Superluminal propagation of pulsed squeezed vacuum

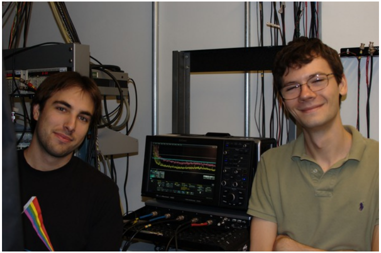
Eugeniy E. Mikhailov,
Travis Horrom, Gleb Romanov, and Irina Novikova

The College of William & Mary, USA

LPHYS, July 16, 2013

People

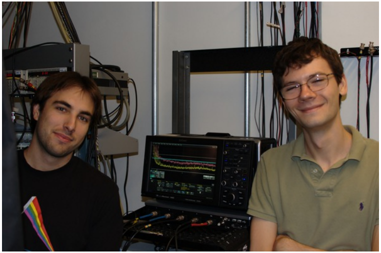
Travis Horrom and Gleb Romanov



Irina Novikova

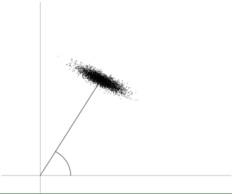
People

Travis Horrom and Gleb Romanov



Irina Novikova

Squeezed state



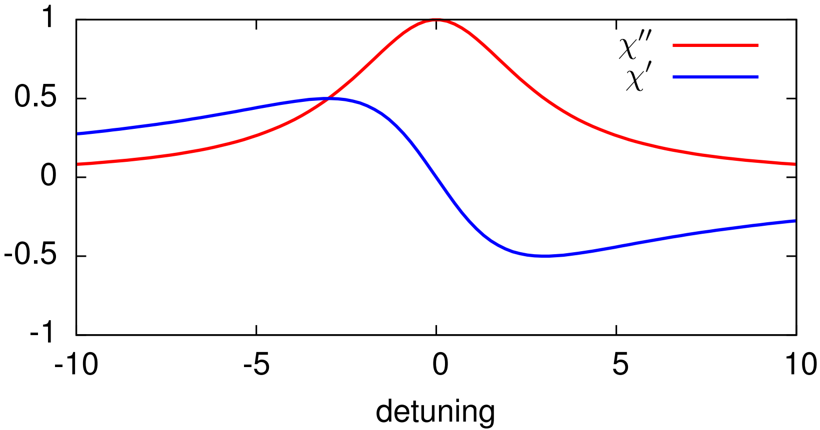
Why superluminal squeezing?

- Quantum memories
- M. S. Shahriar, et al. “Ultrahigh enhancement in absolute and relative rotation sensing using fast and slow light”, Phys. Rev. A 75(5), 053807, 2007.
- Yakir Aharonov, et al. “Quantum Limitations on Superluminal Propagation”, Phys. Rev. Lett. 81, 2190 (1998)

Light group velocity

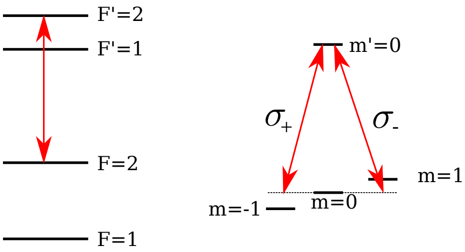
Group velocity $v_g = \frac{c}{\omega \frac{\partial n}{\partial \omega}}$

Susceptibility

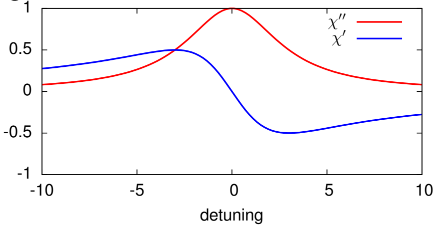


Susceptibility and Faraday effect

^{87}Rb D_1 line



Susceptibility vs detuning with magnetic field



Susceptibility and Faraday effect

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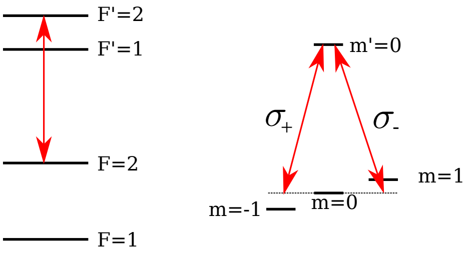

