ACIGA/ANU R&D Program

McClelland, Scott, Gray

- **Data Analysis**
  - LDAS — Searle
  - Networks — Witte, Searle, Cusack
  - Sources — Moylan, Searle
- **Configurations & Quantum Interferometry**
  - Output Optics (signal recycling with VRMs) — Rabeling, Chow, deVine
  - SQL interferometer — Mow Lowry
  - Noise Cancellation — Mow Lowry, Sheard
  - Squeezing — McKenzie (with Lam and Grosse)
  - optical springs, Speed meters etc — Sheard, Mow Lowry, DeVine
- **HOPTF**
  - auto alignment, global control, high power photodetection — Romann, Rabeling, Chow, DeVine
- **'Other'**
  - LISA frequency stabilisation — Sheard, DeVine
  - GR Theory — White, Whale, Moylan
  - Sensors — Chow, DeVine

Data Analysis

- LIGO Data Analysis System development team
  - Data Conditioning Application Programming Interface
  - detector characterisation schemes and line removal algorithm analyses
- Network Analysis
  - discussed yesterday
- Sources
  - Gravitational Lensing

Configurations

- Developed and demonstrated a control scheme for Resonant Sideband Extraction

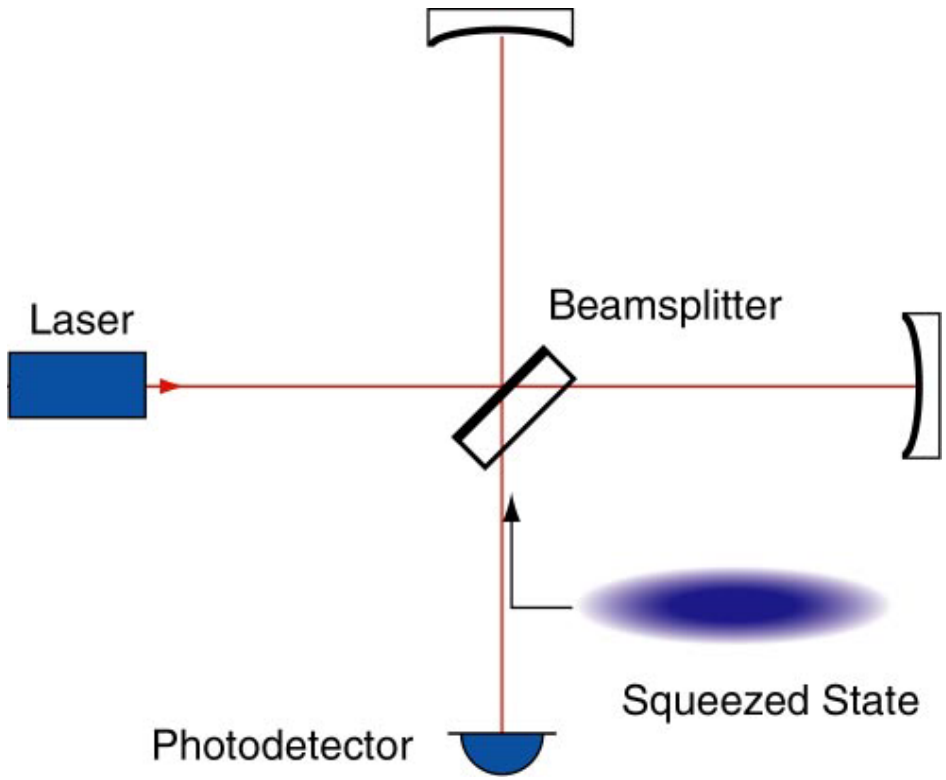
  Shaddock et al, Applied Optics 2003.

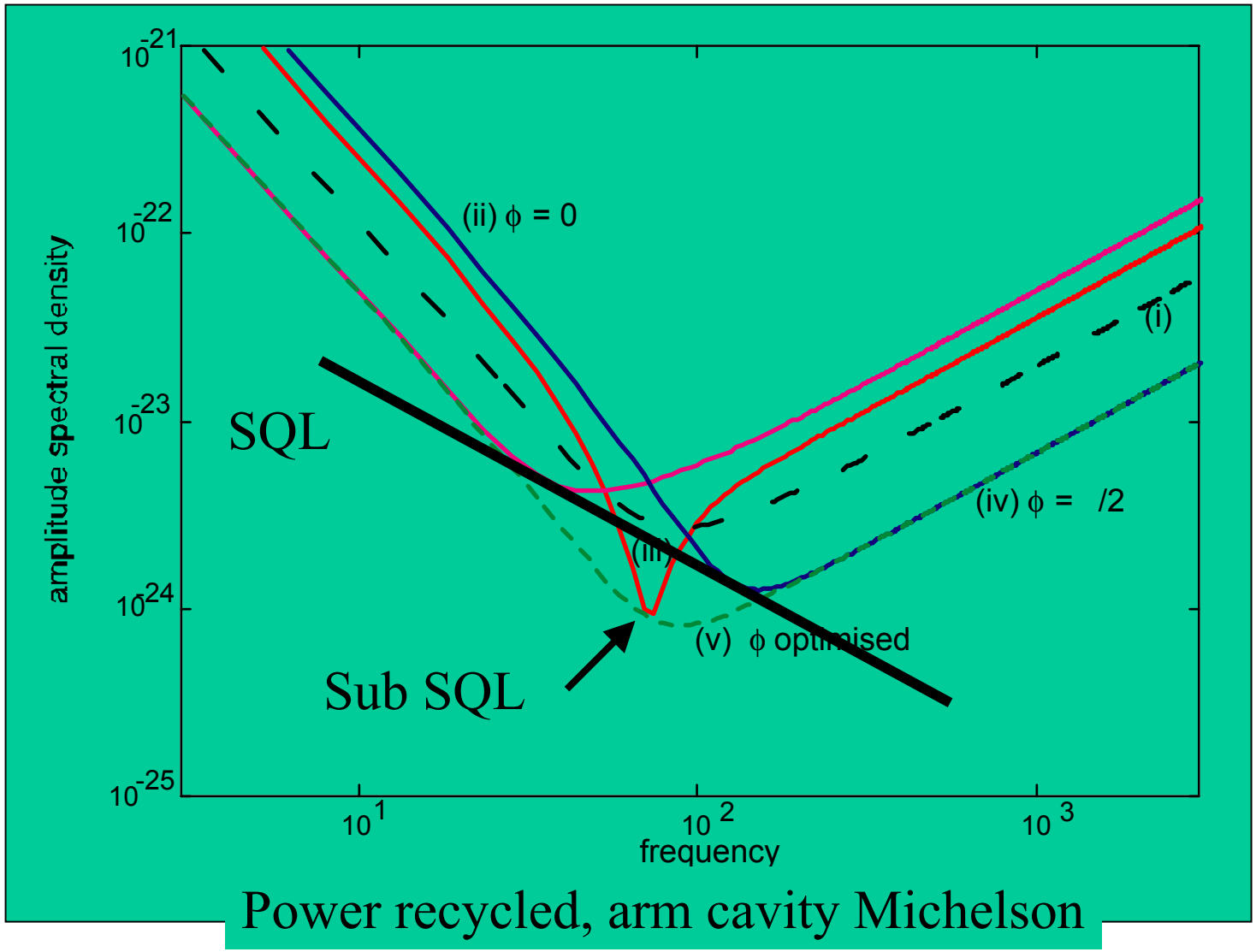
- Output Optics for Advanced LIGO - **A/LIGO partnership**

