NASA LISA Telescope Progress

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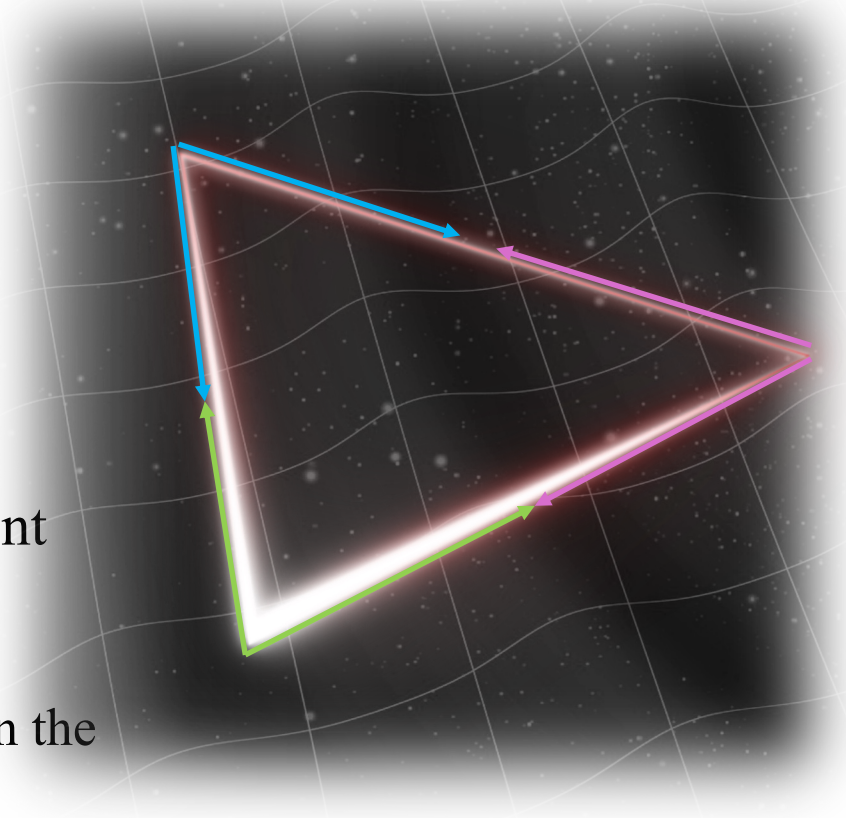
July 2024

Telescope Functional Requirements

- The Telescope is needed to transfer enough laser light over the long-arm (inter-S/C) link (2.5 Gm = 2.5 million km)
- Afocal beam expander:
  - 302.5 mm diameter large pupil
    - Fraction of a nW at the far S/C
  - 2.24 mm diameter small pupil
  - 135x magnification
- Simultaneous transmitter and receiver (TX/RX)
- It has to do this without disturbing the precision length measurement between optical benches (2x telescopes in a link, 6x in the constellation)
  - Optical pathlength within the telescope must be stable to 1 pm/√Hz in the measurement band
  - Tilt-to-length (TTL) effects must be understood and managed
- It also must support constellation acquisition



