PhD thesis proposal

Title: Origin and characteristic of scattered light in very low loss mirrors for gravitational wave detectors.

Supervisors: M^me^ Myriam Zerrad (research engineer, HDR - Institut Fresnel)
M^r^ Jerome Degallaix (researcher - Laboratoire des Matériaux Avancés - IP2I)

Research plan:

As complex high precision optical experiments are getting increasingly more sensitive, the effects of scattered light becomes more and more prevalent. Two detrimental effects can be associated with scattered light: the first one is an additional source of optical loss while the second one is more subtle: the scattered light could recombine with the main light beam and generate additional (phase) noise.

Due to its operation on the dark fringe with hundreds of kilowatt of light circulating in the arm cavities, laser Gravitational Wave Detectors (GWD) exhibit extreme sensitivity to scattered light. As such, every detectors had its sensitivity limited by scattered light at some point in its existence. Despite long lasting efforts to mitigate the consequences of this parasite light with absorbing baffles and careful alignment, it is still believed that in the most sensitive frequency band, current detectors are limited by this phenomena.

Most of the approaches so far aim to eliminate the coupling path between scattered light and the output gravitational wave channel of the detector, but none focus on the origin of the scattered light itself. In this PhD thesis, we will study the characteristics of the scattered light at the level of the optics and understand the mechanism to reduce it. It should be noted that following the impressive progress in the polishing capability, the main source scattered light in very high finesse cavity is likely linked to the multi-layer coating itself.

This PhD thesis will be the cement for a formal joint research program between the team Concept at the Fresnel Institute, expert in scattered light and the Laboratoire des Matériaux Avancés, the provider of the most critical mirrors of GWD. The two laboratories are world leaders in their domains and this synergy will be a unique asset for the Virgo Collaboration.

More specially, the research will focus on characterising the light scattered by state-of-the-art optics like the ones installed at the heart of the Virgo detector. Several tasks are already planned:

- Cross checking of the caracterisation benches (scatterometer and surface defect measurement) installed at Fresnel and LMA.
- Estimation of the amount and direction (BRDF) of the scattered light from high performance mirrors. Understand the influence of the laser beam size on the measurement as the metrology is done with mm size beams whereas in the Virgo interferometer the laser beam radius is around 5 cm.
- Realistic estimation of the loss in the arm cavities of Advanced Virgo, comparison with the measurement (so far we are missing 10-15 ppm of loss per mirror from our model). A definitive scattering loss budget with the contribution of flatness, roughness, coating defects will be calculated.
- Finding the origin of the scattering from the coating, scattering as a function of the deposition parameters to find a recipe to achieve optics with ever lower loss.