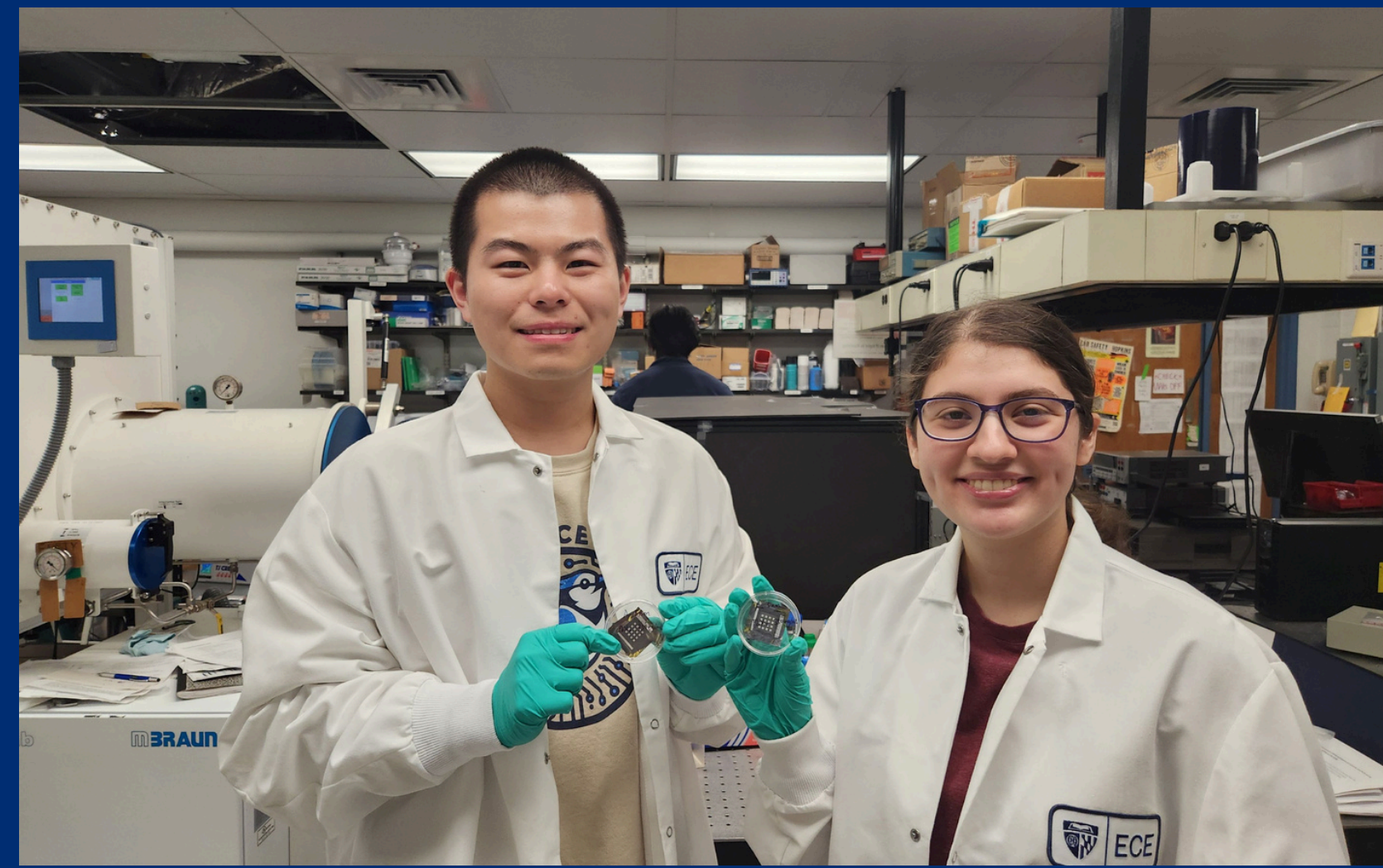


# Mobility Anisotropy in Optoelectronic PbS Colloidal Quantum Dot Films

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## The Challenge with Measuring Charge Transport

Modern technologies like solar panels and LEDs rely on materials that can efficiently move electrical charge. Lead sulfide (PbS) colloidal quantum dots (CQDs) are promising materials for these optoelectronic devices. Their performance depends on how efficiently electrical charges move through the film. Most existing measurements of charge transport in quantum dot films are performed laterally, but many real-world devices operate vertically. This mismatch raises a critical question: do standard measurements outcomes reflect real device behavior?

