Q 59: Quantum information: Quantum computers and communication I

Time: Friday 10:30–12:30 Location: DO26 207

Q 59.1 Fri 10:30 DO26 207

Verification of Effective Entanglement over an Atmospheric Channel — •Bettina Heim[1,2], Christian Peuntinger[1,2], Christoffer Wittmann[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]MPI for the Science of Light, Günther-Scharowsky-Str. 1 / bldg. 24, Erlangen — [2]Institute of Optics, Information and Photonics, University of Erlangen-Nuremberg, Staudtstraße 7 / B2, Erlangen

We present our experimental work on quantum communication using an atmospheric channel of 1.6km in an urban environment. In a prepare-and-measure setup, we encode information into continuous polarization states. The signal states are measured using homodyne detection with the help of a local oscillator. Both, signal and local oscillator, are sent through the free-space quantum channel, polarization multiplexed and occupying the same spatial mode. This leads to an excellent interference at the detection and an auto-compensation of the phase fluctuations introduced by the channel. In addition, the local oscillator acts as a spatial and spectral filter which easily enables daylight operation. We investigate the verification of effective entanglement within the framework of a protocol for continuous variable quantum key distribution (CV-QKD) with a discrete modulation of four signal states. In addition, by again taking into account the fading channel properties, we study a method of probabilistic CV-QKD.

Q 59.2 Fri 10:45 DO26 207

High fidelity spin entanglement using optimal control — •Florian Dolde[1], Ville Bergholm[2], Ya Wang[1], Ingmar Jakobi[1], Boris Naydenov[3], Sebastien Pezzagna[4], Jan Meijer[4], Fedor Jelezko[3], Philipp Neumann[1], Thomas Schulte-Herbrüggen[5], Jacob Biamonte[2], and Jörg Wrachtrup[1] — [1]3rd Institute of Physics, University of Stuttgart, Germany — [2]ISI Foundation, Torino, Italy — [3]Institute for Physics, University of Ulm, Germany — [4]Institute for Physics, University of Leipzig, Germany — [5]Department of Chemistry, Technical University Munich, Germany

Precise control of quantum systems is of fundamental importance in quantum information processing, quantum metrology and high-resolution spectroscopy. When scaling up quantum registers, several challenges arise: individual addressing of qubits while suppressing crosstalk, entangling distant nodes, and decoupling unwanted interactions. We experimentally demonstrate optimal control of a prototype spin qubit system consisting of two proximal nitrogen-vacancy (NV) centers in diamond. Using engineered microwave pulses, we demonstrate single electron spin operations with a fidelity $F \approx 0.99$. With additional dynamical decoupling techniques, we further realize high-quality, on-demand entangled states between two electron spins with $F > 0.82$, mostly limited by the coherence time and imperfect initialization. Finally, by high fidelity entanglement swapping to nuclear spin quantum memory, we demonstrate nuclear spin entanglement over a length scale of 25 nm.

Q 59.3 Fri 11:00 DO26 207

Control of open quantum system: Case study of the central spin model — •Christian Arenz[1], Giulia Gualdi[2], and Daniel Burgarth[1] — [1]Department of Mathematics and Physics, Aberystwyth University, Aberystwyth, Wales — [2]Dipartimento di Fisica ed Astronomia, Universita di Firenze, Firenze, Italy

We study the controllability of a central spin guided by a classical field and interacting with a spin bath, showing that the central spin is fully controllable independently of the number of bath spins. Additionally we find that for unequal system-bath couplings even the bath becomes controllable by acting on the central spin alone. We then analyze numerically how the time to implement gates on the central spin scales with the number of bath spins and conjecture that for equal system-bath couplings it reaches a saturation value. We provide evidence that sometimes noise can be effectively suppressed through control.

Q 59.4 Fri 11:15 DO26 207

Quantum circuits cannot control unknown operations — Mateus Araújo[1,2], •Adrien Feix[1,2], Fabio Costa[1,2], and Časlav Brukner[1,2] — [1]Faculty of Physics, University of Vienna, Boltzmangasse 5, 1090 Vienna, Austria — [2]Institute for Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Boltzmanngasse 3, 1090 Vienna, Austria

One of the essential building blocks of classical computer programs is the "if" clause, which executes a subroutine depending on the value of a control variable. Several quantum algorithms rely on a similar possibility of applying a quantum operation conditioned on the state of a control system.

We prove a no-go theorem, showing that no quantum circuit can conditionally apply a completely unknown unitary. Yet, such a quantum control has been experimentally implemented in interferometric setups. We explain this discrepancy by the fact that every physical realization of a unitary acts nontrivially only on a subspace of a larger Hilbert space, effectively providing some information about the operation.

We argue that the quantum circuit model should be extended for this type of very natural extension. Furthermore, our results open up the possibility to greatly simplify the implementation of quantum algorithms.

