Contribution aux exercices de prospective nationale 2020-2030

*Détecteurs et instrumentation associée*

# Reduction of scattered light in gravitational wave detectors

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1. **Informations générales**

**Titre : Reduction of scattered light in gravitational wave detectors**

**Résumé** *(max. 600 caractères espaces compris)*

*Scattered light is limiting the sensitivity of all current and past gravitational wave detectors. Several improvements are considered for scattered light from benches with small optics, in order to reduce the amount of scattered light and limit their impact on the gravitational wave phase. Optical mounts that are absorbing light and have reduced mechanical motion are being developed and will be tested during the Advanced Virgo Plus upgrades in 2020 and 2024. On a longer timescale semi-conductor photo-detectors with better back scatter properties need to be studied.*

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

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

***Préciser la motivation principale de recherche visée par la contribution :***

* R&D Détection d’ondes gravitationnelles
1. **Description des objectifs scientifiques et techniques
*(1 page max incl. Figures)***

Interferometric gravitational wave detectors and prototypes have been limited in sensitivity by scattered light for the past 40 years. At each generation of detectors additional means of limiting and controlling scattered light are introduced. However as the performance of the detectors is improved, scattered light always limits the sensitivity in some frequency band. The fundamental reason is that gravitational wave detectors are operated in the dark fringe configuration to maximize the optical gain of the interferometer, as a consequence the beam at the output of the interferometer is several orders of magnitude less powerful that the injected light (4 orders of magnitude for the case of Advanced Virgo). The remainder of the injected light is eventually lost as scattered light due to various defects in the interferometer, and it can easily overshadow the much dimmer beam containing the gravitational wave signal.

In this contribution we focus on scattered light from benches with small optics that are located at the various output ports of the interferometer. On these benches the beam size is reduced from several centimeters in radius to a fraction of a millimeter in order to detect the beam with photo-diodes and cameras. The back reflection on all optical surfaces is increased in an inverse proportion to the beam surface, hence scattered light on these benches is often critical.

There are three factors involved in the coupling of scattered light from a surface: the fraction of back scattered light, the large amplitude slow motion (comparable or larger than the 1um laser wavelength), and the small amplitude motion in the detector sensitive band (10Hz-10kHz). In Advanced Virgo the benches have been suspended to reduce the large motion coming from the ground, and put in vacuum to reduced the optics motion that can be acoustically excited. The use of super polished optics and reduced dust contamination from clean room installation and vacuum operations has reduced the fraction of back scattered light.

In view of the Advanced Virgo Plus installation and Einstein Telescope R&D several improvements are proposed:

* Coating all the aluminum optical mounts with absorbing materials such vantablack or anoblack, in order to absorb the scattered light as soon as it leaves the optical path.
* Investigate absorbing coating materials for the bench and vacuum chamber walls that are ultra high vacuum compatible and resistant to abrasion.
* Increasing the rigidity of all optical mounts to push mechanical resonance to higher frequencies where the detectors are limited by quantum shot noise. This can be done through a combination of more massive pedestal and lowering the optical beam height.
* Design mechanical mount dampers to reduce the amplitude of the motion at resonance.
* Systematically install diaphragm and beam dumps to absorb first order ghost beams: in transmission of highly reflective optics, reflections from anti-reflecting coatings, reflections from active absorbing materials (photodiodes, cameras, …).
* Improve bench optical layout design to minimize scattered light by maintaining the beam as large as possible on all optical surfaces.
* Use 3D opto-mechanical simulation to guide the placement of diaphragm and beam dumps, and to optimize the bench optical layouts.
* Research sensors with smaller back reflection, in particular quadrant photodiodes with absorbing material separating the four quadrants.
1. **Livrables associés, calendrier et budget indicatifs (1 page max. incl. figures)**

*Préciser les objectifs décrits (étude conceptuelle, expérience, prototypage, construction…) et leur échéance, en précisant si possible les partenaires envisagés.*

*Evaluer grossièrement l’ordre de grandeur du financement nécessaire (coût complet, en distinguant équipements/consommables et ressources humaines). Préciser s’il existe déjà ou s’il est envisagé d’autres sources de financement.*

The production of absorbing optical mounts has started for the additional optical bench that will be used by the frequency dependent squeezing and installed within the Advanced Virgo Plus project in 2020/2021.

Mechanical dampers made of rubber and a metal reaction mass are being studied and maybe installed on optics on these new benches and in critical location on existing benches in 2020/2021.

Depending on the results of these design, a replacement of all optical mounts on all already existing benches maybe envisaged for the 2023/2025 upgrade break of Advanced Virgo plus.

1. **Impact *(1/2 page max.) (optionnel)***

*Décrire les retombées envisageables par le développement pour des applications sociétales.*

*Le cas échéant, préciser les partenariats industriels envisageables.*

1. **Références**