Continuous-variable quantum information processing at Palacky University Olomouc: Overview and Outlook

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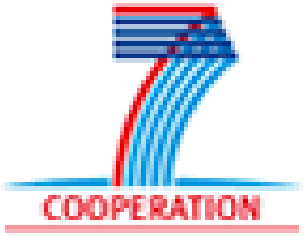


Outline of the talk

- **Group members**
- **Main research interests**
- **Ongoing and possible future collaborations**
- **Future outlook – where are we heading?**

Group members

- **Jaromír Fiurášek** *associate professor*
- **Radim Filip** *associate professor*
- **Ladislav Mišta** *senior postdoc*
- **Petr Marek** *postdoc*
- **Vladyslav Usenko** *junior postdoc*

Quantum state estimation and reconstruction

- **Zdeněk Hradil** *full professor*
- **Jaroslav Řeháček** *associate professor*

Main research areas and interests in CV QIP

- **WP1: Engineering (non-Gaussian) CV quantum operations**
- **WP2: Light-matter quantum interface**
- **WP3: Noise suppression in CV quantum communication**
- ***Estimation and reconstruction of quantum states and processes***

Engineering non-Gaussian quantum operations

Main goal:

Find feasible and compact schemes for implementation of various CV operations on light modes and atomic memories

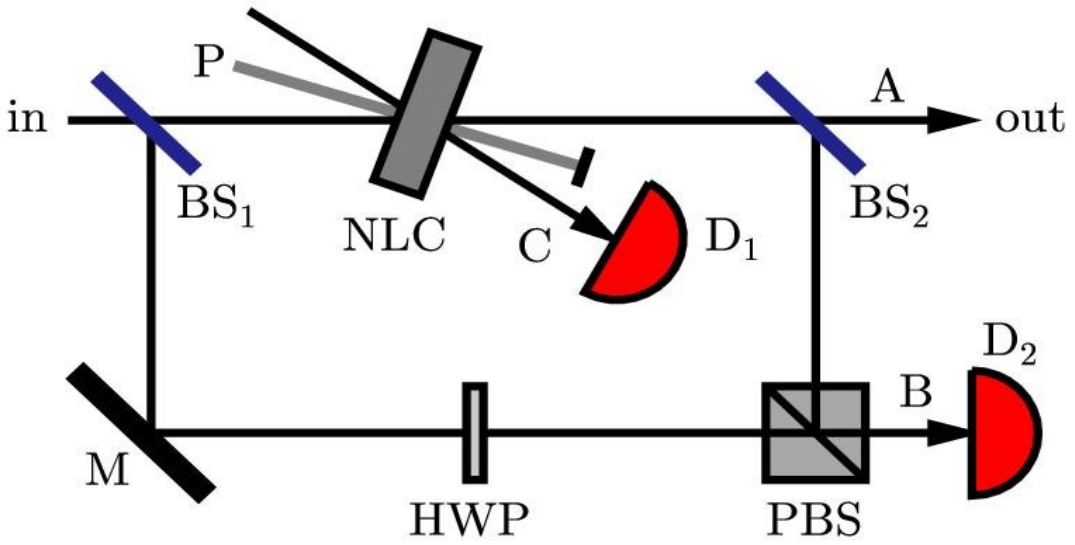
Determine which resources are sufficient for universal CV QIP

Tools and approaches:

- Combination of photon subtraction and addition with Gaussian operations
- Off-line generated resource states – CV analogue of the KLM scheme
- Homodyne and single-photon detection, postselection and feedforward

P. Marek and J. Fiurášek, Phys. Rev. A **79**, (2009).

Engineering arbitrary operation depending on photon number



$$\hat{Z} = f(\hat{n})$$

$$\hat{Z}_N = \sum_{k=0}^{N} c_k \hat{n}^k$$

Probabilistic implementation of an arbitrary operation that can be expressed as polynomial in photon number operator.

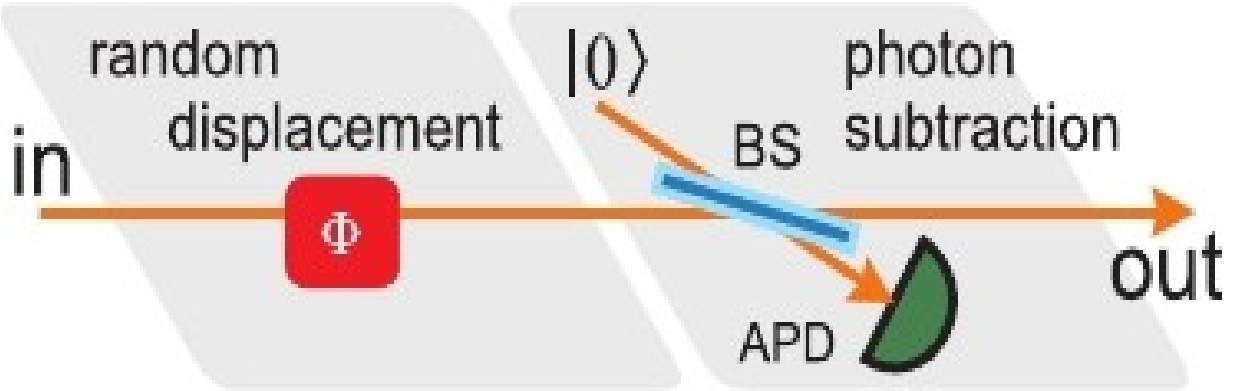
Coherently combines photon addition and subtraction.

