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Testbed for Validating Second-Generation TDI and Clock Noise Correction for LISA

Karin Kruuse

The LISA Satellites

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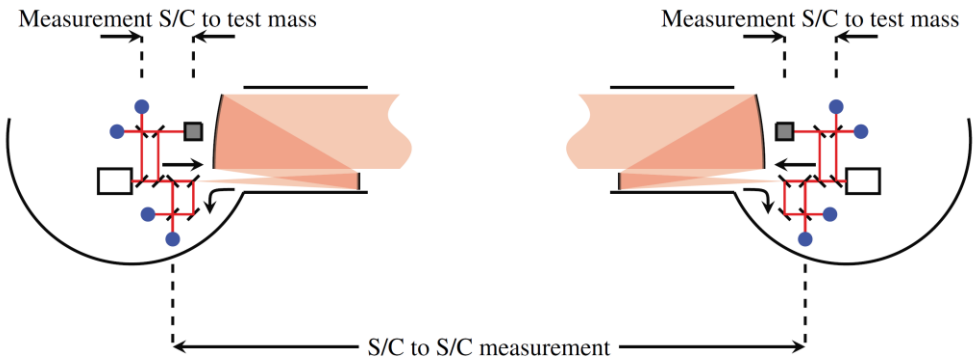
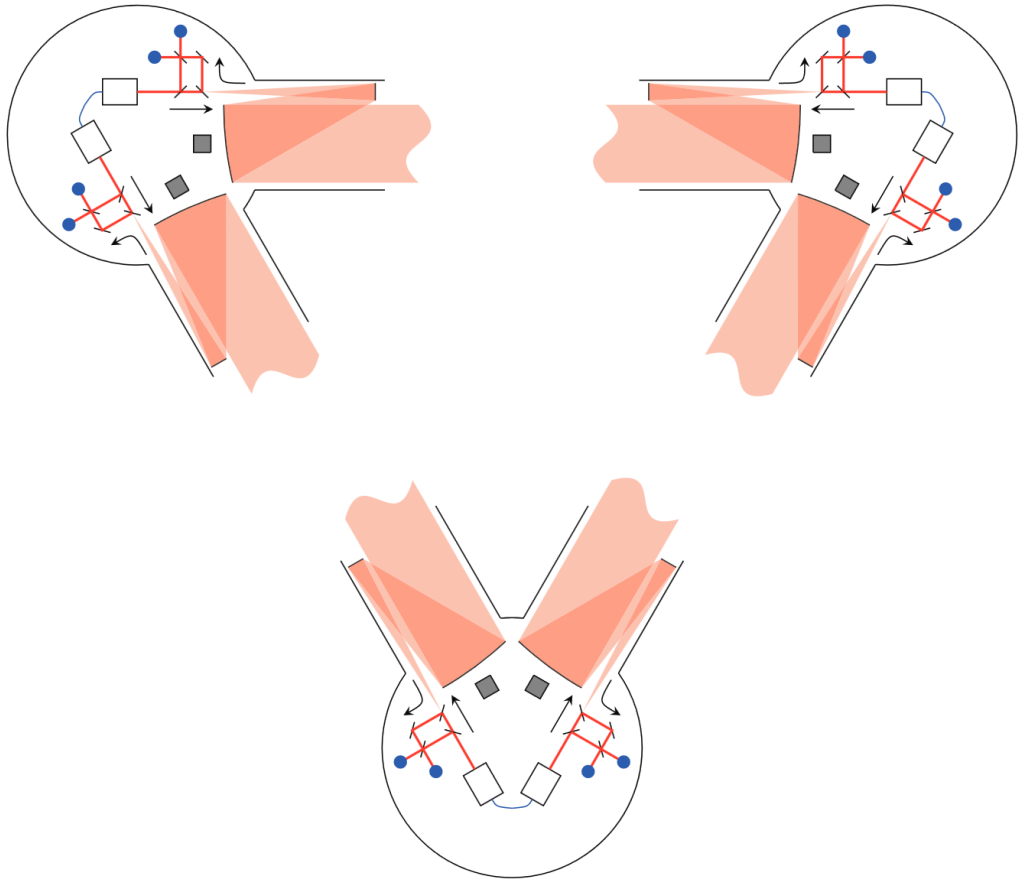
Three satellites surrounding six test masses in free fall

Each satellite houses two lasers, two optical benches and a phasemeter.

Each optical bench houses three interferometers.

The test mass to test mass distances are measured in three parts – this is the so-called split interferometry used in LISA.





