# Development of a portable diagnostic breadboard for laser beam characterization

**Type of contract**
Internship contract for a period of 5 months within the EGO Optics laboratory, funded by the EGO Consortium.
The activity may start on February, 2018.

**Description**
The Virgo interferometer is the most sensitive gravitational-wave detector in Europe. It was realized in partnership between the French and Italian institutes CNRS and INFN. It involves a wide collaboration of almost 250 scientists and engineers. After a deep modification of the interferometer, to give birth to a new generation detector called Advanced Virgo (AdV), and after the successful science run together with the LIGO detectors, the instrument is now being commissioned to become fully operative for the second stage of sensitivity improvement.
The EGO consortium (European Gravitational Observatory), located in Cascina, near Pisa - Italy, hosts the Virgo detector. It has also been deeply involved in the design and construction of Advanced Virgo. In particular, the Optics Group of EGO Interferometer Technology Department is in charge of the input optics (INJ) and scattered light control (SLC) system for AdV. The responsibilities of the Optics Group have now increased with the commissioning phase, including the coordination of the whole laser and injection system, the sensing and control of the interferometer and a major role in the optical characterization of the interferometer.
In this frame, the Optics Group would like to develop a portable diagnostic breadboard that would be used in the optics laboratories to characterize any beam on any bench. Such a breadboard would allow us to uniformize the results that are acquired in the laboratories and to save time by avoiding always having to set up cumbersome characterization setup on different benches.
For all the experiments that we are carrying out in the laboratories, it is indeed of great interest to perfectly know the characteristics of the beam that is used and its temporal fluctuation. For example, while using crystals for laser and interferometric applications (electro-optic modulator, Faraday isolator, Laser power amplification, second harmonic generation…) or optical fibers, one needs to know the information at the input to maximize the efficiency of the component and at the output to see how the input beam has been deteriorate through the component.
So the idea is to have a portable diagnostic breadboard that could be easily move from a bench to another and provide the needed information. As a first step it would give information on power fluctuation, beam jitter, but also on the mode content of the beam thanks to a mode filtering optical cavity. Depending on the time remaining it could also be improved by adding an arduino-based polarimeter and a wavefront analyzer that would give the characteristics of the Gaussian beam under study.
Within the Optics Group, the student will be in charge to design this breadboard, to set it up and to carry out some tests to validate its functioning. She/he will have the opportunity to work on various aspects of the fields: mainly optics, but also to collaborate with the electronics and mechanics groups at EGO.

**Requirements**
Applicants should be in their last years of study in optics or physics. The work will be at a level of Master thesis (equivalent to thesis for 'laurea specialistica' in Italian).
English required. Good attitude to experimental work is mandatory, knowledge in Python will be an asset.
European citizenship, no criminal convictions.

**Place of work**
EGO - European Gravitational Observatory - via E. Amaldi 5 cap 56021 Loc. S.Stefano a Macerata - Cascina (Pisa) ITALY.
This internship will be carried out in the Interferometer Technology Department in the Optics Area.
*Considering the lack of public means of transport to reach the site, it is preferable having a car.*

**How to apply?**
Interested candidates are invited to fill in the Internship Application Form and send it, together with the CV, to jobs@ego-gw.it

**Further information**
For the whole duration of the internship, EGO will pay a gross monthly wage of 500,00 euro and offer the lunch service at its canteen during working days to the student. Interested candidates can have a look at all of the conditions of the agreement here:

- For the Italian Universities: Internship Agreement with project
- For the Foreign Universities: Internship Agreement with project

**Closing date for applications**
Until position is filled

**Contact**
Eric Genin, Ph.D.
Email: eric.genin@ego-gw.it
Phone: +39 050 752 369

# Residual Amplitude Modulation Servo Electronics Design and Implementation

**Type of contract**
Internship contract for a period of 5 months within the EGO Optics laboratory, funded by the EGO Consortium.
The activity may start on February, 2018.

**Description**
The Virgo interferometer is the most sensitive gravitational-wave detector in Europe. It was realized in partnership between the French and Italian institutes CNRS and INFN. It involves a wide collaboration of almost 250 scientists and engineers. After a deep modification of the interferometer, to give birth to a new generation detector called Advanced Virgo (AdV), and after the successful science run together with the LIGO detectors, the instrument is now being commissioned to become fully operative for the second stage of sensitivity improvement.
The EGO Consortium (European Gravitational Observatory), located in Cascina, near Pisa - Italy, hosts the Virgo detector and has been also deeply involved in the design and construction of Advanced Virgo. In particular, the electronics group of EGO Interferometer Technology Department is in charge of the electronics of input optics system for AdV.
An essential part of the detector is the electronics for the front-end associated with light sensors used in the experiment and that of the control systems. Several feedback loops necessary to meet the project sensitivity requirements need to guarantee high performance both in terms of noise suppression and dynamics. This holds true for the Residual Amplitude Modulation Stabilization (RAMS). Its goal is to suppress the unwanted amplitude modulation introduced as a collateral effect of the phase modulation of the Advanced Virgo Laser beam to values of the order of few parts per billion of the sideband amplitude. This represents a very challenging goal and a system with this level of performance cannot simply be bought on the market. Therefore, it must be custom developed.
Within the Electronics Group, the student will be in charge to design and then build the printed circuit board for RAMS Servo electronics using electronic design CAD software packages. Once the unit is fully assembled, its complete characterization will be required with adequate laboratory instrumentation to validate its performance and certify it meets the specifications.
She/he will at first get acquainted with the software tools used at EGO for electronic board design and afterwards become familiar with the instrumentation available in the electronics laboratory up to the point where he can use it autonomously, with confidence, and reliably.

