Low frequency squeezing in Rb vapor

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The College of William & Mary

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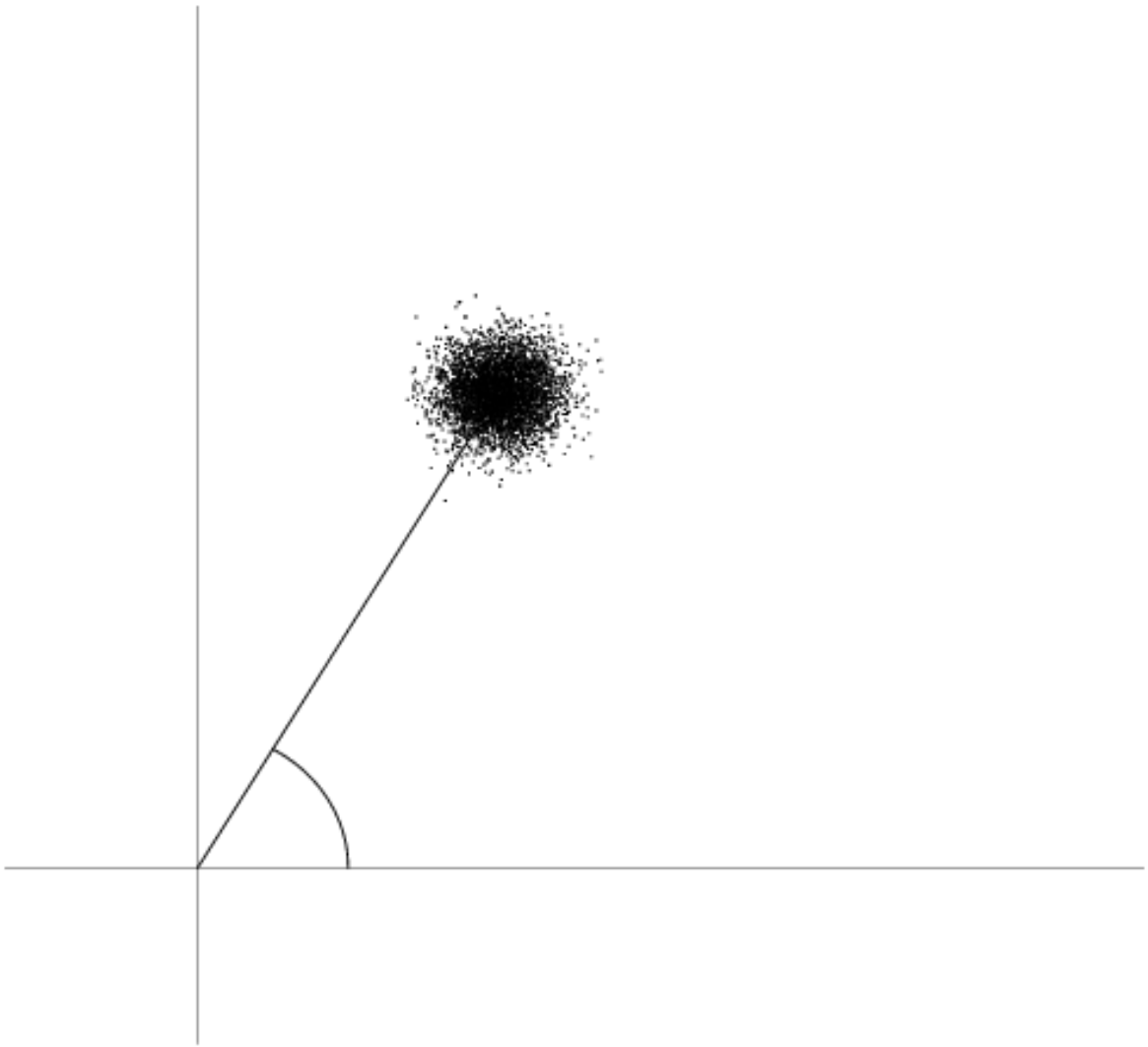
PQE

Noise ball picture



Heisenberg uncertainty principle

Optics equivalent

$\Delta\phi\Delta N \geq 1$

The more precisely the PHASE is determined, the less precisely the AMPLITUDE is known, and vice versa

Optics equivalent strict definition

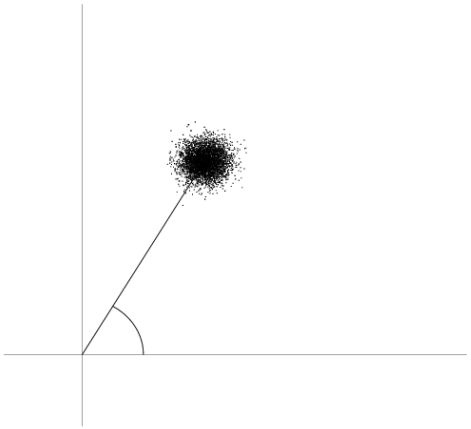
$\langle \Delta X_1^2 \rangle \langle \Delta X_2^2 \rangle \geq 1$

$$X_1 = \frac{a + a^\dagger}{\sqrt{2}}$$

$$X_2 = \frac{a - a^\dagger}{\sqrt{2}i}$$

Coherent states of light

unsqueezed



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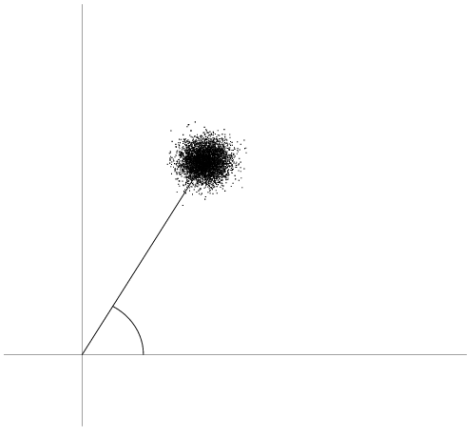
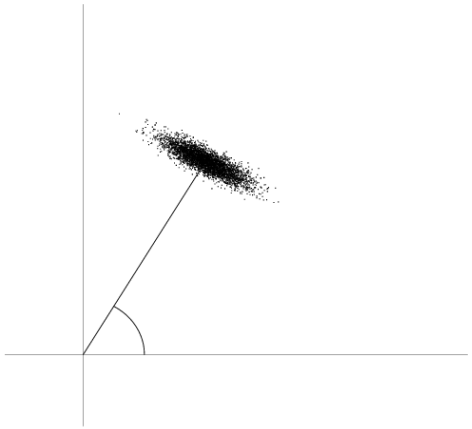


amplitude-squeezed



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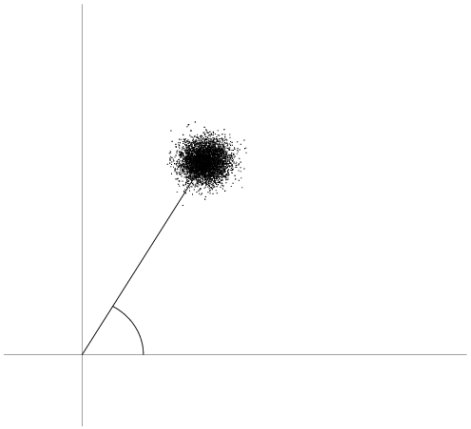

