

IFO configurations & squeezing

McClelland Introduction

" When I was a postdoc in Bell Labs during the 1980s, many of the ideas stimulating our work in quantum optics came from researchers developing sensors for gravitational waves.researchers developed new concepts for manipulating the quantum fluctuations that affect parameters such as an oscillator's position. Concepts **they** invented, such as 'quantum non-demolition measurements' and 'squeezed states',"

Grangier, Journal Club article in the March 28 2008 of 'Nature'.

A giant of the of the "they" was

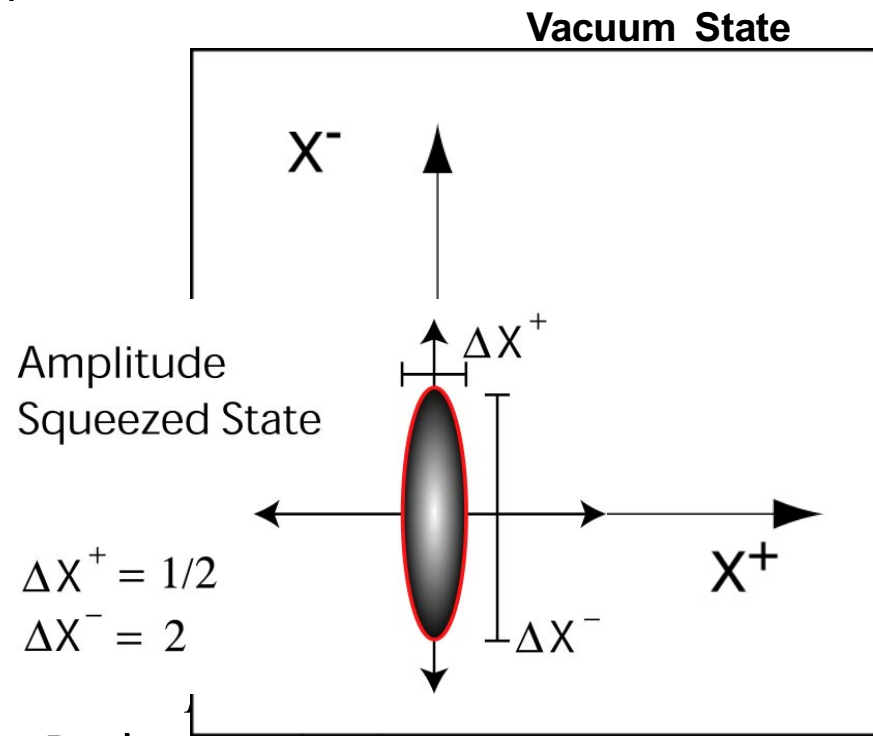
Vladimir Braginsky

What is squeezing

- Light has intrinsic random QM fluctuations
- Described by the Heisenberg uncertainty principle

$$\Delta X^+ \Delta X^- \geq 1$$

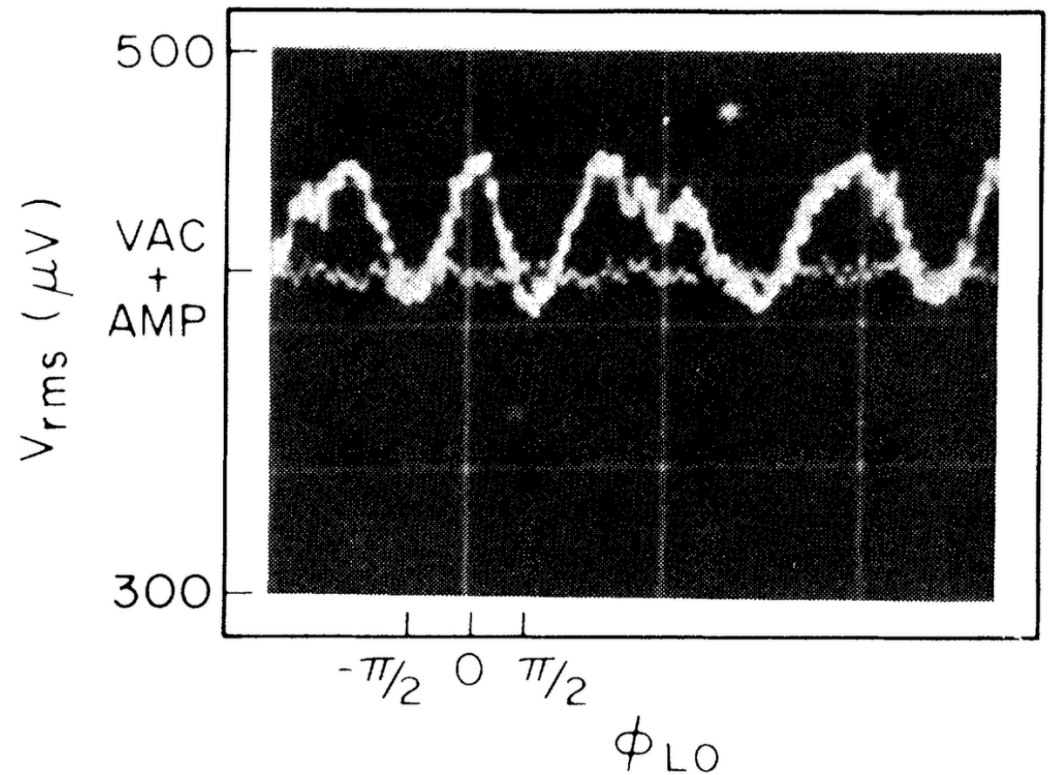
- Two non-commuting quadratures:
 - Phase quadrature, X^-
 - Amplitude quadrature, X^+



