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

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LAPPD Collaboration

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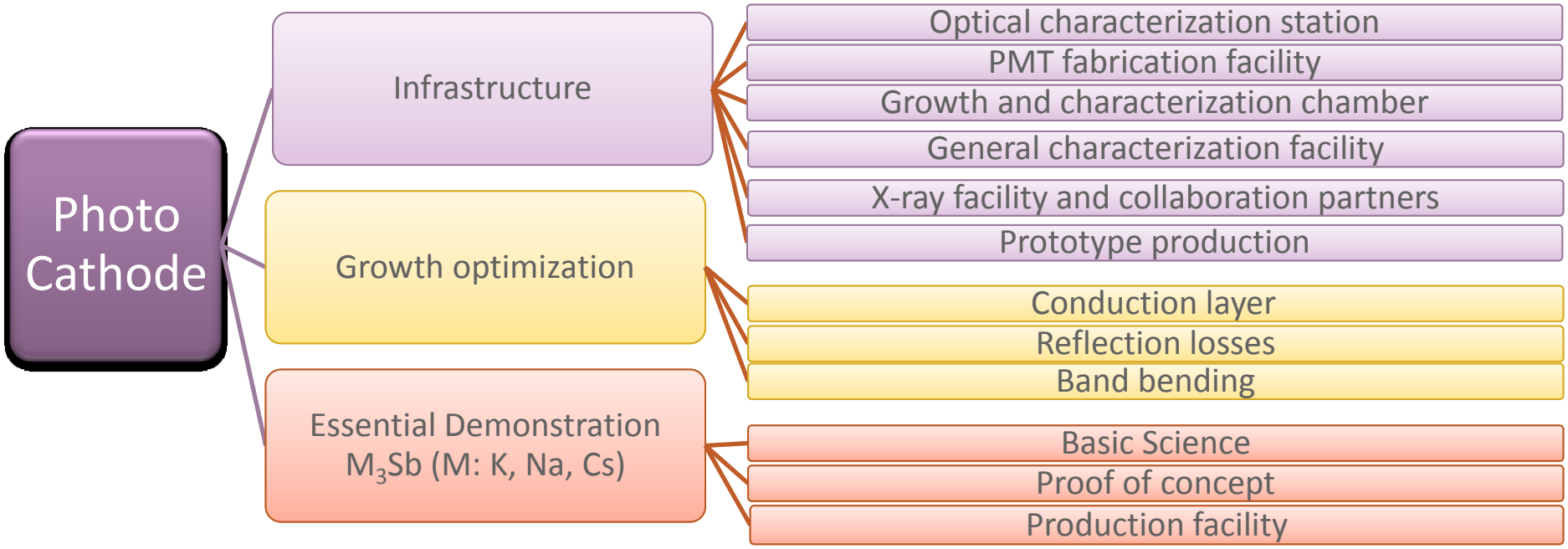
Outline

- 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.

