Radiation Tolerance, Self-Healing and High Temperature Stability of Perovskite Solar Cells

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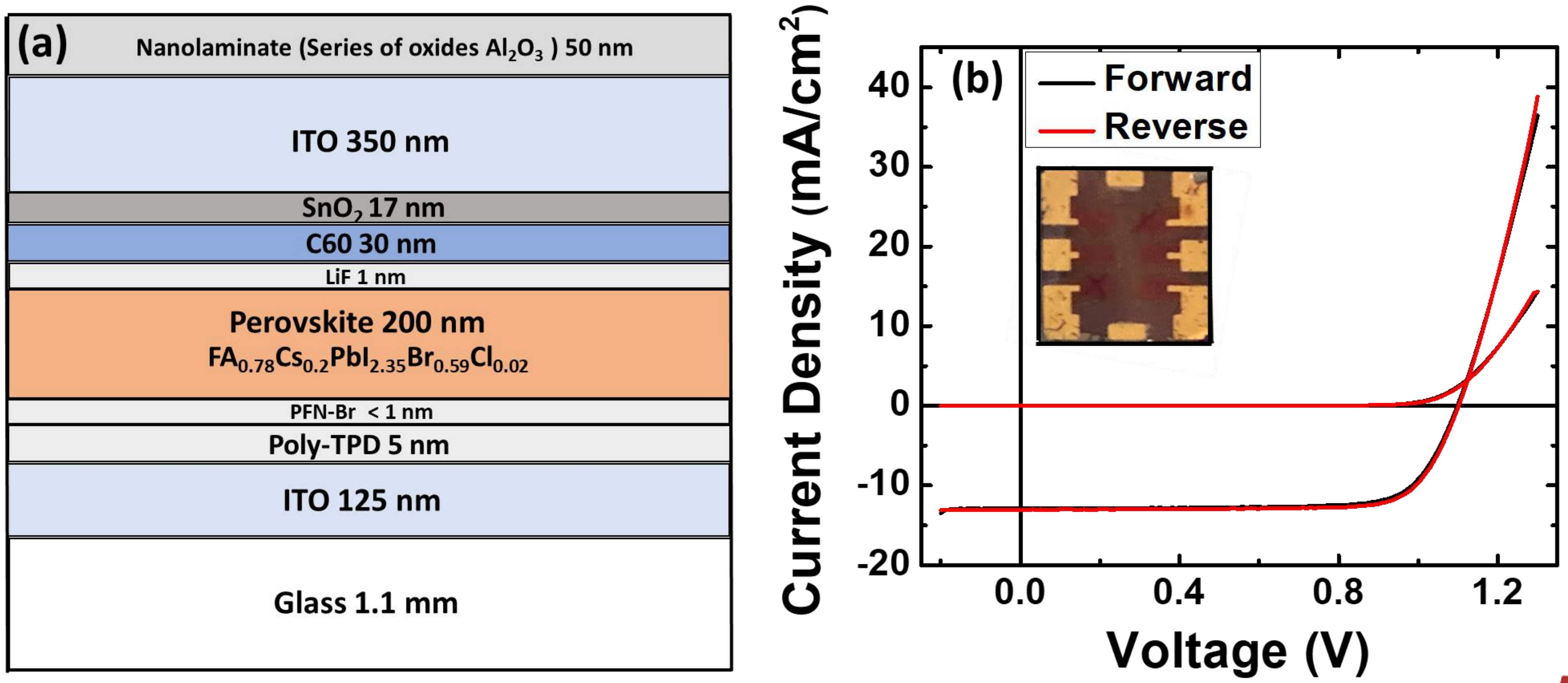
Structure of the solar cell and photovoltaic performance

- Swift Solar provided the triple halide perovskite solar cells ($FA_{0.78}Cs_{0.2}PbI_{2.35}Br_{0.59}Cl_{0.02}$)
- Thickness of the absorber layer is not optimized for spectroscopic purposes
- Lack of the hysteresis in the JV curves, minimized ion migration
- Previous cells with same structure were functional up to 1 year



SwiftSolar

Creating space environment conditions

- Illumination
- Irradiation
- Extreme low and high temperatures
- Proton irradiation and SRIM calculations are performed at the university of North Texas
- Low and high temperature measurements are performed in a cryostat with vacuum environment

