Fast and bright Purcell-enhanced perovskite scintillator (FAPURITE)

Scintillating materials are sensitive to ionizing radiation and are currently used in many detection systems in areas ranging from medical imaging, homeland security, high-energy physics (HEP) calorimetry, energy, industrial control, oil drilling, to quantum sensing. They are converting the high-energy radiation, e. g. X- and gamma-ray, by absorbing its energy and turning it into visible light that can be detected by the conventional photodetectors. The materials namely scintillators have properties that can offer functionalities for applications beyond static radiation imaging, i.e., time-of-flight detection, spectroscopy-, and ultrafast-multi-frame radiation imaging. Two known properties are light yield, which determines the numbers of visible photons that are created per deposited radiation energy, and decay times, which defines how fast those photons being emitted after the radiation. Both affects the derivative value of coincidence timing resolution (CTR) in positron emission tomography (PET), which is proportional to a square root of light yield divided by the decay time, and output counting rate (OCR) in photon counting computed tomography (PCCT) and fast spectral X-ray imaging. The CTR below 30 ps will improve the imaging quality of TOF PET by hugely increasing the gain in signal-to-noise ratio while the OCR of PCCT >20 Mcps/pixels will be better than the current technology CdTe/CZT semiconductor. For PET, The best commercial scintillators, Lu_2SiO_5(LSO):Ce, have CTRs of 60 ps but their cost is about 426 EUR for 20x20x20 mm^3 making the total cost of TOF PET system of about millions EUR. For PCCT, they are not so many progresses in the field as the current one is based semiconductor technology while it requires more stable and reliable detector.

Looking to the photovoltaic industry, solution processable scintillators with perovskite structures, which may reduce the cost down to fifty times than that of LSO: Ce, can be the answer for TOF PET, PCCT, and fast spectral X-ray imaging. They are two potential candidates: two-dimensional hybrid organic inorganic (2D HOIP) and lead-free all inorganic perovskite (AIP) crystals. On one hand, the best 2D HOIP crystals have light yield slightly greater than 20 photons/keV deposited energy and the response time less than 5 ns resulting CTR of 80 ps, slightly worse than LSO: Ce but absorption length only 4 times longer than that of LSO:Ce. On the other hand, the lead-free AIP crystals, which absorption length is the same as that of LSO:Ce, may yield 100 photons/keV but the response times are about μs pushing the CTR back longer than 150 ps. Thus, for 30 ps, CTRs of 2D HOIP and AIP scintillators need to be improved larger than 3 or 5 times. For PCCT, 2D HOIP crystals already yield 10 Mcps/pixel, which is only two less than the current semiconductor technology.

FAPURITE will focus on solving these perovskite scintillator problems through nanophotonics from both enhancement of light yield and improvement of decay time at the same time so that we can decrease the CTR or increase OCR. We confident to achieve the overall objectives through a multi-disciplinary methodology that relies on scientific investigations, dissemination, and exploitation. As a final goal, we want to establish Poland as the industrial leader in the scintillator market for TOF PET, PCCT and fast spectral X-ray imaging as a portion from total 508-million-EUR projected market size in 2026. For the fundamental aspects, Purcell enhanced perovskite scintillators will open new venue of material physics and photonics.