Fast timing detection of charged-particle induced radioluminescence from perovskite quantum dots

Csaba Buga, Mátyás Hunyadi, Lóránt Csige, Attila Csík

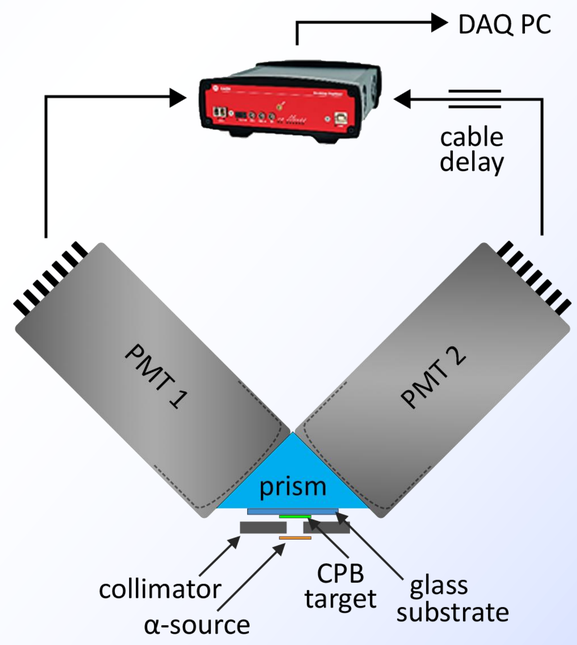
Institute for Nuclear Research (ATOMKI), Debrecen, Hungary

Luminescent quantum dots (QD) are promising candidates for high-precision timing detectors due to their subnanosecond optical response to exposure of charged particle beams like protons or alpha particles. The employment of perovskite nanocrystals are particularly attractive, since they exhibit unique charge carrier dynamics, which leads to superior optoelectronic features with respect to conventional semiconductors.

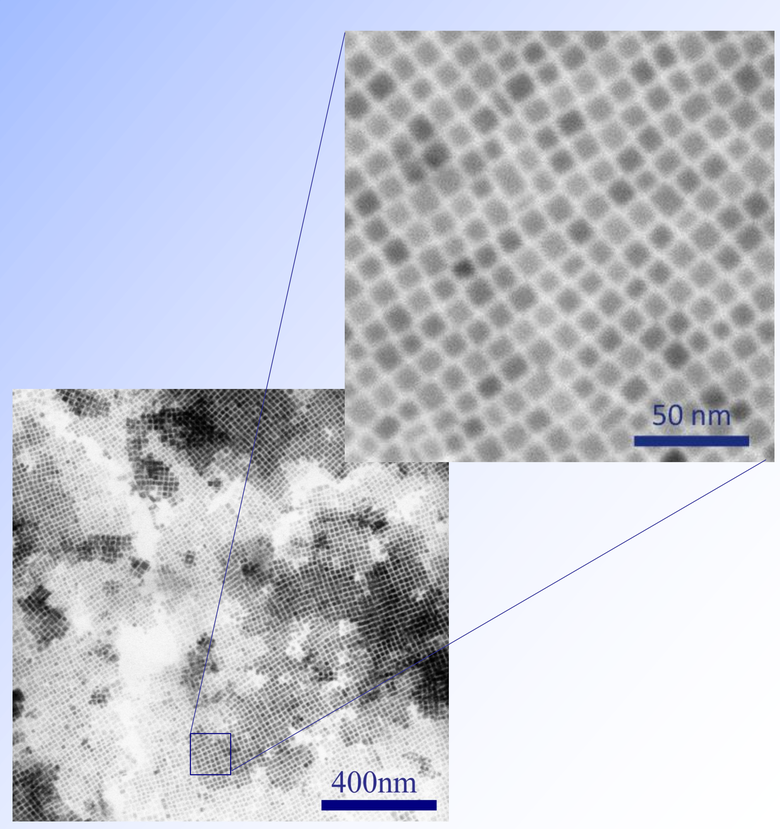
Furthermore, their compositional versatility, reliable operation and facile synthesis may open a gateway toward engineering of new functionalities in sensor technologies. The assembly of packed QD monolayers on photon detectors preferentially operating in avalanche mode may overcome most of the technical obstacles and restrictions in nuclear and particle physics experiments that often require high-precision time-of-flight (TOF) or high-frequency coincidence measurements with suppressed dead-time.

Hot-injection method has been used for preparing the $CsPbBr_3$ nanocrystals (NCs). They were dropped on a glass substrate before the measurement.

