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## Frequency Dependence of Modulated Surface Photovoltage (SPV) to Characterize Surface Defects

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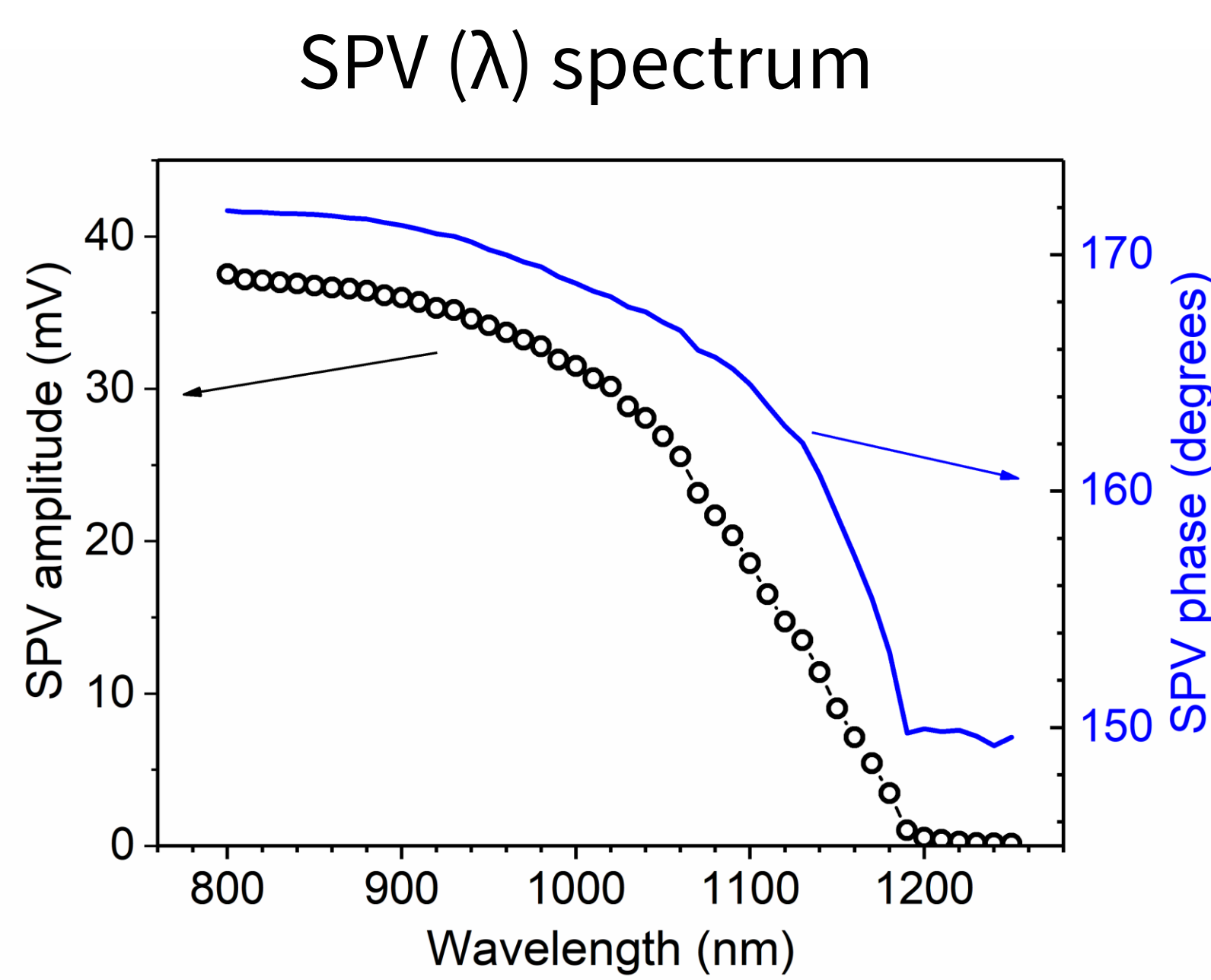
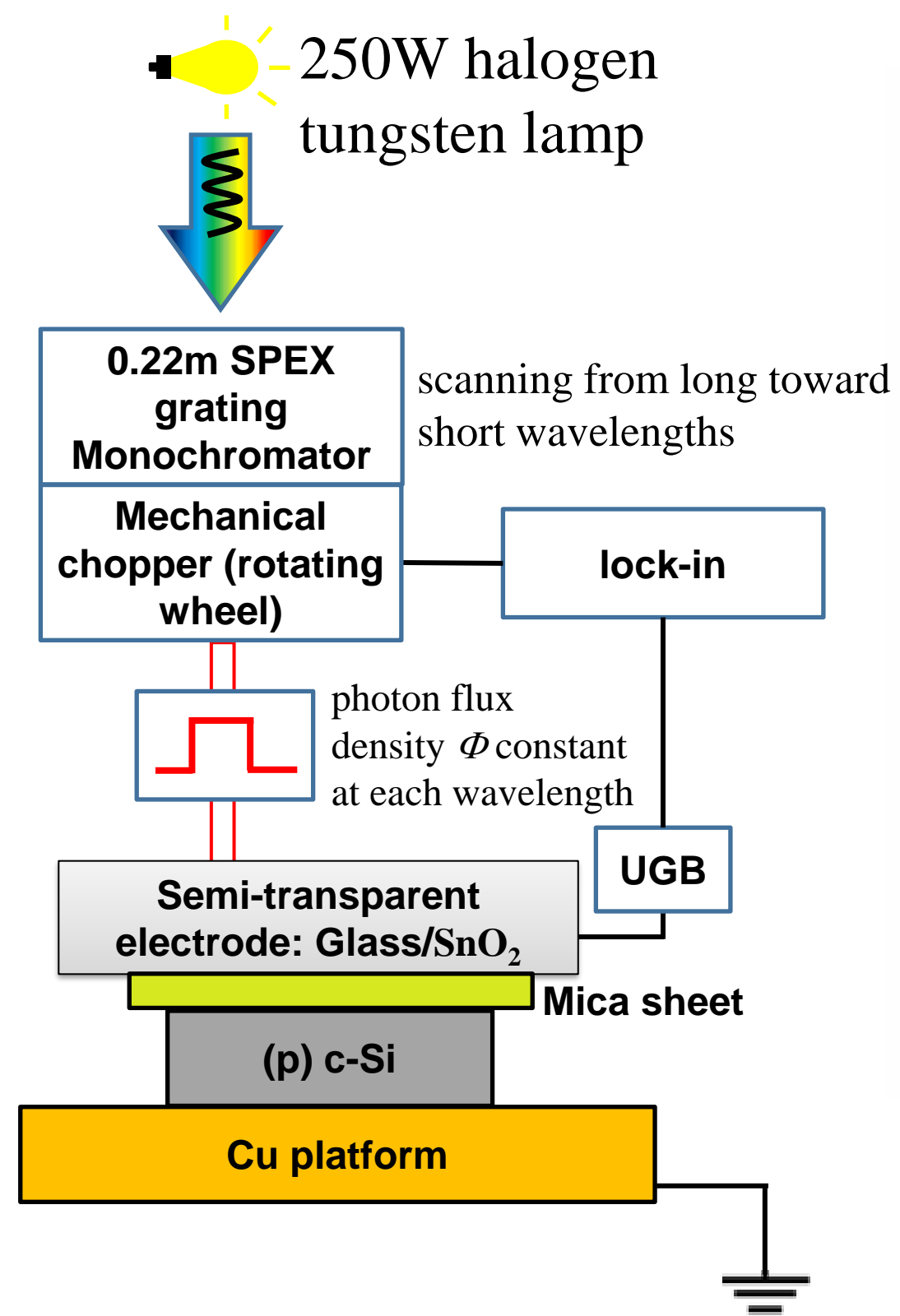
**40th EU Photovoltaic Solar Energy  
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Lisbon – September 2023**