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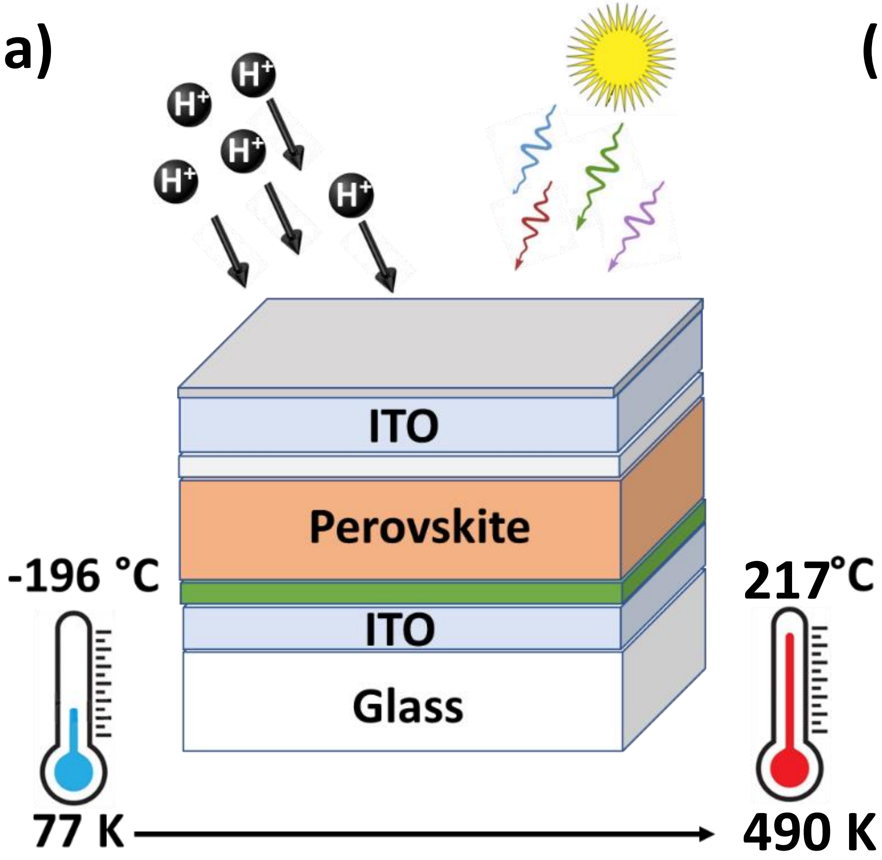
(a)



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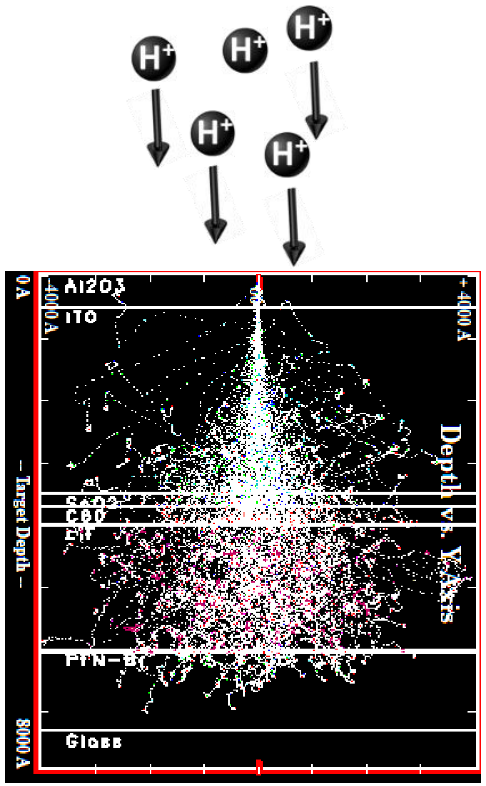
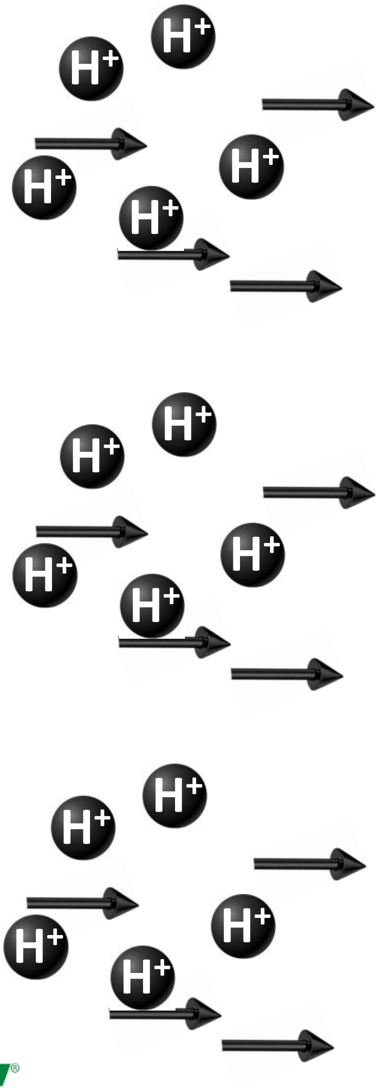