## Objectives

*How might we accurately measure charge transport in the direction that matters for real devices?*

- Standard lateral measurements may not reflect vertical transport in real devices using CQDs, such as solar cells.
- We set out to directly compare in-plane and out-of-plane charge carrier mobility in PbS CQD films using two complementary field effect transistor architectures.

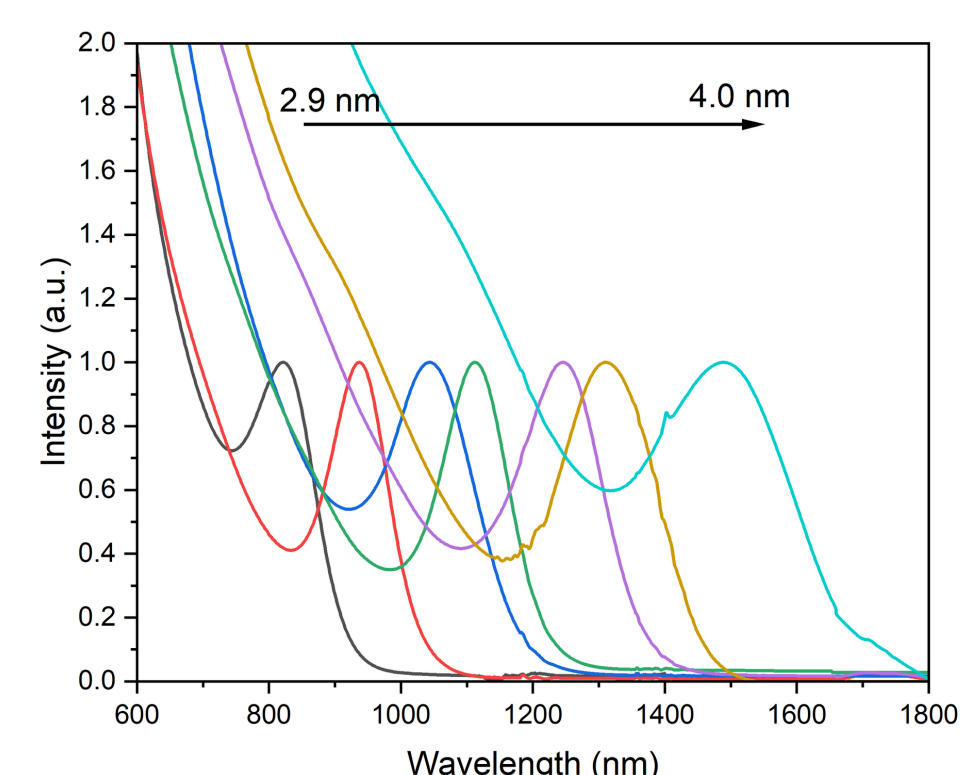
## Materials and Methods

We employed two transistor architectures:

- Lateral Field Effect Transistor (LFET): An established bottom-gate, bottom-contact design where current flows horizontally across the film. Serves as a baseline.
- Vertical Field Effect Transistor (VFET): A novel stacked architecture where current flows vertically through the film, mimicking real device operation.

Measurement Setup

- Devices were characterized using a custom-built illuminated I-V measurement system, combining a solar simulator (AM1.5G) with two source-measure units, allowing us to capture electrical behavior.