Jennrich, 2010

LISA Interferometric Metrology System

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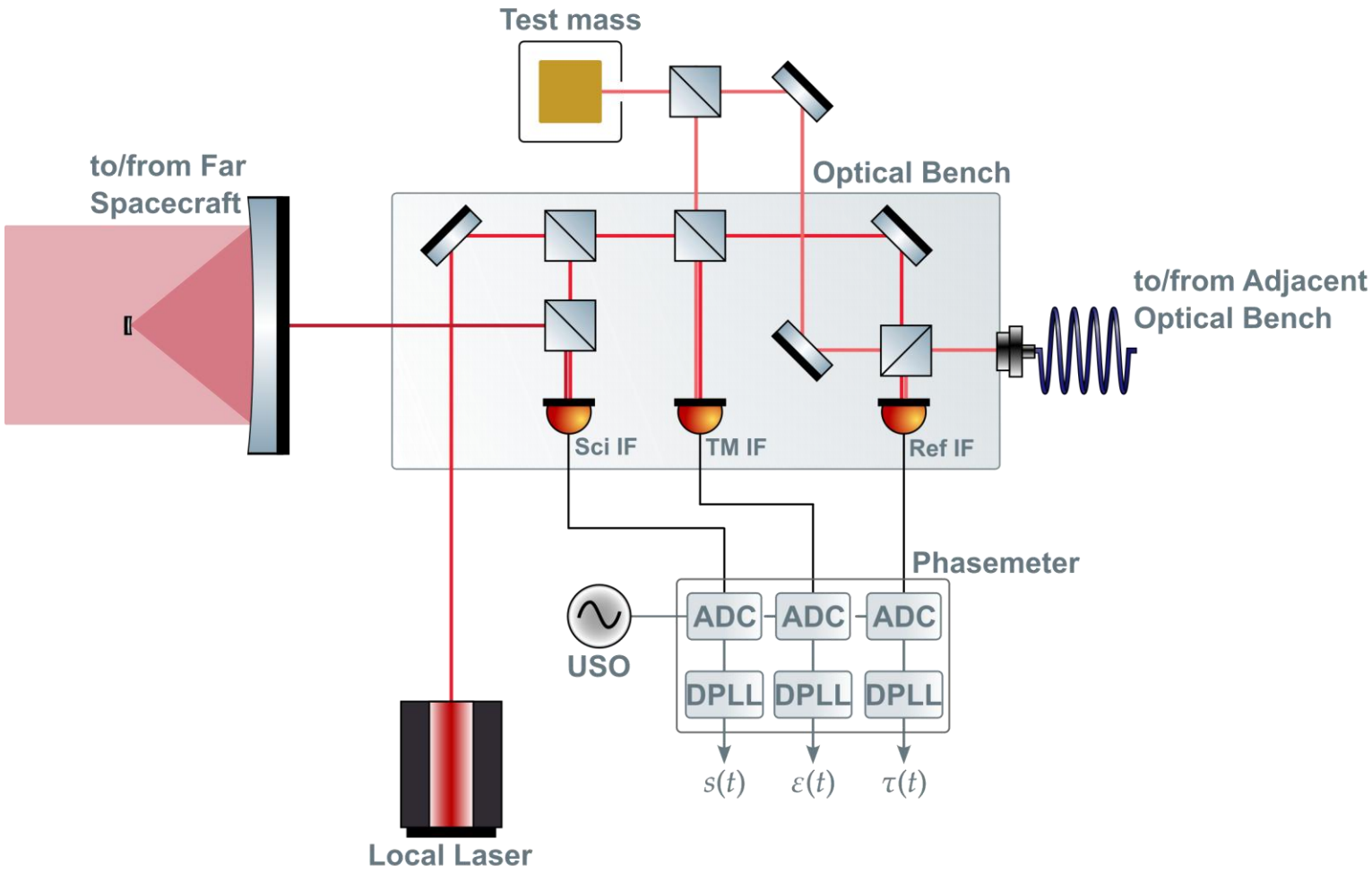

Laser Noise Reduction via TDI

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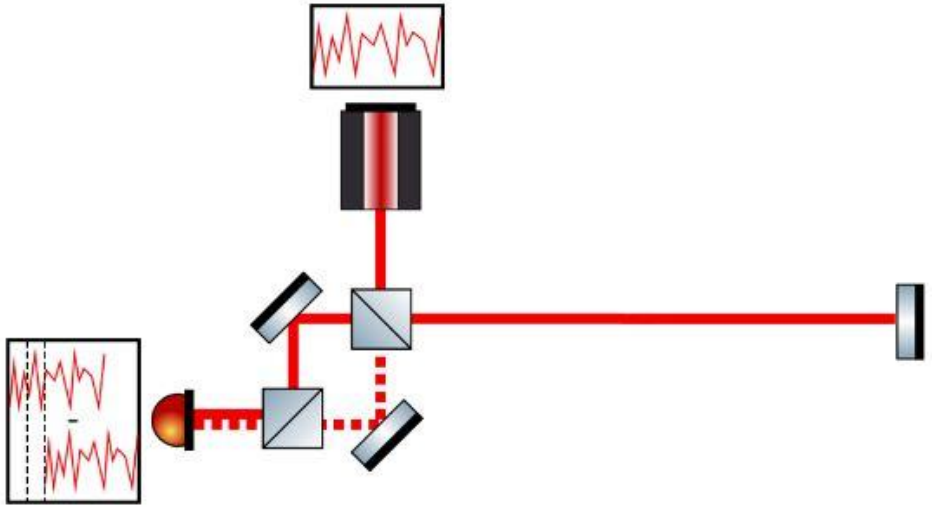
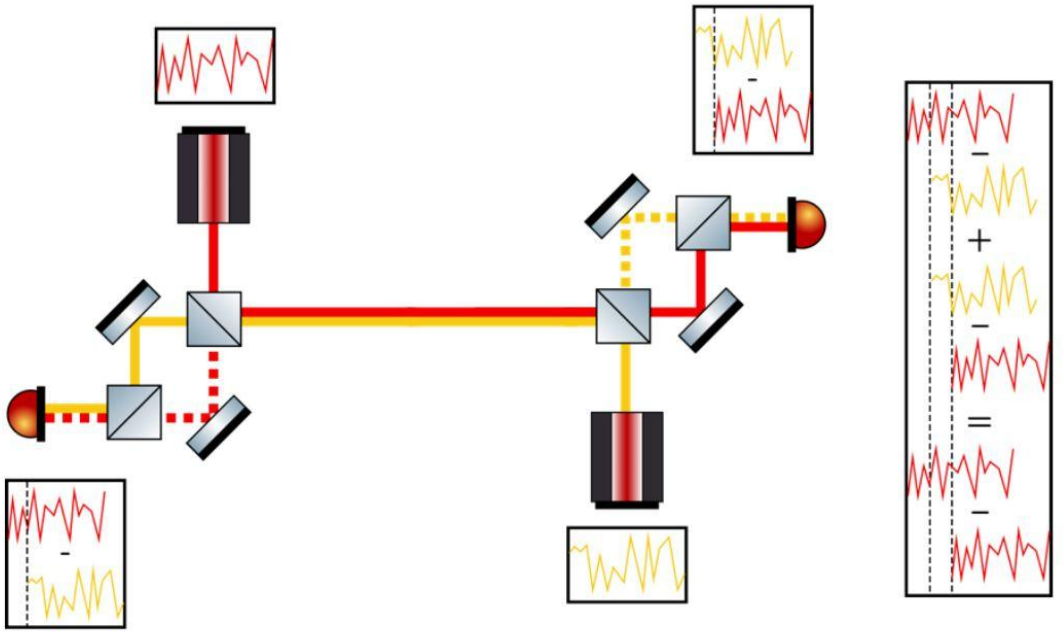
Time Delay Interferometry (TDI) is a cluster of methods to construct virtual equal arms in post-processing.



