Electronic Supporting Information

Optoelectronic synaptic transistors based on upconversion nanoparticles

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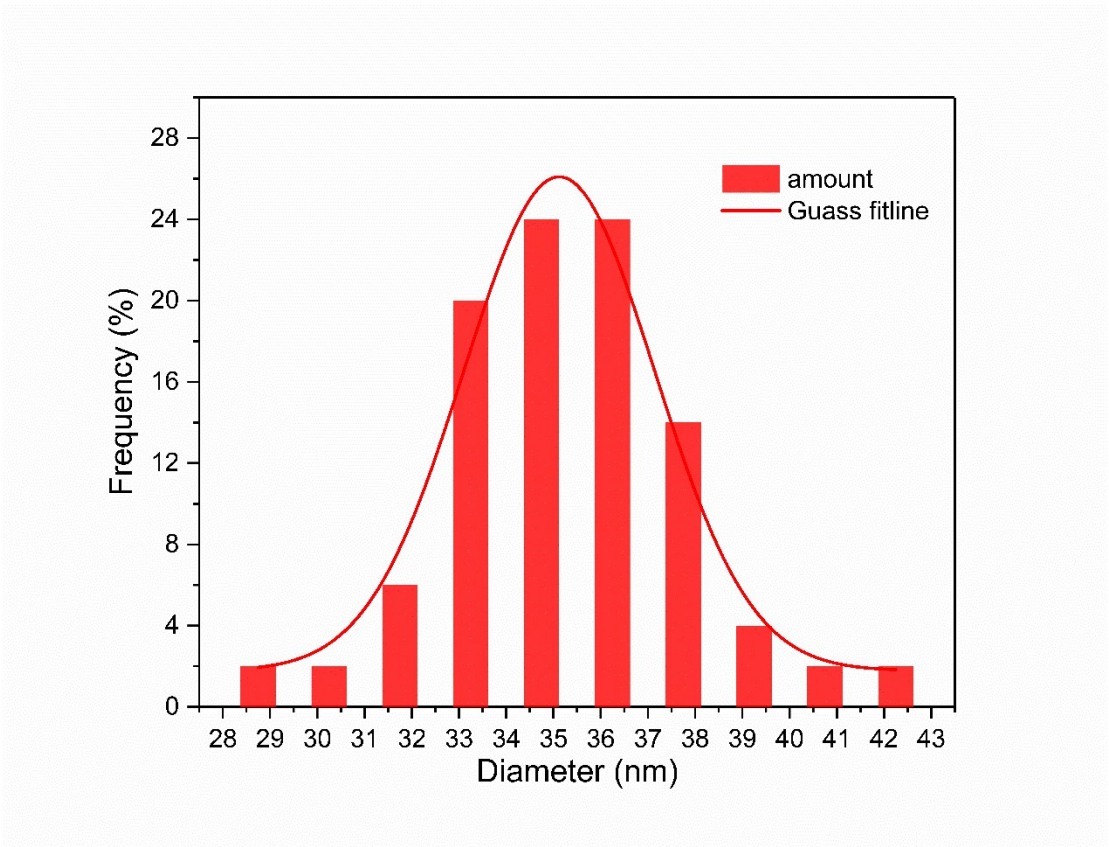

Fig. S1. Statistical particle size distribution of 50 nanoparticles.

