UNIVERSITY OF FLORIDA

A Bench-Top Model of a Space-Based Interferometer

-How to squeeze a 5 Gm instrument into our lab-

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Overview

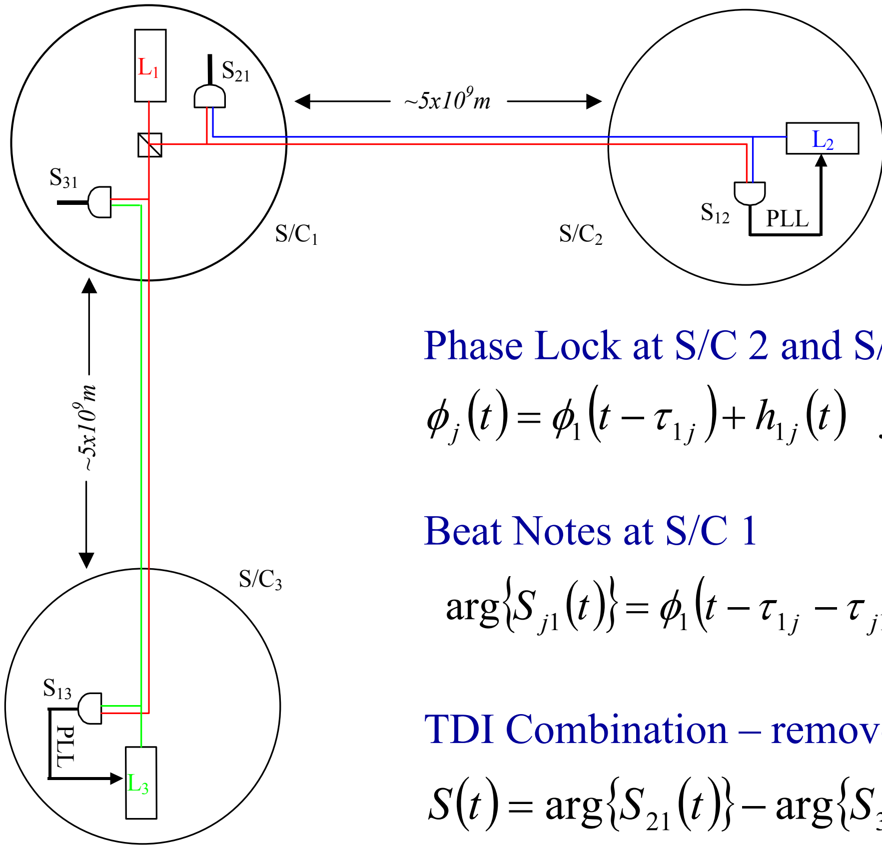
• Eventually the LISA interferometry techniques will need to be tested on Earth

• For Example: testing phase noise correction schemes (TDI)

In This Talk

- A simplified model of TDI in an unequal arm Michelson
- A bench top equivalent
- Canceling phase noise in the bench top
- How to achieve the large time delays

Removing Laser Phase Noise with Unequal Arm Lengths – the famous TDI



Consider a 2-arm interferometer using “optical transponders”