Squeezing

Quantum Noise in a Michelson

- Vacuum noise couples in at the Dark Port.
- By replacing the Vacuum with squeezing the quantum noise can be reduced.
- Not previously demonstrated in a GW detector configuration



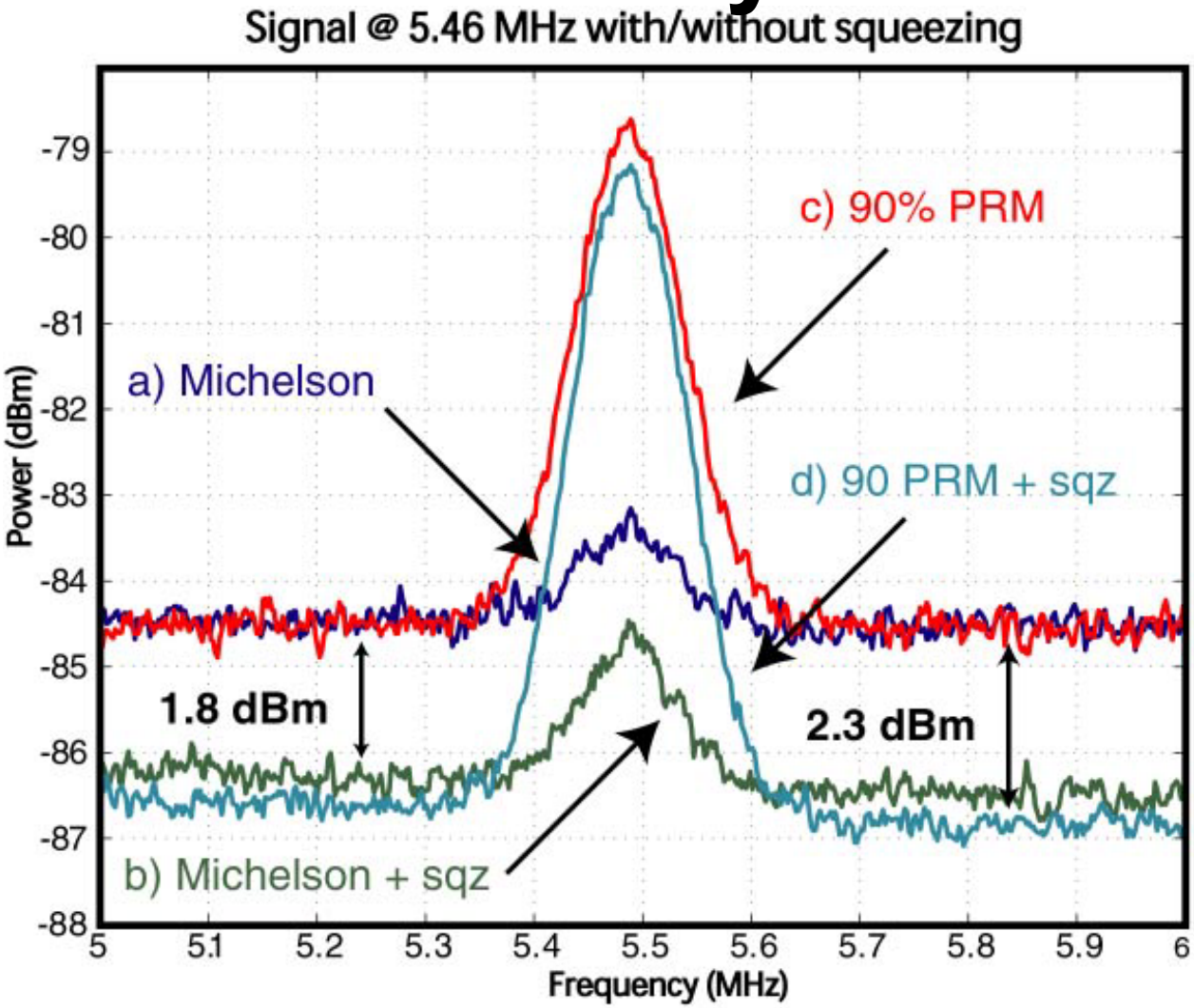


Power recycled, arm cavity Michelson

McClelland et al, TAMA Proceedings 2000

Squeezing enhanced power recycled Michelson

Sensitivity Results



K. McKenzie *et al.* Phys. Rev. Lett., **88** 231102 (2002)

Low frequency squeezing

- Squeezed vacuum state produced using OPO
- to date focus has been on MHz squeezing
- 'Race' is on to produce squeezing in the GW band
  - Bowen et al, 2002, > 120KHz
  - Schnabel et al, 2004, > 80 kHz
  - Laurent et al, 2004, > 50 kHz
- **McKenzie et al, 2004**
  - **> 900 Hz**
  -

Beating the SQL:
Classical Analogue

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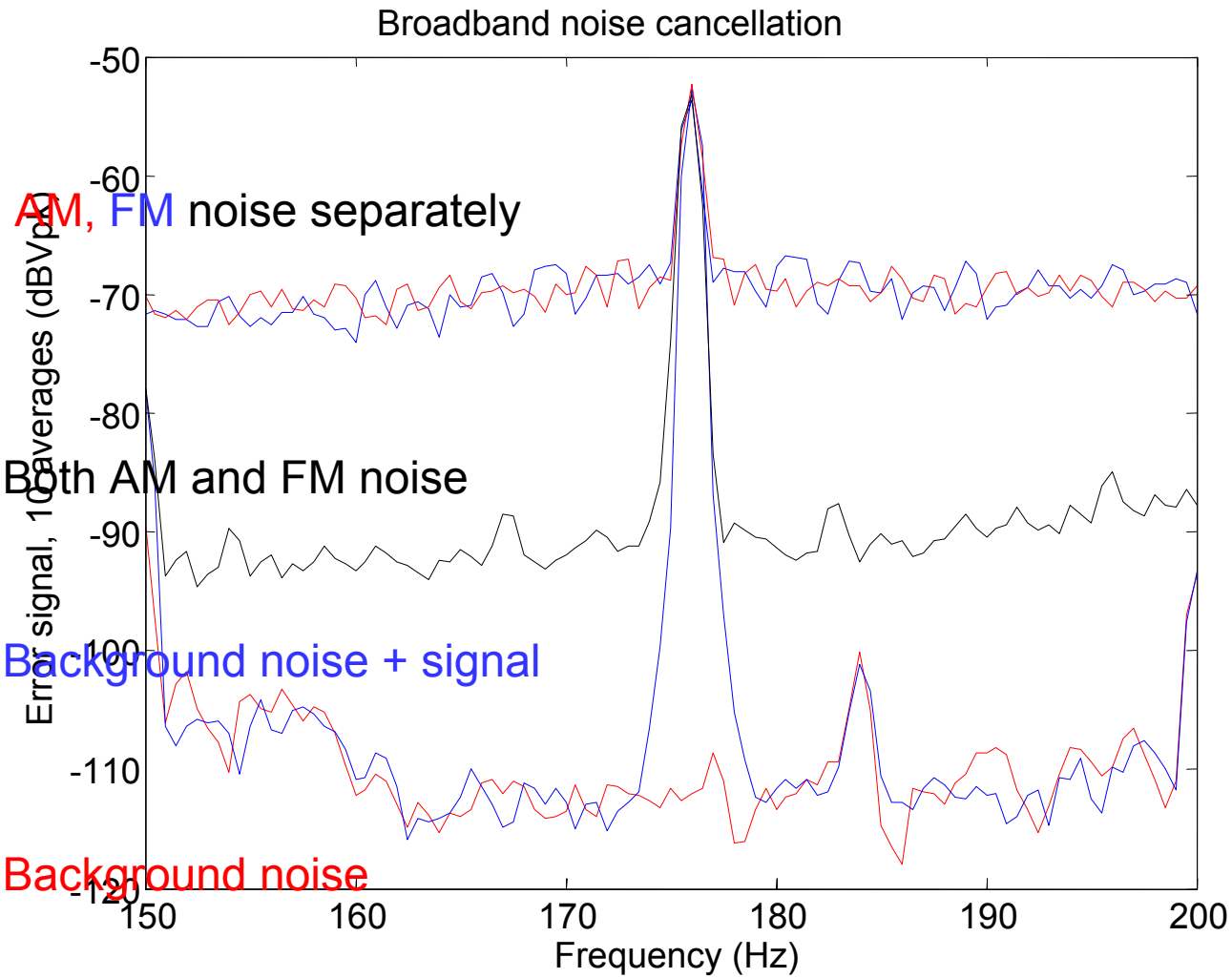
- In the absence of an SQL limited interferometer:
  - performed a bench top classical analogue to breaching the Standard Quantum Limit
  - Amplitude modulation to replace radiation pressure noise, and
  - Frequency modulation to replace shot noise

Classical noise cancellation

Results

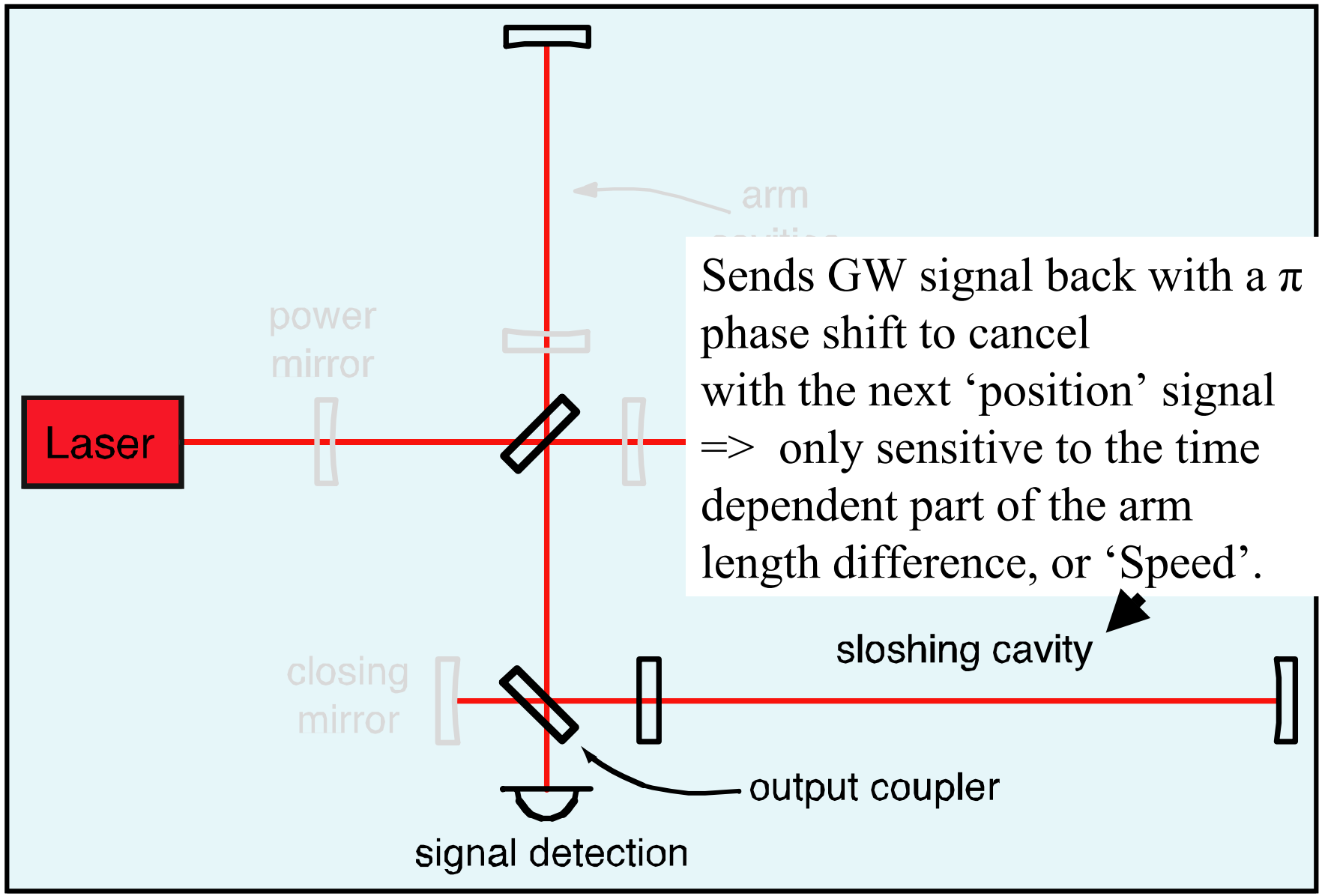
Mow Lowry et al
PRL (2004)
in press

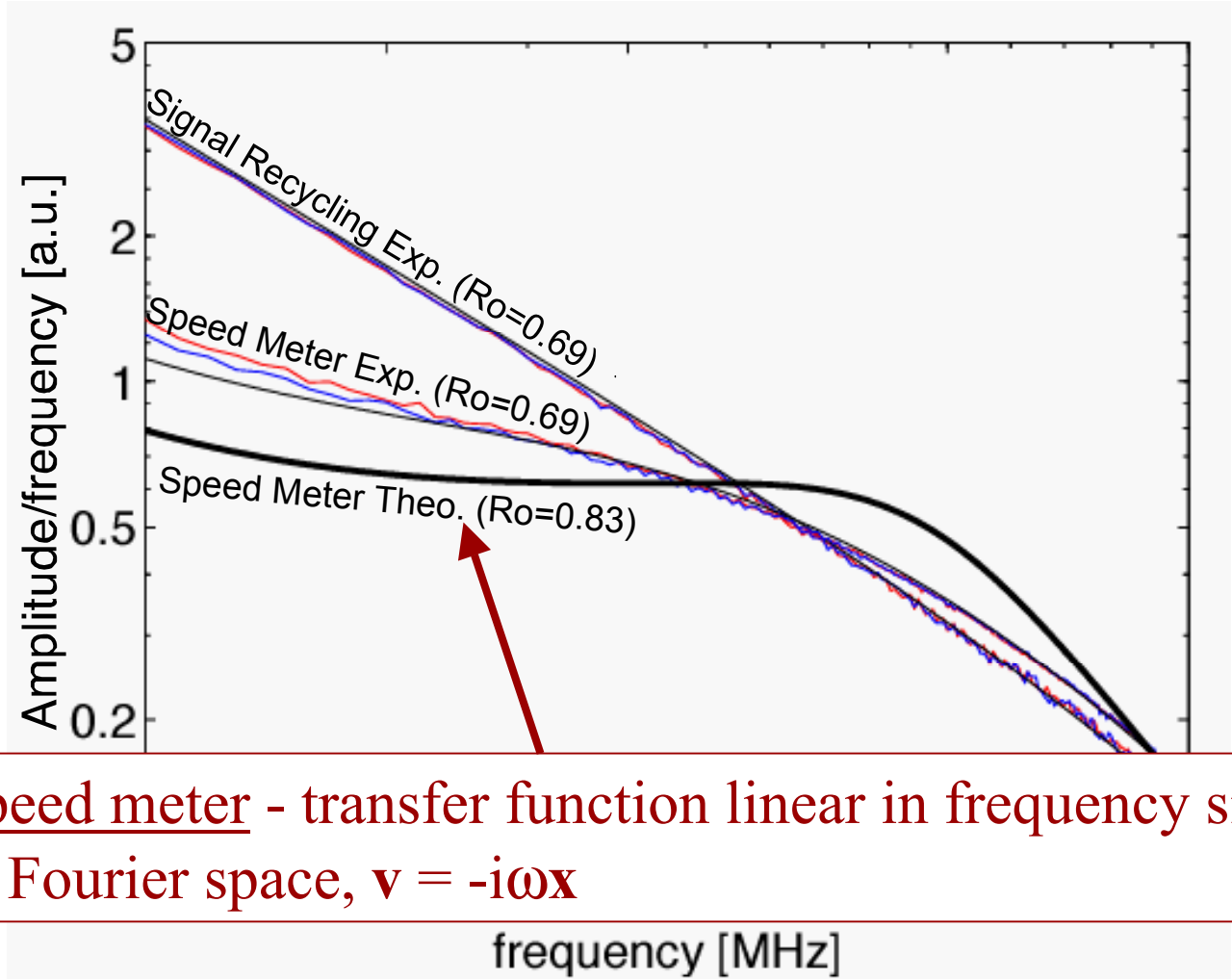


Quantum NonDemolition: Speed Meters

- Standard detectors measure position
  -> position kicked around by quantum radiation pressure during measurment
  -> not a QND variable
- Speed or momentum is a QND observable
  - allows repeated measurement without back action

