Sensing for LIGO II

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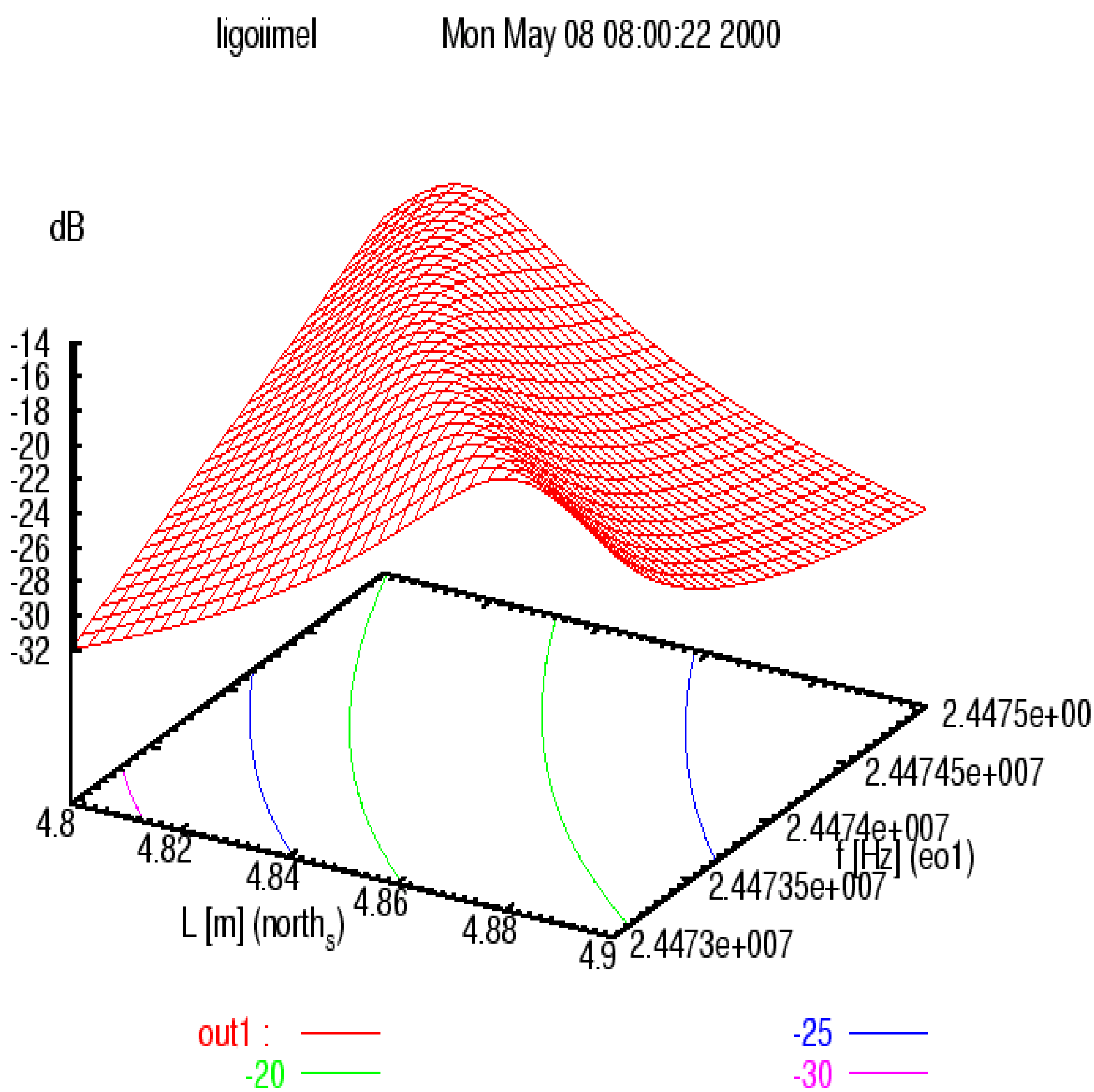
LIGO-G000427-00-D

Tools and Validation -*Finesse*

- *Finesse* is used for single optical mode analyses
  - » It is faster and easier to use than *twiddle.*
  - » Most functions have been validated against other codes.
  - » Caution is needed, the user must perform checks to ensure that functions behave as documented.
  - » The main advantage is *speed*, it takes only a few milliseconds to calculate each point.
  - » *Finesse* was used to explore the properties of a basic sensing scheme which was subsequently extended to the thermally loaded interferometer using Melody.
  - » *Finesse* was written by Andreas Freise, using elements of *LISO* by Gerhard Heinzel.

