XXXIV cycle Ph.D. course in Physics:

Final year report

Student: Beatrice D'Angelo
Supervisor: Fiodor Sorrentino

Research subject and activity

My PhD thesis is dedicated to the study of the sensitivity enhancement of the gravitational wave interferometer Virgo, located near Cascina (PI). In particular, the focus of my work is on the reduction of quantum noise, which is expected to dominate the detector sensitivity in the whole frequency band at the final target laser input power.

Quantum noise can be reduced by using squeezed states of light; in this regard, during my first year my research was carried on both in Virgo and in Genoa.

Research activity on site (Virgo interferometer)

The squeezing vacuum source (squeezer) was delivered in Virgo on January, 2018. My contributions were to align the squeezed light beam to the main laser, to automatize the engagement of the squeezer into the interferometer locking sequence, to develop the auto-alignment, and to perform a coherent-control loop in order to match the phase of the squeezed beam to the main laser's phase.

Virgo joined the third observational run (O3) with a fully functional and operating squeezer: the injection of a squeezed vacuum into the interferometer produces an enhancement in the high-frequency sensitivity up to 3 dB (the horizon for a Binary-Neutron Star detection increases by 2-4 Mpc).

A parallel work was led into the 1500W lab. This laboratory hosts an optical bench built to generate squeezed vacuum, and from November to February I helped with the restore of the optical setup, which ended with the squeezing measurement. From February to September, the main goal was to improve the squeezing level. Some of the activities in this laboratory were: lock of cavities, control loops, CMRR measurement, visibility measurement, parametric gain analysis.

Research activity in Genoa

Starting from January, I built up an optical setup in the optical laboratory in Genoa (L206). The primary scope is to test some devices which are meant to be exploited in the upcoming upgrade of the Virgo squeezer (as a part of the Advanced Virgo + experiment).

Here, I characterized a gaussian beam with some techniques such as the knife-edge, checked the cavity response in terms of Bode diagrams, locked the cavity by using a control loop I developed. Then I tested an Acoustic Optical Modulator (AOM) and analyzed the beat note between the two created beams.

Courses attended

Gravitational Waves:

Credits: 6 (48 hours).

Exam scheduled for 10 October.

Main content:

- General relativity, formalism of Gravitational Waves, gravitational astrophysics (G. Gemme)

- Detectors and detection techniques (F. Sorrentino)
- Data analysis (A. Chincarini)

Optical and Spectroscopic Methods for the Study of Materials:

Credits: 6 (48 hours).

Exam passed on 25th September.

Main content (M. Canepa):

- Classical models: homogeneous and isotropic dielectrics, inhomogeneous materials, anisotropic dielectrics
- Interfaces: reflection and refraction
- Models for the absorption
- Ultra-thin and nanostructured films

Quantum Optics:

Credits: 3 (20 hours).

Exam passed on 24th July.

Main content (D. Ferraro):

- Quantum states of radiation: Fock states, coherent states and squeezed states
- Wigner function and Q distribution
- Photodetection and coherence functions
- Mach-Zehnder, Hanbury-Brown-Twiss, Hong-Ou-Mandel interferometers
- From photons to electrons: wave-guides, beam-splitters and electron sources

Cosmology:

Credits: 3 (20 hours).

Exam passed on 11th September.

Main content (N. Maggiore):

- Expansion of the Universe
- Dark Matter: observational evidences
- Cosmological Constant
- Dark Energy models

Conferences and workshops

10th Young Researcher Meeting in Rome, 17-21 June (poster presentation)

Commissioning Training in Virgo, 23-27 September

Seminar-FRED Optical Simulation in Munich (scheduled for 15-18 October)

Papers

Poster proceeding of the 10th Young Researcher Meeting (under revision)