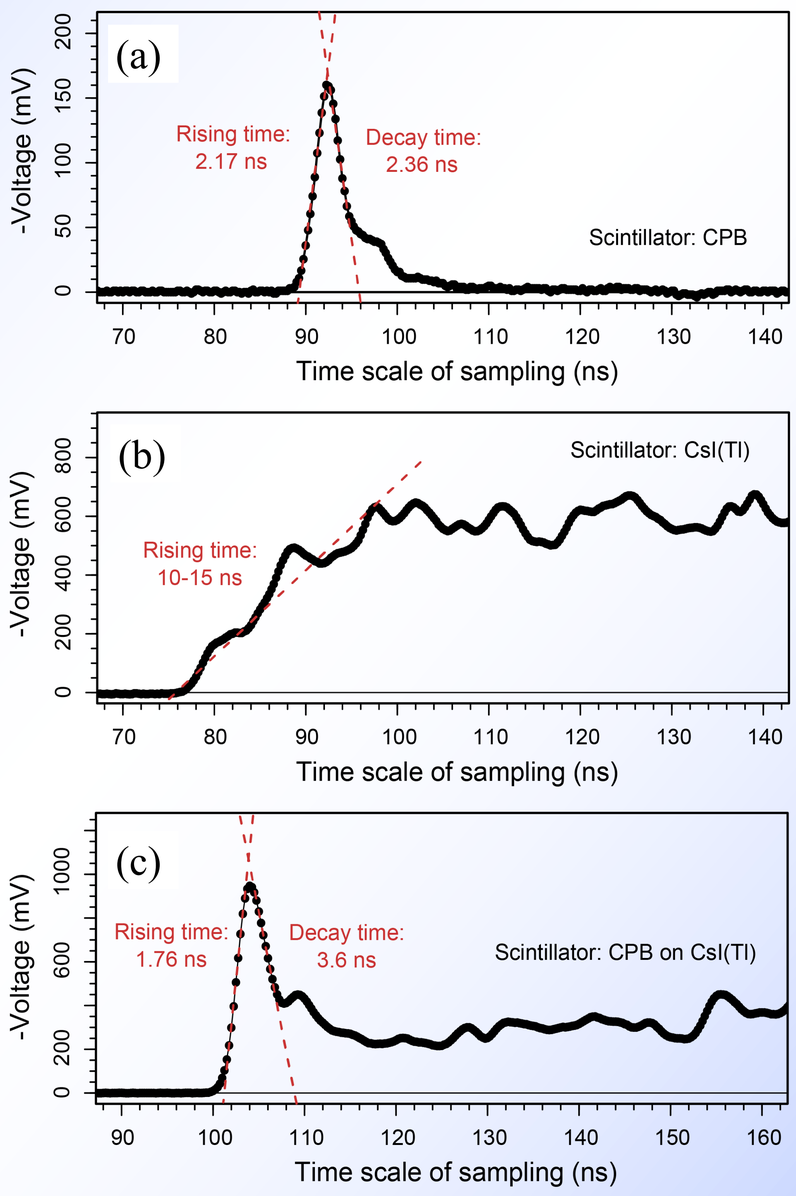
The morphology of the nanoparticles were analyzed by a Scanning Electron Microscope (FIB-SEM, ThermoScientific Scios2). To obtain crystallographic information from the nanocrystals, the X-ray diffraction measurements were performed by Rigaku SmartLab diffractometer.



Schematic view of the experimental setup. Two photomultiplier tubes (PMT) are optically connected to a glass prism, which splits the α-induced radioluminescent light emitted from the $CsPbBr_3$ clusters.



Scanning electron microscope images of as-prepared $CsPbBr_3$ nanoparticles.



Pulse shapes of typical events recorded for a single radioluminescent flash from (a) $CsPbX_3$ NCs, (b) a 3-mm thick CsI(Tl) scintillator and (c) $CsPbX_3$ NCs deposited on the bulk CsI(Tl) crystal.

The rise and decay times of luminescent pulses from the $CsPbBr_3$ nanoparticles are in the range of nanoseconds.

From the scanning electron microscope images the size distribution of these nanoparticles peaks about 10 nm, and they are selforganized in a close-tight cubic structure with a uniform spacing of 3 nm.

The current investigation provided that compared to the most commonly used CsI(Tl) scintillators the $CsPbBr_3$ nanoparticles exhibit a much lower rise and decay times, which are expected beneficial for high-performance timing sensors.

Although, due to the nanoscaled thickness of these luminescent crystals we cannot gain spectroscopic information on the particle energy, their assembly on the surface of fully integrating detectors, the evaluation of the composite pulse shapes enables the precise extraction of energy information with high-speed triggering capabilities.

The work is supported by GINOP-2.3.2-15-2016-00041 project & Széchenyi 2020 Program under Project VKSZ-14-1-2015-0021