

Novel, flexible, and air-stable detectors with PbS Quantum Dots on PEN show high X-ray sensitivity and Imaging capabilities

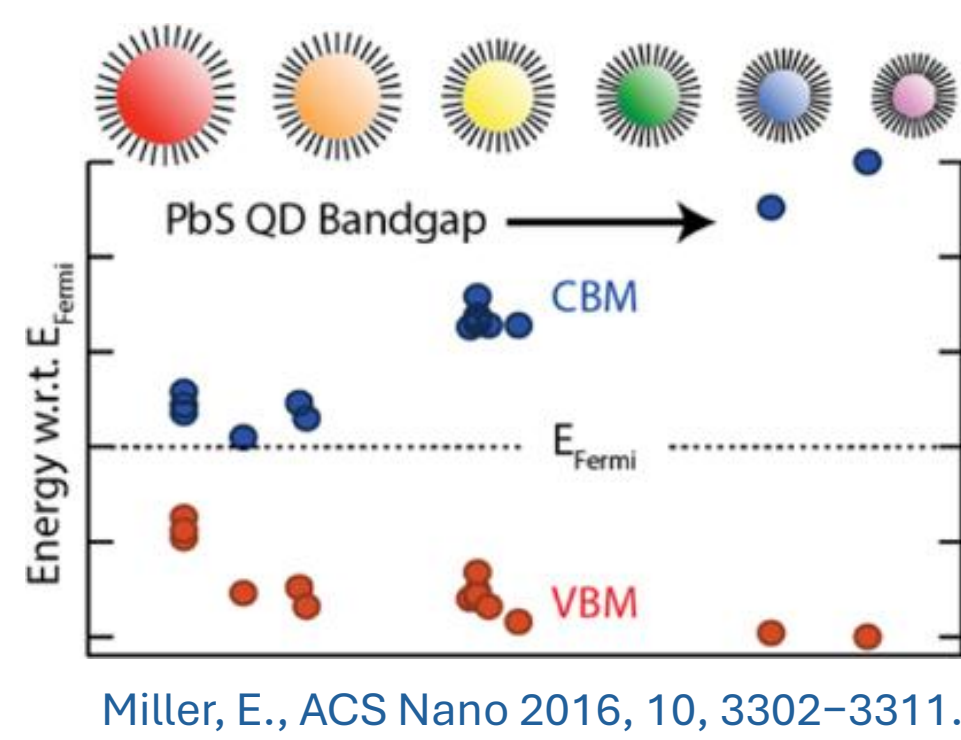
MUHAMMAD WAQAS

PhD for National Interest in Technologies for Fundamental Research in Physics And Astrophysics (40th Cycle)

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Colloidal Quantum Dots

- Quantum dots (QD): Semiconducting nanoparticles (2 – 20 nm)
- Colloidal QDs: New materials for the Radiation Detection
- Optoelectronic properties are size-dependent
- QD-based detectors offer key advantages, including the use of high-Z materials, spectral tunability, and solution processability.