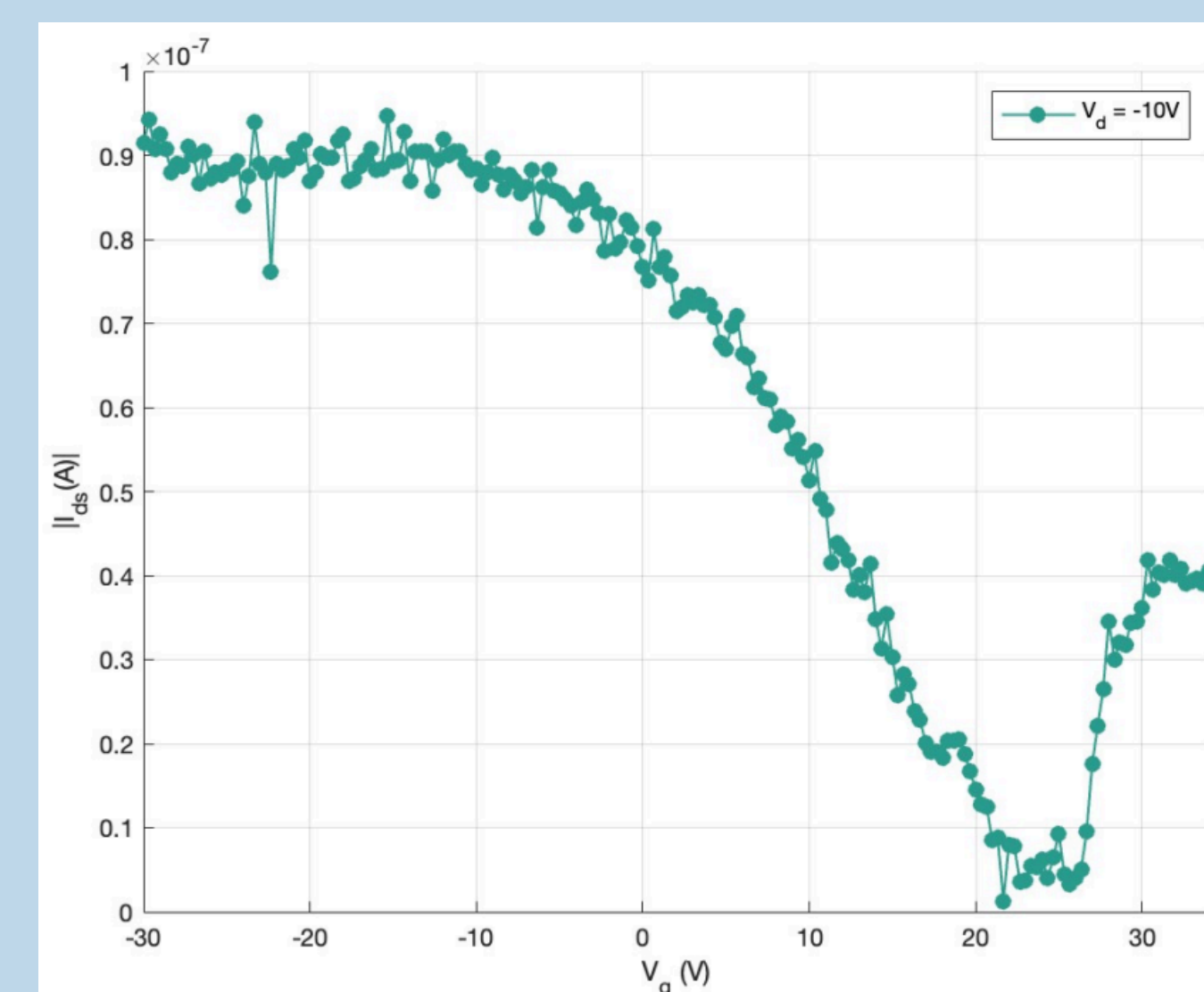
UV-Vis spectroscopy measurements of the quantum dots synthesized in the NanoEnergy lab.

## 1 Establishing the Baseline: LFET Behavior

Our LFET devices demonstrated clear, expected p-type transistor behavior in CQD films:

- Transfer characteristics show a well-defined turn-off, confirming gate control over the channel.
- Output characteristics show current increasing systematically with drain voltage across multiple gate voltages.

This establishes a clean lateral mobility reference our vertical devices can be compared against.



