Squeezed Light Injection and Squeezing Progress

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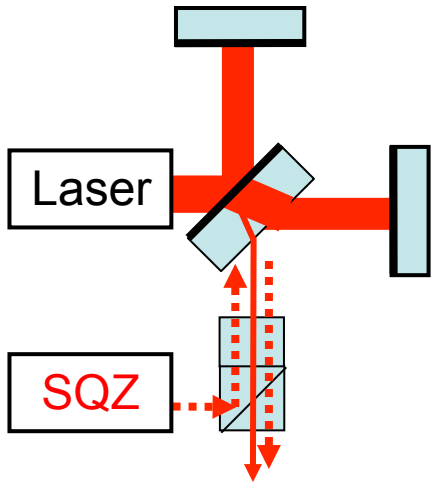
Outline

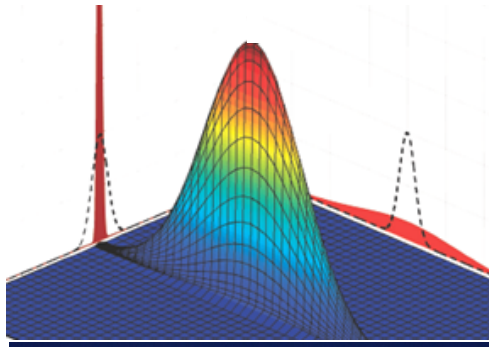


- **Review on Squeezed light injection:**

  Comparison with self-squeezing

- **Squeezed light generation and control:**

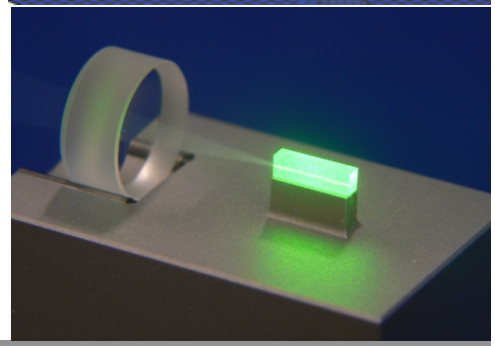
  Transients?



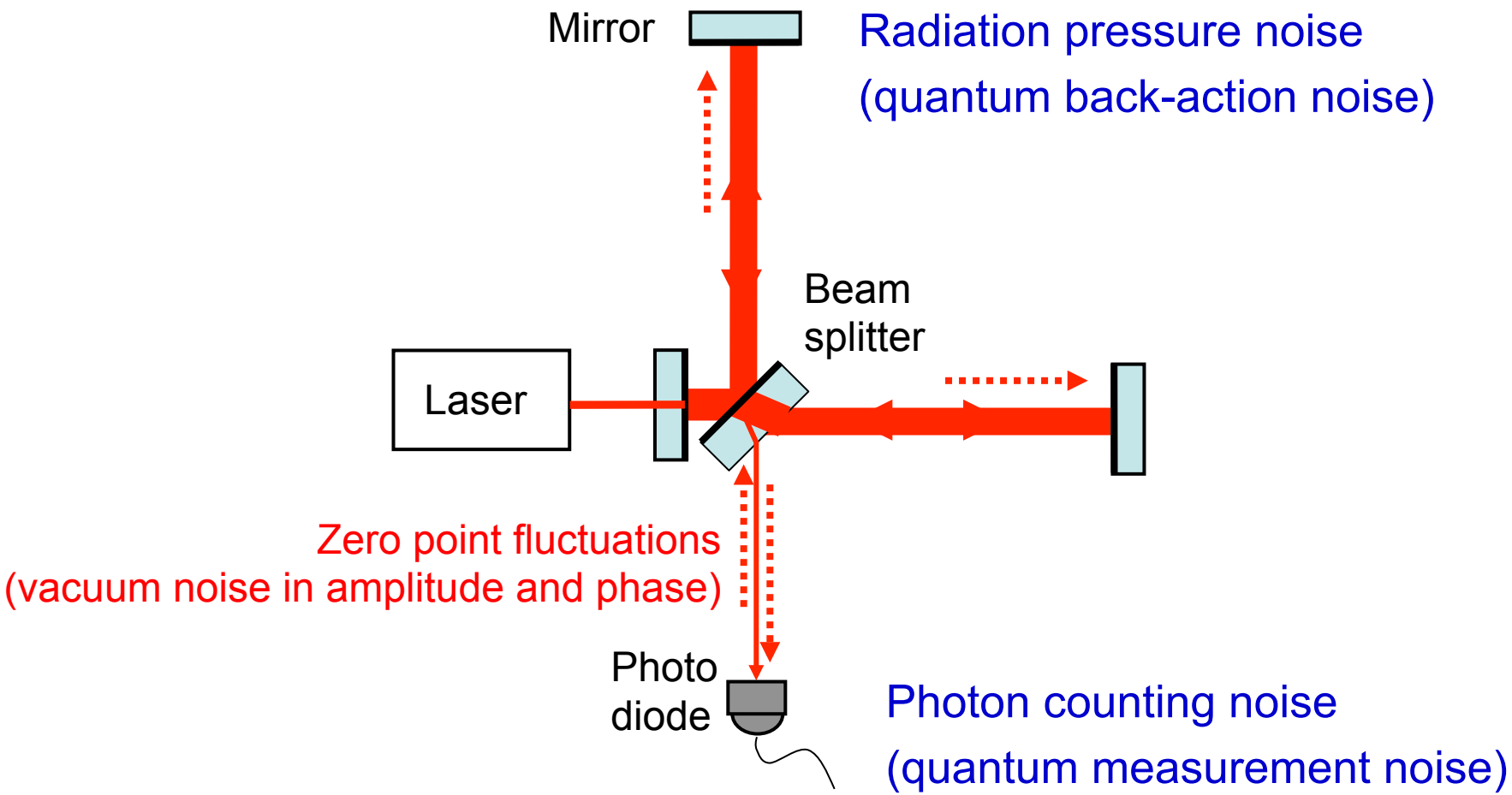
- **Progress on squeezed light lasers:**

  1064 nm

  1550 nm

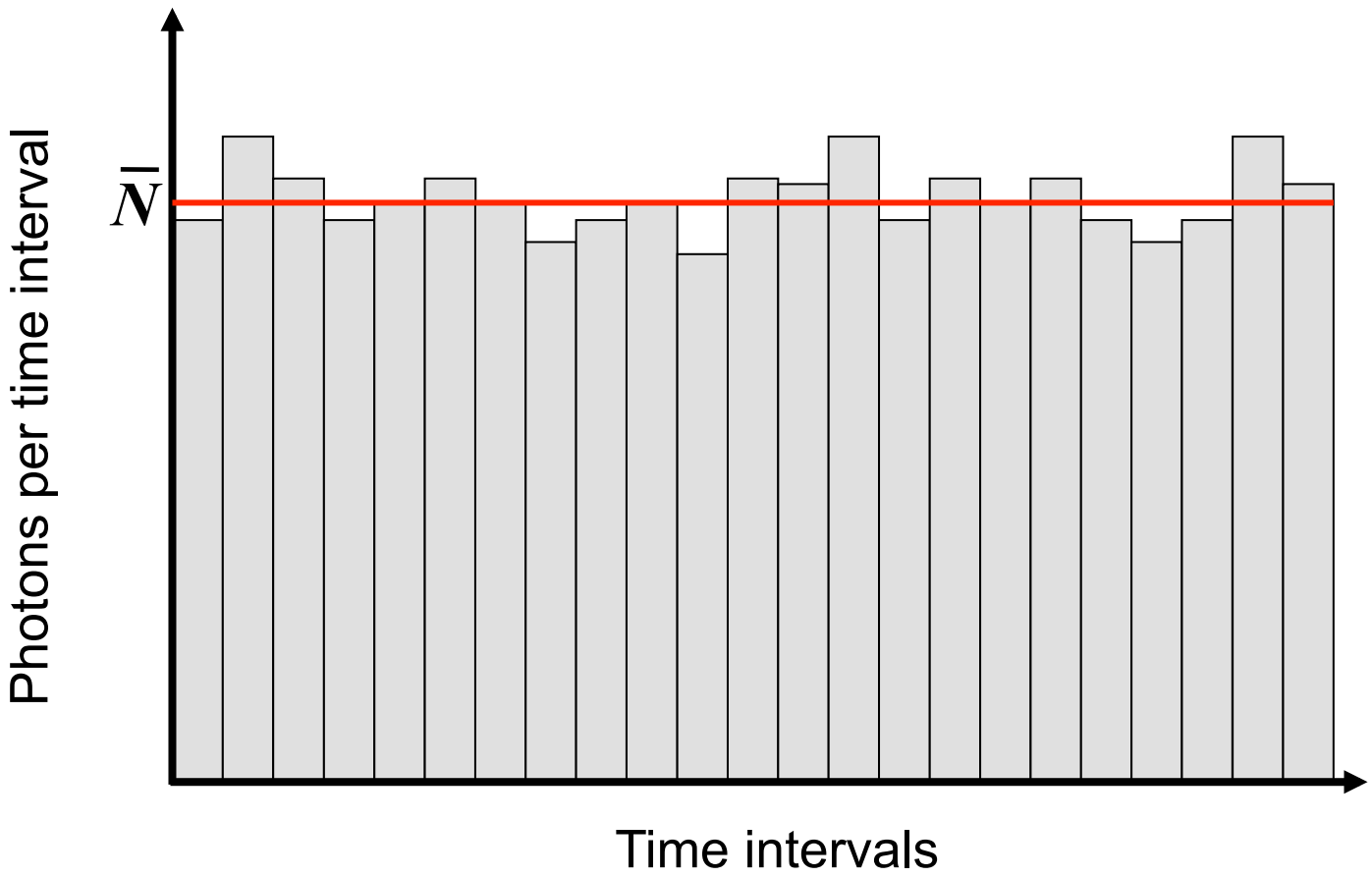


Interferometer Quantum Noise

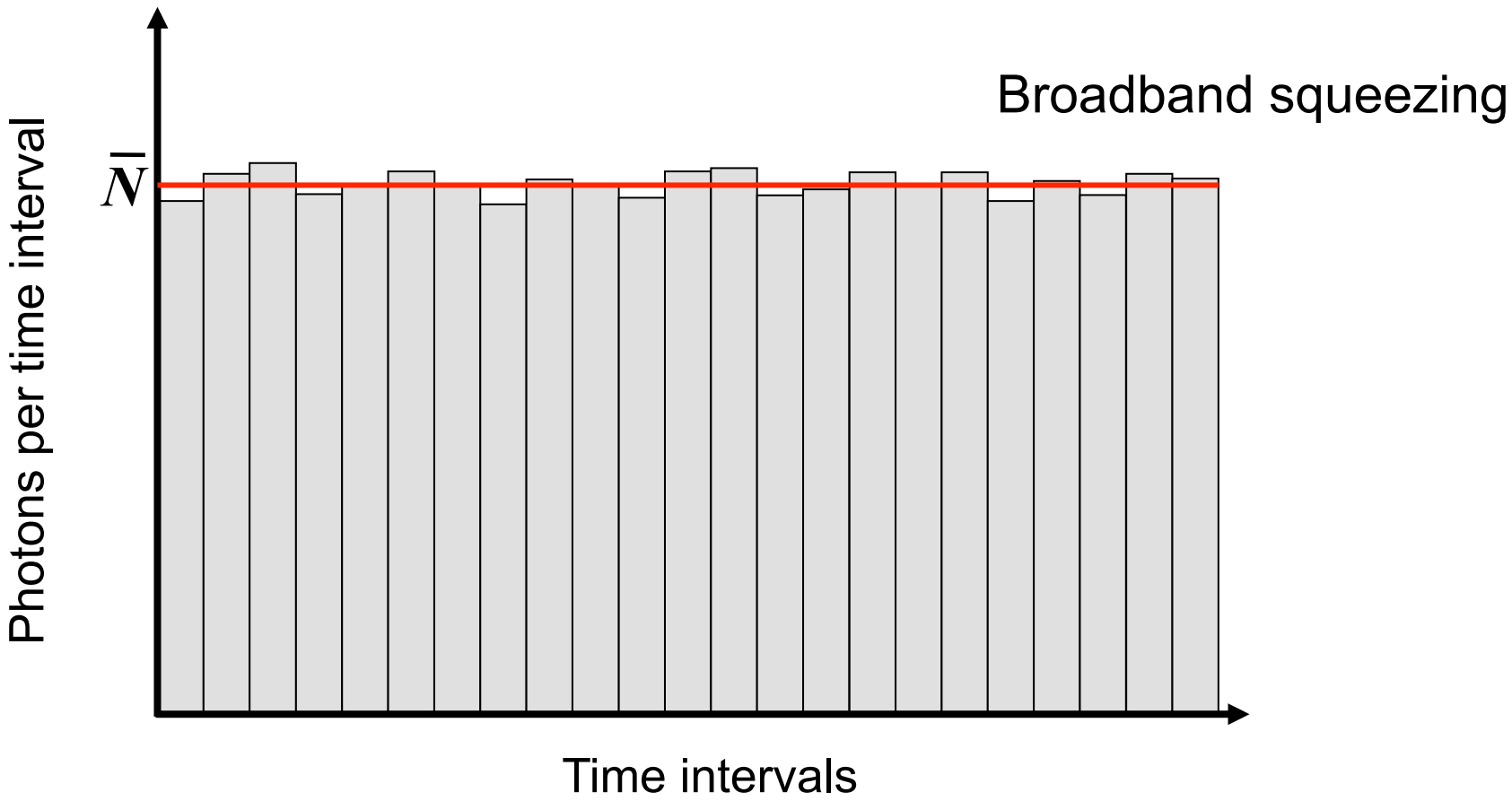


[Caves, Phys. Rev. D 23, 1693 (1981)]

