decoherence of quantum states. With the help of simple system-environment models the basic features of the decoherence dynamics in open quantum systems are discussed, and some standard techniques for the determination of decoherence time scales will be explained, as well as the emergence of pointer states and decoherence-free subspaces.

Invited Talk SYDC 1.2 Tu 14:30 E 415

Fighting Decoherence: Quantum Information Science with Trapped Ca^+ Ions — T. Monz[1], K. Kim[1], A. Villar[1], P. Schindler[1], M. Chwalla[1], M. Riebe[1], C. F. Roos[2], H. Häffner[2], W. Hänsel[1,2], M. Hennrich[1], and •R. Blatt[1,2] — [1]1Institut für Experimentalphysik, Universität Innsbruck, Technikerstraße 25, A-6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, A-6020 Innsbruck, Austria

Trapped strings of cold ions provide an ideal system for quantum information processing. The quantum information can be stored in individual ions and these qubits can be individually prepared; the corresponding quantum states can be manipulated and measured with nearly 100% detection efficiency. With a small ion-trap quantum computer based on up to eight trapped Ca^+ ions as qubits we have generated genuine quantum states in a pre-programmed way. In particular, we have generated GHZ and W states in a fast and scalable way and we have demonstrated the three-qubit Toffoli gate with trapped ions which is analyzed via state and process tomography. High fidelity CNOT-gate operations were investigated towards fault-tolerant quantum computing. All protocols require either avoiding decoherence using appropriate experimental conditions or tailoring decoherence free subspaces. With logical qubits encoded in two physical qubits the universal operations for quantum information processing were demonstrated within a decoherence free subspace [1].

[1] T. Monz et al., Phys. Rev. Lett. 103, 200503 (2009)

Invited Talk SYDC 1.3 Tu 15:00 E 415

Decoherence phenomena in molecular systems: Localization of matter waves & stabilization of chiral configuration states — •Klaus Hornberger — Max Planck Institute for the Physics of Complex Systems, Dresden, Germany

Molecules are ideally suited to study the physics of the quantum-to-classical transition. It is fairly easy to isolate them well enough from their surroundings to render quantum effects observable; at the same time, by increasing the number of constituents and thus the complexity of the considered species, one can approach the generic behavior of mesoscopic objects. The talk will discuss decoherence phenomena in molecular systems by first reviewing interference experiments where the change from a delocalized molecular matter wave to a localized behavior due to endogenous heat radiation was observed in agreement with a microscopically realistic model [1]. A laser grating based interferometer will also be described where decoherence by photon absorption cannot be avoided [2]. In the second part, I will discuss how decoherence due to collisions with an achiral background gas can explain the distinction and stabilization of chiral molecular configurations states [3].

[1] L. Hackermüller et al., Nature 427, 711 (2004)
[2] S. Gerlich, et al., Nature Physics 3, 711 (2007)
[3] J. Trost and K. Hornberger, Phys. Rev. Lett 103, 023202 (2009)

Invited Talk SYDC 1.4 Tu 15:30 E 415

Decoherence of free electron waves and visualization of the transition from quantum- to classical-behaviour — •Franz Hasselbach — Institut für Angewandte Physik der Universität Tübingen, Auf der Morgenstelle 10, D-72076 Tübingen, Germany

Controlled decoherence of free electron waves due to Coulomb interaction with a truly macroscopic, dissipative environment (namely: the electron and phonon gas inside a semiconducting plate of 10mm in length) is studied experimentally by electron biprism interferometry. The electron is one of the most elementary particles, and due to the absence of magnetic fields in the setup, spin is irrelevant. Consequently, no inner degrees freedom can be excited and entangled with the center of mass coordinates. Decoherence is exclusively caused by electromagnetic interaction through irreversible deposition of energy into the environment. In the experiment, two parameters are varied, the height of the coherent electron waves above the plate and, in this plane the lateral distance between the coherent beams. The experiment confirms the main features of the theory of decoherence and can be interpreted in terms of which-path information. The quantitative results are compared with different theoretical models. In contrast to previous model experiments on decoherence, the obtained interferograms directly visualize the transition from quantum- to classical-behaviour.

SYDC 2: Decoherence in the Light of Modern Experiments II

Time: Tuesday 16:30–18:30 Location: E 415

Invited Talk SYDC 2.1 Tu 16:30 E 415

Coherence and the loss of it in molecular photoionization — •Uwe Hergenhahn — Max-Planck-Institut für Plasmaphysik, EURATOM Association, 85748 Garching

A molecule, which is ionized by absorption of a single, energetic photon, can be seen as a complex source of outgoing photoelectron waves. Intramolecular electron scattering phenomena have been known in photoemission for a long time. More interesting questions arise in molecules containing several chemically equivalent sites, homonuclear diatomics being the simplest example. Here, rigourous application of quantum mechanics dictates to consider these sites as coherent emitters of photoelectron waves. I will give an overview about recent experiments which have probed this paradigm.

Invited Talk SYDC 2.2 Tu 17:00 E 415

Decoherence in fermionic interferometers — •Florian Marquardt — Friedrich-Alexander Universität Erlangen-Nürnberg und Max-Planck Institut für die Physik des Lichts

Interference experiments with electrons in solids represent a powerful tool to learn about decoherence and interaction effects. In contrast to interferometers based on single photons, neutrons, atoms or molecules, many-body effects play an essential role. In this talk I will discuss some aspects of the decoherence of electrons. In particular, I will describe the electronic Mach-Zehnder interferometer that is based on electrons traveling chirally along edge channels in the quantum Hall effect regime. We find that, in the appropriate regime, the loss of phase coherence obeys a power-law decay with a universal exponent, independent of the details of the interaction potential.

Invited Talk SYDC 2.3 Tu 17:30 E 415

Quantum diffusion in gravitational waves backgrounds — •Serge Reynaud, Brahim Lamine, Rémy Hervé, and Astrid Lambrecht — Laboratoire Kastler Brossel, CNRS, ENS, UPMC, Paris

The value of the Planck mass (22μg) may lead to the idea that intrinsic fluctuations of spacetime are responsible in some manner for the existence of a natural borderline between quantum and classical worlds. We propose quantitative answers to this question by considering the diffusion and decoherence mechanisms induced on quantum systems by the stochastic gravitational waves (GW) backgrounds generated at the galactic and cosmic scales.

This universal fluctuating environment indeed blurs quantum interferences on macroscopic systems (large masses), while leaving essentially untouched those on microscopic systems (small masses). We give relevant numbers in the context of ongoing progress towards more and more sensitive matter-wave interferometry.

Similar ideas are also worthy of attention in the context of quantum information. For example EPR correlations encoded on photon polarizations are affected by the exposition to the GW backgrounds, and one can wonder whether or not, and to what extent, the correlations survive propagation on long distances.

Invited Talk SYDC 2.4 Tu 18:00 E 415

Quantum coherence and decoherence in biological systems

— •Martin Plenio — Institut für Theoretische Physik, Universität Ulm, Ulm, Germany — QOLS, Blackett Lab, Imperial College London, London SW7 2BW, UK

Quantum dynamics is often subjected to uncontrollable interactions with the environment. These are generally assumed to have a detrimental effect but this is not always the cased. In this talk I will discuss the dynamics of dissipative and noisy quantum networks and will show how noise, both dephasing type and dissipative noise may actually improve the transport performance of the network. I will use the example of the FMO complex to elucidate the principles that govern the dynamics of such networks and use them to explain specific features of this dynamics.