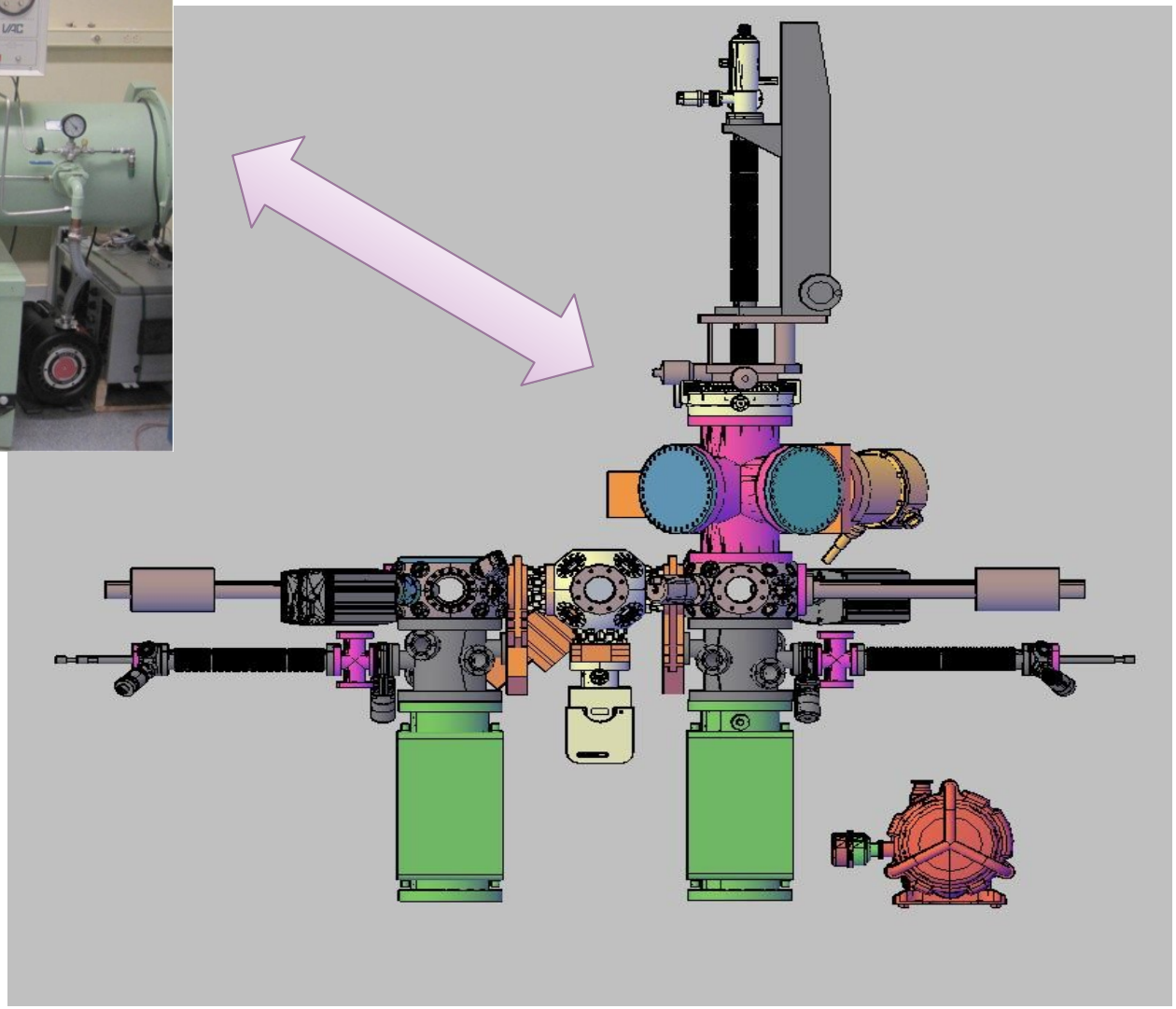
The Photocathode Building Blocks at ANL



- 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)