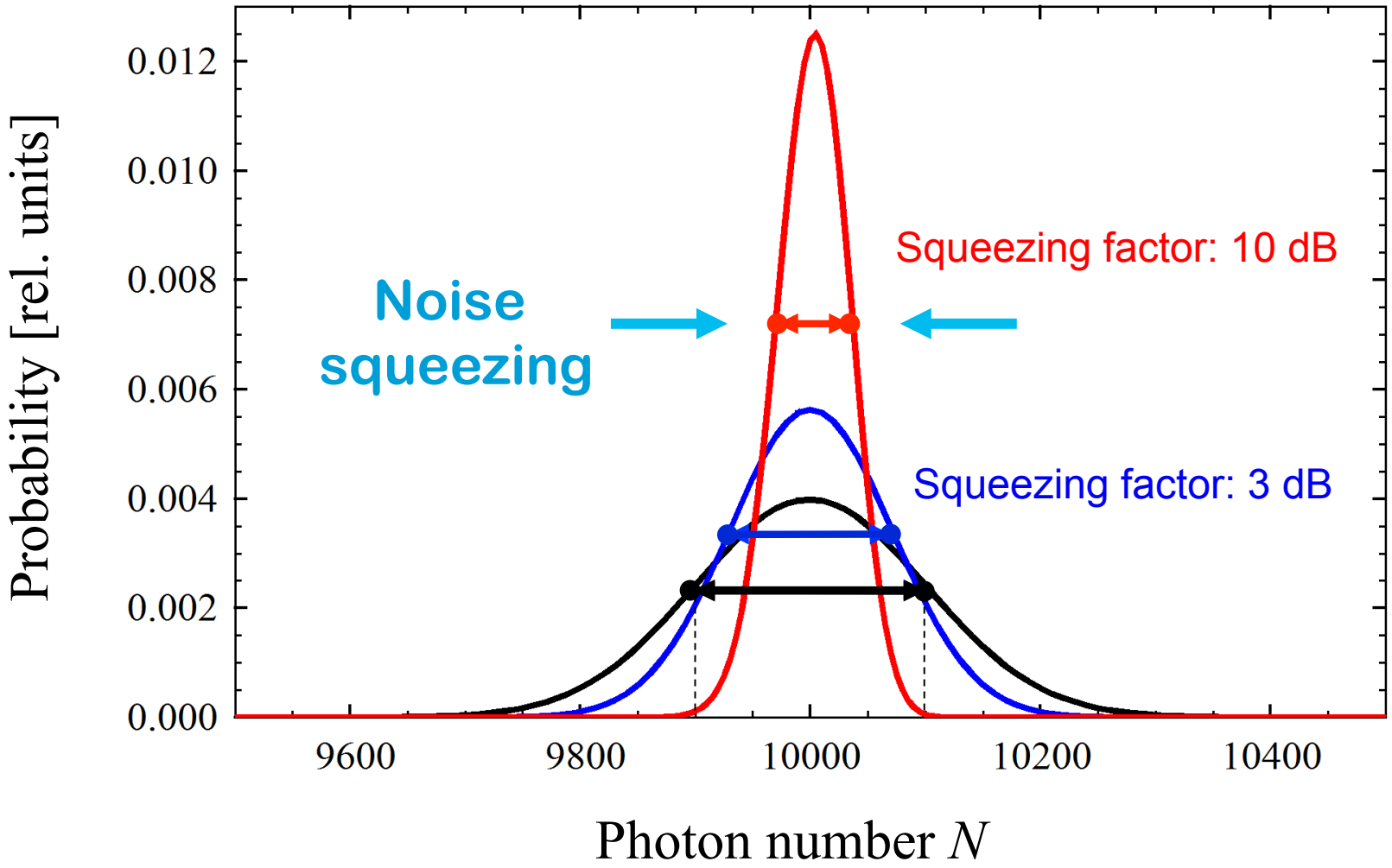
Photon Counting Noise (Shot-Noise)