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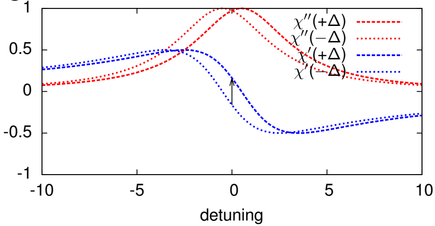

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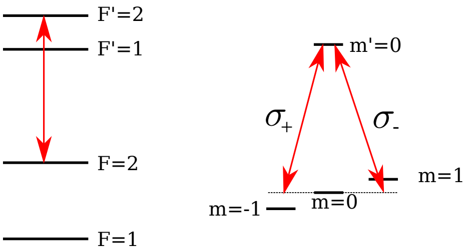
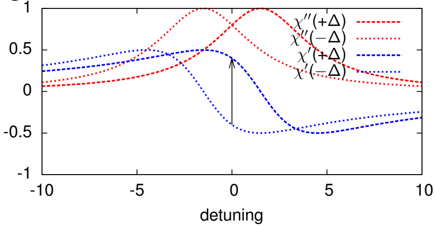


Susceptibility vs detuning with magnetic field



Susceptibility and Faraday effect

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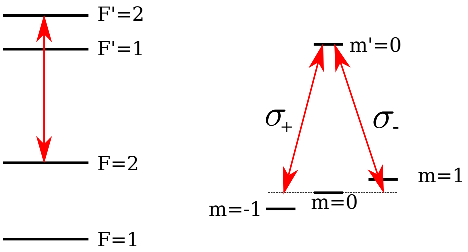
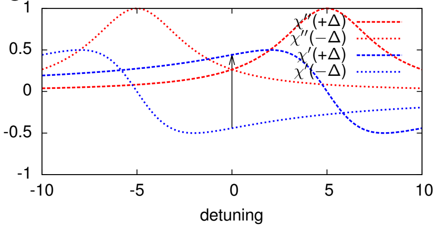


Susceptibility vs detuning with magnetic field



Susceptibility and Faraday effect

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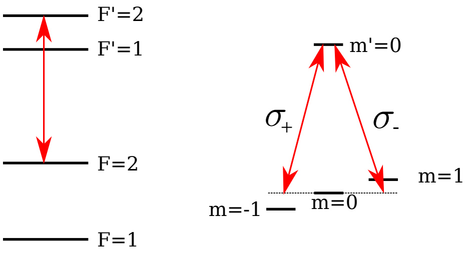

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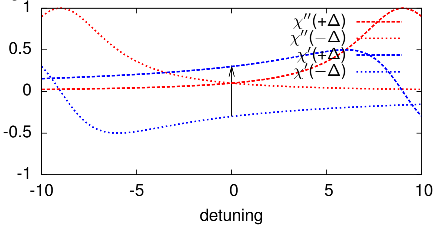

Susceptibility and Faraday effect

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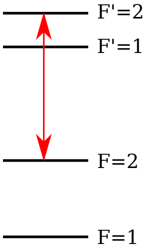
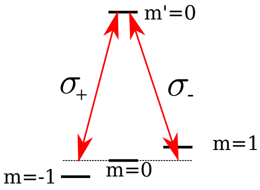
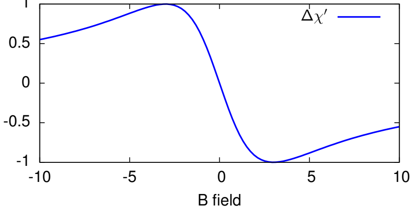
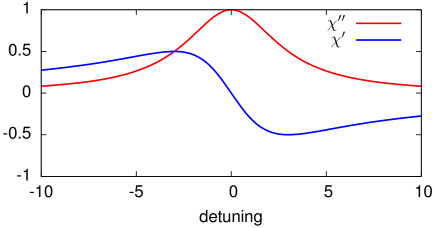