J. Fiurášek, Phys. Rev. A **80**, 053822 (2009).

Generalization of a scheme proposed in:

M. S. Kim, H. Jeong, A. Zavatta, V. Parigi, M. Bellini, *Phys. Rev. Lett.* **101**, 260401 (2008).

Resource-inexpensive probabilistic amplifier



Requires only single-photon subtraction

Photon addition replaced by injection of thermal noise.

Less universal but easier to implement.

Possible application: coherent-state phase concentration.

P. Marek and R. Filip, arXiv:0907.2402 (2009).

Noise suppression in CV QIP

Distillation, purification and concentration of CV entanglement.

Quantum error filtration and correction.

Gaussian protocols for supression of non-Gaussian noise and decoherence

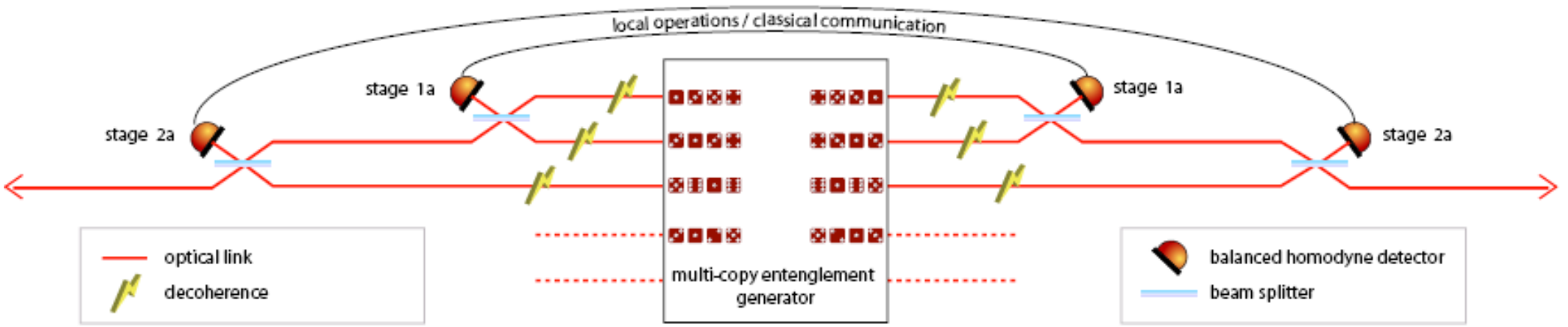
- Phase fluctuations
- Fluctuations of the channel transmittance (atmospheric fading channel)

M. Sabuncu, R. Filip, G. Leuchs, and U.L.Andersen, *Environmental Assisted Quantum Information Correction for Continuous Variables.*

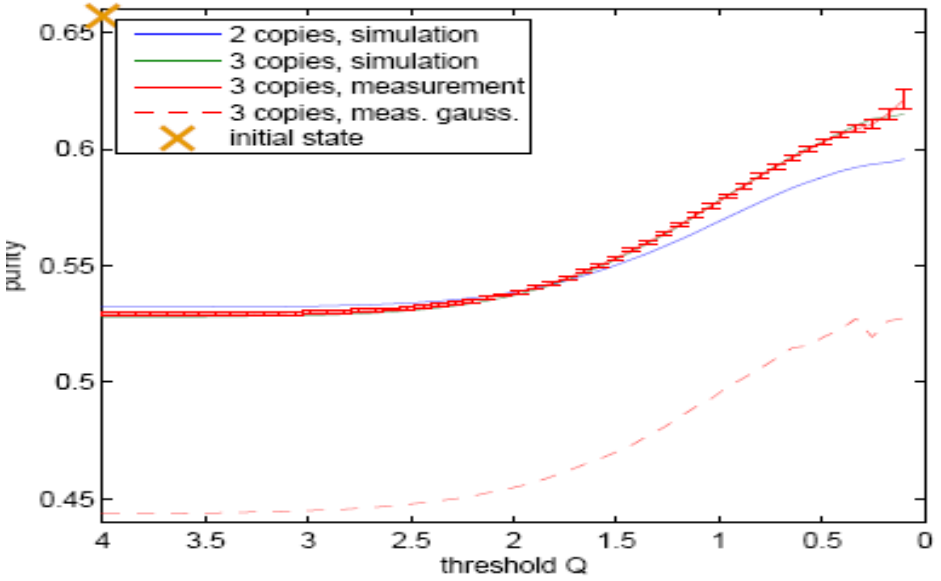
R. Dong, M. Lassen, J. Heersink, C. Marquardt, R. Filip, G. Leuchs and U.L. Andersen, *Continuous variable entanglement distillation of Non-Gaussian Mixed States.*