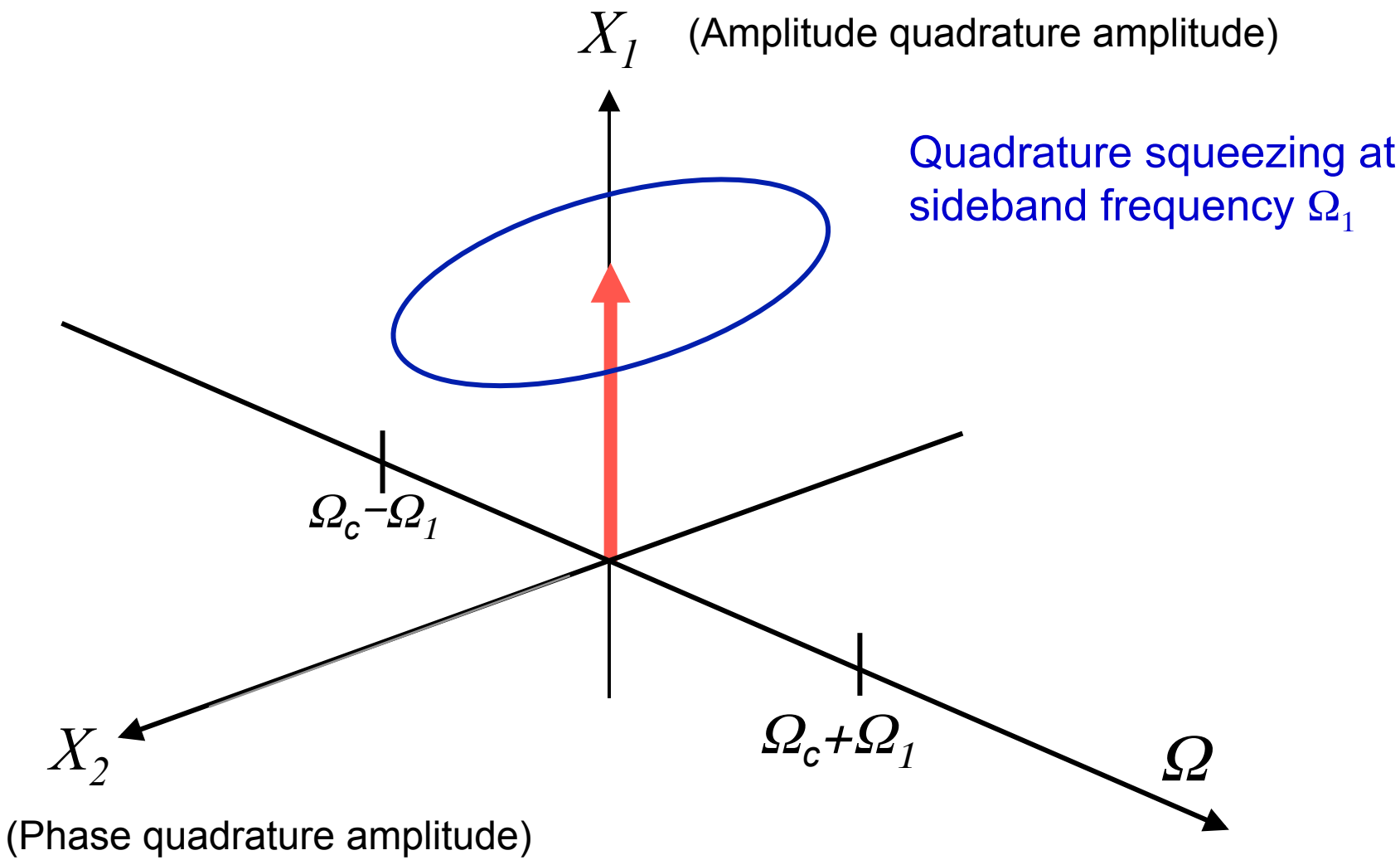
Photon Counting Noise - Squeezed



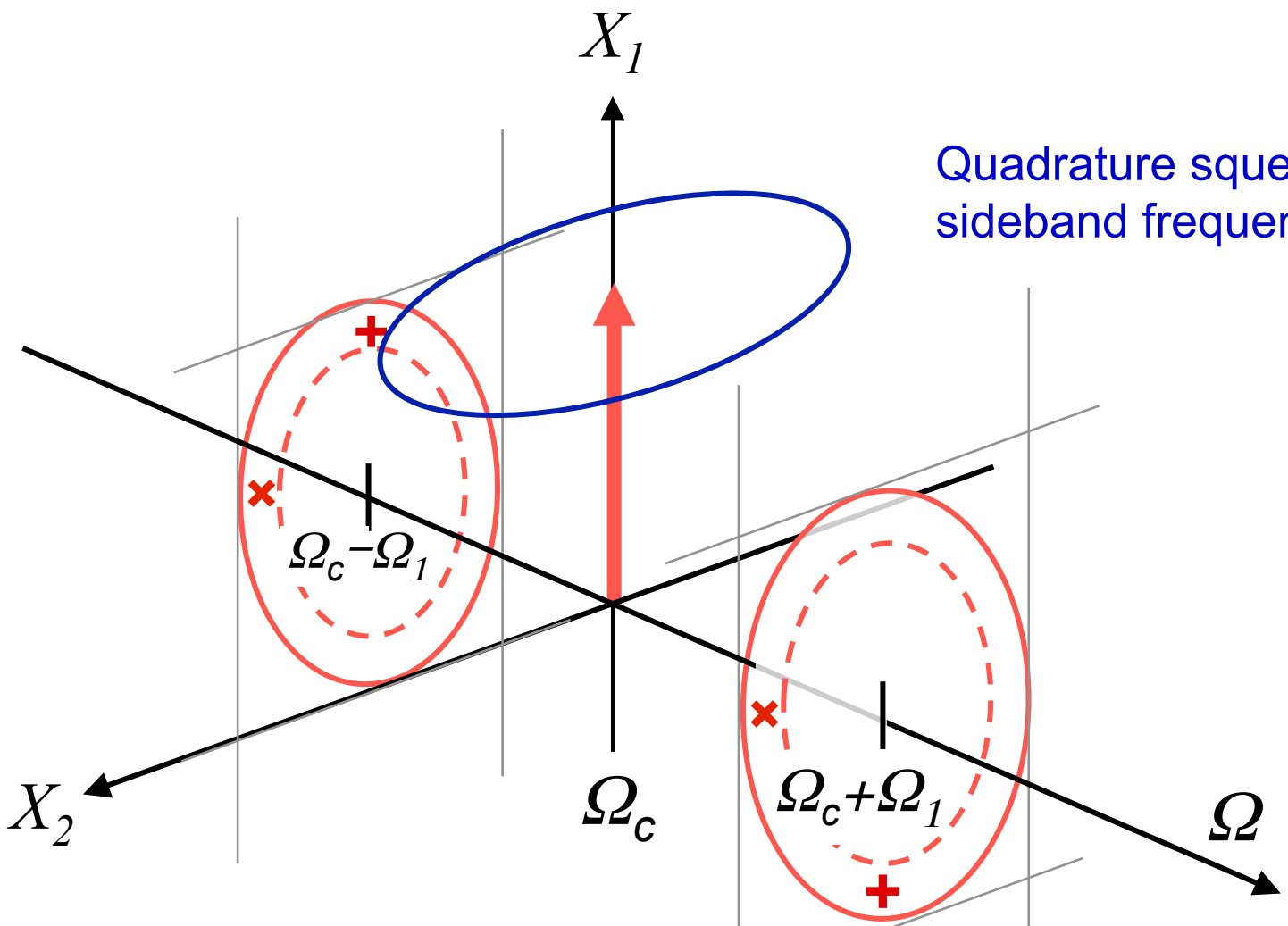
“Squeezed” Counting Statistics



Squeezing in the Wave Picture

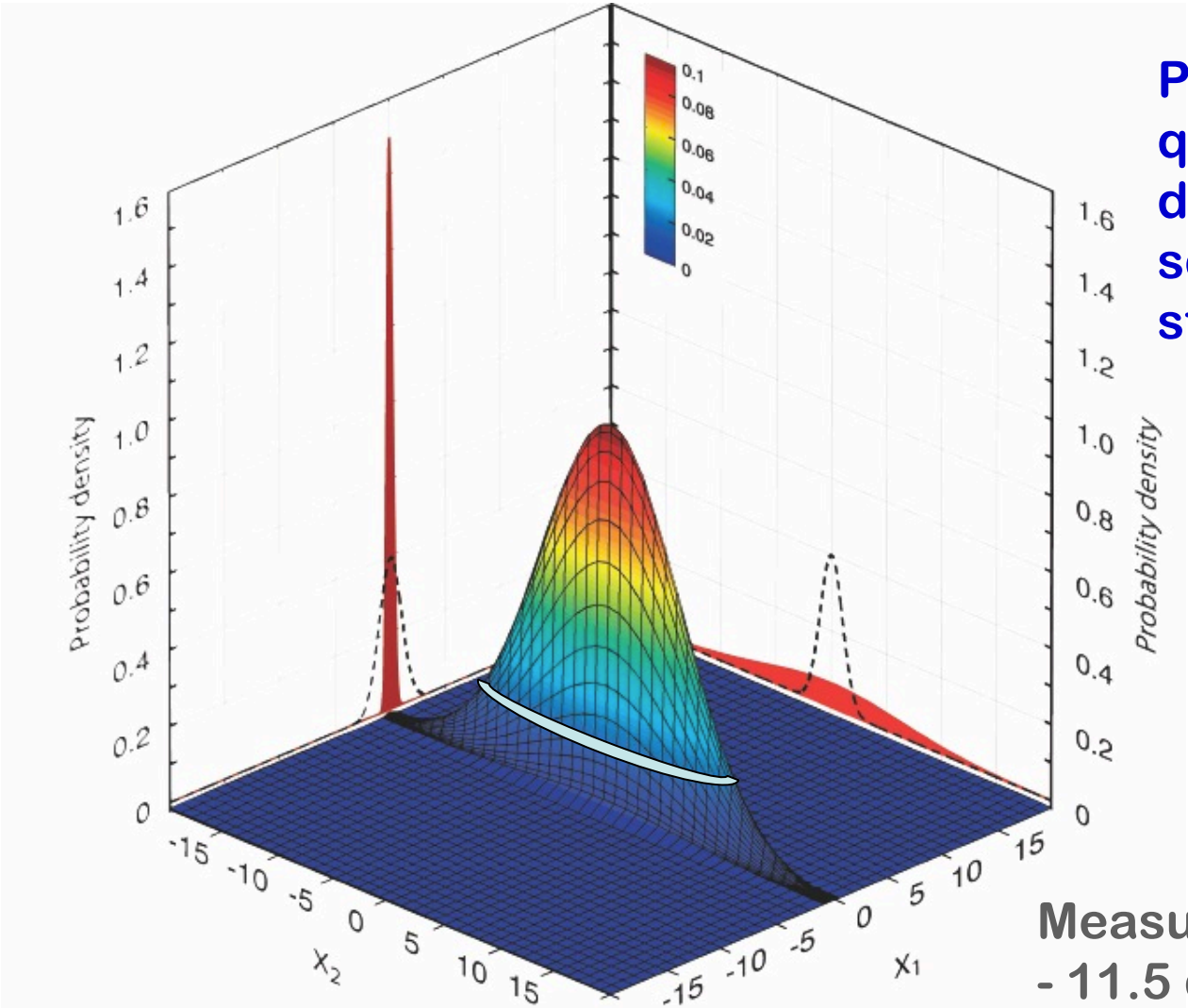


Squeezing in the Wave Picture



Quadrature squeezing at sideband frequency Ω_1

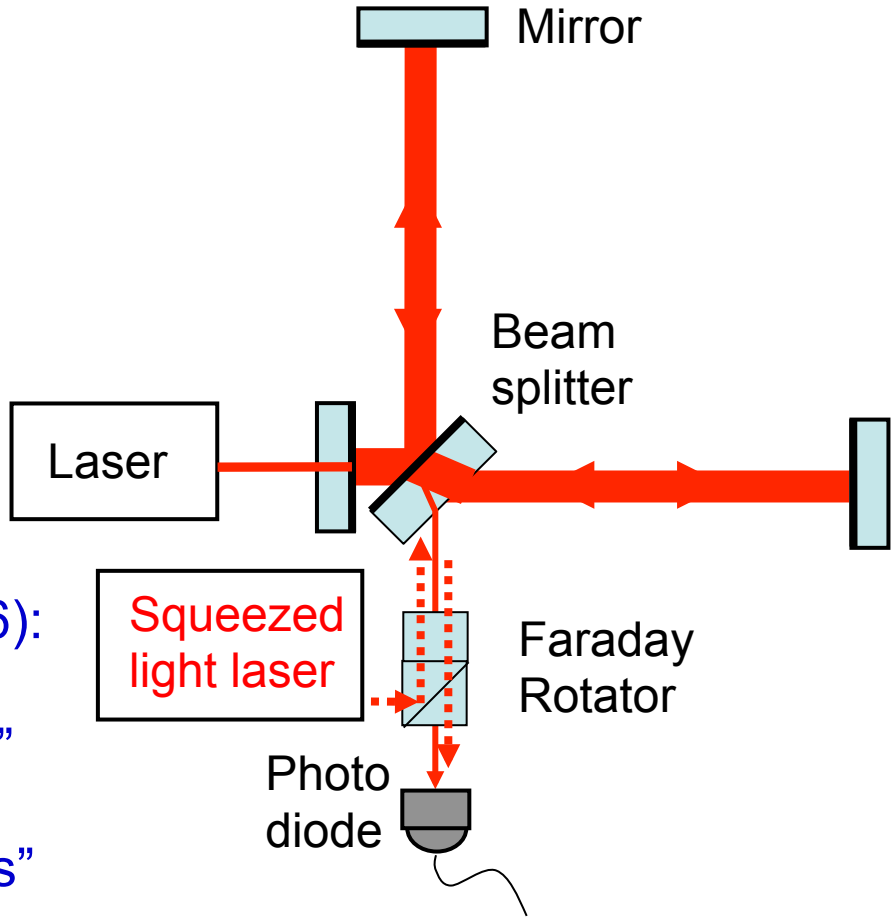
Squeezing in the Wave Picture



Phase-space quasi-probability distribution of a squeezed vacuum state

Measured:
- 11.5 dB / +16 dB@5MHz

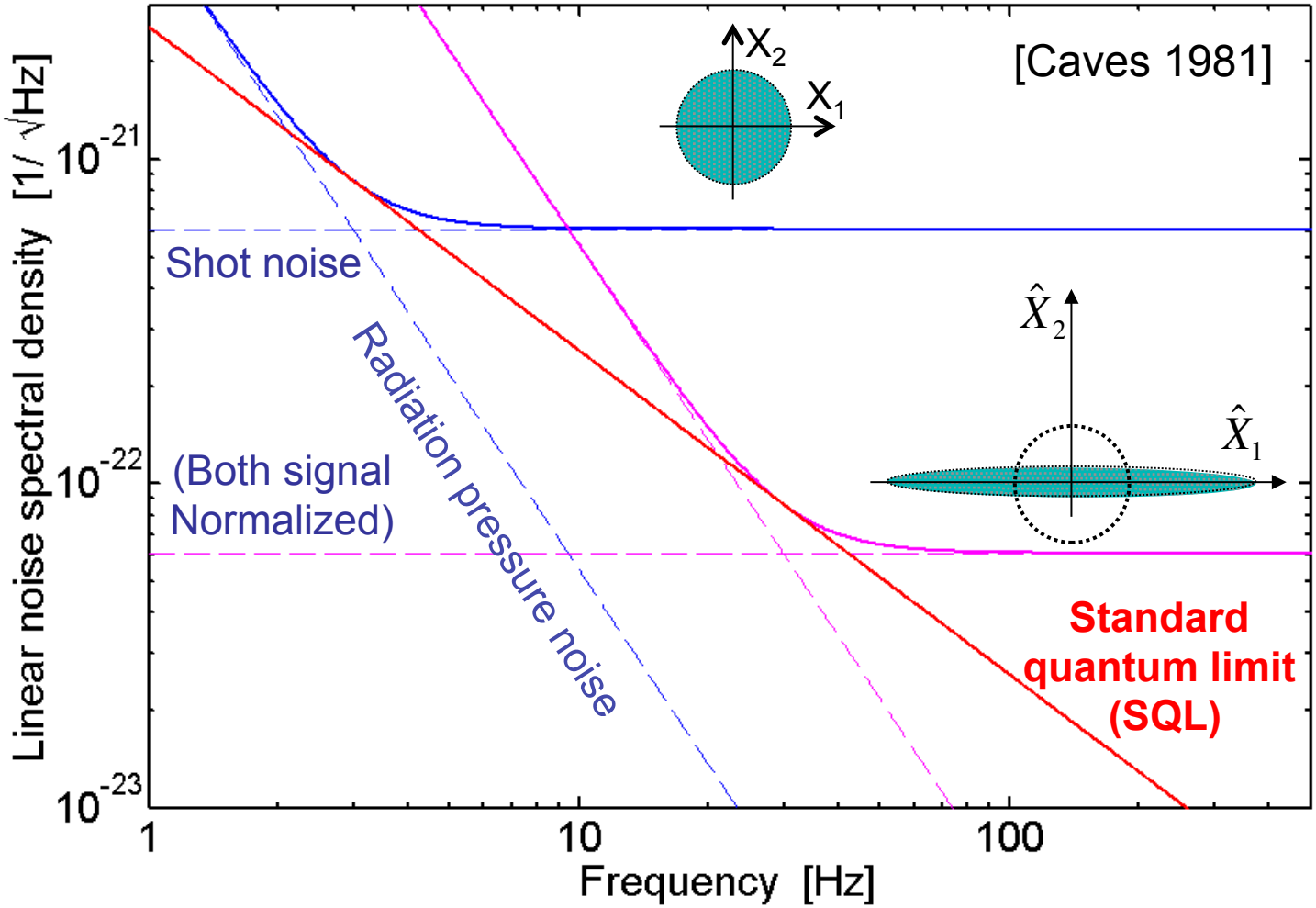