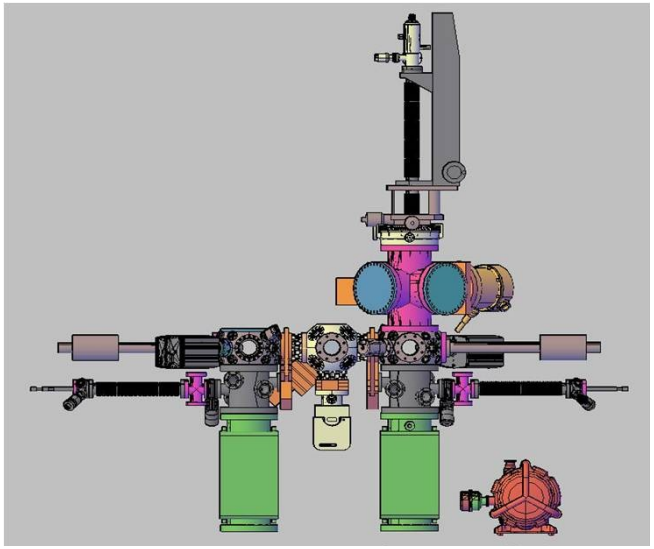
Photocathode Development Instruments

Glove box
-Substrate preparation and contamination level test



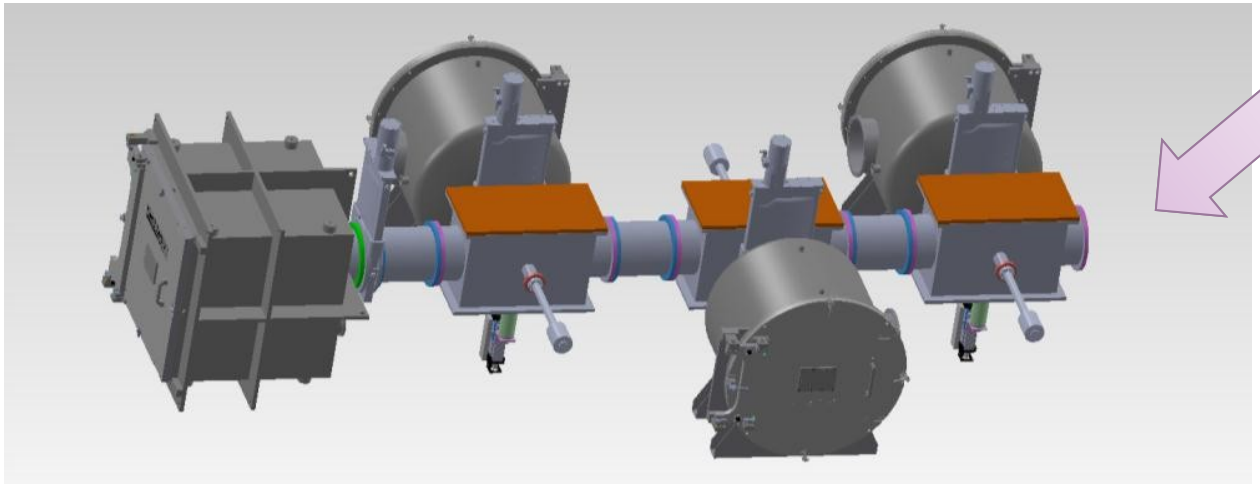
Photocathode Growth / Characterization Chamber
– Basic science study for growth optimization

Photocathode Growth Instruments



Growth / Characterization Chamber

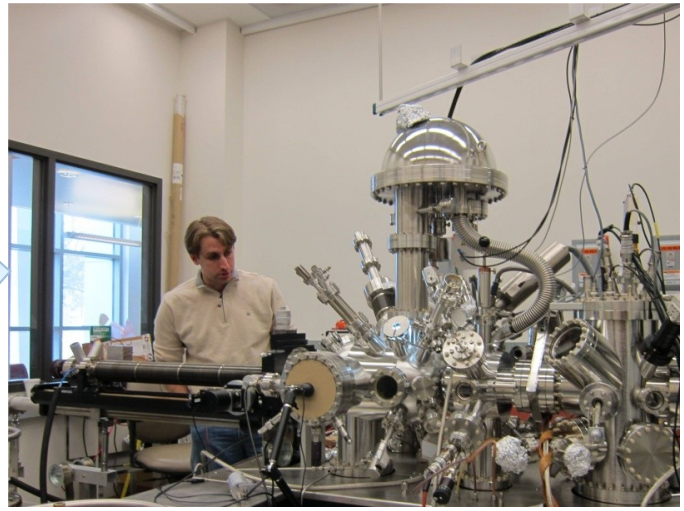
PMT Fabrication facility
for 4’’X4’’ photocathode



Prototype Facility for 8’’X8’’ photodetector
- Industrial approach

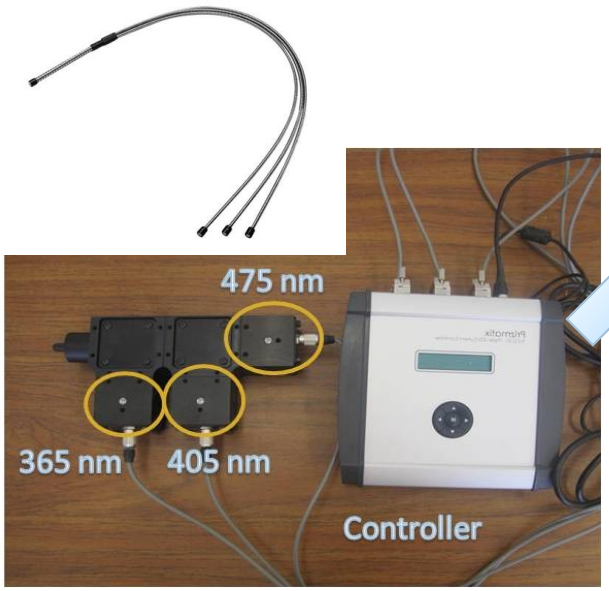
Photocathode Characterization Instruments