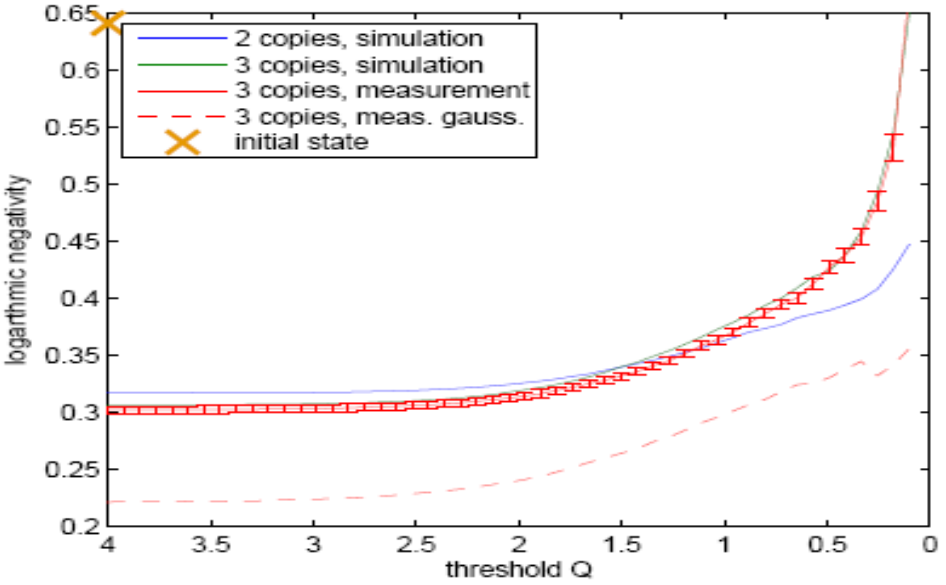
Example: Iterative entanglement distillation

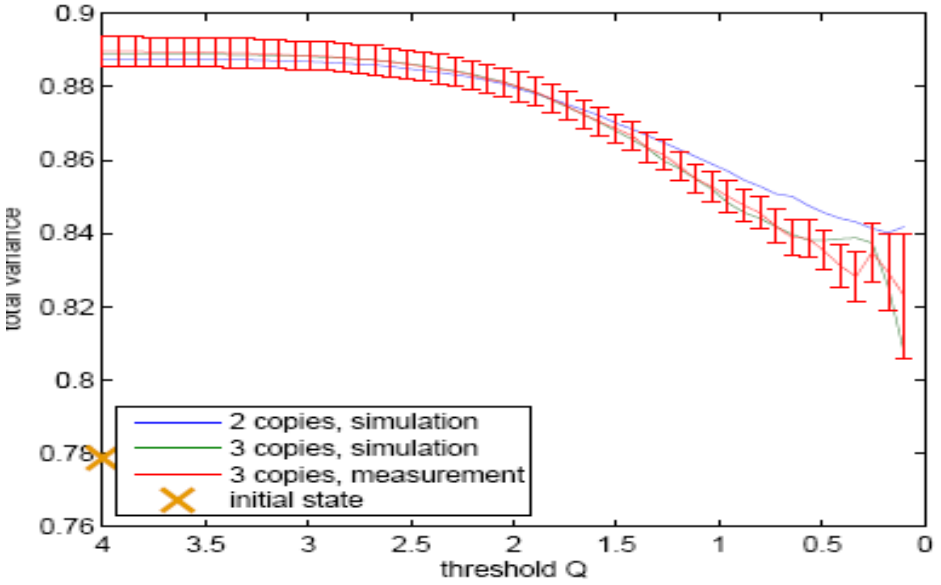
Work in progress in collaboration with the group of Roman Schnabel.