Transponder signal



Virtual transponder signal

Hartwig, 2021

Clock Noise Reduction

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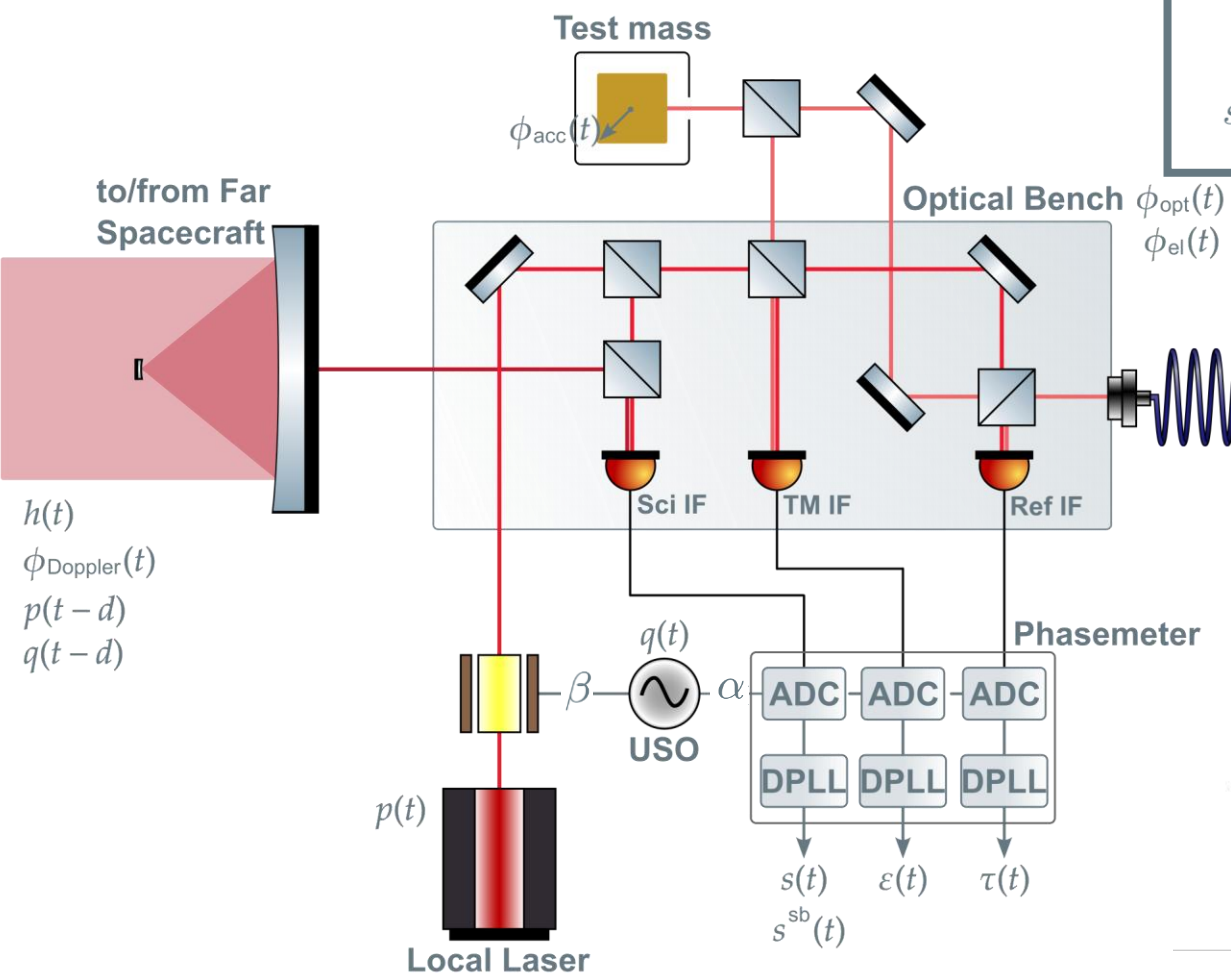
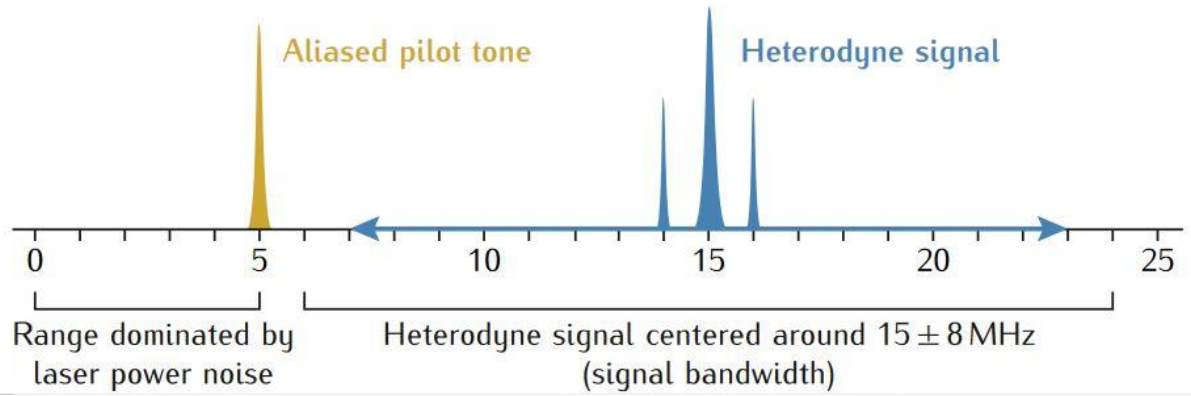
After demodulation, considering laser noise and clock jitter:

$$s(t) = p_1(t) - p_2(t - d_{12}) + \alpha_1 q_1(t)$$

$$s(t)^{\mathrm{SB}} = p_1(t) - p_2(t - d_{12}) + \beta_1 q_1(t) - \beta_2 q_2(t - d_{12}) + \alpha_1^{\mathrm{SB}} q_1(t)$$





Lisa metrology system-final report, 2014

Previous Experiment

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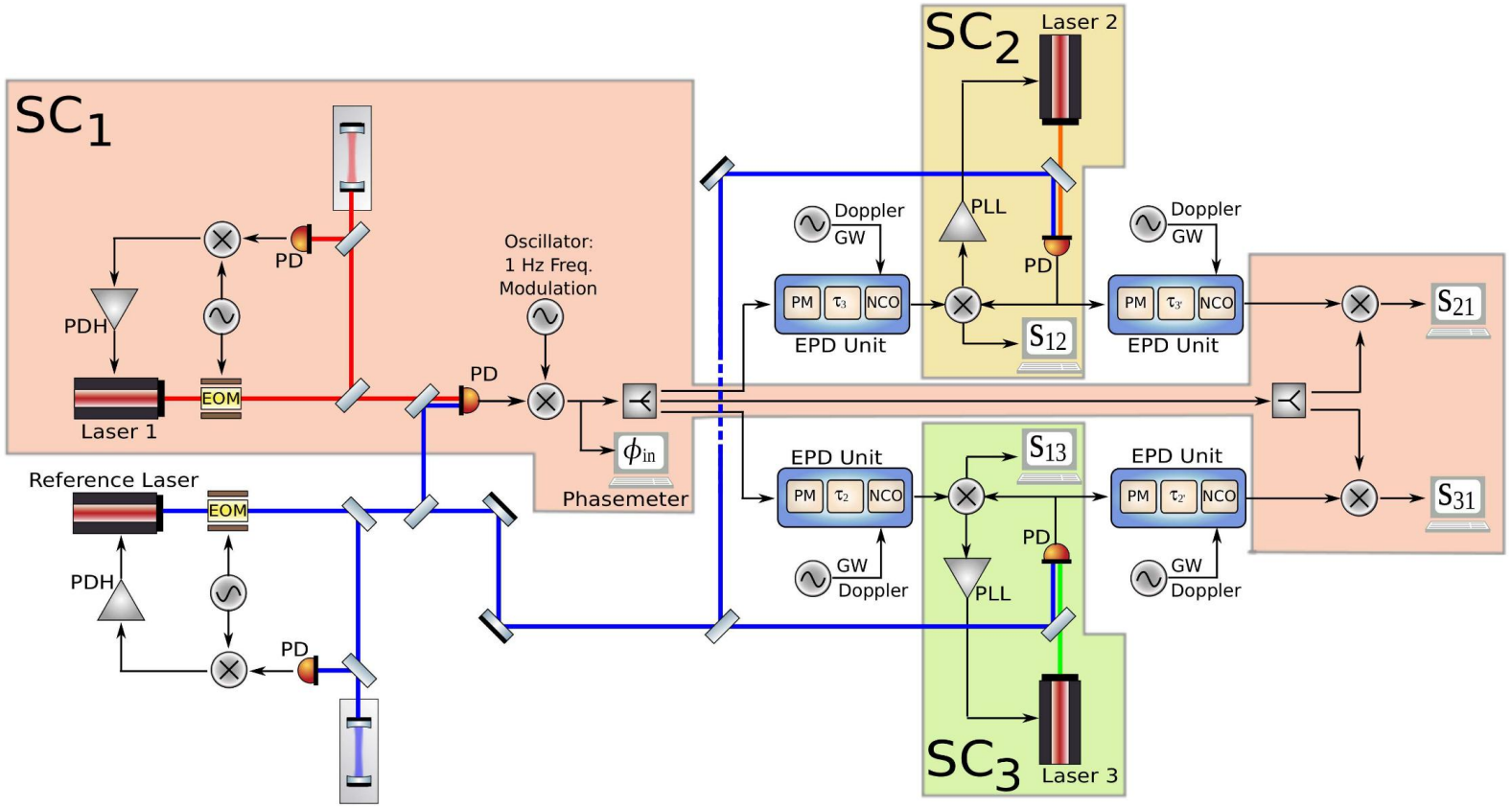

Mitryk, 2012: Laser Noise Mitigation through Time Delay Interferometry for Space-based Gravitational Wave Interferometers Using the UF Laser Interferometer

Laser noise, No Clock Jitter, Realistic Delay

MiniLISA

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MiniLISA is a hardware testbed that aims to simulate LISA's signal chain and test whether we can recover a gravitational wave signal from a realistic, noisy system.

