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Design of a Tx Attenuating Photoreceiver for the LISA stray light assessment instrumentation

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ABSTRACT

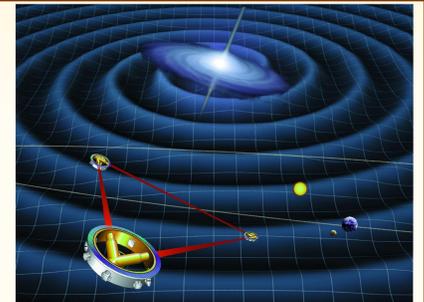
This poster describes the design of a unit called Tx Attenuating Photoreceiver (TAP), dedicated to the measuring and dumping of a 2 W beam with 300 mm diameter. This unit is part of an optical demonstrator which will be created for stray light testing in the LISA mission. The geometry of the instrument is studied to reduce the size of the beam, focus it onto a photodiode, dump its power and minimize scattering and reflections back to the DUT. The setup will be composed by an off-axis parabolic absorber with anti-reflection coating which will absorb most of the beam, reflecting only 0.2 % towards a pinhole and a photodiode.

BACKGROUND

LISA (Laser Interferometer Space Antenna)

- ❖ ESA-NASA mission for detection of gravitational waves, scheduled for launch in 2035
- ❖ Constellation of 3 spacecraft in a 2.5 million km triangular formation, on solar orbit @1AU
- ❖ Separation of free-floating reference surfaces in each satellite is measured using laser interferometry
- ❖ Distance variations, caused by a passing gravitational wave, are measured, down to 10pm/VHz
- ❖ Science objectives: study of gravitational wave sources like binaries of neutron stars and/or black holes and GW background, to gain insight on the dynamics of formation and evolution of stars and black holes and also on astrophysical and fundamental physics

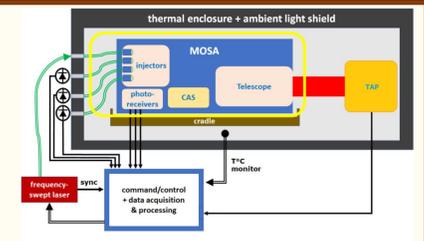
Fig: LISA mission artistic view



SL-OGSE (Stray Light Optical Ground Segment Equipment)

- ❖ Instrumentation foreseen to test and verify stray light performance in the LISA optical bench and telescope
- ❖ It will locate and quantify all stray light sources on the LISA optical path reaching its detectors
- ❖ Method: inject a frequency-ramped laser beam in the LISA optical bench to create fringe signals at frequencies dependent from the nominal/stray light optical path length difference
- ❖ Most of the injected beam will exit the LISA telescope with a power of 2 W and a diameter of 300 mm

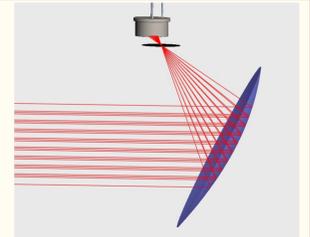
Fig: SL-OGSE setup schematic drawing



TAP (Tx Attenuating Photoreceiver)

- ❖ It will measure the beam power emitted at the telescope and dump it
- ❖ Reducing the beam to a manageable power and size with a curved mirror
- ❖ Measuring beam power fluctuation with a photodiode
- ❖ Avoiding optical return to LISA instrumentation (interferometer detectors and the "CAS" camera used to find the correct spacecraft orientation)

Fig: TAP components representation (not to scale)

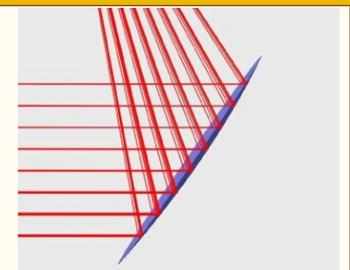


TAP DESIGN

Parabolic mirror

- ❖ Shaped to obtain the correct compromise between:
 - Low divergence of the reflected beam (15° in the final configuration)
 - Limited dimensions of the whole setup and the mirror itself (750x350x350 mm, 388 mm \varnothing respectively)
- ❖ Off axis parabolic with 800 mm curvature radius
- ❖ KG3 Schott glass to absorb \approx the whole power in a 2 mm thickness
- ❖ AR coated to have a reflection of 0.2%, the mW-range residual power is easily recorded by the PD

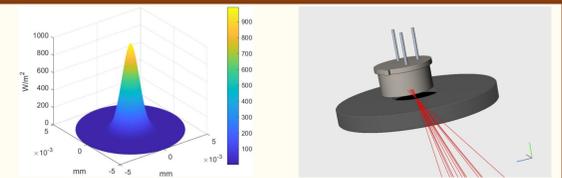
Fig: Zoom on TAP's parabolic reflector



Pinhole

- ❖ In the focus of the mirror
- ❖ 10 μ m in diameter
- ❖ Black coated surface (on both sides)

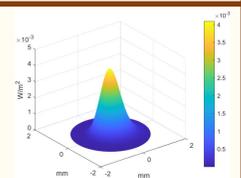
Fig: Simulated beam spot on the focus plane (left) and drawing of the pinhole photodiode ensemble (right)



Photodiode

- ❖ InGaAs photodiode, 0.7 A/W responsivity at 1064nm
- ❖ 3 mm behind the pinhole, the beam covers the surface of the detector without exceeding it
- ❖ Tilted by 22° to avoid backreflection to the system under test

Fig: Beam spot on the PD

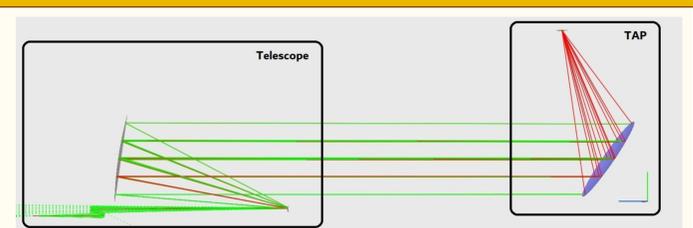


OPTICAL PERFORMANCES

Scattering towards LISA interferometers

- ❖ SL-OGSE will have to measure light scattered by telescope and optical bench elements
- ❖ Laser frequency ramp will allow to separate contributions based on optical pathlength differences
- ❖ TAP must be put far enough for its contribution not to overlap with the ones from the DUT
- ❖ TAP will be put at least 1.5 m away from the DUT

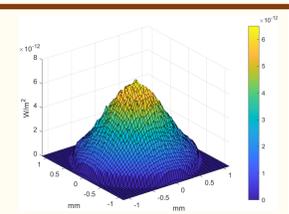
Fig: Optical layout used in FRED to calculate scattering (green rays) from the mirror of the TAP to the telescope pupil (and then to LISA's photoreceivers)



Scattering towards the CAS

- ❖ The CAS is a camera that will have to find the laser spot of the distant spacecraft and use it to correctly orient the instrument
- ❖ Expected back scatter from the telescope: 4nW for 15 Å roughness and CL300 contamination.
- ❖ Signal from TAP must be \ll nW to be negligible
- ❖ FRED software simulations indicate a 1 pW backscattering with even distribution over the CAS area

Fig: Intensity distribution of backscattered light at the telescope small pupil



CONCLUSIONS

We designed a three element setup which is able to handle a 2 W, 300 mm \varnothing beam, measure its power, and dump it, avoiding optical returns to the system under test.