Symposium Spin-Boson Models (SYSB)

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

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The physics of coupled spin-boson dynamics has an astonishingly wide range of applications, from quantum information processing and quantum-enhanced metrology to the realization of non-equilibrium states, such as time-crystals. Further important phenomena include single charge transfer in quantum electronic circuits and superconducting devices as well as quantum heat transfer in atomic and molecular aggregates. This symposium covers recent developments across this broad spectrum of research with internationally renowned speakers presenting both experimental and theoretical results.

Overview of Invited Talks and Sessions

(Lecture hall RW 1)

Invited Talks

SYSB 1.1	Tue	11:00–11:30	RW 1	**Tailoring the quantum dynamics of spins with bosonic baths** — •Giovanna Morigi
SYSB 1.2	Tue	11:30–12:00	RW 1	**Spins, Qubits, and Bosons** — •Guido Burkard
SYSB 1.3	Tue	12:00–12:30	RW 1	**Spin-boson models under strong ac-driving** — •Milena Grifoni
SYSB 1.4	Tue	12:30–13:00	RW 1	**Kibble-Zurek scenario for melting of discrete time crystals** — •Phatthamon Kongkhambut, Hans Kessler, Roy D. Jara Jr., Jayson G. Cosme, Andreas Hemmerich

Sessions

SYSB 1.1–1.4	Tue	11:00–13:00	RW 1	**Spin-boson models**

Related sessions within the Quantum Optics and Photonics Division

Q 9.1–9.7	Mon	17:00–18:45	P 4	**Open Quantum Systems and Spin-Boson Systems I**
Q 33.1–33.8	Wed	14:30–16:30	P 4	**Cavity QED, QED, and Spin-Boson Systems I**

SYSB 1: Spin-boson models

Time: Tuesday 11:00–13:00 Location: RW 1

Invited Talk SYSB 1.1 Tue 11:00 RW 1
Tailoring the quantum dynamics of spins with bosonic baths — •Giovanna Morigi — Universität des Saarlandes

The spin-boson model is a paradigm in the theory of open quantum system. One prominent feature is its capability to describe irreversible processes in a spin system within a quantum mechanical framework. Irreversible processes, such as loss of quantum coherence and quantum dissipation, arise from the lack of control over the bosonic environment, the properties of which are often only known at the macroscopic level. Starting from these premises, this talk will discuss how to design spins quantum states and dynamics by means of the coupling with a bosonic bath. The strategy consists of using external fields for designing fixed points of the spin dynamics. Examples will be provided that can be implemented in existing experimental platforms. We will argue that these strategies could open novel pathways for dealing with noise in quantum technologies.

Invited Talk SYSB 1.2 Tue 11:30 RW 1
Spins, Qubits, and Bosons — •Guido Burkard — Department of Physics and IQST, University of Konstanz, 78457 Konstanz, Germany

The spin-boson model, along with related open-system approaches, constitutes a foundational tool for understanding noise and decoherence in contemporary quantum computing devices. We outline how these models describe realistic qubit properties and capture both temporal and spatial noise correlations. We illustrate the utility of these models across a series of representative scenarios. First, we present a quantum decoherence theory for superconducting qubit circuits, derived from electrical network graph methods and the spin-boson model, leading to Bloch-Redfield dynamics that include leakage beyond the computational subspace. Second, we discuss non-Markovian qubit dynamics under 1/f noise. Third, we investigate temporally correlated noise in superconducting transmon qubits using a time-local, non-Markovian master equation. Extending this framework to driven systems while avoiding both Markov and field-independent approximations enables an accurate tracking of time-dependent decay channels. Turning to spatially correlated noise, we present efficient methods, requiring only single-qubit control and measurement to detect correlated relaxation and dephasing. Finally, we examine temperature-dependent effects in semiconductor spin qubits, demonstrating how spin-phonon interactions may explain the observed non-monotonic qubit frequency shifts. Together, these examples highlight the breadth of noise phenomena captured by spin-boson-type models and their central role in the design and diagnosis of high-fidelity qubit architectures.

Invited Talk SYSB 1.3 Tue 12:00 RW 1
Spin-boson models under strong ac-driving — •Milena Grifoni — University of Regensburg

Quantum two-level systems interacting with the surroundings are ubiquitous in nature. The coupling suppresses quantum coherence and forces the system towards a steady state. Such dissipative processes are captured by the paradigmatic spin-boson model, describing a two-state particle, the "spin", interacting with an environment formed by harmonic oscillators. I will discuss to what extent intense coherent driving impacts the dynamical and stationary properties of the strongly driven spin-boson model, in the case of Ohmic dissipation and for a structured bath. Theoretical predictions will be benchmarked to experiments with platforms based on superconducting qubits coupled to an electromagnetic environment. These results advance fundamental understanding of open quantum systems and bear potential for the design of entangled light-matter states.

Invited Talk SYSB 1.4 Tue 12:30 RW 1
Kibble-Zurek scenario for melting of discrete time crystals — •Phatthamon Kongkhambut[1,2,3], Hans Kessler[1], Roy D. Jara Jr.[4], Jayson G. Cosme[4], and Andreas Hemmerich[1] — [1]Institut für Quantenphysik, Universität Hamburg, Hamburg, Germany — [2]Department of Physics and Materials Science, Chiang Mai University, Chiang Mai, Thailand — [3]Thailand Center of Excellence in Physics, Office of the Permanent Secretary, Chiang Mai, Thailand — [4]National Institute of Physics, University of the Philippines, Diliman, Quezon City, Philippines

The Kibble-Zurek mechanism (KZM) describes spontaneous symmetry breaking and universal scaling resulting from the breakdown of adiabaticity, leading to topological defect formation as systems are driven across critical points at finite rates. While KZM has been studied in systems transitioning into static spatially ordered phases, we investigate it in systems exhibiting spatiotemporal ordering into a discrete time crystal, a dynamical phase emerging from the spontaneous breaking of discrete time-translation symmetry under periodic driving. Using a weakly dissipative atom-cavity system with all-to-all interactions, we observe hallmark KZM signatures: order parameter freezing and universal scaling governed by critical exponents as the system transitions from a dynamical discrete time crystal to a static superradiant phase.