Movable optical station

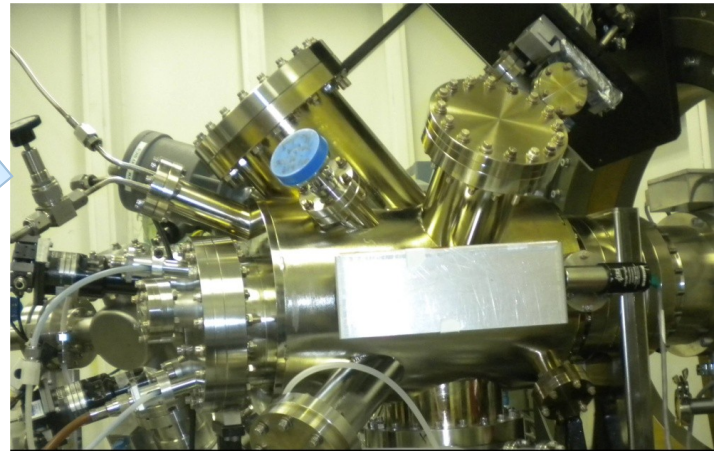


X-ray, AFM Facility
- Visualization of growth and activation process (APS, BNL)

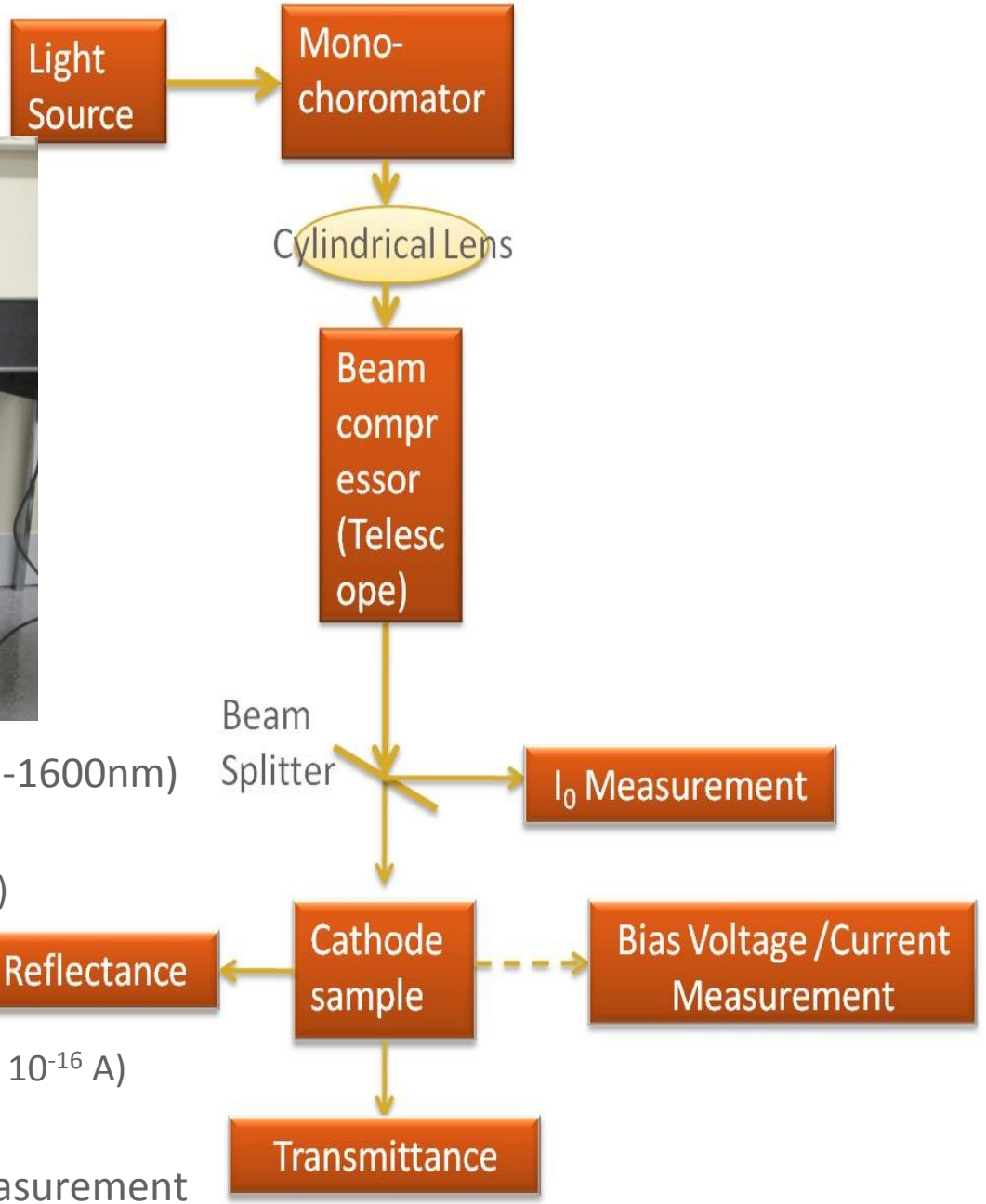
Photocathode Characterization



LED light source and fiber optics



Optical Station



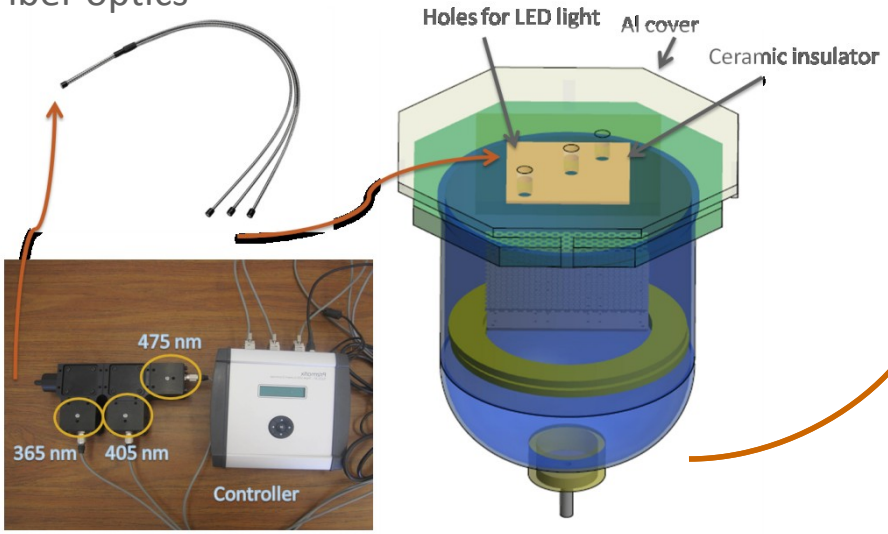
- Optical spectroscopy (UV-VIS) (200nm-1600nm)
  - Transmission and reflection
  - Angle dependence (with Goniometer)
- Electrical characterization
  - I-V curve, QE
  - Dark current (minimum detectable I: 10^{-16} A)
  - Photo-conductivity
- Movable to be shared with in-situ measurement

