Performance of an optical three-signal test for the LISA metrology

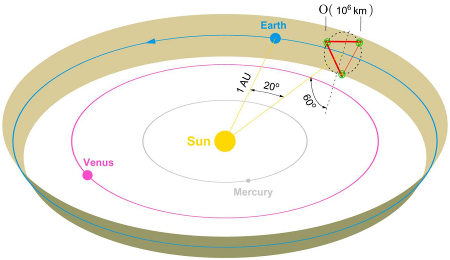
Thomas Schwarze for the AEI LISA metrology team

September 6th, 2016

Contents

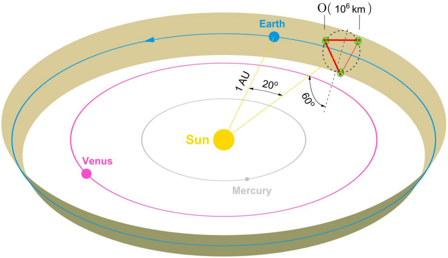
The LISA metrology

LISA metrology



- Main task: phase readout system: electronic readout of interferometer phase
- Auxiliary functions needed to complete the metrology chain
- Implementation: phasemeter (PM)

LISA metrology



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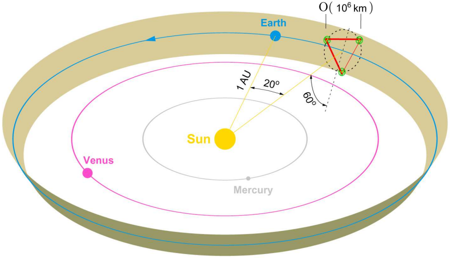
- Requirements?

Related LISA specifictations



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- Independently changing with up to several m/s
- Heterodyne interferometry with $\frac{\text{pm}}{\sqrt{\text{Hz}}}$ precision

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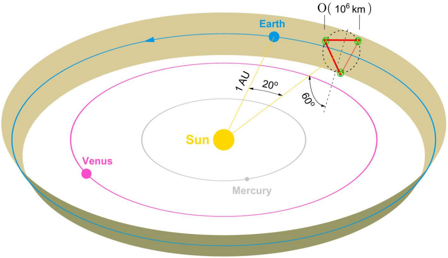

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→ 3 (a.o.) technical issues and related requirements for PM

Issues → requirements

- Frequency noise amplification → TDI with ranging information

$$\delta x = \frac{\Delta L}{f} \delta f$$

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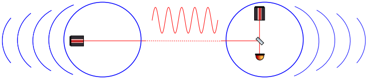

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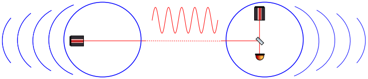

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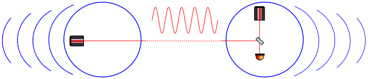

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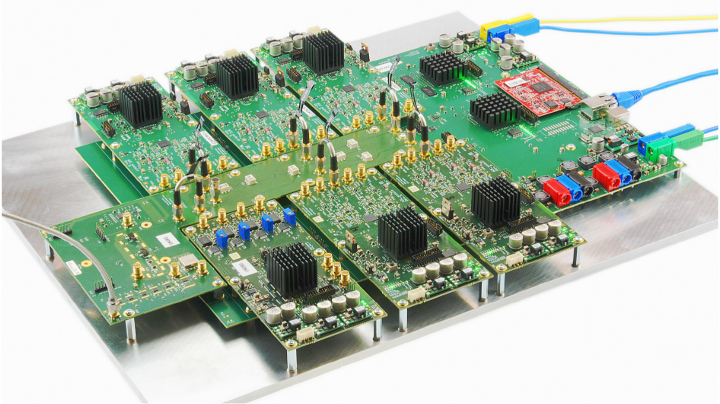

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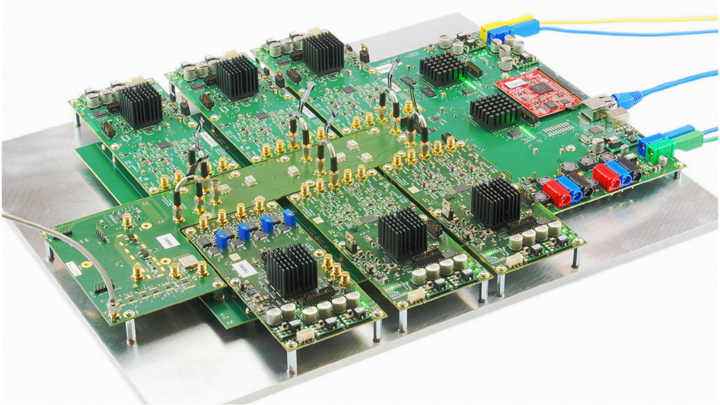


- All nice and shiny, but does it work!?