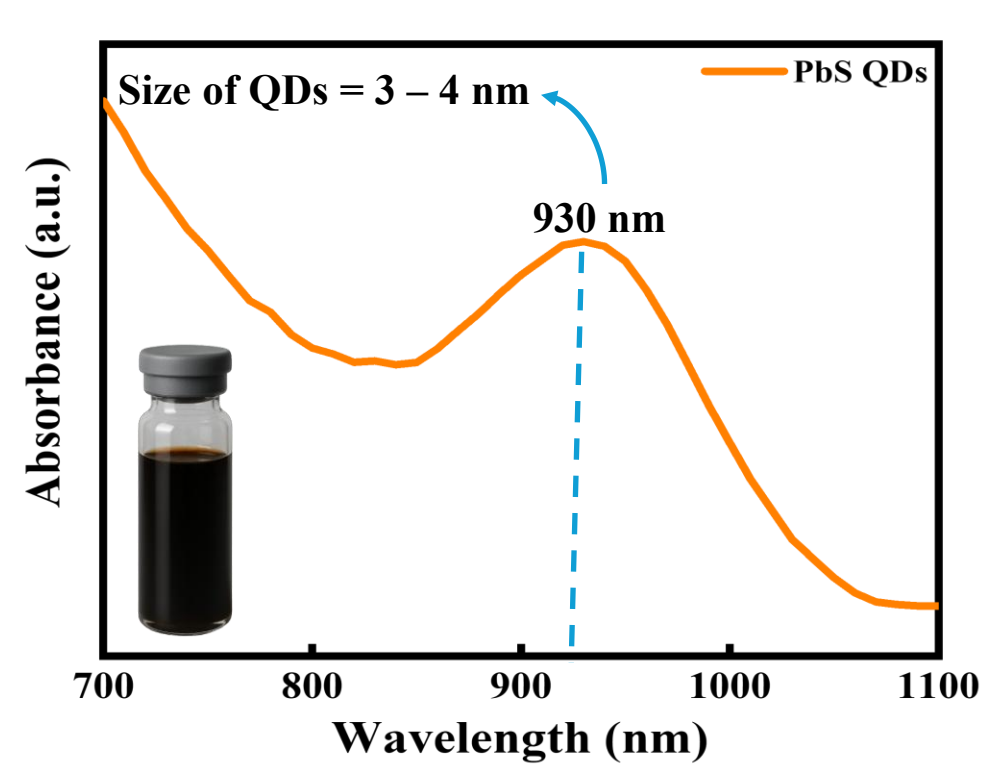


Aim of this work

Fabrication of PbS QD-based photodetector