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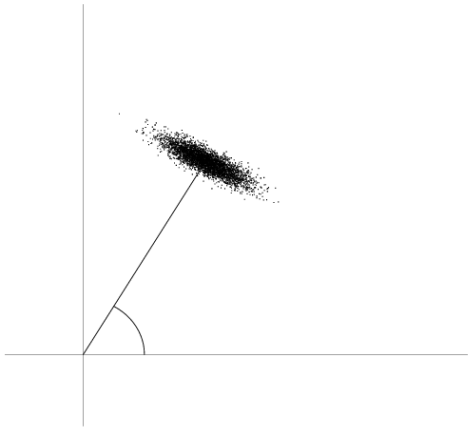
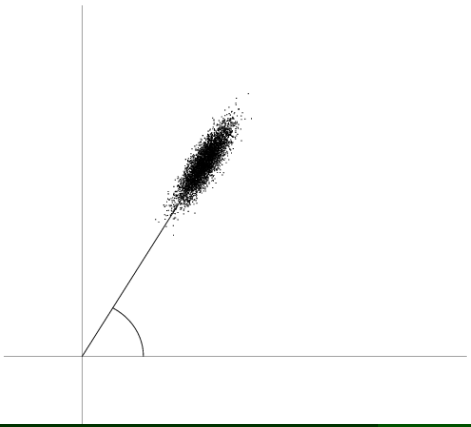
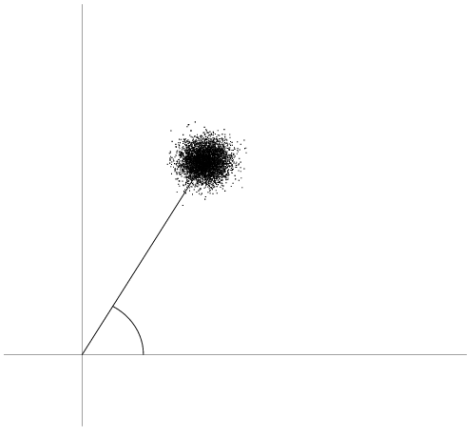


phase-squeezed

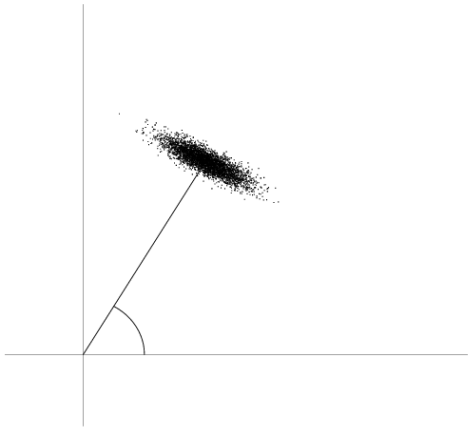


Coherent states of light

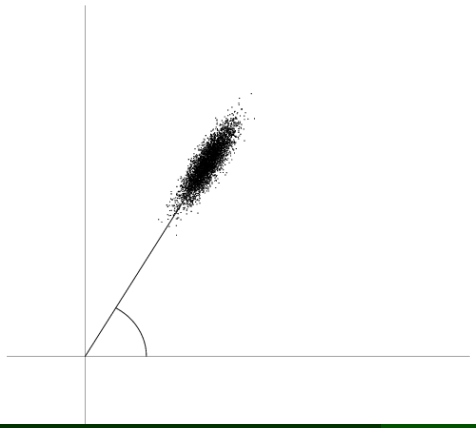
unsqueezed



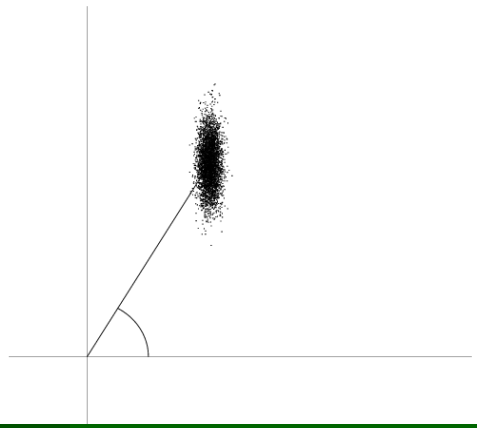
amplitude-squeezed



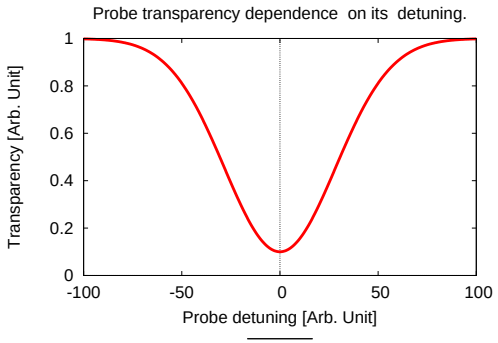
phase-squeezed

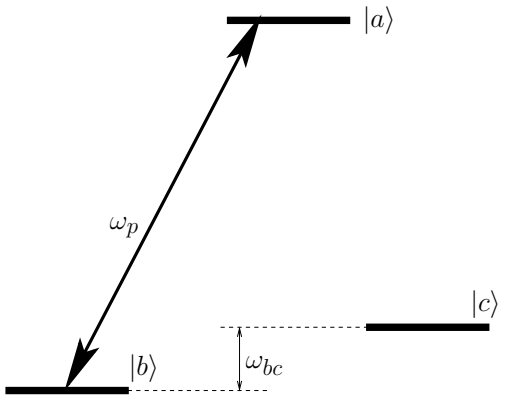


angle-squeezed



Quantum memory with atomic ensembles





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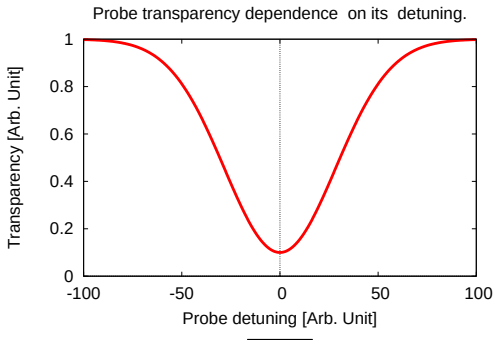

