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Transportable setup for amplifier phase fidelity measurements

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Breadboard laser for LISA 10 years ago

 NPRO 1.2 W output power, 30 Hz/rtHz, fiber-coupled pump module



LISA laser concept today

- Master oscillator fiber amplifier
- Developments ongoing at
 - Lusospace / LZH
 - GSFC
- Hardware with flight heritage



LTP RLU FM



Amplifier for laser com. terminal



- Phase modulator between seed laser and amplifier for
 - Clock noise transfer
 - Ranging
 - Data communication



Phase modulator between seed laser and amplifier for

- Clock noise transfer
- Ranging
- Data communication

USO clock tone transfer chain

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USO clock tone transfer chain

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USO phase noise measurement







$$\begin{array}{ll} \text{Phase read-out:} & \Delta\phi_{1\,\text{pm}} \leq \frac{1\,\text{cycle}}{1064\,\text{nm}} \cdot \frac{1\,\text{pm}}{\sqrt{\text{Hz}}} \cong \frac{1\,\mu\text{cycle}}{\sqrt{\text{Hz}}} \cong \frac{6\,\mu\text{rad}}{\sqrt{\text{Hz}}} \\ \text{Ancillary Modulation Error:} & \Delta\phi_{AME} \leq \Delta\phi_{1\,\text{pm}} \cdot \frac{f_{EOM}}{f_{het}} \cong \frac{2.4\,\text{GHz}}{24\,\text{MHz}} \cdot \frac{6\,\mu\text{rad}}{\sqrt{\text{Hz}}} \\ \text{LISA frequency band:} & \Delta\phi_{AME} \cdot (f) \leq 0.6 \cdot \sqrt{1 + \left(\frac{2.8\,\text{mHz}}{f}\right)^4} \frac{\text{mrad}}{\sqrt{\text{Hz}}} \end{array}$$

Requirements – EOM frequency

• Shot noise limit of both sideband-sideband beats combined: $93.2 \text{ pm}/\sqrt{\text{Hz}}$



$$\Delta \phi_{correction} = \Delta \phi_{combined} \cdot \frac{f_{\text{het}}}{f_{\text{EOM}}}$$

• For
$$\Delta \phi_1 \text{ pm} \leq \frac{1 \text{ pm}}{\sqrt{\text{Hz}}} \rightarrow \frac{f_{\text{het}}}{f_{\text{EOM}}} \leq 1/100$$

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Sources of differential phase noise in amplifiers

- amplifier length changes ΔL due to
 - changes in ambient temperature
 - pump power changes
 - seed power changes

$$\Delta \varphi = \frac{2\pi \cdot f_{\rm EOM}}{c} \cdot \Delta L$$

combined effect measured
ΔL≤12 µm/√Hz

 nonlinear dispersion and laser frequency changes



 Effect measured for passive fiber and found to be negligible

5 W flight-representative amplifier by Tesat tested



Tesat amplifier results



- Seeded by LISA-like signal (narrowband carrier + two sidebands with 17% power each)
- No sign of SBS visible in backscattered signal (was monitored live)

Tesat amplifier results



- Relative power noise (RIN) was measured at 2.2 W output power
- RIN compatible with LISA requirements

EOM phase fidelity



- Phase fidelity of waveguide EOM fulfills LISA requirements
- Space-qualified version available

Breadboard amplifier phase fidelity



Breadboard amplifier phase fidelity





Setup to measure phase noise introduced by fiber amplifier



- Breadboards, modular setup, and electronics in rack ensure transportability
- room temperature fluctuations \rightarrow passive thermal isolation
- power dependent phase shift in mixers \rightarrow active amplitude stabilizations



















Sensitivity of test setup



Sensitivity of test setup

Summary

- Laser system with flight heritage available
- TEAT



 Transportable test setup is in place*



- Next measurement windows are
 - end June mid July
 - end August mid October







g+ LISAcommunity



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