on PEN substrate

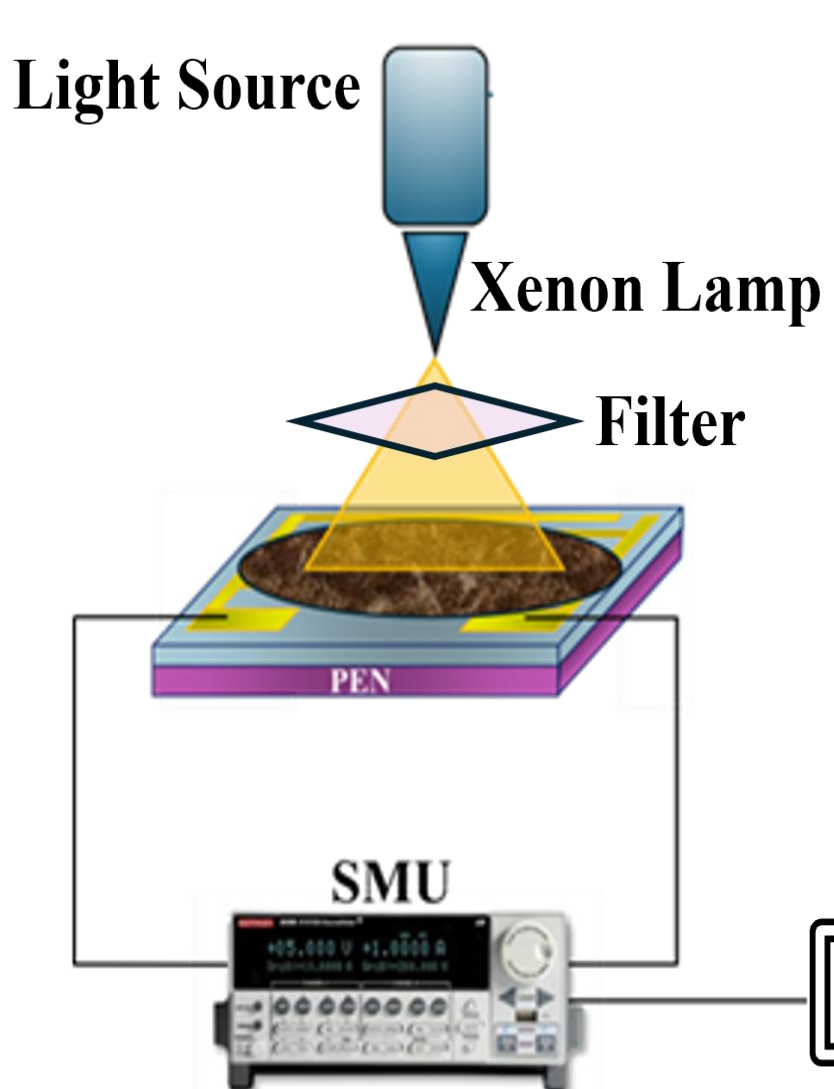
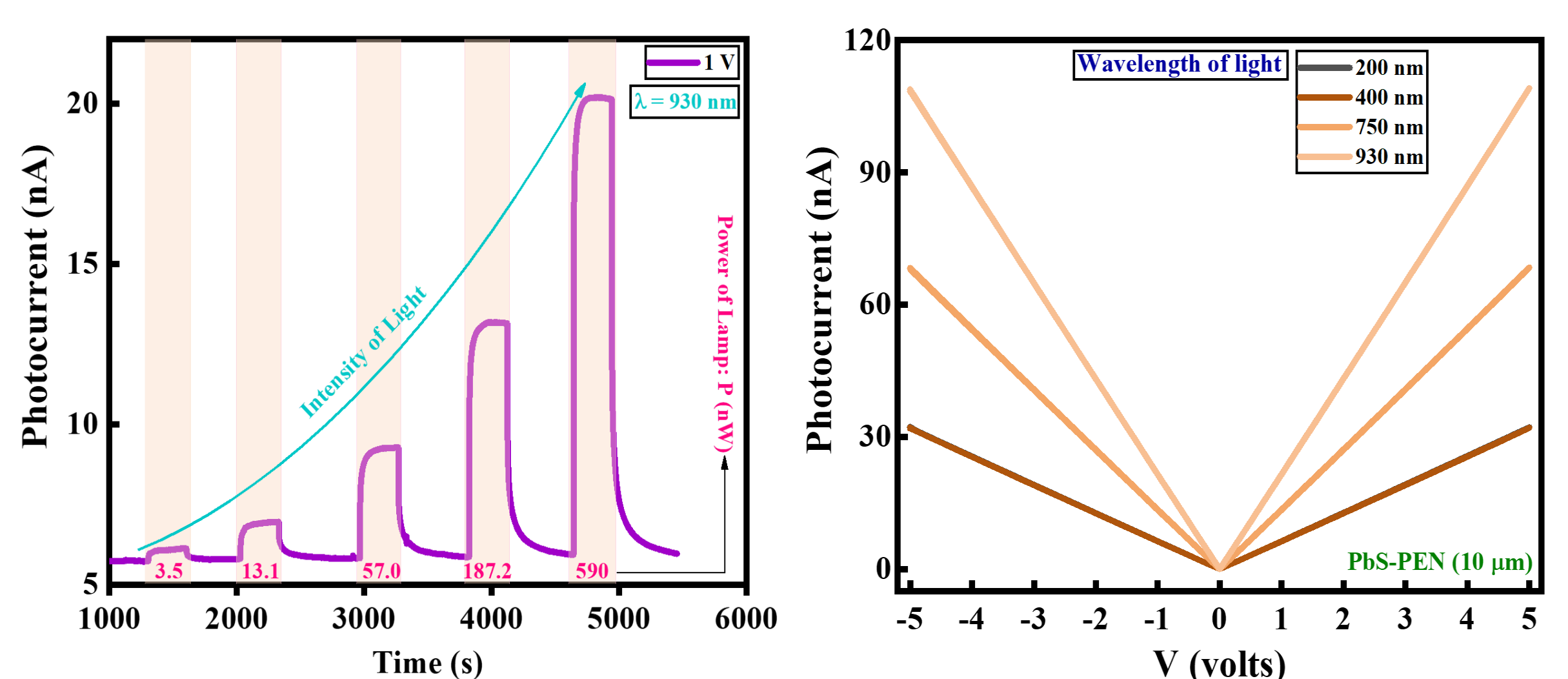