Squeezing the Shot-Noise



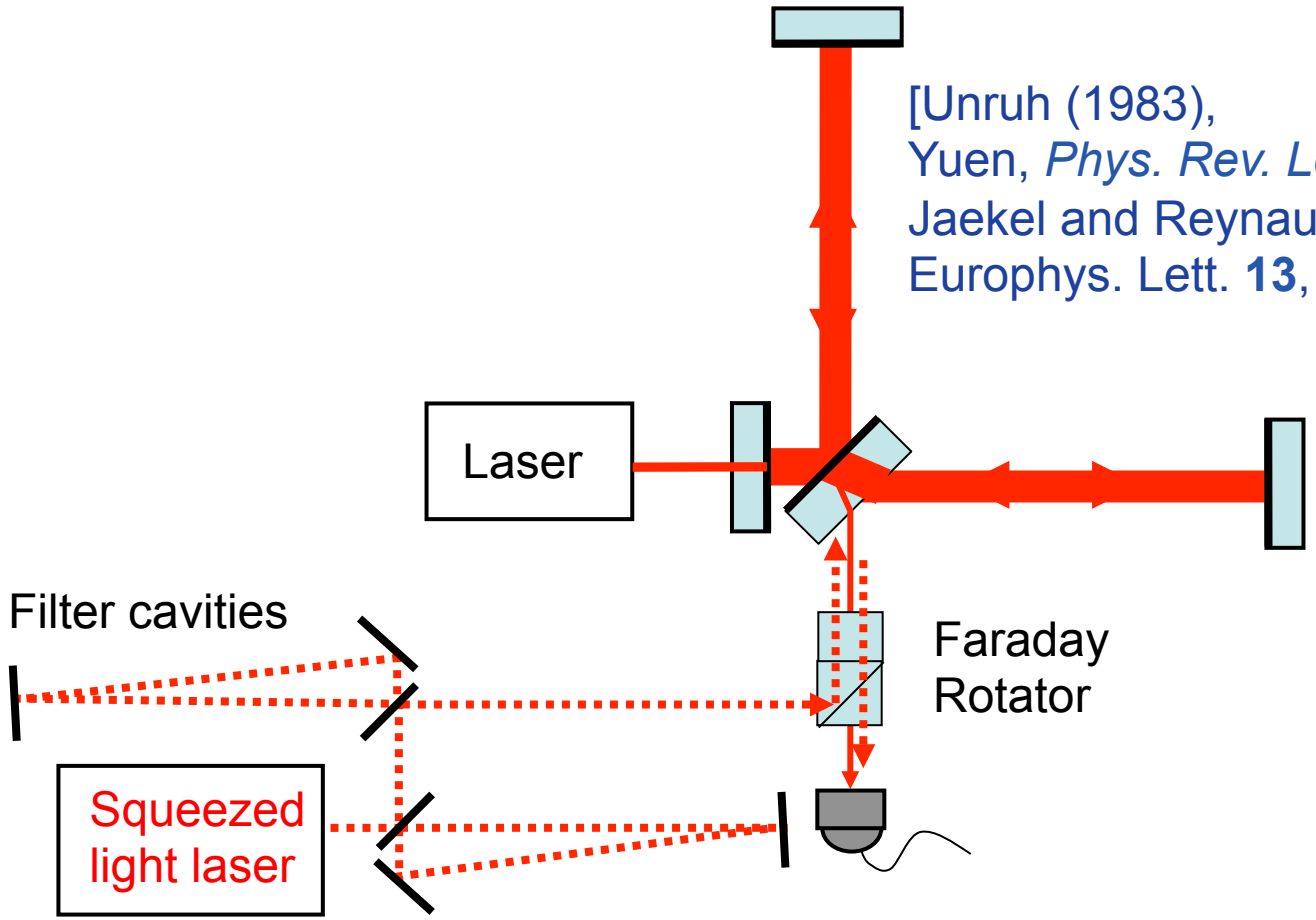
Yuen, PRA (1976):
"Two-Photon
coherent states"
later: ➔
"Squeezed states"

[Caves, Phys. Rev. D 23, 1693 (1981)]

Squeezing the Shot-Noise



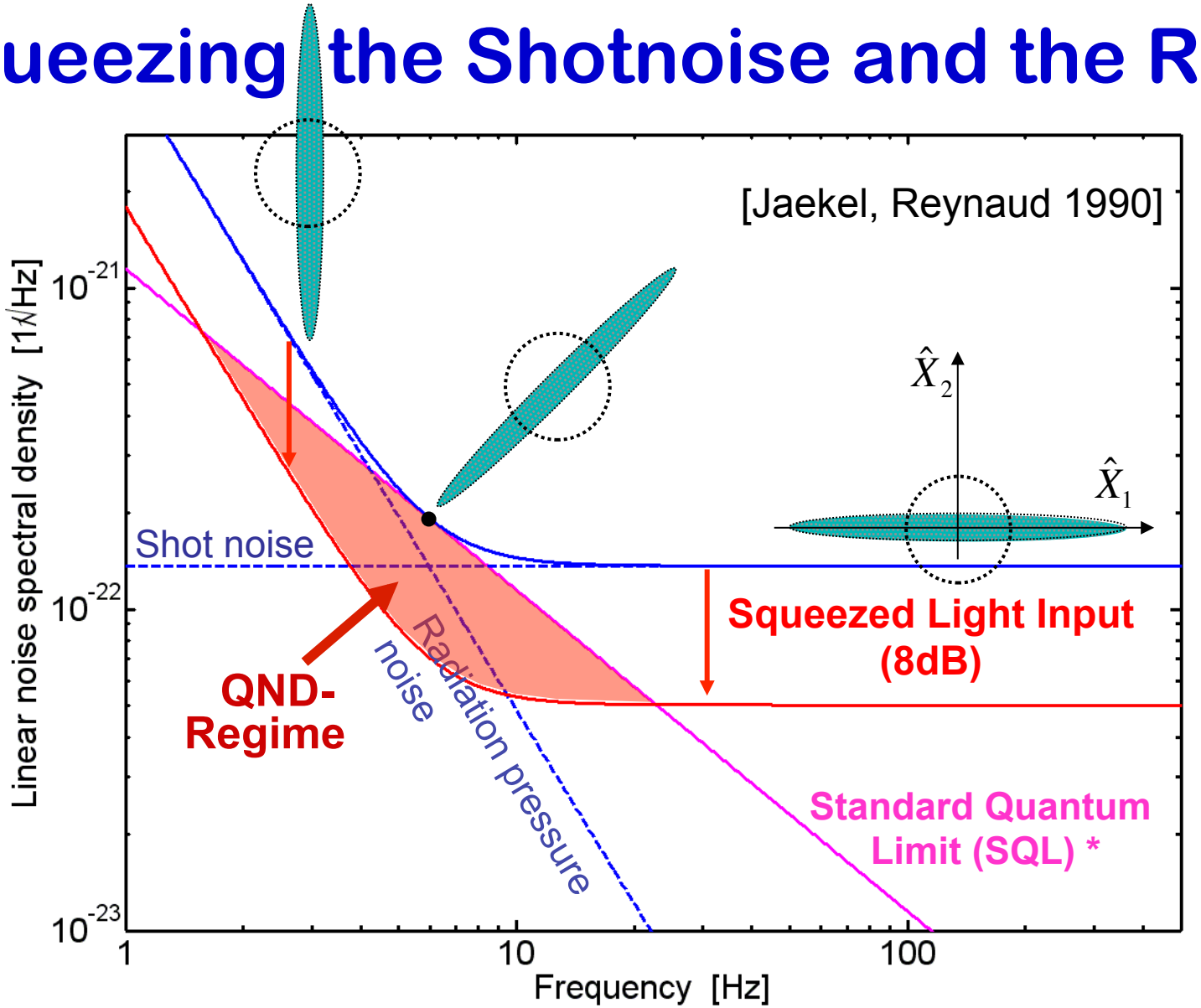
Squeezing the Shot-Noise (SN) *and* the Radiation Pressure Noise (RPN)



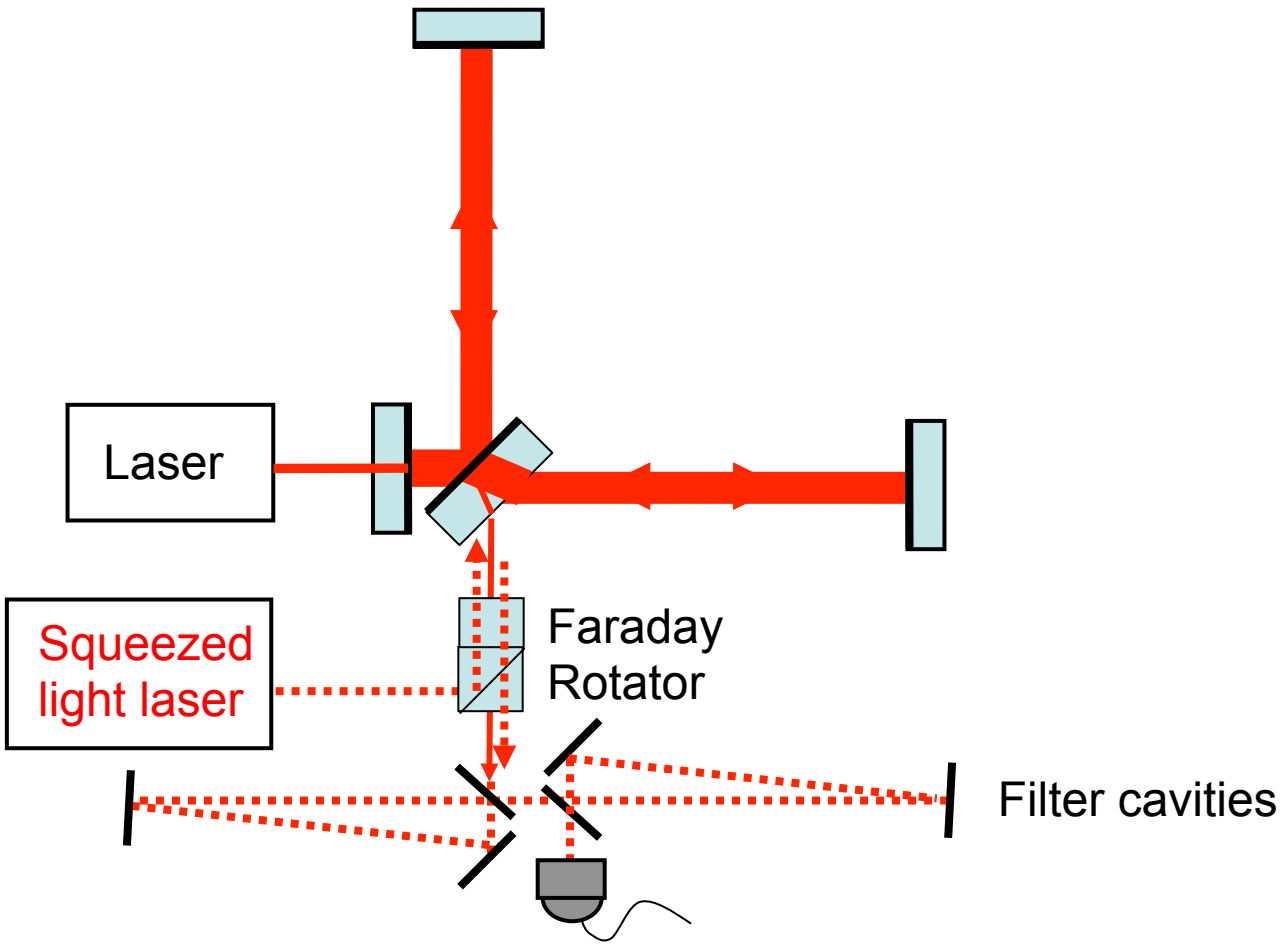
[Unruh (1983),
Yuen, *Phys. Rev. Lett.* **51,** 719 (1983);
Jaekel and Reynaud,
Europhys. Lett. **13**, 301 (1990)]

[Kimble *et al.*, Phys. Rev. D **65**, 022002 (2001)]