PMT Fabrication Equipment

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

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

High Temperature
Fiber optics

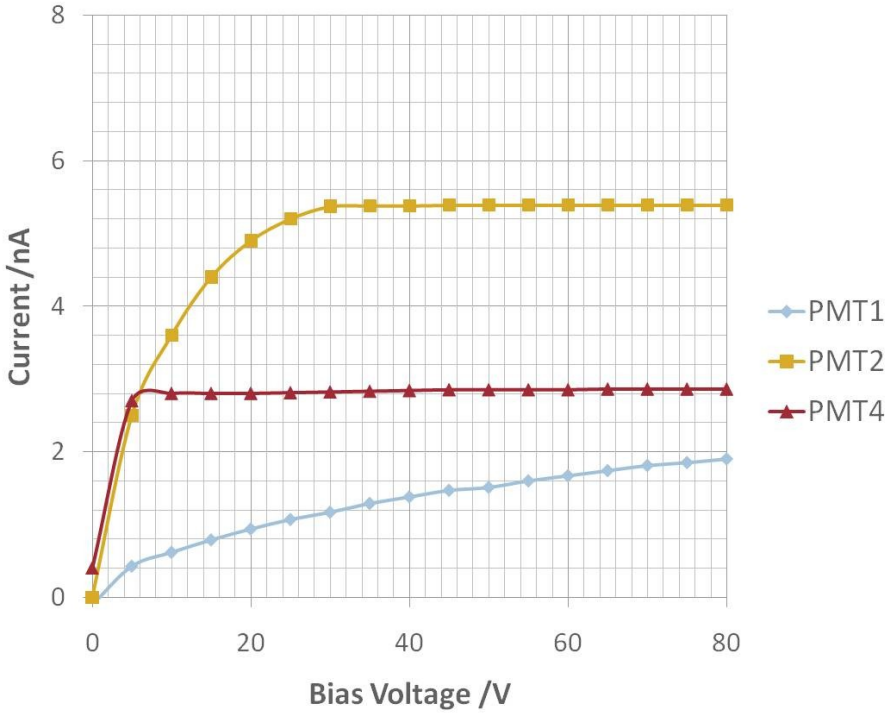


LEDs are used as light source and introduced into the oven to monitor the in-situ QE