  Braginsky et al
- Most practical design to date due to Chen and Purdue (2002)
  - Involves the addition to the standard configuration of a "sloshing" cavity and a signal cavity output coupler for signal extraction

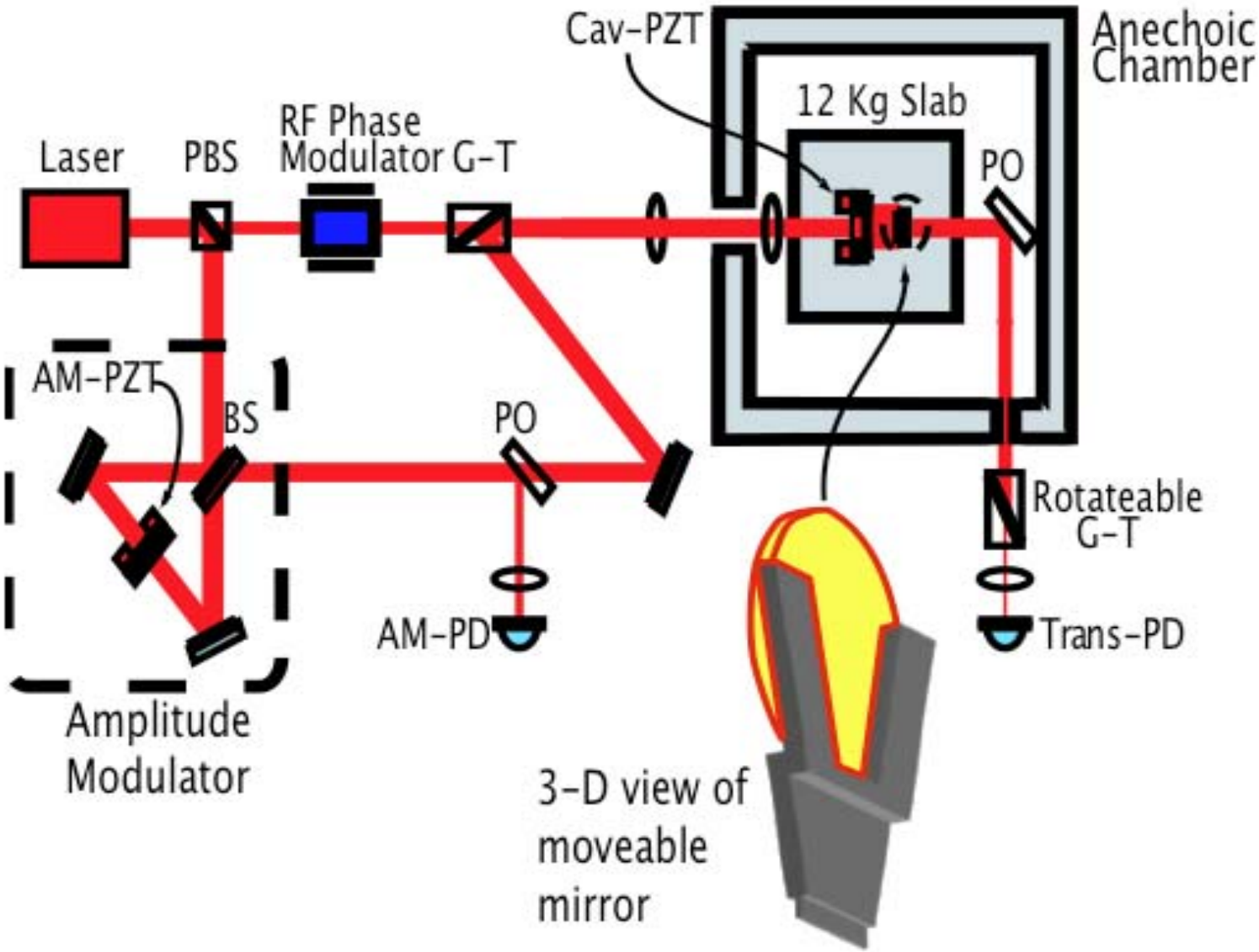

arm
power
mirror
Laser
Sends GW signal back with a π
phase shift to cancel
with the next 'position' signal
=> only sensitive to the time
dependent part of the arm
length difference, or 'Speed'.
sloshing cavity
closing
mirror
output coupler
signal detection



Speed meter - transfer function linear in frequency since, in Fourier space, $\mathbf{v} = -i\omega\mathbf{x}$

deVine et al, Phys.Lett.A 2003.

Optical Spring



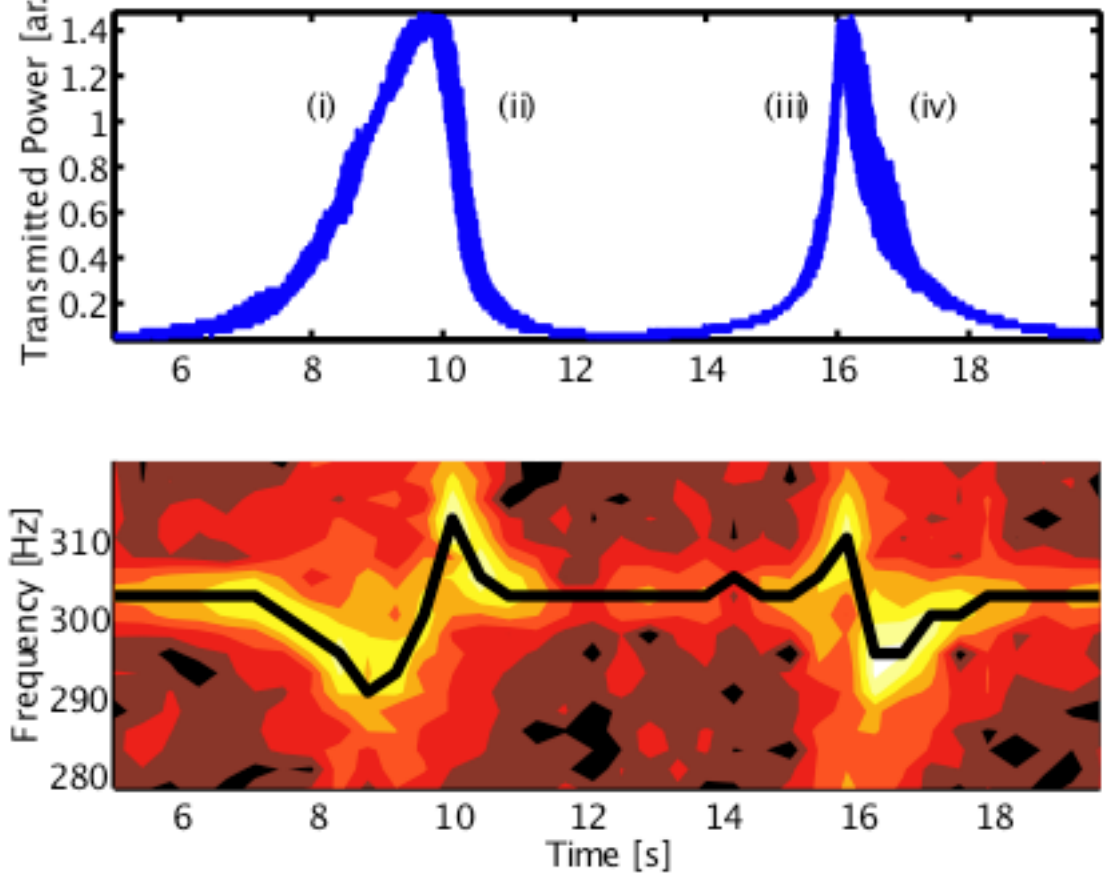
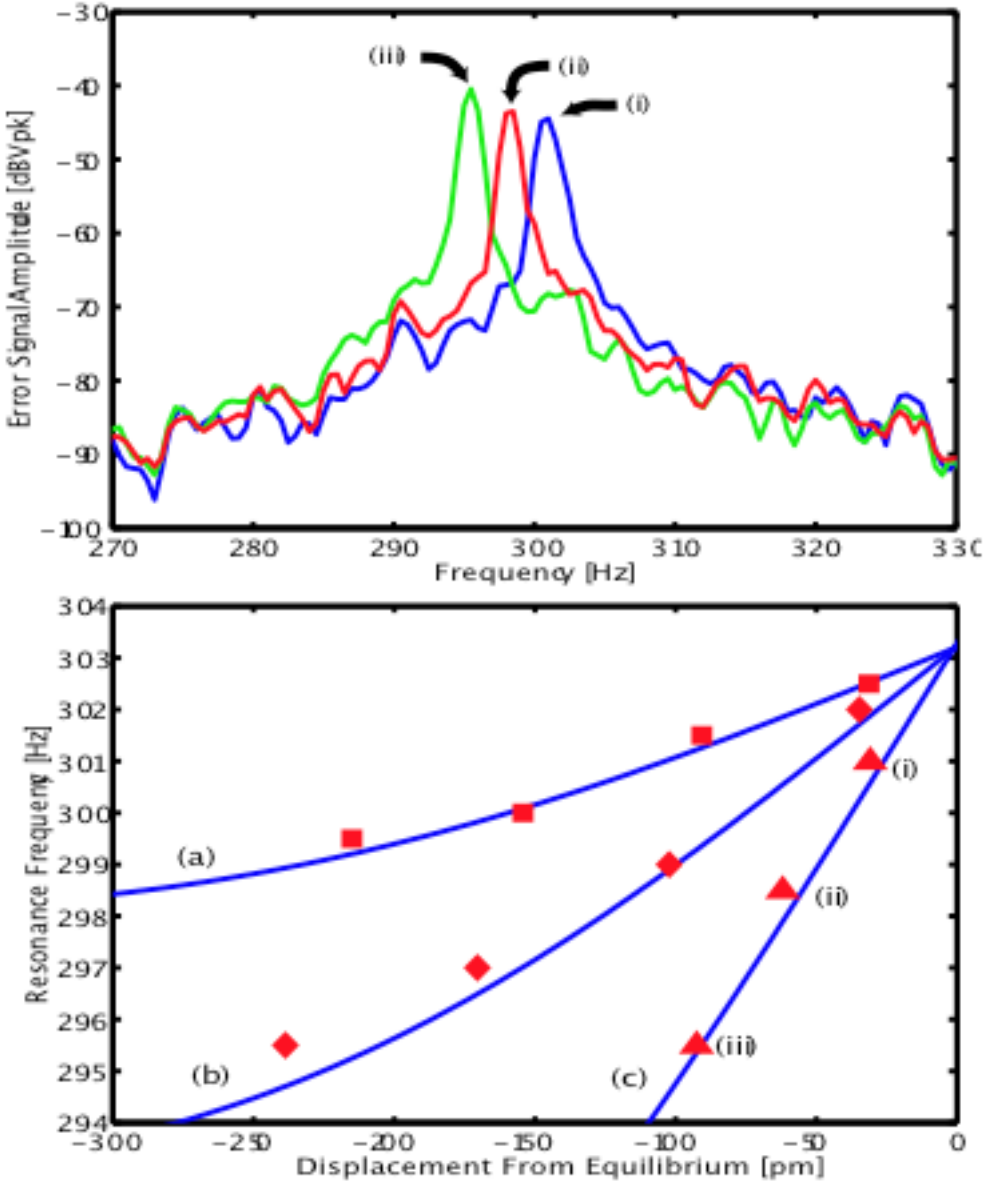
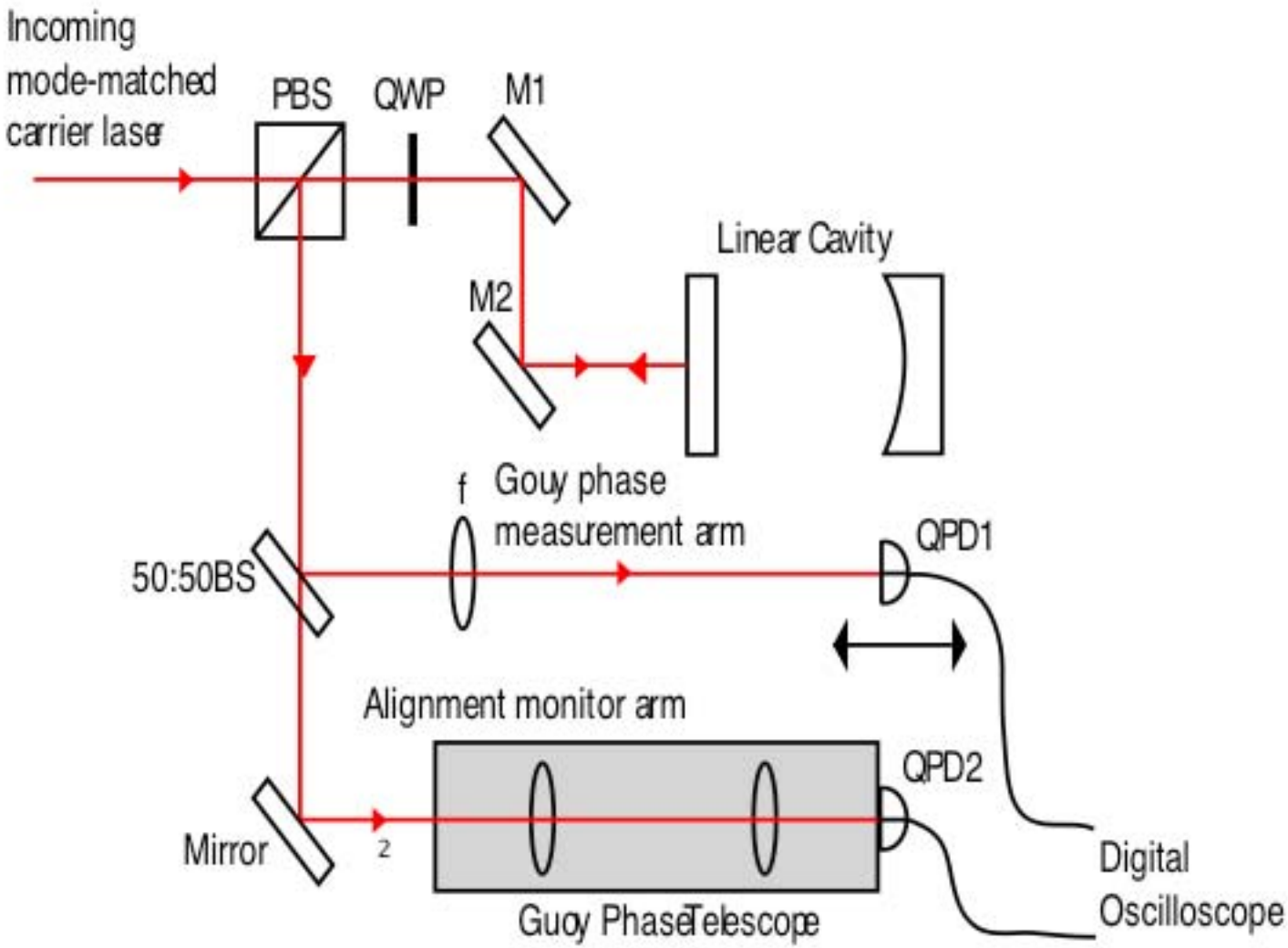