To start with, we want to test the combination of second generation TDI and the clock noise removal post-processing methods on experimental data.

MiniLISA could also offer a substitute to modelled noise sources included in current data analysis.

Current Status

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A fully electronic implementation of the interferometry system together with a delay and gravitational wave injection has already been developed and is being tested.

- Time varying delays
- Doppler shifts for both the carrier and sidebands
- Gravitational wave injection

The Delay Line

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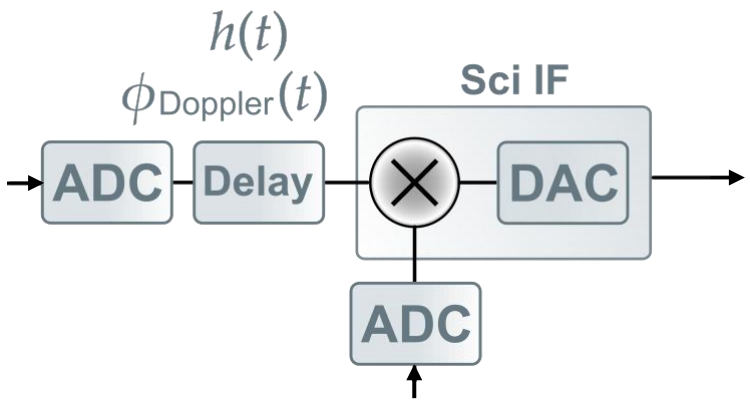
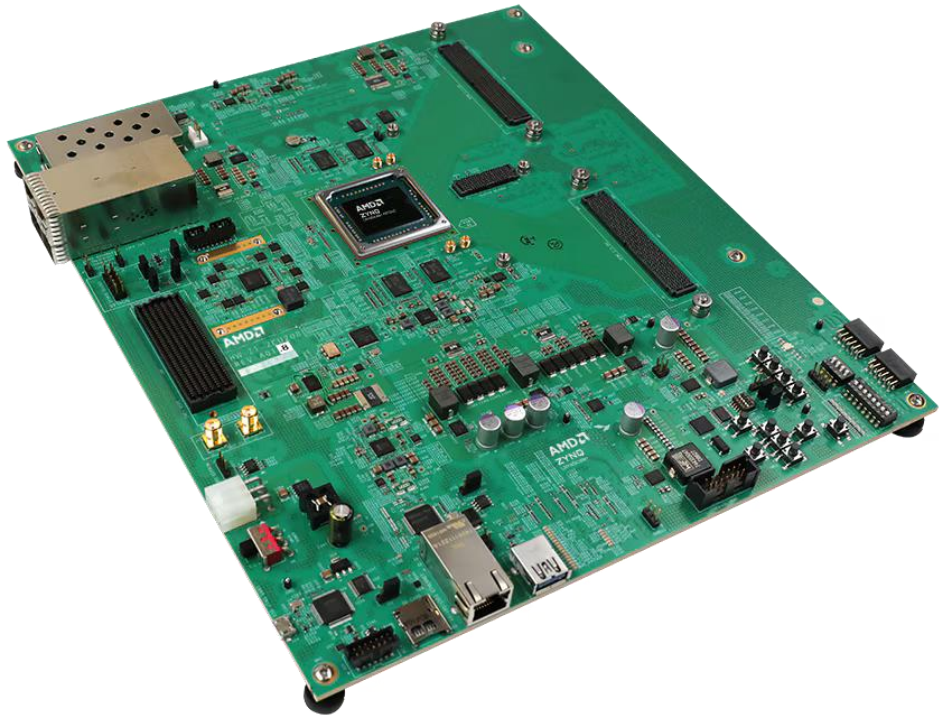
The center of the experiment is the delay line.

The added varying delays, gravitational wave signals and Doppler shifts are controllable via a Python-based interface.





AMD Zynq™ UltraScale+™ RFSoC ZCU208 Evaluation Kit

Signal Processing on the Delay Line

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The evaluation board includes enough to take in two photodetector readings and output the corresponding LISA-like beat note as an electrical signal.

