COMPAS meeting Brussels - 30.11.2009
Partner FAU
Friedrich-Alexander Universität Erlangen-Nürnberg

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FOR THE SCIENCE OF LIGHT

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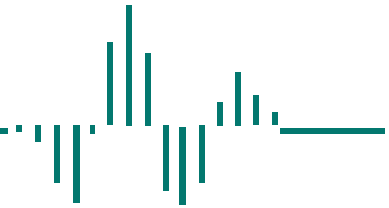
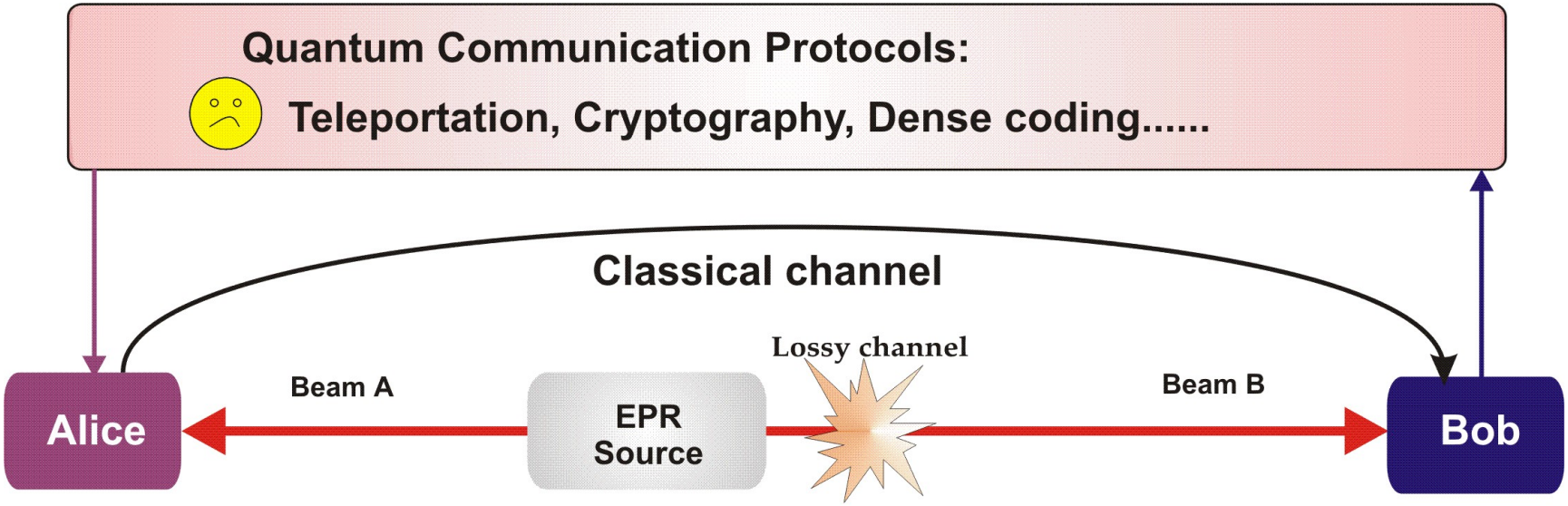
Topics



- Entanglement distillation of non-Gaussian noise
  - results for T3.4 and outlook
- New sources of squeezed light
  - resource for non-Gaussian state generation

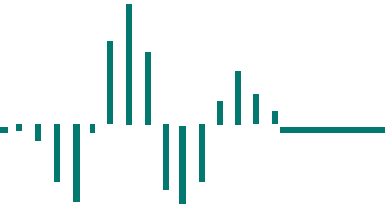
Entanglement distillation of non-Gaussian noise

Entanglement distillation



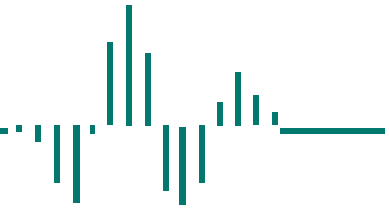
- **To combat the losses and decoherence, entanglement distillation is demanding**
  - *extracts a subset of highly entangled states from an ensemble of less entangled states*.

