MON 19: Foundational / Mathematical Aspects – Quantum Optics and Quantum Information

Time: Monday 16:30–18:15 Location: ZHG008

MON 19.1 Mon 16:30 ZHG008

Operational theory for photonic circuits: the Hong-Ou-Mandel effect — •Ismael Septembre[1], Matthias Kleinmann[1], and Martin Plavala[2] — [1]University of Siegen, Germany — [2]University of Hannover, Germany

In this presentation, I will introduce a method that allows studying photonic circuits in a general operational probability theory in position-momentum space (phase space). We use our method to thoroughly study beam splitters. We show that the Hong-Ou-Mandel dip (often cited as a truly quantum effect) is a universal feature of all theories with no state preparation uncertainty, such as classical optics. We then discuss where does the 50% visibility of standard classical optics come from and construct alternative classical theories that reproduce the 100% visibility of quantum optics. Our work paves the way to the study of photonic quantum computing in a generalised setting and the origin of its alleged computing advantage.

MON 19.2 Mon 16:45 ZHG008

Preventing the Breakdown of the Tight Binding Approximation in Waveguide Quantum Optics — •Konrad Tschernig[1], Florian Huber[2], Janik Wolters[1,3], and Jasmin Meinecke[2,3] — [1]Deutsches Zentrum für Luft- und Raumfahrt, Institut für Weltraumforschung, Berlin, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany — [3]Technische Universität Berlin, Berlin, Germany

Many scientific advancements rely on the tight-binding approximation, which simplifies the description and prediction of complex system behaviors. In waveguide quantum optics, this approximation describes the dynamics of the single photon field by examining the coupling between the guided modes of individual single-mode waveguides. However, a crucial and often overlooked assumption in this framework is the mutual orthogonality of the guided modes. This assumption can fail when the waveguides are positioned very close to each other. We analyze the breakdown of the tight-binding approximation in scenarios involving small distances and then introduce the solution called Symmetric Löwdin Orthogonalization (SLO). By using SLO, we restore the orthogonality of the guided modes, leading to a closer alignment with the full continuous theory and improved agreement with experimental data compared to the standard tight-binding approach. Additionally, we explore the origin of nonreciprocal coupling in detuned waveguide systems within the SLO framework, which has previously been attributed to non-Hermitian effects.

MON 19.3 Mon 17:00 ZHG008

Causal influences in quantum many-body systems — •Leonardo Silva Vieira Santos and Otfried Gühne — Universität Siegen

In this contribution, I will present a quantum information-theoretic framework for consistently formulating cause-and-effect in quantum many-body systems. We define an operational measure of quantum causal influence, which quantifies how information and correlations propagate through the system. This reveals a causal interpretation of the 2nd law of thermodynamics, arising from the monogamy of entanglement and thus with no counterpart in classical physics. Finally, we show how causality constrains quantum dynamics and can be used to infer properties of many-body Hamiltonians, formulating a "converse Lieb-Robinson problem".

MON 19.4 Mon 17:15 ZHG008

Projective simulability of noisy SIC-POVMs — Raphael Brinster, Hermann Kampermann, Dagmar Bruss, and •Nikolai Wyderka — Institut für Theoretische Physik III, Heinrich-Heine-Universität Düsseldorf, Universitätsstraße 1, 40225 Düsseldorf, Germany

Generalized measurements, i.e., POVMs, are known to yield an advantage over usual projective measurements in tasks like state discrimination, state tomography and entanglement detection. While any POVM can be realized as a projective measurement using auxiliary systems, some of them can be simulated through the process of classical randomization of projective measurements in the original system. Such POVMs are called projectively simulable, and every POVM becomes simulable if enough noise is added to it. While the exact amount of required noise (a quantity related to the so-called critical visibility) is in general unknown, it was conjectured that symmetric informationally complete POVMs (SIC-POVMs) are most robust against becoming simulable.