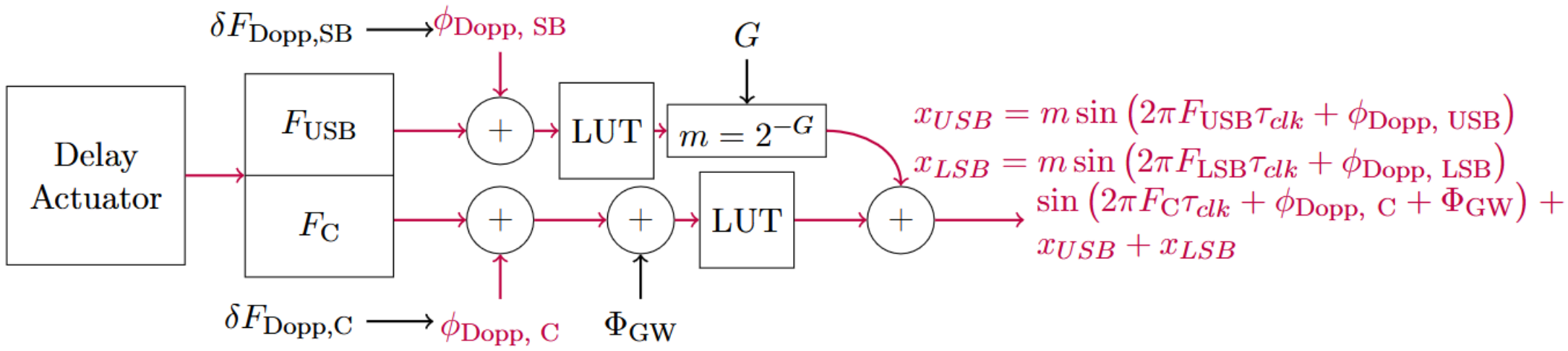

Figure 3: Block diagram of Doppler- and GW-derived phase modulation of the carrier after the delay.

Credit: Reid Ferguson

One-arm Phase Measurement

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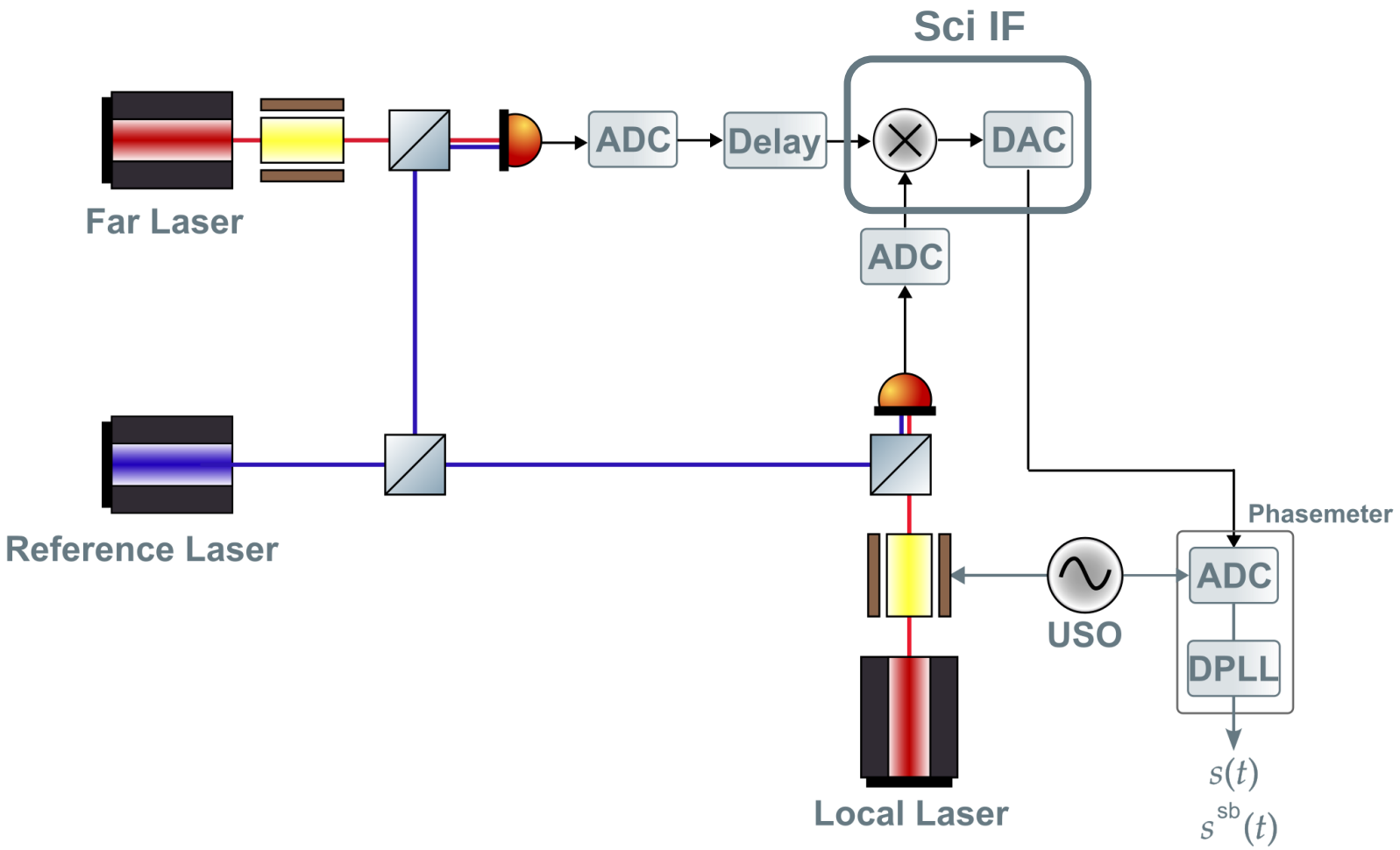
Set up for generating one LISA-like science interferometer readout.