Background



- **Entanglement distillation has been theoretically and experimentally demonstrated for spin 1/2 (or qubit) systems exploiting a posteriori generated polarization entangled states.**
  - *C.H. Bennett, et al, Phys. Rev. Lett. 76 (1996) 722; E.M. Rains, Phys. Rev. A 60 (1999) 173; Z. Zhao, et al, Phys. Rev. A 64 (2001) 014301.*
  - *J.-W. Pan, et al, Nature 423 (2003) 417; Z. Zhao, et al, Phys. Rev. Lett. 90 (2003) 207901.*
- **The implementation of distilling entanglement of continuous variable (CV) systems is an experimental challenge.**

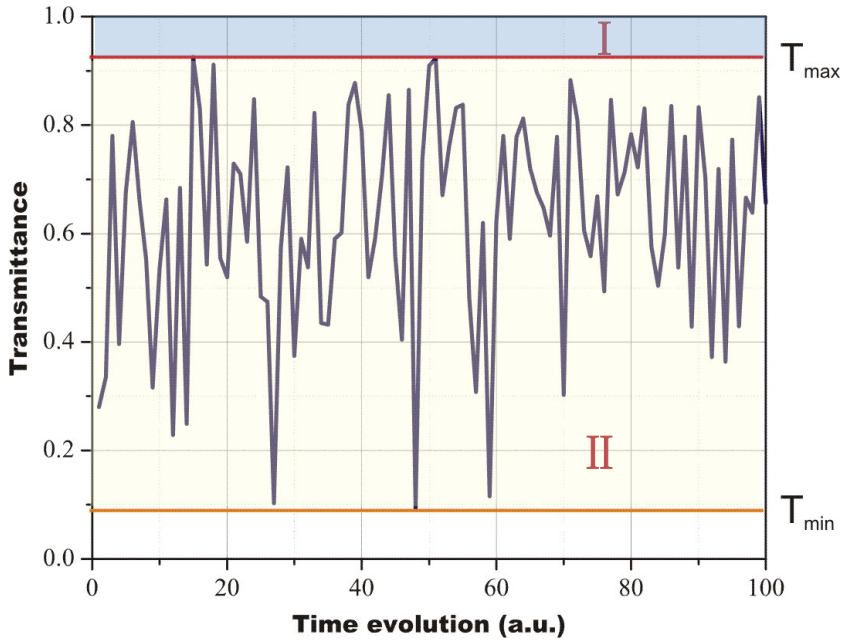
Background



- **The entanglement distillation of Gaussian states can be done only by utilizing non-Gaussian (thus difficult) operations.**
  - *J. Eisert, et al, Phys. Rev. Lett. 89, 137903(2002); J. Fiurasek, Phys. Rev. Lett. 89 (2002) 137904; G. Giedke, J.I. Cirac, Phys. Rev. A 66 (2002) 032316.*
- **Several protocols using non-local and non-Gaussian operations have been put forward and proof of principle experiments have recently been implemented.**
  - *T. Opatrny, et al. Phys. Rev. A, 61, 032302 (2000); L.-M. Duan, et al. Phys. Rev. Lett. 84, 4002-4005 (2000); D. E. Browne, et al. Phys. Rev. A 67, 062320 (2003); J. Fiurasek, et al. Phys. Rev. A 67, 022304 (2003).*
  - *A. Ourjoumtsev, et al. Phys. Rev. Lett. 98, 030502 (2007).*
  - *Progress in groups of COMPAS (Grangier, Polzik) and elsewhere (Sasaki, Walmsley, …)*

Motivation

- **In many practical scenarios, however, the transmitted quantum state will be non-Gaussian:**
  - e.g. *transmission of light through a turbulent atmospheric channel where the attenuation factor fluctuates in time (lossy channel)*



