LISA Laser Transponder

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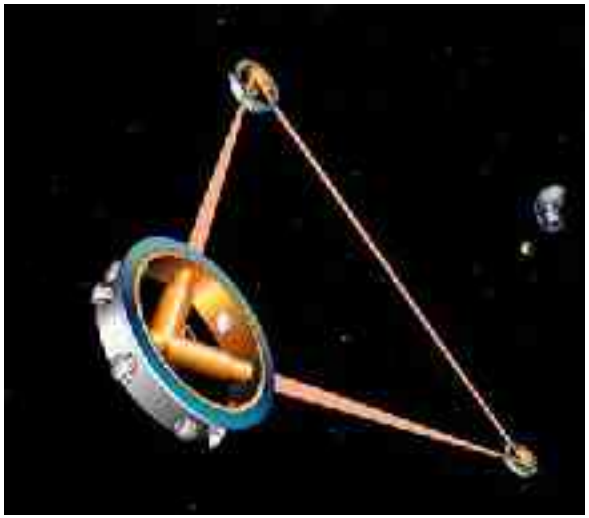
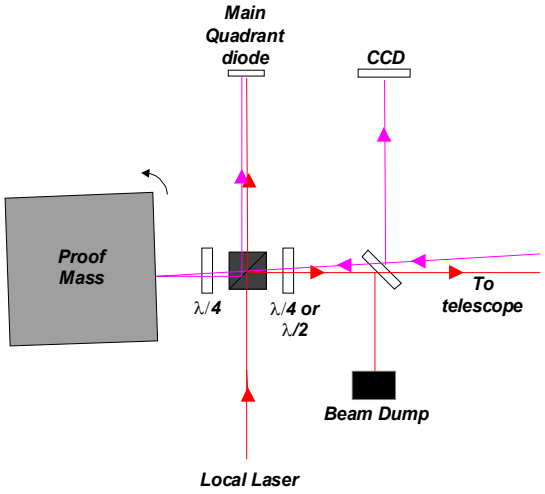
Introduction

- ***Detected power from distant s/c***
  (assuming ~13% of light lost between telescope and photo-detector)
  - *1W transmitted through 30cm telescope*
    - *~120pW detected on main quadrant detector*
    - *Shot noise limit ~48μrad/√Hz*
  - *1W transmitted through 40cm telescope*
    - *~375pW detected on main quadrant detector*
    - *Shot noise limit ~27μrad/√Hz*