Example *Finesse* Output: sideband optimisation



LIGO

Sensing

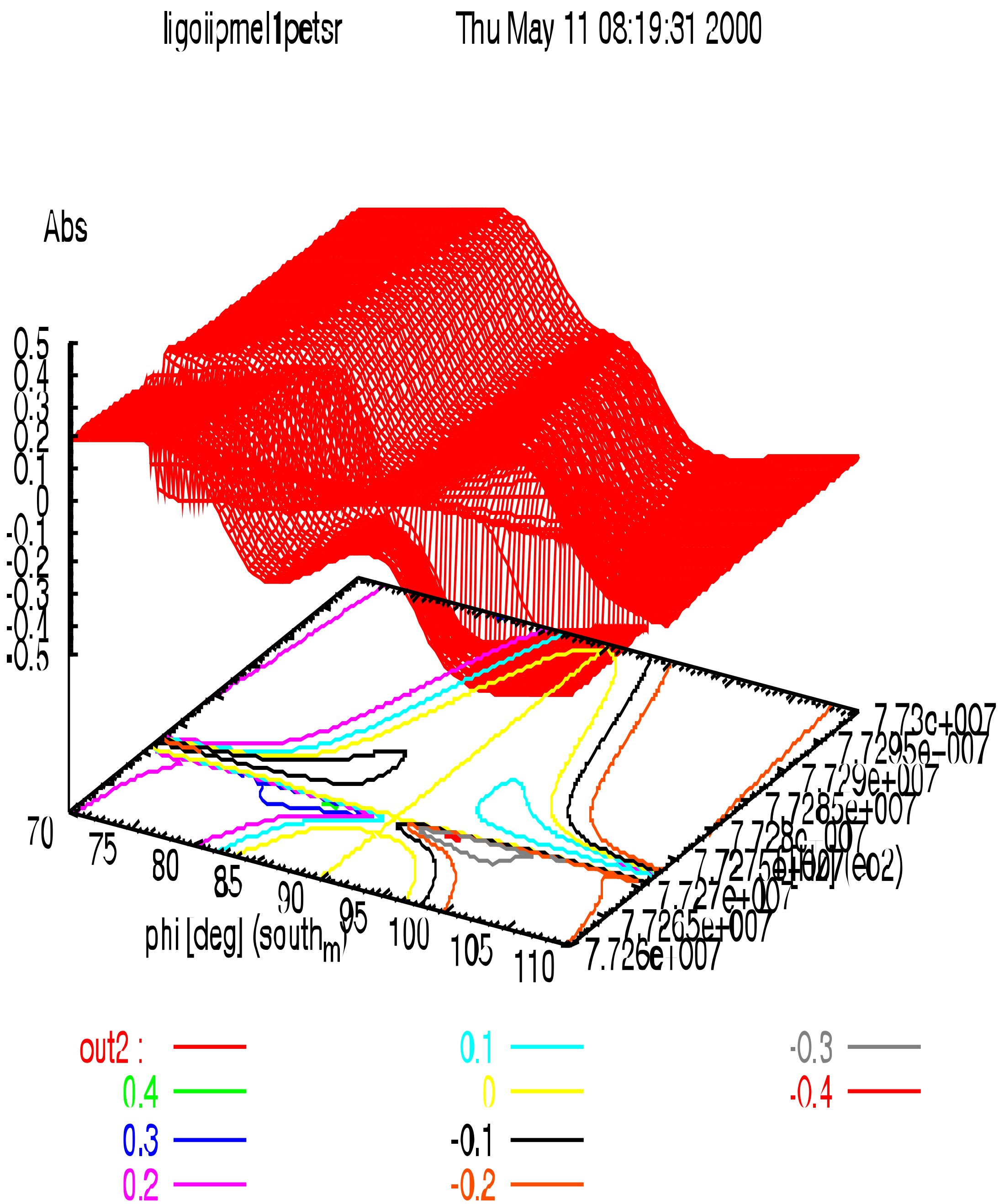
- Several methods of sensing the required variables have been identified
  - » some have been or are being tested experimentally.
  - » Ref: Mar 2000 AIC transparencies, AIC group (LIGO-G000055-00-D, LIGO-G000053-00-D)
- Sensing L_- :two options are considered
  - » RF Schnupp-based scheme
  - » DC local oscillator (offset lock) scheme

Sensing (what's new)

- Sensing the SR phase is new.
- Option 1: to demand a zero-crossing signal at a single operating point
  - » always possible by adjusting the modulation frequency and the BS-SR mirror spacing. (Sensing light anywhere in the central optics except in the SR arm
  - » ideal for a broadband system with fixed or nearly constant tuning
  - » changing the modulation frequency might be quite complex and *might* not allow enough tuning for a general purpose detector
- Option 2: to allow a DC offset to control the tuning
  - » allows a wide tuning range
  - » increases some noise couplings

SR control example.

Signal from BS AR pick-off.



Sensing (evaluation)

- flexibility: ease of achieving all operating modes
- philosophy: staying close to established methods
- noise couplings: extensive calculations should allow selection and optimisation of the selected scheme.
  - » Most significant noise couplings relate to the GW signal
  - » The PR system should, again, be quite like LIGO I
  - » The SR system is less critical, noise on the SR mirror couples to the output relatively weakly.
- some methods depend on choice of mode-cleaner, etc.

RF Schupp-based L_- *sensing example*

- Similar to LIGO I
  - ~25 MHz in-line modulation, β = 0.25 to 0.5
  - PR, SR mirrors about 5m from BS
  - ITMS 4.5 and 4.9m from BS, respectively
  - Arms 4000.000m
- The result is
  - Efficient throughput of modulation energy
  - ~1W per sideband at main (dark fringe) detector
  - May need an output mode-cleaner.

Sensing Schemes

- Mason uses independent LO, adds sub-carrier (or AM sidebands) at *fmod/3*
  - » (short mode-cleaner then restricts frequencies e.g. 75/25MHz)
  - » Produces beat note at difference frequency at PRC pickoff
  - » All other signals as in LIGO I (but different coupling matrices)
  - » Few cm ***l***- asymmetry optimises for one tuning, but for large tuning requires repositioning of mirror, or change of modulation frequency,
- Shaddock uses 75MHz PM + tuneable sub-carrier with 15MHz PM sidebands (same ports)
  - » Changes discussed at LSC meeting under test