# Versatility of perovskite semiconductors as detectors for visible and high energy photons

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Lead halide perovskites emerged as excellent absorber materials in photovoltaic research a few years ago. Thereafter they were demonstrated as versatile photonic sources [1] and photon detecting materials [2]. As to the latter, detecting capability has been reported in two distinct spectral ranges: visible light and high energy photons (X-ray and gamma-rays). Detectors of such hard radiation that are low-cost, are highly-sensitive and operate at ambient temperatures are highly desired for numerous applications such as in defence, medicine, as well as in research. Recently we have shown that $MAPbI_3$ polycrystalline films work as sensitive detectors of soft X-ray radiation [2]. We also demonstrated that 0.3-1 cm, solution-grown single crystals (SCs) of semiconducting hybrid lead halide perovskites ($MAPbI_3$, $FAPbI_3$ and $I^-$treated $MAPbBr_3$, where MA=methylammonium, FA=formamidinium) can serve as solid-state gamma-detecting materials [3]. This possibility arises from a high mobility(μ)-lifetime(τ) product of 1.0-1.8 $10^{-2}$ $cm^2$ $V^{-1}$, the low dark carrier density of $10^9$ - $10^{11}$ $cm^{-3}$ and low density of charge traps of $10^9$ - $10^{10}$ $cm^{-3}$, and a high absorptivity of hard radiation by the lead and iodine atoms.

Lead halide perovskites are highly compelling materials for the detectors operated in the visible spectral range, as they feature high optical absorption coefficients and excellent compositional tunability of their bandgaps, easily achievable via inexpensive solution growth. This allowed as constructing a full-colour sensor with three layers, complimentary detecting blue, green and red photons [4]. We find that this prototype detector could faithfully reproduce simple one-dimensional images and realistic two-dimensional images with excellent colour resolution. Such vertically layered detectors offer several advantages over traditional Bayer-type dissipative and subtractive optically filtered detectors: a potentially higher spatial resolution improves optical efficiency suppresses the occurrence of colour moiré and de-mosaicing artefacts.

[1] S. Yakunin, L. Protesescu, F. Krieg, M. I. Bodnarchuk, G. Nedelcu, M. Humer, G. De Luca, M. Fiebig, W. Heiss, and M. V. Kovalenko. Nature Communications, **2015**, 9, 8056.
[2] S. Yakunin, M. Sytnyk, D. Kriegner, S. Shrestha, M. Richter, G. Matt, H. Azimi, C. J. Brabec, J. Stangl, M. Kovalenko and W. Heiss. Nature Photonics, **2015**, 9, 444-449.
[3] S. Yakunin, D. Dirin, Y. Shynkarenko, V. Morad, I. Cherniuh, O. Nazarenko, D. Kreil, T. Nauser and M. Kovalenko. Nature Photonics, **2016**, 10, 585–589.
[4] S. Yakunin, Y. Shynkarenko, D.N. Dirin, I. Cherniukh and M.V. Kovalenko (submited).