Advanced LIGO Sensing and Control
Readout schemes for Advanced LIGO

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R&D Progress

- Three step program
  - 1) benchtop experiments
    - complete (4 papers published Appl. Opts. 1st March)
  - 2a) Glasgow SR experiment (no PR)
    - complete - most goals achieved
  - 2b) Glasgow RSE experiment (with PR)
    - start delayed - results expected late 2003
  - 3) 40m program
    - excellent progress reported - on schedule

R&D outcomes

1) Bench top experiments
   - input to selection of baseline scheme
2) Glasgow phase A (SR only) Bryan Barr
   - 100 MHz/ 12 MHz modulation with 12, 100 and 88 MHz demodulation, works, practical
   - all control matrix elements have predicted values
   - results will be made available in thesis (soon) – they do not push us to change the design (but working with 180 MHz won’t be trivial)

Sensing for control

- Baseline design
  - two harmonically related modulation frequencies (9 & 180 MHz) with double demodulation
  - to give good separation of all signals
  - both resonant in PR cavity, one in SR (one sideband) – good signals

Sensing for control (2)

- Proposed scheme gives reasonable control matrix, fits with mode-cleaner etc.
- It is NOT good for sensing the GW signal (180 MHz high QE photodiode?) and would have to be revisited should RF GW sensing be required.

Sensing for control (3)

- 3rd Harmonic Demodulation scheme
  - input field has 9 and 18 MHz with 27 MHz suppressed
  - 1st and 3rd harmonic demodulation used to read out
  - can give good control matrix, clean signals
  - some (l_- l_s signals are smaller than in baseline
  - avoids need for 180 MHz
  - care needed to avoid unwanted mixing products (in mixers)
- perhaps revisit looking for a compromise

Sensing for GW readout

- Selection & design
  - require good understanding of quantum noise balance, with respect to project science goal
  - require detail knowledge of technical noise couplings (laser noise)
- RF (heterodyne) or DC (homodyne) readout

Sensing for readout (2)

- DC has the traditional problem of the need to achieve shot-noise limited amplitude in the measurement band
- BUT
  - this is needed in any case (technical RP noise)
  - an output modecleaner means little light is detected (mW)
  - some laser noise requirements (frequency stability) are relaxed as local oscillator is derived from long arms

Sensing for readout (3)

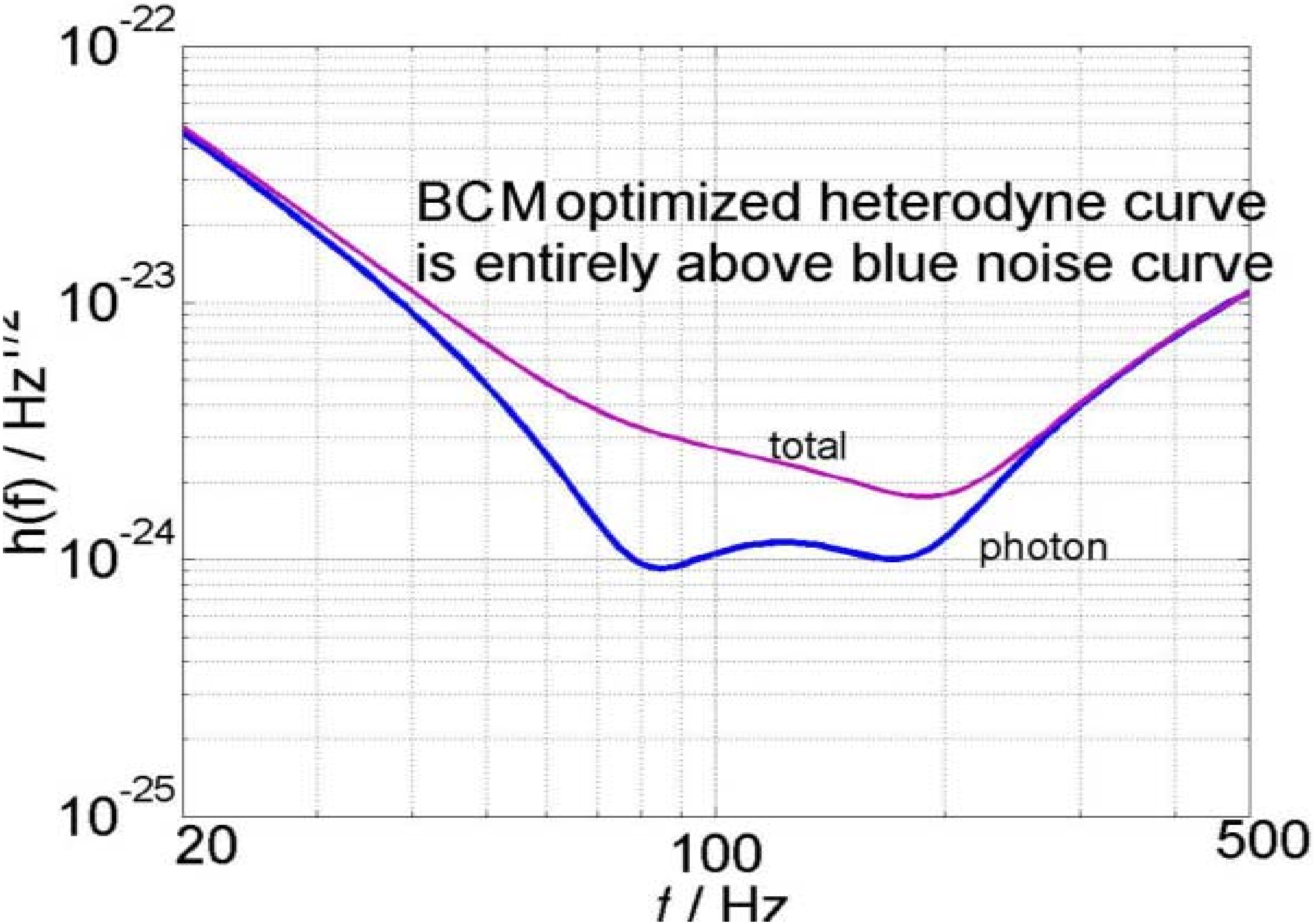
- RF scheme has the traditional advantage ...
- BUT
  - phase noise requirements on the modulation are SEVERE (due to unbalanced detection)