Q 59.5 Fri 11:30 DO26 207

Reservoir-assisted coherent control of a quantum dot spin qubit — •Jack Hansom[1], Carsten H. H. Schulte[1], Claire Le Gall[1], Clemens Matthiesen[1], Jacob M. Taylor[2,3], and Mete Atature[1] — [1]Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, United Kingdom — [2]Joint Quantum Institute, University of Maryland, College Park, Maryland 20742, USA — [3]National Institute of Standards and Technology, Gaithersburg, Maryland 20899, USA

In semiconductor quantum dots, the confined electron wavefunction is spread over $O(10^5)$ lattice sites, and statistical fluctuations in the nuclear spin bath lead to a finite effective B-field: the Overhauser (OH) field [1]. By measuring the electron spin dynamics in the absence of an external B-field, we show that the fluctuating OH field leads to a sub-linewidth effective Zeeman splitting of the electron spin states, as well as the presence of spin-flip Raman transitions. We harness this hyperfine-generated Λ-system by performing two-laser coherent population trapping experiments, thus allowing for sub-linewidth creation of spin superpositions. Through phase control of one of the excitation lasers, we furthermore demonstrate coherent manipulation of the CPT basis. The demonstrated sub-linewidth coherent control lends itself to quantum information protocols requiring slow Larmor precession, such as photonic cluster state generation [2].

[1] Urbaszek *et al.*, Rev. Mod. Phys. **85**, 79-133 (2013).
[2] Lindner *et al.*, Phys. Rev. Lett. **103**, 113602 (2009).

Q 59.6 Fri 11:45 DO26 207

Reconstruction of continuous variable quantum squeezed states after passing a fading atmospheric channel — •Christian Peuntinger[1,2], Bettina Heim[1,2], Christian Müller[1,2], Christian Gabriel[1,2], Christoph Marquardt[1,2], and Gerd Leuchs[1,2] — [1]Max-Planck-Institut für die Physik des Lichts, Günther-Scharowsky-Str. 1 / Bau 24, 91058 Erlangen, Deutschland — [2]Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 7 / B2, 91058 Erlangen, Deutschland

We investigate the distribution of continuous variable squeezed states through a turbulent atmospheric channel of 1.6 km length in an urban environment. As polarization encoding is well suited for atmospheric transmission we use bright polarization squeezed states of light. Still atmospheric turbulence leads to fluctuating transmission values and this has to be taken into account at the detection. Thus, we developed a post-selection protocol using the classical side information drawn from the respective channel transmission. By this we retrace the intensity fluctuations and are able to perform a quantum state reconstruction of the received signals based on a maximum likelihood algorithm.

Q 59.7 Fri 12:00 DO26 207

Hybrid Error Correction — •Jörg Duhme[1], Christoph Pacher[2], Fabian Furrer[3], and Reinhard Werner[1] — [1]Leibniz Universität Hannover, Institut für Theoretische Physik, AG Quanteninformation — [2]Austrian Institute of Technology, Wien — [3]The University of Tokyo, Graduate School of Science

We present an error correction (EC) scheme directly designed for the entanglement based CV-QKD protocol using entangled squeezed gaussian states (PRL 109, 100502 (2012)). The starting point of our hybrid EC is the description of errors in the raw keys given by Bob's gaussian state conditioned on Alice former measurement outcome. We write the noisy alphabet elements of the raw keys as linear combination of two new alphabets. The idea is, to reduce the noise in the first step of the hybrid EC to only one of the two new alphabets. The errors left by the first step can in the second step be corrected by for example non-binary LDPC.

Q 59.8 Fri 12:15 DO26 207

Decrease in query complexity for quantum computers with superposition of circuits — •Mateus Araújo[1,2], Fabio Costa[1,2], and Časlav Brukner[1,2] — [1]Faculty of Physics, University of Vienna, Boltzmanngasse 5, 1090 Vienna, Austria — [2]Institute of Quantum Optics and Quantum Information (IQOQI), Austrian Academy of Sciences, Boltzmanngasse 3, 1090 Vienna, Austria

The standard model for quantum computation assumes that quantum gates are applied in a specific order. One can relax this assumption by allowing a control quantum system to switch the order in which the gates are applied. This provides for a more general kind of quantum computing, that allows for transformations on black box quantum gates that are impossible with fixed circuits [1]. Here we show that this model of quantum computing is physically realizable, by proposing an interferometric setup which can implement such a quantum control of the order of the operations. We also show that this new resource provides a reduction in computational complexity: we propose a problem that can be solved using $O(n)$ queries to the black box unitaries, whereas the best known quantum algorithm with fixed order between the gates requires $O(n^2)$ queries.

[1] G. Chiribella, G. M. D'Ariano, P. Perinotti, and B. Valiron, "Quantum computations without definite causal structure", Phys. Rev. A 88, 022318 (2013),