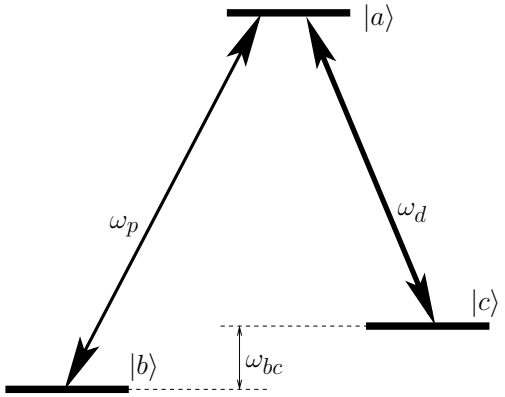

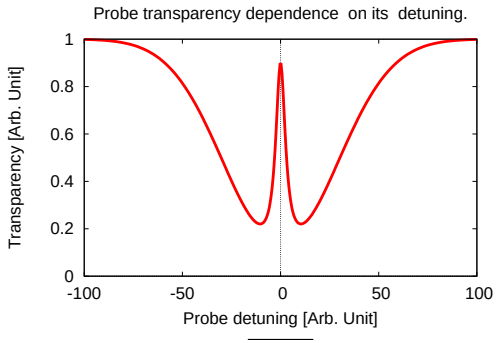

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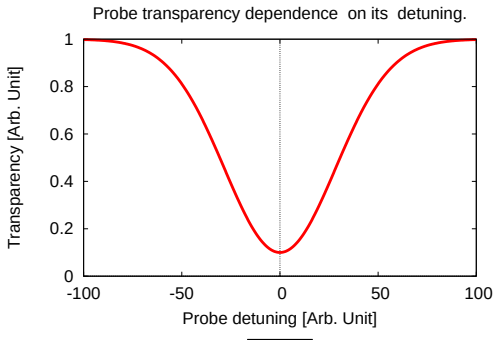
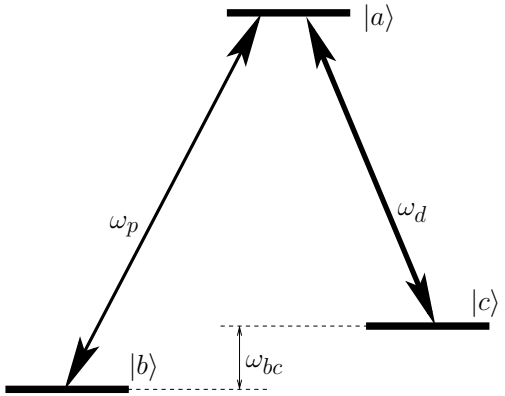
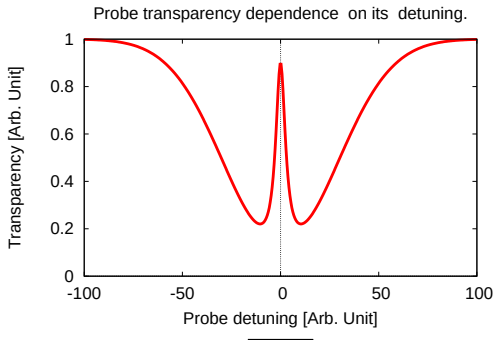
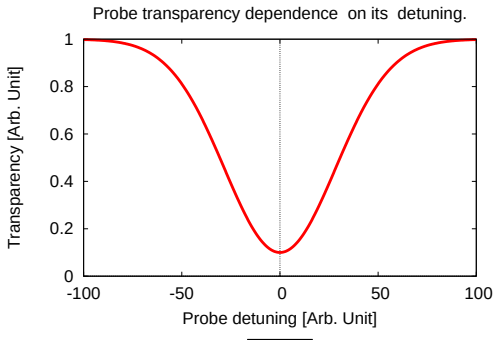


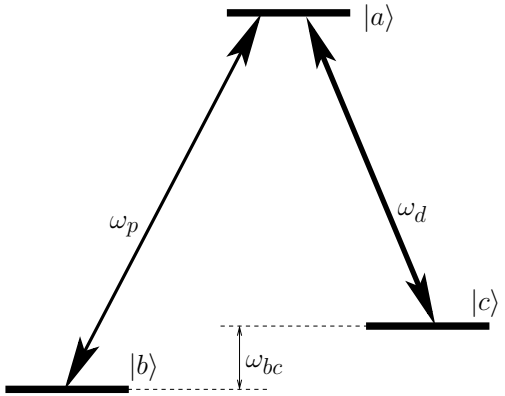


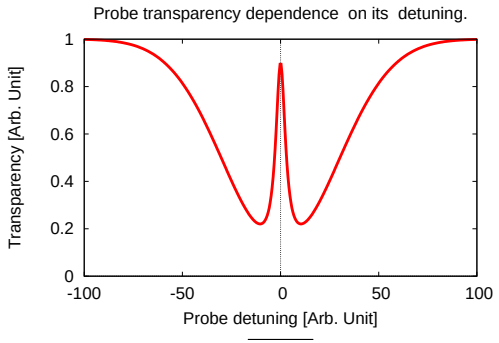


Storage and retrieval

Quantum memory with atomic ensembles



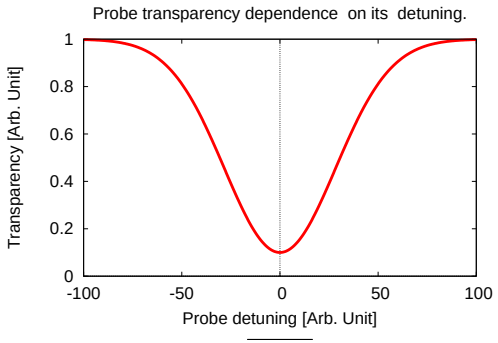


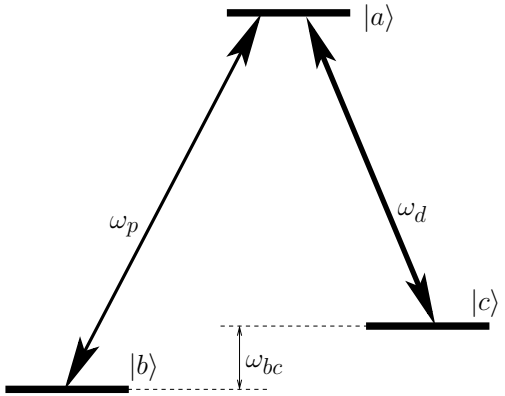


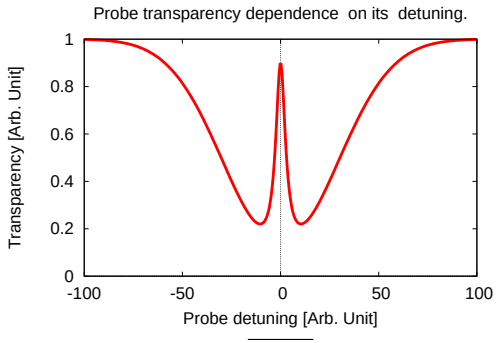
Storage and retrieval

- single photon

Quantum memory with atomic ensembles







Storage and retrieval

- single photon
- squeezed state (Furusawa and Lvovsky PRL **100** 2008)

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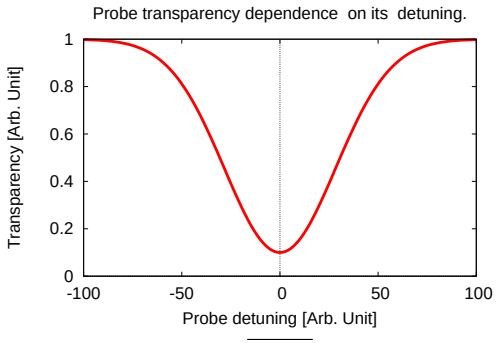