Design Drivers

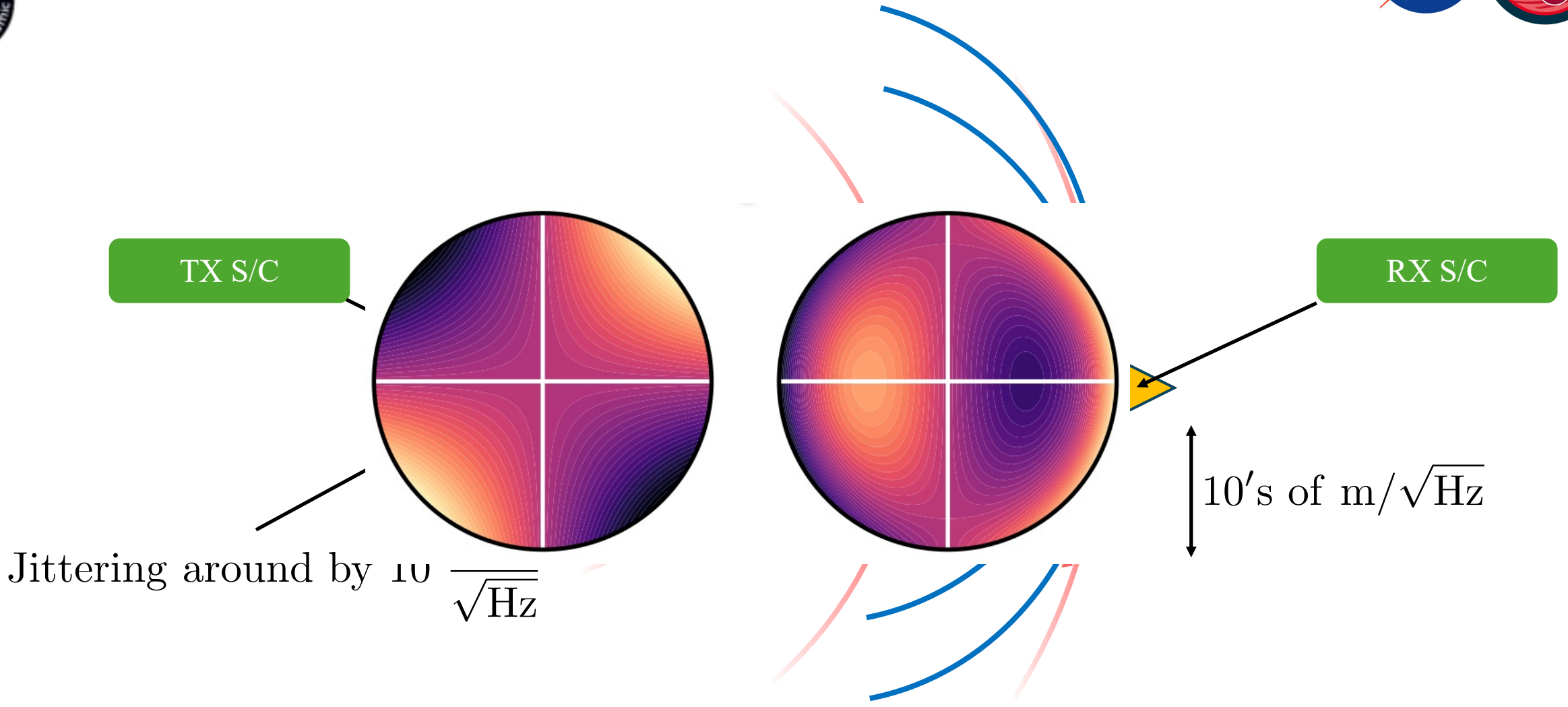
- Dimensional Stability
  - For the in-band path-length stability the solution is ‘easy’: construct the entire telescope out of an ultra-low CTE material and keep the temperature environment quiet
  - GSFC and L3Harris have built prototype telescopes out of ZERODUR® glass-ceramic and we have a testing program underway with the University of Florida.
  - We will stand up a testing lab at GSFC soon.
  - Brian form L3Harris will describe the build shortly
  - Alex from UF will describe the OPL testing as well

Images Credit NASA / Denny Henry

Design Drivers

- Tilt-to-length effects are myriad in the metrology system, and the telescope contributes in several ways:
  - The measurement axes between optical benches and proof masses must be overlaid, so the telescope must accurately relay the lasers from ‘small beam space’ to ‘big beam space’
  - Field dependent effects (pupil wander/OPL gradients) can also cause apparent path-length variations. Joe from GSFC will talk about this.
  - In addition to other harm, wavefront aberrations can couple tilts of the TX S/C into an apparent length signal. We need to keep the WFE low (< 40 nm rms over a ±20 µrad science field of view). WFE also:
    - Degrades the quality of the interference (heterodyne effiency)
    - Can confuse the attitude control
    - Diverts power away from the beam axis
  - A Beam Alignment Mechanism (BAM) on the optical bench can help null TTL: we need to characterize the telescope over many possible beam locations. GSFC has a testing lab for this ready, there is a poster by Shannon here at the Symposium.

WFE Effects


TX S/C
RX S/C
Jittering around by 10 $\frac{}{\sqrt{\text{Hz}}}$
10′s of m/$\sqrt{\text{Hz}}$

OMS Simulations

- Budgeting of tilt-to-length effects turned into a WFE effect Monte Carlo simulation which is turning into an integrated Optical Metrology System (OMS) simulation
  - Broad set of Telescope and Optical Bench tolerances are included
  - Near field effects (RX interferometer) and far-field effects (long-arm diffraction) are calculated simultaneously for each realization
    - Beam propagation solutions found with arbitrarily sampled Fourier methods
  - Representative Structural/Thermal/OPtical (STOP) sensitivities are modeled (on-orbit environments, drifts, &c.)
  - GSFC work pursued in close contact with UK ATC/ESA, feeds into the performance budgeting efforts
  - Expected to grow both in scope and detail, especially once more as-built test data starts to be included

Conclusions and Next steps

Progress so far:

- Prototype program is addressing all major technical risks
  - Pathlength stability and tilt-to-length effects all look promising
  - Some work to do on mechanical interfaces

Next steps:

- We have an in-house research program at GSFC on bonded joints, as we have had some trouble with this
- Continue to develop modeling
- Pursue flight telescope contract

Questions?

Images Credit NASA / Denny Henry