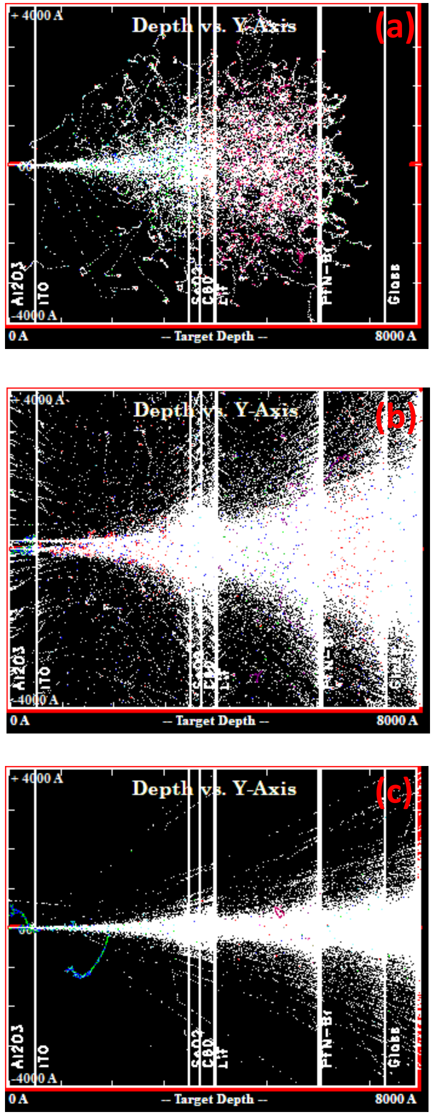
Proton irradiation with different energies and fluences

