Artificial optic-neural synapse realized in all-inorganic perovskite quantum dots

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ABSTRACT

This project proposes the use of $CsPbBr_3$ QDs as a basis, to effectively integrate optical sensing and memory devices, and create an advanced artificial visual-neural synapse. The synapse exhibits typical resistive switching characteristics and synaptic behavior, including paired-pulse facilitation (PPF), long-term potentiation (LTP), long-term depression (LTD), excitatory postsynaptic current (EPSC), and spike-number-dependent plasticity (SNDP). The results validate our $CsPbBr_3$ QDs synaptic devices open up a brand-new horizon for the advanced application of artificial optic-neural learning capabilities.

I. MOTIVATION

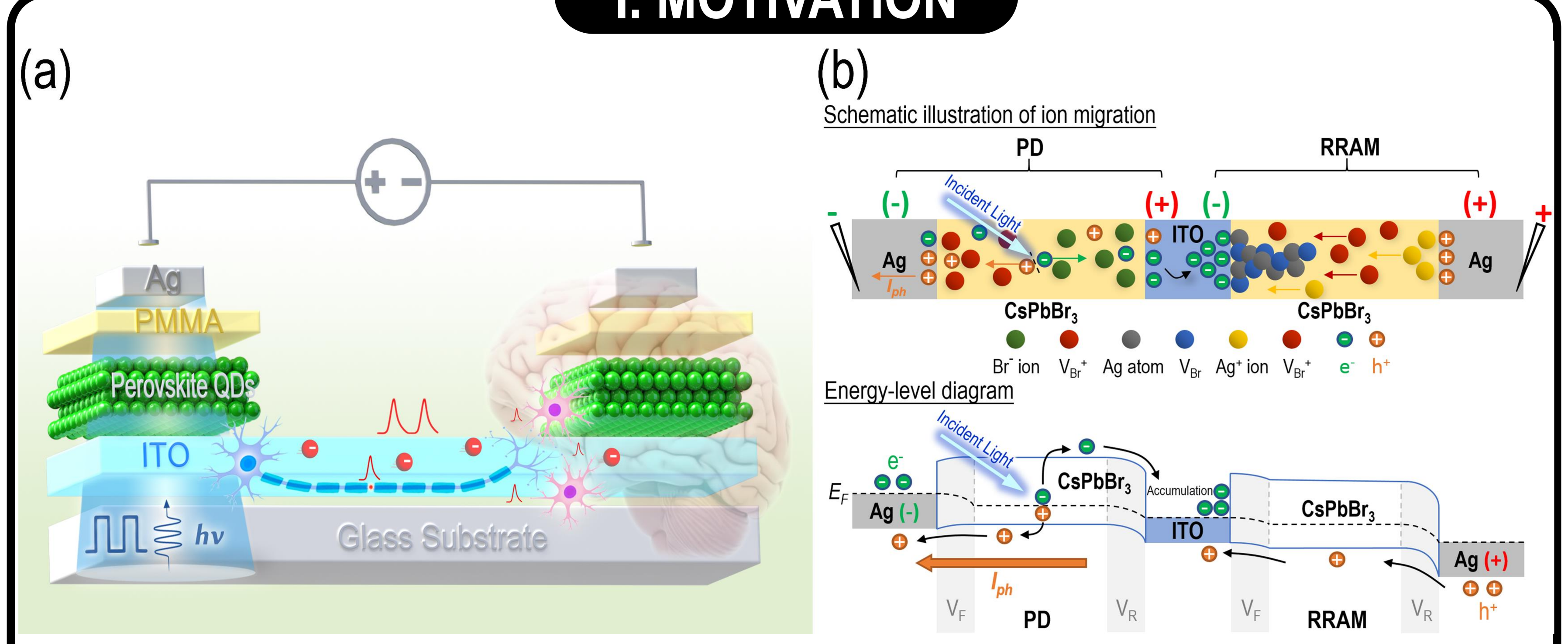

Fig. 1 Schematically illustrating the principle of artificial visual-neural synapse realized by all-inorganic perovskite quantum dots.