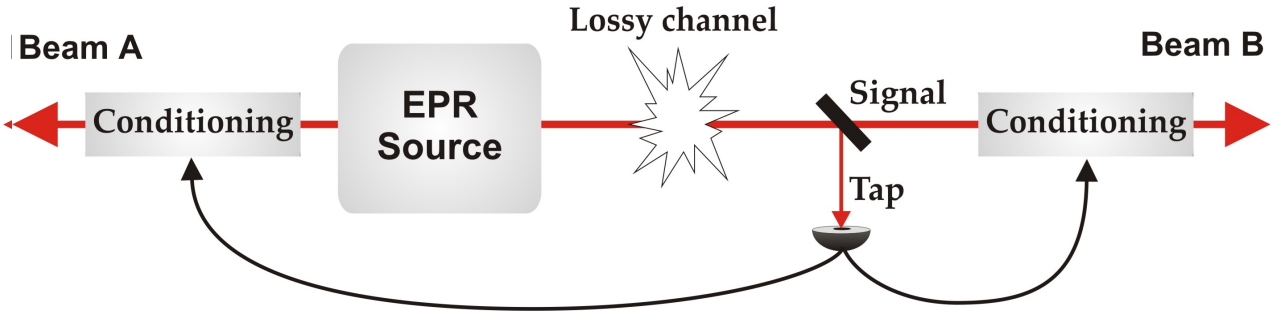
After the channel:

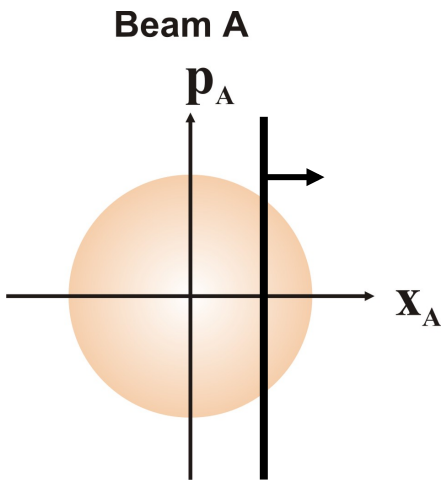
$$\hat{X}(t) = \hat{X}(0)\cdot\sqrt{\eta(t)} + \hat{N}\cdot\sqrt{1-\eta(t)}\text{d}$$ by

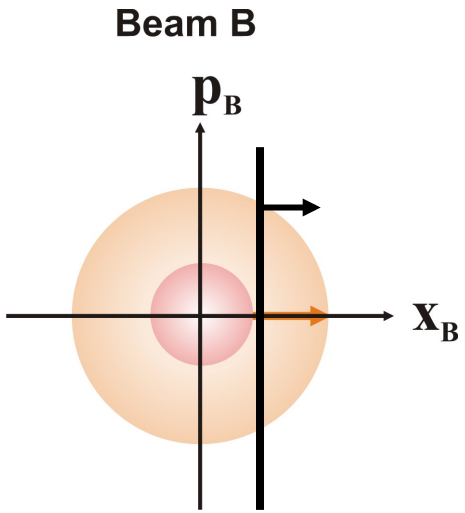
$W(X) =$ **non-Gaussian distribution** **Gaussian distribution**

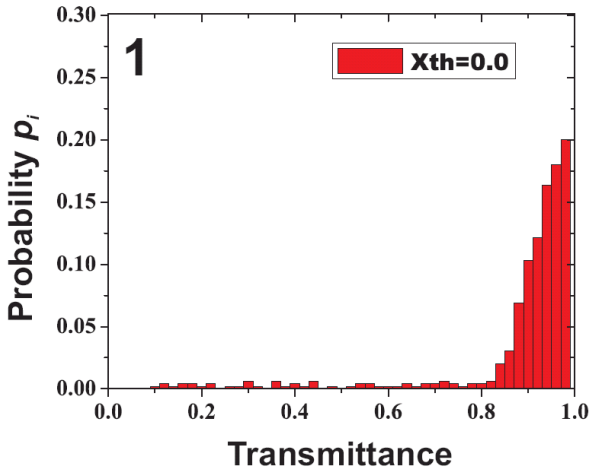
means of linear optical components, a simple measurement induced Gaussian operation and classical communication.