75 keV
10^{13} 1/cm²

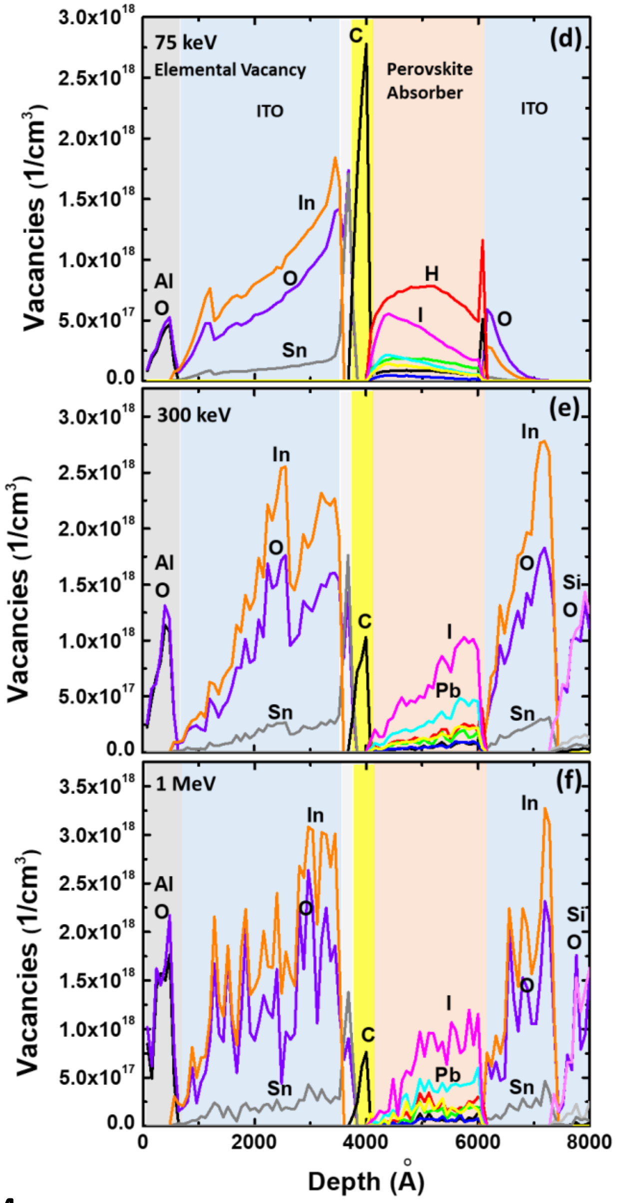
300 keV
10^{14} 1/cm²

1000 keV
4×10^{14} 1/cm²

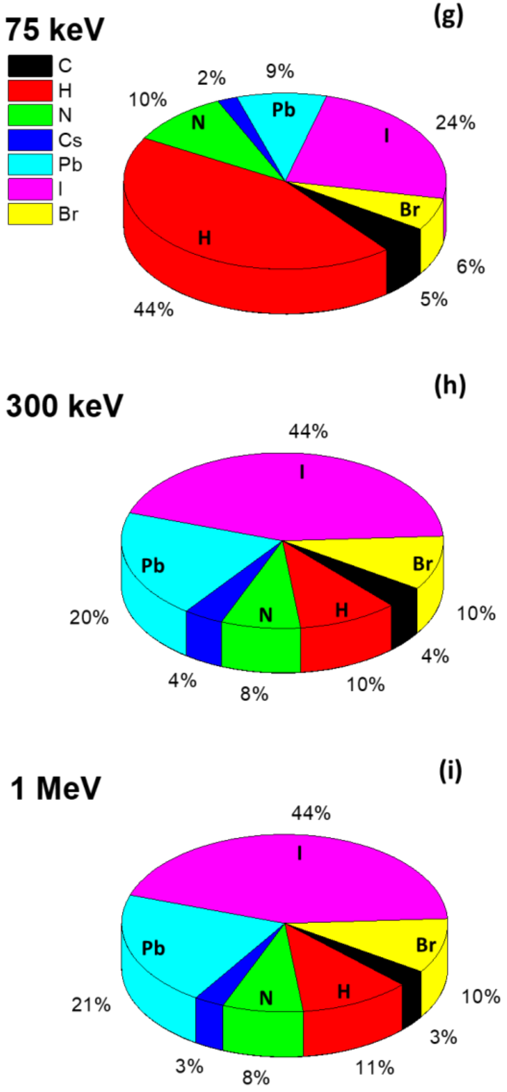




Trajectory of protons in the solar cell using SRIM



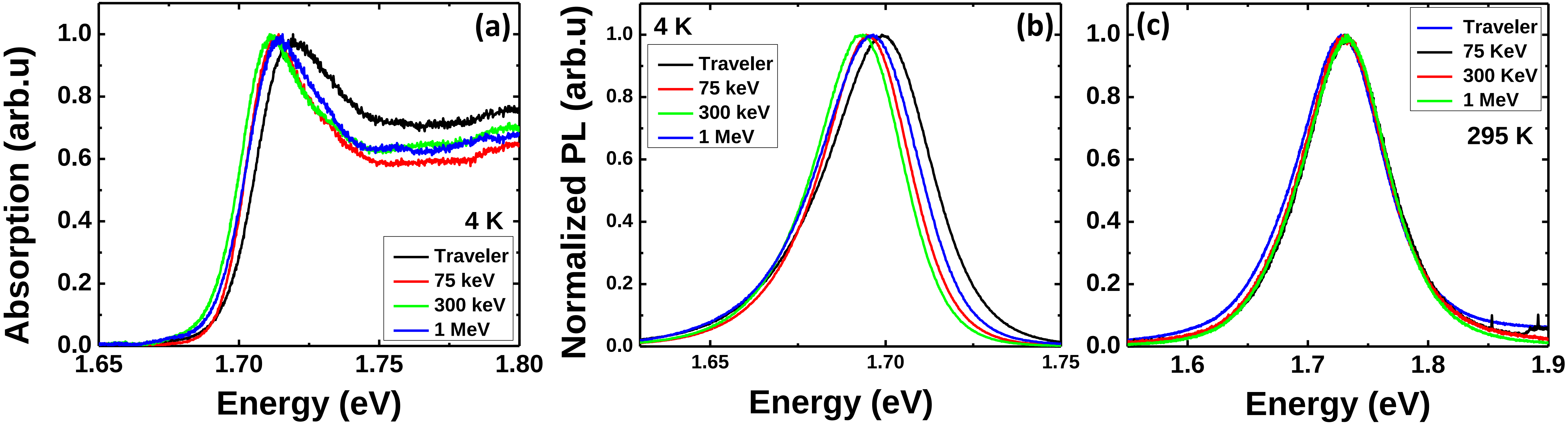
Induced vacancy defects, SRIM



Share of vacancies in the absorber layer, using SRIM