II. CHARACTERISTICS

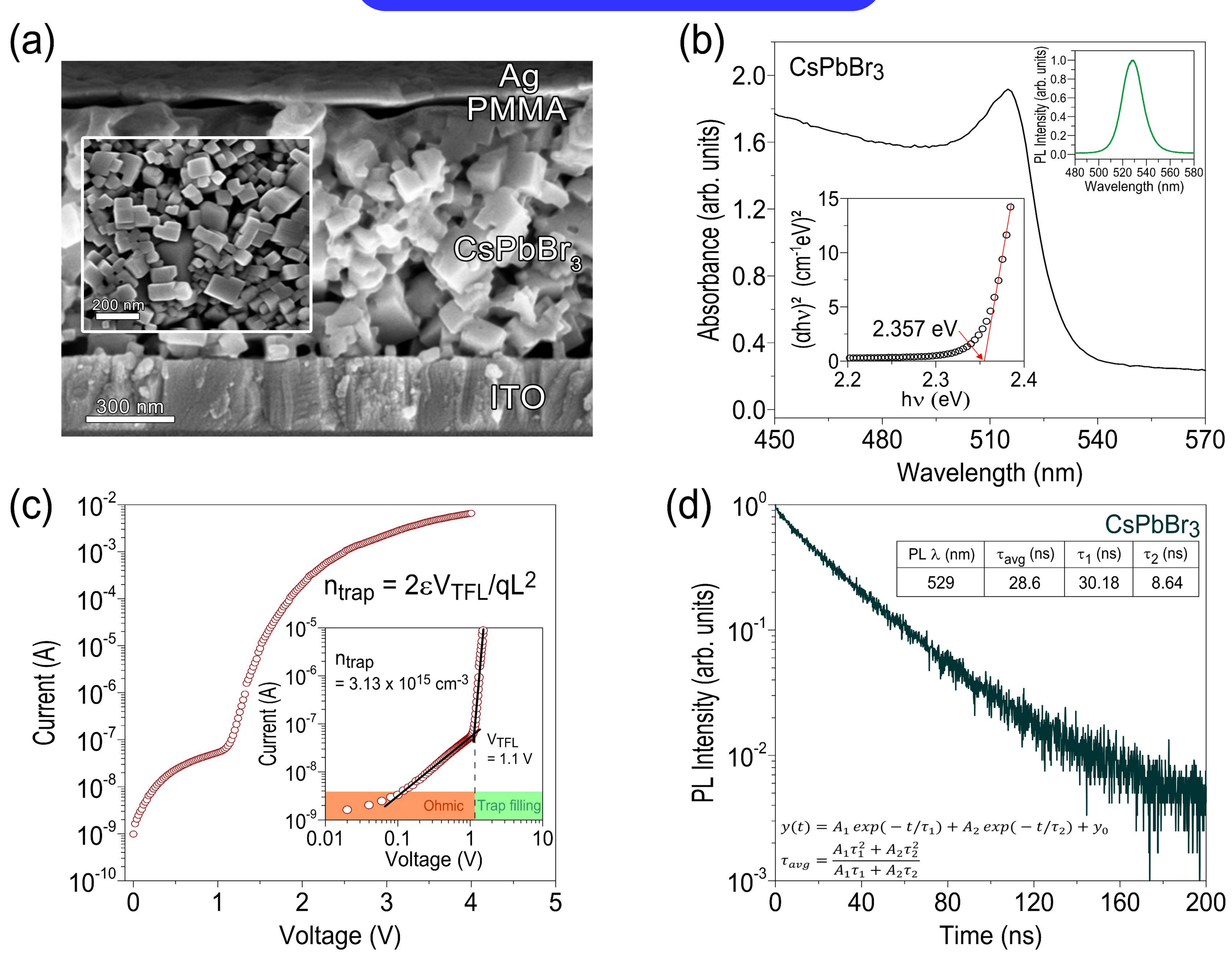

Fig. 2 (a) SEM image of $CsPbBr_3$ QD-based optic-neural synapse device. (b) Absorption and PL spectra of $CsPbBr_3$ QDs. (c) Analyzing *I-V* characteristic of $CsPbBr_3$ QDs by space charge limited current method to extract trap density. (d) TR-PL Spectrum of $CsPbBr_3$ QDs with bi-exponential fit to extract decay time constants.