Squeezing the Shotnoise and the RPN

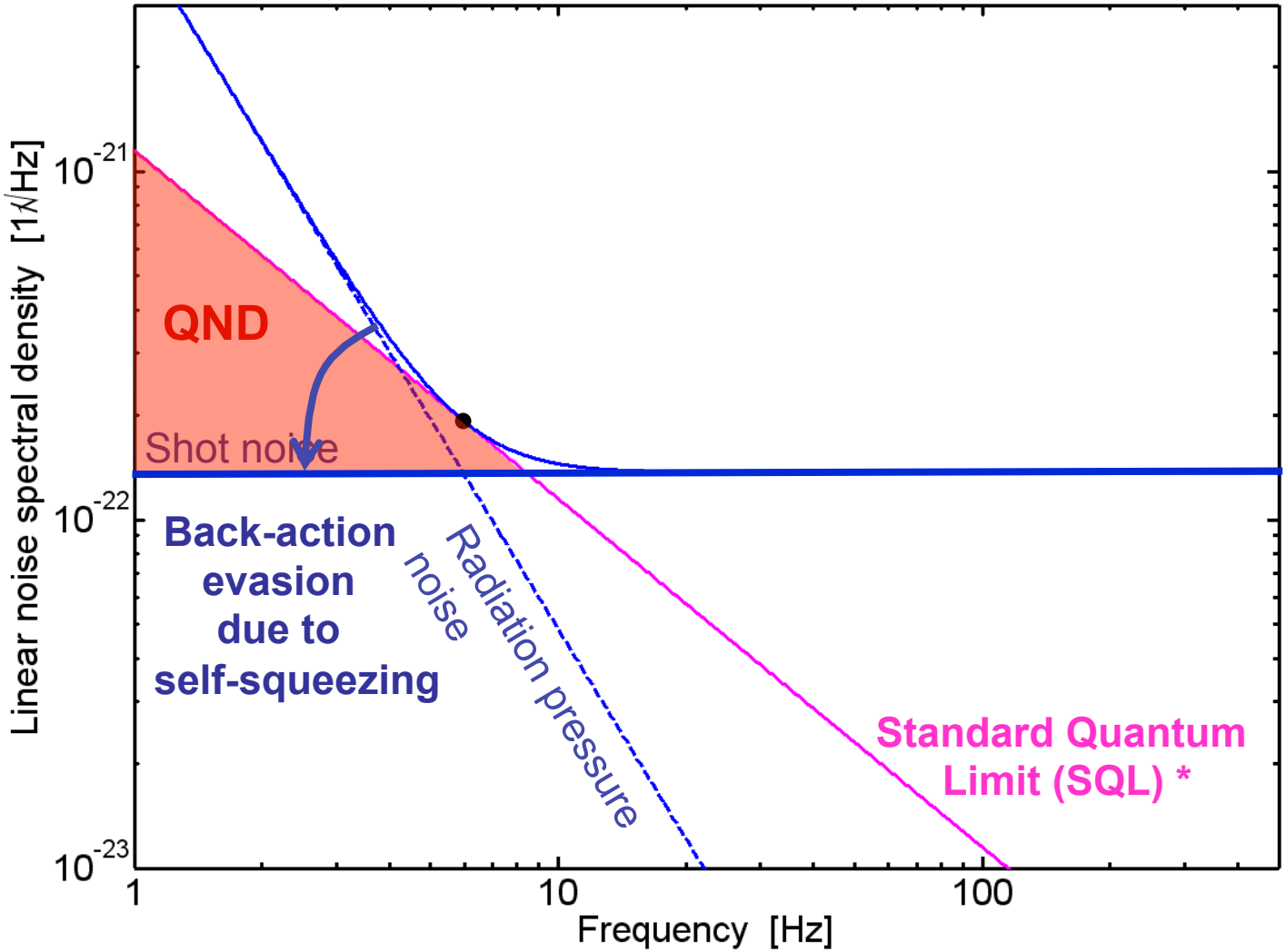


Squeezed Input and Output Filtering

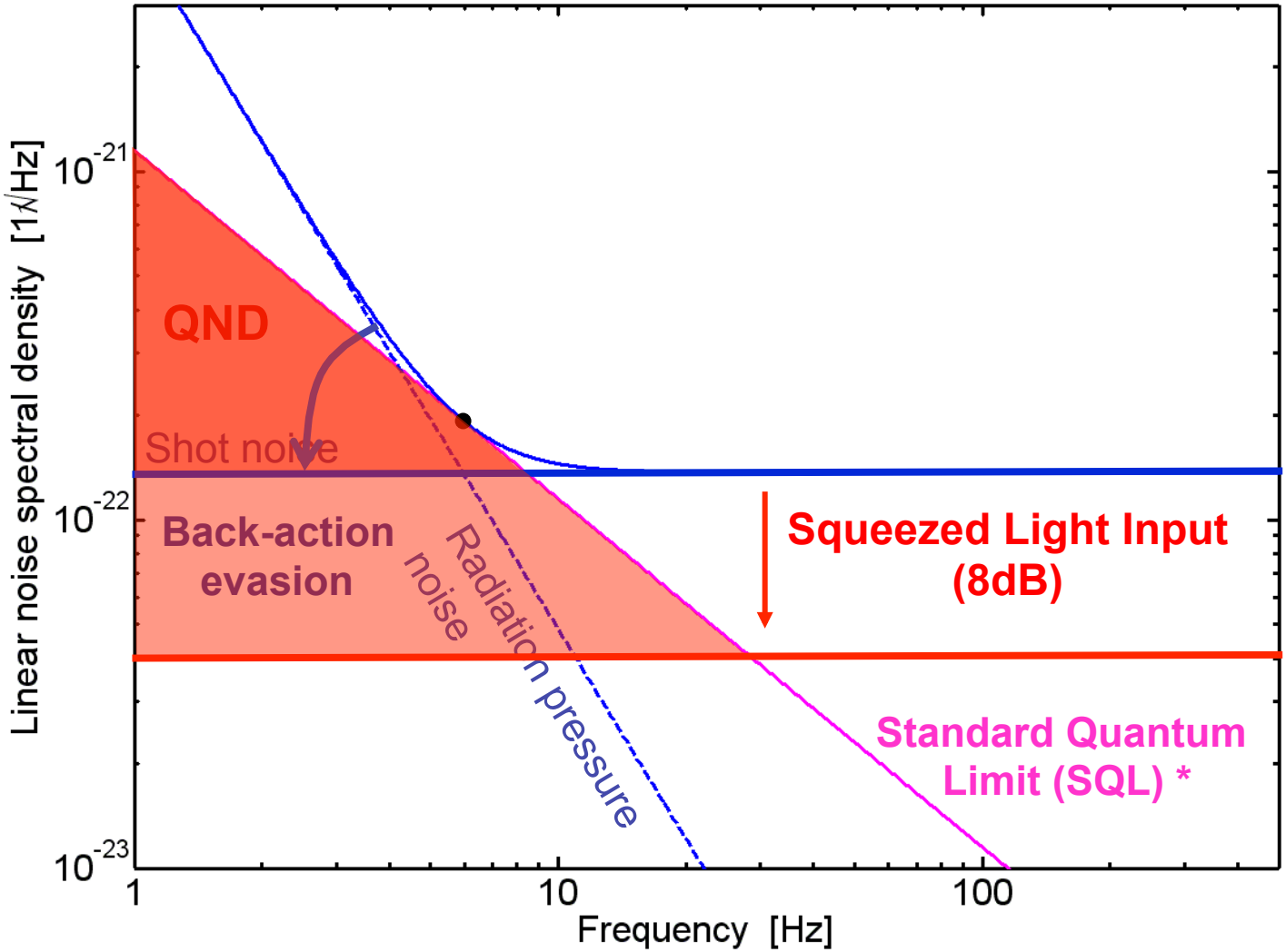


[Kimble *et al.*, Phys. Rev. D **65**, 022002 (2001)]

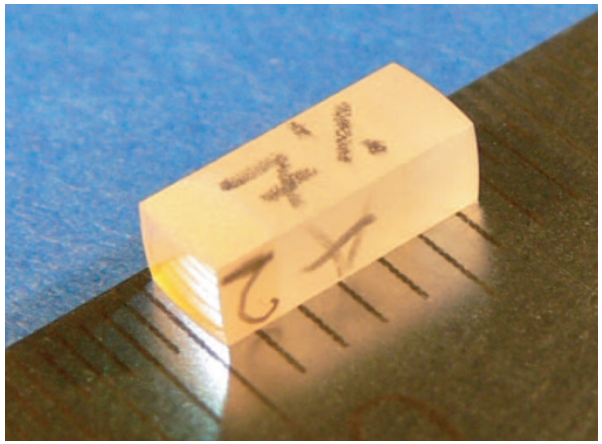
Output Filtering



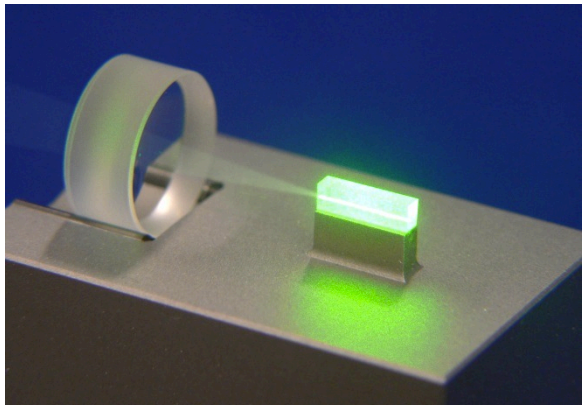
Output Filtering and Squeezed Input



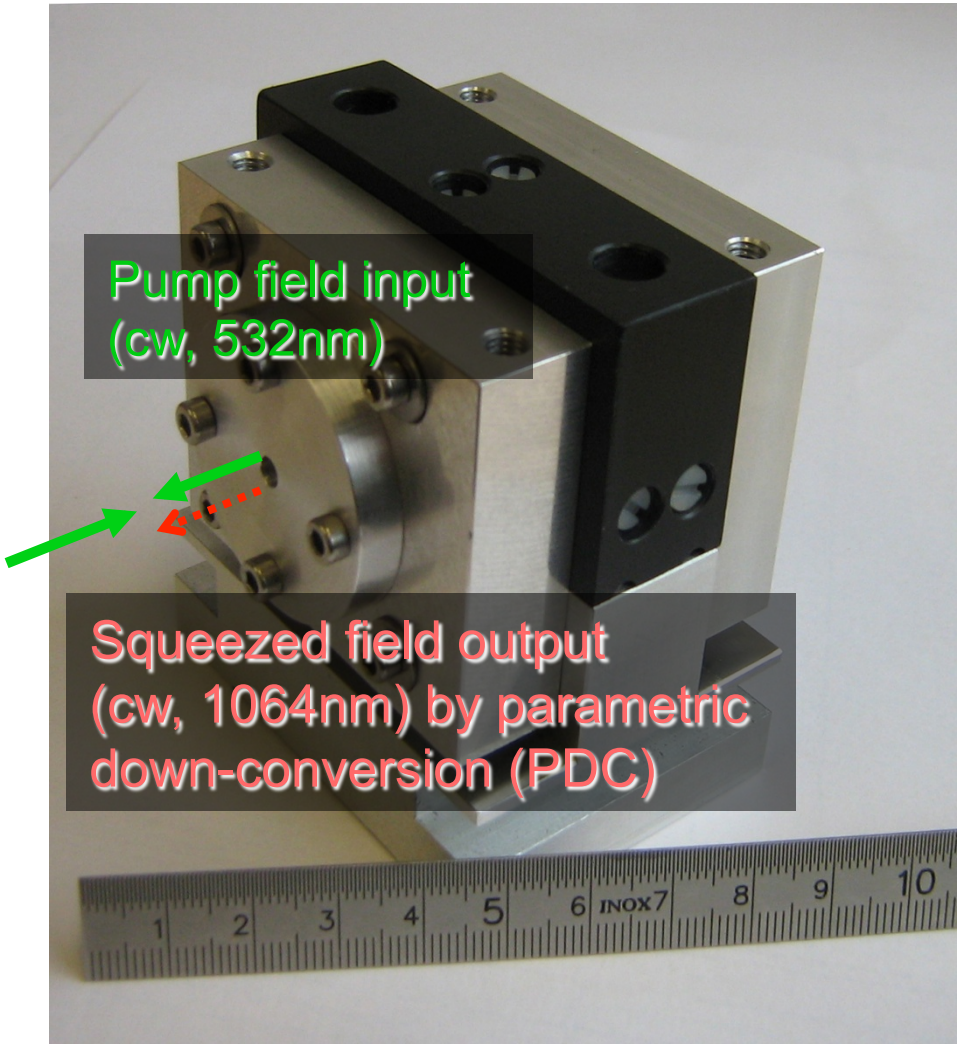
Generation of Squeezed Light (PDC)



