# Remote Investigation of the Photoconductivity and Degradation Behavior of Methylammonium Lead Iodide Perovskite Thin Films

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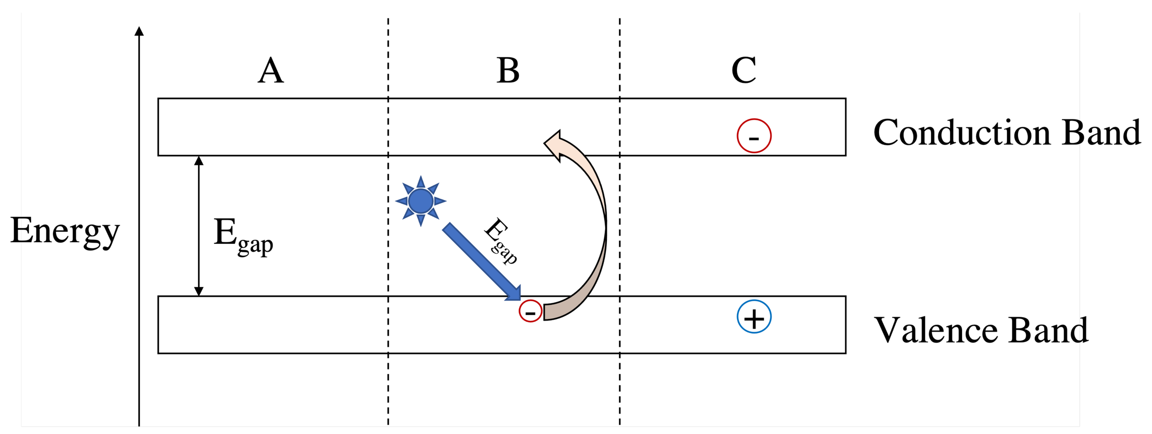
## Abstract

Methylammonium lead iodide ($MAPbI_3$) thin films are a promising alternative to conventional silicon for use in solar cells. While the photoconductivity of these materials has been well-studied, some details of their conductive behavior is not yet well-understood. Typically, photoconductivity is studied with the use of solar simulators. We make an extension to this approach by employing multiple narrow-band light emitting diode light sources and examine the intensity dependence in detail. During recent months of the pandemic, it was desirable to seek ways to acquire data remotely to the degree possible. A remote, automated approach allows for consistent data collection while also remaining within public health guidelines. In a preliminary analysis, the computer-automated data acquisition program offers promising results. In the future, the program can be used to better understand the connection between film degradation and the photoconductivity.

## Background

- Current climate change crisis; need to decrease fossil fuel reliance and focus on clean energy
- Solar cells have an **active layer** that creates a current under light illumination
  - Typically made of **silicon**; expensive, hard to make
    - Record lab efficiency: 26.7%[1]
  - $MAPbI_3$ offers high efficiency (22%)[2]; cheap, easy to make
    - Degrades easily and rapidly in many conditions
    - How can this be improved? Must look at conductive behavior
- **Photoconduction**: Ability of a material to conduct electricity when exposed to light
- **Semiconductors** have energy bands separated by band gap energy $\mathbf{E_{gap}}$
  - Light excites electron from **valence band** into conduction band, creating a conducting electron-hole pair (Fig. 3)
  - MAPbI3: 1.59eV[2]




- Photoconductivity in the steady state:[4]
  - Photon flux (F): Photons/unit area/second

$$\frac{dn}{dt} = kG - \frac{n}{\tau_{tr}} - \gamma n^2 = 0$$

$e^-$ or $h^+$ ($n$); Photoexcitation density; e-h creation constant ($k$); Trap-limited lifetime ($\tau_{tr}$); e-h recombination constant ($\gamma$)

$$F \propto G$$

Film is ideal: (No traps)

