Laser prototype for space-based gravitational wave detector

September 18 2019

Prototype laser for the LISA gravitational wave space mission. Credit: CSEM

Researchers have announced a prototype for a laser at the heart of the first space-based gravitational wave observatory, known as the Laser Interferometer Space Antenna (LISA) mission. The team's new laser nearly meets the stringent requirements outlined for LISA's instrumentation, representing an important step toward bringing the

ambitious observatory program to fruition.

"What a motivating challenge it was to realize a laser system with state-of-the-art performances, capable of meeting the stringent reliability requirements of a space mission," said Steve Lecomte with the Swiss research firm CSEM, who will present details of the prototype's performance at The Optical Society's (OSA) 2019 Laser Congress, held 29 September to 3 October in Vienna, Austria.

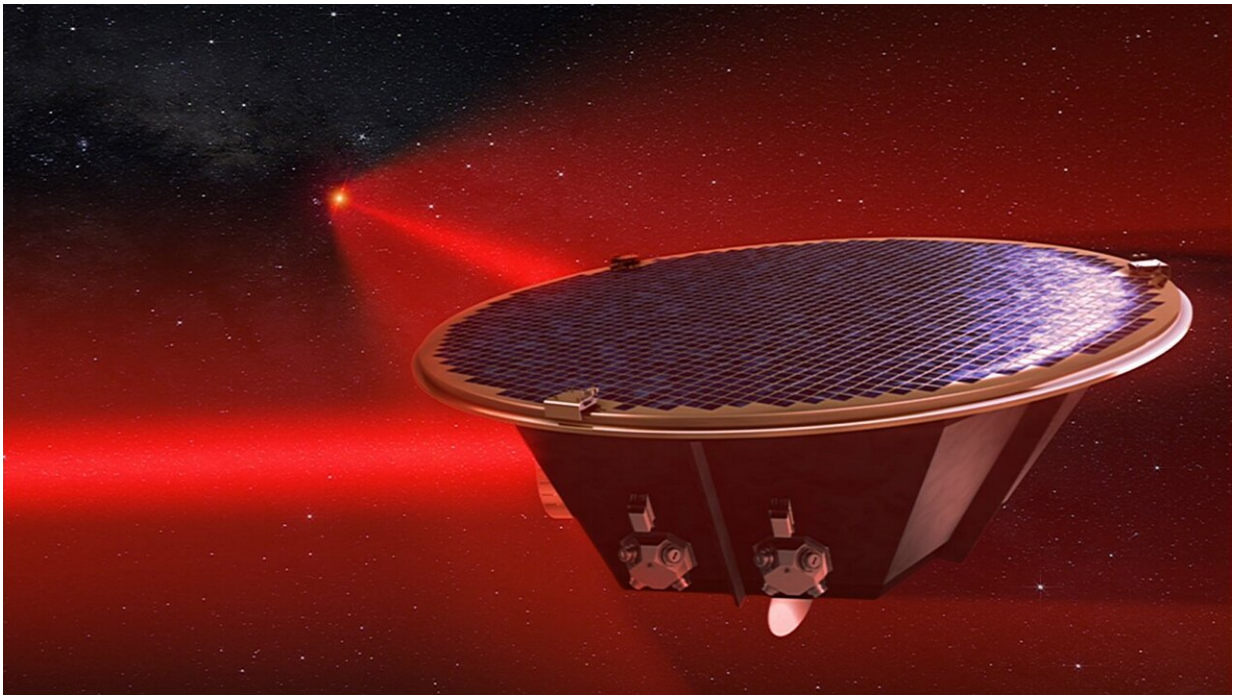
LISA will complement ground-based gravitational-wave detectors, like the U.S. National Science Foundation (NSF)-funded Laser Interferometer Gravitational-wave Observatory (LIGO), by deploying a gravitational wave detection system in space. In 2016, NSF announced that LIGO had made the first-ever direct observations of gravitational waves, ripples in the fabric of space and time that were predicted by Albert Einstein 100 years earlier in his general theory of relativity.

Both the LIGO and LISA observatories rely on lasers to detect gravitational waves. In addition to the precision and reliability required for any gravitational wave detector, the laser onboard the LISA mission must meet additional criteria to ensure it is suitable for long-term use in space.

LISA is led by the European Space Agency (ESA) in collaboration with the U.S. National Aeronautics and Space Administration (NASA).

Exacting requirements for precise measurements

LISA, scheduled to launch in the early 2030s, will consist of three spacecraft arranged in a triangle millions of kilometers across. The spacecraft will relay laser beams back and forth and combine their signals to find evidence of gravitational waves.



Artist impression of the ESA/NASA LISA space-based gravitational-wave observatory. Recent prototype tests of its laser indicate that it is one step closer to operation. Credit: ESA/NASA

The multitude of components within the LISA system must function perfectly individually and together in order for the mission to succeed. For its part, the laser must meet exacting standards in terms of power output, wavelength, noise, stability, purity and other parameters.

The researchers developed a laser that meets nearly all of the requirements outlined by ESA and NASA. All of the laser system's optical and electronic components are either compatible with the space environment or based on technologies for which space-grade components are available.

The system starts with a seed laser, the first packaged self-injection locked laser to be realized at the mission-specified wavelength of 1064 nanometers. The light emitted by the seed laser is injected into a core-pumped Yb-doped fiber amplifier (YDFA), which boosts the average power from 12 to 46 milliwatts. A fraction of the amplified light is then directed to an optical reference cavity, which improves the spectral purity and stability of the laser by orders of magnitude.

The main part of the light then crosses a phase-modulator, which adds features that will allow the mission to compare signals across the three spacecraft through a process known as interferometry. Finally, a second core-pumped YDFA and a double-clad large mode area YDFA amplify the signal to almost 3 watts. Additional components help stabilize the power output.

Confirming performance

The team created a special test station to assess their prototype laser system. They used a cavity-stabilized ultra-narrow 1560 nanometer laser, an optical frequency comb, an active H-maser and temperature-stabilized low-drift photodetectors as references for measuring the stability of the system's frequency and amplitude.

The tests demonstrated compliance with LISA specifications over the full frequency range, with exceptions below 1 megahertz and above 5 megahertz, as well as excellent compliance with regard to noise. Where the tests show minor deviations from the specifications, the researchers have identified likely causes and proposed solutions to fine-tune the system. These solutions include some technical improvements of the seed laser, like adding a drop port to the resonator to reduce high-frequency noise.

"While a launch date shortly after 2030 might appear far away, there is

still substantial technological development to be performed. The team is ready to further contribute to this exciting endeavor," Lecomte said.

Provided by The Optical Society

Citation: Laser prototype for space-based gravitational wave detector (2019, September 18) retrieved 10 May 2024 from https://phys.org/news/2019-09-laser-prototype-space-based-gravitational-detector.html