Contribution aux exercices de prospective nationale 2020-2030

Détecteurs et instrumentation associée

PHOTO DETECTEURS INGAAS

INGAAS PHOTO DETECTORS

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1. Informations générales

Titre : InGaAs photodetectors

Acronyme : *(optionnel)*

Résumé

Indium Gallium Arsenide (InGaAs) photodiodes are of primary interest for short infrared laser light detection (ex: 0.9 µm to 1.7 µm) in space physics experiments as well as in high-energy physics experiments. The space applications include optical interferometers for gravitational wave detection (ex: LISA) [1, 2] or Earth ocean, geology and climate studies (ex: Grace-FO) [1, 3]. High-speed LIDAR sensors and inter- and intra- satellite optical communication links [3] are other space applications that can be named. The high-energy physics applications include digital optical data links and high speed optical wireless transmission system (ex: HL-LHC experiments at CERN) [4, 5, 6].

This perspective concerns an experimental R&D activity on InGaAs photodiodes, in particular on the study of their performances for space or ground optical interferometers.

***Préciser le domaine technologique** (plusieurs choix possibles)*

- Détecteurs semi-conducteurs (Si, Ge, HgCdTe, Diamant, InGaAs)
- Photo-détecteurs (SiPM, PMT, InGaAs)
- Mécanique, integration

Préciser la motivation principale de recherche visée par la contribution :

- R&D Détection d'ondes gravitationnelles

2. Description des objectifs scientifiques et techniques

Recent studies [7] showed that InGaAs photodiodes are more than three orders of magnitude more sensitive to displacement damage than silicon-based photodiodes. To guarantee the long term functionality of InGaAs detectors in space or high energy physics experiments, their performance degradation under irradiation and the involved physical mechanisms have to be studied. The critical parameters like responsivity, dark current, and capacitance are of particular interest. Moreover, the vacuum and thermal environment impact on the electro-optical characteristics of InGaAs photodiodes represent also important items of study.

In the framework of the LISA mission (Laser Interferometer Space Antenna) dedicated to gravitational wave detection in space, the InGaAs quadrant photodiodes are to be used for the measurement of the laser interferometric signals. The optical powers impinging on the detectors are quite low; for example, the optical power beam coming from the far spacecraft is of ~ 500 pW. Therefore, InGaAs quadrant photodiodes with specific requirements (ex: large area up to 2 mm diameter and low capacitance of 4.5 pF/mm^2*) are actually under development within the international LISA Photoreceiver Working Group (Netherland, Belgium, Japan, Germany, France, UK).*

The performances of the flight InGaAs photodiodes should be guaranteed during full LISA mission, corresponding to about 12.5-year data taking. The performance degradation under radiation of solar wind type (ex: protons are predominant) and the physical mechanisms of the displacement damage need to be studied on the specific InGaAs prototypes dedicated to the LISA mission.

The InGaAs photodiodes will be also used for the development of precision interferometric test-benches, dedicated to the performance tests of the LISA instrument during the Assembly, Integration, Verification and Test (AIVT) phases. In this context, an activity is actually on-going in ARTEMIS laboratory, with the CNES support. This implies the development of a photoreceiver assembly, composed of an InGaAs quadrant photodiode, connected to a custom-made low noise front-end electronics (FEE), everything assembled in a custom-made mechanical mounting support (MMS) satisfying specific thermal and alignment requirements. Many of the aspects addressed in this activity are contributing to the mechanics and integration technological developments.

3. Livrables associés, calendrier et budget indicatifs

This perspective includes three steps development.

The 1st step is related to development of the InGaAs photoreceiver assembly dedicated to precision interferometric test-benches for the LISA AIVT. This activity is actually on-going in ARTEMIS laboratory, with the CNES, OCA (Cote d'Azur Observatory) and UCA (University Cote d'Azur) financial support and in collaboration with French laboratories (APC, CEA Saclay, CPPM).
The InGaAs photoreceiver assembly is composed of a commercial InGaAs quadrant photodiode, connected to a custom-made FEE and assembled in a mechanical mounting support (MMS) developed by ARTEMIS laboratory. The 1st FEE prototype is under tests and the 2nd one is already in fabrication. The design of the MMS is in progress too. Few prototypes of InGaAs photoreceiver assembly are expected to be ready by the middle of 2020. Their electro-optical performances will be study during 2020-2022. The 1st step development of InGaAs photoreceiver assembly is compatible with the LISA Phase A project and it will continue during next phases of the LISA project (B1, B2 and C).

The 2nd step is related to the InGaAs quadrant photodiodes (QPD) performance degradation under proton irradiation and the study of the involved physical mechanisms.
This activity will start using the InGaAs QPDs fulfilling the flight LISA instrument requirements, actually under manufacturing in Netherland. The first QPDs prototypes are expected to be ready by the middle of 2020 and the first irradiation studies are planned for the period 2020-2021. This is an R&D activity planned to continue at least up to the qualification of the flight QPDs for LISA mission (2026). Financial requests for equipment and human resources will be made to develop this activity.

The 3rd step is a more ambitious and long term R&D activity that can be envisaged, described shortly in the next section.

4. Impact

The Alcatel Thales III-VLab group in France (Palaiseau) have already developed InGaAs technology (photodiodes arrays of 320 x 256 & 640x512) and specific space qualification tests have been carried out for the MicroCarb mission [8].
A further development of InGaAs fabrication technology in France, including applications like optical interferometry or optical links for the high energy physics experiments would be very desirable.

5. Références

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