**Davide Regaldo**, James Connolly, Kiril Kirilov, Vesselin Donchev, Christophe Longeaud, Jean-Baptiste Puel, José Alvarez, Philip Schulz, Jean-Paul Kleider.

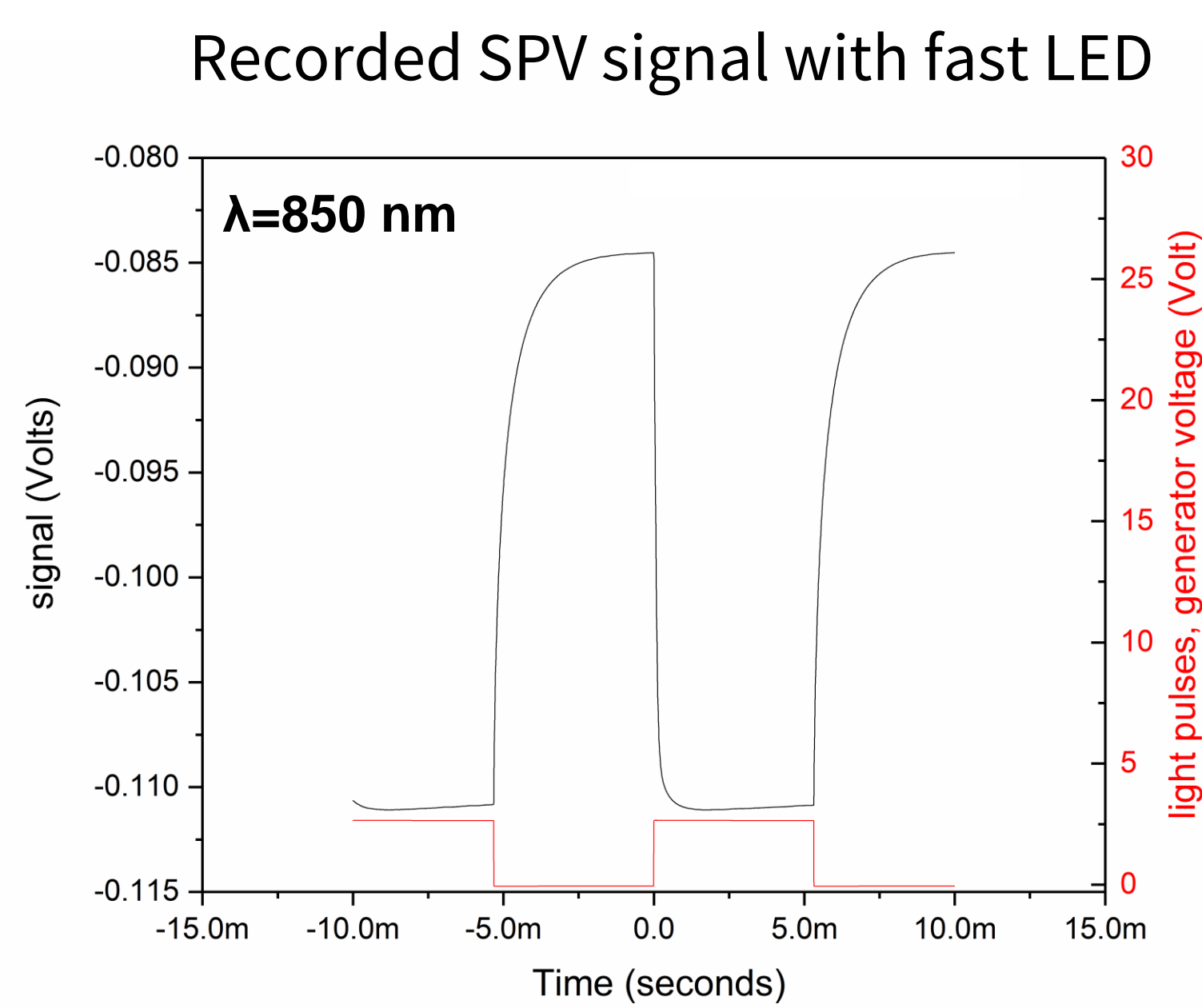
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**Frequency Dependence of Modulated Surface Photovoltage (SPV) to Characterize Surface Defects**

