Experimental Demonstration of Secure Communication based on Quantum Illumination

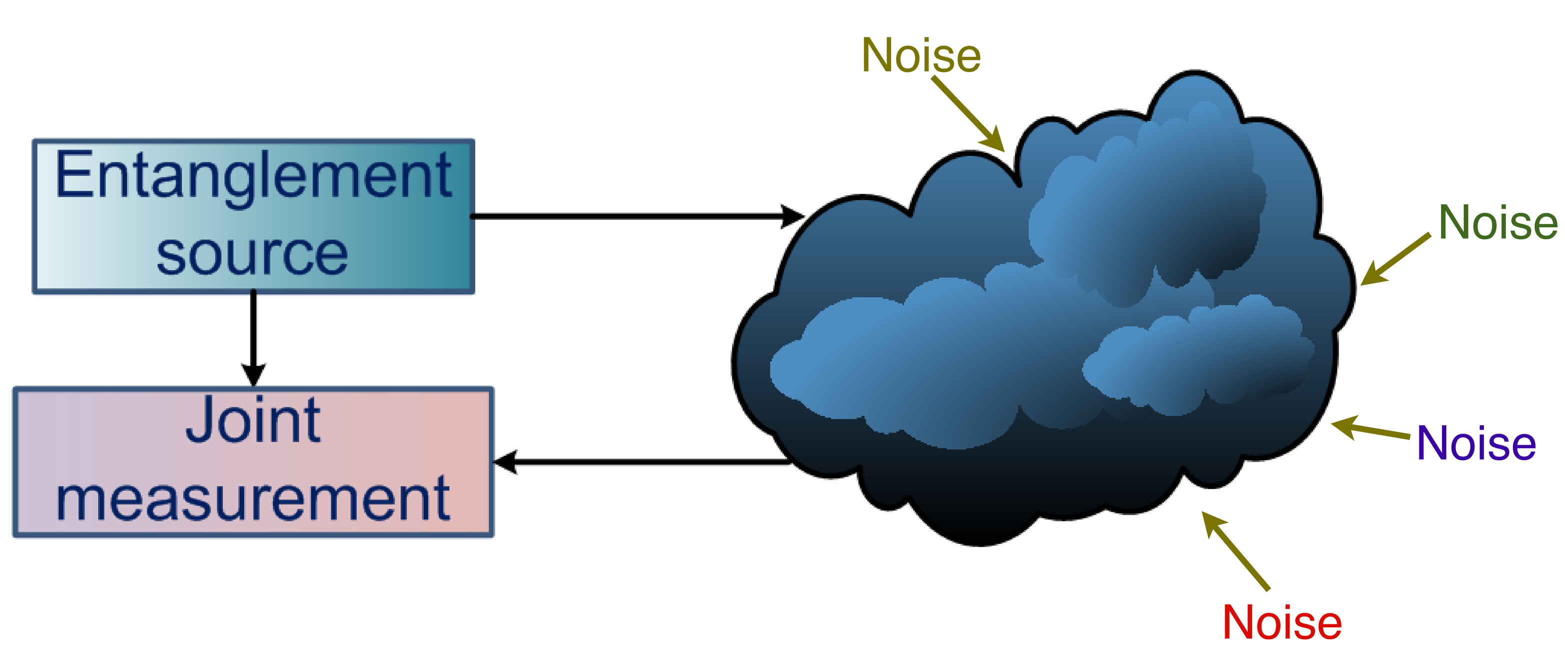
Zheshen Zhang, Maria Tengner, Tian Zhong, Franco N. C. Wong, and Jeffrey H. Shapiro

Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

Motivations

In this work, we experimentally implement a secure communication protocol using entanglement to achieve a performance advantage over Eve, despite the communication channel completely destroying the initial entanglement. Compared to QKD, this scheme allows direct transmission of encrypted messages. Our work also implies that entanglement can be beneficially used in lossy and noisy situations, i.e., practical scenarios.