Phase Lock at S/C 2 and S/C 3

$$\phi_j(t) = \phi_1(t - \tau_{1j}) + h_{1j}(t) \quad j = 2,3$$

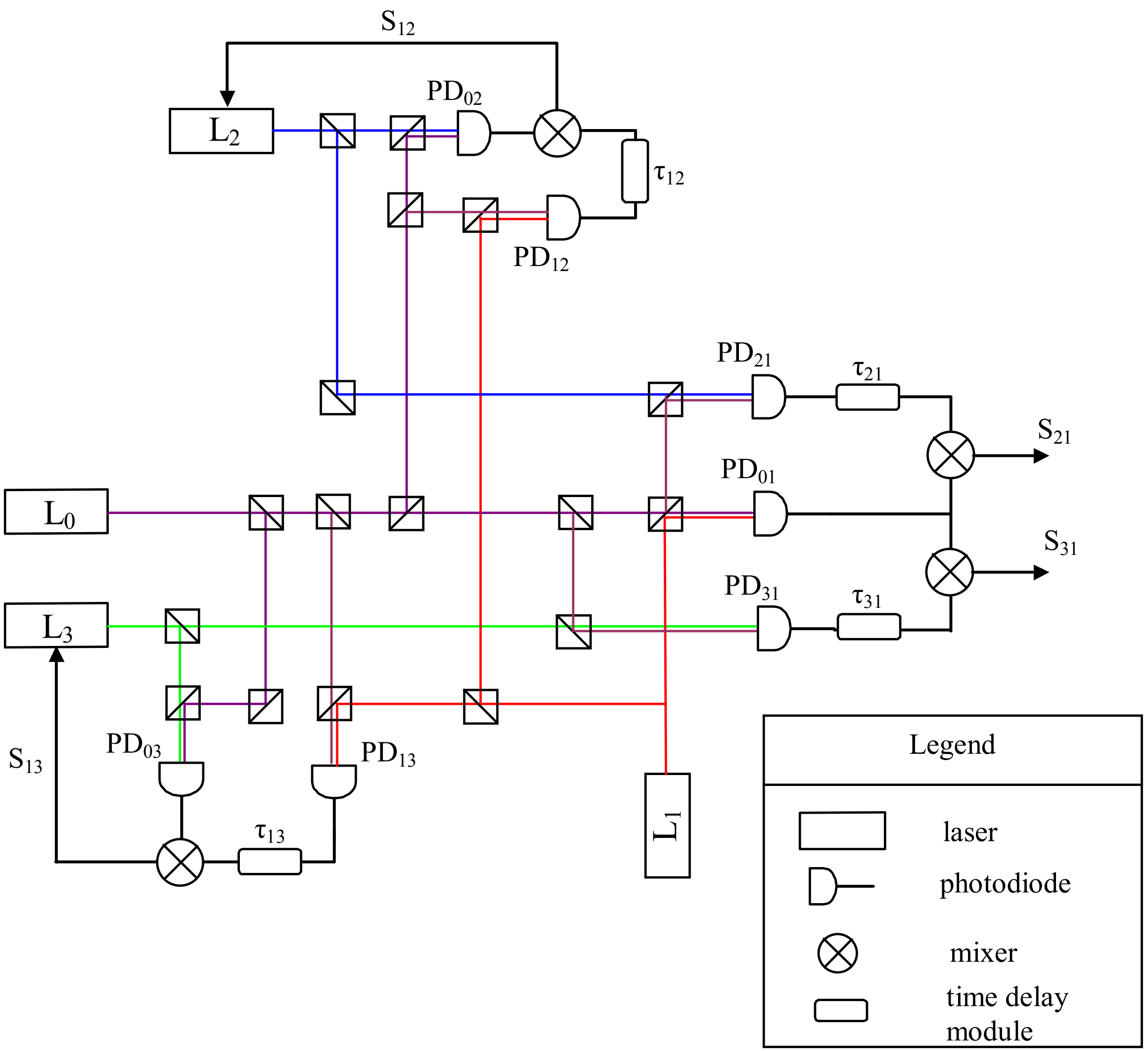
Beat Notes at S/C 1

$$\arg\{S_{j1}(t)\} = \phi_1(t - \tau_{1j} - \tau_{j1}) + h_{1j}(t - \tau_{j1}) - \phi_1(t) - h_{j1}(t)$$

TDI Combination – removes phase noise

$$S(t) = \arg\{S_{21}(t)\} - \arg\{S_{31}(t)\} - \arg\{S_{21}(t - \tau_{13} - \tau_{31})\} + \arg\{S_{31}(t - \tau_{12} - \tau_{21})\}$$
$$= h_{13}(t) - h_{13}(t - \tau_{31}) - h_{13}(t - \tau_{12} - \tau_{21}) + h_{13}(t - \tau_{31} - \tau_{12} - \tau_{21})$$
$$- h_{12}(t) + h_{12}(t - \tau_{21}) + h_{12}(t - \tau_{13} - \tau_{31}) - h_{12}(t - \tau_{21} - \tau_{13} - \tau_{31})$$