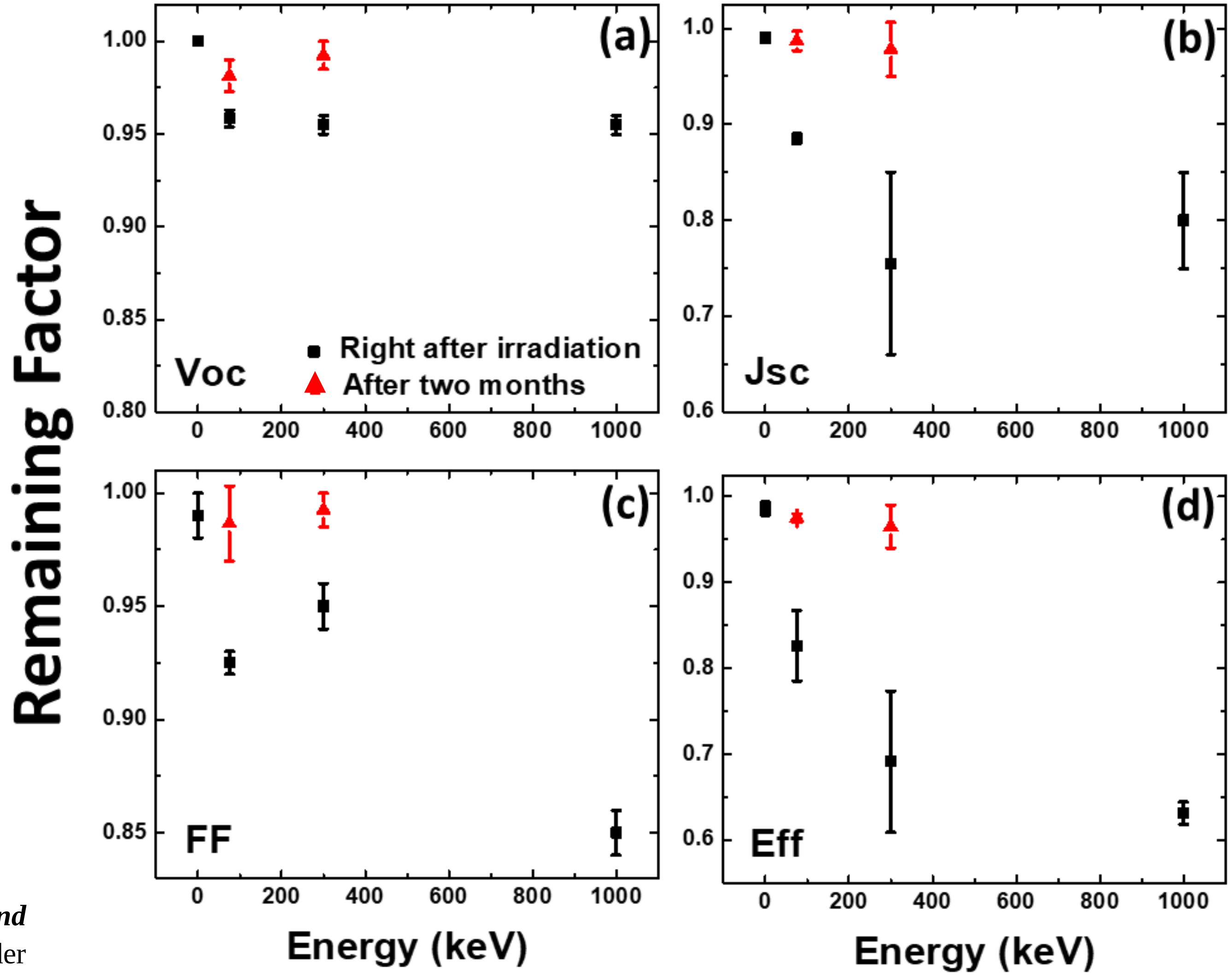
Effect of irradiation on the absorber material

- There is not additional defect related peak or broadening due to irradiation
- After irradiation there is a small (7 meV) red shift in PL and absorption peaks at 4 K
- Red shift not seen at room T due to the thermal energy of electrons



