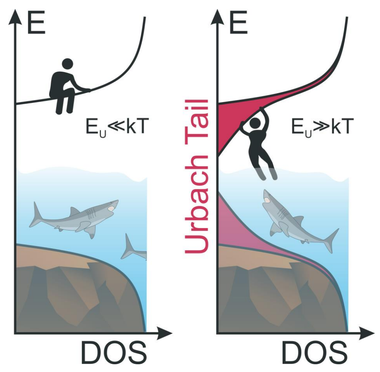
DEFECTS IN HALIDE PEROVSKITES

Vlk A., Hlaváč R., Landová L., Hájková Z., Ridzoňová K., Remeš Z., Holovský J., Fejfar A., Ledinský M.

ELECTRONIC QUALITY

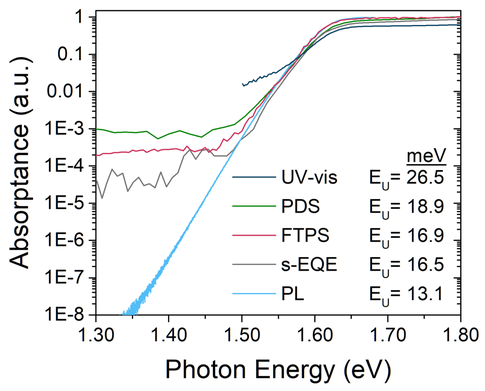
Urbach Energy



Defects and structural disorder cause bending of the electronic bands.

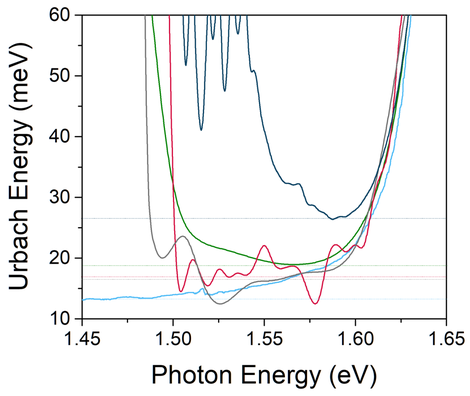
The bending affects the steepness of the absorption edge which is described by the Urbach energy.

$$\alpha(E,T) = \alpha_0 exp\left(\frac{E - E_C}{E_U(T)}\right)$$



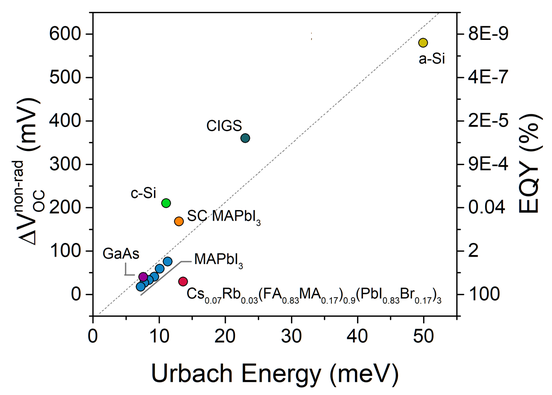
Precise absorption measurement with high dynamic range is important for determination of Urbach energy.

$$\frac{d(ln(\alpha))}{d(E)} \cong \frac{1}{E_U(T)}$$



Taking the first derivative of the absorption spectra leads to more precise and reproducible determination of Urbach energy.

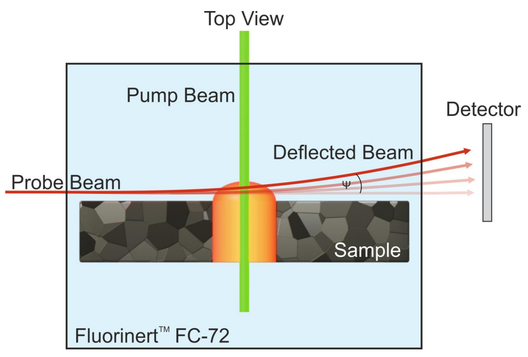
$$\Delta V_{OC}^{non-rad} \sim 14 \frac{E_U(T)}{q}$$



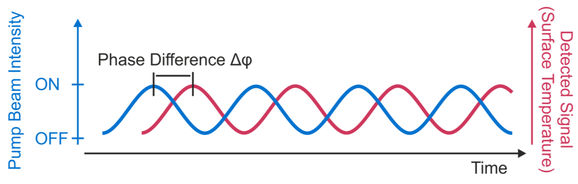
Non-radiative losses of $\Delta V_{OC}^{non-rad}$ are proportional to the Urbach energy.