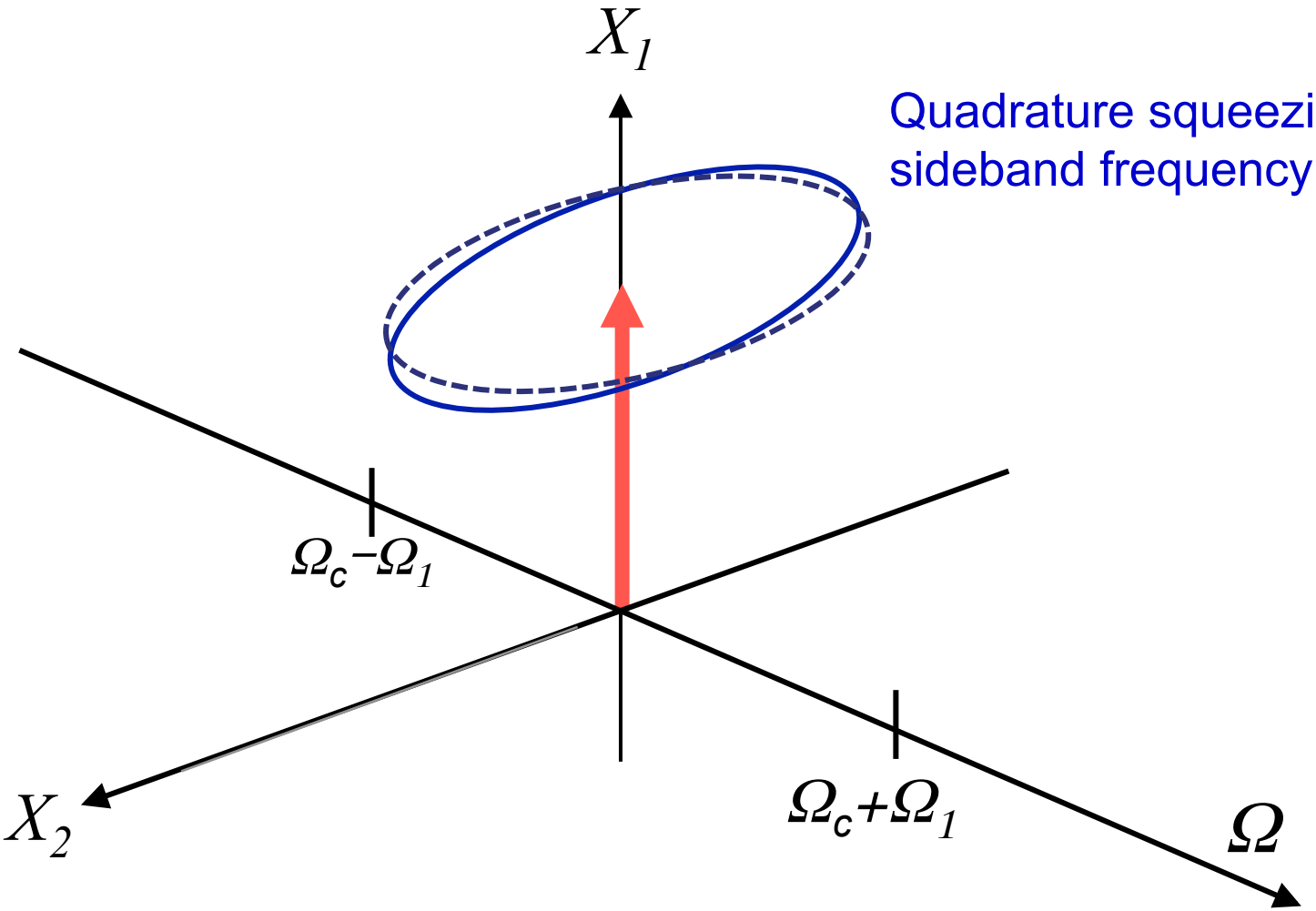
χ_2-nonlinear crystal:
$MgO:LiNbO_3$ or PPKTP



Standing wave cavity

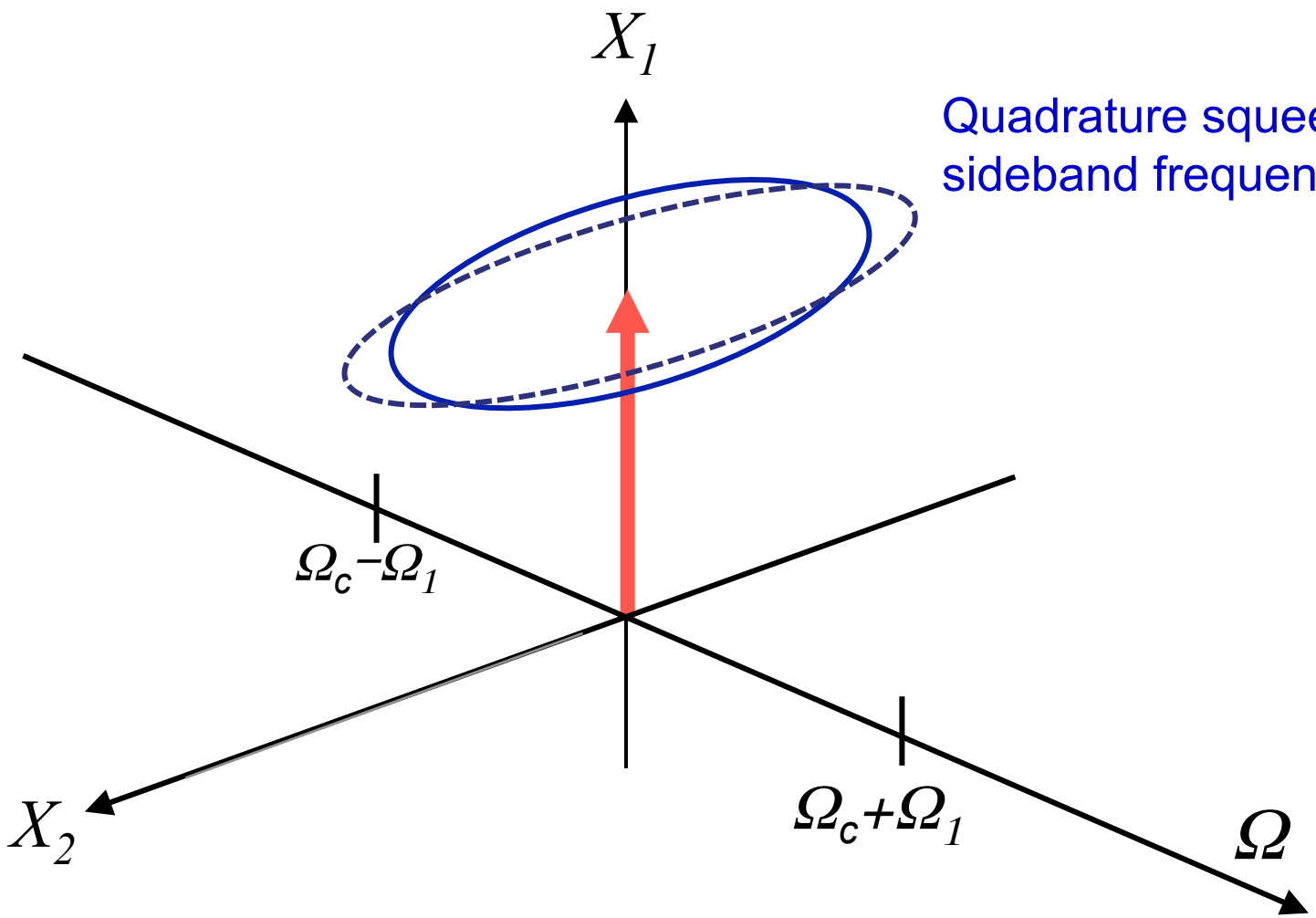


Phase Fluctuations of Pump Field



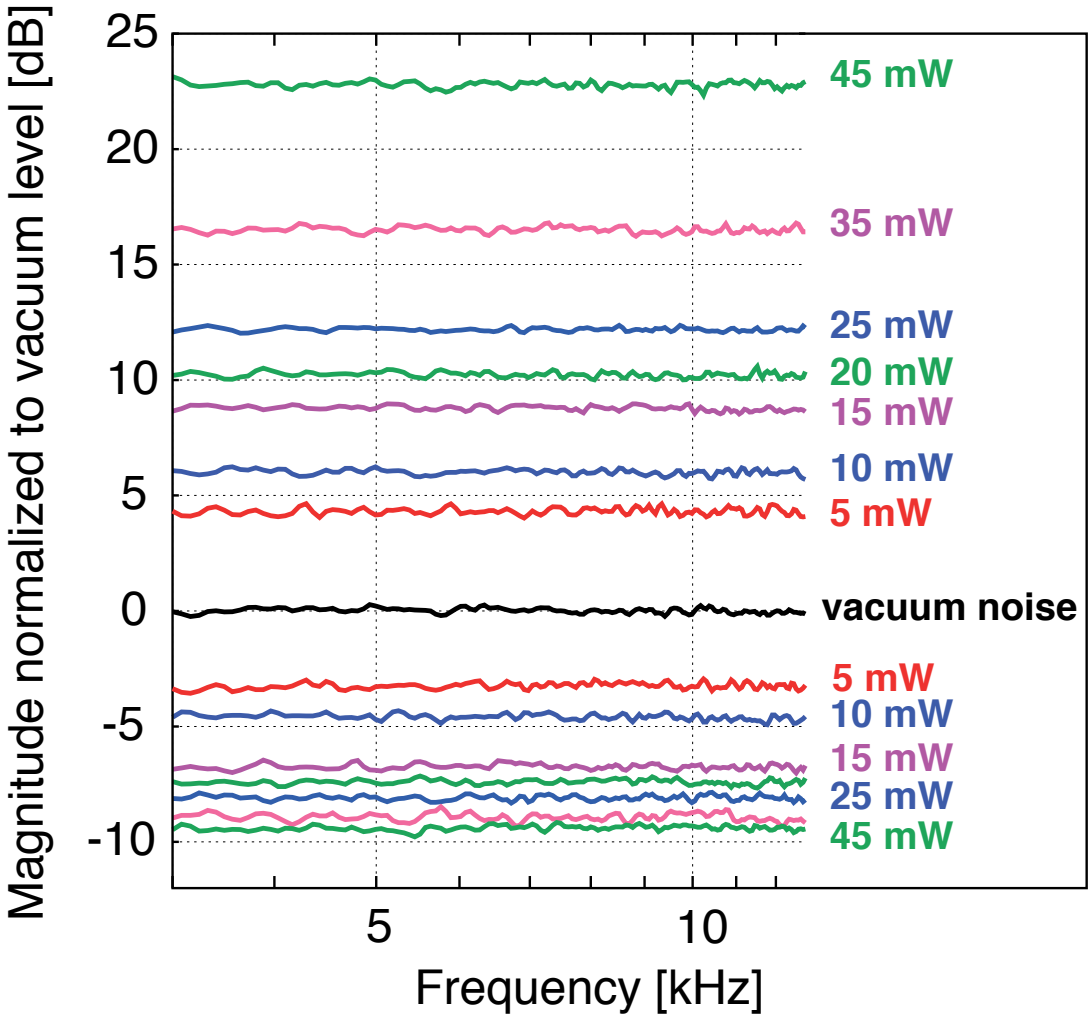
Quadrature squeezing at sideband frequency Ω_1