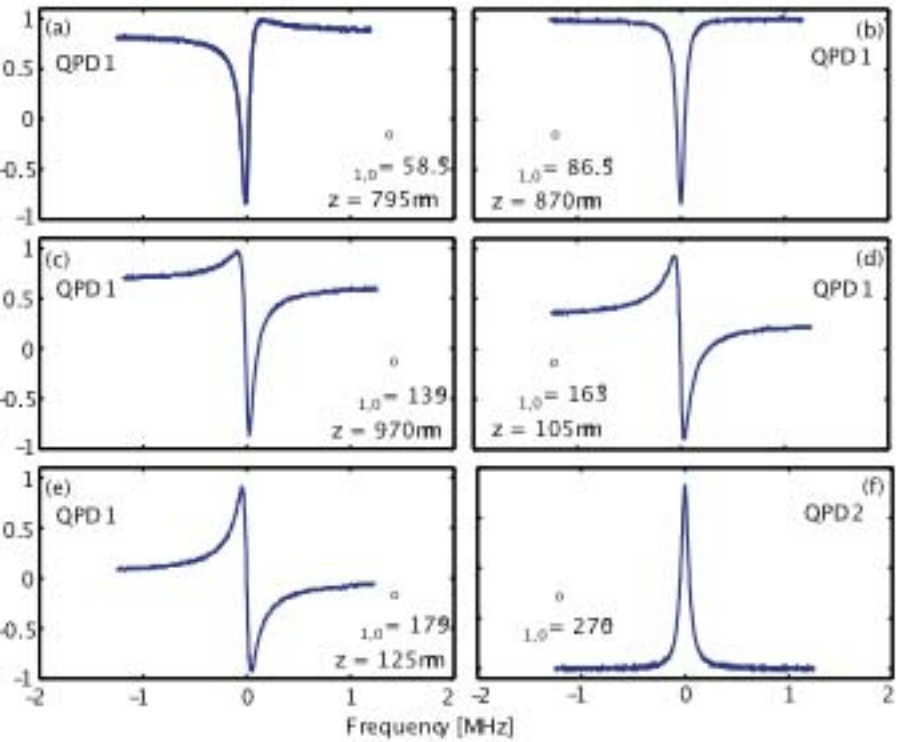
FIG. 4: The top trace shows the transmitted power as a function of time as the laser frequency is scanned through resonance. The sample rate was 500 Hz. The data in this trace has been decimated by a factor of 10. The bottom trac shows the mechanical resonant frequency shifting due to the optical spring e ect either side of resonance. The thick black line in the bottom trace is the frequency with the largest amplitude corresponding to the observed mechanical resonant frequency.

