Some questions I wish someone had time to explore (by simulation or otherwise) and give me some answers

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e2e Meeting

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G010387-00-D

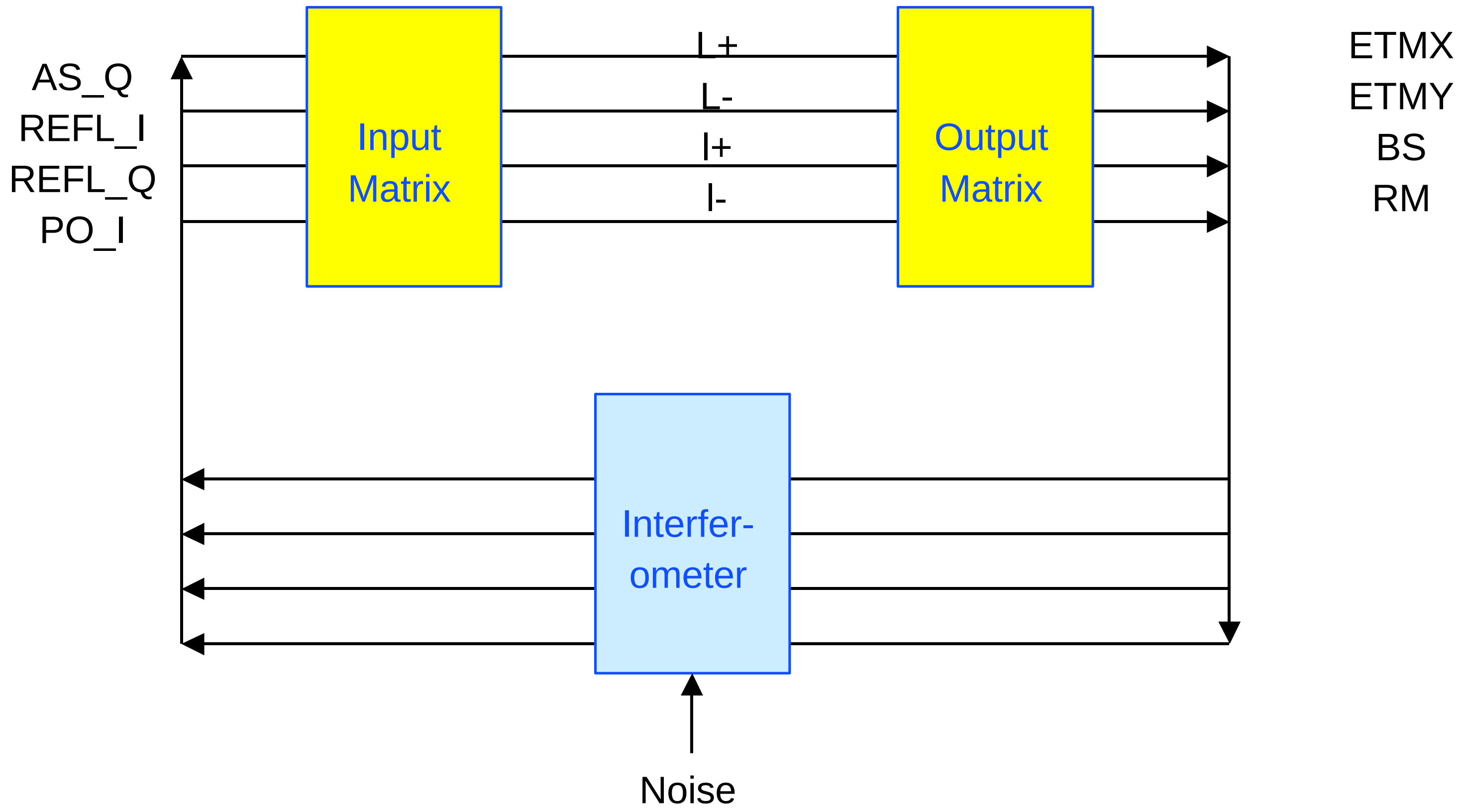
Goal / Disclaimer

- Outline a set of real interferometer problems that *might* be addressable by a combination of e2e and analytical methods, combined with experimental data
  - » Will try to give reasonable guesses for some of the undocumented parameters….