**The Metal-insulator-semiconductor SPV experiment**

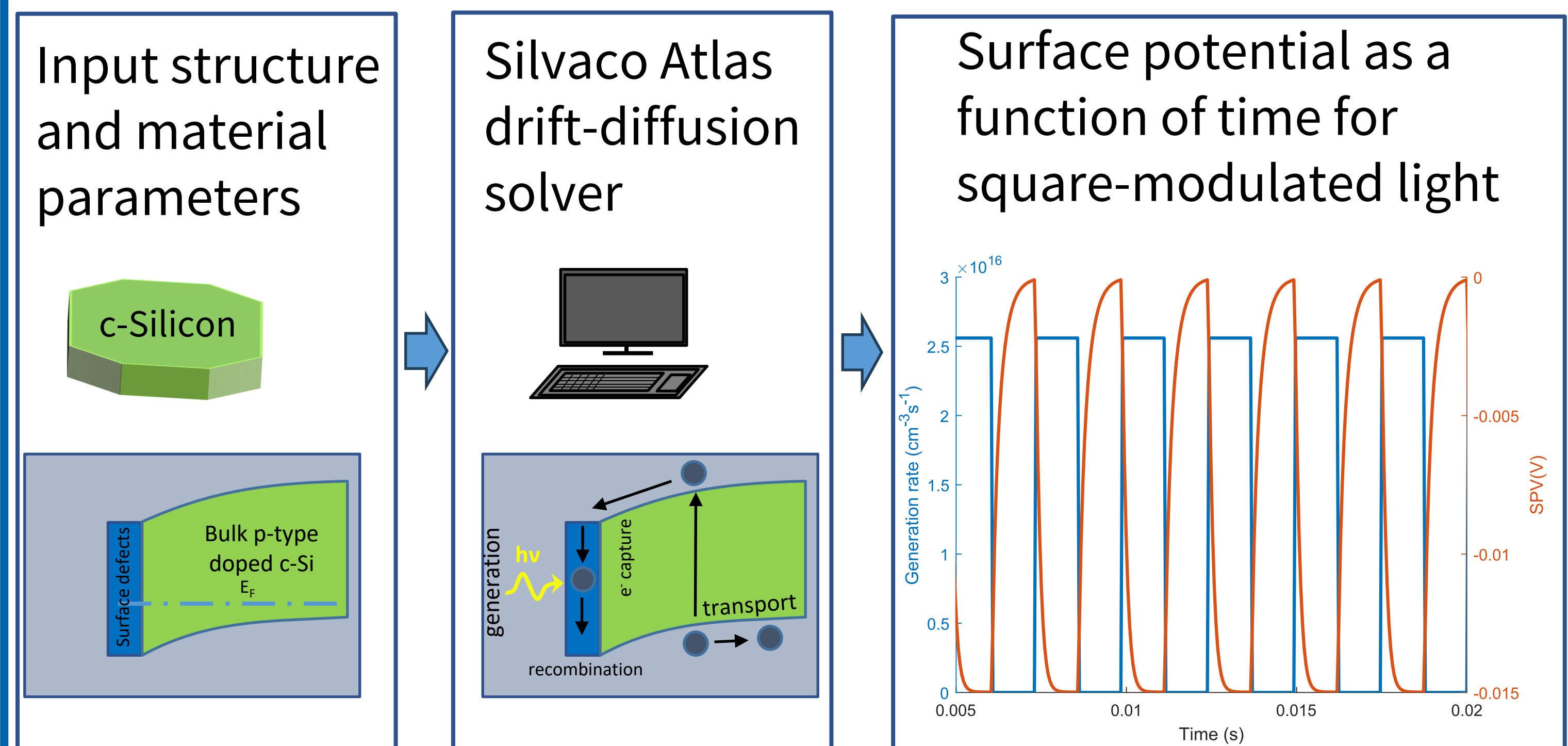


SPV = the illumination-induced change in the surface potential  $\Delta V_s = V_s^{light} - V_s^{dark}$  as a result of the spatial separation of the photogenerated electrons and holes, for instance driven by the built-in electrical field in the surface space charge region of the semiconductor.