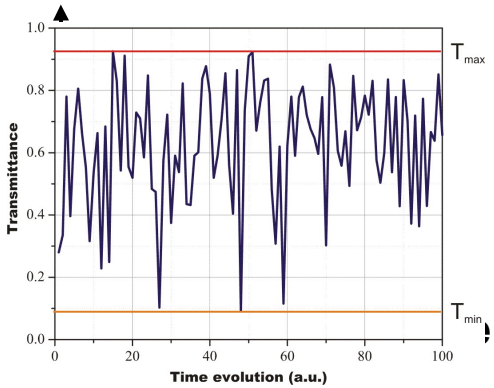
Distillation Theory







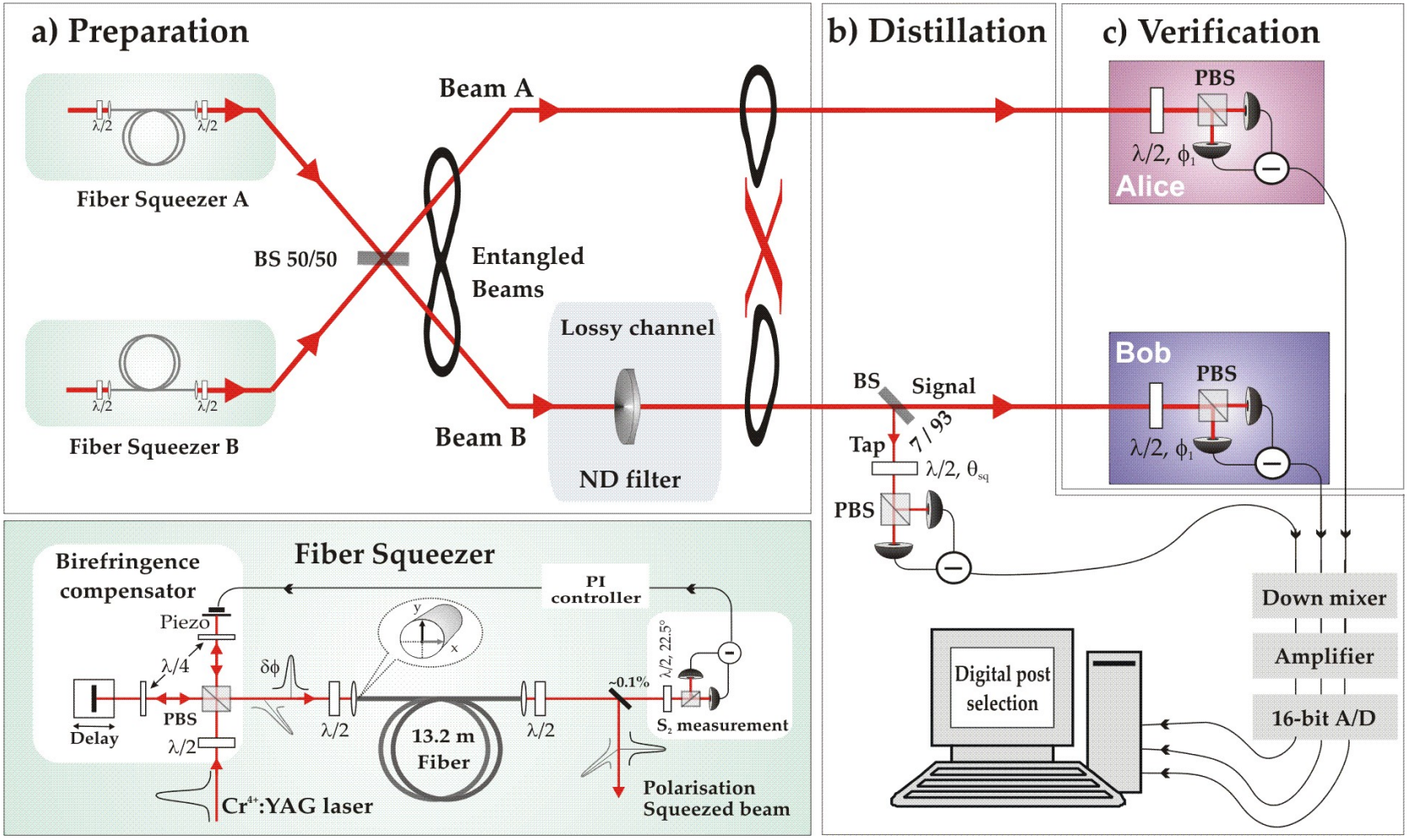




$$W = p_1 W_1 + p_2 W_2$$

