

# Learning curves from long-term outdoor testing and indoor optoelectronic characterization of perovskite mini-modules

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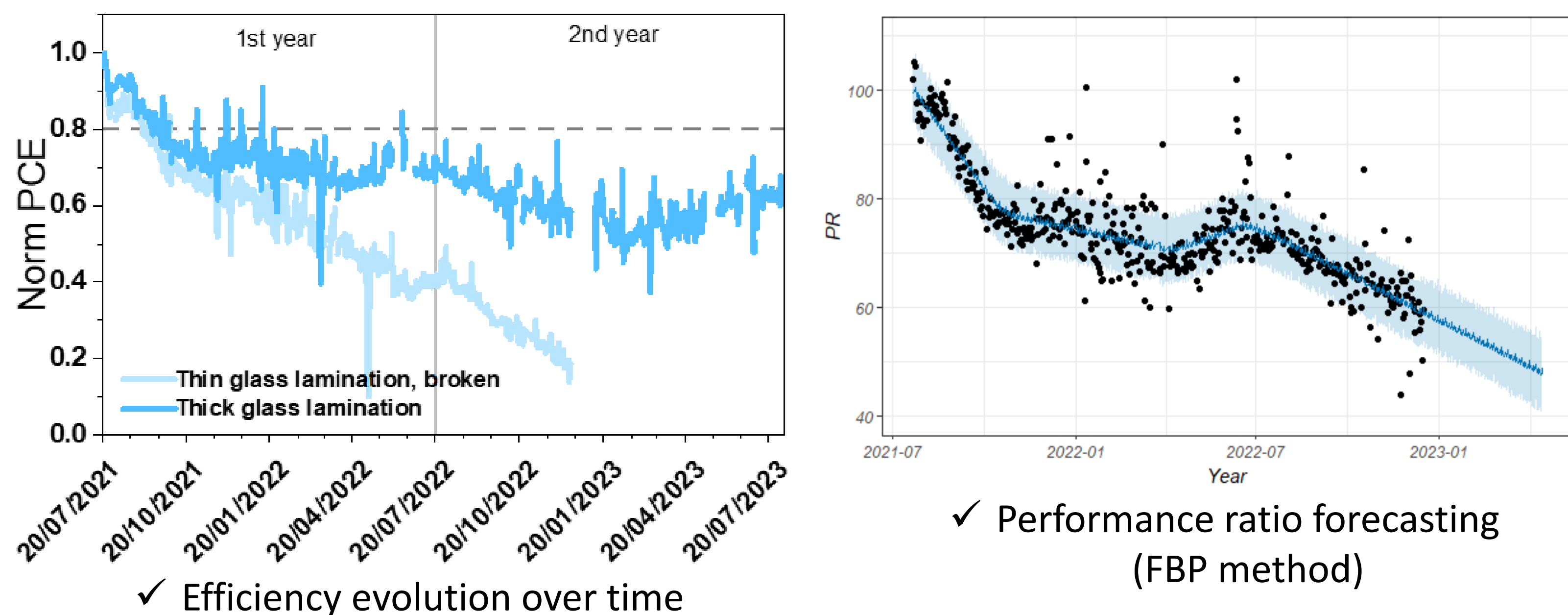
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## Outdoor Results: Degradation Analysis

