Laser Head Demonstrator for the Gravitational Wave Observatory in Space

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The recent detection of gravitational waves with ground-based interferometers opened a new eye on the Universe. The Laser Interferometer Space Antenna (LISA) mission candidate of the European Space Agency (ESA) has the ambitious goal to put such a gravitational wave observatory in space in 2034. Contracted by ESA, CSEM developed a breadboard of the laser system and the necessary metrological tools. CSEM has demonstrated that its laser breadboard essentially fulfills the demanding mission requirements.

The recent detection of gravitational waves [1] has opened a totally new window on the Universe. This groundbreaking discovery followed by new observations leads to better understanding of the machinery of gravity at cosmic scale. Together with earlier electromagnetic field detectors they now bring the era of multi-messenger astronomy [2] which is expected to lead to future major discoveries. Ground-based gravitational wave detectors rely on optical interferometry and the low frequency of the detection band is limited by the seismic noise. A space borne instrument with low frequency detection band spanning [30 µHz; 1 Hz] will complement the ground-based instruments coverage. The LISA mission, led by the European Space Agency (ESA), exactly aims at implementing such an observatory in space. Recently the LISA pathfinder mission validating key technologies for LISA implementation was successfully completed [3]. In order to meet a launch date around 2034, the required technology has to be swiftly developed.

A key payload item of the LISA mission is the laser system. Indeed, the mission science capabilities are intimately linked to the laser system performance. Key specifications of the continuous-wave laser system include (i) 2 W of average output power in a diffraction limited beam, (ii) carrier wavelength of 1064 nm, (iii) polarization extinction ratio larger than 20 dB, (iv) low amplitude noise over a large frequency band covering [30 µHz; 5 GHz] and, (v) good frequency stability and spectral purity over [30 uHz; 1 MHz].

The CSEM laser breadboard is based on a master oscillator power amplifier (MOPA) architecture (Figure 1). The oscillator is a custom laser from OEwaves (US) and the amplifiers are made of efficient and robust Yb-doped fiber technology. Crucially, these technologies are well-suited to be space qualified. The system can emit close to 3 W of average output power in a diffraction-limited beam and with over 20 dB polarization extinction ratio.

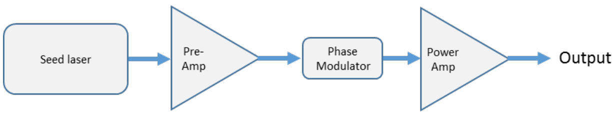

Figure 1: Laser system architecture.

Demanding frequency and amplitude metrology is requested to cover the over 12 orders of magnitude in frequency band. In Figure 2, the results of these measurements, in line with the required specifications, are shown [4].

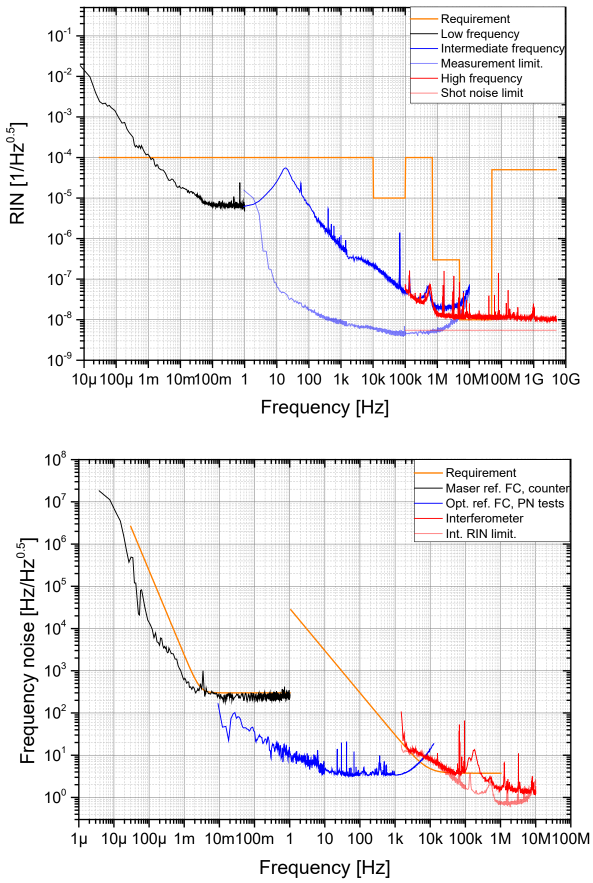

Figure 2: Top Relative intensity noise (RIN) and bottom frequency noise of the CSEM laser breadboard. The orange lines represent the required specifications.

In conclusion CSEM demonstrated a space-compatible laser head with performances meeting the LISA mission specifications. The full metrology apparatus was also developed and served to characterize the laser system. Further CSEM involvement in the LISA mission is expected.

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