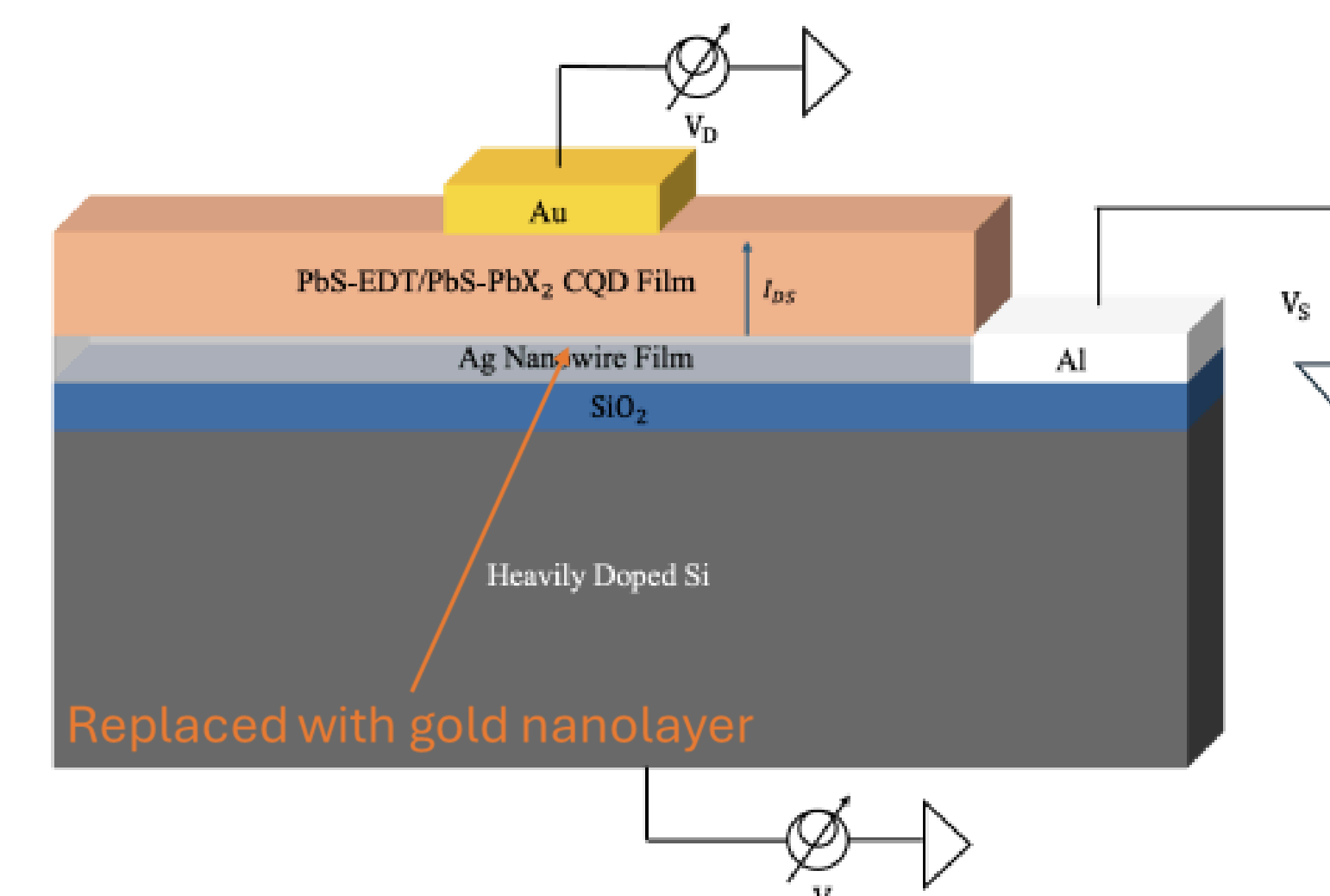
Transfer characteristic curve of the LFET device