$$W = \sum_{i=1}^{45} p_i W_i$$

Experimental Details



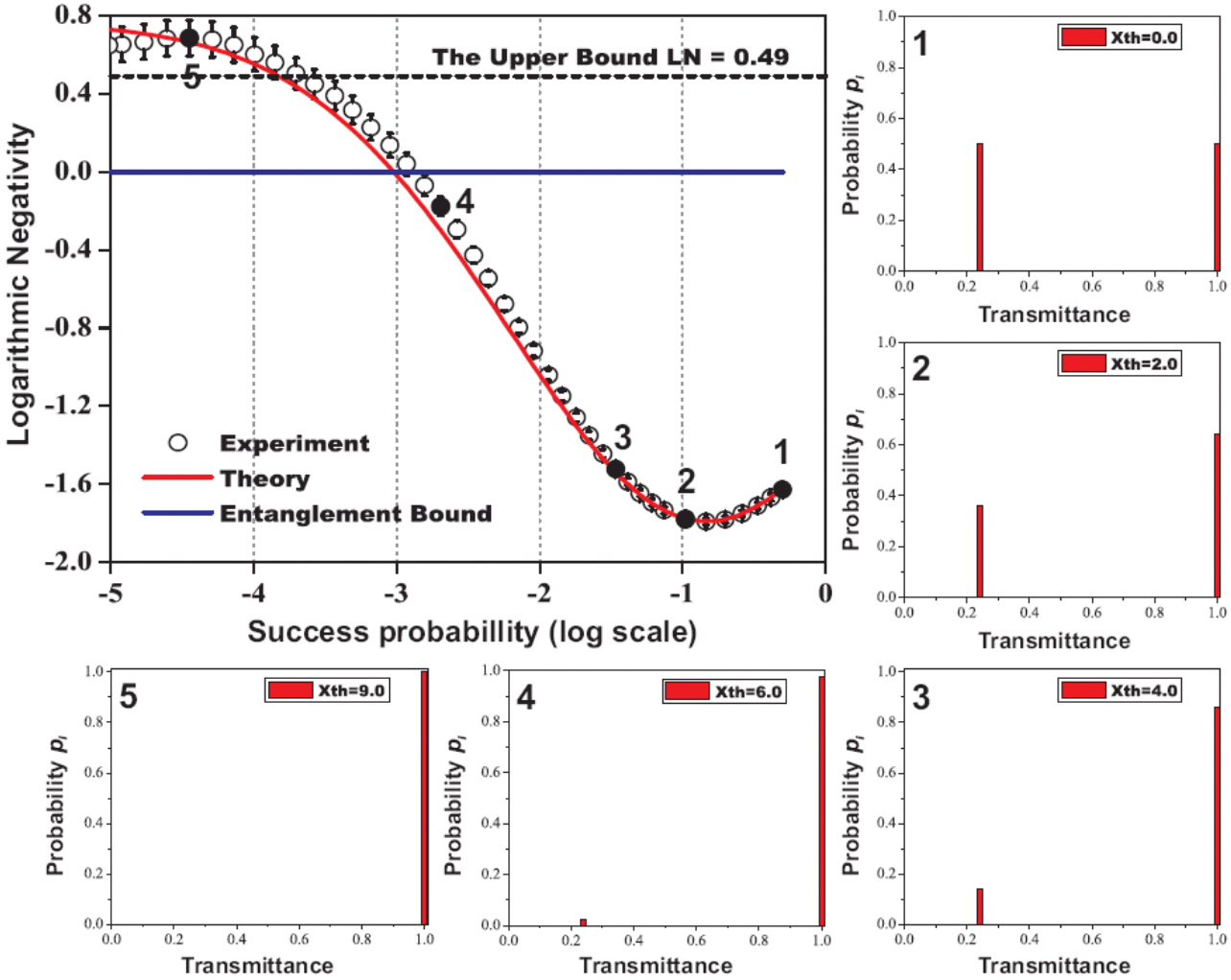
R. Dong et al., Nature Physics, 4, 919-923 (2008)