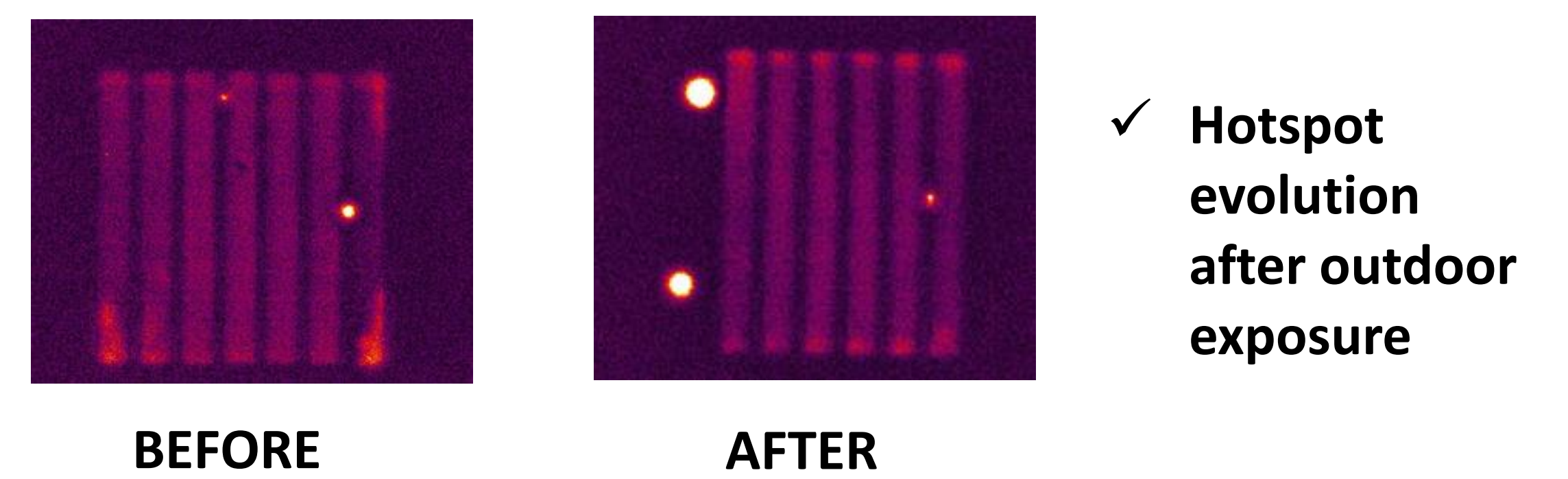
- Assessment of perovskite mini-module outdoor response and degradation.
- Stability at real environmental conditions.