**Requirements**
The applicant should have completed (or complete soon) his/her third year of Electronics study at University level (Bachelor/Laurea triennale).
English required. Good attitude to electronic experimental work is an asset.
European citizenship, no criminal convictions.

**Place of work**
EGO - European Gravitational Observatory - via E. Amaldi 5 cap 56021 Loc. S.Stefano a Macerata - Cascina (Pisa) ITALY.
This internship will be carried out in the Interferometer Technology Department in the Electronics Area.
*Considering the lack of public means of transport to reach the site, it is preferable having a car.*

**How to apply?**
Interested candidates are invited to fill in the Internship Application Form and send it, together with the CV, to jobs@ego-gw.it

**Further information**
For the whole duration of the internship, EGO will pay a gross monthly wage of 500,00 euro and offer the lunch service at its canteen during working days to the student. Interested candidates can have a look at all of the conditions of the agreement here:

- For the Italian Universities: Internship Agreement with project
- For the Foreign Universities: Internship Agreement with project

**Closing date for applications**
Until position is filled

**Contact**
Flavio Nocera
Email: flavio.nocera@ego-gw.it
Phone: +39 050 752 368

# Characterization of CHRAC for thermal compensation of optics surface defects

**Type of contract**
Internship contract for a period of 5 months within the EGO Optics laboratory, funded by the EGO Consortium.
The activity may start on February, 2018.

**Description**
The Virgo interferometer is the most sensitive gravitational-wave detector in Europe. It was realized in partnership between the French and Italian institutes CNRS and INFN. It involves a wide collaboration of almost 250 scientists and engineers. After a deep modification of the interferometer, to give birth to a new generation detector called Advanced Virgo (AdV), and after the successful science run together with the LIGO detectors, the instrument is now being commissioned to become fully operative for the second stage of sensitivity improvement.
The EGO consortium (European Gravitational Observatory), located in Cascina, near Pisa - Italy, hosts the Virgo detector and has been also deeply involved in the design and construction of Advanced Virgo. In particular, the Optics Group of EGO Interferometer Technology Department is in charge of the input optics (INJ) and scattered light control (SLC) system for AdV. The responsibilities of the Optics Group have now increased with the commissioning phase, including the coordination of the whole laser and injection system, the sensing and control of the interferometer and a major role in the optical characterization group of the interferometer.
One of the main conditions to be fulfilled in order to reach the design sensitivity is to have a perfectly destructive interference between the beams recombining at the detector output. This condition can be satisfied only if the wavefronts reflected by the two arms perfectly cancel with each other.
However, it can happen that residual mirror defects can enhance high order modes resonating in the cavity: this would increase the Fabry-Perot cavity losses on the one hand and spoil the symmetry between the reflected fields, eventually preventing a perfect destructive interference between the wavefronts at the output of the detector.
In order to limit this effect, it is possible to correct the residual mirror roughness using an adaptive optics system based on thermal compensation. The basic principle of thermal compensation consists of changing the mirror shape by heating it up in specific points, correcting the unwanted defects.
A new system of thermal compensation, which has been developed in collaboration between the Optics Group and the Virgo Pisa Group is the Central Heating Residual Aberration Correction (CHRAC).
The CHRAC system is made up of a matrix of pixels emitting thermal radiation with a black body spectrum: an optical telescope images the correction matrix on the mirror surface which, in turn, absorbs radiation and deforms accordingly, following the projected correction map (see schematics).
The CHRAC prototype currently realized has been sized for Advanced Virgo mirrors (350 mm diameter), and is made up of 61 1cm2 ceramic resistors.
The residual mirror roughness, or surface map, can be decomposed in a base of polynomials called 'Zernike polynomials'. Therefore, the ability of reproducing each element of the Zernike base allows also inducing any deformation given by their linear combination.
In order to reproduce on the mirror surface a controlled deformation, a complete characterization of the system is needed. This consists of a first 'calibration' phase of each actuator (resistor) and then a following phase where more complex deformations are induced, from the Zernike polynomials to any kind of deformation maps.
The student will be in charge to set up the CHRAC and to carry some tests to validate its functioning. She/he will have the opportunity to work on various aspects of the fields: mainly optics, but also to collaborate with the electronics and mechanics groups at EGO.

**Requirements**
Applicants should be in their last years of study in optics or physics. The work will be at a level of Master thesis (equivalent to thesis for 'laurea specialistica' in Italian).
English required. Good attitude to experimental work is mandatory, familiarity with control systems and related hardware/software will be an asset.
European citizenship, no criminal convictions.

**Place of work**
EGO - European Gravitational Observatory - via E. Amaldi 5 cap 56021 Loc. S.Stefano a Macerata - Cascina (Pisa) ITALY.
This internship will be carried out in the Interferometer Technology Department in the Optics Area.
*Considering the lack of public means of transport to reach the site, it is preferable having a car.*

**How to apply?**
Interested candidates are invited to fill in the Internship Application Form and send it, together with the CV, to jobs@ego-gw.it

**Further information**
For the whole duration of the internship, EGO will pay a gross monthly wage of 500,00 euro and offer the lunch service at its canteen during working days to the student. Interested candidates can have a look at all of the conditions of the agreement here:

- For the Italian Universities: Internship Agreement with project
- For the Foreign Universities: Internship Agreement with project

**Closing date for applications**
Until position is filled

**Contact**
Eric Genin, Ph.D.
Email: eric.genin@ego-gw.it
Phone: +39 050 752 369