Experimental Results

$$W = p_1 W_{Good} + p_2 W_{Bad}$$

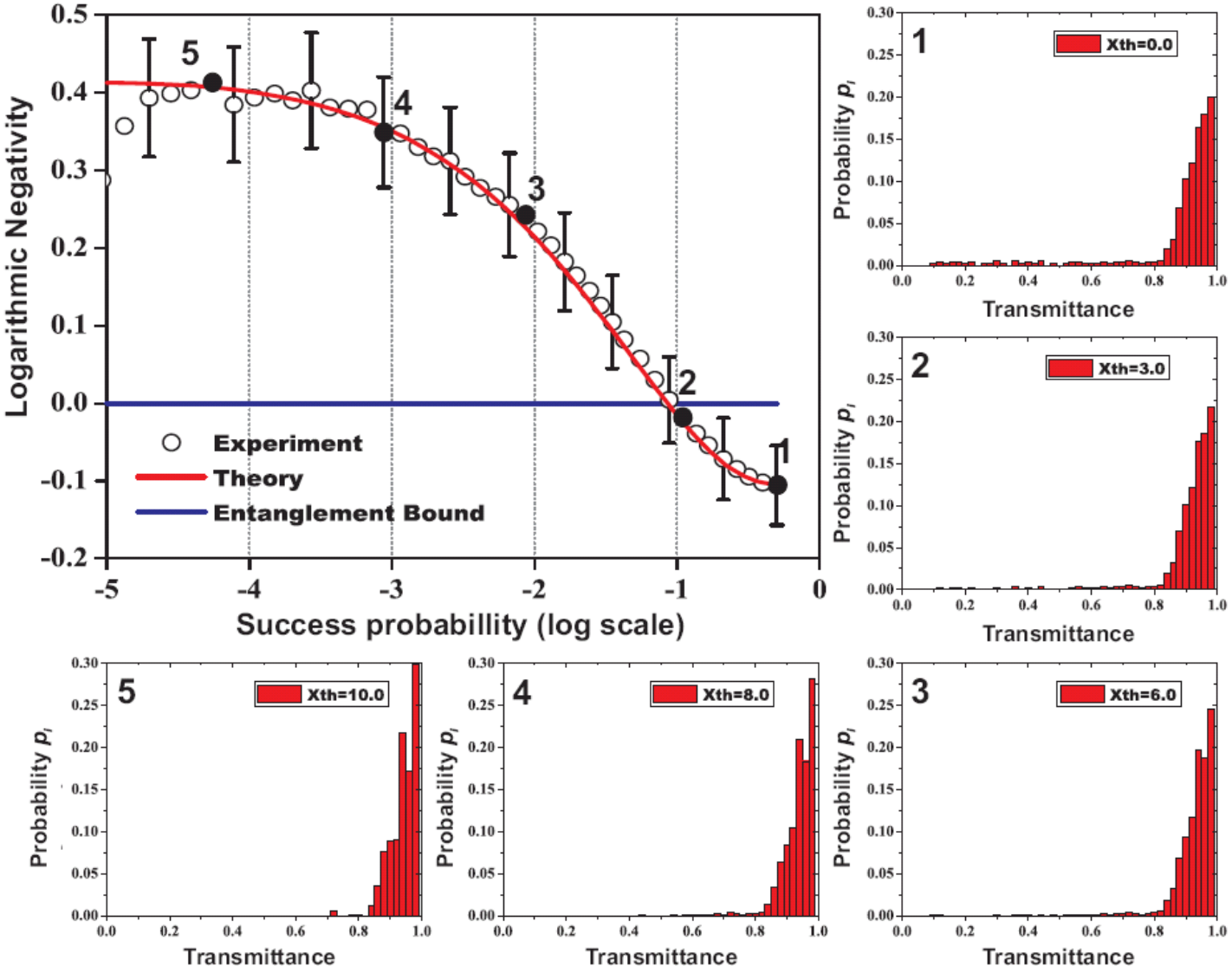
Gaussian logarithmic negativity:

$$LN = -Log_2 \mu_{min}$$



Experimental Results

$$W = \sum_{i=1}^{45} p_i W_i$$



Results distillation

- **Successful distillation of continuous variable entangled states from non-Gaussian mixtures**