## 2 First Steps Toward Vertical Transport Measurement

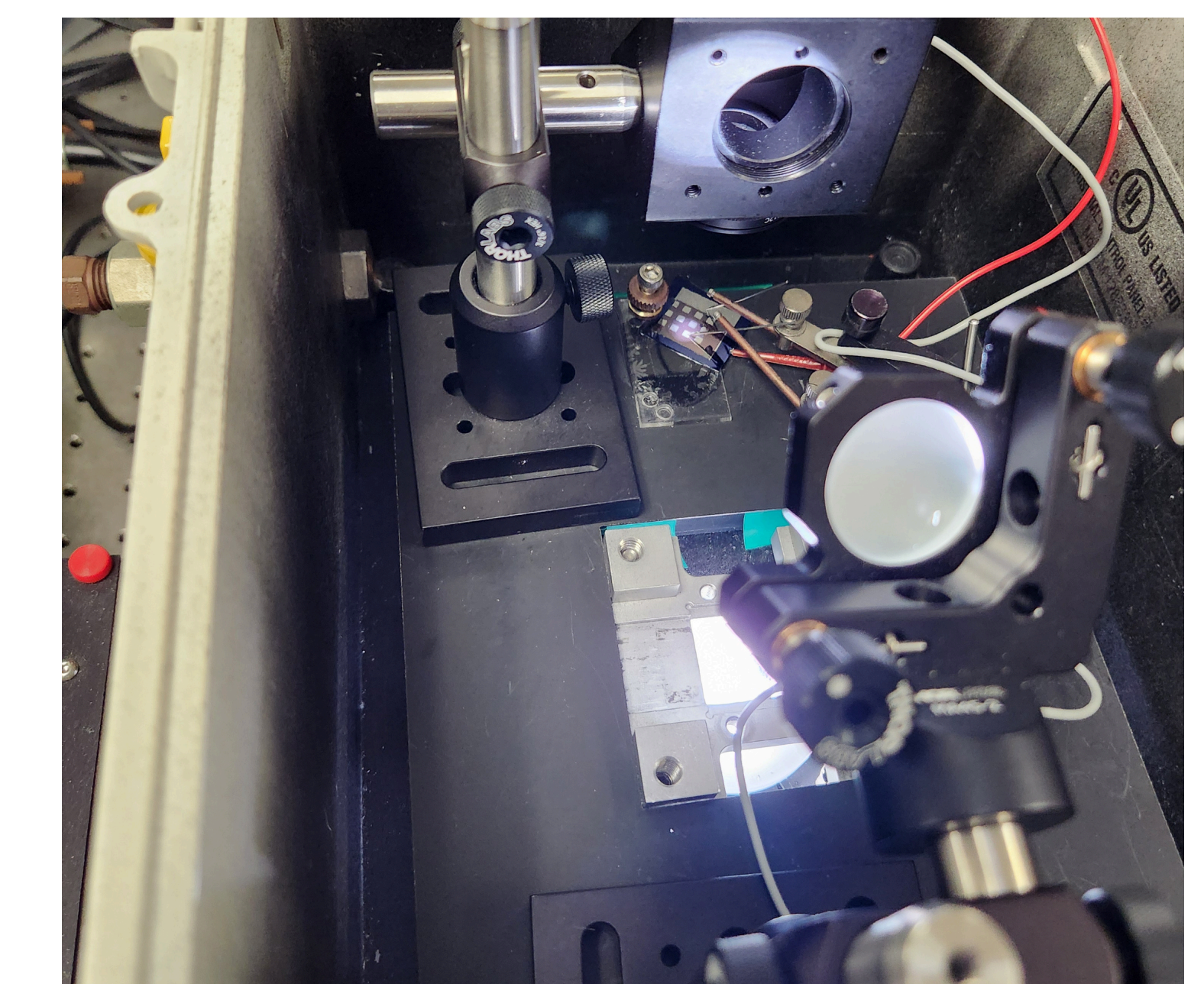
Our VFET devices show early evidence of transistor behavior in CQD films:

- Transfer characteristics show a current minimum consistent with gate-controlled switching.
- Output characteristics reveal breakdown, saturation, and ohmic regions, suggesting vertical charge transport through the channel.

