Q 15: Quantum Information (Concepts and Methods) II

Time: Monday 14:00–16:00 Location: K 1.019

Group Report Q 15.1 Mon 14:00 K 1.019

Pushing the Limits of Reachable States by Optimal Control — •Thomas Schulte-Herbrüggen[1], Ville Bergholm[1,2], Frank K. Wilhelm[3], and Michael Keyl[4] — [1]Technical University of Munich (TUM) — [2]University of Helsinki — [3]University of Saarbrücken — [4]Dahlem Centre for Complex Quantum Systems, FU-Berlin

Resorting to optimal control methods often is key to achieving high fidelity in actual experiments. Examples meanwhile pertain to quantum information processing, quantum simulation, and quantum sensing.

Recently, we have extended our optimal-control platform DYNAMO by allowing for fast switchable noise on top of coherent controls. We suggested implementation by superconducting qudits (GMons) with tunable coupling to an open transmission line.

Here we show how to use these features as internal cooling device replacing measurement-based closed-loop feedback control for arbitrary interconversion between quantum states (pure or mixed). Finally, we give an outlook on further experimental implementations, where optimal control paves the way to achieving unprecedented states.

Q 15.2 Mon 14:30 K 1.019

Precision bounds for gradient magnetometry with atomic ensembles — •Iagoba Apellaniz[1], Iñigo Urizar-Lanz[1], Zoltán Zimborás[1,2,3], Philipp Hyllus[1], and Géza Tóth[1,3,4] — [1]Theoretical Physics, University of the Basque Country UPV/EHU, E-48080 Bilbao, Spain — [2]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, 14195 Berlin, Germany — [3]Wigner Research Centre for Physics, H-1525 Budapest, Hungary — [4]IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain

We study gradient magnetometry with an ensemble of atoms with arbitrary spin. We consider the case of a very general spatial probability distribution function. We calculate precision bounds for estimating the gradient of the magnetic field based on the quantum Fisher information. For quantum states that are invariant under homogeneous magnetic fields, we need to measure a single observable to estimate the gradient. On the other hand, for states that are sensitive to homogeneous fields, the measurement of two observables are needed, as the homogeneous field must also be estimated. This leads to a two-parameter estimation problem. We present a method to calculate precision bounds for gradient estimation with a chain of atoms or with two spatially separated atomic ensembles feeling different magnetic fields. We also consider a single atomic ensemble with an arbitrary density profile, in which the atoms cannot be addressed individually, and which is a very relevant case for experiments. Our model can take into account even correlations between particle positions.

Q 15.3 Mon 14:45 K 1.019

Lower bounds on the quantum Fisher information based on the variance and various types of entropies — •Géza Tóth — Theoretical Physics, University of the Basque Country UPV/EHU, E-48080 Bilbao, Spain — Wigner Research Centre for Physics, H-1525 Budapest, Hungary — IKERBASQUE, Basque Foundation for Science, E-48011 Bilbao, Spain

We examine important properties of the difference between the variance and the quantum Fisher information over four, i.e., var(A)-F_Q[rho,A]/4. We find that it is equal to a generalized variance defined in Petz [J. Phys. A 35, 929 (2002)] and Gibilisco, Hiai, and Petz [IEEE Trans. Inf. Theory 55, 439 (2009)]. We present an upper bound on this quantity that is proportional to the linear entropy. As expected, our relations show that for states that are close to being pure, the quantum Fisher information over four is close to the variance. We also obtain the variance and the quantum Fisher averaged over all Hermitian operators, and examine their relation to the von Neumann entropy.

Q 15.4 Mon 15:00 K 1.019

Information Disturbance Tradeoff in Quantum Measurement — Lukas Knips[1,2], •Jan Dziewior[1,2], Anna-Lena Hashagen[3], Jasmin Meinecke[1,2], Michael Wolf[3], and Harald Weinfurter[1,2] — [1]Department for Physics, LMU, 80797 Munich — [2]Max-Planck-Institute for Quantum Optics, 85748 Garching — [3]Zentrum Mathematik, TUM, 85748 Garching

One of the most characteristic features of quantum mechanics is that every measurement which extracts information from a physical system necessarily causes an irreducible disturbance. While this fundamental complementarity has been considered in numerous works, recently an analysis of unprecedented generality has been performed [1]. In particular it provides a dimension-independent optimal tradeoff relation for general von Neumann measurements based on the cb-norm for quantum channels as a distance measure. We evaluate this relation experimentally for the observation of a qubit by implementing the full range of possible measurements and determining the amount of accessible information for a given disturbance. The various measurements are realized by a tunable Mach-Zehnder-Interferometer, which supplies the ancillary degrees of freedom necessary to implement arbitrary POVMs and quantum channels for the measurement of a polarization qubit. Not only are we able to show the validity of the fundamental bound, but, furthermore, achieve the demonstration of its tightness by saturating it with high significance.

[1] Hashagen, A., Wolf, M., Universality and Optimality in the Information-Disturbance Tradeoff, in preparation.

Q 15.5 Mon 15:15 K 1.019

Reduction of a quantum state in time-of-flight measurements — •Fabio Di Pumpo and Matthias Freyberger — Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm, D-89069 Ulm

We discuss quantum mechanical time-of-flight momentum measurements, which are motivated by the classical time-of-flight concept. Our setup is modeled by a Hamiltonian for a free particle interacting with two quantum pointers. For this model we can solve the corresponding three-particle dynamics in the Heisenberg picture. This allows us to examine two fundamental aspects: First, we verify that the expectation value of the operational momentum operator equals the one of the original momentum operator describing the single-particle system. Second, we analyze in what sense position measurements on the pointers reduce the conditional quantum state of the particle and hence define its momentum.

Q 15.6 Mon 15:30 K 1.019

Prime number decomposition using the Talbot effect — Karl Pelka[1], •Jasmin Graf[1], Thomas Mehringer[1,2], and Joachim von Zanthier[1,2] — [1]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [2]Erlangen Graduate School in Advanced Optical Technologies (SAOT), Universität Erlangen-Nürnberg, 91052 Erlangen, Germany

The Talbot effect is a near field diffraction effect describing the self imaging of a coherently illuminated transmission grating. Mathematically, this effect can be described by Gauss sums, which are connected to prime number decomposition. We present a novel algorithm for prime factorization which exploits the appearance of Gauss sums in the near field intensity distribution behind a single slit of the grating. We discuss the theoretical framework of this algorithm and report on an experimental implementation displaying an impressive agreement with the theoretical predictions.

We also investigate the regime of an incoherently illuminated grating where no first order interference signal is obtained. However, all relevant information can be regained by measuring the intensity correlations of second order. We explain how Gauss sums appear in the second order correlation function and how this signal can be used for prime number decomposition. As an outlook we present the experimental setup for measuring incoherent Talbot-like effects.

Q 15.7 Mon 15:45 K 1.019

Assessing and tailoring the quantumness of damped two-level-systems — •Alexander Friedenberger and Eric Lutz — Friedrich-Alexander-Universität Erlangen

One of the lynchpins for the conception and application of quantum technologies is the identification and harnessing of nonclassical properties of a given system. We perform a detailed analysis of the nonclassical properties of a damped two-level system. We discuss how these properties can be tuned with the help of external driving fields. We show in particular how the nonclassicality of a two-level system can be maximized at any desired time by choosing an appropriate driving field.