Channels	LN (before)	LN (after)	Success rate P_S
Perfect	0.76 ± 0.08	0.76 ± 0.08	1
Discrete	-1.63 ± 0.02	0.67 ± 0.09	1.69×10^{-5}
Semi-continuous	-0.11 ± 0.04	0.39 ± 0.07	1.66×10^{-5}

- **The distillation protocol provides a crucial step towards transmitting continuous variables quantum states over long distances in channels inflicted by non-Gaussian noise.**
- **Phase rotation noise ➔ Experiment of Hannover group B. Hage et al. Nature Physics 4, 915 - 918 (2008)**

Outlook distillation

➢**COMPAS:**
Improve protocol for different non-Gaussian noise models

How to effectively combine non-Gaussian noise and Gaussian noise distillation protocols?

➢**Q-Essence:**
Characterize atmospheric noise at realistic free space link

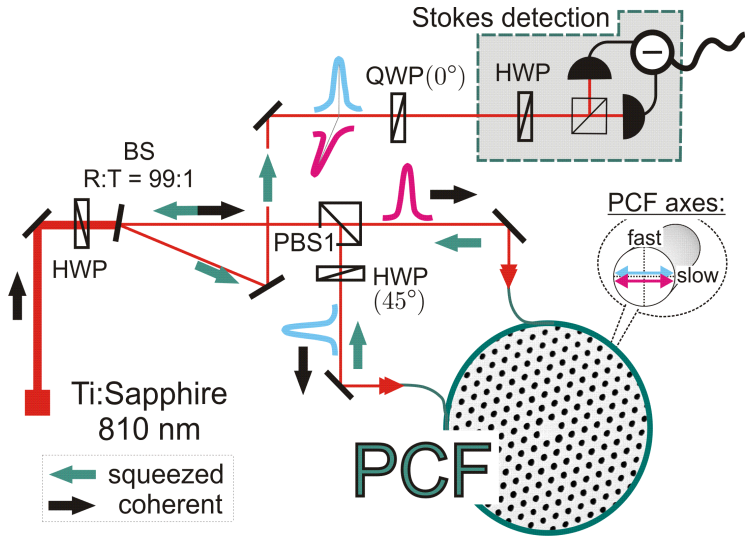
Polarization states ➔ attenuation channel

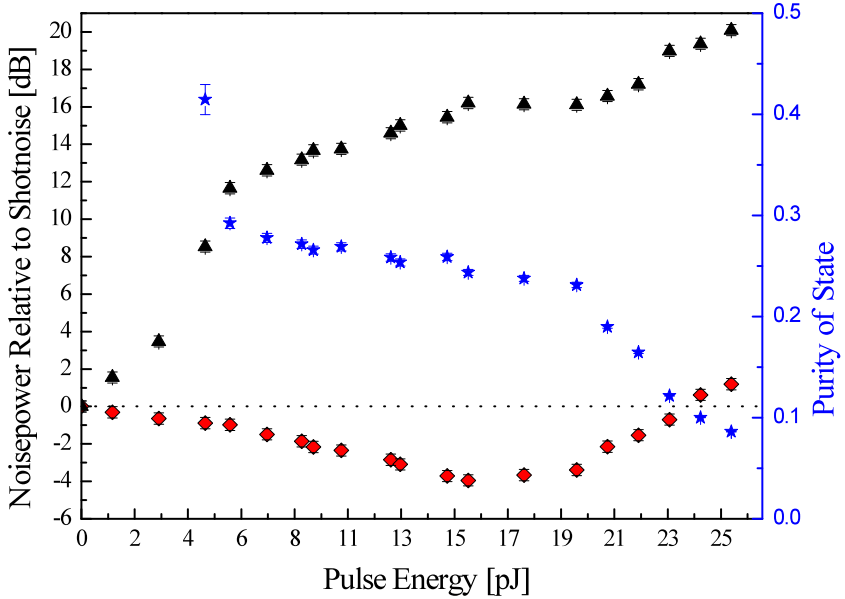
• Test distillation protocol on atmospheric link