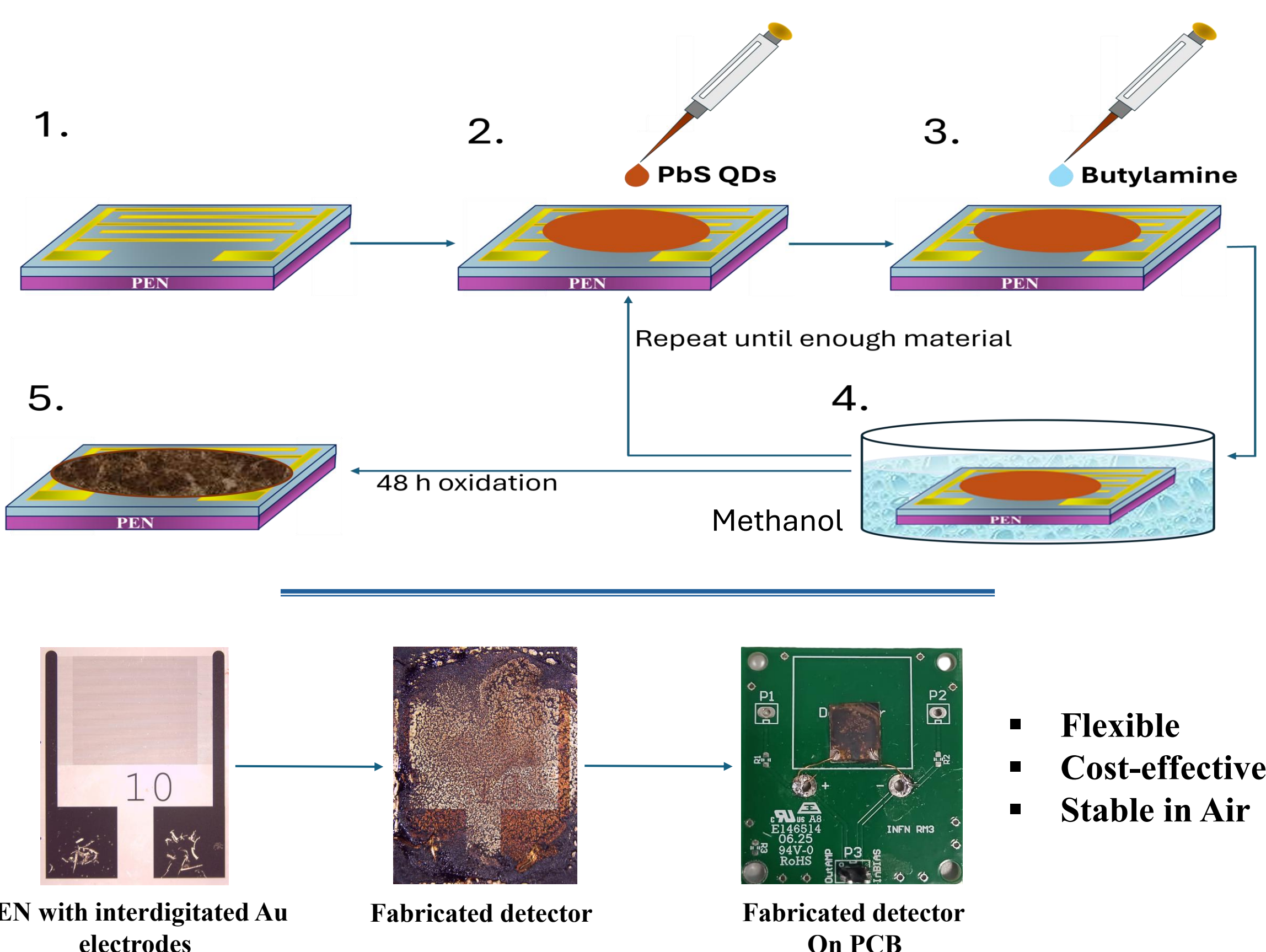
Photodetection of X-ray Radiation and Imaging