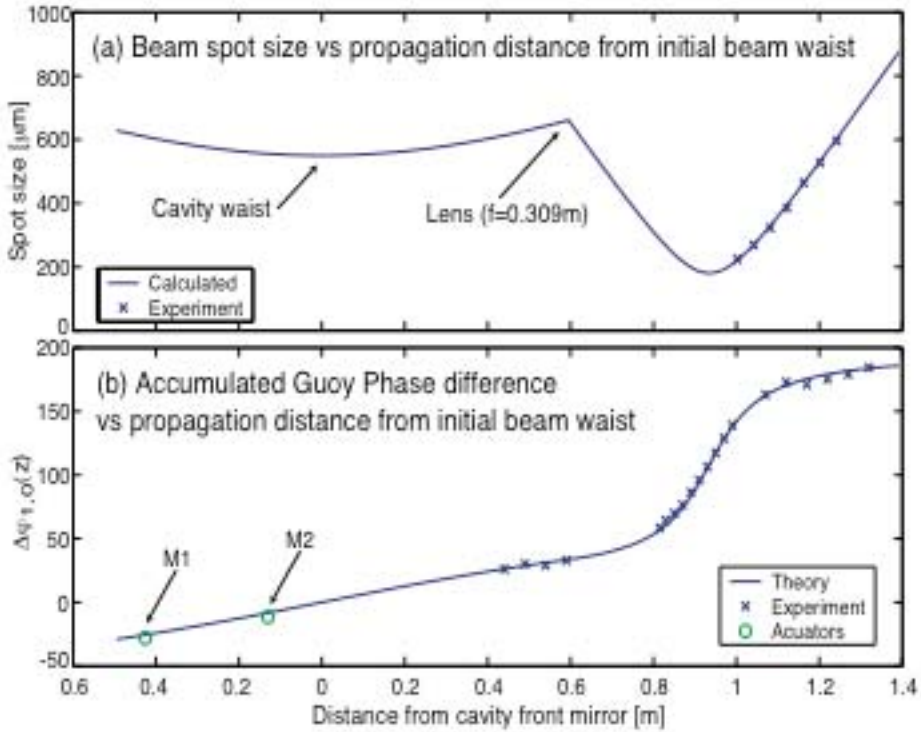


Sheard et al, PhysRevA Rapid Comm., in press

Measuring Gouy phase of higher order modes

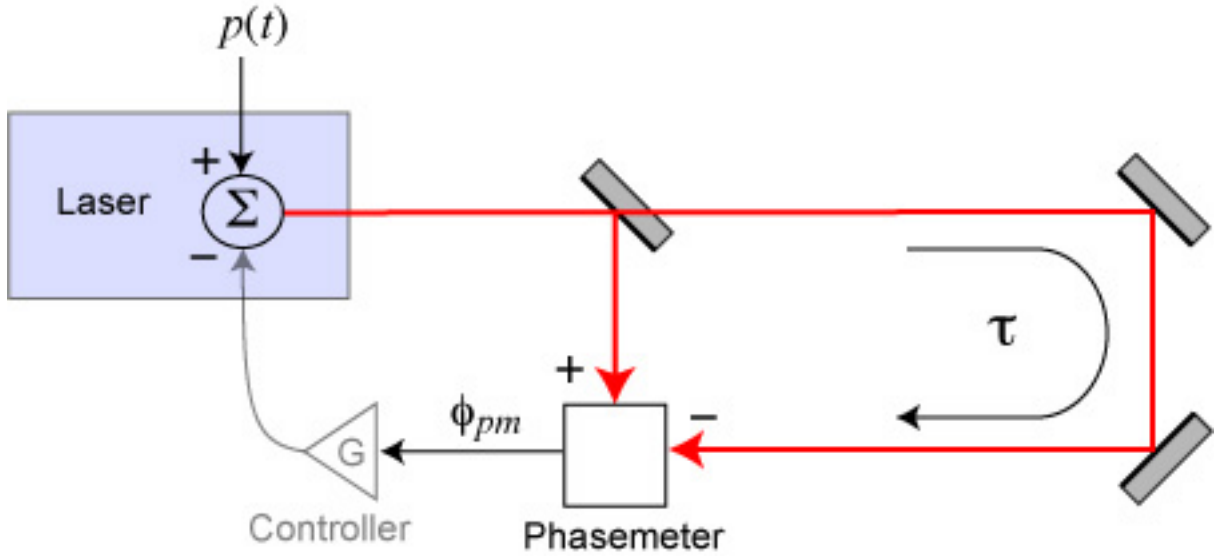






Chow et al, Optics Letters submitted.

Basic model of a LISA arm as a length reference



Phasemeter output is the phase difference between prompt signal (local oscillator) and delayed signal (from the far spacecraft).

Feedback phasemeter output to the laser phase/frequency to the laser with high gain and high bandwidth.

By careful design of controller response, this system can be stable for high gains, yielding significant frequency noise reductions across the LISA signal bandwidth.

Further details, see Sheard et al, Phys.Lett.A

Acknowledgements

International Visitors, in particular
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ACIGA
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