Calibration of the Dual-Recycled GEO600

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Dual-recycled GEO600

signal-recycling mirror added

North

North arm (600m)

Power-recycling mirror

East arm (600m)

Signal-recycling mirror
General approach

- Undo the effects of any transfer functions from differential displacement to output voltage
  - optical transfer function
  - differential lock servo-loop
- Convert recovered differential displacement to strain
Simplified detector model

- High-power diode (Q)
- High-power diode (P)
- Quad diode (low-power)
- Split feedback Path

differential displacement

High-power diode (Q)
High-power diode (P)

get h(t) here!

Low-power diode (P')

Calibration signal
• Frequency dependent optical gain
  • different from power-recycled case (flat optical response)
  • time-varying overall gain – what about time-varying frequency response?

PR → DR
Measured optical response

DC Gain: 5740
Pole f: 1225 Hz
Pole Q: 2.7
Zero f: 1400 Hz
Calibration Lines

- Injected into ESD actuator using purpose built generator

![Graphs showing Amplitude (RMS) vs Frequency (Hz)]
Calibration Equation

\[ d(t) = F'_{opt}\left\{P_{EP}(t)\right\} + F_{FB}\left\{P_{EP}(t)\right\} \]

High-frequency (open-loop) correction – inverse optical response

Low-frequency (closed-loop) correction – response of feedback paths

\[ h(t) = \frac{d(t)}{1200} \]
System identification

- Recover parameters of optical response
- Form transfer function from calibration lines to detector output
- Fit model transfer function to measurements
- optimisation routine – hfit() - runs once per second
  - returns Pole freq, Pole Q, Zero freq, DC gain
  - gives $\chi^2$ measure of fit (see later)
Analysis of S3 week 1

- Optical response corrected with fixed frequency dependence – good assumption?
- What does the $\chi^2$ tell us?
- How good is the calibration?
Recovered optical parameters
Distribution of optical parameters

DC Optical Gain

- $\mu = 6033.1$
- $\sigma = 232.4$

Pole f

- $\mu = 1220.2$
- $\sigma = 14.1$

- 1225Hz used

Pole Q

- $\mu = 2.7$
- $\sigma = 0.1$

- 2.7 used

Zero f

- $\mu = 1369.9$
- $\sigma = 33.1$

- 1400Hz used
Optical response variations

Recovered responses taken every 5000 secs of the first week of S3

Recovered responses / nominal $< +2^\circ$
$\chi^2$ triggers

- nominal $\chi^2 \sim 50$
- 591 triggers $> 200$ in 604,800 secs
## Quality channel

- Quality channel contains information about data quality and detector status in 16 bits
  - Lock indicator
  - Maintenance time
  - $\chi^2$ threshold crossings
  - Extendable to more....
- Highest quality is 0

<table>
<thead>
<tr>
<th>BIT</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
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</thead>
</table>
| lock status | maintenance condition | $\chi^2$ threshold 1 | $\chi^2$ threshold 2 | $\chi^2$ threshold 3 | $\chi^2$ threshold 4 | ...

*GWDAW8 2003*
Calibrated $h(t)$
Summary

- Good so far...
  - calibration good to ~5% across most of the detection band
    - still dominated by calibration actuator
  - good confidence in parameter recovery
  - fast processing (4x real-time on my laptop)

- Where to go from here?
  - more validation
    - freq-domain comparisons, simulations
  - on-line updating of optical correction filters using estimated parameters
  - Include other quadrature (Q) in calibration process