III. DISSCUTION

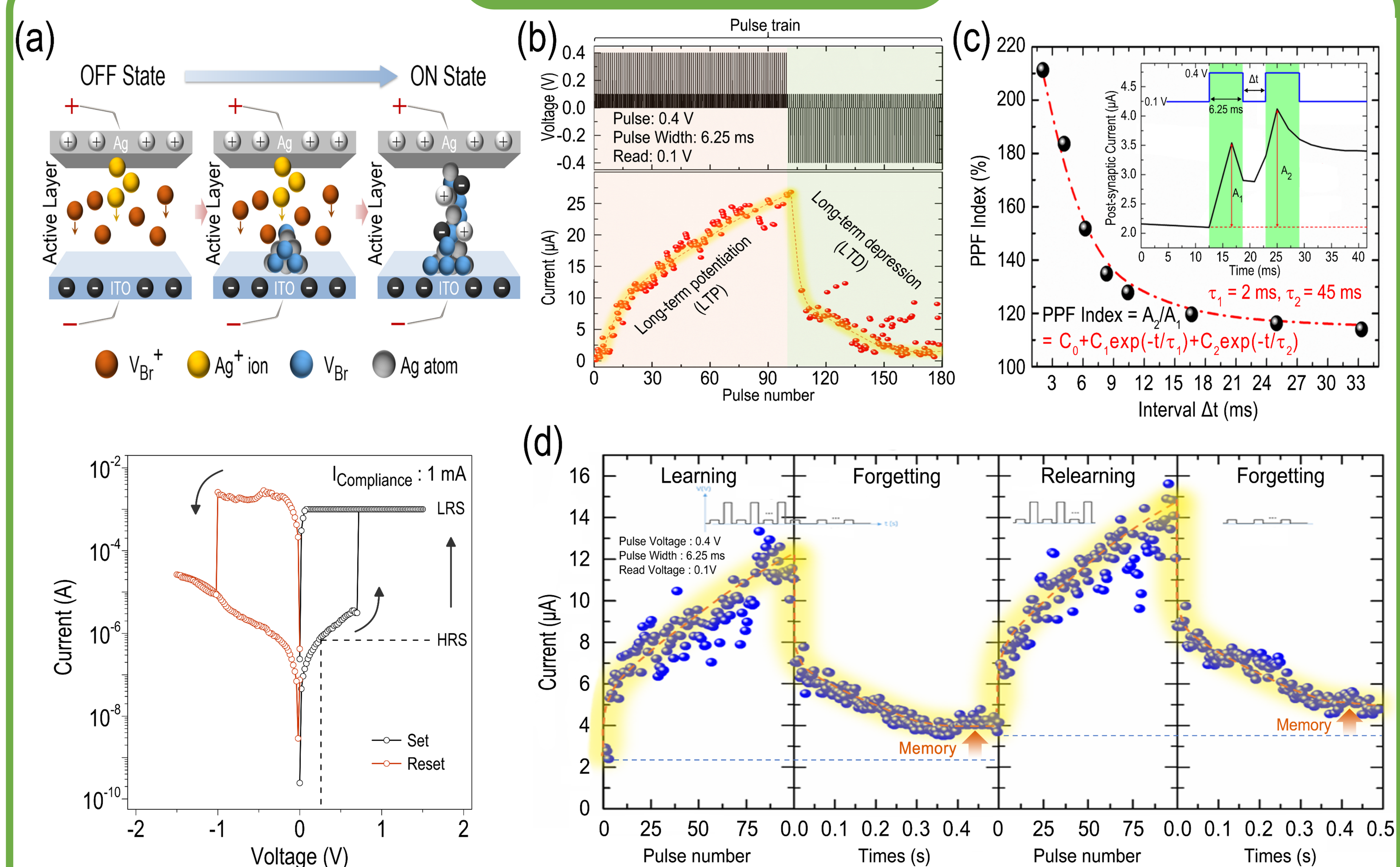

Fig. 3 (a) (top) Mimicking synaptic behavior achieved by the $CsPbBr_3$ QD-based RRAM, and (bottom) the corresponding *I-V* characteristic. (b) Synaptic LTP and LTD plasticity of the $CsPbBr_3$ QD-based RRAM triggered by 100 positive (+0.4V) and 80 negative (-0.4V) pulses train (c) PPF and (d) multiple learning processes demonstrated by the $CsPbBr_3$ QD-based RRAM.