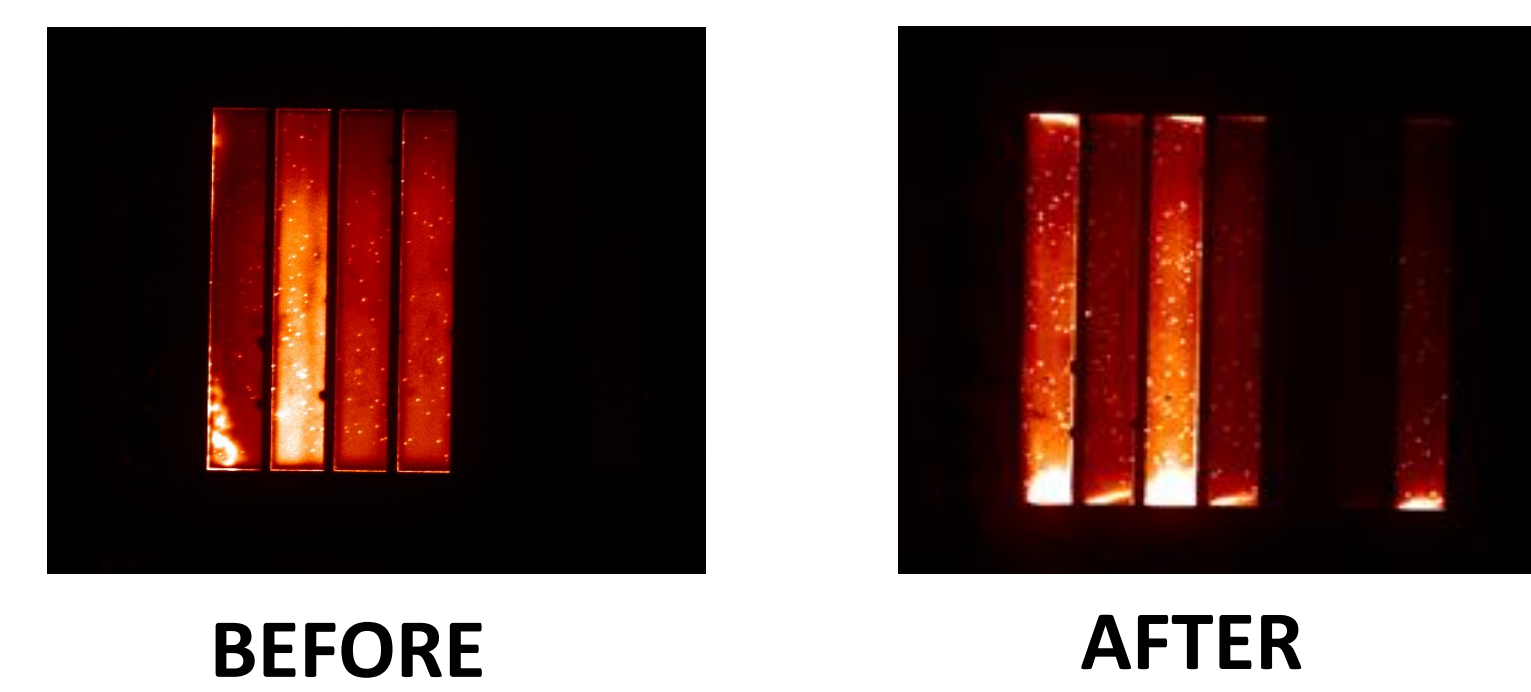
## Spectroscopic Investigation

- Several indoor optoelectronic techniques have been utilized at different degradation stages to reveal the changes in carrier relaxation dynamics, hotspots evolution and defect behavior over time.

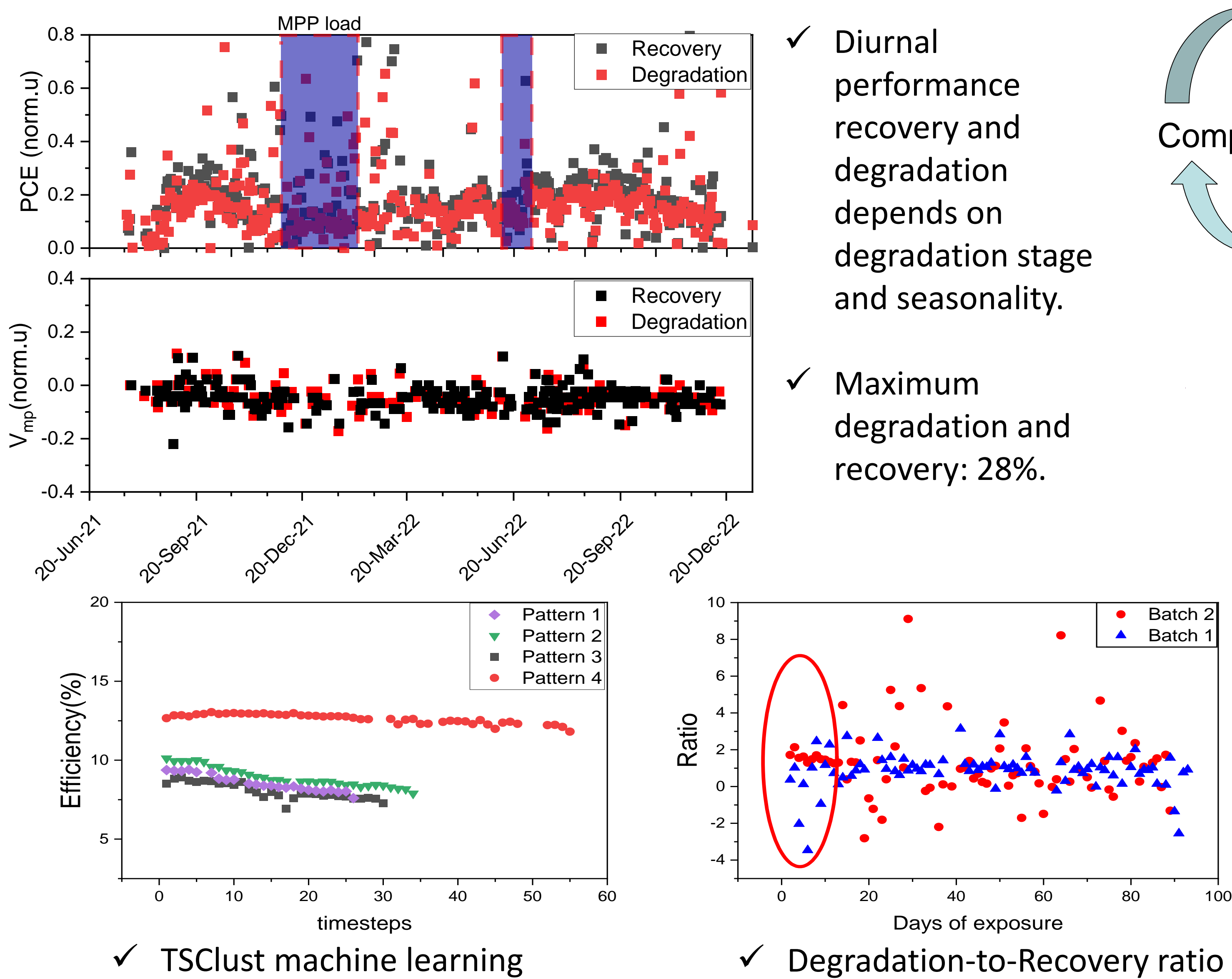
### Dark Lock-In Thermography measurements