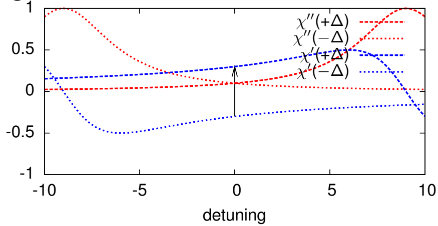
Polarization rotation vs B



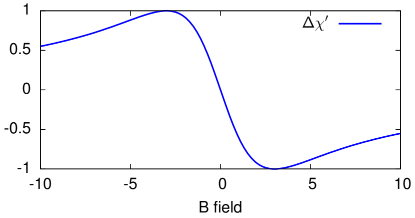
Susceptibility



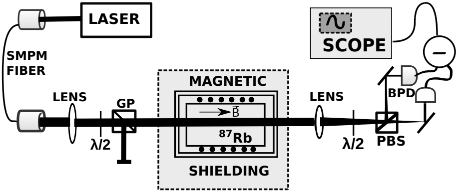
Susceptibility vs detuning with magnetic field



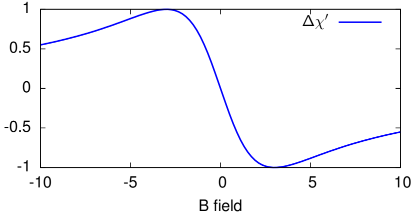
Naive model of rotation

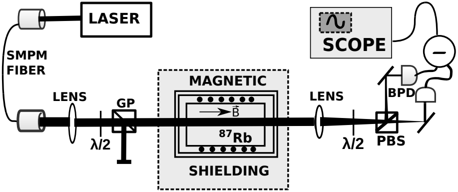


Experiment

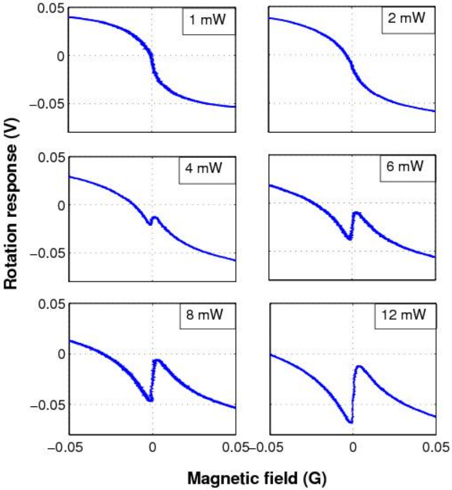


Naive model of rotation





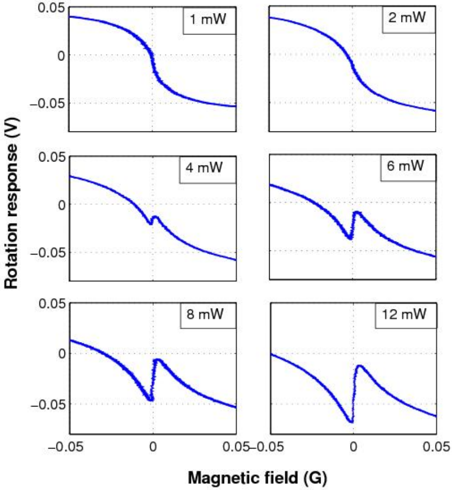
Experiment



Light group velocity

Group velocity $v_g = \frac{c}{\omega \frac{\partial n}{\partial \omega}}$

Delay $\tau = \frac{L}{v_g} \sim \frac{\partial n}{\partial \omega} \sim \frac{\partial R}{\partial B}$



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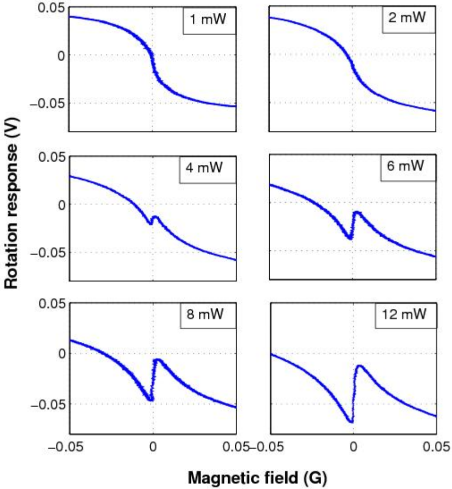
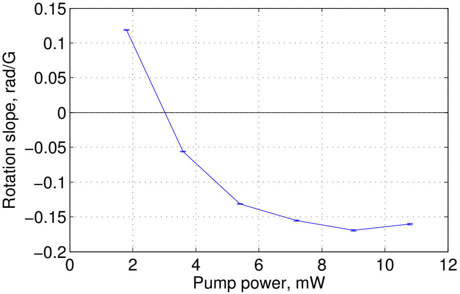




Heisenberg uncertainty principle and its optics equivalent

Heisenberg uncertainty principle

$\Delta p \Delta x \geq \hbar/2$

The more precisely the POSITION is determined, the less precisely the MOMENTUM is known, and vice versa

Optics equivalent

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

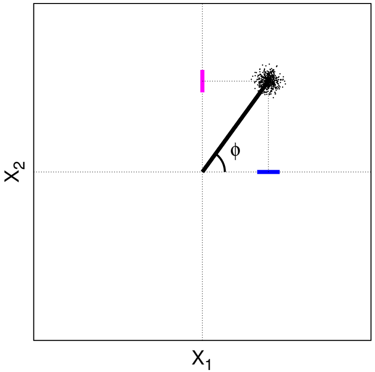
The more precisely the PHASE is determined, the less precisely the AMPLITUDE is known, and vice versa

Optics equivalent strict definition

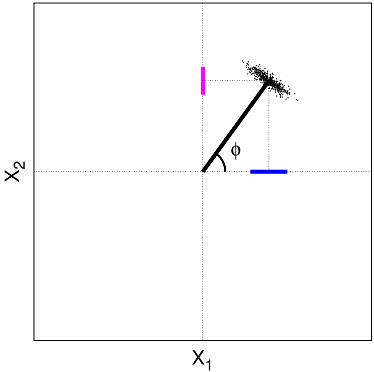
$\Delta X_1 \Delta X_2 \geq 1/4$

Minimum uncertainty (coherent) states

Coherent state



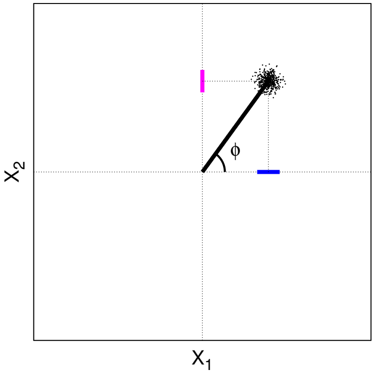
Squeezed state



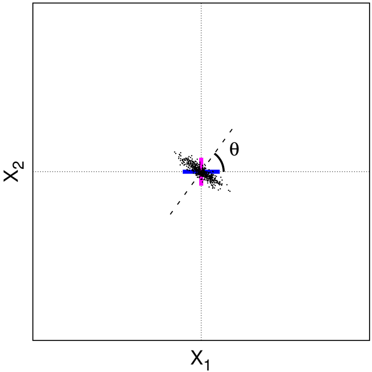
$$\Delta X_1 \Delta X_2 \geq 1/4$$

Minimum uncertainty (coherent) states

Coherent state

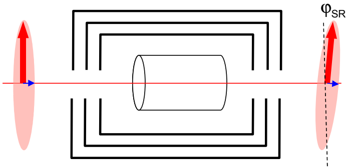


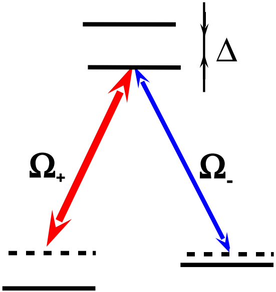
Squeezed state



$$\Delta X_1 \Delta X_2 \geq 1/4$$

Self-rotation of elliptical polarization in atomic medium

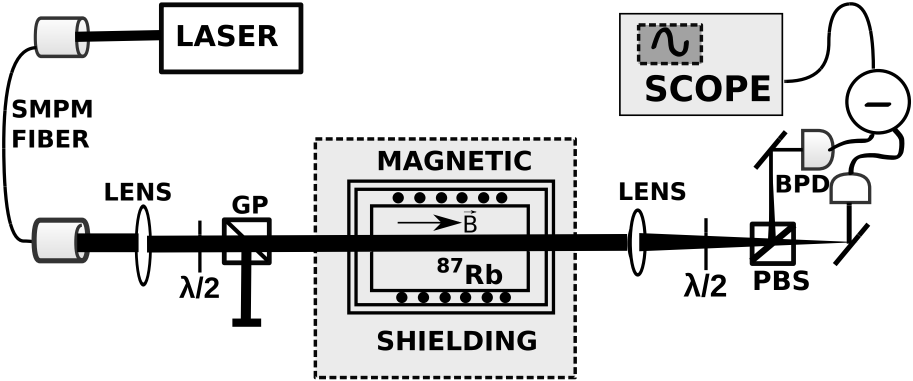




$$a_{out} = a_{in} + \frac{igL}{2}(a_{in}^{\dagger} - a_{in})$$

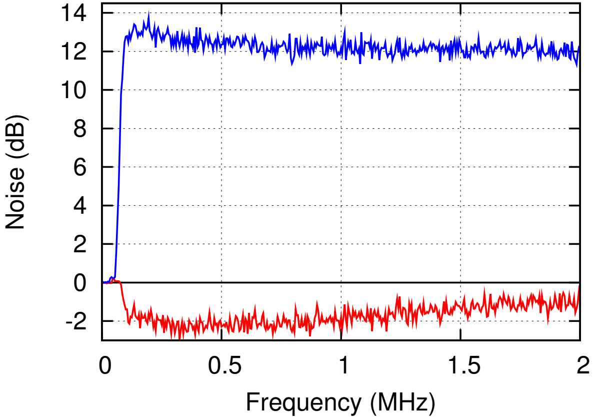
- **theory :** A.B. Matsko et al., PRA 66, 043815 (2002)

Setup


LASER
SMPM
FIBER
LENS
GP
λ/2
MAGNETIC
SHIELDING
$\vec{B}$
^{87}Rb
LENS
λ/2
PBS
BPD
SCOPE

Maximally squeezed spectrum with ^{87}Rb

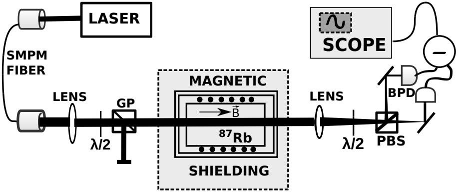
W&M team. ^{87}Rb $F_g = 2 \rightarrow F_e = 2$, laser power 7 mW, T=65° C

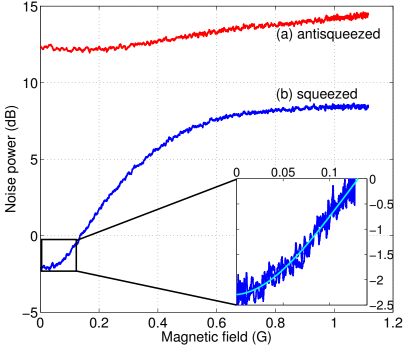


Lezama et.al report 3 dB squeezing in similar setup
Phys. Rev. A 84, 033851 (2011)

Squeezing vs magnetic field

Spectrum analyzer settings: Central frequency = 1 MHz, VBW = 3 MHz, RBW = 100 kHz





Travis Horrom et al. "All-atomic source of squeezed vacuum with full pulse-shape control", Journal of Physics B: Atomic, Molecular and Optical Physics, Issue 12, 45, 124015, (2012).

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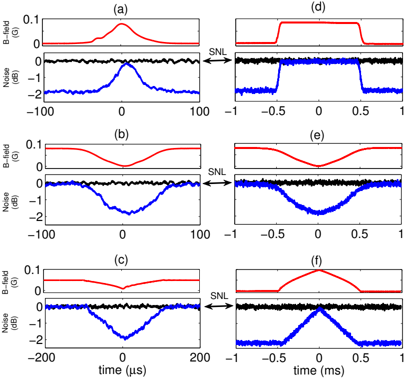
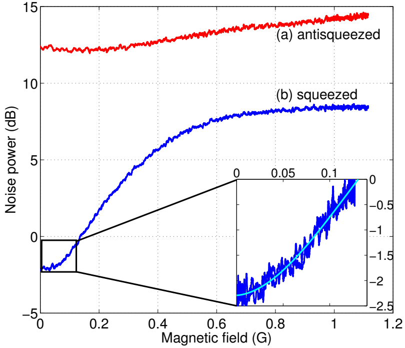
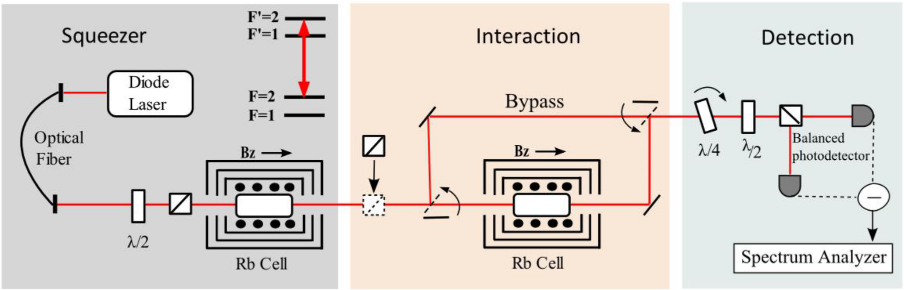


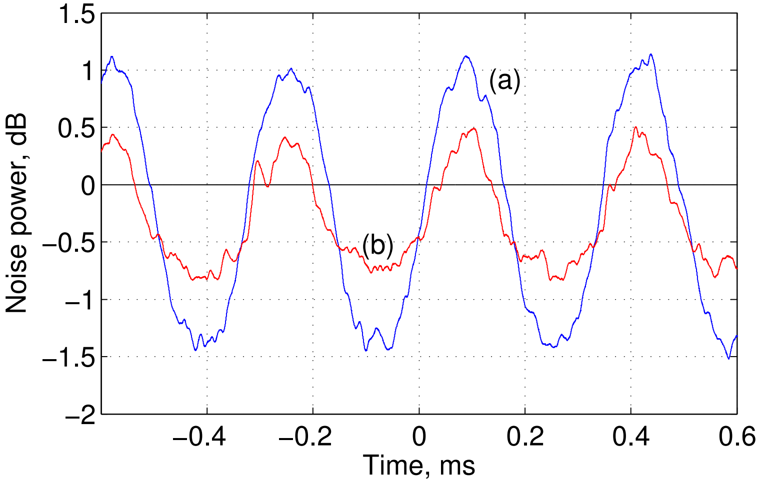


Travis Horrom et al. "All-atomic source of squeezed vacuum with full pulse-shape control", Journal of Physics B: Atomic, Molecular and Optical Physics, Issue 12, 45, 124015, (2012).

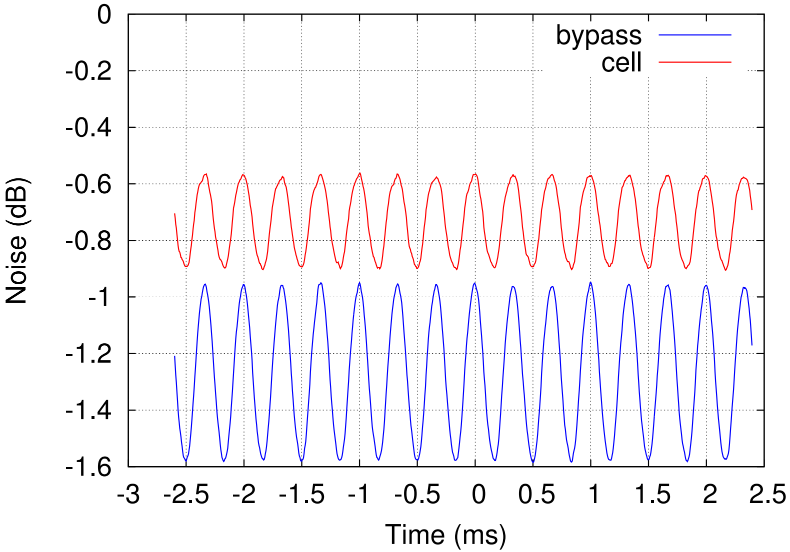
Time advancement setup



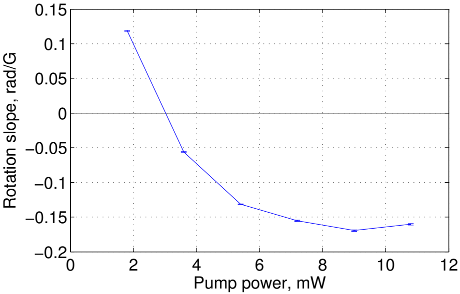
Squeezing modulation and time advancement



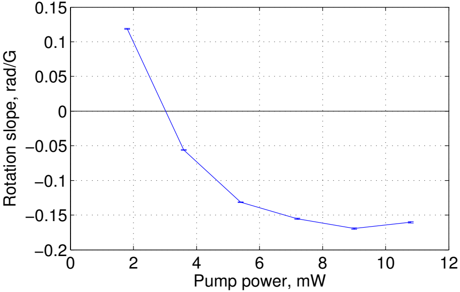
Squeezing modulation and time advancement