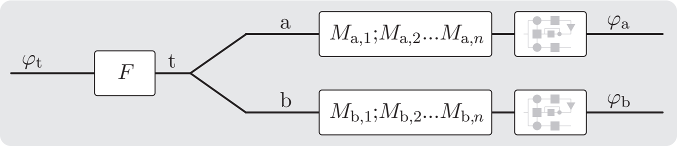
Testing schemes for phase readout performance

Phase measurement performance

- No absolute test possible (lack of reference)

Phase measurement performance

- No absolute test possible (lack of reference)
- Test Phasemeter against itself: split/null measurements
  - → Split one signal in two channels

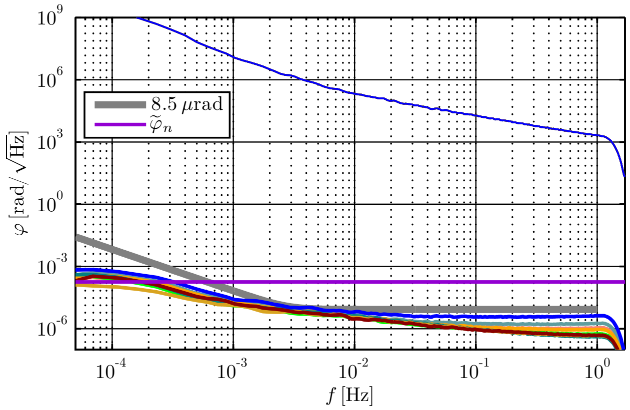


→ $\varphi_a - \varphi_b \overset{!}{=} 0$

- Difference gives performance estimate and shows nonlinearities

Phase measurement performance

- Electrical split measurement with ADC jitter correction (O.Gerberding, PhD Thesis 2014)



Two signals vs. Three signals

- However, split measurements cannot show noise common in channels
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  $\rightarrow$ Three-signal test
- Combine initial phase signals φ_1, φ_2, φ_3 to three intermediate ones

$$s_\mathrm{a} = \varphi_1 - \varphi_2 \qquad s_\mathrm{b} = \varphi_2 - \varphi_3 \qquad s_\mathrm{c} = \varphi_1 - \varphi_3$$

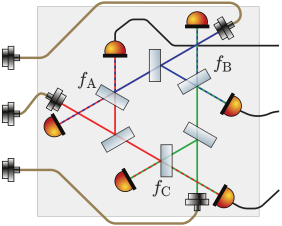
- Measure s_a,s_b and s_c in different Phasemeter channels and add up:

$$s_\mathrm{a} + s_\mathrm{b} + (-s_\mathrm{c}) \stackrel{!}{=} 0$$

$\rightarrow$ Nonlinearities that are common in split measurement can be revealed

Optical three-signal test

→ Optical testbed: hexagonal optical bench with 3 recombination beamsplitters



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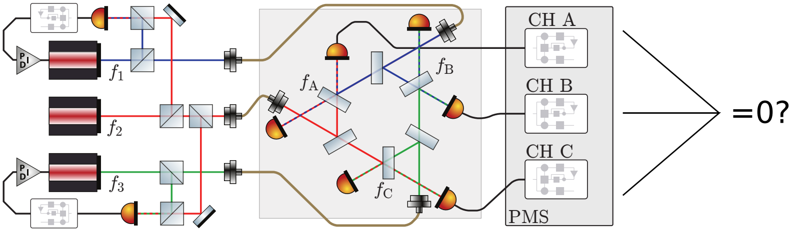

Extension: the LIME experiment

- Optical testbed allows for testing auxilliary functions of metrology chain

→ 3 EBBs: LISA metrology experiment (LIME)

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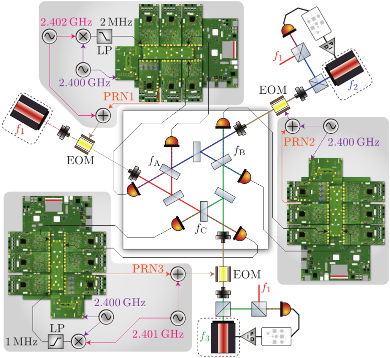

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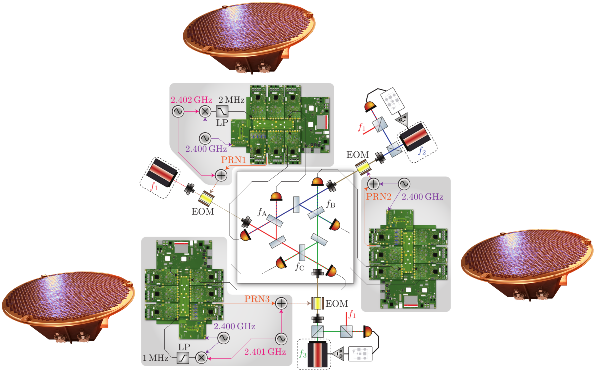