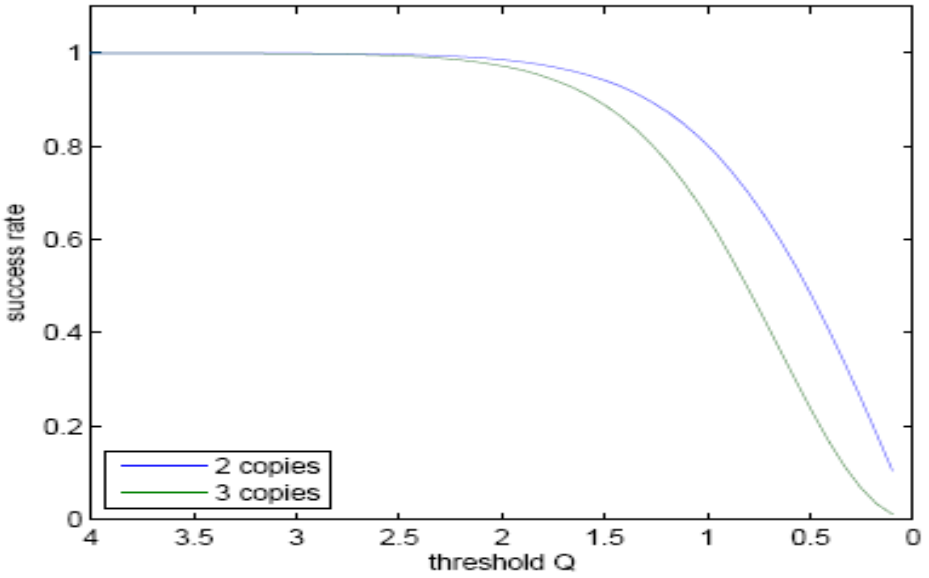


Example: Iterative entanglement distillation









Quantum interface between matter and light

Quantum memory for light – optimal storage and readout

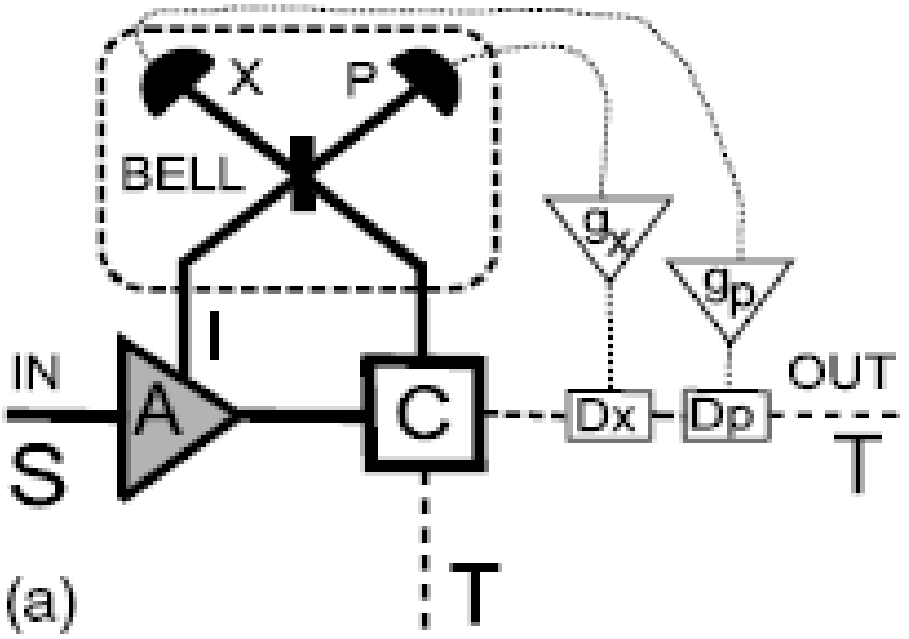
Preparation of nonclassical states of light in atomic quantum memory

Purification and distillation of entanglement of two quantum memories

Exploitation of coupling of light and a vibrational mode of a mechanical oscillator

K. Lemr and J. Fiurášek, Phys.Rev. A **79**, 043808 (2009).

Perfect mapping of a state into noisy quantum memory via linear coupling with limited strength



The scheme combines phase-insensitive amplifier, CV Bell measurement and feedforward.

High fidelity transfer of any quantum state to noisy target system through arbitrary weak linear coupling C.

R. Filip, Phys. Rev. A **80**, 022304 (2009).

Currently active collaborations

Other COMPAS groups:

Nicolas Cerf, Brussels
Gerd Leuchs, Erlangen
Ulrik Andersen, Lyngby
Natalia Korolkova, St. Andrews

Groups outside COMPAS:

Roman Schnabel, Hannover
Myungshik Kim, Belfast

Past/future collaborations

Other COMPAS groups:

Eugene Polzik, Copenhagen
Philippe Grangier, Paris

Groups outside COMPAS:

Marco Bellini, Firenze

Plans for the future

- Resource inexpensive quantum state manipulation
- Measurement-induced information processors with semiclasical or quantum resources
- Quantum error correction for entanglement-breaking processes
- Analysis of non-classicality for quantum information processing
- Quantum interfaces and entanglement transfer to noisy matter systems
- Distillation and purification of states in quantum memory
- Theoretical analysis of CV quantum repeater