Preliminary test for Proton detection capabilities



- Synthesis of PbS QDs by **Hot-Injection**
- Ligand exchange enhances conductivity
- Device fabricated by **Drop-Casting**

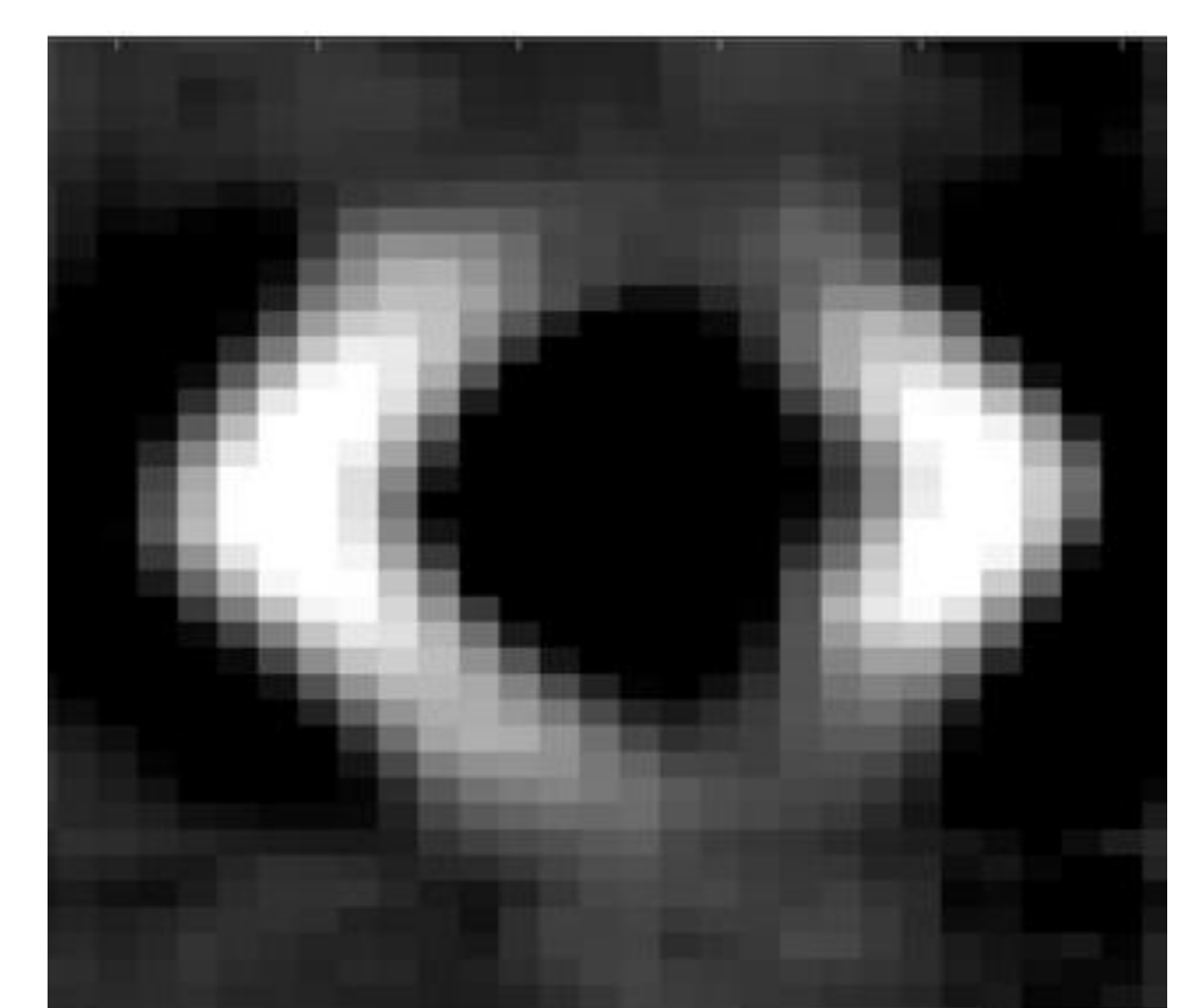
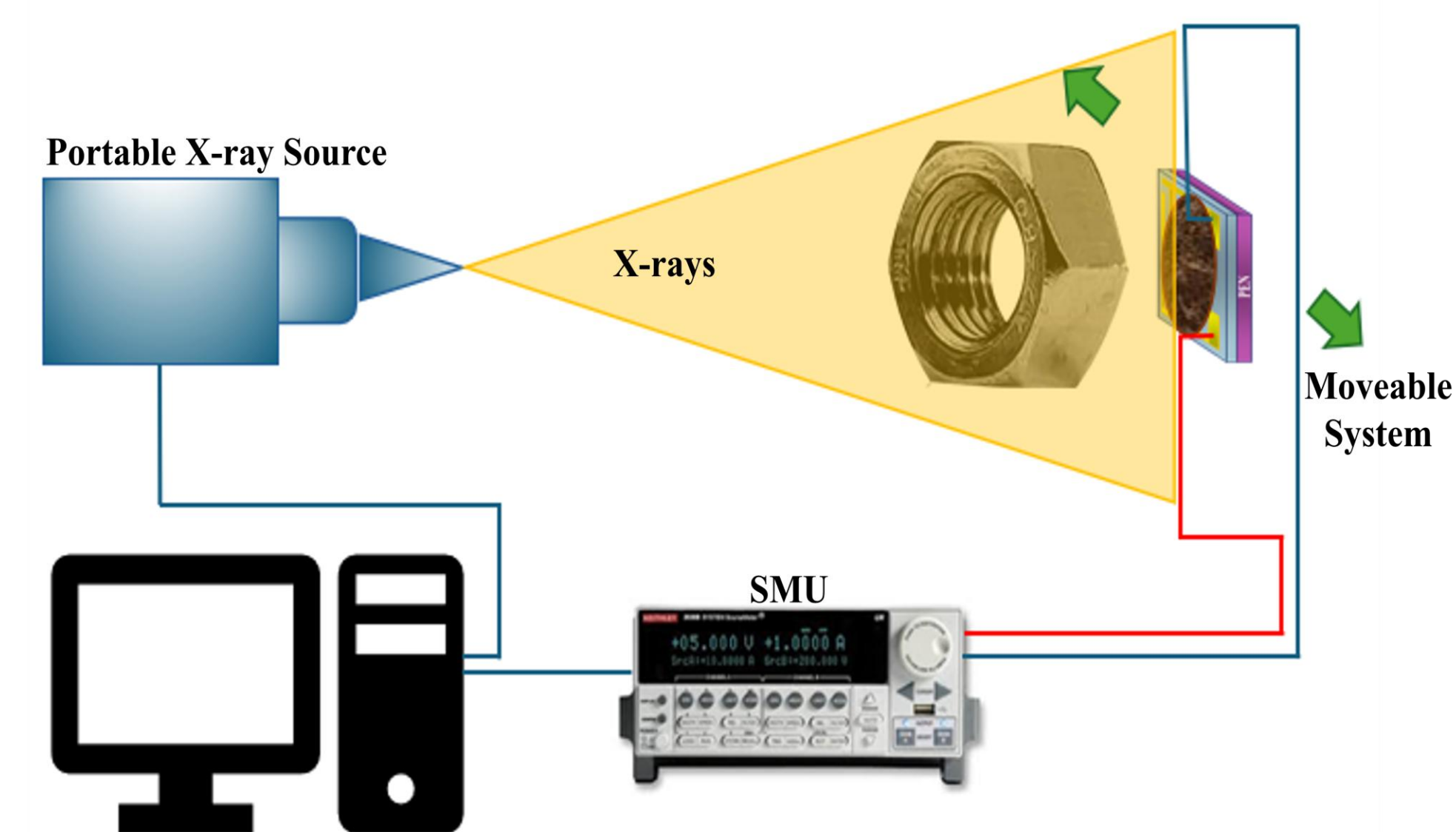
