Jittery Presentation

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Commissioning Meeting, 11/11/16

Why does PSL noise couple into the interferometer?

- Intensity noise sensor after IMC
  - At 10-20mW shot noise level below 1kHz
- Frequency noise:
  - Plenty of gain: FSS / IMC / REFL
- Angular jitter:

$$a_{10}(f) < 2.5 \times 10^{-6} \sqrt{1 + \left(\frac{100\,\mathrm{Hz}}{f}\right)^4} \frac{1}{\sqrt{\mathrm{Hz}}}$$

- But: Broad 500Hz hump at 50W (ang. jitter ruled out)
- But: HPO/PMC length noise shows up in ifo much too strong (freq. & intensity coupling ruled out)

HPO / PMC Connection

- HPO produced huge amount of jitter
  - But: After filtering thru PMC it is smaller than periscope/mount peaks at frequencies >100 Hz
  - No indication that jitter below 100 Hz is a problem
  - Still: Coherence between HPO jitter and DARM
- More gain in HPO servo reduces peaks
  - Injection locking servo (ILS) is gain limited
- PMC:
  - HPO peaks visible in error signal
  - However: Increasing ugf will make peaks worse
  - PMC length locking is limited by sensing noise (offset errors)

PMC Length Noise Coupling

- PMC length noise which corresponds to frequency noise at the 1Hz/√Hz level (at 1kHz) will show up in DARM
  - Free running laser noise is higher (coupling thru freq. ruled out)
  - Visible in ISS second loop, but too small (intensity noise ruled out)
  - Visible in IMC WFS as jitter (jitter coupling too small & ruled out)
- Not ruled out:
  - Error point offsets into IMC or REFL; but how?
  - Jitter by other higher order modes (e.g., beam size jitter)
  - Polarization jitter
  - Some (really) strange electronics pick-up

Length Noise in Cavities Can Generate Jitter

- Input field: $TEM_{00} + \varepsilon E_x$
  - E_x can be TEM_{nm} or $E_{p\text{-}pol}$
- Cavity: TEM_{00} resonant
  - Length noise will generate frequency noise on resonant mode
  - Higher order modes will typically not be resonant and experience frequency shifts at a much smaller scale
  - Transmission (PMC, IMC): higher order mode attenuated
  - Reflection (all): no attenuation, used for reflection locking
- Down stream frequency noise sensor
  - The freq. stab. will remove any frequency noise on the carrier
  - But will effectively imprint it on the higher order mode

Higher Order Mode Coupling in Interferometer

- A misaligned optics will shift carrier into TEM_{10}
  - Symmetric matrix: TEM_{10} jitter shifts to TEM_{00}
  - Same mechanism for curvature/beam size mismatch
  - Differential arm cavity misalignment/curvature/size mismatch can generate AS port intensity noise
  - Curvature/size mismatch fields can be 100x higher than misalignment
- REFL port is vulnerable too
  - Above mechanism works for RF modes too
  - Generates error point offsets which will be imprinted on the frequency noise
  - Frequency noise coupling above 100 Hz much higher than simple double cavity pole
  - But signal is reduced by double cavity pole

Closing Remarks

- We do not meet the traditional beam jitter requirement
  - Requires <1 nrad rms misalignment
  - Jitter coupling seems to get worse with thermal loading
- Do we need more filter cavities?
  - In-air: double PMC on laser table
    - Doesn’t solve the traditional jitter requirement
    - Will eliminate HPO/PMC jitter noise
  - In-vacuum: PMC style in HAM1(?)
    - Will solve the jitter problem, odd mirror # will also reject polarization
    - Will require in-vac modulators & relay optics
    - IMC detector in vac?
- Other options:
  - Active mode matching?
  - Active jitter suppression: hard to do with PZTs