DEFECT LOCALIZATION

How Does PDS Work ?



Lock-in Technique

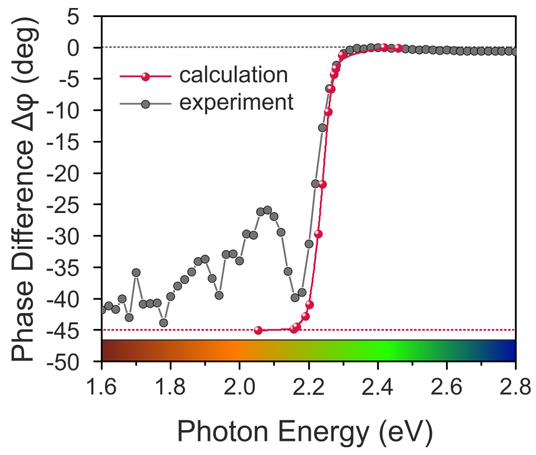


We are measuring amplitude and phase.
Amplitude is proportional to the absorbed signal within the probed volume.

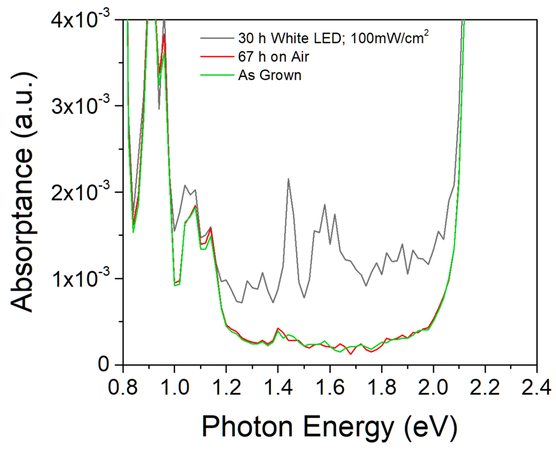
~probed volume ↕ Sample Thickness / Thermal Diffusion Length μ_T

