Contribution ID: **23** Type: **Contributed talk**

Theoretical modeling and experimental characterization of the light retro-reflected and/or backscattered by optical components

Tuesday, 1 October 2024 15:10 (20 minutes)

The performance of a giant interferometric detector such as Virgo or LISA can be affected by the presence of coherent stray light. In particular, it can be generated by the scattering of laser beams at the various interfaces of the instrument. It is therefore particularly important to be able to characterize in amplitude and phase the fraction of this scattered light that interacts coherently with the incident beam.
This is made possible by the BARRITON (for Back-scattering And Retro-Reflection by InterferomeTry with lOw coherence) bench developed by the Light Scattering group at the Institut Fresnel. As the acronym suggests, it is a balanced detection interferometer used in white light. The white light source here is a superluminescent diode covering the spectral band between 1000 nm and 1100 nm, while the balanced detector was developed specifically for our application by the Light Detection and Analysis group at THORLABS Germany. A motorized delay line, using a hollow cube corner as a moving element, allows the optical path difference inside the interferometer to be varied, providing sequential access to the different scattering interfaces of the component under test (remember that the interferometric signal is only visible near zero path difference). The difference between the currents supplied by each of the photodiodes of the balanced receiver is converted into a voltage by a transimpedance amplifier with adjustable gain and then digitized at high speed (1 Msamples/s) by a 16-bit analog-to-digital converter. A discrete Fourier transform applied to the signals recorded near each zero optical path difference provides access to the spectrum of the corresponding backscattered light in amplitude and phase. The angular orientation and lateral position of the device under test can be changed with very high resolution movements (µm and milli-degrees).
In this paper, we present a detailed theoretical modeling of the operation of this test bench based on the use of artificial surfaces whose waviness and roughness can be independently adjusted, showing the fast variations in amplitude and phase of the signal induced by tiny changes in the position of the surface. The main conclusions of this modeling are confirmed by experimental results obtained with BARRITON on various elementary components (antireflective coated windows, silver coated mirrors, photodiodes or beam dumps).
The authors thank the AMIdex Talents Management Program, the University of Aix Marseille, and the French National Space Center (CNES) for financial support, and the Virgo Collaboration for fruitful discussions.The authors would like to thank the AMIdex Talents Management Program, Aix Marseille University, and the French National Space Center (CNES) for their financial support, and the Virgo Collaboration for fruitful discussions.

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Session Classification: Stray light mitigation

Track Classification: Stray light mitigation