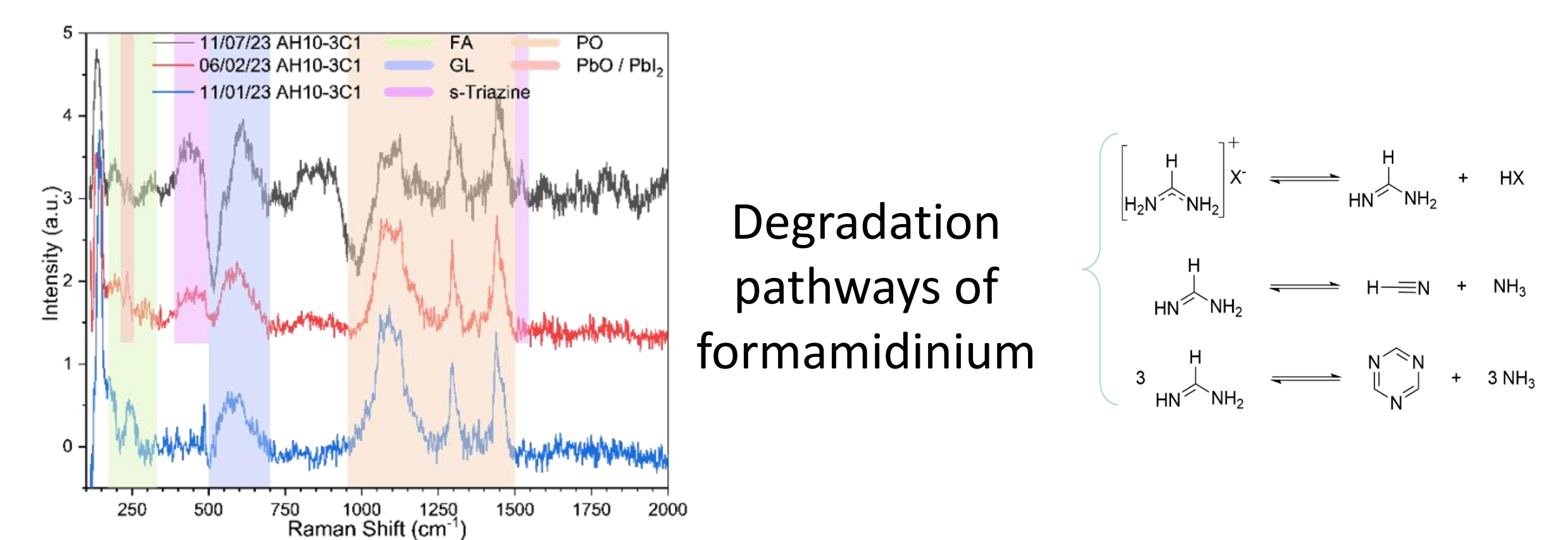
### Spatially-resolved Electroluminescence measurements