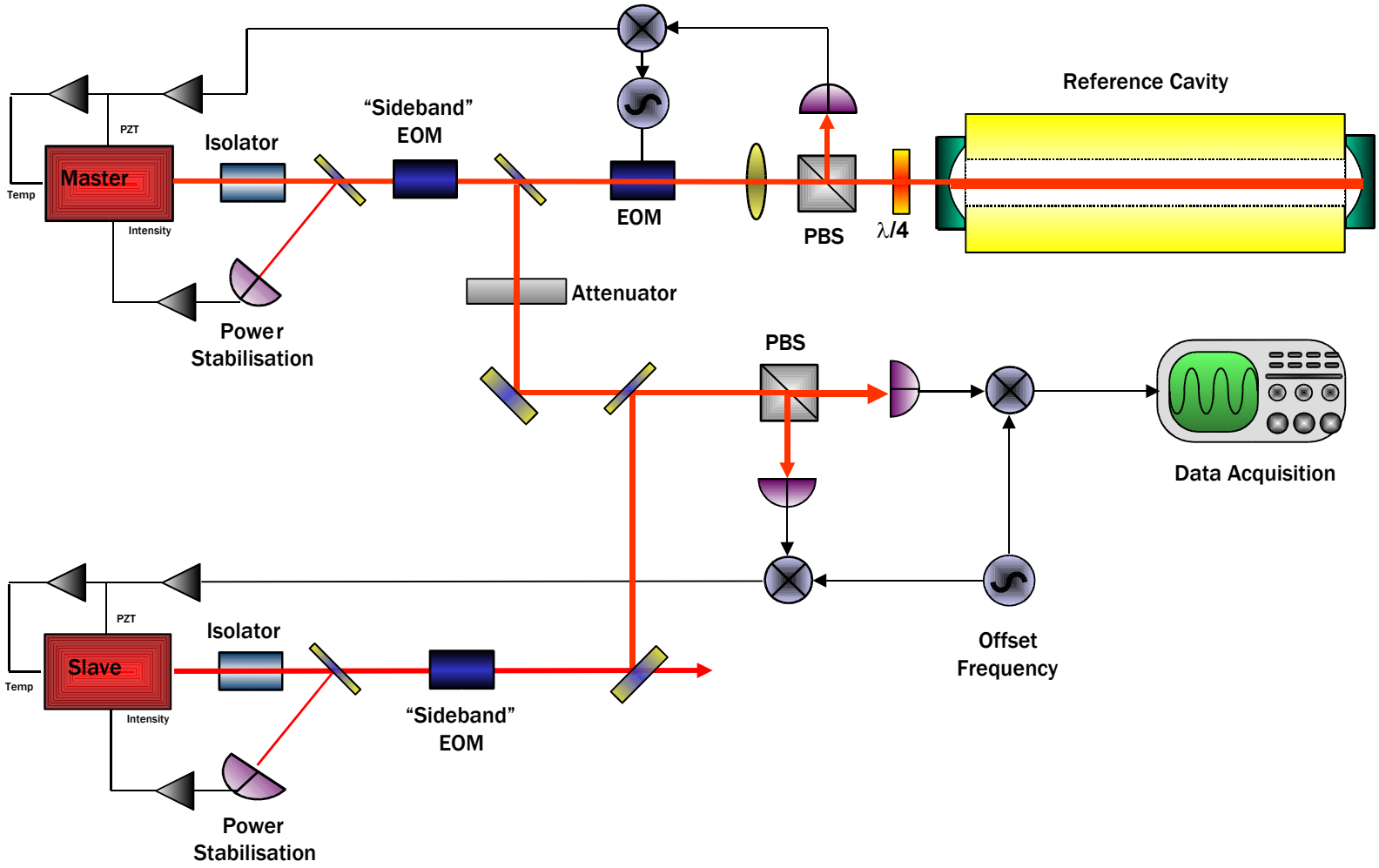
- ***Local laser power on quadrant diode ~100μW***
- ***Light from distant s/c has "Top-Hat" intensity profile, local laser has Gaussian intensity profile***
- ***Beams will be co-linear, but may not be superimposed***
  - *Depends on whether proof mass is used for point-ahead compensation*



Experimental Goals

- ***Demonstrate basic LISA phase locking requirements in lab environment***
- ***Create realistic LISA beams and demonstrate phase locking requirements***
  - *Addition of phase modulation sidebands*
    - *Clock, ranging, data*
  - *Varying Doppler shift*
  - *Different intensity profiles*
- ***Bring system to TRL5/6 compatibility***