Amplitude Fluctuations of Pump Field



Quadrature squeezing at sideband frequency Ω_1

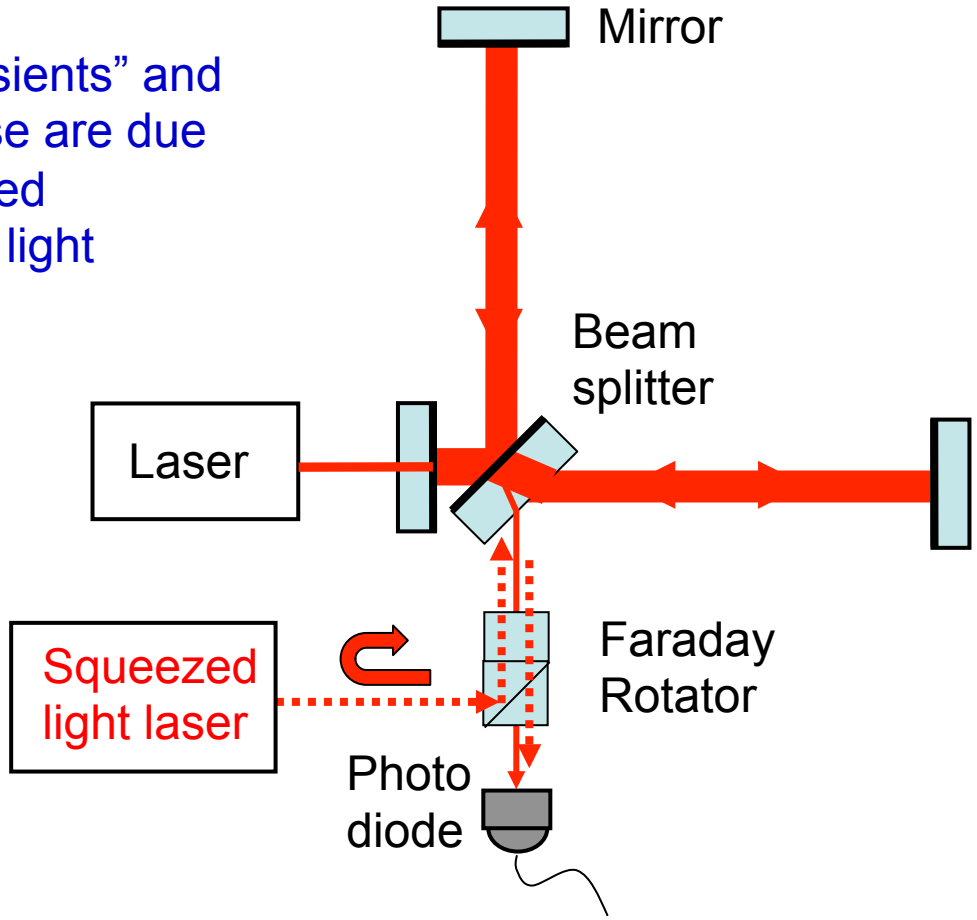
Power Changes of Pump Field



[Measurements performed on the GEO600 squeezed light source]

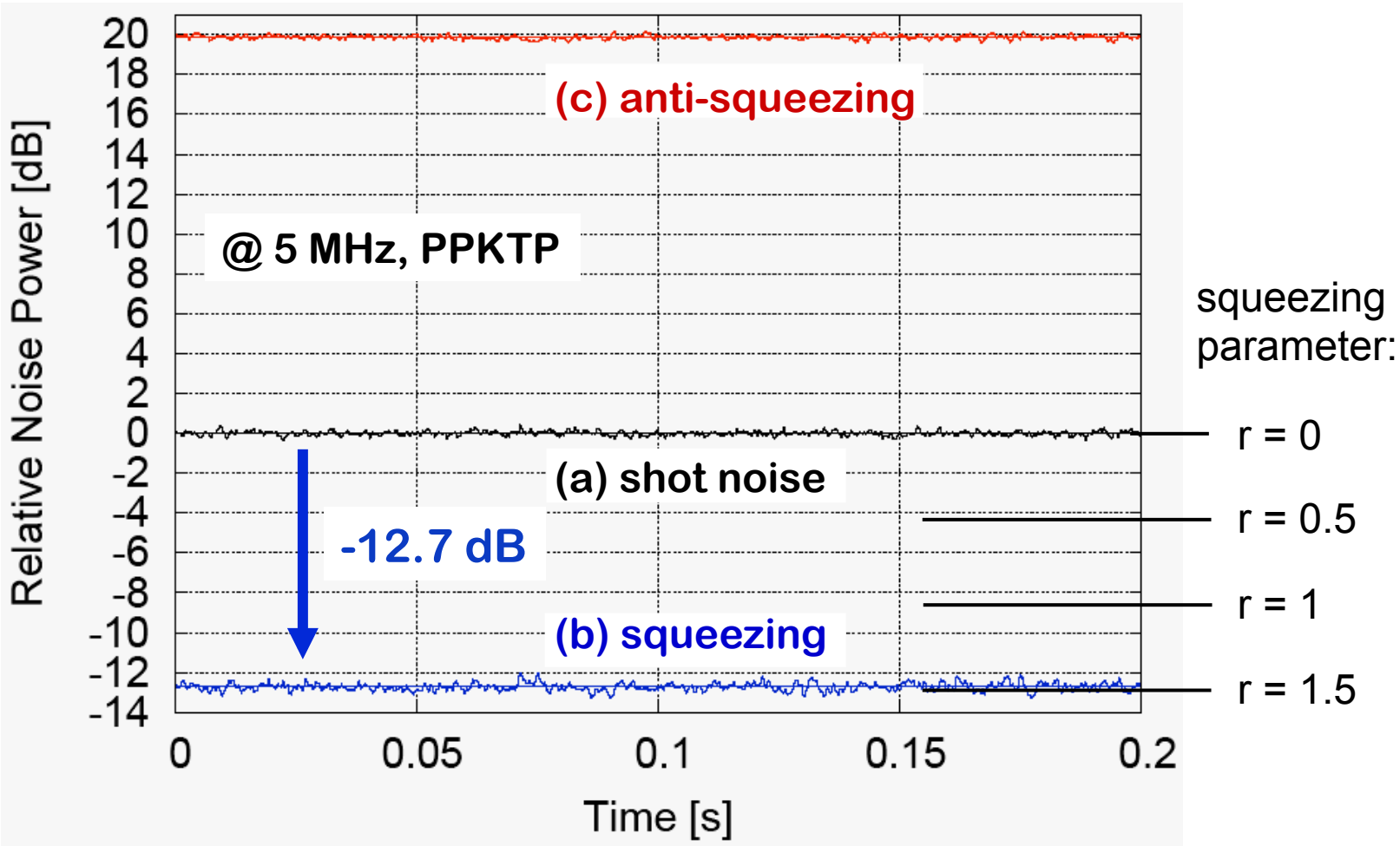
Squeezed Light Injection

Possible “transients” and stationary noise are due to retro-reflected interferometer light



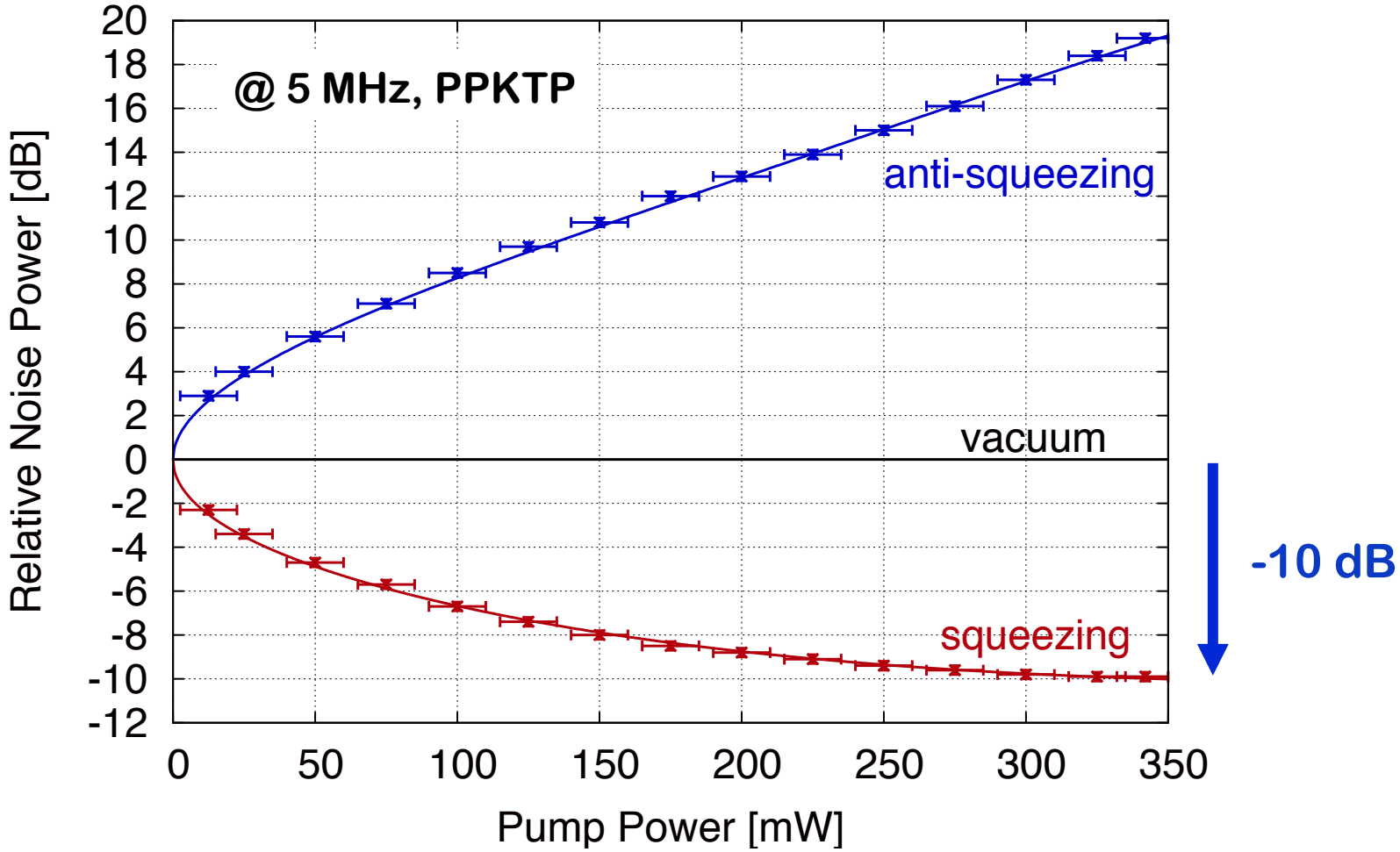
[Caves, Phys. Rev. D 23, 1693 (1981)]

Squeezing Progress at 1064 nm



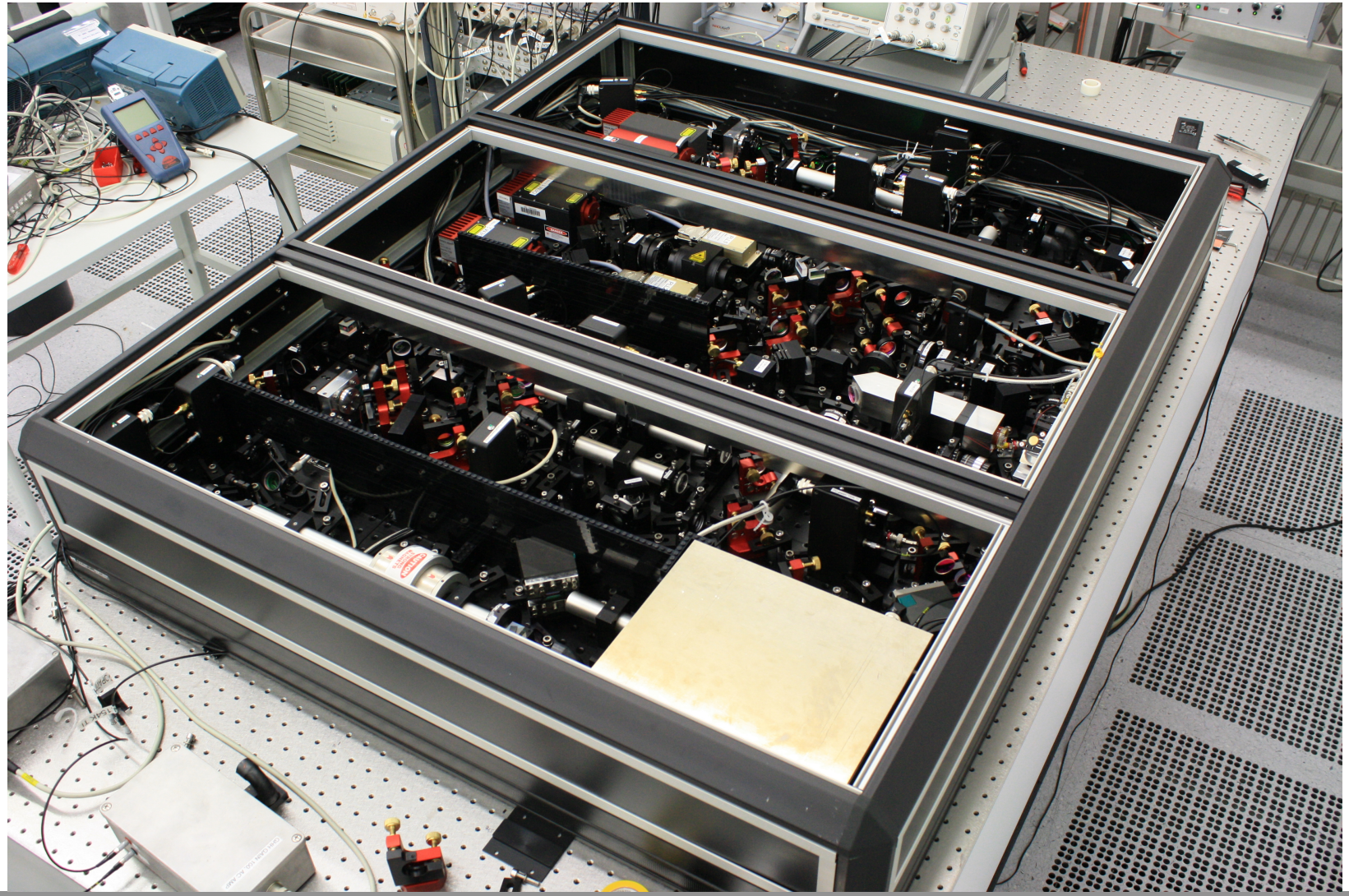
[T. Eberle *et al.*, Phys Rev. Lett. **104**, 251102 (2010).]