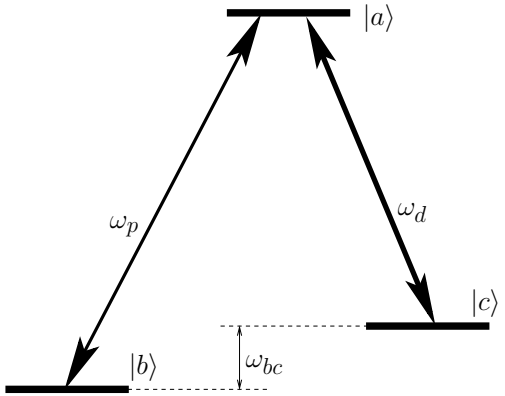

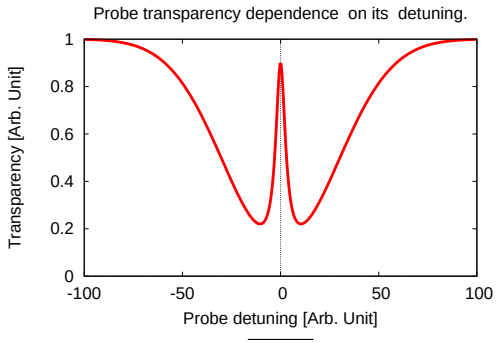

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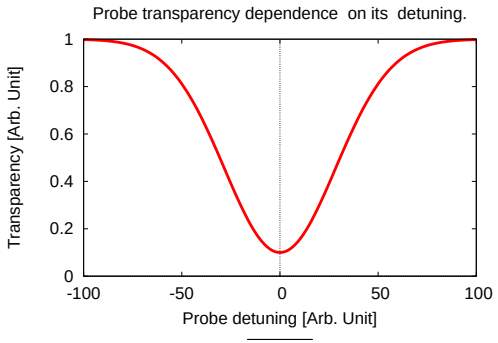
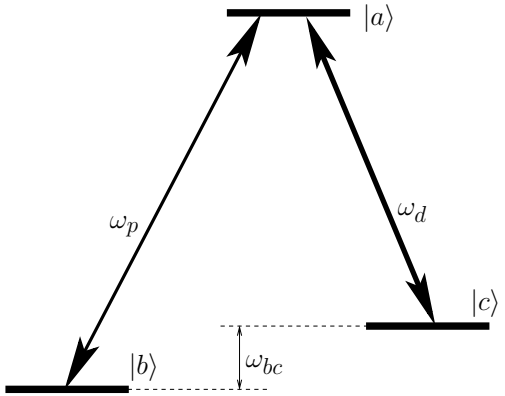
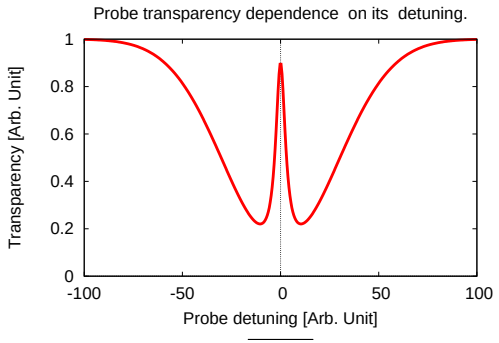
Squeezed state requirements for a quantum memory probe

Quantum memory with atomic ensembles







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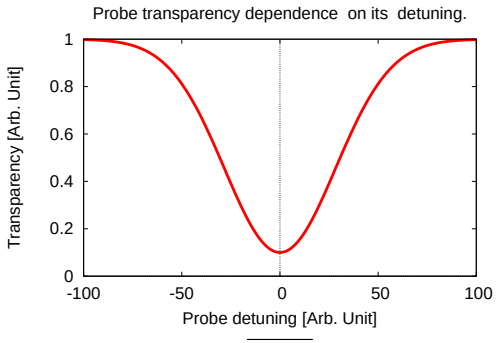
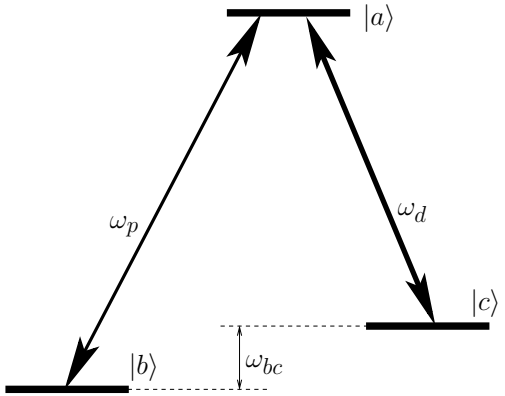
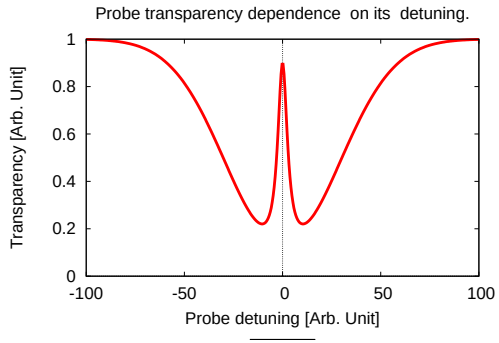
Squeezed state requirements for a quantum memory probe

- squeezing carrier at atomic wavelength (780nm, 795nm)
- squeezing within narrow resonance window at frequencies($<$100kHz)

Quantum memory with atomic ensembles







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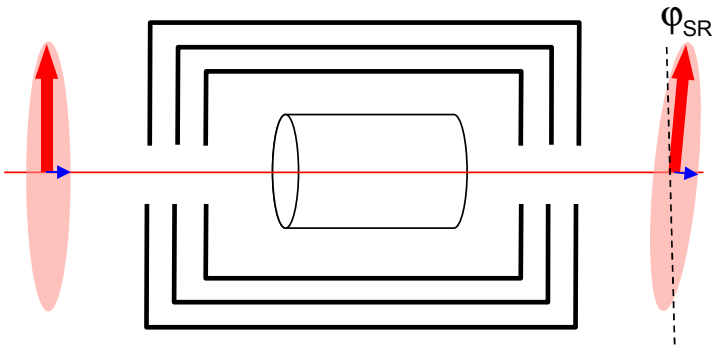
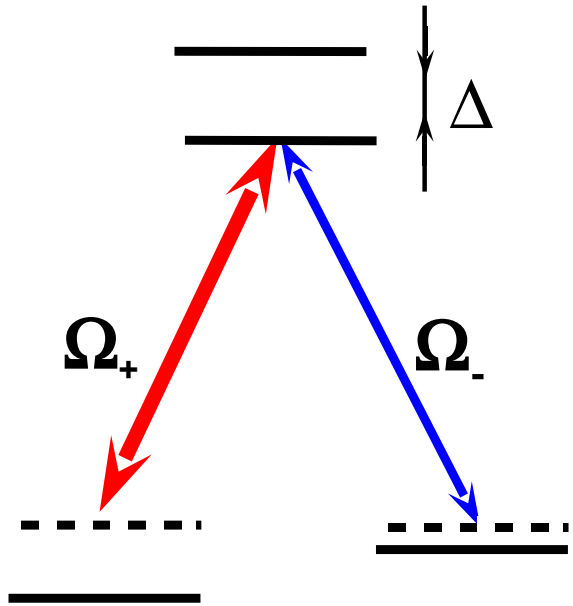
Traditional nonlinear crystal based squeezers are capable of it, but they are extremely technically challenging especially at short wave length.

