

# MASTER IN PHOTONICS – PHOTONICS BCN EUROPHOTONICS-POESII MASTER COURSE

## PROPOSAL FOR A MASTER THESIS

**Dates: April - September 2017**

**Laboratory : Gravitational Astronomy Group**  
**Institution: Institut de Ciències de l'Espai (IEEC-CSIC)**  
**City, Country : Bellaterra, Spain**

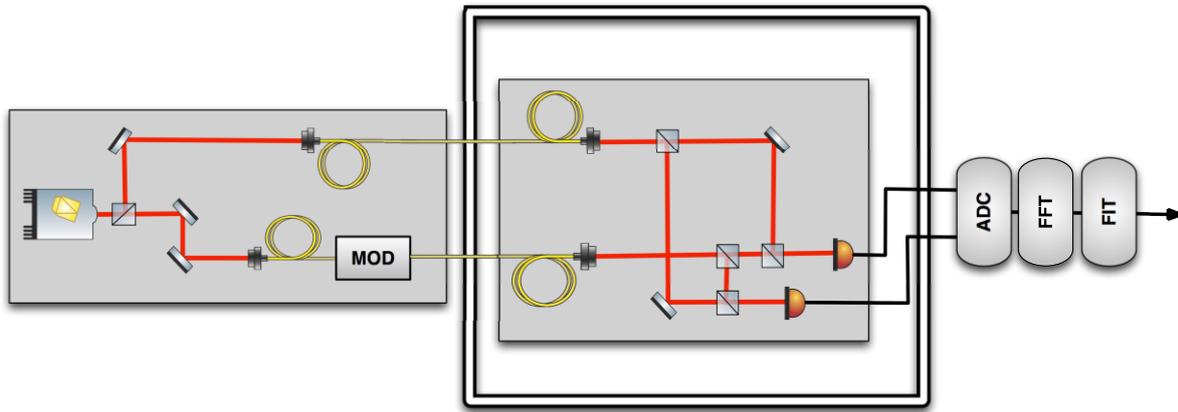
**Title of the master thesis: Optical metrology noise reduction techniques for space-based gravitational wave detectors**

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### **Summary of the subject:**

Gravitational waves are a prediction of Einstein's General Relativity recently detected by on-ground laser interferometers. LISA (Laser Interferometer Space Antenna) is an ESA proposed mission designed to detect gravitational waves in space, aiming to detect gravitational radiation by putting three satellites in heliocentric orbit separated 1 million km one from each other, forming a triangle. The Gravitational Astronomy group at the Institut de Ciències de l'Espai (IEEC-CSIC) has provided the Data and Diagnostics Subsystems of LISA Pathfinder, a precursor mission launched in December 2015 and currently in operations, which has successfully measured the residual acceleration of two free-falling test masses in space down to the  $5 \times 10^{-15}$  m/s<sup>2</sup>/√Hz in the millihertz band [1].

Our group is currently developing the techniques required for the future LISA mission. In particular the design of an ultra-stable thermostat able to create a space-like environment allowing high precision optical metrology experiments in the millihertz band. The setup consists of an interferometer implementing the deep phase interferometer scheme [2] in a ultra-stable CFRP (Carbon Fiber Reinforced Polymer) bench. The phase measuring system is a FPGA with LEON3 soft-core processor while the temperature read-out subsystem is a replica of the control unit currently flying in the LISA Pathfinder satellite.



Schematic of the setup with the modulation bench (left), the Mach-Zehnder interferometer inside the vacuum chamber (middle) and the postprocessing taking place in the FPGA (right).

The candidate will work in the implementation of optical metrology noise reduction techniques in the very low-frequency band, i.e. the millihertz. This includes the implementation of phase stabilisation loops based on optical pathlength difference, frequency noise [3] and environment temperature disturbances [4].

**Keywords : Gravitational Waves, Optical Metrology, Low-frequency noise**

**Additional information :**

- Required skills : optics, electronic instrumentation, signal processing, and control loops.
- Miscellaneous :

[1] M. Armano *et al.* Sub-Femto-g Free Fall for Space-Based Gravitational Wave Observatories: LISA Pathfinder Results, *Phys. Rev. Lett.* 116, 231101 (2016)

[2] G Heinzl et al. Deep phase modulation interferometry *Optics express* 18 (18), 19076-19086 (2010)

[3] G Hechenblaikner *et al.* Digital laser frequency control and phase-stabilization loops in a high precision space-borne metrology system. *IEEE Journal of Quantum Electronics* 47 (5), 651-660 (2011).

[4] M Nofrarias *et al.* Subtraction of temperature induced phase noise in the LISA frequency band. *Physical Review D* 87 (10), 102003 (2013).