By employing a hierarchy of semidefinite programs together with constructing specific simulable decompositions for classes of noisy SIC-POVMs, we significantly enlarge the collection of POVMs for which exact critical visibilities are known. Finally, we show that there are POVMs which are more robust than certain SIC-POVMs.

MON 19.5 Mon 17:30 ZHG008

Understanding quantum theory — •Adán Cabello — University of Sevilla, Sevilla, Spain

"Nobody understands quantum mechanics" in the sense that nobody can "reduce it to the freshman level". Here, we ague that John Bell's observation that quantum theory is about "experiments" (rather than about "measurements"), together with a convenient rephrasing of four technical results, two of them about general theories of experiments [taken from G. Chiribella et al., Phys. Rev. Res. 2, 042001(R) (2020)] and two of them about sets of correlations in general physical theories [taken from B. Amaral et al., Phys. Rev. A 89, 030101(R) (2014) and A. Cabello, Phys. Rev. A 100, 032120 (2019)] provide a compelling narrative for understanding quantum theory and "where does it come from".

MON 19.6 Mon 17:45 ZHG008

Outcome communication cannot explain nonlocality — Carlos Vieira[1], •Carlos de Gois[2,3], Sébastien Designolle[4], Pedro Lauand[5], Lucas E. A. Porto[5,6], and Marco T. Quintino[6] — [1]IMECC, Unicamp, Brazil — [2]Naturwissenschaftlich-Technische Fakultät, Uni Siegen, Germany — [3]Inria, Université Paris-Saclay, France — [4]Zuse Institute Berlin, Germany — [5]IFGW, Unicamp, Brazil — [6]LIP6, Paris, France

Sixty years ago it was established that quantum theory cannot be completed by local hidden variables. This fact implies a fundamental separation between classical and quantum systems, and has since become a central aspect of quantum information. However, it does not rule out the possibility of non-local completions. In particular, it is known that local hidden variable models augmented with two bits of classical communication can explain the correlations of any two-qubit state. Would this still hold if communication is restricted to measurement outcomes? We show that any qubit-qudit state can be explained by outcome communication if and only if it is local. In other words, outcome communication does not help explain qubit-qudit correlations. In contrast to the standard local model, where only rank-1 measurements must be reproduced, the outcome communication model must explicitly account for full-rank measurements. This is not a limitation of our proof, but a general fact. To prove this, we construct an explicit outcome-local model for all rank-1 measurements on a nonlocal state, thus showing that the equivalence between the two models does not hold for these measurements alone.

MON 19.7 Mon 18:00 ZHG008

Lie Meets von Neumann for Symmetry Characterisation of Compact Lie Algebras — Emanuel Malvetti[1], Robert Zeier[2], and •Thomas Schulte-Herbrüggen[1] — [1]Technical University of Munich (TUM) — [2]Forschungszentrum Jülich GmbH, Peter Grünberg Institute, Quantum Control (PGI-8)

Von Neumann's celebrated double-centraliser theorem completely characterises an operator algebra by its symmetries/commutant. How can this idea be taken over to symmetry-characterise all simple compact Lie algebras (i.e. subalgs of $\mathfrak{u}(N)$) in finite dimension N?

Early contributions (inspired by Noether, Artin, van-der-Waerden) see group algebras to (regular representations of) finite groups as first incarnations of von Neumann algebras—still in finite dimensions.

For compact Lie groups and their Lie algebras, we elucidate the add-ons to central isotypic projections (via the commutant to the adjoint representation) that allow for such a full symmetry characterisation. We thus give a general algorithm that identifies a compact simple Lie algebra just from a given set of generators based on its joint symmetries thus substantially driving our earlier work [1-3] to a full classification.

Our algorithmic approach can be applied to problems in various fields such as measurement-based quantum computing, stabiliser design via Clifford algebras, phases of many-body systems—and last but not least quantum control.

[1] *J. Math. Phys.* **52**, 113510 (2011)
[2] *Phys. Rev. A* **92**, 042309 (2015)
[3] *J. Math. Phys.* **56**, 081702 (2015)