$$kG \approx \gamma n^2 \qquad \sigma \propto F^{\frac{1}{2}}$$

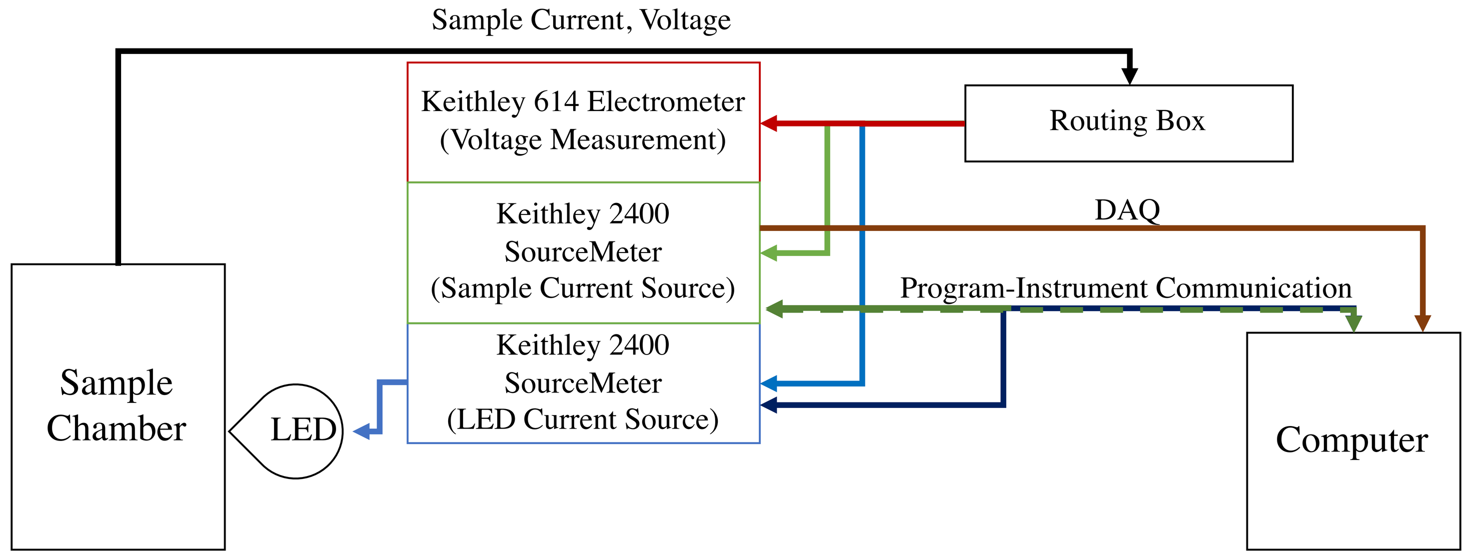
Film is imperfect: (Traps dominate)

$$kG \approx \frac{n}{\tau_{tr}} \qquad \sigma \propto F$$

## Method

$MAPbI_3$ films synthesized and sputter-coated with gold electrodes:

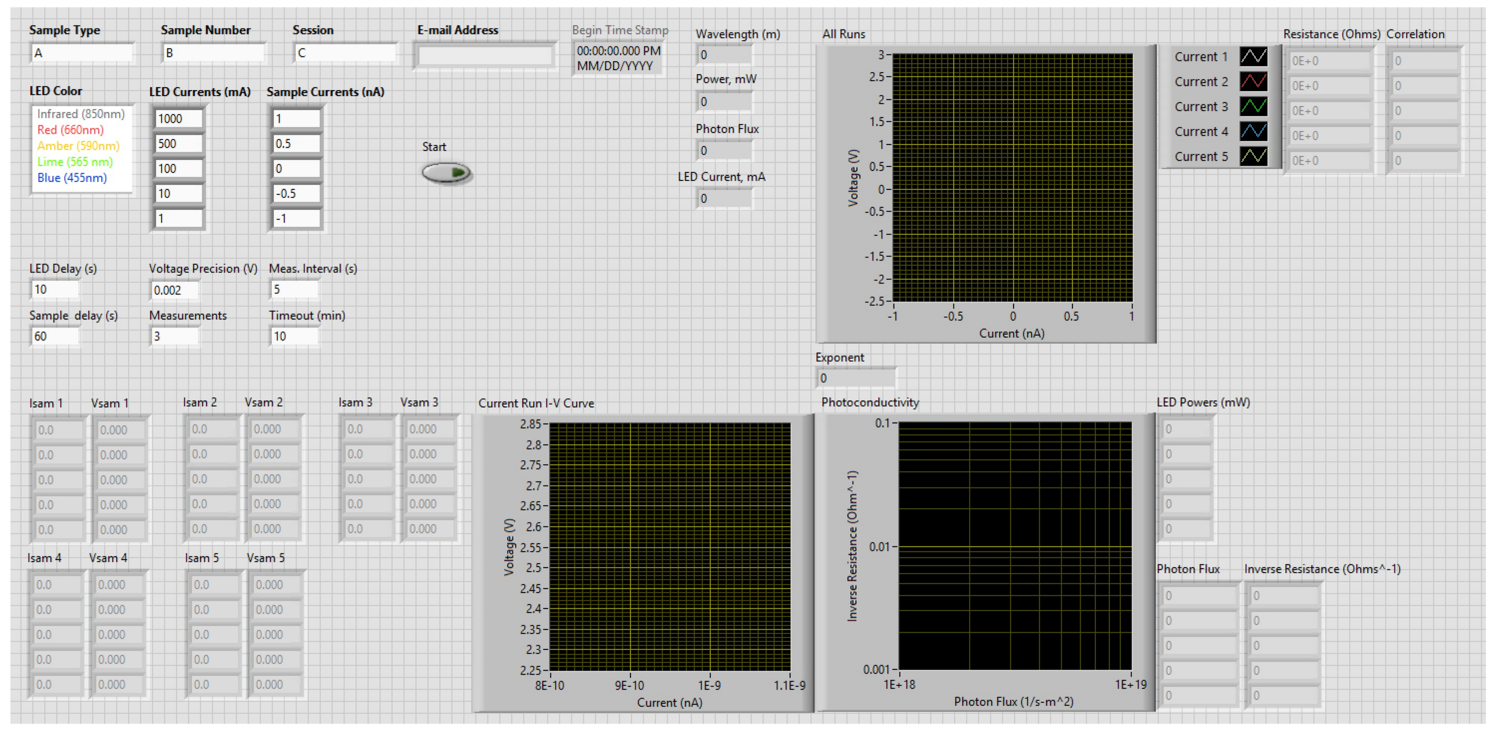

Schematic of apparatus:




Outline of National Instruments LabVIEW program:

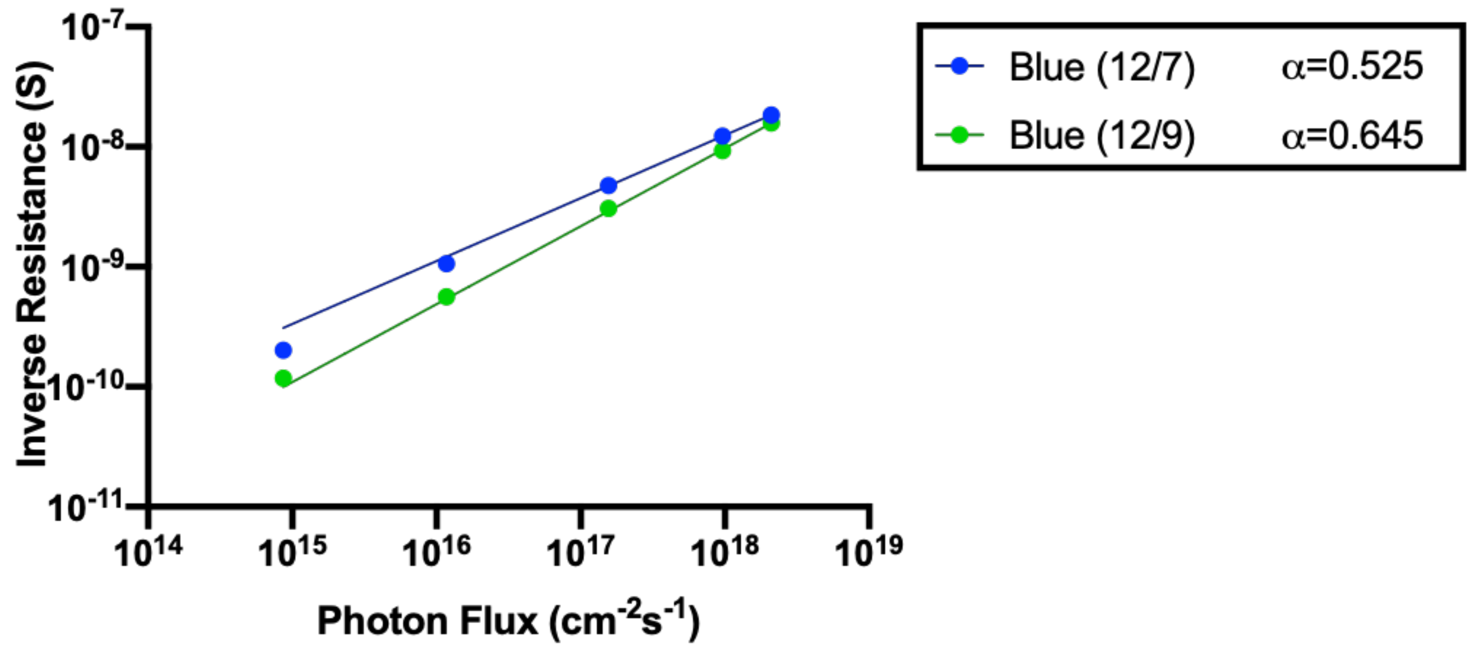
- Provide measurement parameters, desired precision, and identifying information
- Create data file
- For each LED current:
  - Create custom IV curve, calculate resistance
  - Add inverse resistance and photon flux to array
- Final data:
  - Graph of photon flux vs. inverse resistance
  - Power law curve-fitting

Program interface:



## Results

Final curve for measurements using 465nm blue light:




Conclusions:

- Consistent data collection with high correlation
- Degradation likely observed between measurements
  - Consistent with manual data collection

## Future Directions

Improving the program

- Efficiency improvements
- Further customization of data points (e.g., adding more currents)

Future directions:

- How does conductivity change with degradation?
  - Combine with x-ray diffraction to study change in composition

## Acknowledgements

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