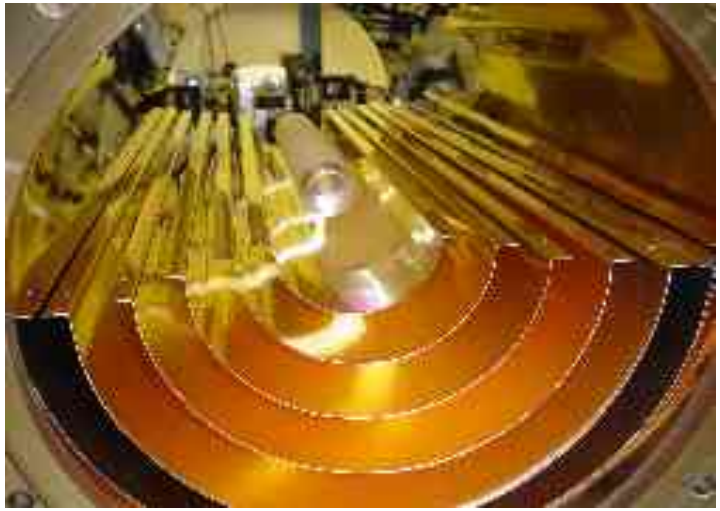
Experimental setup



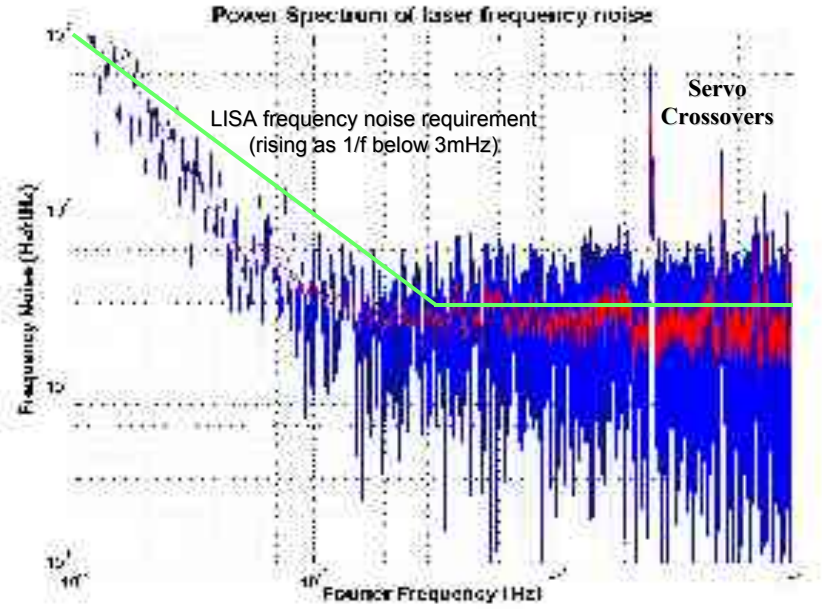
Experimental Description

- ***Master laser locked to high finesse, temperature stable, ULE cavity***
- ***Master laser attenuated by***
  - *Transmission through high reflecting mirror (~10ppm)*
  - *Leakage through polarising beam splitter cube (500ppm)*
  - *Total attenuation ~$5x10^{-9}$*
    - *Master Laser Power **~13pW***

Master Laser



- *Frequency reference cavity manufactured from ULE cylinders with fused silica mirrors optically contacted to end faces*
- *Cavity housed in 5 layers of gold coated stainless steel in*