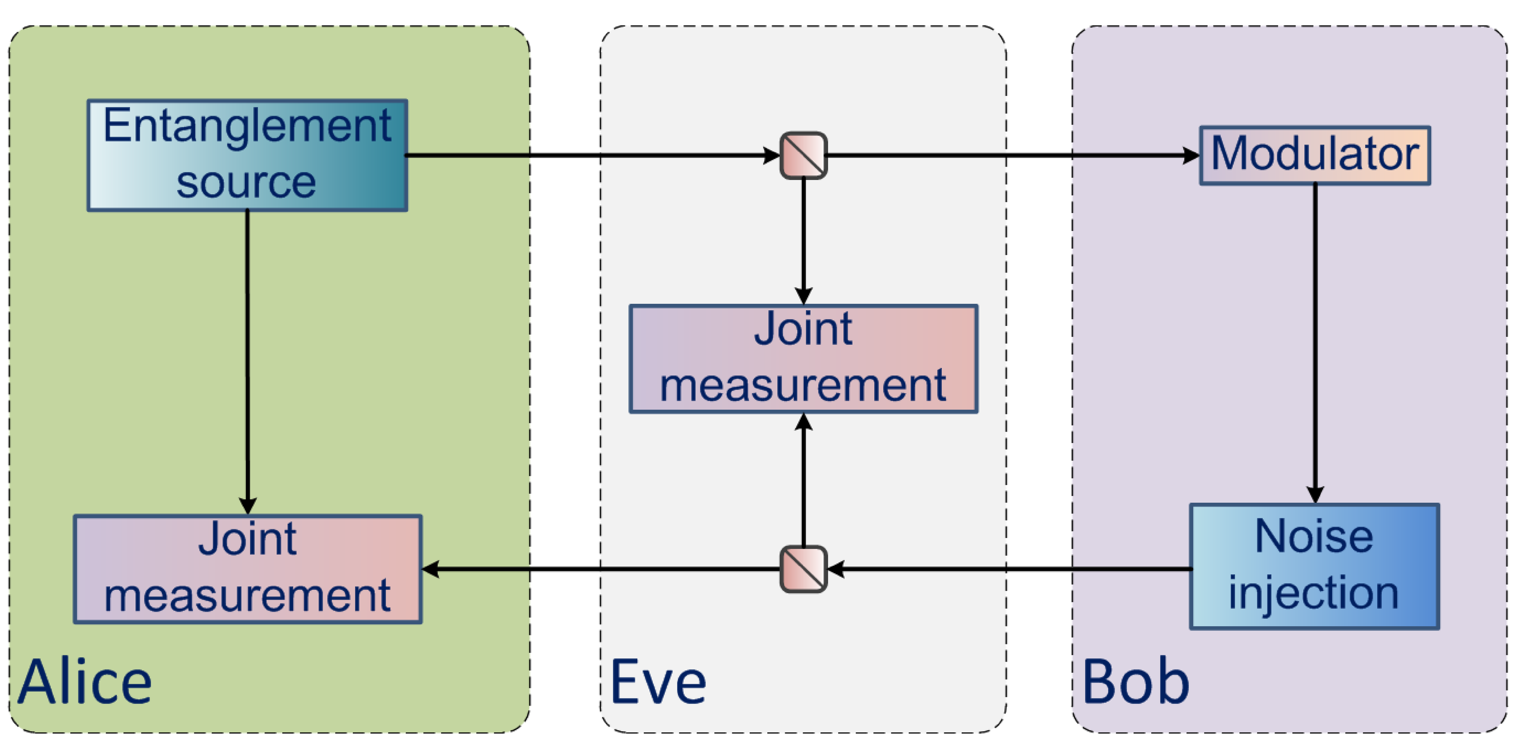
Quantum illumination [1]



Multi-mode entanglement enables detection enhancement even in a lossy and noisy environment.

Quantum illumination has been theoretically proposed to enable secure communication against passive Eve [2].