Sensing for readout (4)

- The tools are all in place to enable a decision
  - noise analyses (Mason, Mueller, Fritschel...)
  - quantum analysis (Buonanno, Chen, Mavalvala gr-qc 0302041)
- which alternative best meets the science goals ?

Sensing for readout (5)

- RF scheme provides a simple way of doing frequency dependent readout phase (mix of AM and PM quadratures)
- RF scheme has extra noise over DC scheme
- IT SEEMS that the RF scheme will fail to provide any single advantage over DC



BCM optimized heterodyne curve
is entirely above blue noise curve
total
photon
10^{-22}
10^{-23}
10^{-24}
10^{-25}
h(f) / Hz$^{1/2}$
20
100
500
f / Hz

Intergroup issues (ISC/COC)

- Sapphire / silica downselect
  - assume sapphire, would want to change arm finesse to make best use of fused silica (significant perturbation but can be handled)
- Noise couplings
  - based on agreed targets for mirror loss, cavity finesse mismatch etc.
  - these need to be considered at the time of coating method selection

Control Issues

- Bandwidth of control
  - there must be good gain and phase in the long cavity servos around the optical spring resonance (100 Hz)
  - during acquisition the servo-systems must be able to counter the radiation pressure impulse
  - it could be problematic to provide a control bandwidth reaching or exceeding the first silica ribbon violin mode (based on observations at GEO not fully understood as yet)

Control issues (2)

- The control matrix is more diagonal than that of initial LIGO
- The phase space has an extra dimension and the target volume will be small
- Extra locking steps will be required to lock the OPMC

Control issues (3)

- Variable signal recycling mirror
  - added capability given ACIGA funding
  - require study of implications for ISC R&D, integration, etc.
  - thermal-tuned system (baseline) has been demonstrated (Garching 30m, Kawabe & Winkler) in a DRMI – modest extra control complexity anticipated (can the ifo acquire in every state of VSRM?)

Options and timescale

- Downselect DC or RF (summer '03)
  - if DC develop detection subsystem (short OPMC, photodiode – for both readout - 10 mW efficient, and 1 W handling for intensity control)
  - if RF develop modulation stability and revise ISC scheme to provide low to moderate frequency readout of GW signal and long OPMC

Options and timescale (2)

- Further analysis of '3rd Harmonic' scheme shows
  - that it is not much less efficient than baseline scheme
  - it avoids the need for VHF photodiodes
  - but much more consideration is required before it could become the baseline (40m team likely to look at this)

LIGO III Configurations

- QND workshop descoped
  - aim to have a bigger session in Hannover
- Progress
  - significant new idea – Sagnacs as speedmeters offer several possibilities for relatively simple interferometers operating sub-SQL over significant band (Yanbei Chen gr-qc/0208051) can be combined with variational readout, more tolerant of loss
  - other more sophisticated ideas still under development (intracavity readout)

LIGO III Configs (2)

- Squeezing – expect to get from 5 dB up to 10 dB by pushing down loss
  - ANU and MIT will push this for improved high frequency performance
- Time to start to move QND into the lab
  - preparatory experiments at ANU
  - options for QND experiments in several locations but it is VERY hard to get clear of thermal noise

LIGO III configs (3)

- The challenge is clear – how to improve performance over a wide band simultaneously for both quantum noise (want high power) and thermal noise (cold, so low power)
- Isolated developments without coordination are unlikely to converge to a useful solution in time (technical readiness by 2010)