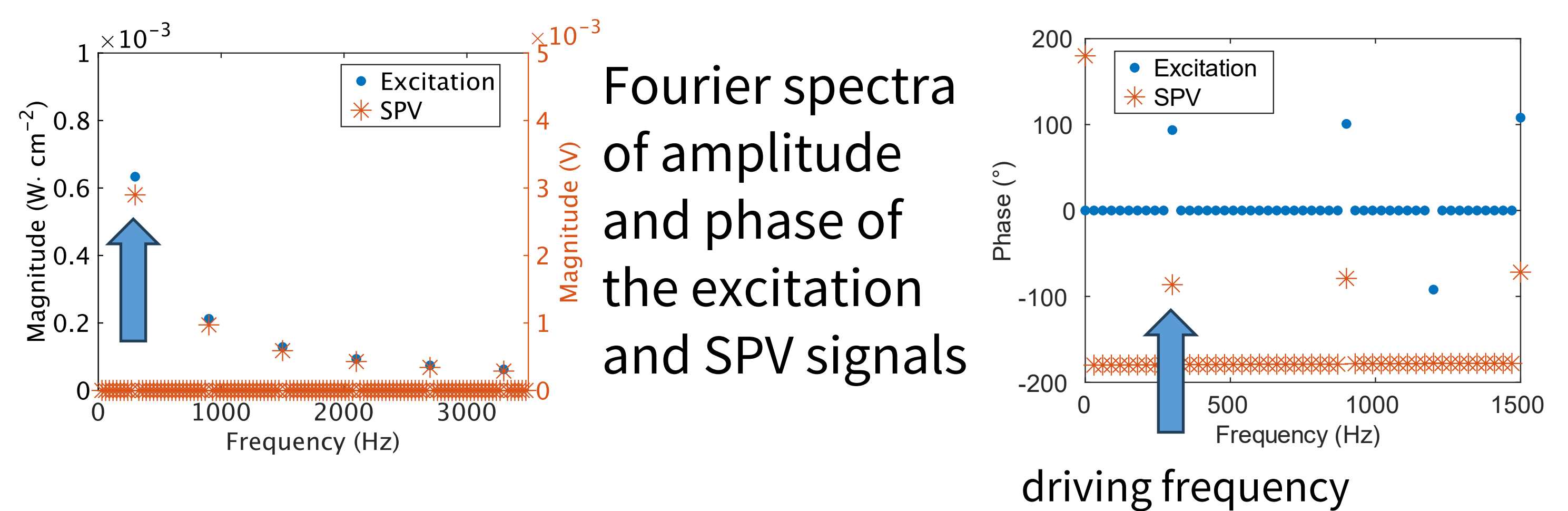


When the structure is illuminated with chopped light, the periodic changes of  $V_s$  due to the photovoltaic effect induce a periodic voltage between the capacitor plates ( $\text{SnO}_2$  electrode and Cu platform). This voltage is fed to a high-impedance unity gain buffer (UGB) and measured by a lock-in amplifier (SR830) that extracts amplitude and phase of the fundamental frequency.