QI secure communication protocol [2]



Bob intentionally breaks the entanglement by injecting noise to mask the message

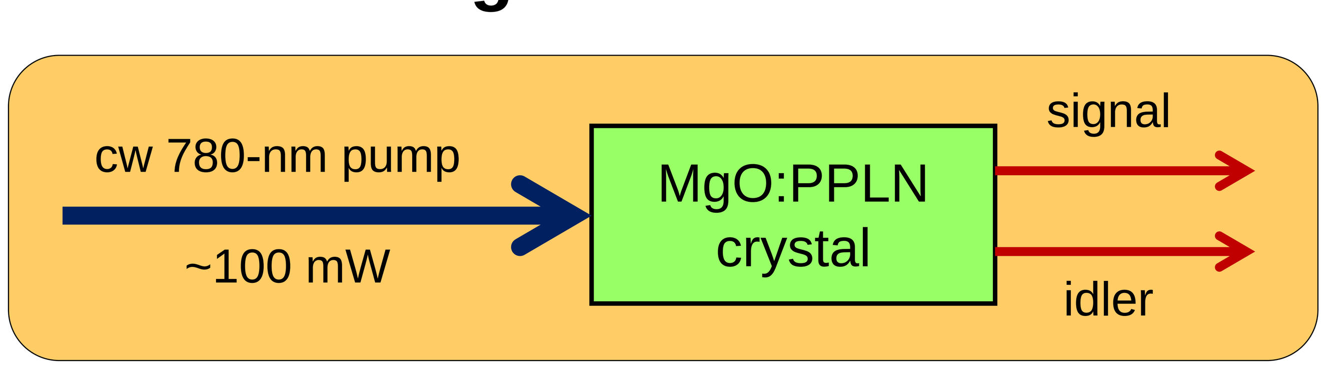
Alice: $$\mathrm{SNR}_A \propto \frac{M\zeta_A^2 \boxed{N_S(N_S+1)}}{\sigma_A^2}$$