Self-Healing of the perovskite solar cell

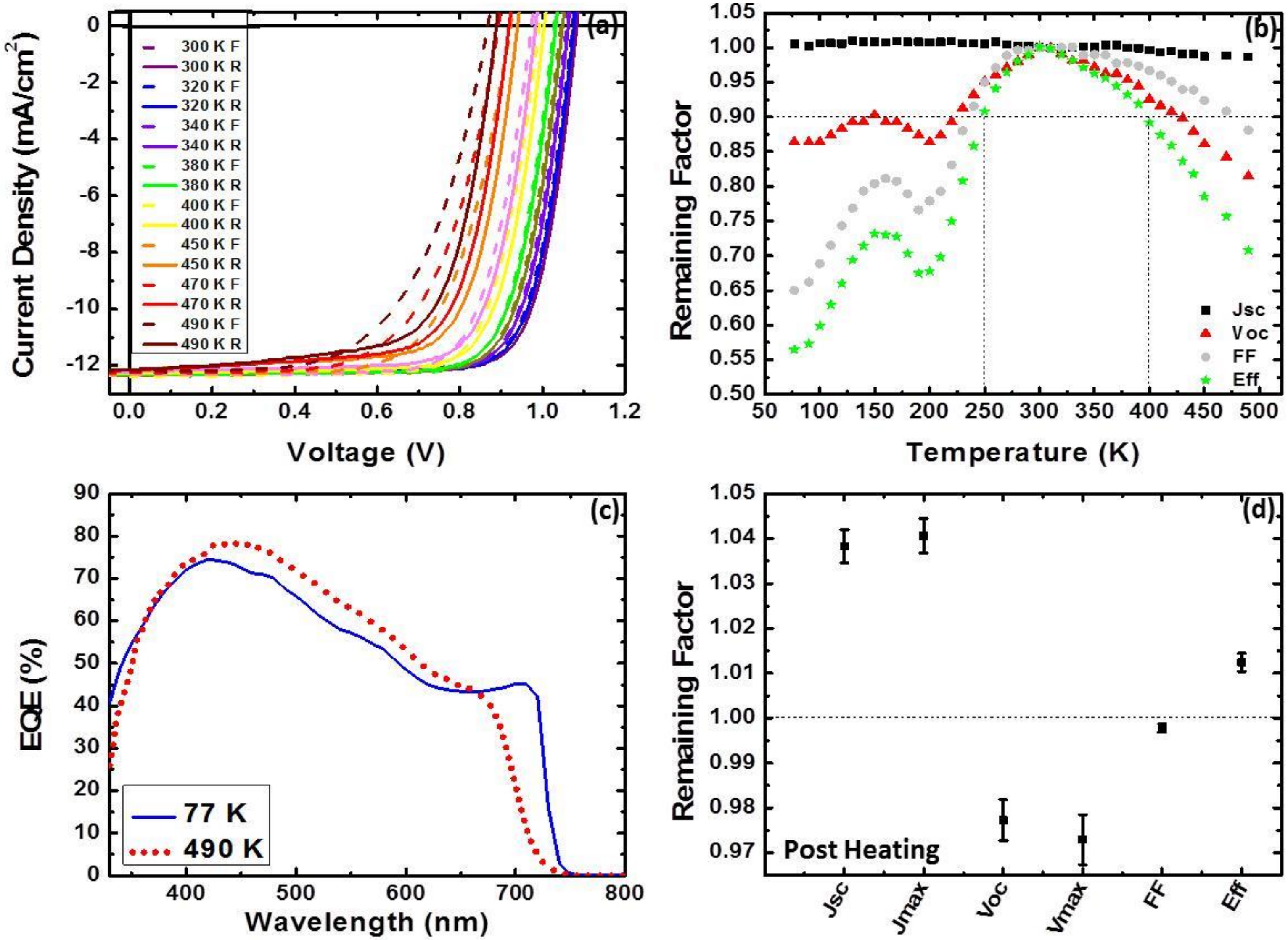
- Remaining factor = final value/initial value
- After irradiation all the PV parameters are reduced, **but temporarily**
- V_{OC} receives the lowest damage
- J_{SC} receives the highest damage
- After 2 months solar cell performance is similar to the non-irradiated cell (traveler)
- The 1 MeV irradiated solar cell stopped working when measured after 2 months



Hadi Afshari, Ian R. Sellers, et al "***Radiation tolerance, self-healing, and high-temperature operation of triple halide perovskite solar cells***" Under preparation

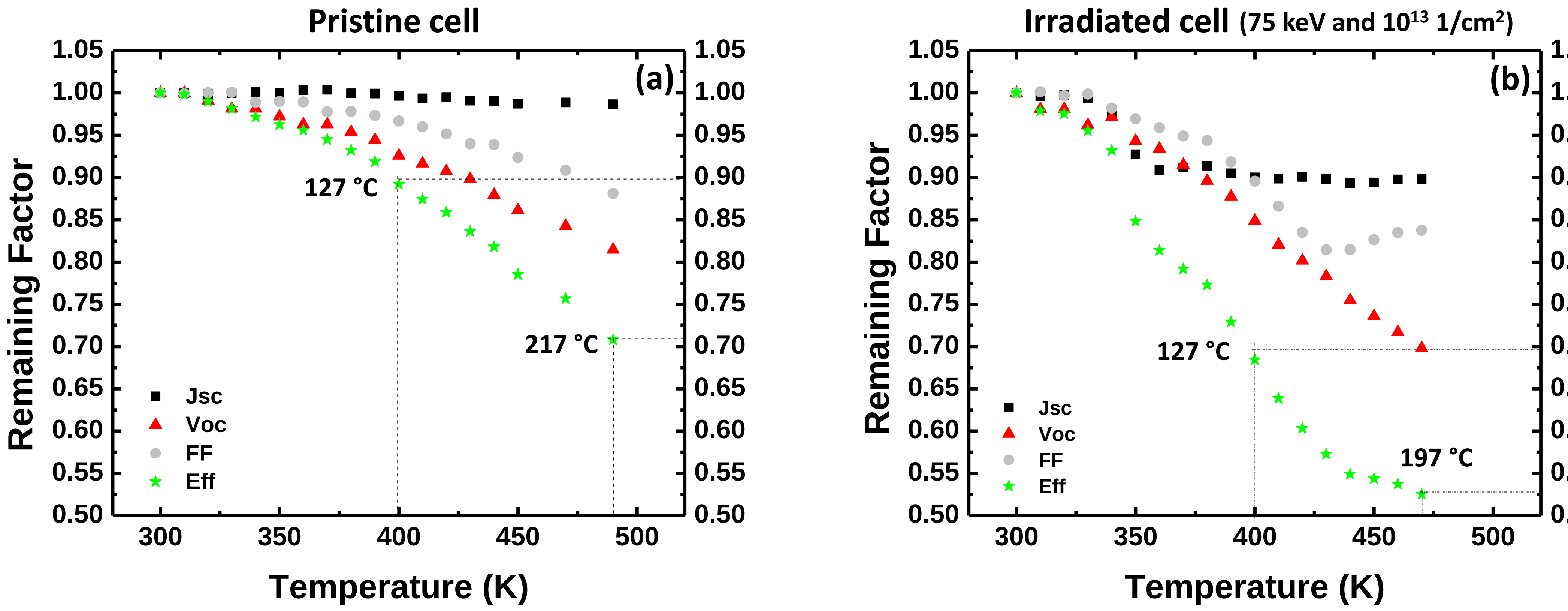
Performance at extreme low and high temperatures