**Modulated SPV simulations**

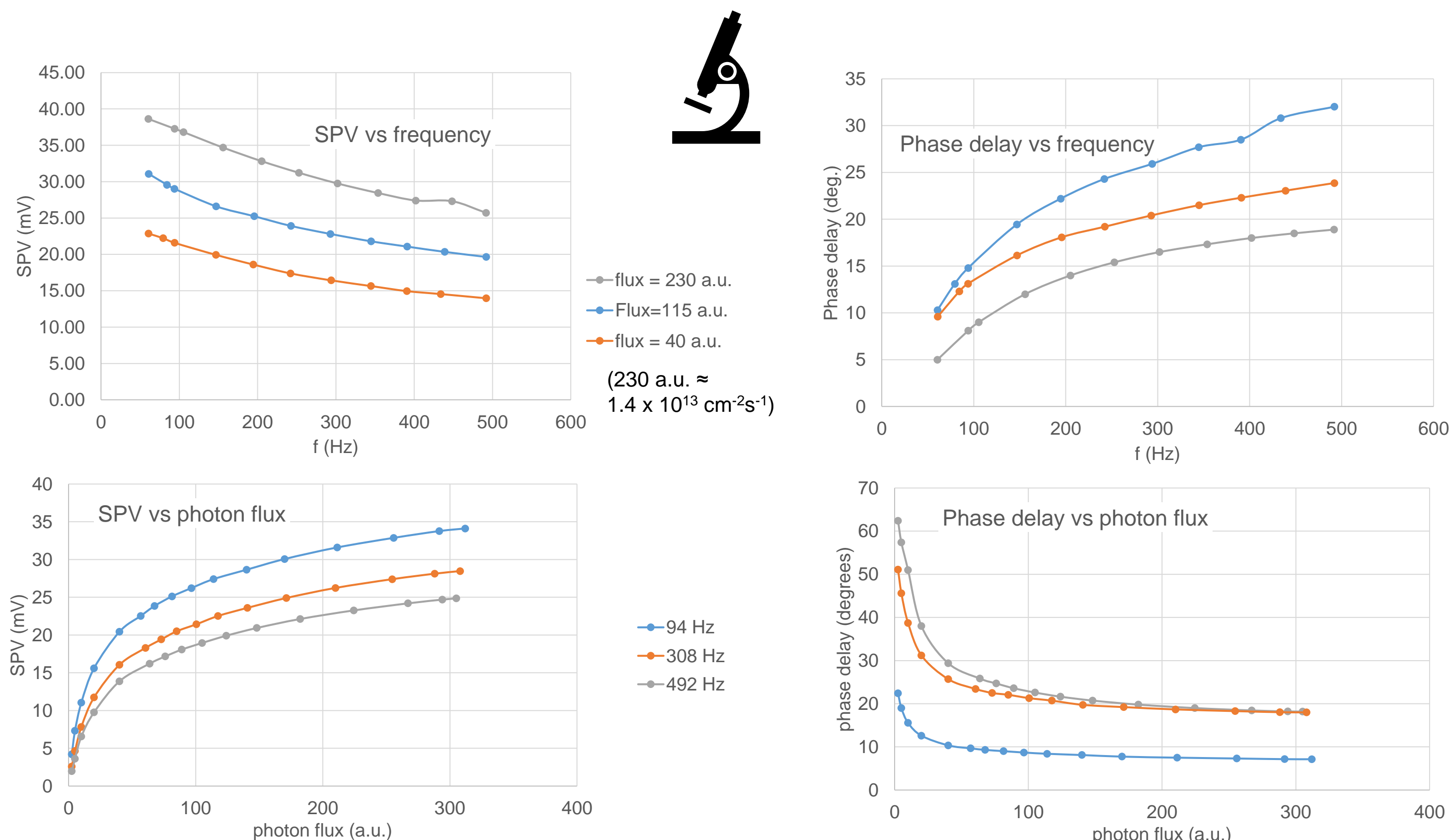


**Silvaco Fast-Fourier Transform method**



Extract the SPV amplitude and phase at the fundamental frequency (1<sup>st</sup> harmonic)

**Frequency and flux dependence of SPV**



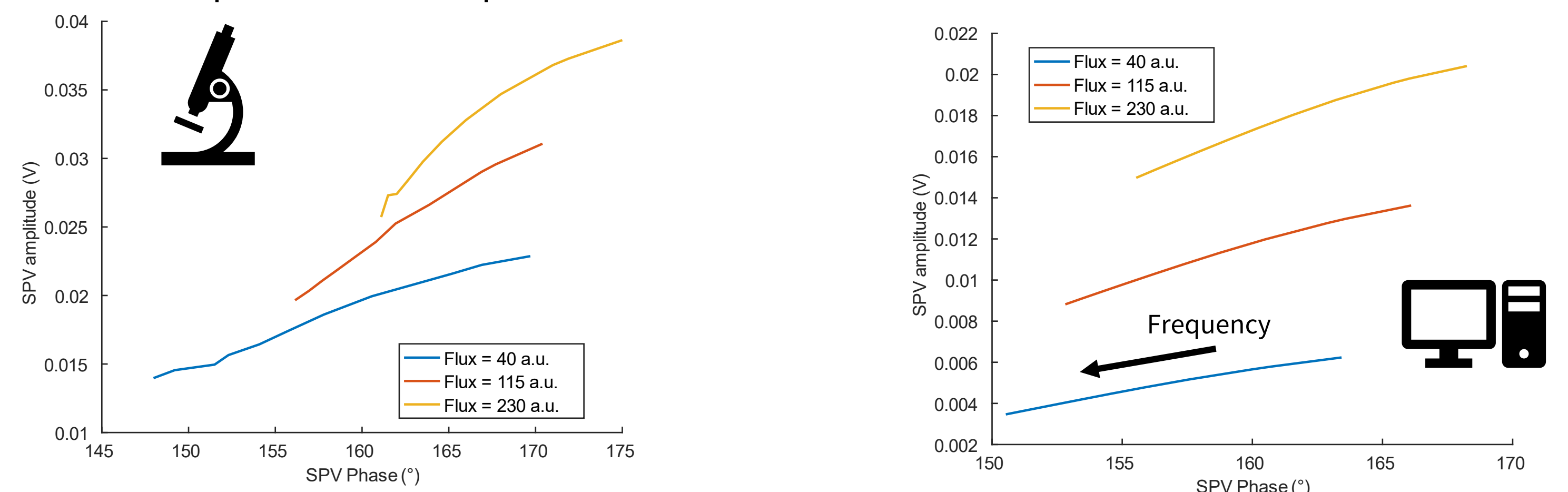
**Interpretation with the DD model**

The model reproduces the measured surface defect density of states across the Si bandgap

Amplitude/Phase curves experiment vs model:

Similar trends were achieved by varying p-doping, defect density, and capture cross-sections.

Other defect distributions could lead to a better reproduction of experimental data



**REFERENCES**

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Donchev V, Regaldo D, Georgiev S, Bojar A, da Lisa M, Kirilov K, Alvarez J, Schulz P, Kleider JP. **Surface Photovoltage Study of Metal Halide Perovskites Deposited Directly on Crystalline Silicon**. ACS Omega. 2023 Feb 24;8(9):8125-8133.