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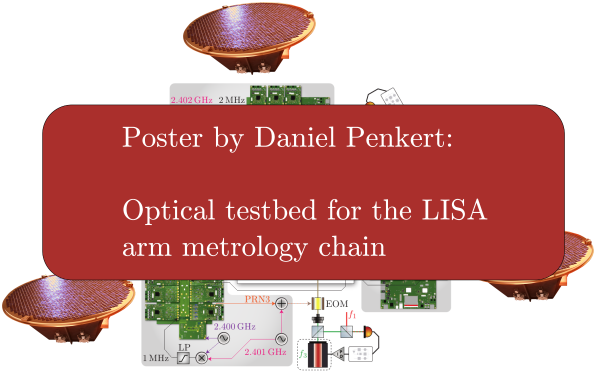
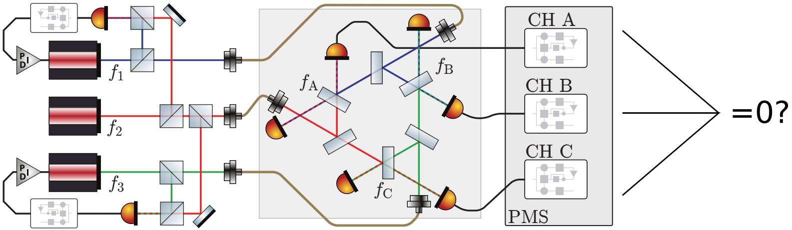


Poster by Daniel Penkert:

Optical testbed for the LISA arm metrology chain

Implementation of the three-signal test



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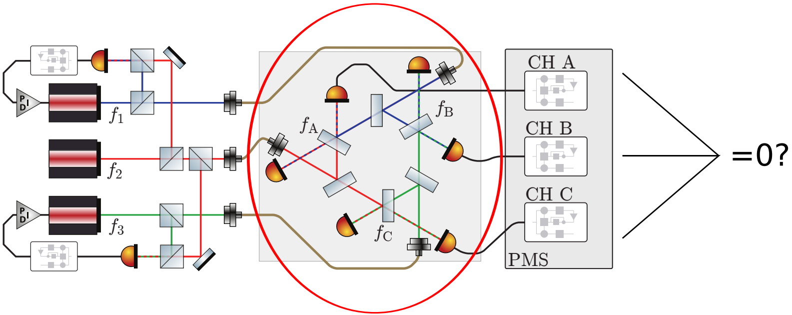

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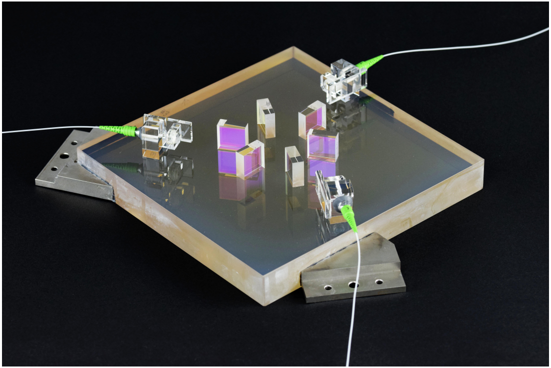

Picture courtesy: D.Penkert

Implementation of the three-signal test

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Three-signal test measurements

Initial measurement

- Time to measure!

Initial measurement

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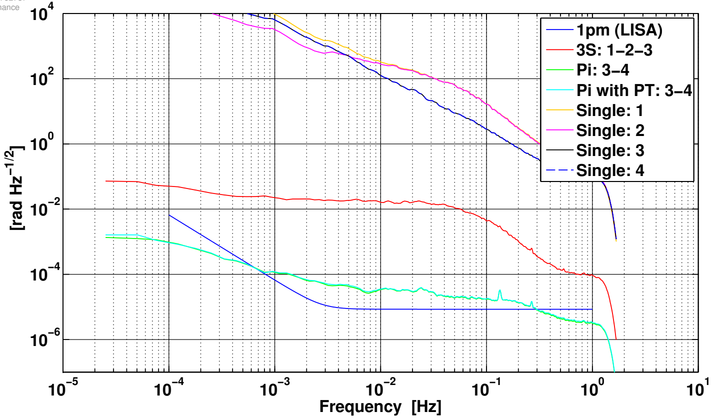
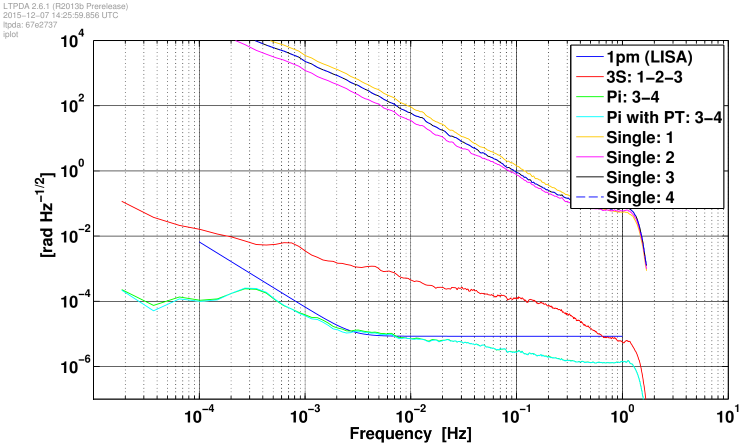
- Initial measurement