Self-rotation of elliptical polarization in atomic medium





A.B. Matsko et al., PRA 66, 043815 (2002): theoretically prediction of 4-6 dB noise suppression

$$a_{out} = a_{in} + \frac{igL}{2}(a_{in}^{\dagger} - a_{in}) \qquad (1)$$

Will something so simple work?

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- Yes! J. Ries, B. Brezger, and A. I. Lvovsky, Experimental vacuum squeezing in rubidium vapor via self-rotation, PRA **68**, 025801 (2003).
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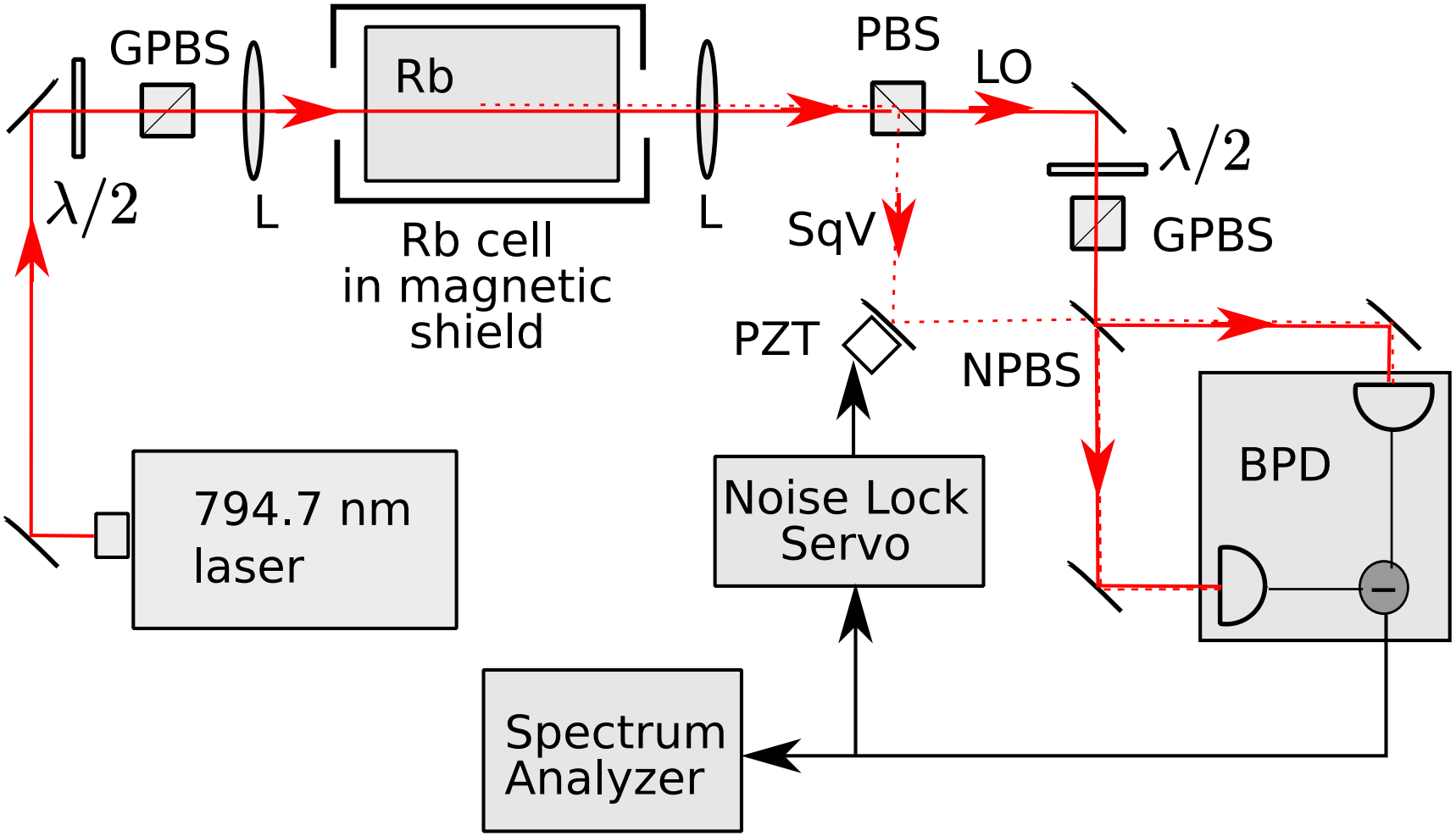
- Possible. A. Lezama et al., PRA **77**, 013806 (2008).

