

# Quantum enhanced measurements group

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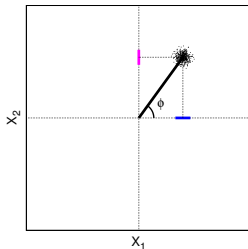


CM-AMO mini-retreat, 14 January 2015

# Squeezed states of light, go beyond shot noise

$$E(\phi) = |a|e^{-i\phi} = |a|\cos(\phi) + i|a|\sin(\phi) = X_1 + iX_2, \quad \phi = \omega t - kz$$

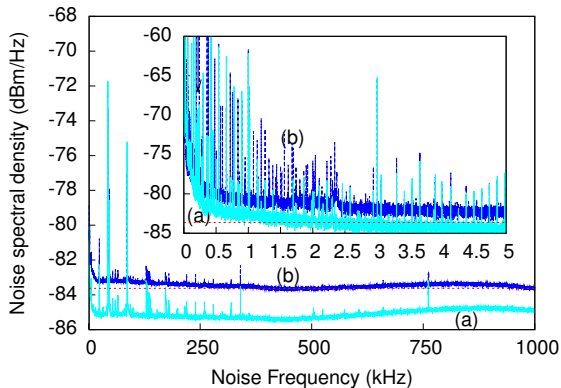
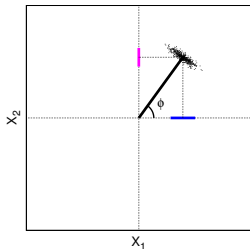
- $[a, a^\dagger] = 1$
- $[X_1, X_2] = i/2$
- $\Delta X_1 \Delta X_2 \geq 1/4$



# Squeezed states of light, go beyond shot noise

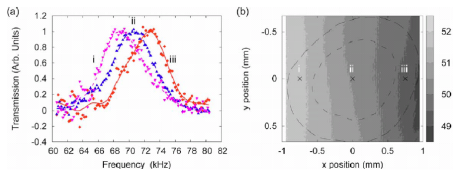
$$E(\phi) = |a|e^{-i\phi} = |a| \cos(\phi) + i|a| \sin(\phi) = X_1 + iX_2, \quad \phi = \omega t - kz$$

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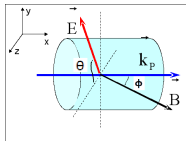


# Magnetometry

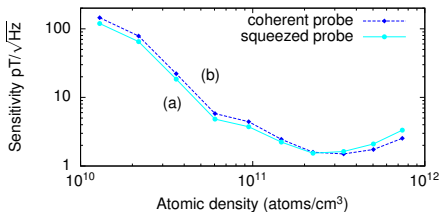
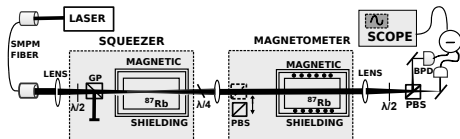
## Magnetic field map



## Magnetic field compass



## Magnetometer with squeezing enhancement

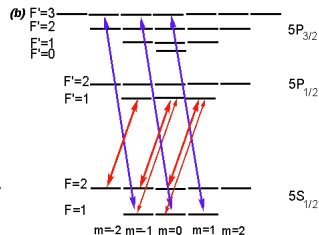
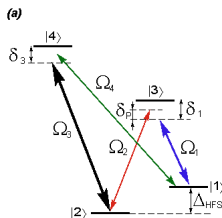


# Fast optical gyroscope



$$\Delta f = \frac{4A\Omega}{\lambda P c} \frac{c}{n + f \frac{\partial n}{\partial f}}$$

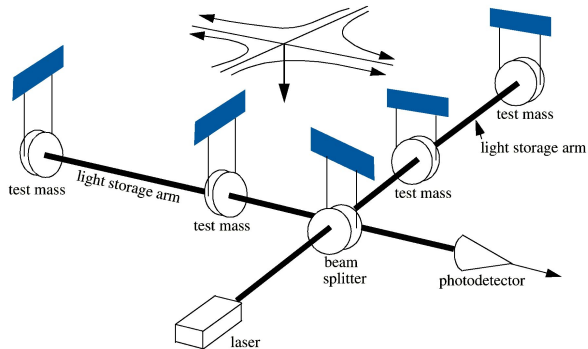
$$= \frac{4A\Omega}{\lambda P c} v_g$$



# Gravitational wave detectors



- $L = 4 \text{ km}$
- $h \sim 2 \times 10^{-23}$
- $\Delta L \sim 10^{-20} \text{ m}$

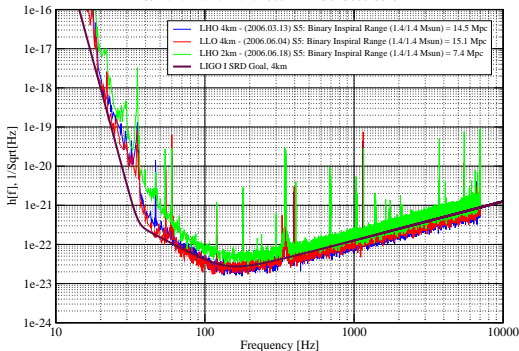


# Gravitational wave detectors



## Strain Sensitivity for the LIGO Interferometers

S5 Performance - June 2006 LIGO-G060293-02-Z



- $L = 4$  km
- $h \sim 2 \times 10^{-23}$
- $\Delta L \sim 10^{-20}$  m