# Letter of Intent

To: EGO Director - EGO Council Chair - Virgo Spokesperson

Date: May 2025, 9th

**From:** Institut Fresnel Group, (Aix Marseille Université – Ecole Centrale Méditerranée -CNRS) at Marseille, France. Contact Person : Myriam Zerrad, <u>myriam.zerrad@fresnel.fr</u>

Subject: Expression of Interest to join VirgoLab

Dear Sir/Madam,

This letter serves as a formal expression of interest by the Institut Fresnel Group to join the VirgoLab, as described in VIR-1025B-24. We understand that VirgoLab operates, commissions, and upgrades the Virgo interferometer, and we are willing to contribute to its mission and to the achievement of its goals.

### 1. Introduction

The Institut Fresnel Group is a group coordinated by the Institut Fresnel (Marseille) which includes members from 4 other French laboratories: Institut Lumière Matière – iLM, Laboratoire Navier, Institut des Nanotechnologies de Lyon – INL, Institut de NanoSciences de Paris – INSP.

- ✓ The Institut Fresnel is a joint research unit affiliated to Aix Marseille University, the CNRS (UMR 7249) and the Ecole Centrale Méditerranée. The main research topics of concern optical coatings & optical components, electromagnetic theories, extreme optical metrology, light scattering, thermal radiation, laser induced damage, metamaterials & metasurfaces, nano-antennas, hyperfrequencies & microwaves, image and signal processing.
- ✓ The Institut Lumière Matière (ILM) is a multidisciplinary research institute of the Université Claude Bernard Lyon and the CNRS (UMR 5306) that provides a unique roof under which scientific competence in the domains of physics and chemistry, from molecules to materials, and from optics to nanosciences, is gathered. The study of such materials and of its interfaces proceeds by multi-scale approaches, both in terms of space (from nanometers to meters) and of time (from attoseconds to seconds). Among all physical and chemical properties under investigation, optical, spectroscopic and luminescence properties emerge as common lines of research for the majority of the 19 research groups (about 300 people strong in total) of the institute.
- ✓ Navier is a joint research unit between the Ecole des Ponts-ParisTech, Université G. Eiffel and CNRS (UMR 8205), with scientific competences in diverse topics at the interface between mechanics, physics and material science, in connection with various domains of application. The involved partner at Navier possesses a long-standing expertise in the numerical simulation of glassy solids, that has recently expanded towards the construction of models of vacuum deposition of thin oxide films.
- ✓ The Institut des Nanotechnologies de Lyon (INL) is a Joint Research Unit (UMR 5270) whose supervisory bodies are the CNRS, ECL, INSA, the University of Lyon 1 and CPE

Lyon. The INL's mission is to develop multidisciplinary technological research in the field of micro and nanotechnologies and their applications. The research carried out ranges from materials to systems, and the laboratory is supported by Lyon's NanoLyon technology platform.

✓ The Institut des NanoSciences de Paris is a joint research unit (UMR 7588) of the CNRS and Sorbonne University. The INSP brings together a wide range of skills, both in terms of manufacturing resources (aggregate growth, self-organisation, molecular jet epitaxy, laser ablation, lithography, etc.) and characterisation and study resources (high-resolution spectroscopy-microscopy, local probes, fast ion and multi-charged ion sources, numerical simulation, etc.).

Our expertise and ongoing research activities are highly relevant to the operation, commissioning, and potential upgrades of gravitational wave interferometers.

We believe that our participation in VirgoLab would be mutually beneficial, allowing us to contribute our knowledge and resources to the advancement of gravitational wave science in Europe and beyond, while also providing our members with valuable experience and opportunities within a leading international collaboration.

This letter outlines our main areas of interest and potential contributions to VirgoLab.

## 2. Scientific / Technological Case or Context of Opportunity

Our group has a strong background in many fields related to VirgoLab activities.