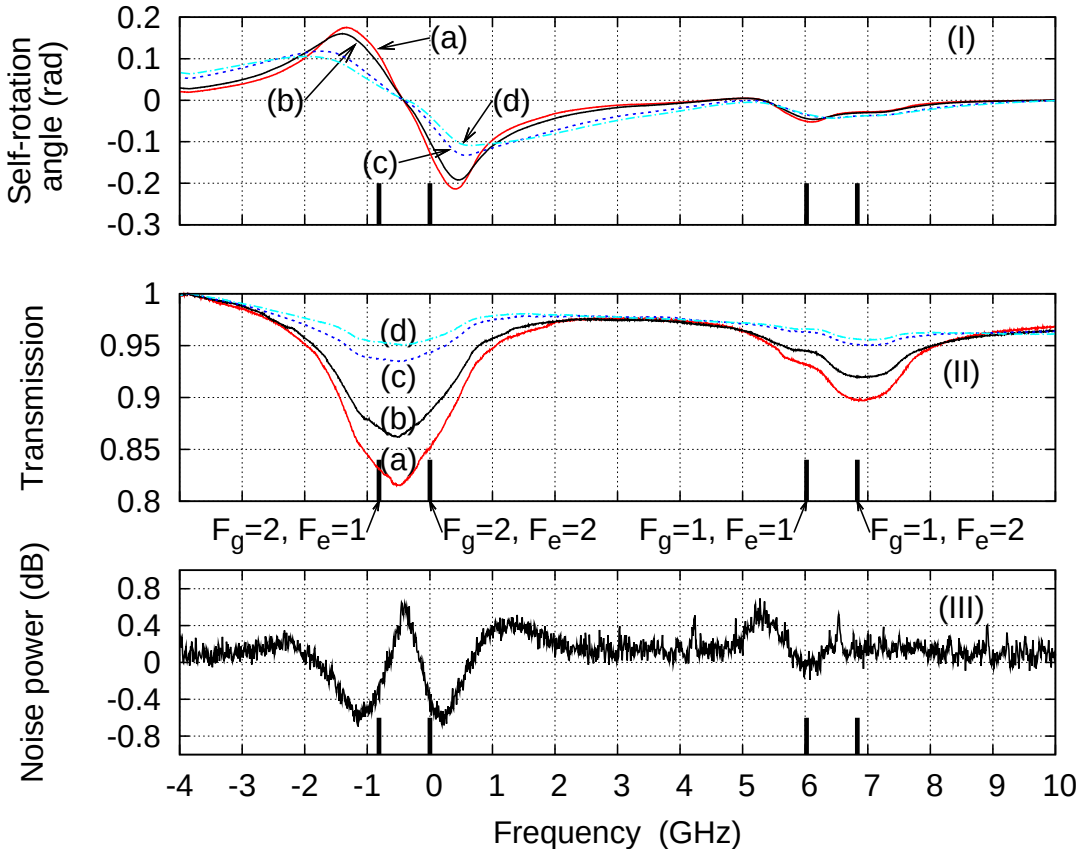
Setup


GPBS
Rb
PBS
LO
$\lambda/2$
L
Rb cell
in magnetic
shield
L
SqV
$\lambda/2$
GPBS
PZT
NPBS
BPD
794.7 nm
laser
Noise Lock
Servo
Spectrum
Analyzer

Squeezing vs detuning in ^{87}Rb at 795 nm

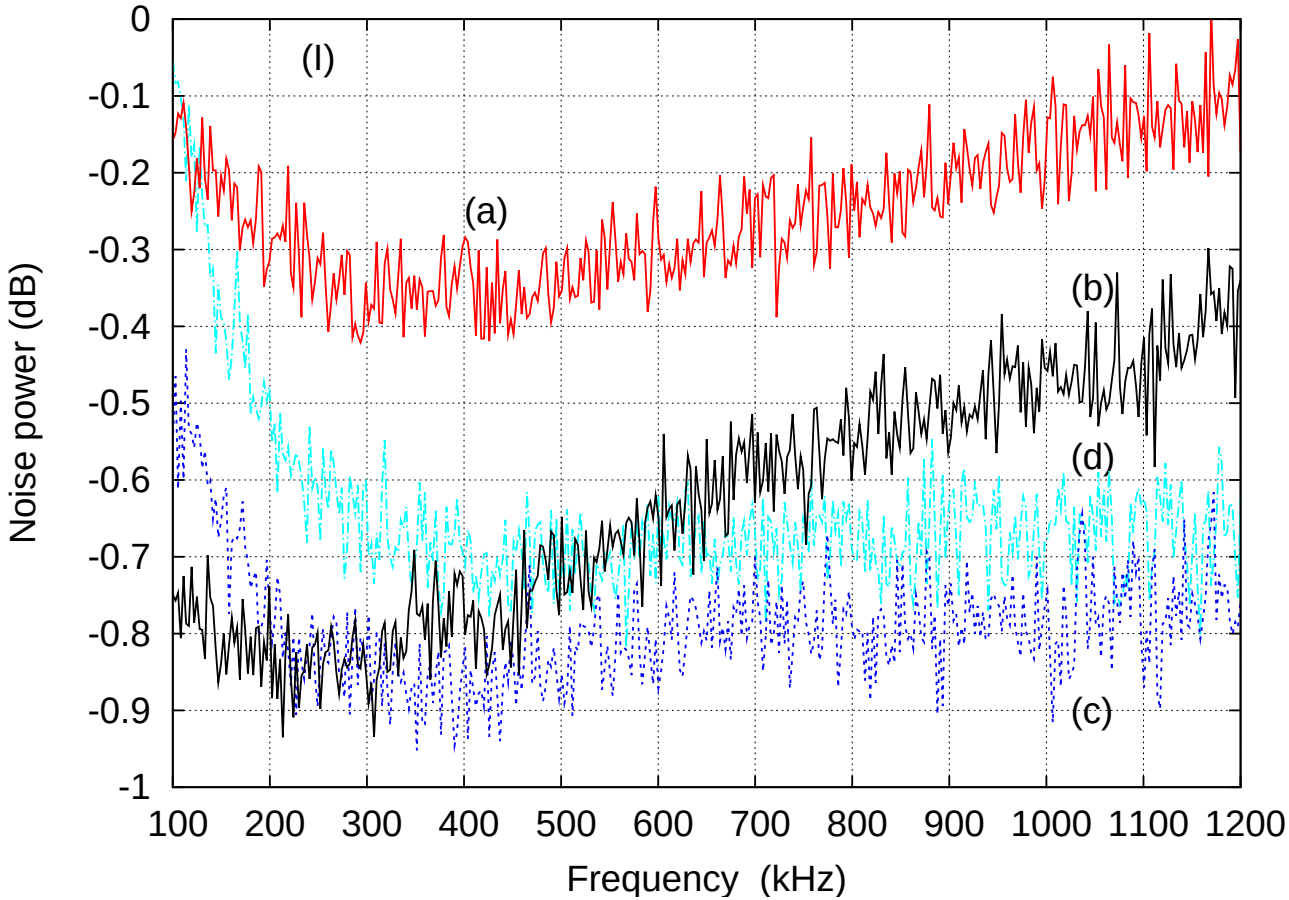
^{87}Rb cell + 2.5Torr Ne

(a) P=1.0 mW, (b) P=1.5 mW, (c) P=4.2 mW, (d) P=6.6 mW



Low frequency squeezing vs noise sidebands frequency in ^{87}Rb at 795 nm

^{87}Rb cell + 2.5Torr Ne, T=63.3°C
(a) P=1.0 mW, (b) P=1.5 mW, (c) P=4.2 mW, (d) P=6.6 mW