$$\mu_T = \sqrt{\frac{2k}{\omega \rho C}}$$

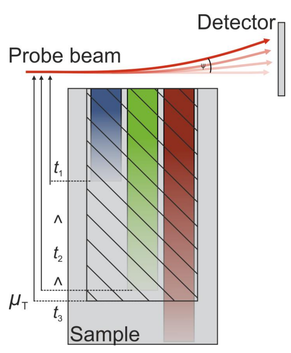
Phase Analysis of PDS



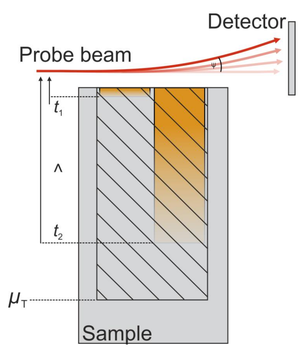
Example of Surface Defects

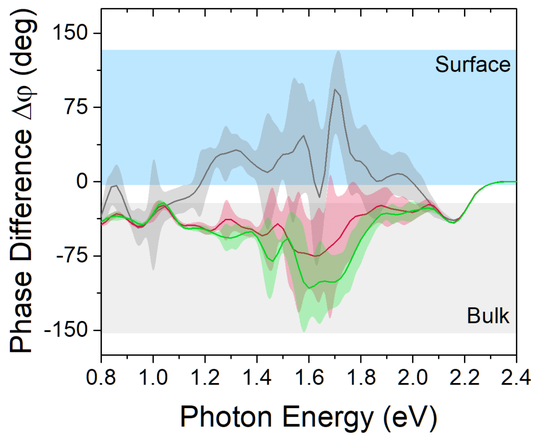


Expected Behaviour



With Surface Defects



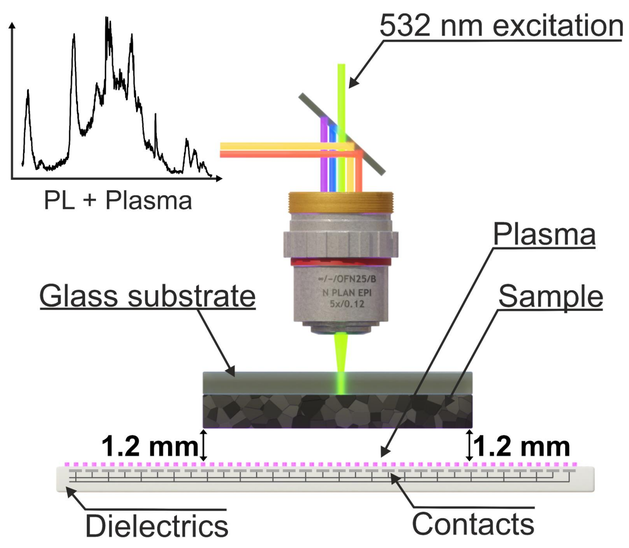


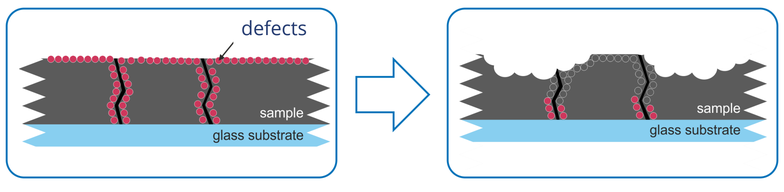
TREATMENT

DCSBD plasma generator

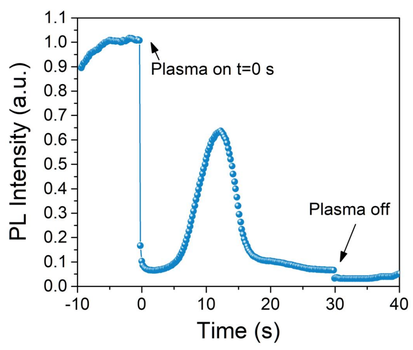
- Power: 230 VAC.
- Plasma parameters: 40 W (7 kV, 20 kHz).
- Plasma area: 50 mm × 20 mm.
- 0.2 mm thin plasma layer.
- Low temperature -> ideal for perovskites.
- Atmospheric pressure.

Used for:
- Polymer activation.
- Glass cleaning.
- Plant seeds treatment.

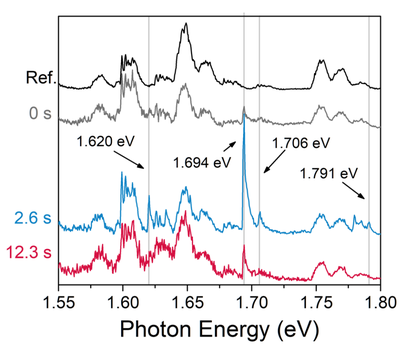




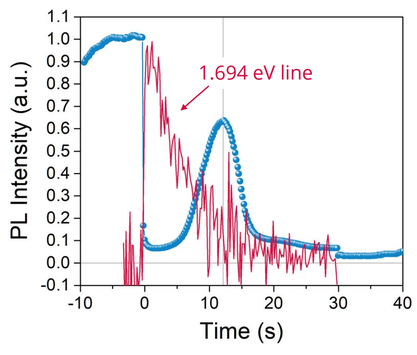
In-Situ Measurement



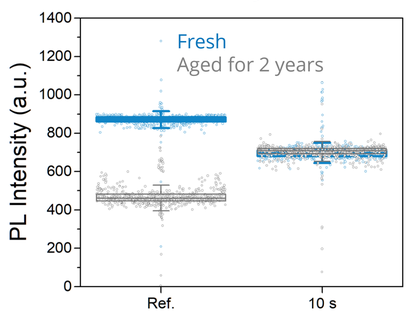
Plasma Spectra



Evolution of Plasma Line



Stability Test



SUMMARY

- **Non-radiative losses of V_{OC} are proportional to Urbach energy.**
- **PDS can be used to distinguish between surface and bulk defects.**
- **Plasma treatment removes defects from grain boundaries and increases long-term stability of the perovskite layer.**

Life on the Urbach Edge

Spatial Localization of Defects in Halide Perovskites Using PDS

COLLABORATIONS

S. de Wolf, E. Aydin, E. Ugur, T. Allen

M. Morales-Masis, J. Solomon Sathiaraj, T. Soto Montero

N. Mrkyvkova, P. Siffalovic, V. Held

C. Ballif, C. Wolf, F. Haug, A. Faes, B. Paviet Salomon, G. Nogay

T. Homola, J. Vida, J. Fujera

AFFILIATION

(1) Laboratory of Thin Films, Institute of Physics, ASCR, Cukrovarnická 10, 162 00 Prague, Czech Republic

ACKNOWLEDGEMENT

We acknowledge the use of the CzechNanoLab research infrastructure (LM2023051), the CEPLANT research infrastructure (LM2023039) and projects LUASK 22202 and 9F23003 supported by the MEYS. Furthermore, we acknowledge the support of GACR Project No. 24-11652S.

A. Vlk: vlkal@fzu.cz
M. Ledinský: ledinsky@fzu.cz