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UNIVERSITÀ
DEGLI STUDI
DI PADOVA

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

Annual report

Name and surname: MUHAMMAD WAQAS
Cycle and a.a.: 40th cycle, 2024/2025
Supervisor: ANDREA FABBRI

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

- **Aim of the Project:**

The project focuses on the development of advanced 2D detection systems for radiotherapy and hadron therapy based on quantum dots (QDs) deposited on Polyethylene Naphthalate (PEN) substrates. By combining the high sensitivity and tunable optical properties of QDs with the flexibility and radiation hardness of PEN, the research aims to create lightweight, cost-effective, and precise detectors for the accurate monitoring of X-rays and proton beams in medical applications.

- **Research Activities Carried Out:**

During this year, the following research activities were carried out:

- (1): Lead Sulfide (PbS) and CdZnTe QDs were successfully synthesized using the hot injection method.
- (2): The synthesized QDs were characterized using spectroscopic techniques like UV-Vis, PL, and DLS.
- (3): PbS QD-based photoconductors were fabricated on PEN substrates using both Drop-Casting and Spin-Coating techniques, and different architectures.
- (4): The morphology of the active film was investigated and compared to reference samples by Stylus Profilometry.
- (5): PbS QD-based detectors were evaluated under X-ray and proton beam irradiation to assess their response, measuring their photocurrent at different beam intensities.
- (6): Moreover, Gold nanorods (NRs) were successfully synthesized using a two-step method and subsequently characterized for their potential application in advanced drug delivery systems for cancer therapy.

- **Difficulties and Action Taken:**

(1): Achieving homogeneous and defect-free QD films on PEN substrates was challenging with drop-casting due to the formation of cracking and fragmentation of the film.

Action Taken: Tested alternative solvents, changed deposition technique to spin coating, and optimised the deposition protocol to obtain a uniform film.

(2): Limited availability of X-ray and proton beamlines to secure scheduled beam access.

Action Taken: Strengthened collaborations with different research centers to foster new possibilities for testing the devices with different radiation sources.



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

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|--|-------------------------------|
| 1. Design of Readout Integrated Circuits For Particle Detectors: | Attended, and Passed the Exam |
| 2. Advanced Electronic Sensing Devices: | Attended, and Passed the Exam |
| 3. Cabling and Shielding for Low Noise Applications: | Attended, and Passed the Exam |
| 4. Electronics Systems in High Energy Physics: | Attended, and Passed the Exam |
| 5. Programmable System on Chip (SoC): | Attended, and Passed the Exam |
| 6. Microelectronics of Radiation Detector II: | Attended, and Passed the Exam |
| 7. Photodetection Scintillators and Silicon Photomultipliers: | Attended |
| 8. Italian language course - intensive and communicative: | Ongoing |
| 9. Cyber Security – Basic: | Attended, and Passed the Exam |
| 10. Chemical Safety Course: | Attended, and Passed the Exam |

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

1. TECH-FPA PhD Retreat 2025, L'aquila
2. Authentic Impact Workshop by B.V. Bakel on Team Development

- **List of published papers/proceedings:**

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- **Thesis title (even temporary):**

Advanced Detection Systems for Medical Devices in Radiotherapy and Hadron Therapy

Date, 09/09/2025

Signature...

Seen, the supervisor