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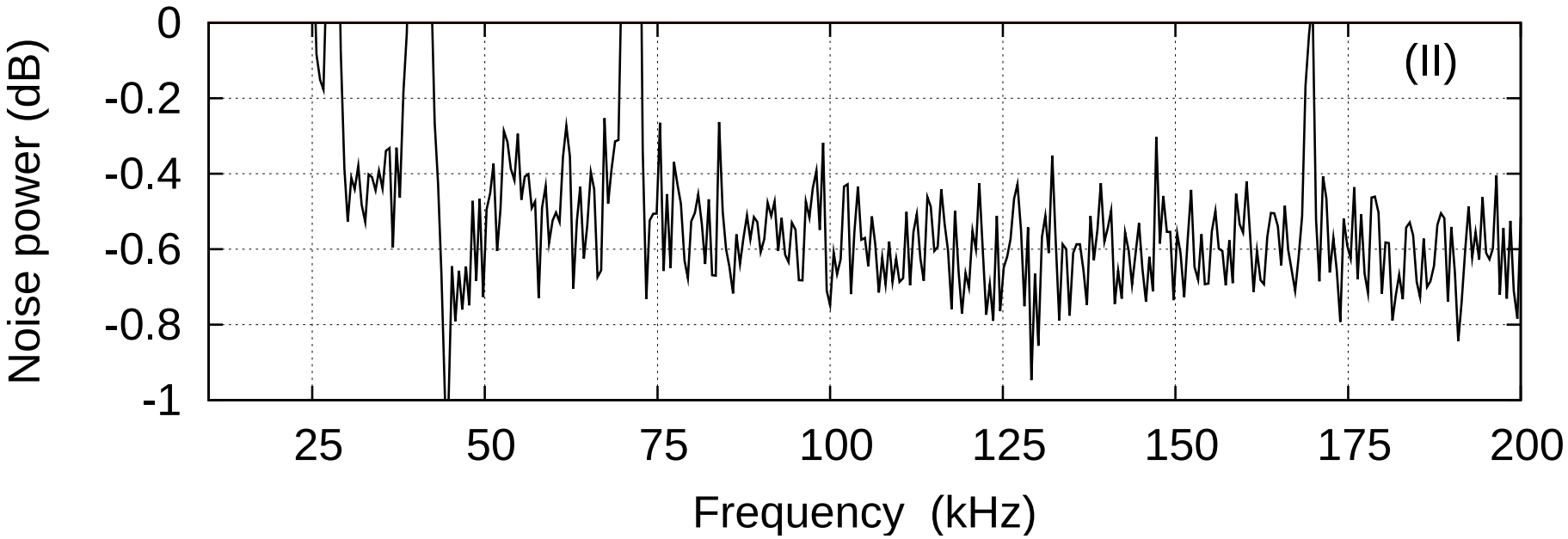
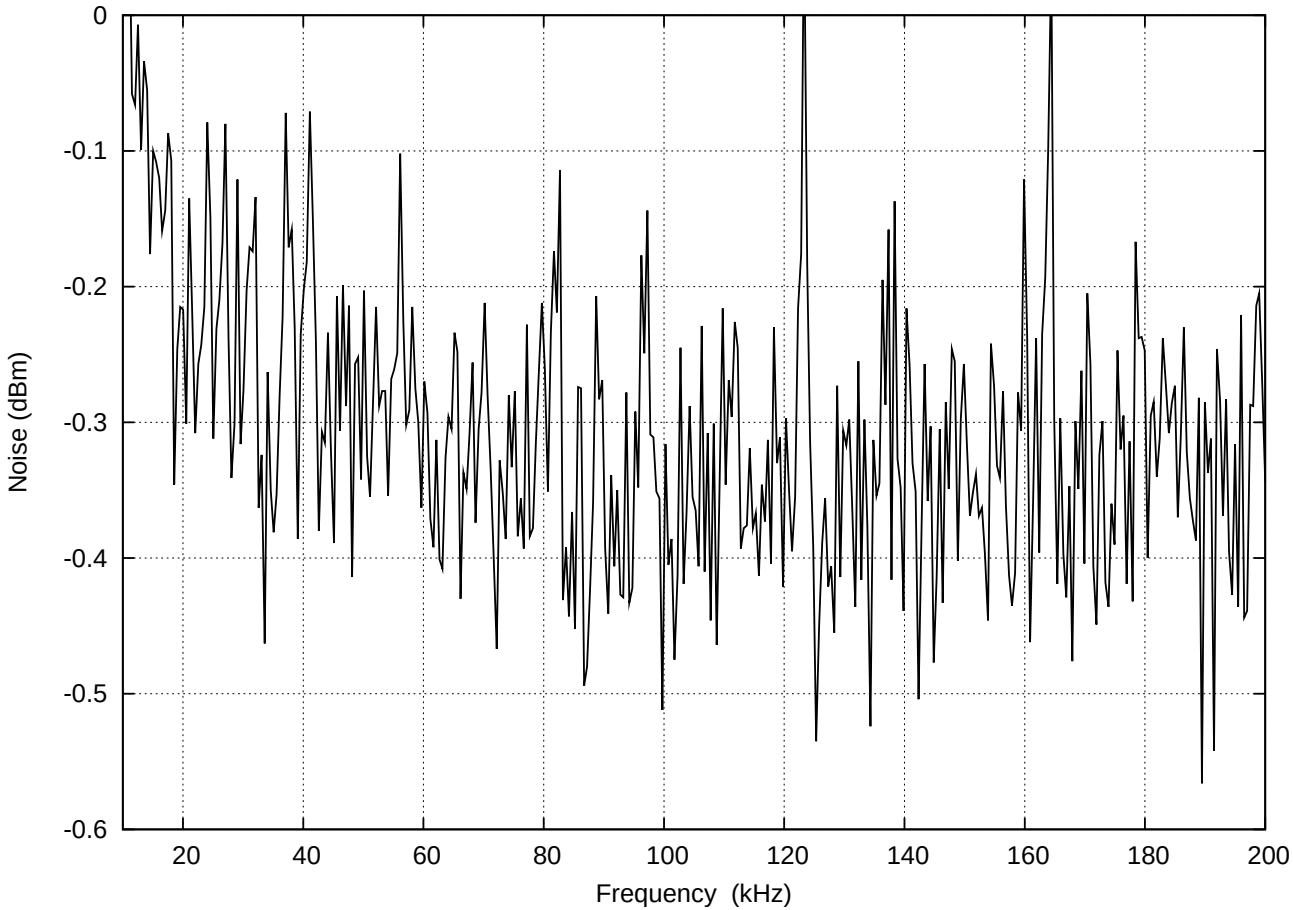


Eugeniy E. Mikhailov, Irina Novikova: Optics Letters, Issue 11, 33, 1213-1215, (2008).