One-arm Phase Measurement

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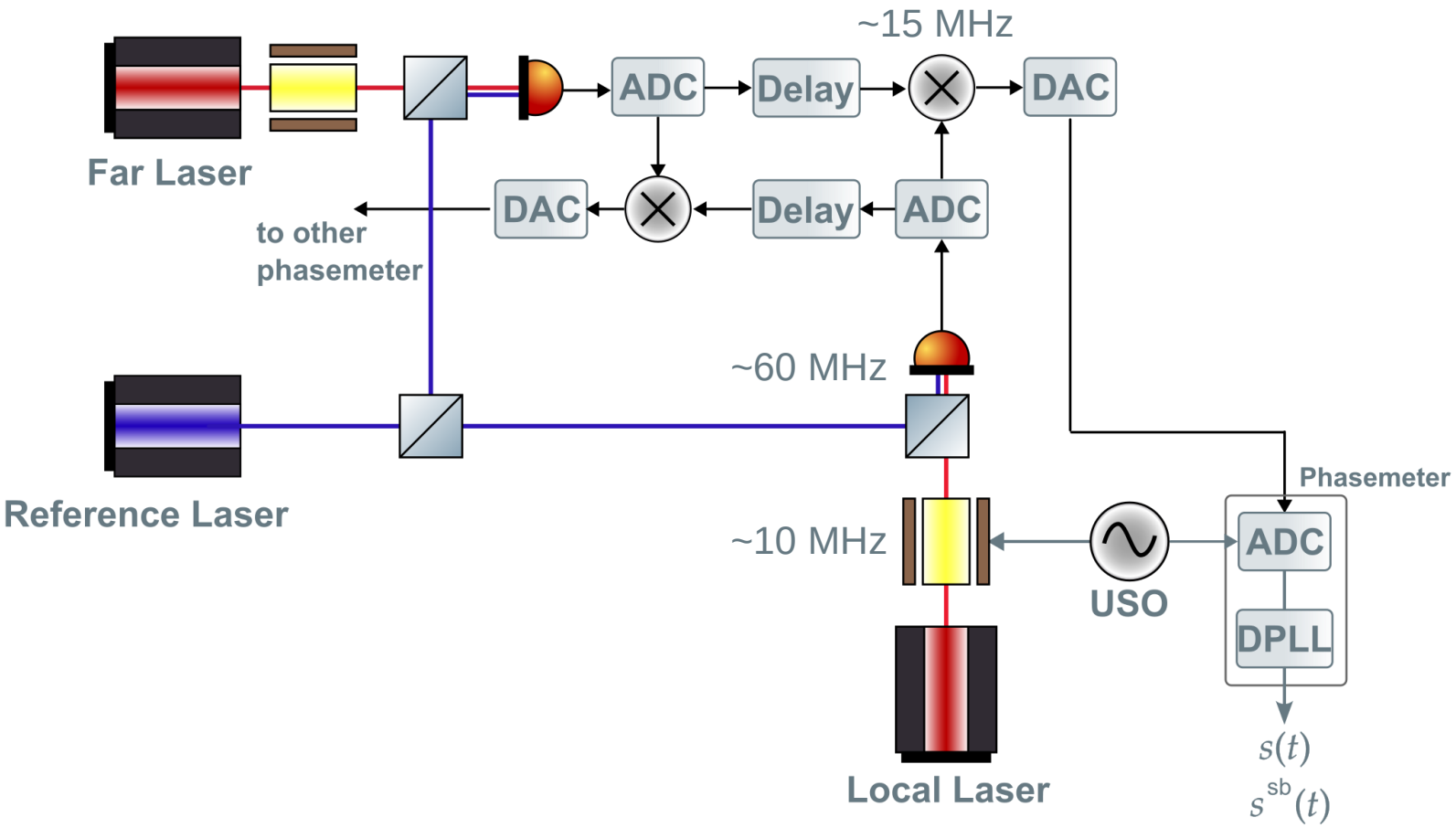
Set up for generating one LISA-like arm link.



Two-arm Testbed

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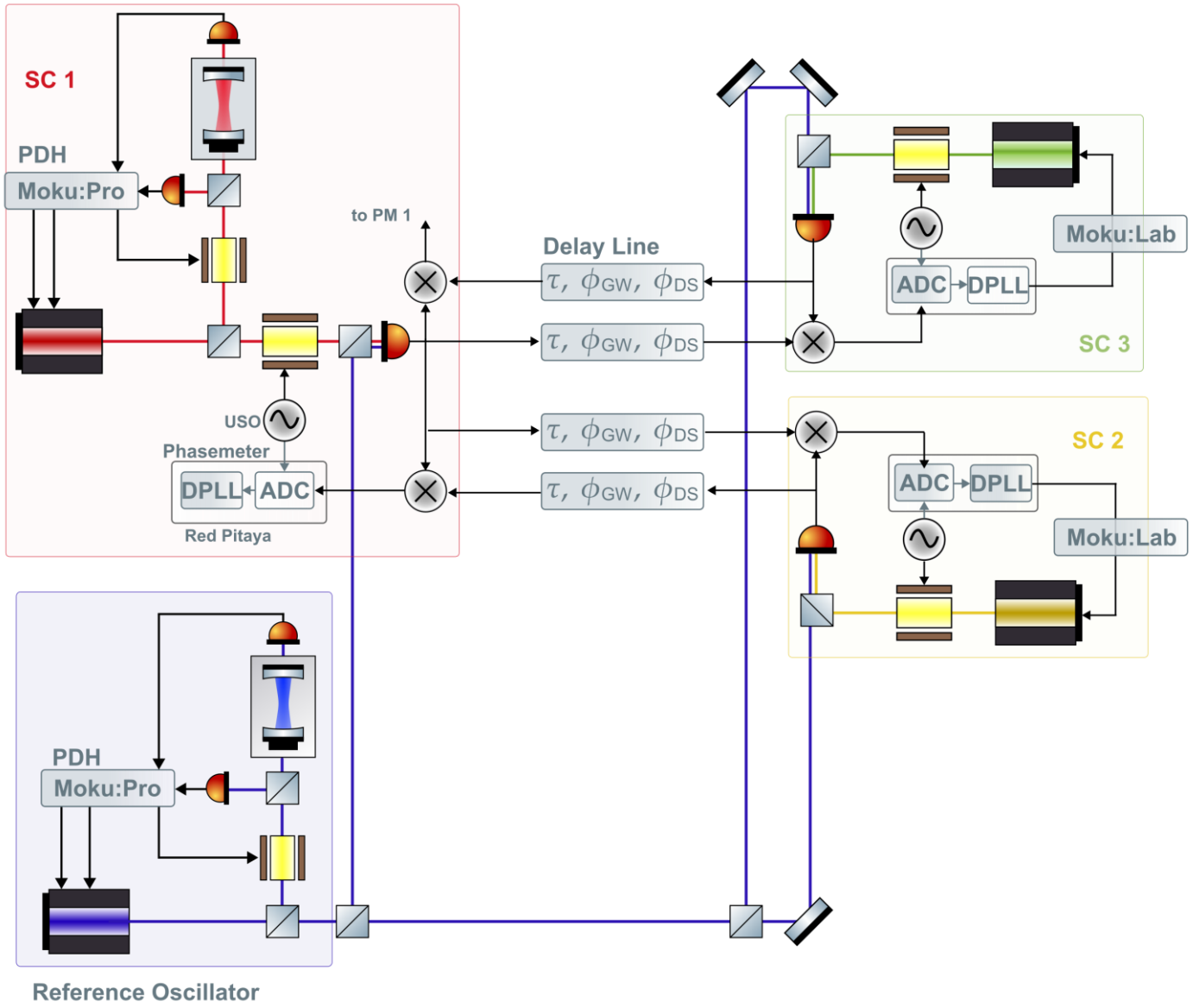