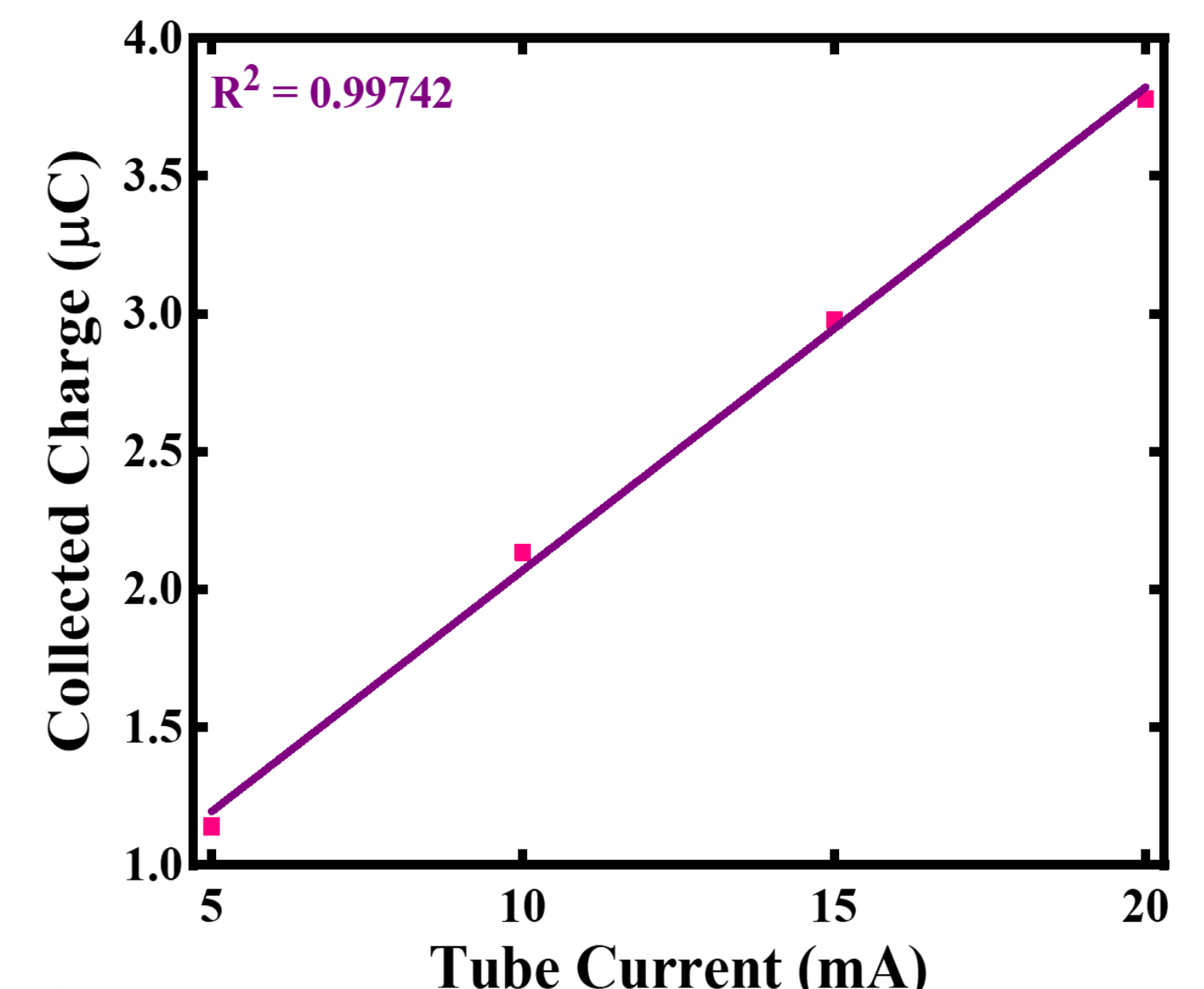
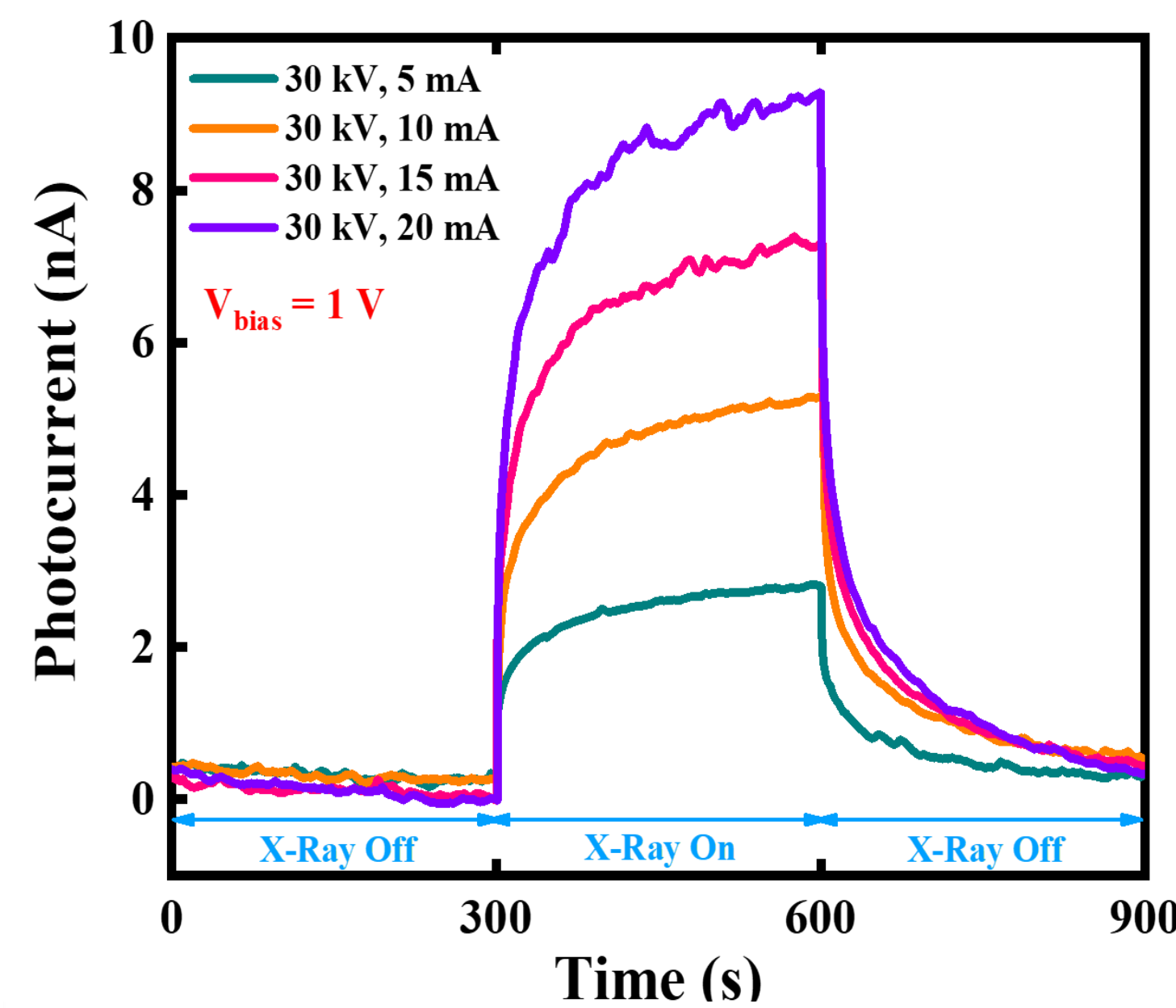
Detector Fabrication