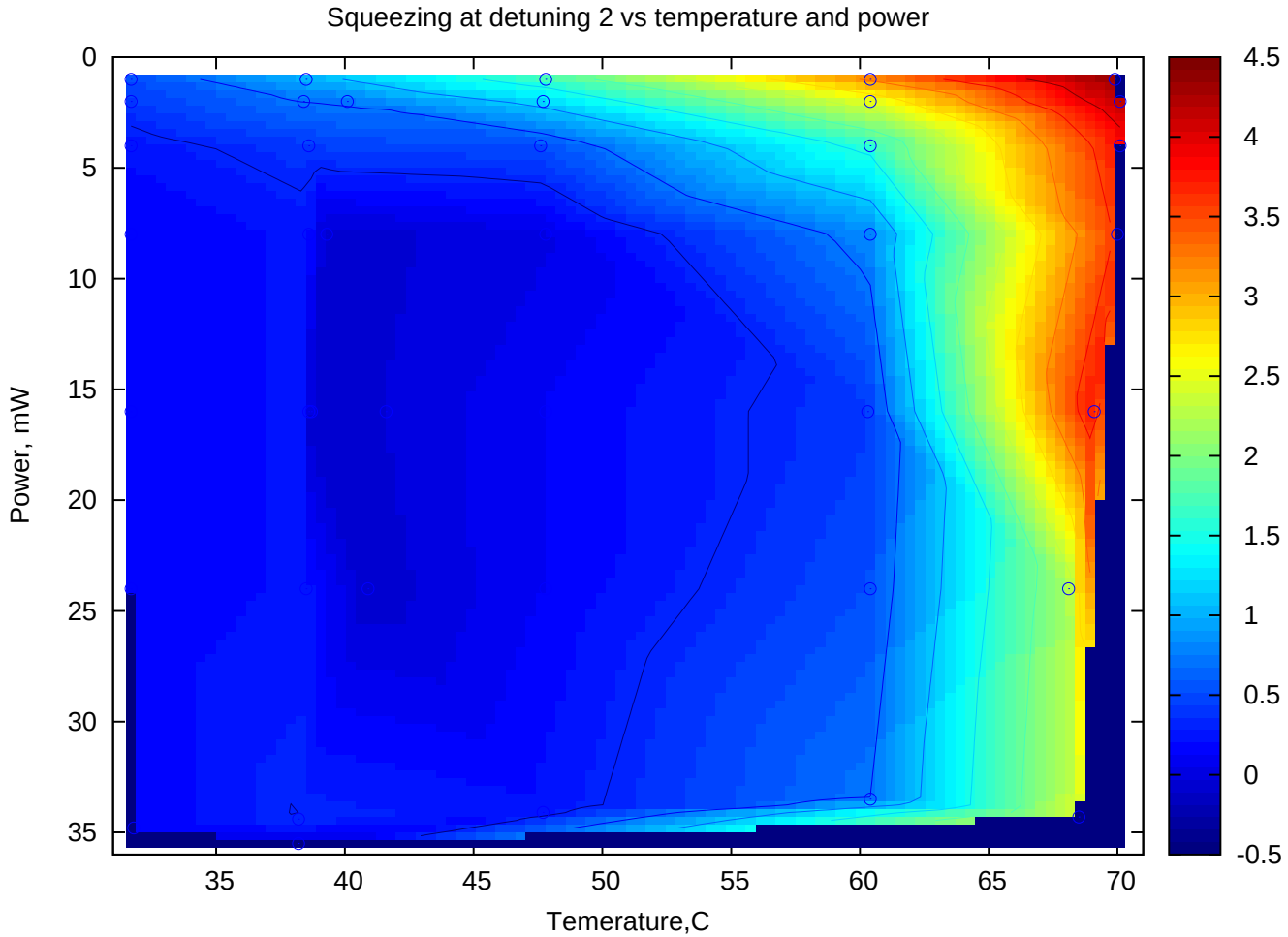
Low frequency squeezing vs noise sidebands frequency in ^{87}Rb at 795 nm

^{87}Rb cell + 5Torr Ne, T=63.3°C
P=0.5 mW



Excess noise and the source of the controversy

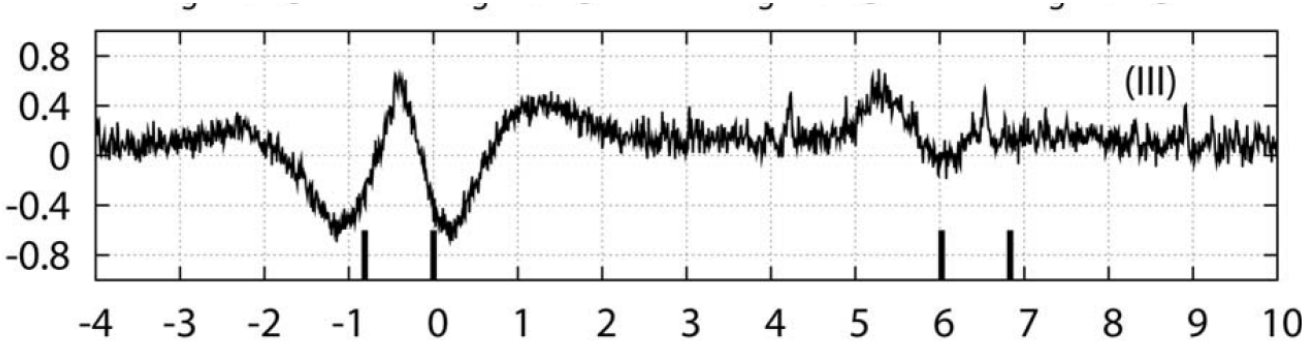
No buffer gas near $F_g = 2 \rightarrow F_e = 2$ transition

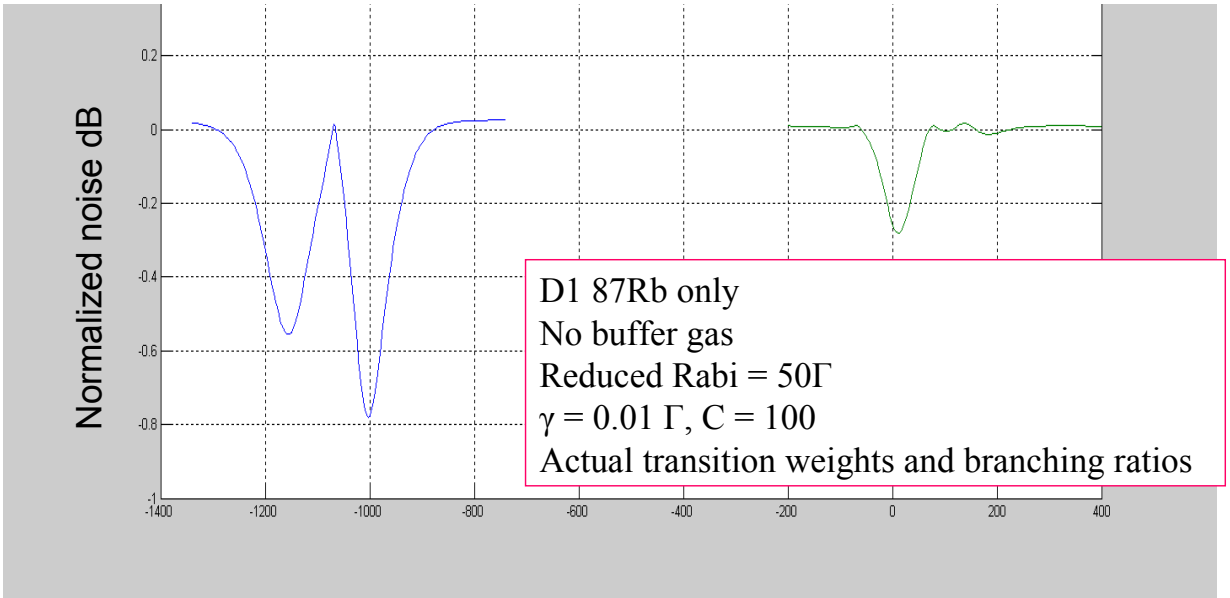


Squeezing occurs in the rather narrow parameters space

Squeezing vs detuning in ^{87}Rb theory vs experiment

^{87}Rb cell + 2.5Torr Ne. P=1.5 mW





Numerical calculations are done by Dr. Arturo Lezama

Summary

- Self-rotation based squeezing is possible
  Eugeniy E. Mikhailov, Irina Novikova: Optics Letters, Issue 11, 33, 1213-1215, (2008).
- Squeezing is generated in the range from 10 kHz to several MHz
- Such vacuum squeezing is suitable for atomic quantum memory tests

People involved

- Eugeniy E. Mikhailov
- Irina Novikova
- Tom Noel