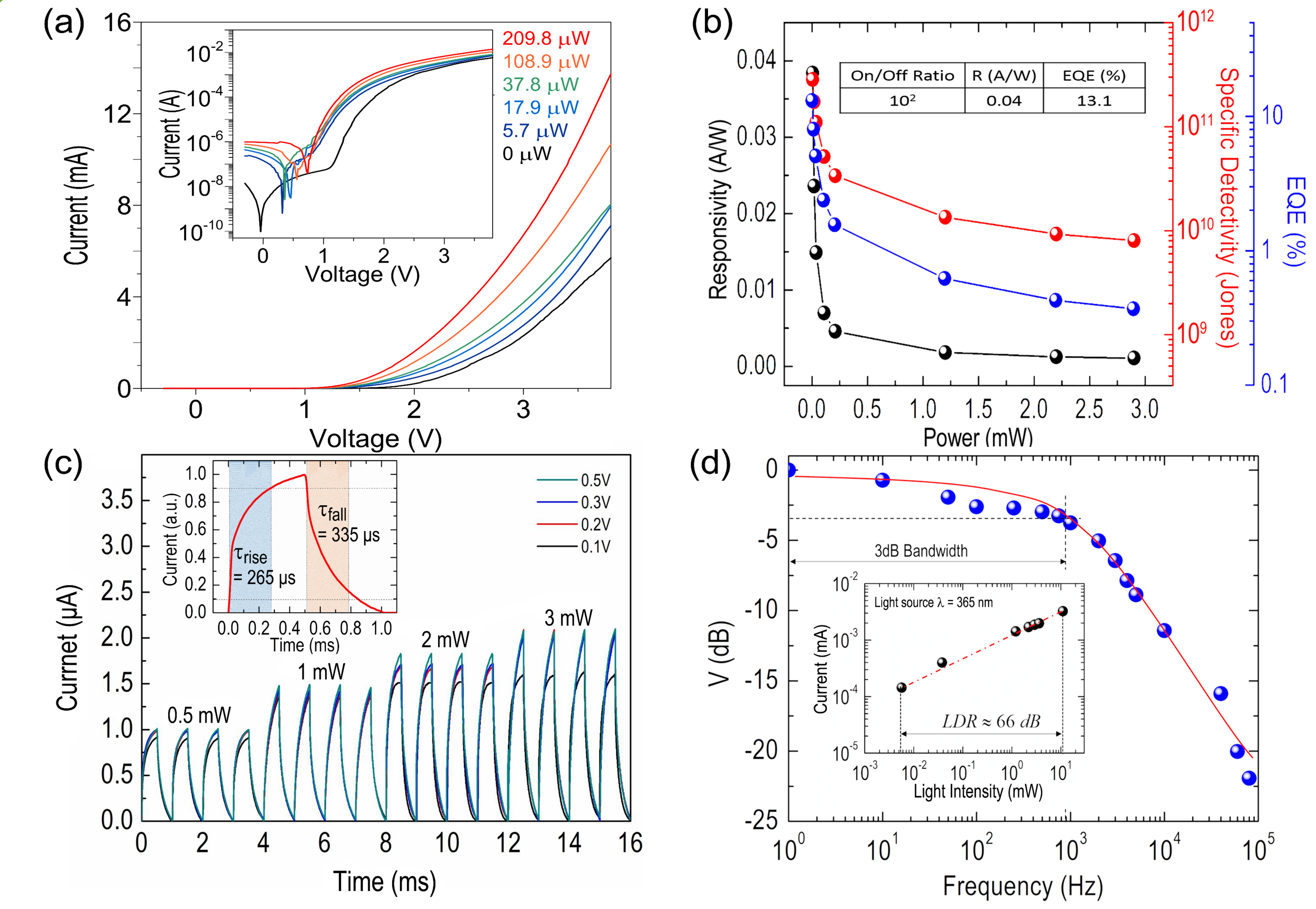

Fig. 4 (a) *I–V* characteristic of $CsPbBr_3$ QD-based optical sensor EQE vs. illumination power and (b) the corresponding photoresponsivity, specific detectivity, and EQE. (c) Time domain photoresponse speed at 1kHz under light illumination.(**λ** = 365 nm) (d) Relative photoresponse vs. light-modulation frequency. Inset: detected photocurrent vs. external light intensity.