- Disclaimer:
  - » I don’t know the answers to these questions, though some others might. In some cases, I have guesses, but not high confidence that they are correct.
  - » Some of the questions may be too complex to be tractable, others may turn out to be trivial, or uninteresting, or just plain embarassing.
  - » The list changes on the timescale of a 3-9 months

Cross-coupling in the Servos

- Servos to lock interferometer involve two LIGO-defined and one Nature-defined basis transformations



What Kinds of Imperfections in Nature-defined Transformation?

- Interferometer asymmetries
  - » BS not exactly 50-50
  - » Different ITM transmissions
  - » Arm cavities have different losses
  - » Different losses from BS to ITM and back
    - » AR coatings, pick-offs
  - » Unequal sideband amplitude in incident light
  - » BS not perfectly flat (Hard !)

What happens if the LIGO-defined transformations is off?

- Basic lock of interferometer is unaffected…
  - » Mistakes in the matrices are equivalent to a basis transformation
  - » Origin in (L+’, L-’, l+’, l-’) basis same as origin in (L+, L-, l+, l-) basis
- Noise may be affected
  - » Gain may be reduced for some degrees of freedom
  - » Noise may be coupled from one degree of freedom to another (e.g., frequency noise on input light may get into differential arm signal)
- Question 1:
  - » How accurately do these matrices need to be determined? 5%… easy (probably), 1%….harder, 0.1%…..
- Question 2:
  - » Is there a robust procedure for measuring the input and output matrices in the presence of interferometer asymmetries?
  - » Example: setting rf phases

Questions, continued

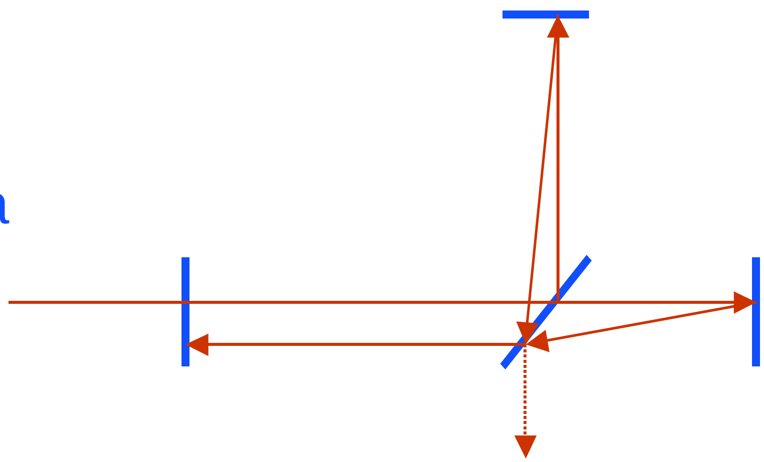
- Question 3:
  - » Is there a signature for different types of errors in the matrix?
  - » Example: Coherence between AS_Q and CARM_CTRL (L+ drive) might indicate incorrect output matrix?
- Question 4:
  - » Are there "false optima"?
  - » Solutions where compensating errors in the input and output matrices give "sensible" results (e.g, drive ETMX' and ETMY' and get equal but opposite signals in L+' and L-')
  - » If so, are there any simple tests to distinguish the real optimum from the false optima? If we are on one of these false optima, does this change the answer to Question 1?
- Question 5 (HARD!):
  - » Do matrices measured with a "cold" PRM still apply when the PRM is "hot"?

How can we measure the recycling cavity length?

- Recycling cavity length matched to rf modulation frequency
- Sensitive method for measuring modecleaner cavity
  - » Sweep frequency of transmitted sidebands and look for dip in reflected signal measured on rf PD
  - » Sharp minimum when rf = n x free spectral range
- No easy analog for sweeping rf fringes incident on PRM
  - » Frequencies not multiples of MC FSR are blocked

Why does alignment of PRM affect relative sizes of sidebands?

- Observed (on 2 km interferometer) that relative amplitudes of upper and lower sidebands are affected by PRM alignment
- Use optical spectrum analyzer to measure amplitudes at antisymmetric port
  - » Not a subtle effect! Easy to get factor of 2 changes
  - » Presumably reflects build up in PRM (…caveats…)
- FFT code?
- Speculation:
- Can anyone put together a real explanation?



What causes the violin modes to appear and disappear?