Eve: $$\mathrm{SNR}_E \propto \frac{M\zeta_E^2 \boxed{N_S^2}}{\sigma_E^2}$$

Cross correlation

$N_S(N_S+1) \gg N_S^2$ for $N_S \ll 1$ so Alice defeats Eve

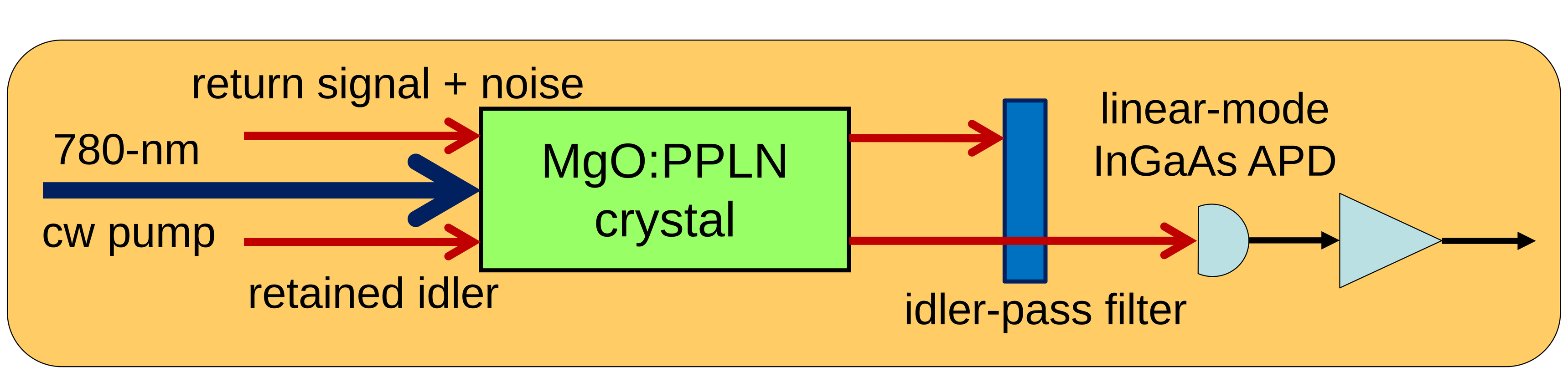
Entanglement source



Source: type-0 spontaneous parametric down conversion

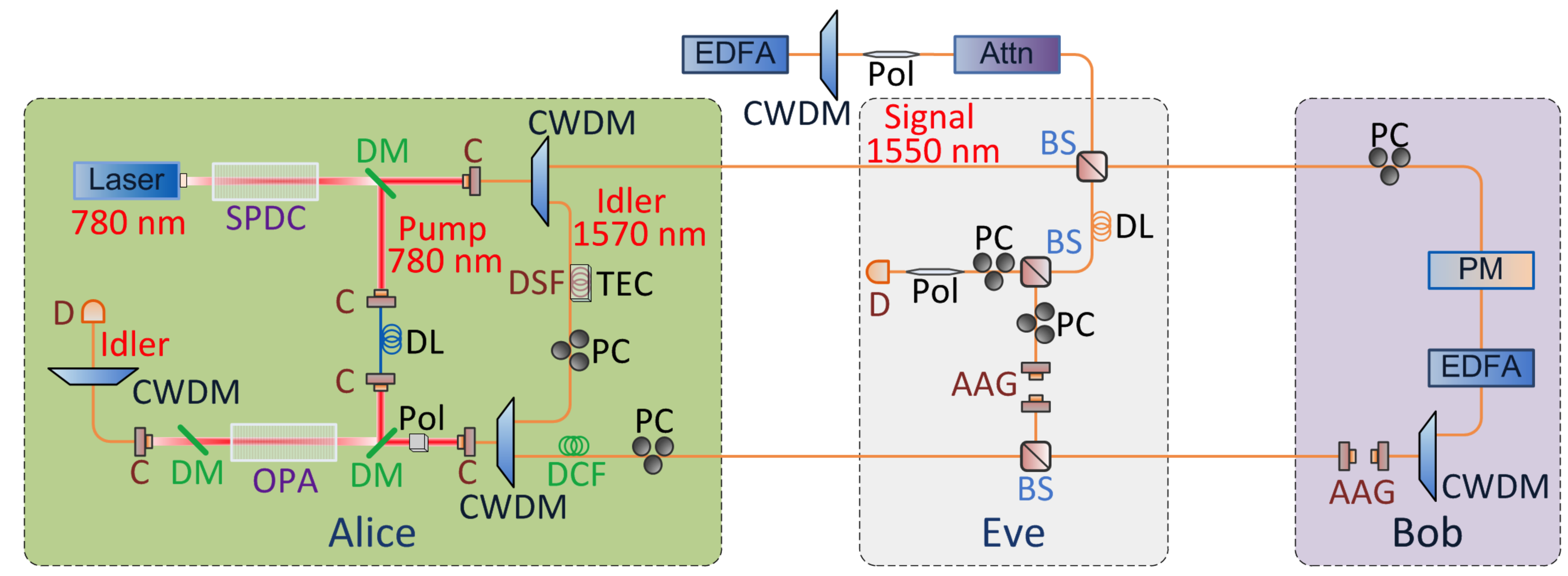
2-μs bit duration: ~4000 photons/bit and 4 x 10^6 temporal modes/bit

Joint quantum receiver [3]



Receiver: optical parametric amplifier, efficiently converting the phase correlations between the signal and idler into idler amplitude modulation.

Experimental demonstration [4]