Squeezing Progress at 1550 nm

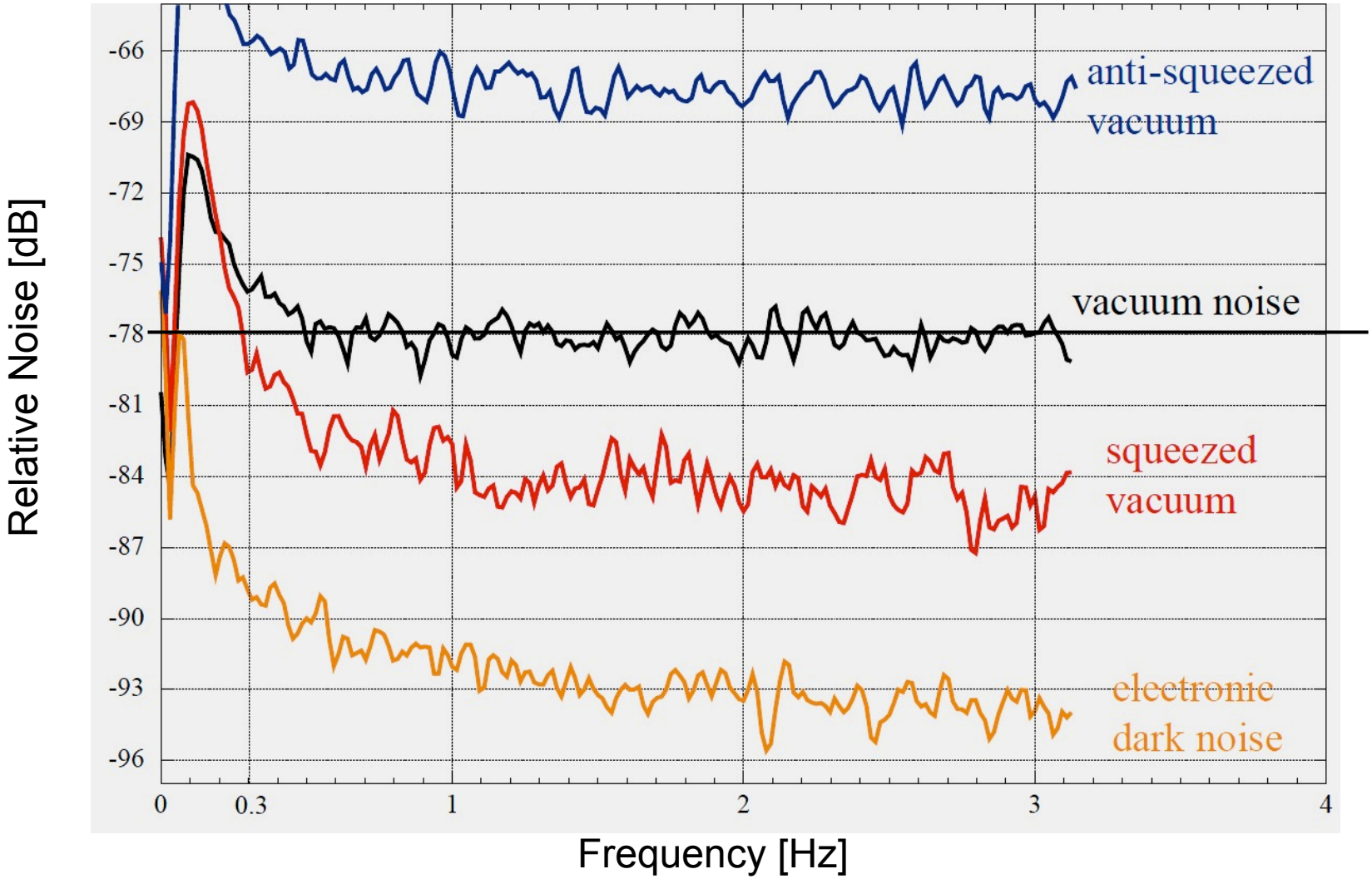


[T. Eberle *et al.*, Phys Rev. A, accepted (2011).]

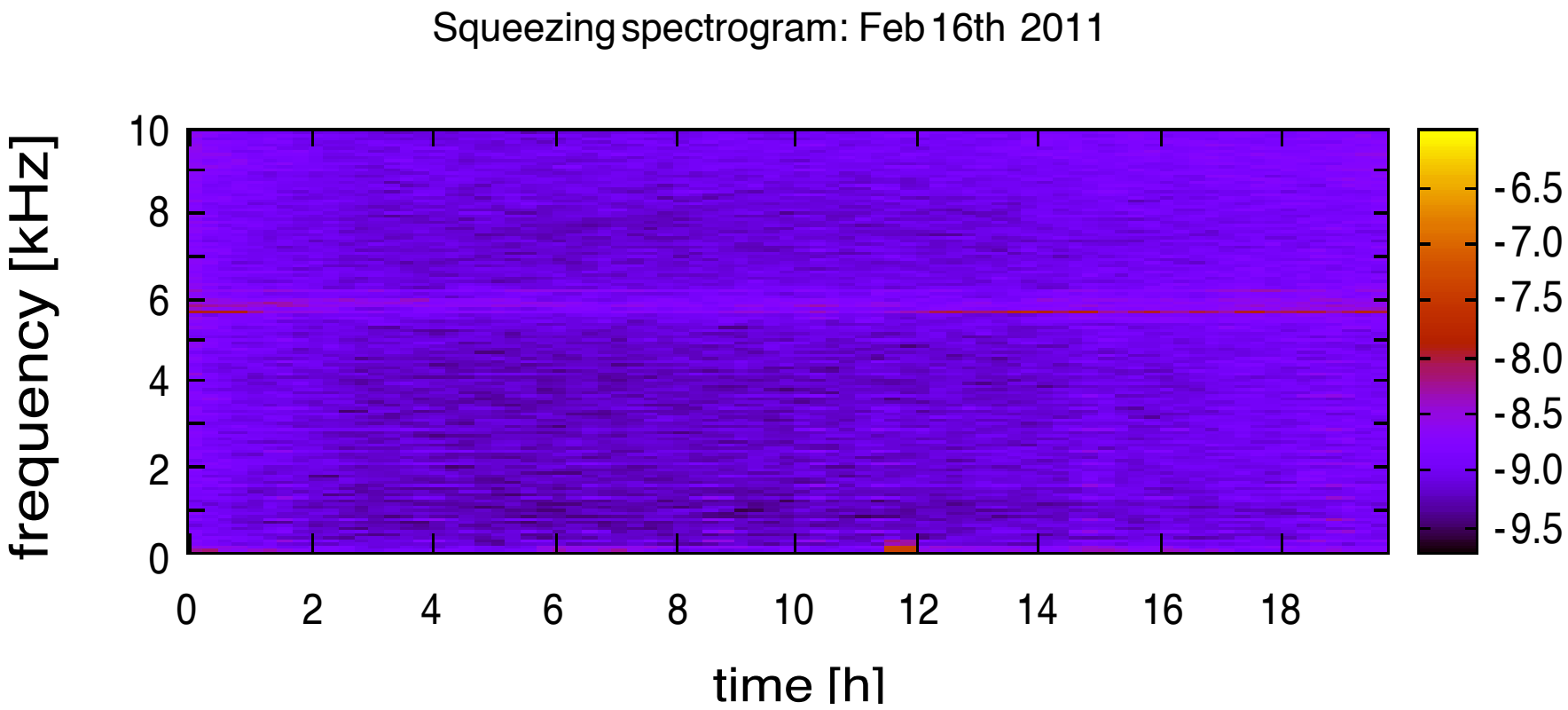
The GEO600 Squeezed Light Source



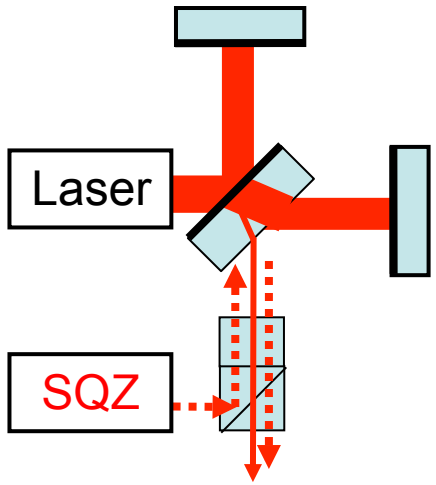
Low-f Progress: Squeezing below 1 Hz



Progress on Long-Term Stability

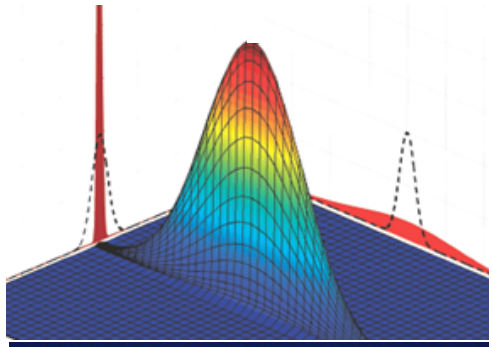


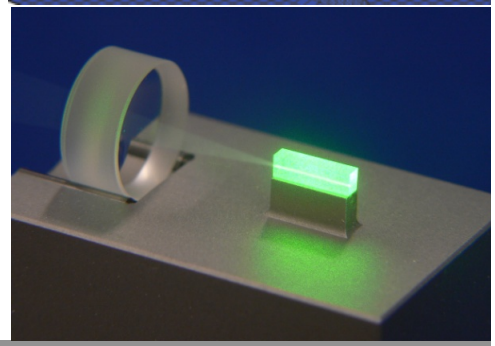
Summary



- **Only injected squeezing can reduce shot-noise and radiation pressure noise**
- **"Mode control of squeezed vacuum is not critical." Transients from the source are not expected.**
- **Progress on squeezed light lasers:**
  12.7dB @ 1064nm, 5MHz
  12.0dB @ 1550nm, 5MHz
  ~5dB @ 1064nm, <1Hz
  ~9dB @ 1064nm, 10Hz-10kHz for 20h

  [R.S. *et al.*, Nat. Comm. **1**:121 (2010)]





Centre of Excellence:
Quantum engineering and space time research

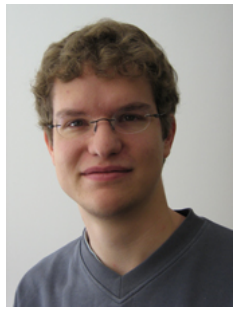
PhD Students and Postdocs

H. Vahlbruch

A. Khalaidovski

J. DiGuglielmo

B. Hage


S. Steinlechner

M. Mehmet

A. Thüring

A. Samblowski

H. Müller-Ebhardt

N. Lastzka

J. Bauchrowitz

T. Eberle