- Reduce noise in one quadrature at the expense of increase in the other

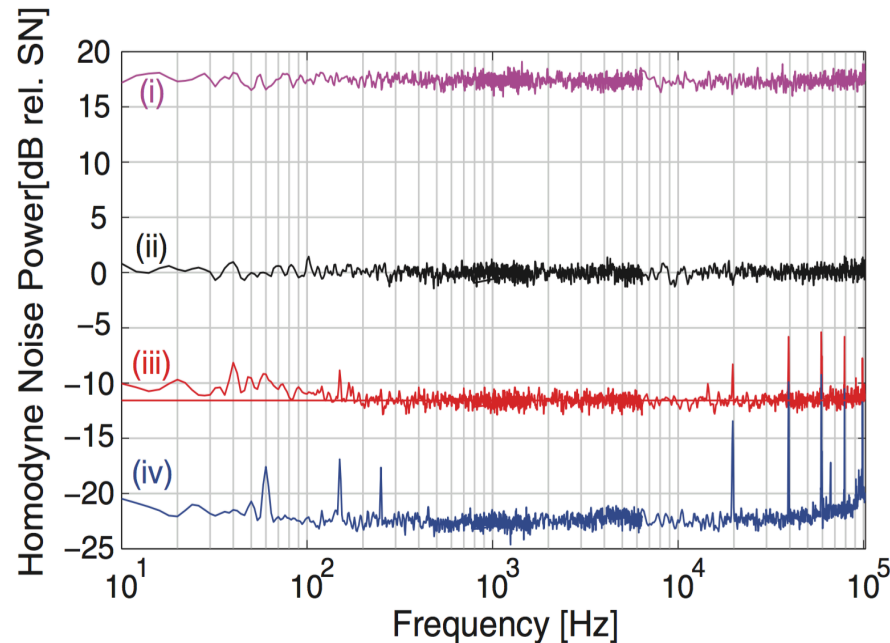
A brief history of squeezing

- 1985 Bell Labs 1 dB squeezing, 420 MHz.
- 1999 ANU 7.1 dB squeezing at 3 MHz
- 2000 – factor of 2 improvement using squeezing in GWD – ‘why bother’
- 2002 10 dB consortium ANU, AEI, MIT
- 2004 ANU breakthrough - first squeezing in the audio-band
- 2006 AEI coherent control system
- 2007 AEI squeezing down to 1 Hz
- 2011 AEI 12.3 dB @ 1550nm; 5MHz frequencies



0.7 dB, 420 MHz; 50% QE
Produced ~ 1 dB

- 2012 ANU/AEI 10db @ 1064nm from 10 Hz



- 2011 AEI squeezing in GEO600; now routine
- 2013 MIT/ANU/AEI squeezing in enhanced LIGO
- 2015 MIT Frequency Depn squeezing in audioband;
- 2015 ANU: Squeezer in vacuum
- 2016 MIT/ANU 1 mrad phase noise observed

Today

- 09:10 **Squeezing at 1064nm** Henning Vahlbruch (AEI Hannover)
- 09:30 **Squeezing at 1550nm and across the wavelengths** Axel Schoenbeck (Hamburg University)
- 09:50 **Arm Cavity as Squeezing Filter cavity via Entanglement Swapping** Yanbei Chen (Caltech))
- 10:10 **Intracavity anti-Squeezing II** Kentaro Somiya (Tokyo)
- 11:00 **Quantum dense metrology** Sebastian Steinlechner (University of Glasgow)
- 11:30 **New Topology Speedmeter** Shtefan Danilishin (University of Glasgow)
- 12:00 **Atom Interferometer GW Detectors** Philippe Bouyer (Bordeaux)