Contribution aux exercices de prospective nationale 2020-2030

Détecteurs et instrumentation associée

LOW-NOISE FAST DIGITAL ELECTRONICS AND REAL-TIME CONTROL AND DATA ACQUISITION

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Informations générales

Titre : Low-noise fast digital electronics and real-time control and data acquisition

Résumé

Controls of the terrestrial gravitational wave detectors as Virgo have been more and more moved from analogue to digital in the past decades. An architecture based on a centralized timing distribution and an optical fibre network for real-time data exchange and real-time data processing have been developed and setup. It allows in particular more flexibility of the controls and the development of integrated optical benches in the context of diffuse light reduction. In view of Einstein Telescope, different R&D are anticipated to pursue such

developments towards lower noise from digital electronics and further decoupling of the suspended optical benches from their environment.

Préciser le domaine technologique

- Electronique, informatique

- Acquisition de données, Temps réel

Préciser la motivation principale de recherche visée par la contribution :

- R&D Détection d'ondes gravitationnelles

1. Description des objectifs scientifiques et techniques

The terrestrial gravitational wave Recycled Fabry-Perot interferometers as Virgo are controlled onto a precise working point in order to optimize their sensitivities. Numerous control loops are setup using adapted ADC and DAC channels, in particular to control the longitudinal position and the alignment of the mirrors, the laser frequency, the position and alignment of optical benches, etc… Pound-Drever Hall technique is used to extract error signals from photodiodes sensing the laser beam at the different output ports of the interferometer: the input laser is phase-modulated at frequencies in the range 6 MHz to 130 MHz and the photodiode signals are demodulated at these frequencies. In the past decade, more and more loops have been moved from analogue to digital control. Using fast digital control loops puts stronger constraints on the phase noise of the timing distribution, but allows for much more flexibility in the loop design and configurations during commissioning of the detector. In particular, the demodulation of the photodiode signals being digital allowed for easy addition/removal of demodulation frequencies at the configuration level (instead of hardware level in case of analogue demodulation) following the commissioning evolutions and needs. In the context of reduction of the diffuse light, optical benches have been suspended and placed in vacuum. Ditigal controls have permitted to strongly integrate the electronics within the optical benches to use short (few meters) RF cables to readout the photodiode output. In order to setup such fast controls and allow flexible data exchange between all the different sub-systems of the interferometer, a network for timing distribution used to synchronize all the digital parts of the detector, and an optical fibre network for real-time data exchange were developed and installed in Virgo.

In view of Einstein Telescope control, different R&D paths are anticipated, most of them can be tested in AdvancedVirgo upgrades in the next decade:

- reduce the phase noise of the timing distribution, in particular along the long distance of the arms (3 km for Virg, 10 km for E.T.) using an optical fiber distribution. The WhiteRabbit technique must be evaluated in this context.

- reduce phase noise, digital noise and improve phase tuning reproducibility of the digital demodulation technique.
- reduce noise of ADC and DAC channels, and provide the architecture to run fast control loops, with unity gain frequencies up to few tenth of hertz.
- tests and develop hardware/protocol for power transmission in priority, but also data transmission and timing transmission, with low electro-magnetic noise. This would reduce seismic noise transmitted to the suspended benches and position constraints from copper cables rigidity. It would also remove a source of ground connection issues. In the context of cryogenic detectors, it can remove some thermal couplings.
- reduce the power consumption of digital electronics. This is mainly interesting for electronics located in an air-tank attached below the in-vacuum optical benches, to limit heating of the bench and possible bench vibrations induced by air convection in the tank.
- investigate availability and compatibility of off-the-shelve protocols and hardware for real-time data exchange (instead of home-made data format and network routers).
- develop corresponding software and user interfaces for configuration of electronics input and output, and real-time signal processing, signal filtering and loop logic.
- upgrade the Virgo data collection tool but keeping the nice flexibility it provides (on-the-fly possibility to add and remove channels, providers of data, …).

2. Références