Instrumentation for Theory-Inspired Photocathode Development within the Large Area Picosecond Photo Detector (LAPPD) Project

Junqi Xie


LAPPD Collaboration

1Argonne National Laboratory, Argonne, IL
2University of Chicago, Chicago, IL
3Fermi National Accelerator Laboratory, Batavia, IL
Outline

➢ Motivation
➢ The Photocathode Building Blocks at ANL
➢ Instrumentation for Photocathode Development
➢ Optical Station
➢ PMT Growth Facility
➢ Growth and Characterization Chamber
➢ Summary
Motivation

- Thin planar large area photo detectors with good position and time resolution can be widely used in Cherenkov-counter particle identification readout, muon trigger systems, segmented calorimeters, medical imaging and time-of-flight systems.

- The production cost of the detection system would be dramatically reduced using large area MCP-PMT detectors compared to conventional small photo-tubes and bases.

- Many fundamental detector properties such as dark current, quantum efficiency, response time, and lifetime are determined by the properties of the cathode.

- Instrumentation is critical to study the film physical characteristics and the complex growth behavior for obtaining high quality photocathodes.
The Photocathode Building Blocks at ANL

- **Goal:** 8”x8” multi-alkali Photocathodes
- **Path to the goal:** Utilization of existing lab infrastructure, design and build new instruments
- **Resources:**
  - LAPPD collaboration (all partners)
  - Accelerator community
  - X-ray detector community (APS@ANL /NSLS@BNL)
Glove box
- Substrate preparation and contamination level test

Photocathode Growth / Characterization Chamber
- Basic science study for growth optimization
Photocathode Growth Instruments

PMT Fabrication facility for 4”X4” photocathode

Growth / Characterization Chamber

Prototype Facility for 8”X8” photodetector

- Industrial approach
Photocathode Characterization Instruments

Movable optical station

LED light source and fiber optics

X-ray, AFM Facility
- Visualization of growth and activation process (APS, BNL)
Optical Station

- Optical spectroscopy (UV-VIS) (200nm-1600nm)
  - Transmission and reflection
  - Angle dependence (with Goniometer)
- Electrical characterization
  - I-V curve, QE
  - Dark current (minimum detectable I: 10^{-16} A)
  - Photo-conductivity
- Movable to be shared with in-situ measurement
PMT Fabrication Equipment

- Pathway to make photocathodes which can be incorporated into a working detector

- PMT fabrication equipment
  - Exact recipe test
  - Engineering issues of evaporators

High Temperature
Fiber optics

LEDs are used as light source and introduced into the oven to monitor the in-situ QE
The I-V curve and QE of three PMT cathodes grown using fabrication facility were measured using the optical station
The Growth and Characterization Chamber

- Pathway to develop photocathode

- Modifications of recipe
  - Cleaning procedure (ion/atomic source)
  - Base pressure influence on growth and functionality
  - Evaporation versus sputter
  - Sequential versus co-evaporation

- Influence of inter layer
  - Electronic properties
  - Frequency response
  - Optical properties
Growth / Characterization chamber under construction

- Compact and Efficient
  - Heating, Quenching
  - Activation
    - Compatible for various types of activation materials (Cs, O, K, Sb etc.)
  - In-situ characterization
    - Optical characterization
    - Electrical characterization
- Can Host Variety of Samples
  - Type - III-V or Alkali
- Designed to transfer samples to other modules under vacuum
In-situ Characterization Chamber

- Pathway to develop photocathode

Various characterizations can be integrated to study the influence of different parameters and optimize growth recipe:

- Fiber optic integrated: laser
- Optical characterization:
  - Transmittance, Reflectance, Absorbance
    - Function of wavelength
- Electrical characterization:
  - Quantum Efficiency QE (\(\lambda\))
  - Dark Current D(T)
  - Photo-conductivity
  - Temperature dependent I-V curves
  - Lateral and transversal conductivity

Sample centered in chamber
Temperature Range: 4K – 1050K
Rotatable \(r \& q\)
Summary

- A working laboratory for the development of cost-effective large area photocathodes at Argonne National Laboratory is being designed and commissioned.
- The instrumentation allows the study of optical properties, electrical behavior (I/V-curves, photoconductivity), and spectral response of the cathode (quantum efficiency).
- The system is part of a network using various DOE user facilities allowing in-situ experiments to determine the microscopic and chemical structure of the cathode.
- Long term goals:
  - Establishing a photocathode center (collaboration with other labs)
    - Provide access to state-of-the-art basic sciences tools
    - Foster collaborations inside the community
    - Bridge the gap between basic sciences and industry
Thanks for your attention!