- Temperature is changed from 77 K up to 490 K (-196 °C to 217 °C)
- Hysteresis increases at higher temperatures
- High temperature performance is better than low temperature performance
- J_{SC} is constant for all the temperatures studied
- EQE confirms almost constant J_{SC} at low and high temperatures
- At high temperature EQE tail shifts towards higher energies
- Low temperature EQE reflects an exciton related peak
- After undergoing the thermal stress, the J_{SC} and Eff improves while V_{OC} degrades



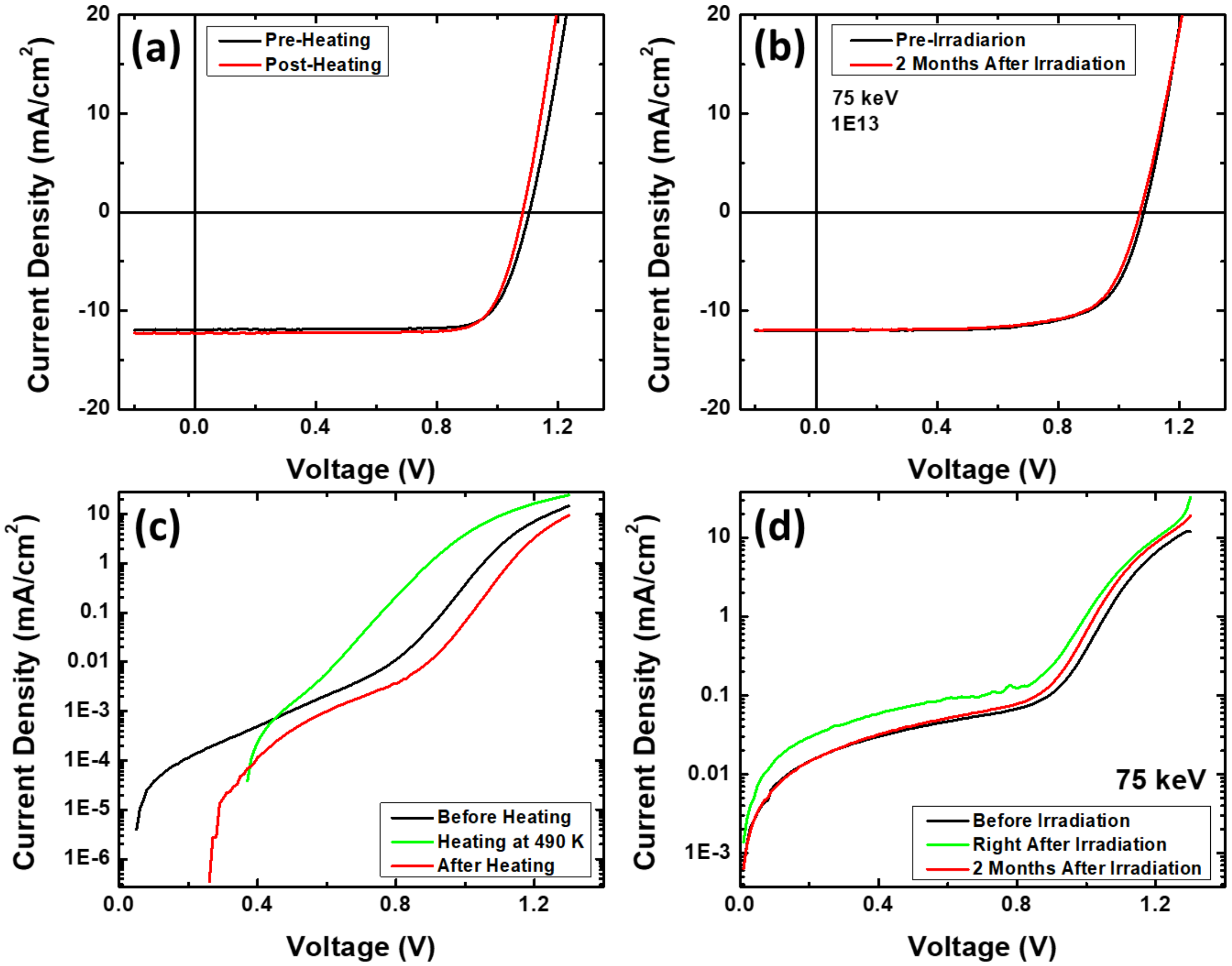
Irradiation plus thermal stress at high temperatures