- *Master laser frequency noise beneath 30Hz/√Hz above 2mHz*

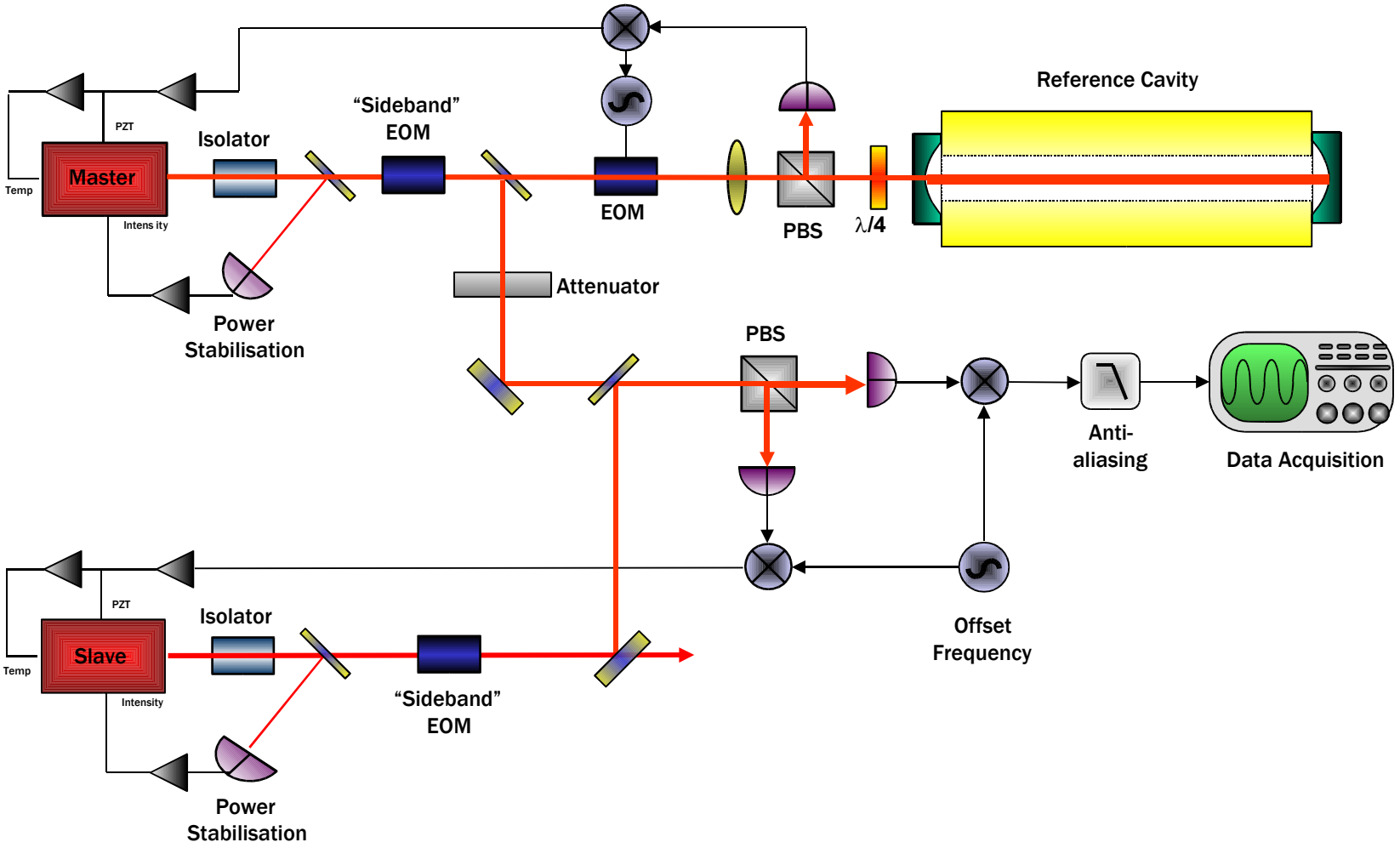
Experimental Description

- *Slave laser free running*
- *Slave laser power ~1mW*