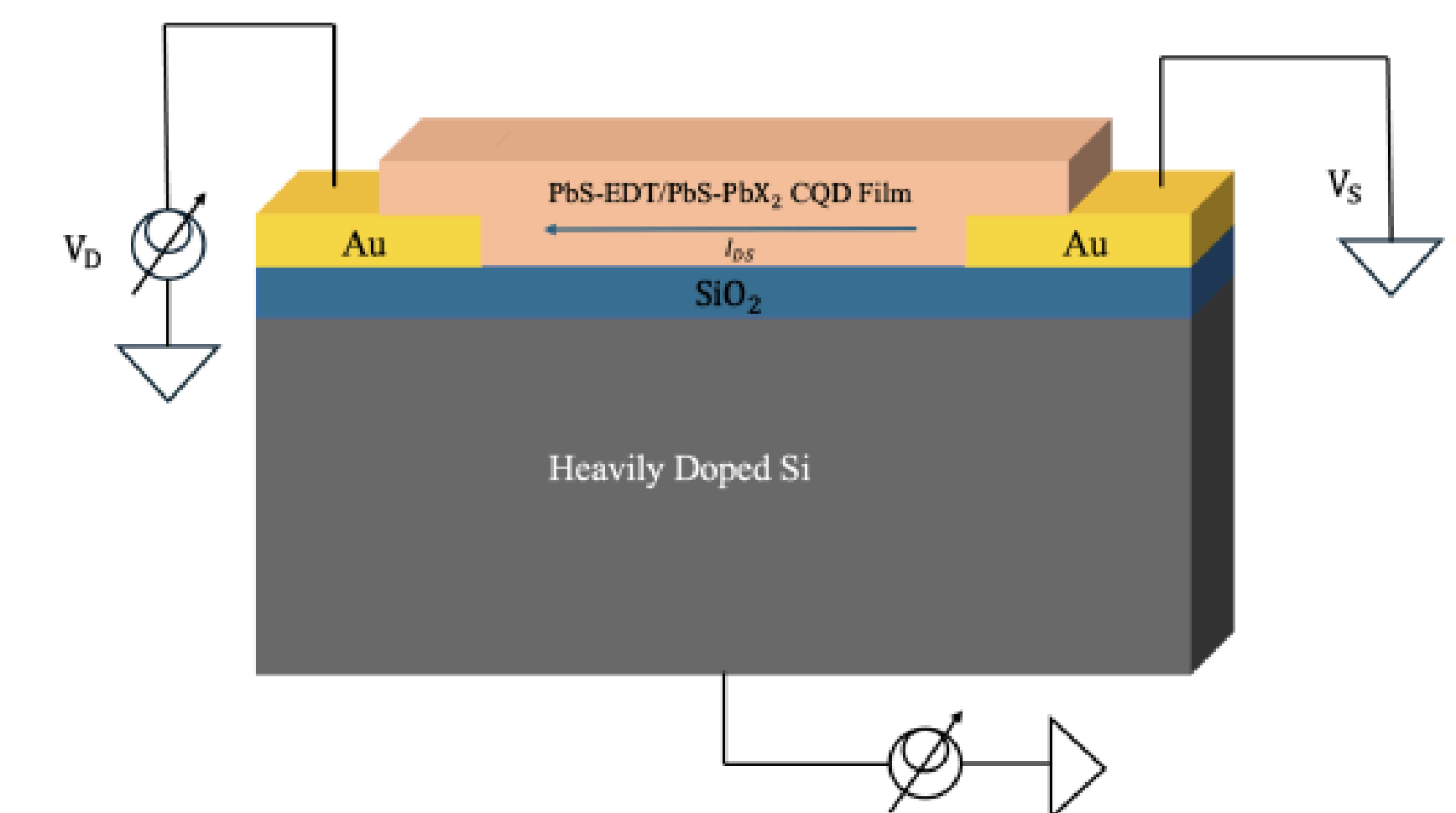
These preliminary results demonstrate a functioning vertical measurement platform.



Vertical architecture (VFET) device structure.