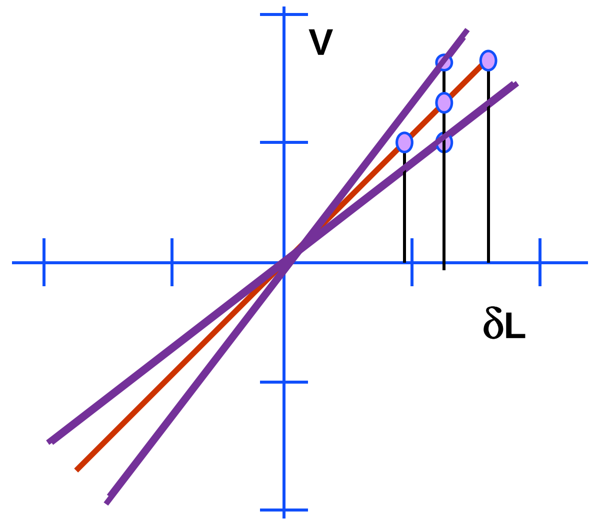
- Basic violin mode mechanism "understood"
  - » Typical loop UGF ~100 Hz, falling like 1/f
  - » Resonance gives a big increase in mechanical gain and large phase shift
  - » At some overall loop gain, violin resonance peeks up above unity gain and all hell breaks loose
- Observation that the violin modes seem to come and go—some days/weeks they seem to be excited easily and other times not
- Speculation:
  - » Small changes in optical alignment change coupling

Violin modes , continued

- Question 1:
  - » Are the violin modes really modes of individual wires or are they coupled modes? (LHO elog gives 343.820 and 344.055 Hz for ETMX frequencies)
  - » Affects coupling to the optical spot
- Question 2:
  - » Is the excitation of the violin modes “intrinsic” to the OSEM drive or is it enhanced an imbalance in the drive to the various OSEMs?
- Question 2:
  - » Does this whole scenario hang together, quantitatively? (almost certainly yes, because we observe it…..)
- Question 4:
  - » How large a change in alignment is required to make a significant change in the couple of the feedback to the violin mode, or of the sensing to the violin mode?

Stan's Hobbyhorse: Bilinear Noise Sources

- Simplest Example:
  - » Sensing of arm length difference is proportional to input laser intensity



$$"\Delta L"(t) \approx I(t)dL(t)$$

$$"\Delta \tilde{L}"(w) \approx \tilde{I}(w_1)d\tilde{L}(w \pm w_1)$$

- Noise term linear in two variables ("bilinear") creates output noise at sum and difference frequency

Importance of Bilinear Noise Mechanisms

- Our interferometer configuration is insensitive to (most) first order noise sources
- “Traditional” noise investigation techniques (transfer functions, coherence) don’t pin-point bilinear sources
  - » Requires alternative techniques (e.g., addition of band-limited white noise)
- Understanding full nature of noise source gives experimenter two chances to reduce the output noise
- Bilinear noise sources are fairly common
- Most importantly, e2e is a good tool for investigating bilinear noise sources

Sideband Amplitude Fluctuations

- Similar mechanism to intensity noise
  - » EOM produces sideband amplitude $J_1(\Gamma)$, carrier $J_0(\Gamma)$
  - » Signals proportional to A_sA_c
- Intensity noise moves A_s and A_c together, while variations in Γ move them oppositely
  - » Partial cancellation
- Question:
  - » Is there anything deeper than that? (possibly not, but then again ….)

Beam Clipping?

- Mundane noise source, but of some immediate relevance….
- Possibility that the edge of a mirror or other aperture inside the vacuum system blocks part of the beam exiting at a sensing port
- Motion of clipping aperture introduces time-varying optical gain for interferometer
  - » (Optical gain = volts per meter of displacement)
  - » Coupling similar to intensity noise (first order guess!)
- Differs from pure intensity noise because it is different for different ports

Beam Clipping, continued

- Plausible assumptions:
  - » Assume beam waist given by COS design (~5 mm)
  - » Edge clips 0.001- 0.01 of power on average
  - » Motion of edge equal to motion at top of HAM stack
- Question 1:
  - » How does the induced intensity noise compare to input requirement ($\Delta P/P \sim 10^{-8}$ Hz $^{-1/2}$)? (Simple analytic result)
- Question 2:
  - » Is there a signature that would identify such a mechanism as the dominant noise source in a given region? (remember that HAM stack spectrum shows up in laser frequency noise…)
  - » Is the signature different on different ports?

Discussion

- Questions?

- Comments?

- Advertisement:
  - » Detector commissioning meeting at 8:15 every Monday morning, and all e2e-ers are very welcome!