LTPDA 2.6.1 (R2013b Prerelease)
2015−11−20 14:54:35.575 UTC
ltpda: 67e2737
Performance



Measurement in vacuum

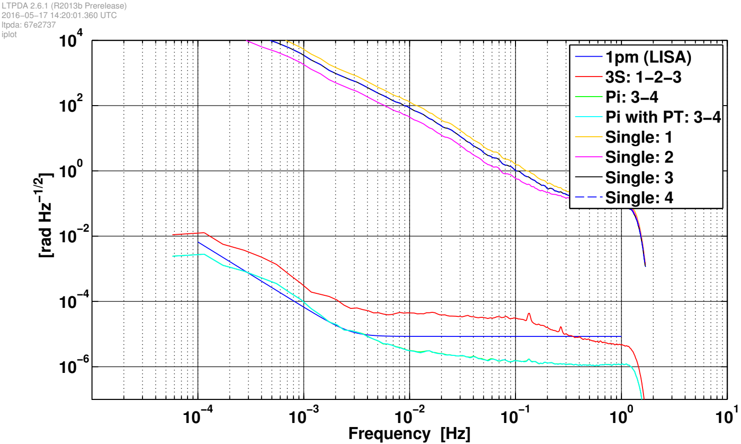
- Vacuum @ 10^{-5} mbar



Measurement with proper working points

- Identify overlap of mode-hop-free temperature ranges of three lasers

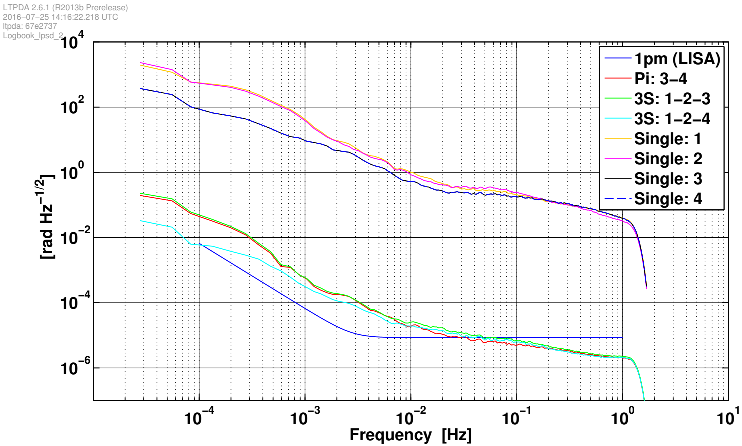
→ (Coupling not entirely clear, likely amplitude fluctuation coupling)



Measurement with synchronous clocks

- Sync clocks of auxiliary PM and main PM

→ Single channel noise improved



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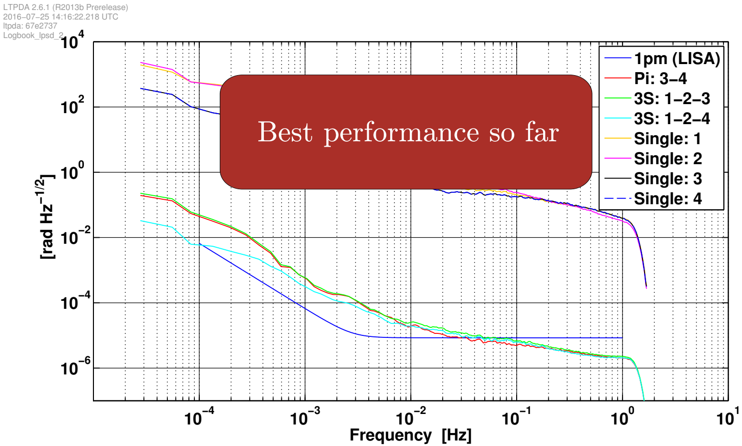

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- Full metrology test: LIME

→ see Daniel's Poster

To be continued..

Thank you for your attention!

Image courtesy: NGO Yellow book, O.Gerberding, D. Penkert