Passive Eve takes 50% from the A-to-B channel and 10% from the B-to-A channel

Operating conditions

Data rate: 500 kbps

# of modes per bit M = 4 x 10^6

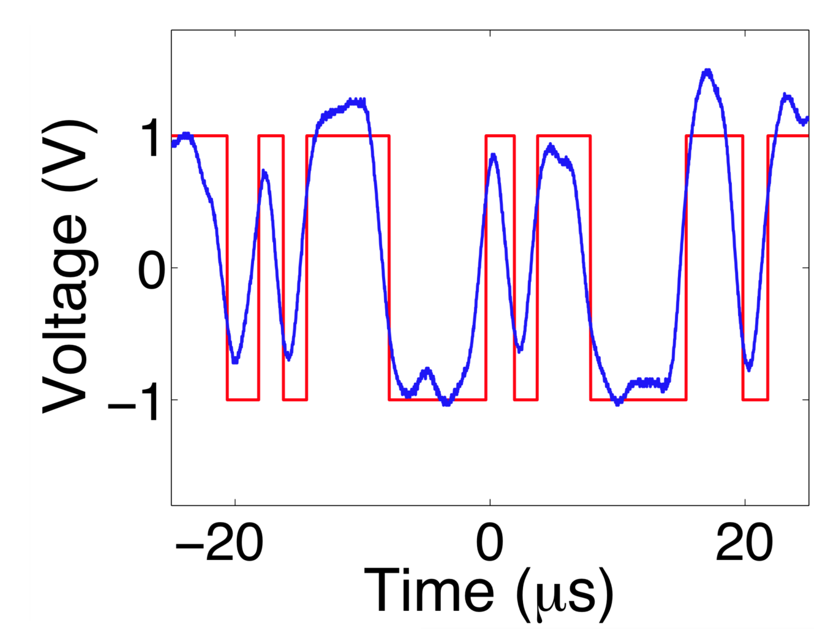
EDFA gain G = 1.34 x 10^4

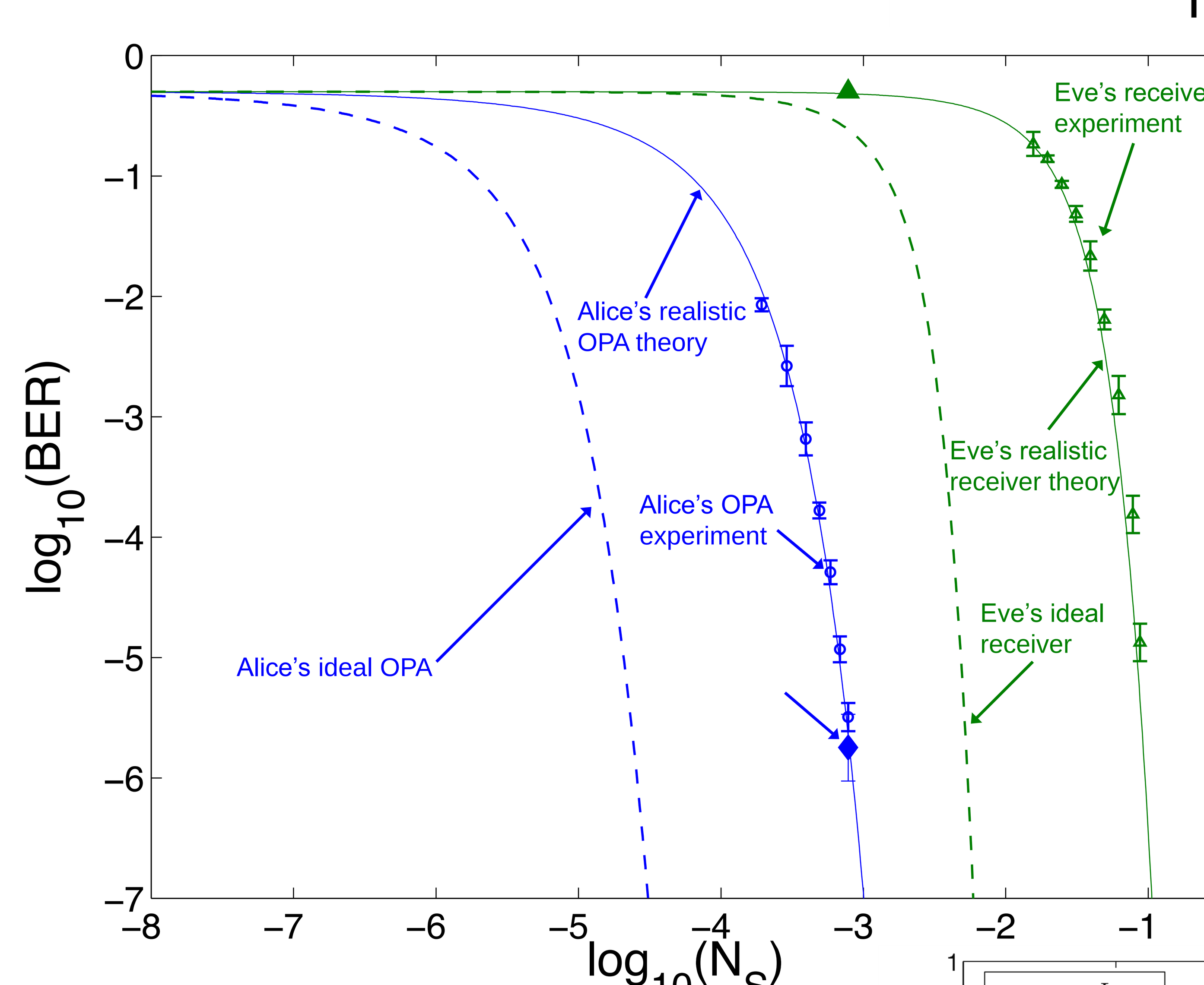
Noise photon # N_B = 1.46 x 10^4

OPA gain G_{OPA} – 1 = 1.86 x 10^{-5}

Signal transmissivity κ_S = ~0.1

Idler transmissivity κ_I = ~0.4





BER vs N_S

pump power 100 mW

Photons/mode N_S = 7.81 x 10^{-4}

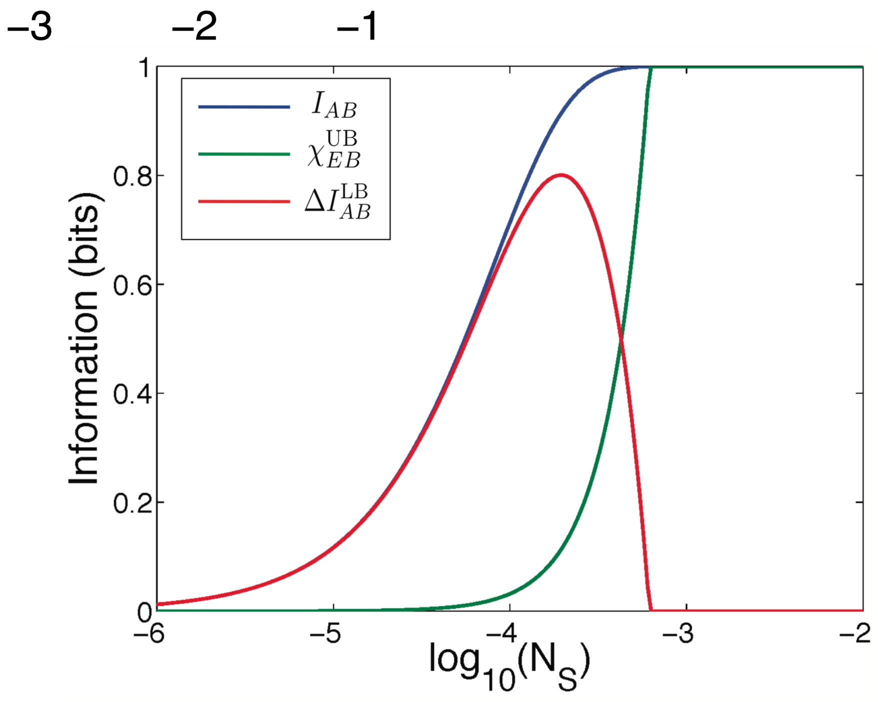
Measured BER 1.67 x 10^{-6} @ ◆

8.3 dB above entanglement-breaking threshold

Information advantage vs N_S

Over 0.8 bits/transmitted bit

Secure against optimal Eve



[1] S. Lloyd, Science **321,** 1463 (2008).

[2] J.H. Shapiro, Phys. Rev. A **80,** 022320 (2009).

[3] S. Guha and B. Erkman, Phys. Rev. A **80,** 052310 (2009).

[4] Z. Zhang *et al*, Phys. Rev. Lett. **111,** 010501 (2013).

Funding: ONR Basic Research Challenge grant

RESEARCH LABORATORY OF ELECTRONICS AT MIT www.rle.mit.edu

Massachusetts Institute of Technology