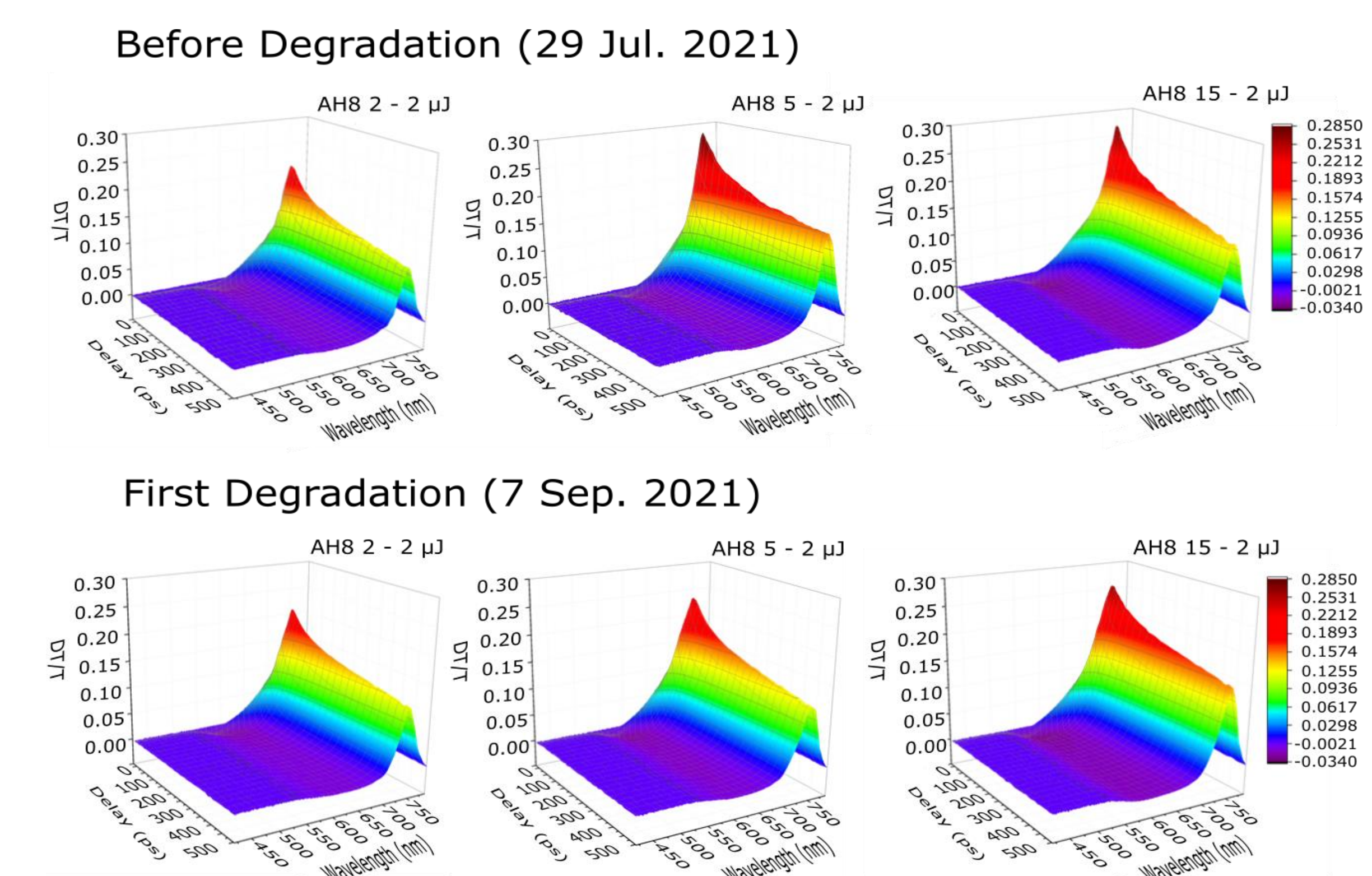
## Diurnal Performance Degradation & Recovery Analysis