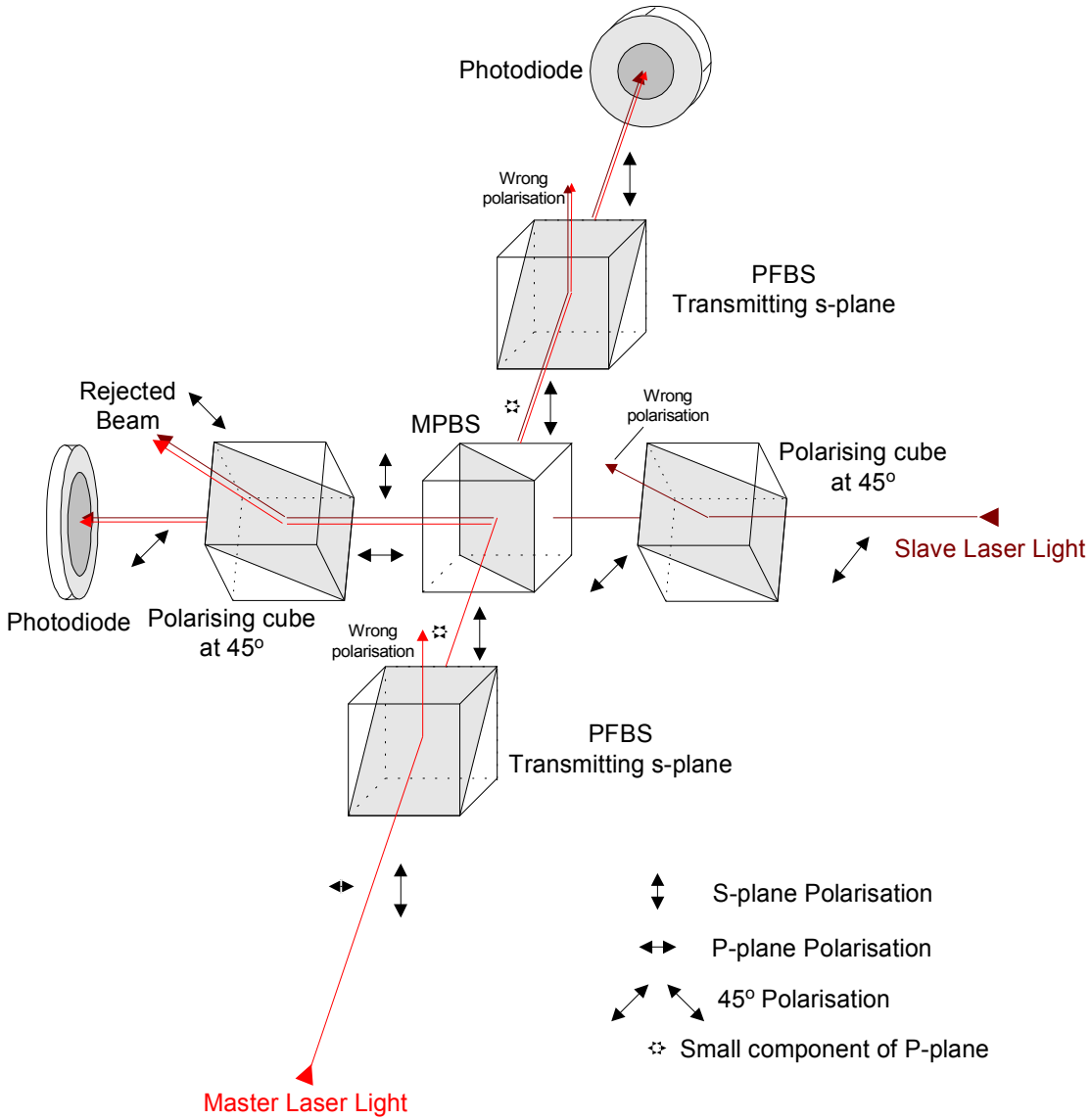
- *Beams combined on polarising beam splitter cube*
  - *One port used for in-loop feedback*
  - *Second port used for analysis*