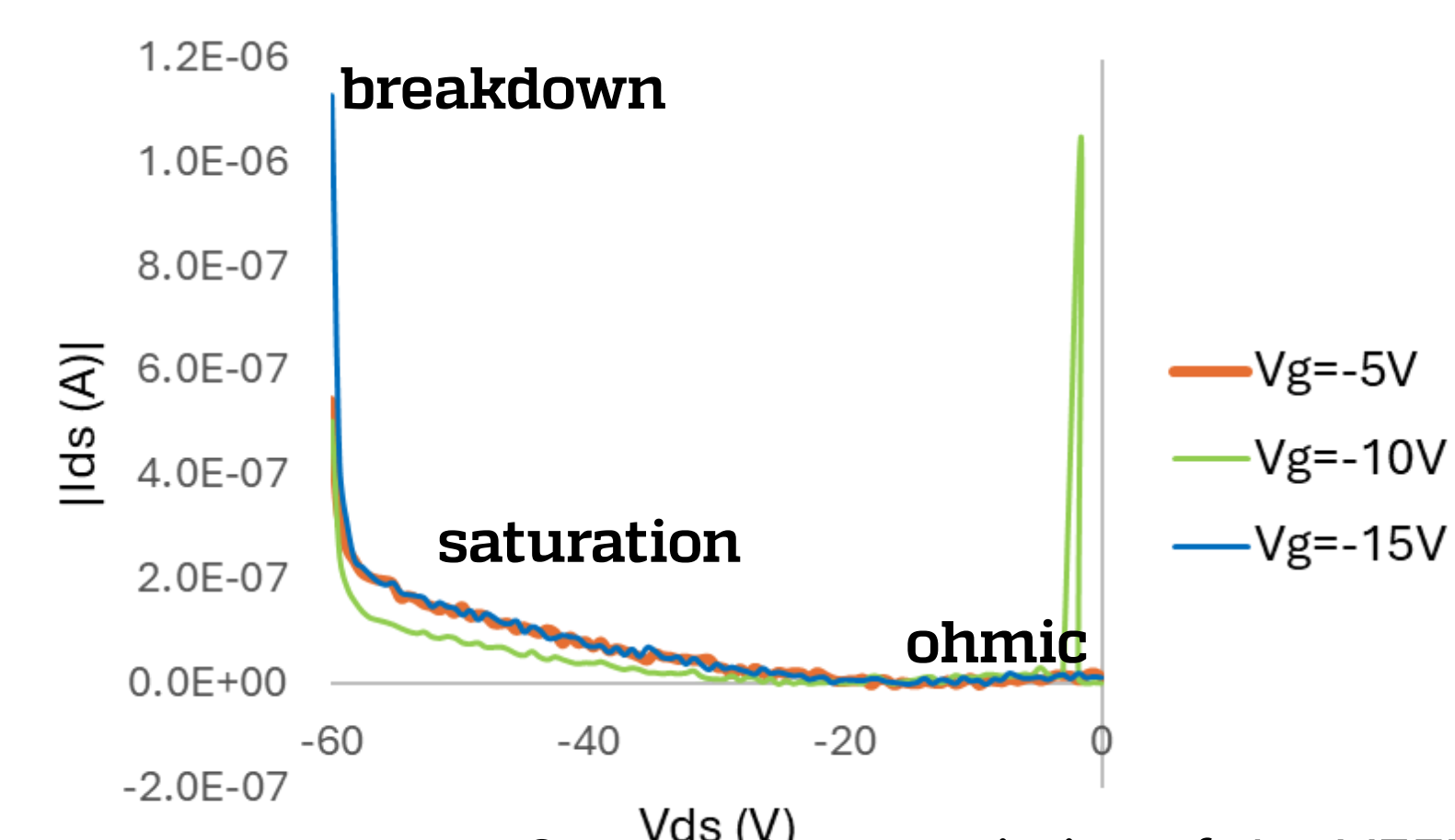
Illuminated I-V Measurement System



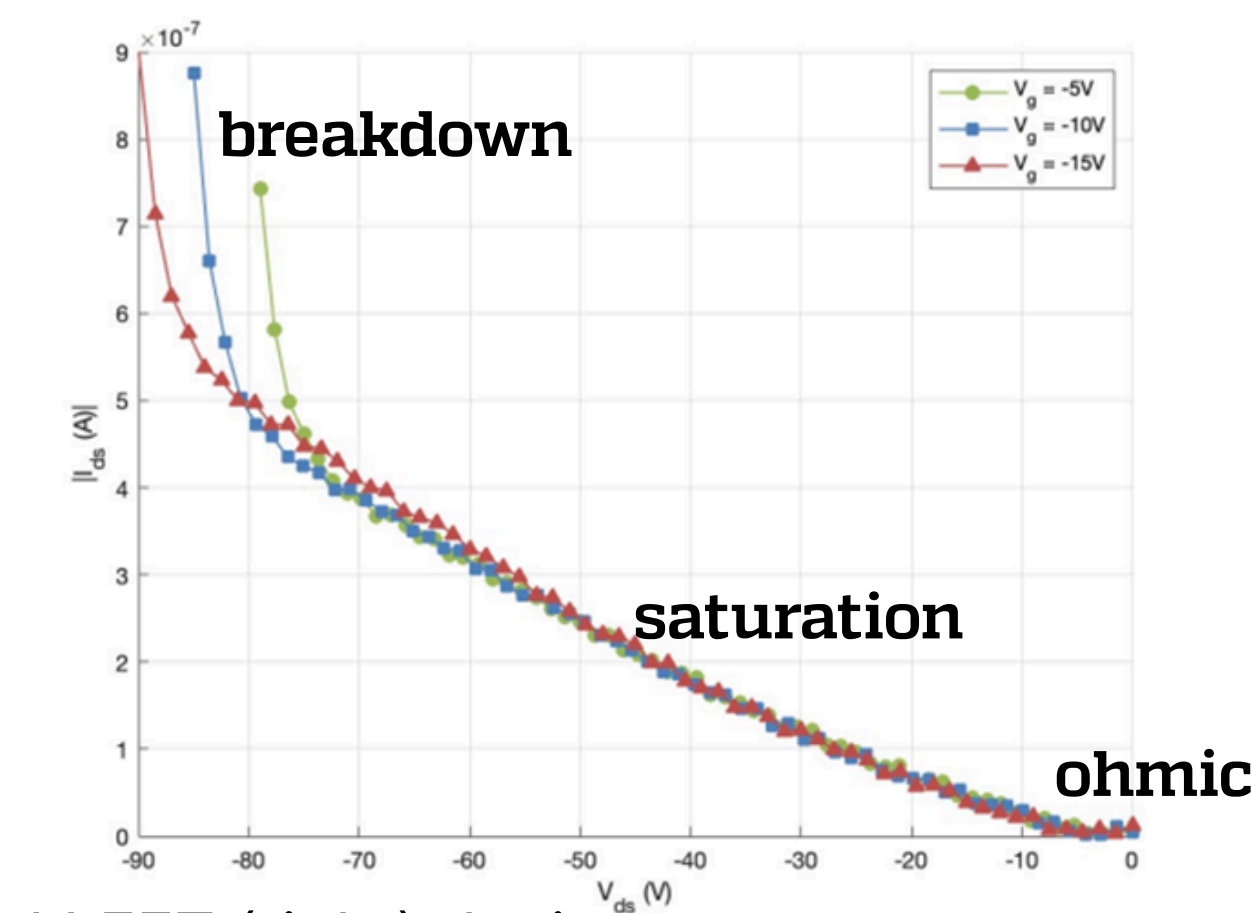
Lateral architecture (LFET) device structure.

## 3 Preliminary Results

Both devices show breakdown, saturation, and ohmic regions—confirming transistor behavior in both architectures. The VFET data shows irregularities when compared with the LFET data, indicating that refinement of the device structure is needed.



Output characteristics of the VFET (left) and LFET (right) devices.



## Future Steps

By fabricating and testing both lateral and vertical phototransistor architectures, we established a working VFET platform showing preliminary vertical transistor behavior for the first time in our fabrication process. Next Steps:

- Optimize CQD concentration and Au nanolayer thickness to improve device operation.
- Perform direct mobility comparison between lateral and vertical devices.
- Use results to inform more accurate simulations of real CQD device architectures.

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