- Effect of high temperatures is investigated/compared on pristine and irradiated (75 keV and 10^{13} 1/cm^2 fluence) solar cell
- The high temperature tolerance of the irradiated sample is reduced considerably. At 197 °C the irradiated sample stopped working
- At 400 K (127 °C) pristine sample works with 90% of initial efficiency while irradiated sample works with 70% of initial efficiency



Stability against irradiation and thermal stress

- Pre-Heating and Post-Heating light JV results are very similar
- Pre-Irradiation and 2 months after irradiation light JV results are very similar
- At high temperatures dark current is increased significantly due to the increased intrinsic carrier density
- After irradiation dark JV results show an increase in the dark current which decreases significantly after 2 months
- Increase in the dark current after irradiation is due to the increased non radiative centers due to irradiation consistent with reduction of V_{OC}



Conclusions

● The triple halide perovskite solar cells ($FA_{0.78}Cs_{0.2}PbI_{2.35}Br_{0.59}Cl_{0.02}$) show high stability against irradiation and high temperatures

● High performance, longevity and lack of hysteresis initially indicates effective structure and design

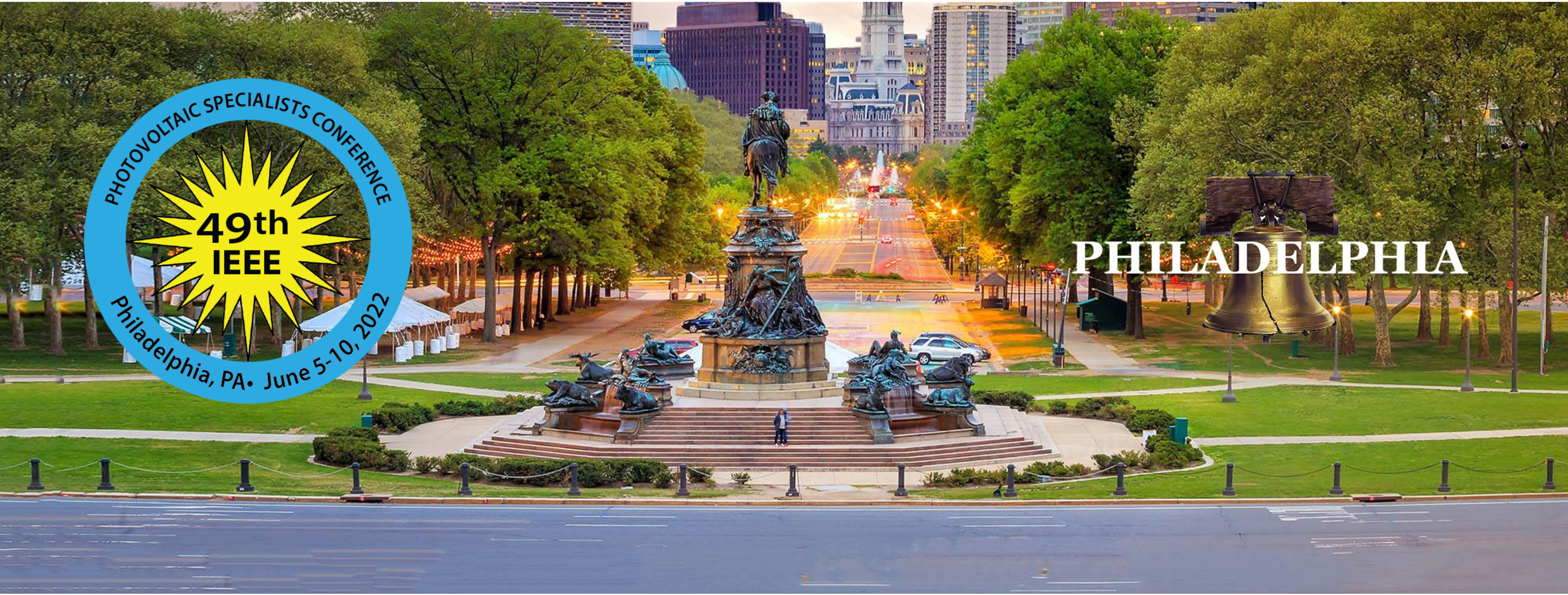
● There is a small red shift in emission and absorption after irradiation

● The irradiated solar cells self-heal after about 2 months

● After a thermal stress up to 490 K the efficiency improves when measured at room T, due to the effect of annealing

● Important take away: using proper transport material and packaging this system can have very good tolerance against high temperatures

Thank you for your time and attention



Questions?

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