PhD course of National Interest in Technologies for
Fundamental Research in Physics and Astrophysics

Annual report

Name and surname: Prajkta Nehete
Cycle and a.a.: Cycle 40 – 2024/2025
Supervisor: Francesco Quochi

- **Research activity carried out during the year**

Research Topic- Optics and thermo-optics of dielectric coatings for gravitational wave interferometer.
The topic focuses on the deposition and characterization of thin films for gravitational wave interferometers, aiming to increase sensitivity by at least one order of magnitude.
The Einstein Telescope is the biggest project in Europe. It will have 6 interferometers, 10km each, arranged in a triangular shape geometry where one triangle will operate at room temperature and the other one will operate at cryogenic temperature (10K-20K). This will increase the detection band for the gravitational waves, allowing us to detect waves back from the dark ages, which is thousands of years after the Big Bang.

The current gravitational interferometer (Advanced LIGO) uses a technique of Bragg reflector coating, which is layers of high refractive index material and low refractive index material. The more the refractive index contrast between the two layers, the more the coating will turn out to be reflective. The coatings are made of a mixture of amorphous oxides Ta_2O_5:TiO_2; this combination is considered to be the best by far for the high-index material. For the low-index material - SiO_2, with Ion beam sputtering as the deposition technique.

The work mainly involves two things –

1. The deposition of thin films using different kinds of materials or mixtures of materials, for example, metal oxides, mixtures of metal oxides, fluorides, Silicon nitrides, Amorphous silicon, and silicon carbides to increase the refractive index contrast between the two Bragg layers and create high-reflective coatings with less thermal loss and noise.

2. Characterization of the coatings, which includes instruments like Atomic force microscopy, Spectroscopic ellipsometry, and reflectometry for measuring the thickness, surface roughness, and reflectance or transmittance, etc.

Theoretical Work-
To better understand the concept of thin films, I reviewed the basics of thin film deposition, including the various techniques CVD and PVD, their different types, and their subtypes. Also learned about vacuum technologies, which are useful for controlled evaporation during thin film deposition.
I deepen my knowledge, I dedicate my time to reading papers about the Gravitational wave interferometer and the factors that affect its sensitivity.
I gained the theoretical knowledge for Atomic force microscopy and the basics of Ellipsometry. Both these techniques are useful for analysing the optical and surface properties of thin films.
I have studied MATLAB to pass the respective coursework exam by presenting a project work.

Practical Work-
1. Atomic Force Microscopy- I got trained for the Atomic Force Microscopy, with which I can

measure the surface properties of the sample. I have been collaborating with my group to analyse hybrid and single-crystal perovskites with the help of AFM. I was also experimenting to figure out the Kelvin Probe measurements and Conductive measurements.

2. Electrical measurements- I took a training course for Electrical measurements, with the exfoliation method.
3. Evaporator- I received training for the Evaporator, along with the glove box, from the company at June end. The evaporator has 3 sources – LTE, THE, E-Beam. To be familiar with the software and the whole system, I tried to deposit Al contacts with E-beam on a glass substrate. Since we are still in the process of receiving our order for the materials, the actual deposition is yet to be done.
4. Ellipsometer – In July 2025, I received training for the Ellipsometer from the company. Since then, I have been conducting troubleshooting experiments with the Ellipsometer to see the theoretical data with the experimental data and how they match.
   I have tried to use different samples and figure out the best fit for the same. I have tried to measure the deposited Al contacts with the Ellipsometer. I have tried measuring Metals, Oxides, and transparent samples. The work is ongoing on the transparent samples. Right now, I'm collaborating with my group to measure 2D and Mixed perovskites with the help of Ellipsometry.

Ongoing work and future work-

1. Troubleshooting for the Ellipsometer and working on transparent samples.
   To characterize 2d and halide perovskites with ellipsometry.
2. Future work- Deposition of thin films with the evaporator to compare the results, and then make the necessary steps to achieve the final output.
3. Characterization of the thin films.

- **List of attended courses and passed exams**

1. Scientific programming MATLAB – Passed (Credit points – 6)
2. Machine Learning for Physics – Exam pending

Courses willing to attend-

1. Radiation matter interaction - Enrolled
2. Semiconductor Light Sources for Engineers

- **List of attended conferences, workshops and schools, with mention of the presented talks**

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Summer school - 2025 Characterization of Materials Summer School.
From 2nd September 2025 to 5th September 2025.

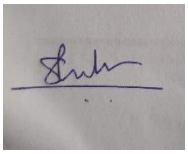
- **List of published papers/proceedings**

  Collaboration paper - One-pot growth of 2D/3D hybrid perovskite vertical heterostructures.

- **Thesis title (even temporary)**

Deposition and Characterization of dielectric coatings for the Gravitational wave interferometer.

Date,

12/9/2015 **Signature** 

Seen, the supervisor