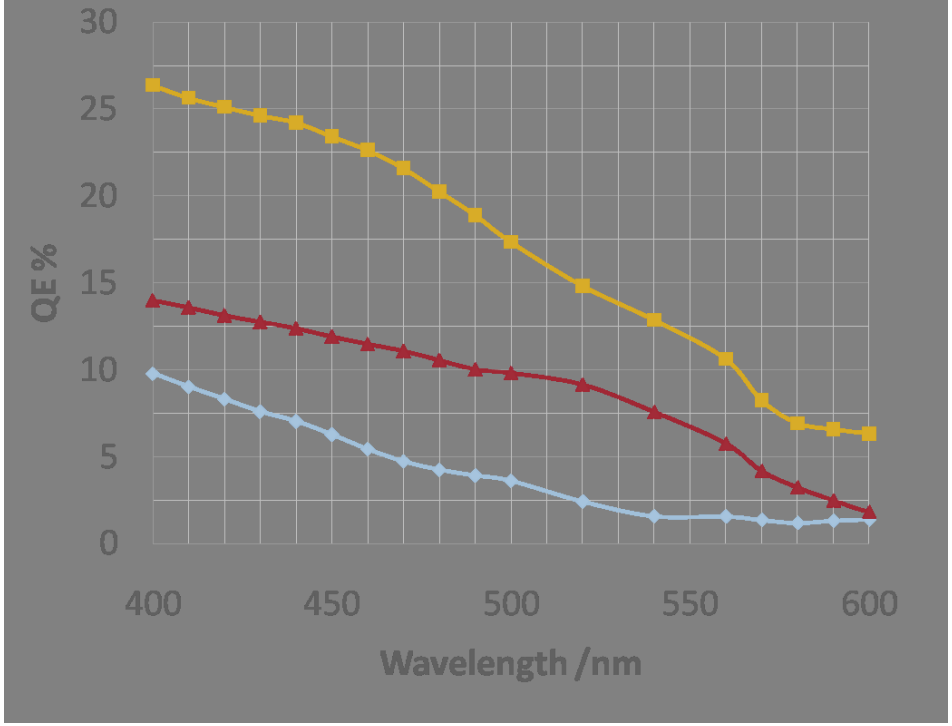
I-V Curve and QE of PMT Cathodes

Small PMT

I-V curve of three cathodes



QE of three cathodes

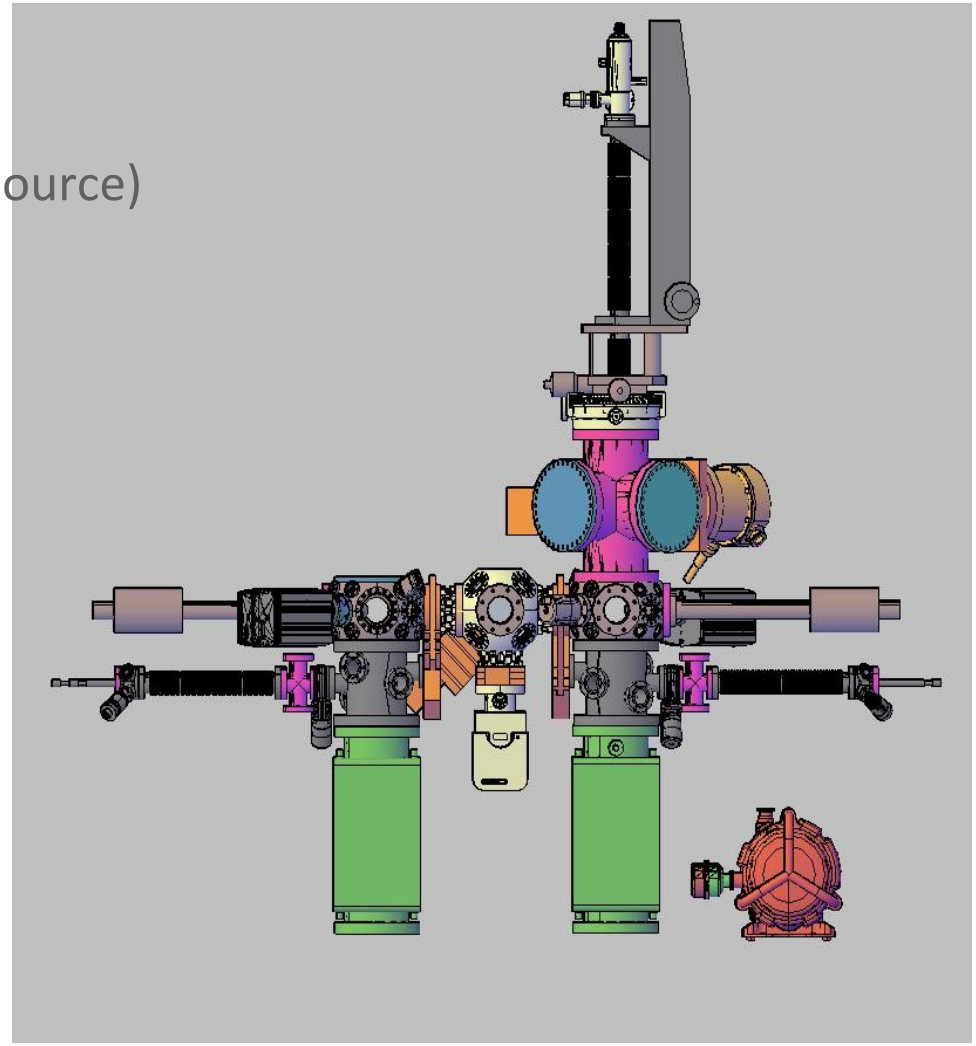


The I-V curve and QE of three PMT cathodes grown using fabrication facility were measured using the optical station