- *Calibrated analogue mixer used as phase meter*

Experimental setup

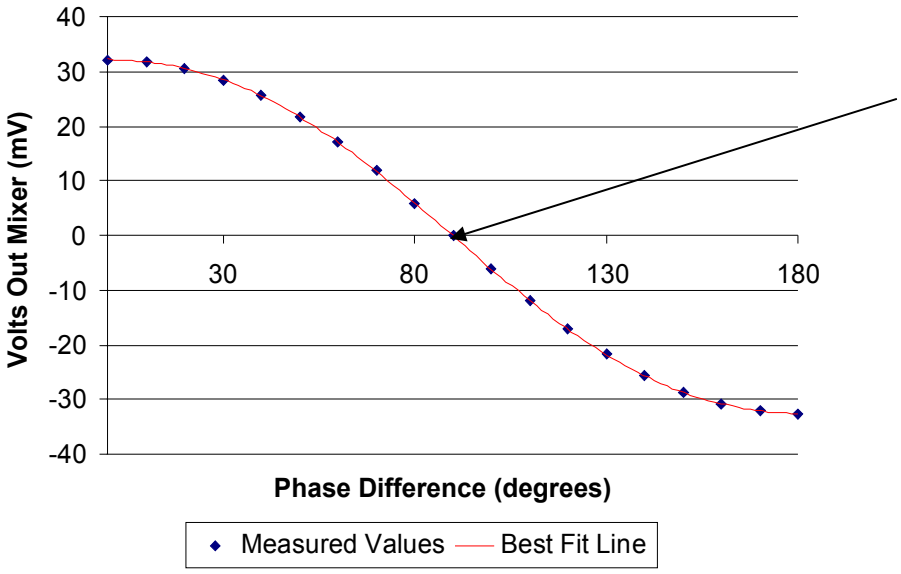


Combining Beamsplitter



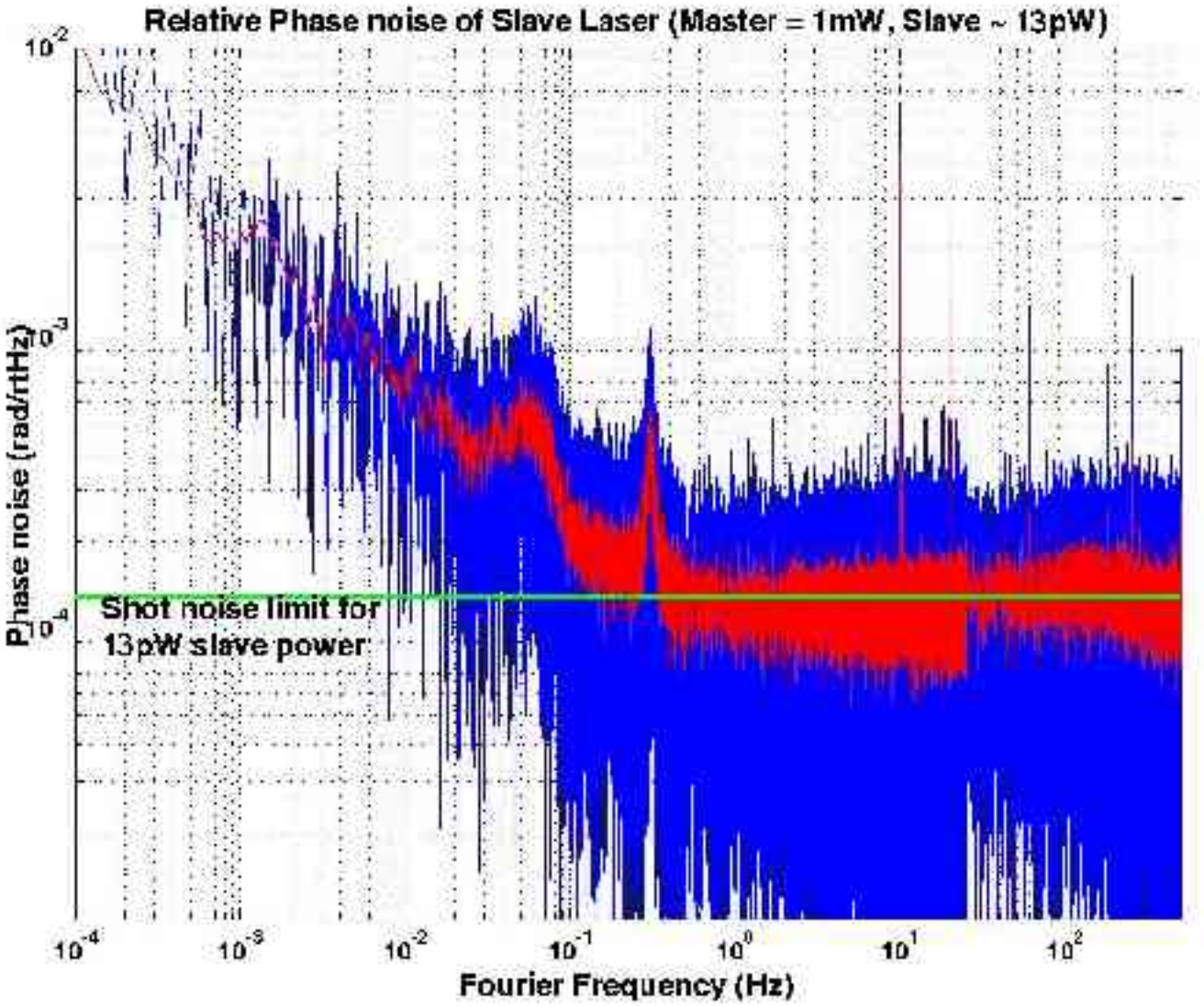
Phase meter

- *Calibrated analogue mixer (SRA-1) used as phase meter*
- *Low frequency performance limited by temperature induced drift in mixer output*



- *Phase of LO set to be in quadrature with beat signal*
  - *using linear part of curve*

Initial Phase Locking Results



Initial Results

- ***Master laser power lower than LISA case***
  - *Master laser power = 13pW*
  - *Laser power attenuated in steps – not variable*
- ***Shot noise limit for 13pW of detected power 1.3×10^{-4} rad/√Hz***
  - *Shot noise limit for 30cm LISA case = 4.8×10^{-5} rad/√Hz*
  - *Shot noise limit for 40cm LISA case = 2.7×10^{-5} rad/√Hz*
- ***Slave laser phase noise is shot noise limited above 0.4Hz***
  - *Further investigations required to reduce low frequency noise*

Possible Noise Sources

- ***Room temperature fluctuations***
  - *Phase locking beam splitter and photo-detectors are NOT in vacuum*
    - *Components housed in "box" on optical bench, and optical bench surrounded by plastic sheet to minimise effect of air currents*
- ***Differential drifts in feedback and analysis mixers***
  - *Mixers not temperature stabilised*
- ***Laser intensity noise***
  - *Low frequency intensity noise limited by voltage reference stability*
  - *May be limiting noise source at low frequencies*
- ***Further work required to identify limiting noise source***

Further work

- ***Investigate limiting noise sources***
  - *Temperature/mixer drift*
  - *Laser intensity noise*
- ***Move critical components into vacuum***
  - *Remove air currents*
  - *Better temperature stabilisation*
- ***Increase master laser power to LISA level***
- ***Incorporate LISA-type phase meter into system***
- ***Investigate effect of mixing "Top-Hat" and Gaussian intensity profiles***
- ***Add "LISA Sidebands" to master and slave laser***
  - *Clock, ranging, data*
- ***Investigate effect of variable Doppler Shift***