- Photoconductive behaviour
- Typical dark resistance $\approx 1 - 10 \text{ M}\Omega$
- Bias voltage = 1 V (Low-power device)
- Benchmark using optical response
- Better optical response leads to Better X-ray response**
- Observed zero-biased response – Still under investigation!

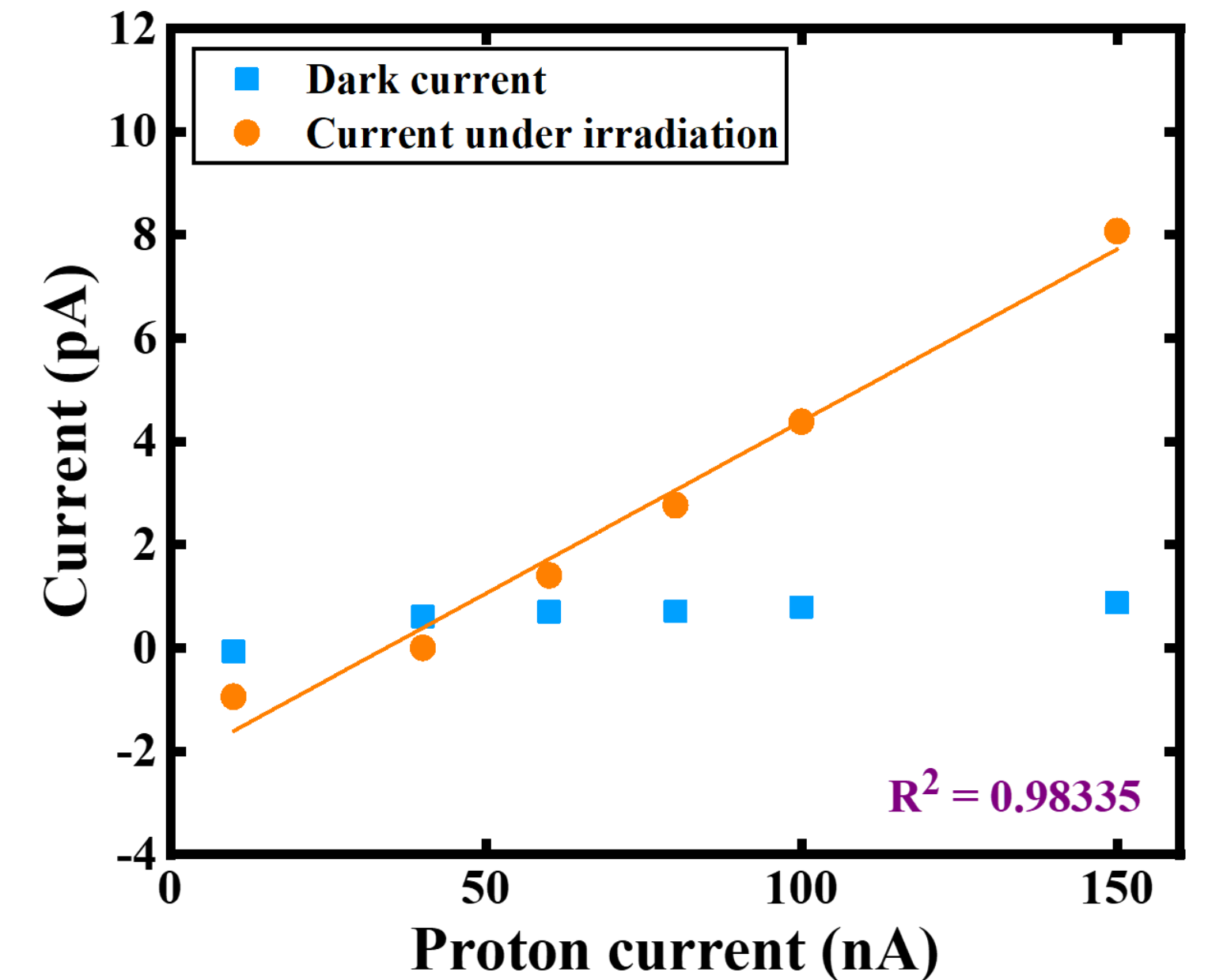
X-ray Response and Imaging Capability

- Operates at low power (Bias = 1 V) under X-ray irradiation (Co anode: $K_\alpha = 6.93 \text{ keV}$)
- Long** rise and fall times
- Linear correlation** between collected charge and source current
- Imaging capability** under X-ray irradiation (Mo anode tube: $K_\alpha = 17.45 \text{ keV}$) at 5 V bias



Proton Beam Response

- Zero bias voltage**
- Current linearity** with proton current $> 40 \text{ nA}$
- No failure** of the PbS QD-based detector
- Irradiated with a **constant beam** of protons in TIFPA (Trento), Italy



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Fabrication of Detector on PEN substrate

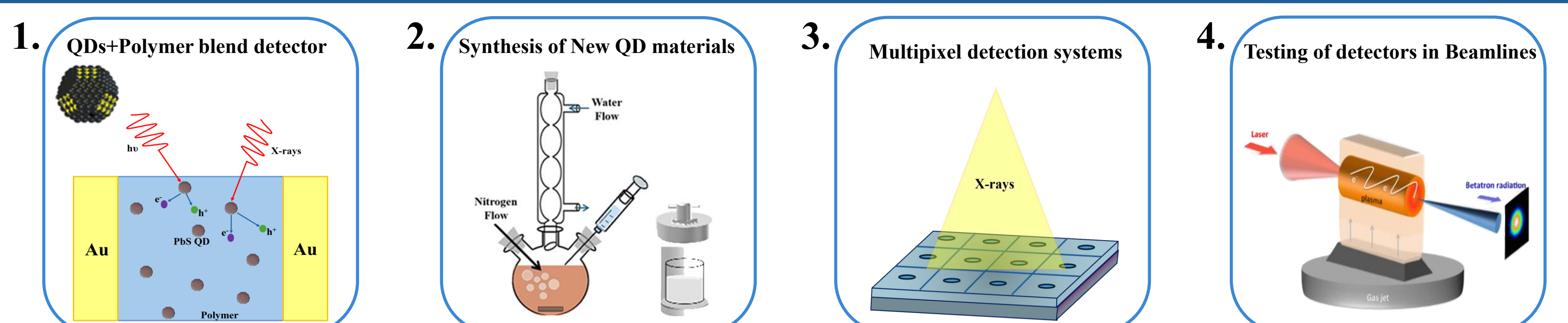
- Easy fabrication
- Stable in air
- Easy testing under optical illumination
- Zero bias response!**

Photodetection of X-ray Irradiation and Imaging

- Photoconductive behavior
- Low power (1 V)
- Charge vs current linearity
- Long rise and fall times**

Detector's response under a Proton Beam

- Positive response
- Current linearity with proton current
- Zero bias voltage
- No damage
- Need further experiments!**



- [1] Ruggieri, M.; Colantoni, E.; Marconi, E.; Fabbri, A.; Branchini, P.; Colace, L.; Tortora, L.; De Iacovo, A. Low-Voltage and Highly Sensitive PbS Quantum Dot Thin-Film X-Ray Monitors. ACS Appl. Electron. Mater. **2023**, 5 (10), 5642–5650. <https://doi.org/10.1021/acsaelm.3c00986>.
- [2] Ruggieri, M.; Mitri, F.; Fabbri, A.; Branchini, P.; Graziani, V.; Colace, L.; Tortora, L.; De Iacovo, A. Electrohydrodynamic Jet-Printed X-Ray Sensor Based on Iodide-Exchanged Lead(II) Sulfide Quantum Dots. ACS Appl. Electron. Mater. **2025**, 7 (12), 5549–5558. <https://doi.org/10.1021/acsaelm.5c00527>.