## Resonance Raman spectroscopy measurements

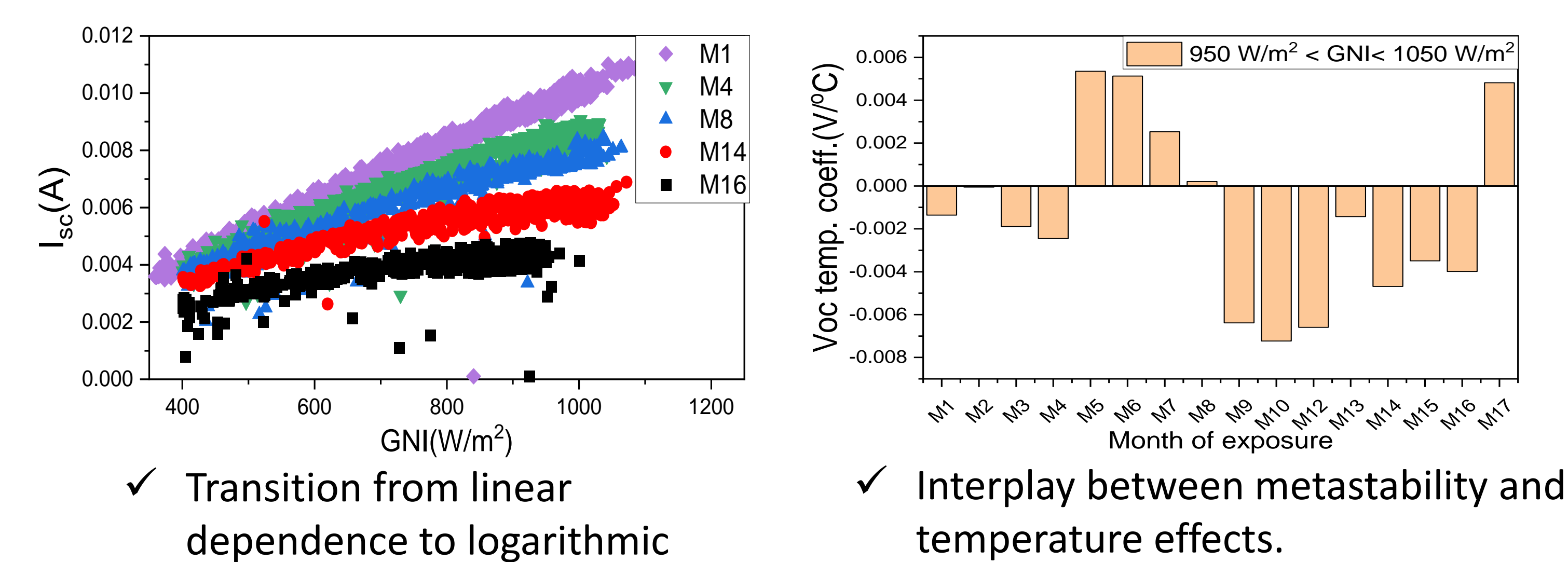


## Ultrafast spectroscopy measurements



Pump-probe differential transmission data on three selected samples taken on 29th of July 2021 (top) and 7th September 2021 (bottom). Pump was set at 400 nm and fluence at 200 μJ/cm<sup>2</sup> for all samples.

## Impact of Irradiance & Temperature



## Conclusions

- Diurnal performance degradation and recovery present significant changes with degradation stage and seasonality.
- Different diurnal performance patterns are obtained in outdoor testing. The origin of performance degradation and recovery is the current.
- Different spectroscopic and optoelectronic methods applied before and after outdoor testing reveal severe changes in carrier relaxation mechanisms, hotspots/defect evolution and chemical composition.

## Acknowledgments

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In collaboration with:

