

# Squeezing manipulation with atoms

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# About the college of William and Mary

## “Public Ivy”

- Chartered on February 8, 1693, by King William III and Queen Mary II of England
- The second oldest college in America
- 6,071 undergraduates and 2,129 graduate students



# About Physics department

- 30 faculty members
- 40 - 60 undergraduates majoring in physics
- 60 graduate students
- brand new additional research labs wing with enhanced temperature stability



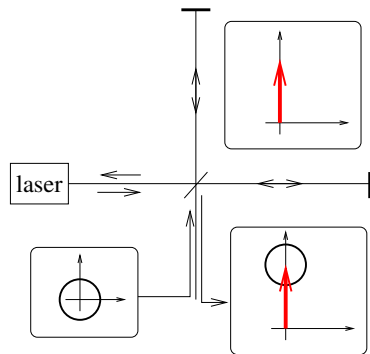
## Our interests

- Squeezing generation
- Quantum memory prototypes
- Quantum enhanced magnetometers
- Squeezed state manipulation



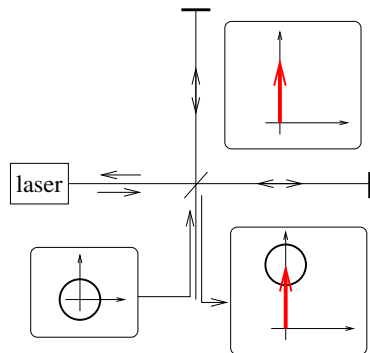
# Quantum enhancing of GW interferometer

Vacuum input

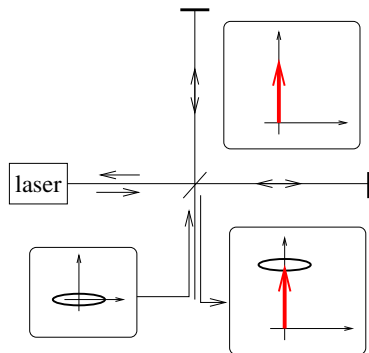


# Quantum enhancing of GW interferometer

Vacuum input

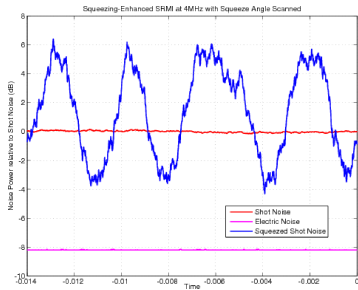


Squeezed input

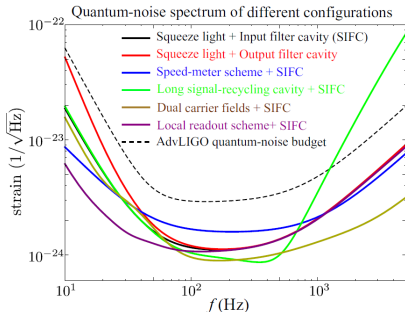


# Interferometer sensitivity improvement with squeezing

“A quantum-enhanced prototype gravitational-wave detector”,  
Nature Physics, **4**, 472-476, (2008).

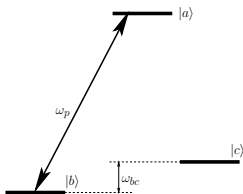
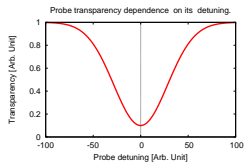


Projected  
advanced LIGO sensitivity  
LIGO-T1100309-v5



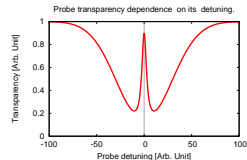
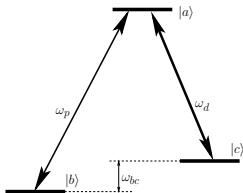
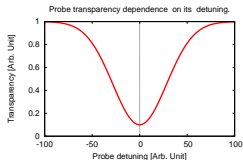
General filtering requirements:  
Narrow resonance ( $< 1$  kHz) and high transmission ( $\approx 100\%$ )

# Electromagnetically Induced Transparency (EIT)

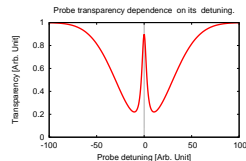
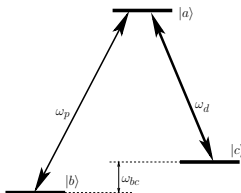
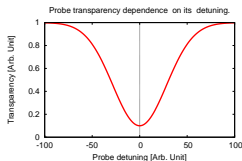




# Electromagnetically Induced Transparency (EIT)



# Electromagnetically Induced Transparency (EIT)



Eugeniy E. Mikhailov, Keisuke Goda, Thomas Corbitt, Nergis Mavalvala, “Frequency-dependent squeeze-amplitude attenuation and squeeze-angle rotation by electromagnetically induced transparency for gravitational-wave interferometers”, *Physical Review A*, 73, 053810, (2006).

# Cavity vs atomic filters

## Cavity filters

### Pros

- well understood
- within current technology

### Cons

- large even with super mirrors
- with typical size larger than 10 m
- require active stabilization
- require good seismic and other noise sources isolation
- **super expensive**

## Atomic filters

### Pros

- small in size (10 cm)
- resonance position is stable
- noise isolation requirements are low
- economical

### Cons

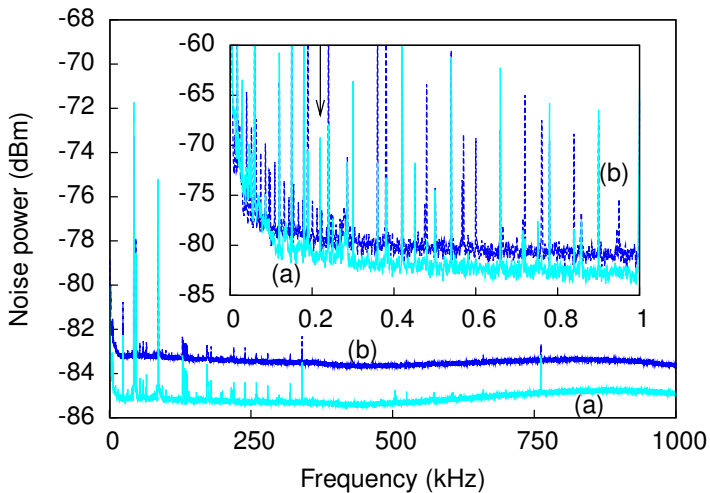
- Non existing at current LIGO wavelength (i.e. 1064 nm)

# Proposed research

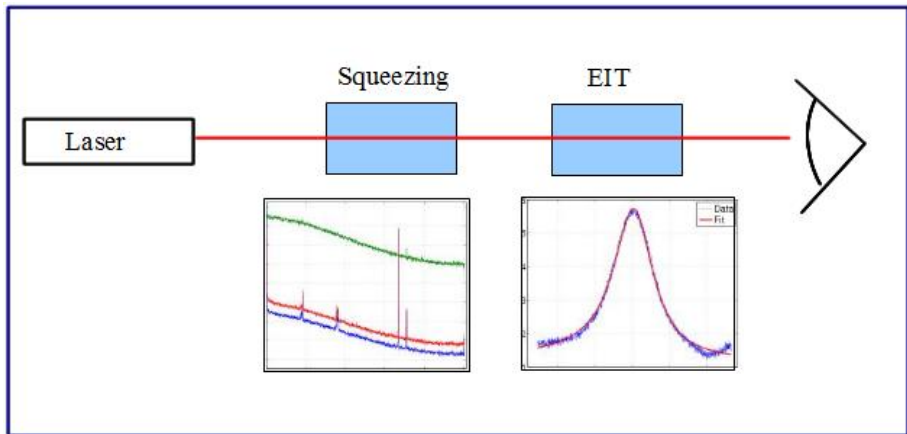
- development atomic amplitude squeezing filters
- characterization of the slow and fast group velocity of squeezing or coherent light propagation through atomic ensembles
- experimental studies of modification and back action of atoms on light quantum noise
- development and improvement of economical squeezing sources (though not at current designs wavelength) suitable for prototype testing

Most of above activities are outlined as TODO in the LIGO-T1100309 document

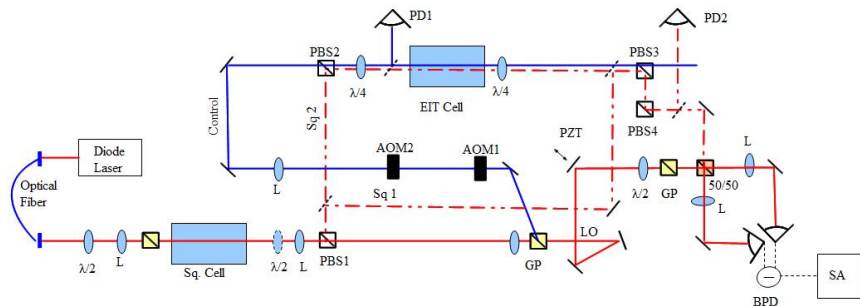
# Atomic low frequency squeezing source



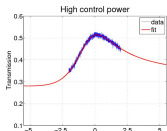
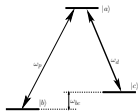
# Squeezing and EIT filter setup