Primitive Optical Mock-Up of 2-arm Interferometer



- Beat notes are taken with an additional (frequency stabilized) reference laser
- Electronic time-delay modules simulate long arms

Removing Phase Noise in Mock-Up

Photodiode signals

$$\arg\{PD_{ij}(t)\} = \phi_i(t) - \phi_0(t) \quad i,j = 1,2,3 \quad i \neq j$$

$$\arg\{PD_{0j}(t)\} = \phi_j(t) - \phi_0(t) \quad j = 1,2,3$$

Mixer Outputs

$$\arg\{S_{ij}(t)\} = \phi_i(t - \tau_{ij}) - \phi_0(t - \tau_{ij}) - \phi_j(t) + \phi_0(t)$$

Phase-Locked Loops at S/C 2 & S/C 3

$$S_{1j} = 0 \Rightarrow \phi_j(t) = \phi_1(t - \tau_{1j}) - \phi_0(t - \tau_{1j}) + \phi_0(t) \quad j = 2,3$$

Beat Notes at S/C 1

$$\arg\{S_{j1}(t)\} = \phi_1(t - \tau_{1j} - \tau_{j1}) - \phi_0(t - \tau_{1j} - \tau_{j1}) - \phi_1(t) + \phi_0(t) \quad j = 2,3$$

Combination to remove laser phase noise

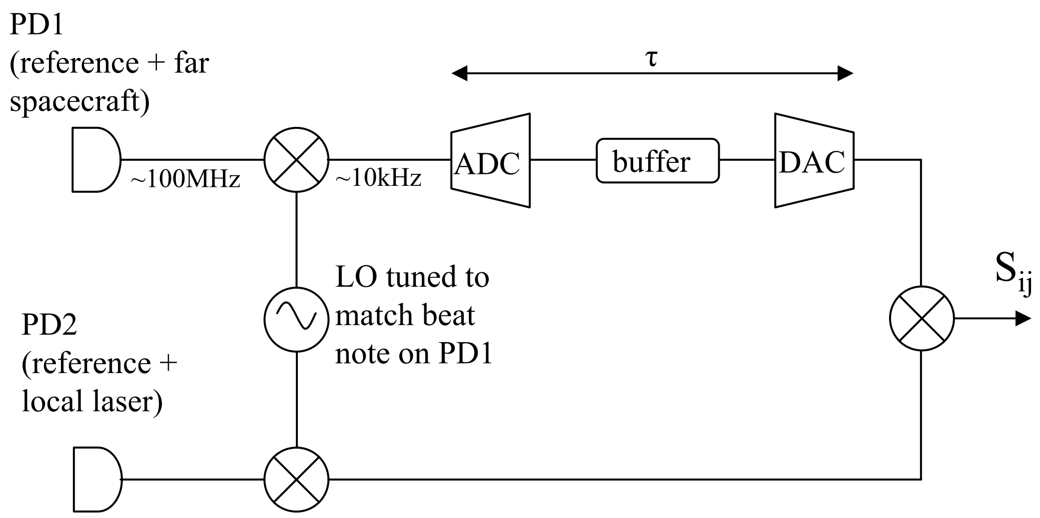
$$S(t) = \arg\{S_{21}(t)\} - \arg\{S_{31}(t)\} - \arg\{S_{21}(t - \tau_{13} - \tau_{31})\} + \arg\{S_{31}(t - \tau_{12} - \tau_{21})\} = 0$$

How do we achieve time-delay?

For LISA, $\tau \sim 16s$

- too long to achieve with physical delay

- solution: use digital delay



Status

Optics

- 2 Nd:YAG lasers
- building frequency stabilization (RF-lock to Optical Cavities)
- developing phase-locked loops

Electronics

- Selected and purchased PC-based DAQ boards to do time delay
- Working to demonstrate time-delay using electronic signals

Crew

- 1 Professor – Guido Mueller
- 2 Grad Students – Rachel Parks & Ira Thorpe
- 3 Undergrads – Rodrigo Delgadillo, Derek Mulder, Shannon Sankar

Thanks/Questions?