Two-arm Testbed

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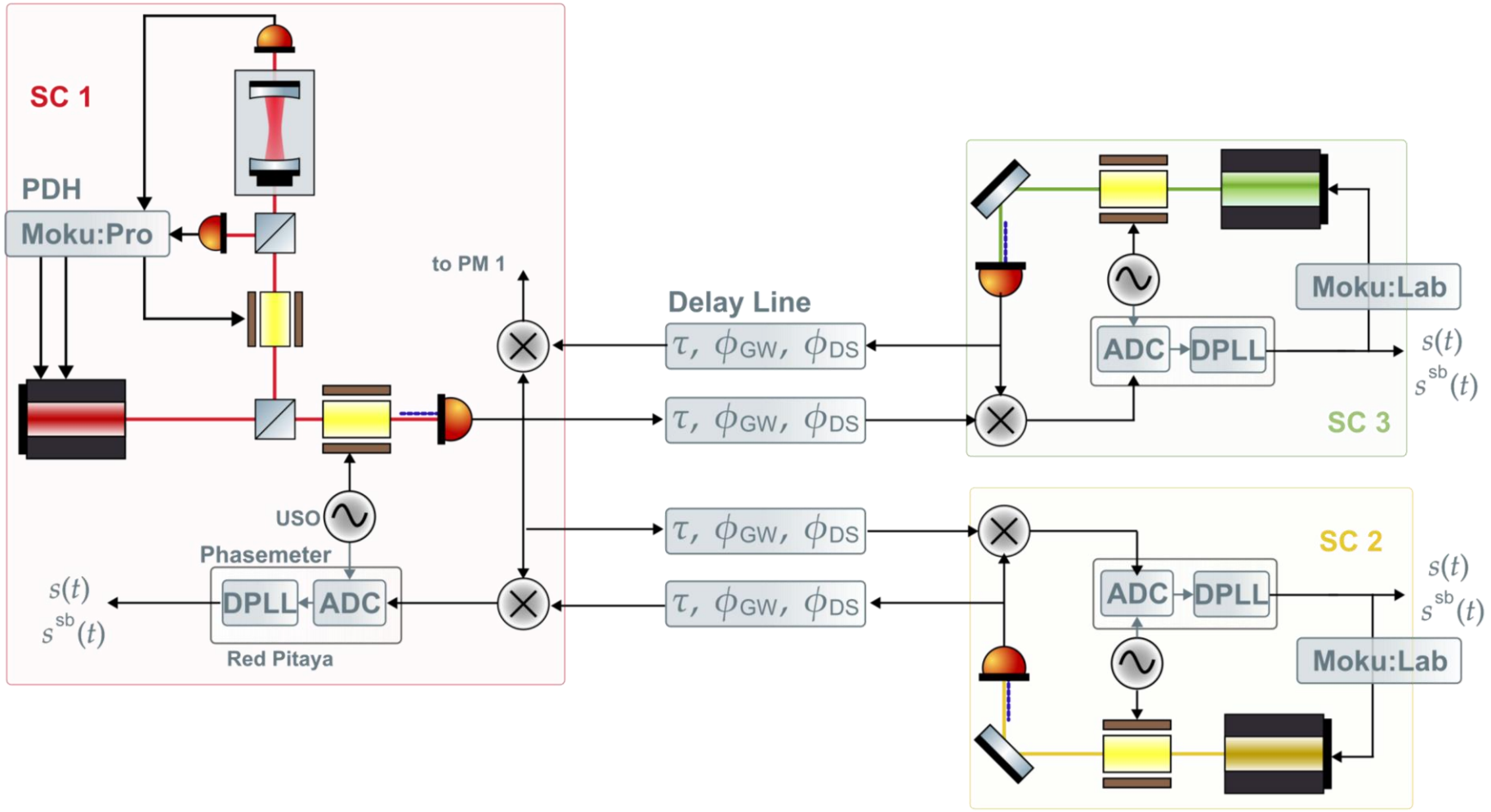


Thank you for listening!