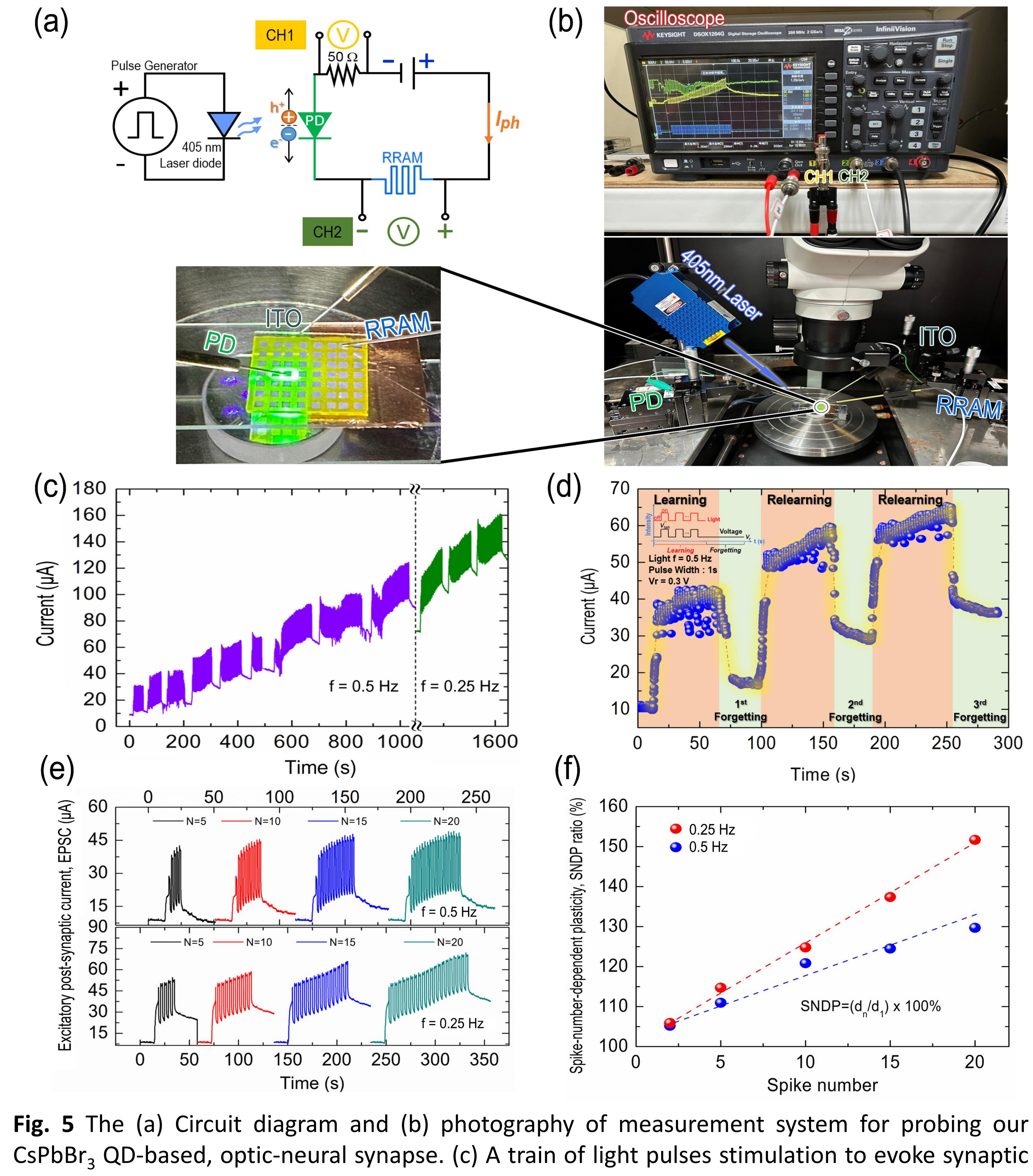

Fig. 5 The (a) Circuit diagram and (b) photography of measurement system for probing our $CsPbBr_3$ QD-based, optic-neural synapse. (c) A train of light pulses stimulation to evoke synaptic signals and (d) to emulate "learning-experience". (e) Variations of EPSC response with 5-20 continuous optical pulse stimulations (top: f = 0.5Hz =; bottom: f = 0.25Hz). (f) SNDP ratio (d_n/d_1) vs. the number of optical pulses for both stimulated light frequencies of 0.25Hz and 0.5 Hz.

IV. SUMMARY

1. We have realized an advanced, one-material ($CsPbBr_3$ QD-based) synaptic device that enables the emulation of optic-neural plasticity triggered in the human brain.
2. Several important plasticity behaviors, such as PPF, LTP, LTD, ESPC and SNDP, are clearly observed and evidently realized in the $CsPbBr_3$ QD-based optic-neural synaptic device.
3. We believe this work could lead to a more advanced application associated with a more complicated device architecture, featuring learning and cognition functionalities.