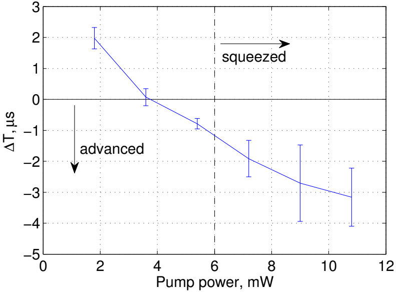


Advancement vs power

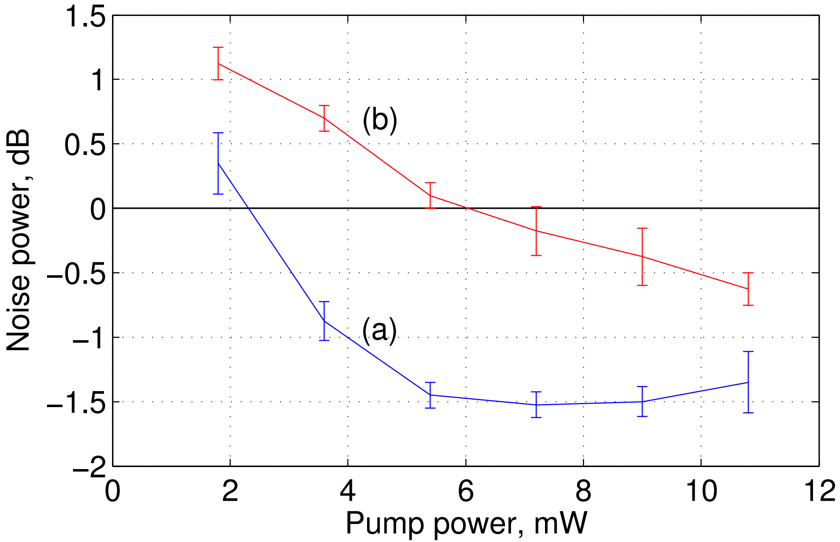


Advancement vs power



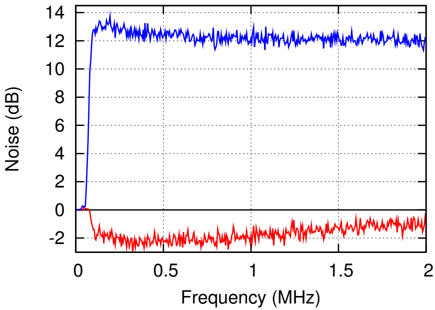


Squeezing level before and after advancement cell

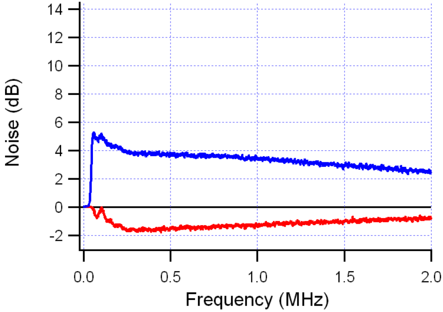


Vacuum cell vs coated cell

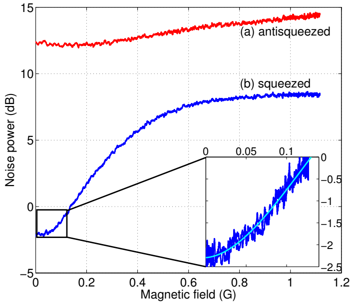
Vacuum cell



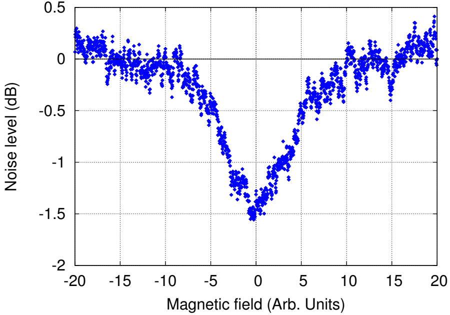
Coated cell



Vacuum cell



Coated cell



Summary

- First demonstration of superluminal squeezing propagation with $v_g = -c/16000$ or time advancement of 4 μS