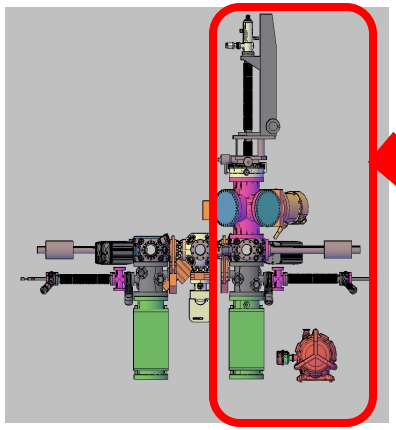
The Growth and Characterization Chamber

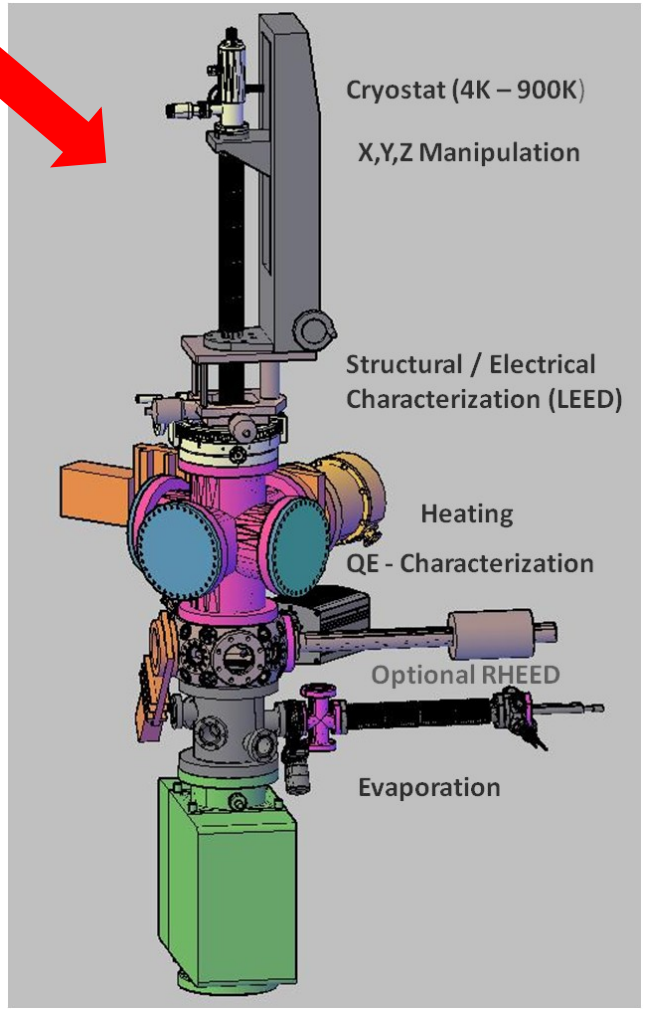
- Pathway to develop photocathode

- 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

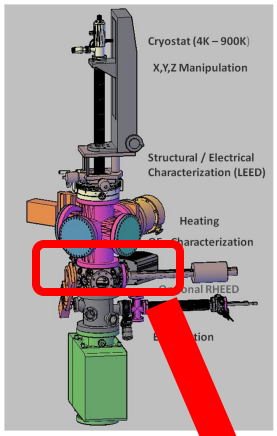




- Compact and Efficient
  - Heating, Quenching
  - Activation
    - Compatible for various types of activation materials (Cs, O, K, Sb etc.)
  - In-situ characterization
    - Optical characterization
    - Electrical characterization
- Can Host Variety of Samples
  - Type - III-V or Alkali
- Designed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

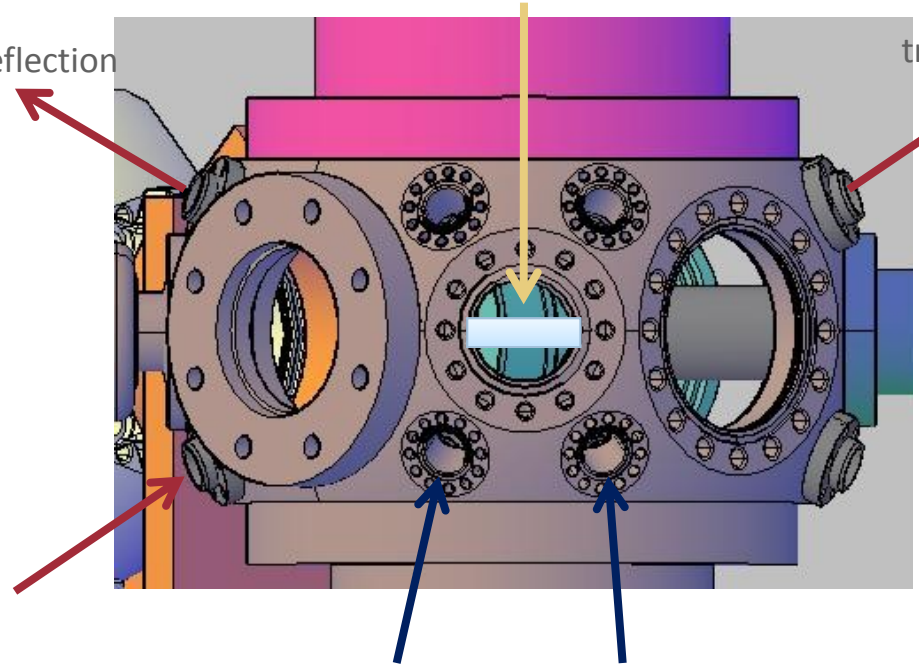
In-situ Characterization Chamber

- Pathway to develop photocathode



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

Sample centered in chamber
Temperature Range: 4K – 1050K
Rotatable f & q



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

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!