New sources of squeezed light

Squeezing in PCF

- **Efficient generation of polarization squeezed light in photonic crystal fibres**
  - tunable broadband squeezed light source



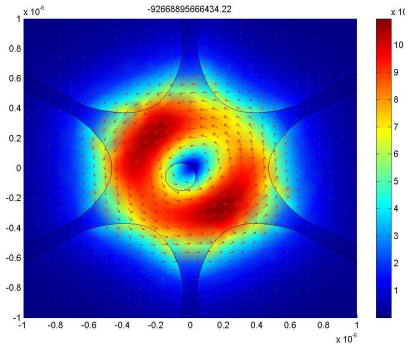


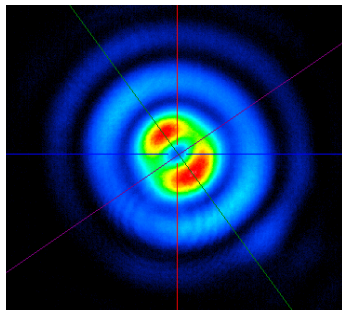
J. Milanovic, et al., " A NovelMethod for Polarization Squeezing with Photonic Crystal Fibers ", arXiv:0902.4597v1

Goal: Highly tunable, stable broadband squeezing – increase purity

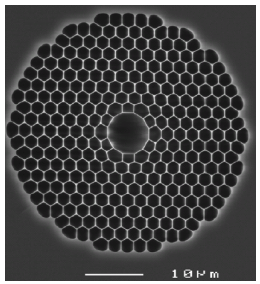
Squeezing in PCF

- **Complex spatial – polarization squeezing**
  - add more degrees of freedom to state preparation
  (interesting for multimode protocols / cluster states)



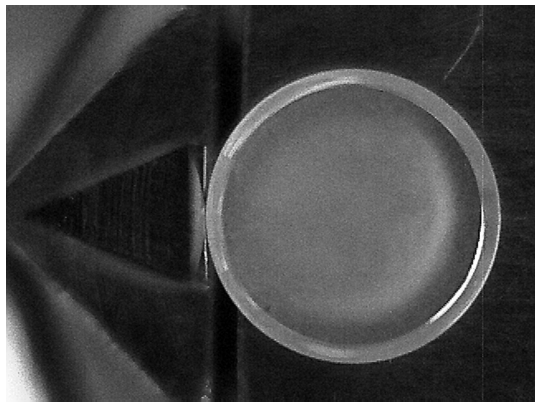


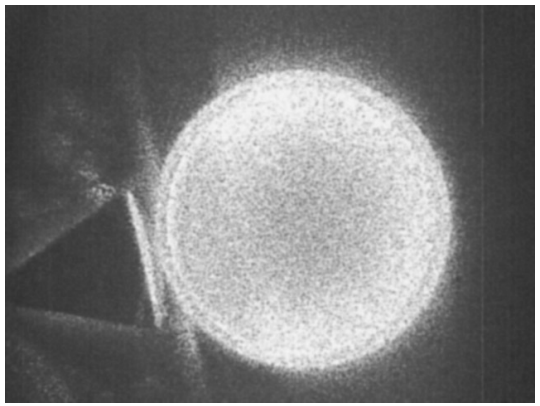
- **Investigate filled hollow core PCF with resonant / non-resonant interactions**



Squeezing in disk resonators

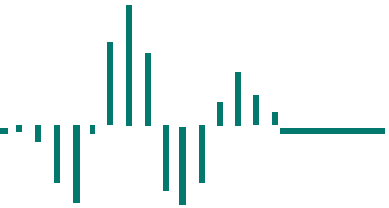
- **Whispering gallery modes in high Q disk resonator cavity (material can be Lithium Niobate)**





Extremely low threshold, stable, coupling parameters changeable

FAU projects



- Non-Gaussian noise entanglement distillation (improve protocol, combine with protocols for Gaussian noise)
- New sources of squeezed light (resources for non-Gaussian state generation:
  - Photonic crystal fibres (tunable, stable, broadband, filled hollow core fibres)
  - Chi(2) Disk resonator cavities (Extremely low threshold, stable, coupling parameters changeable)