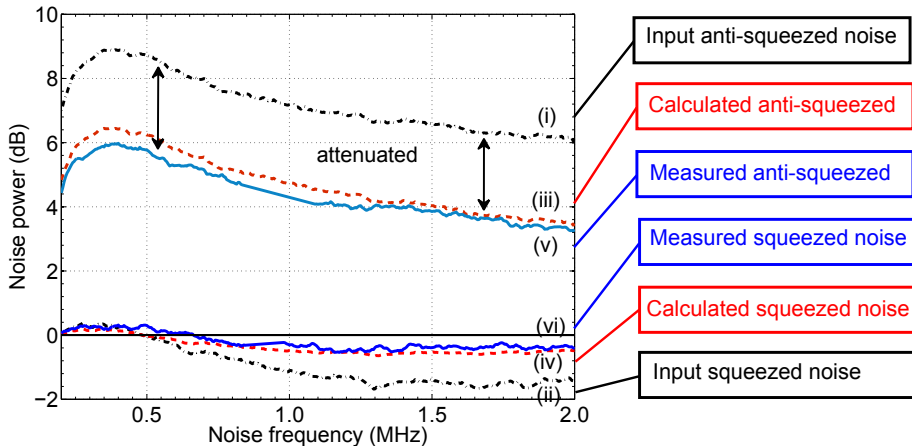
# Squeezing and EIT filter setup



# Wide EIT filter and squeezing

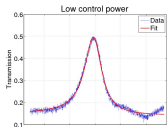
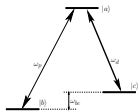


- Peak transmission = 52%
- FWHM = 4 MHz

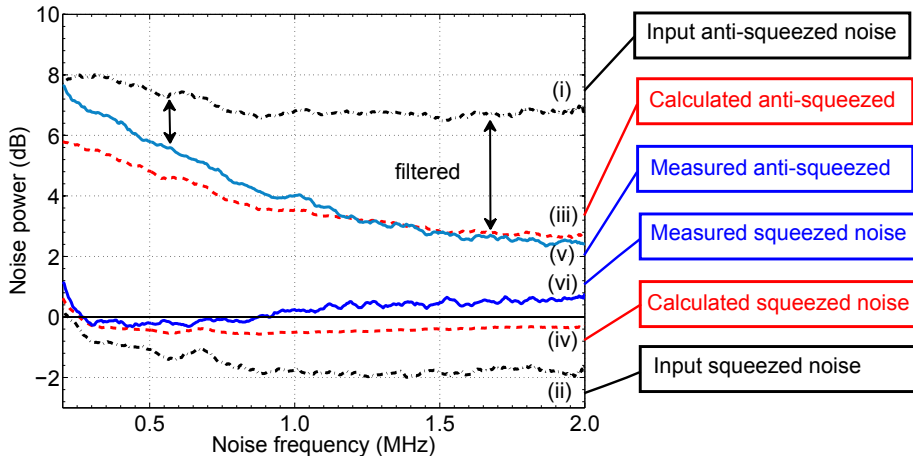




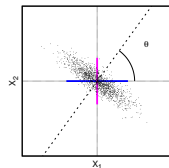
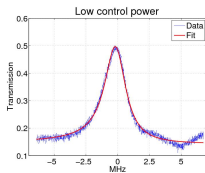
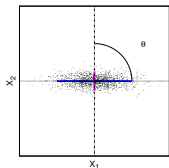
# Narrow EIT filter and squeezing



- Peak transmission = 50%
- FWHM = 2MHz

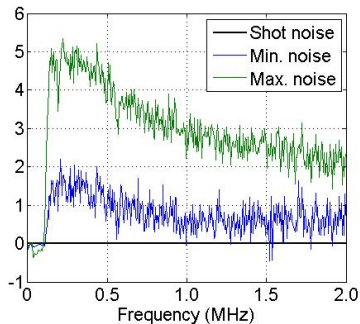
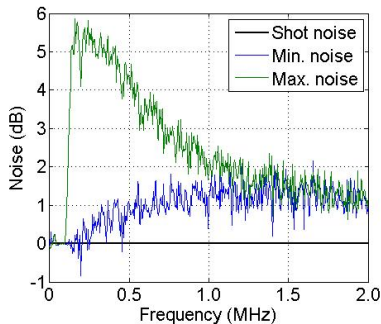


# Squeezing angle rotation

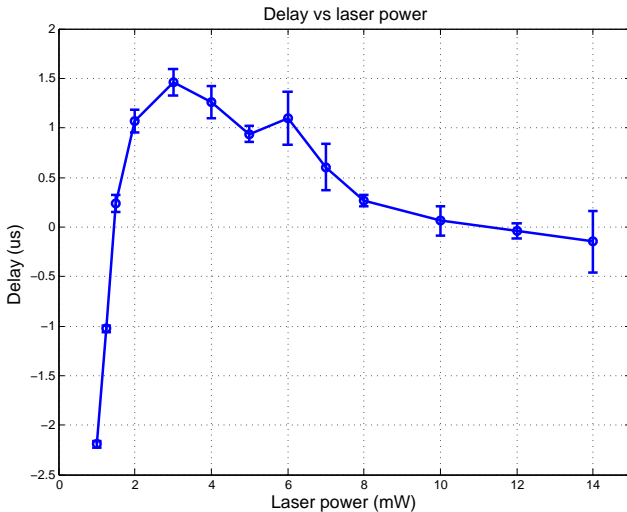


Locked at 300kHz

Locked at 1200kHz



# Delay and advancement of squeezing



# Conclusion

- I hope you favor my group application
- and find proposed research directions suitable to improve further generation of the GW antennas.