- Optical Coatings: iLM, Navier, INL and INSP focus on material research for coatings, substrates and suspensions performing instrumental developments, characterization, synthesis of films and crystals, simulations of amorphous materials and estimation of detector performance. While iLM, INL and INSP are in charge of all experiments and provides technical assistance to the systems Mirrors and Suspensions; Navier carries out all numerical simulations and accompanies the formulation of experimental tests, and the development of phenomenology, models, and theories in the domain of coatings. Institut Fresnel is expert is the development of instrumentation for the measurement of optical properties of new materials for optical coatings: Transmittance/Reflectance, absorption, scattering and thermal properties. They can also develop models to predict these parameters. They are working on the development of dedicated metrological set-up to record a direct measurement of coating thermal noise.
- Light Scattering : The Institut Fresnel is expert in Light Scattering phenomena, and more generally in the prediction and analysis of optical losses in the case of high performances optical components including complex optical interference coatings. They already developped a metrology platform (DIFFUSIF) dedicated to light scattering characterization with more than 5 scatterometers designed and developed by the group. The metrological performances are today the international state of the art in the field of scattering measurements. Among them, are the instruments SALSA (Spectral and Angular Light Scattering characterization Apparatus), SPARSE (SPatially and Angularly Resolved Scatterometry Equipment) and BARRITON (BAckscattering and Retro-Reflection by InterferomeTry with IOw cohereNce). The agreement between the measurement results

obtained with these scatterometers and the numerical models is excellent, even for optical coatings with hundreds of layers, and has no equivalent at present.

## 3. Description of the Proposed Contribution

Our proposed involvement in VirgoLab would encompass the following potential contributions:

- Optical coatings R&D :
  - Contributing to the identification of optimal production parameters for for oxides, nitrides, and amorphous semiconductors
  - Working on the correlation of the mechanical losses to the coordination number (and structure in general) of amorphous materials
  - Studying the impact of crystallization on TARs
  - Identifying optimal mixtures for high-index metal oxide glasses
  - Understanding the origin of optical absorption in amorphous coatings and reduce that of nitrides and of aSi and other semiconductors.
  - Working on coating thermal noise: metrology and modeling: The design of a setup allowing the direct measurement of the thermal noise of the coating will be carried out, then implemented.
  - Working on the development of an optical bench for the measurement of the effect of local absorbing points
- Straylight :
  - Calculate the light scattered and backscattered by planar optical components with home made softwares based on electromagnetic theories. These theories include the case of surface (roughness) and bulk (inhomogeneities)) scattering, and localized defects for substrates and coatings. They also consider trapped light scattering (transferred to guided modes) in the energy balance.
  - Measure the light scattered and backscattered by planar optical components with the already existing benches or with dedicated new benches if required and funded. These benches may allow the identification and discrimination of scattered light generated by: roughness, bulk inomogheneities, localised defects and coatings

We are also open to contributing to other areas based on the evolving needs of VirgoLab and the expertise within our group. We are keen to engage with the existing VirgoLab Technical Teams and Projects to identify areas where our skills and resources can be most effectively utilized.

#### 4. Costs, Calendar and Resources

Initially, our contribution would primarily involve the effort of our existing personnel Paul Rouquette, Michel Lequime, Anael Lemaitre, Gianpiettro Cagnoli, Claude Amra and Myriam Zerrad.

We understand that the successful accomplishment of VirgoLab tasks, particularly the timely installation and commissioning of the O5 upgrade, will demand strong and continual presence at EGO site. Our group commits to support that effort as much as reasonably possible.

We anticipate the need for at least, 1 engineer and an annual grant to maintain cleanrooms. Other needs will have to be discussed specifically for each project/activity.

We understand that Member Labs are in charge of maintaining and operating the equipment they provide, and we are prepared to discuss the provision of scattering measurements within the frame of DIFFUSIF platform as part of a Memorandum of Agreement (MoA).

We are aware that financial resources are allocated by EGO Council, national funding agencies, or research organizations. We will explore potential funding opportunities through our institution and national agencies to support our involvement in VirgoLab.

We are prepared to work towards the establishment of a MoA with EGO should our application be successful.

5. Stakeholders and Requirements

Our primary stakeholders are Aix Marseille Université, CNRS, Ecole Centrale Méditerranée, Université Claude Bernard Lyon, Ecole des Ponts-ParisTech and Université G. Eiffel and AMIDEX Fundation.

We understand that as a contributing group, our main requirements would be to have effective communication channels within VirgoLab, opportunities for our members to actively participate in relevant projects and technical teams, and recognition for our contributions to the scientific and technical advancements of Virgo.

We are committed to adhering to the policies and procedures of VirgoLab, including those related to resource allocation and publications.

We are ready to discuss our potential participation further and provide any additional information that may be required. We look forward to the possibility of joining the VirgoLab and contributing to its continued success.

Sincerely,

per la

Myriam ZERRAD Head of Light Scattering Group, Institut Fresnel On behalf of the Institut Fresnel Group May 2025, the 9<sup>th</sup>