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The sixth sense: a new detector to observe the universe

The first direct detection of gravitational waves [1] opens a new era in the observation of the universe. The kilometers long laser interferometers developed since the 1990's have now proven to be sensitive enough to measure the minuscule variations in displacements caused by massive astronomical bodies. This discovery will boost gravitational wave physics with interferometers and Europe is investigating two facilities to enhance the gravitational wave research infrastructure. In 2028 Einstein Telescope should be an operational facility with a ten-fold improved sensitivity and in 2034 eLISA will be the first gravitational wave observatory in space. To reach unprecedented precision both projects rely on further research and development of innovative detector technologies. We will discuss detector systems based on novel opto-electronics, (MEMS) accelerometers, and sensitive readout electronics to reduce limiting noise sources in laser interferometry, especially at low frequencies.

Future GW interferometers require seismic sensor networks for subtraction of gravity gradient noise, caused by direct gravitational coupling of mass density fluctuations to suspended components of the interferometer. Nikhef has started the development of a novel seismic sensor: an ultra-sensitive miniaturized accelerometer made in MEMS technology in combination with extremely low-noise low-power integrated readout electronics in CMOS technology. For this system, the signal bandwidth is in the 1-100 Hz frequency band where the typically dominant flicker noise has to be 'beaten'by several orders of magnitude with a limited power budget. Innovations in both the MEMS design and in the electronics system will target acceleration resolutions in the order of 1 ng/√Hz. Nanometer CMOS technologies provide better high frequency behavior for readout and actuating of MEMS devices. Since these sensors are part of a large area network they need to communicate and transmit data via wireless links.

Nikhef is also developing a monolithic accelerometer with interferometric readout, aiming at fm/√Hz to measure the residual motion of the optical components of GW interferometers since no (commercial) sensor with sufficient sensitivity is available. Another development is a novel Phase Camera for high resolution wavefront sensing to provide a measure of the transverse spatial profile of a laser field. This will allow to determine mirror aberrations at sub-nanometer level which may then be compensated using a thermal compensation system. These sensor systems are some examples that require further development and will benefit from future developments in MEMS technology in combination with integrated (photonic) circuits. The applications of these sensors are manifold: from monitoring and control of accelerator components (including FELs, synchrotrons, etc.) to consumer electronics and oil & gas exploration.

[1] Observation of Gravitational Waves from a Binary Black Hole Merger, B.P. Abbott et al. (LIGO Scientific Collaboration and Virgo Collaboration), Phys. Rev. Lett. 116, 061102 –11 February 2016

Summary

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