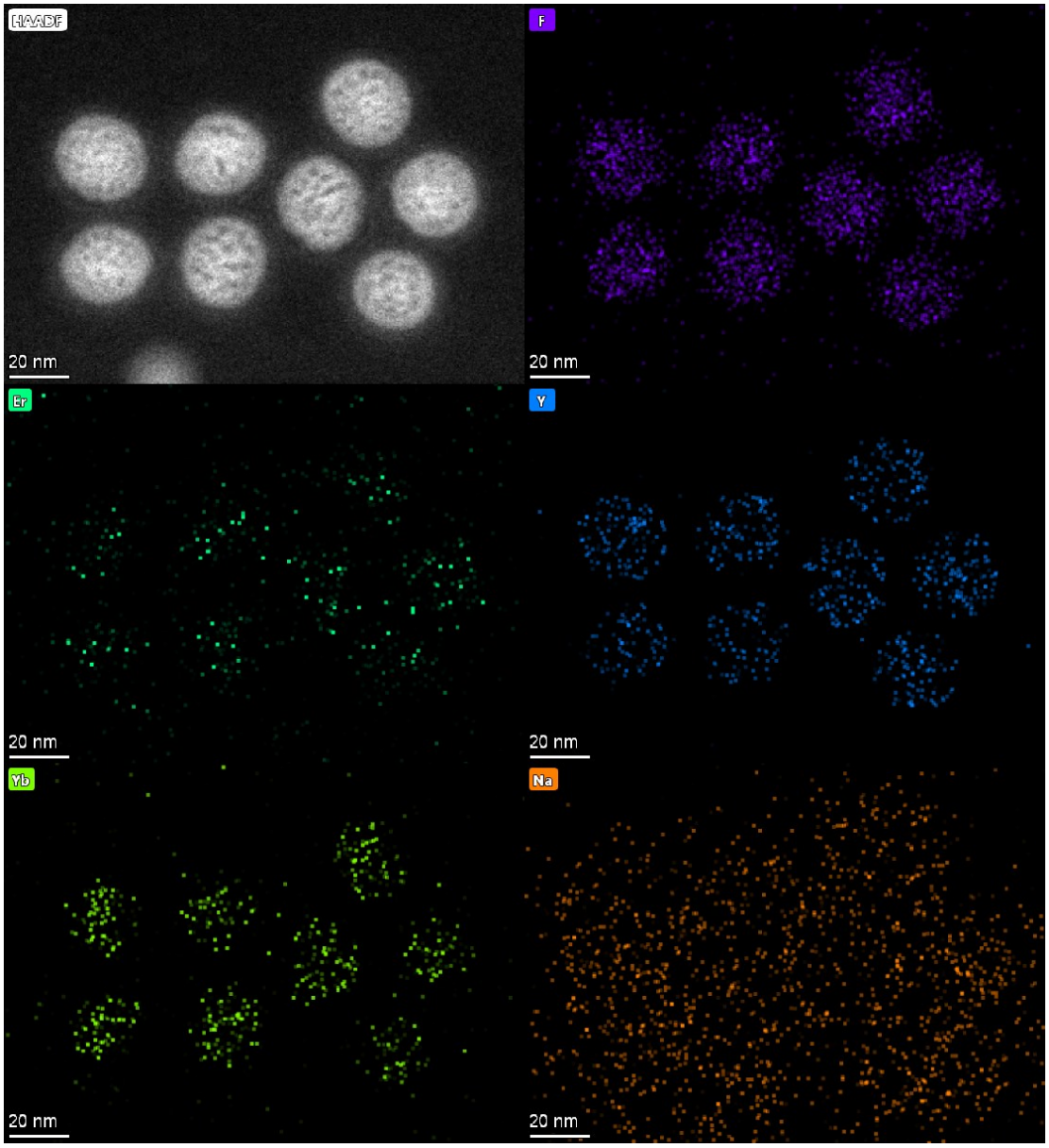

Fig. S2. High-angle annular dark-field (HAADF) image and corresponding elemental mapping.

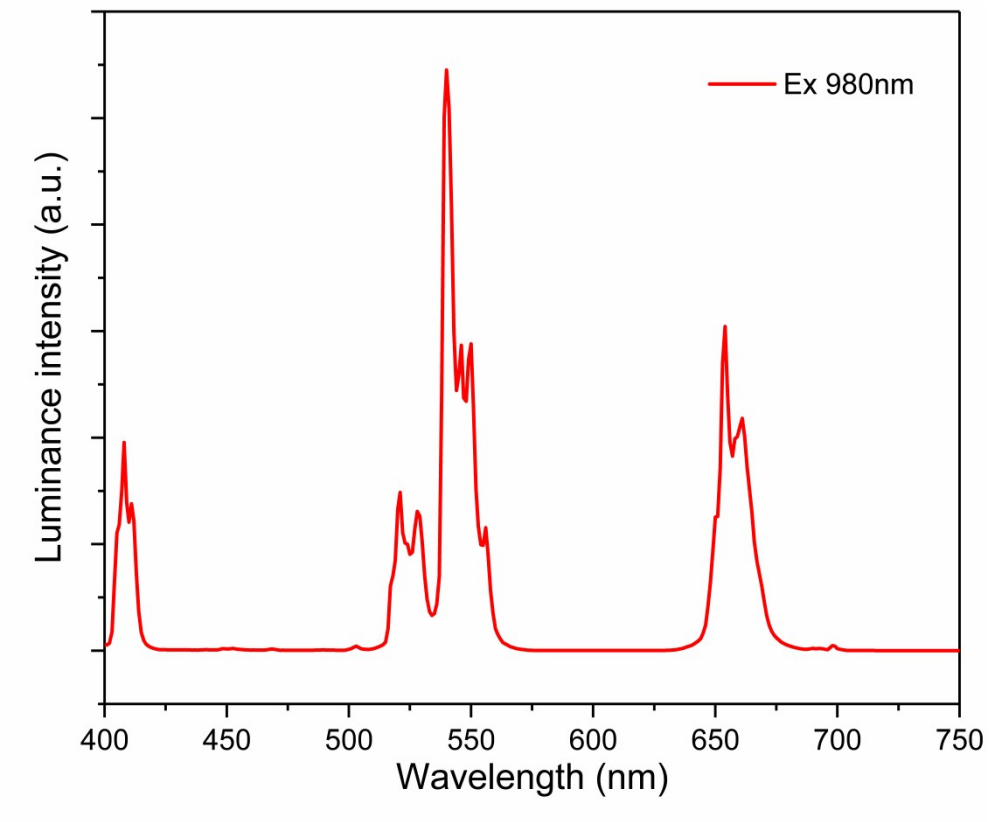

Fig. S3. PL emission spectrum of $NaYF_4:Yb^{3+}/Er^{3+}@NaYF_4@SiO_2$ nanoparticles.

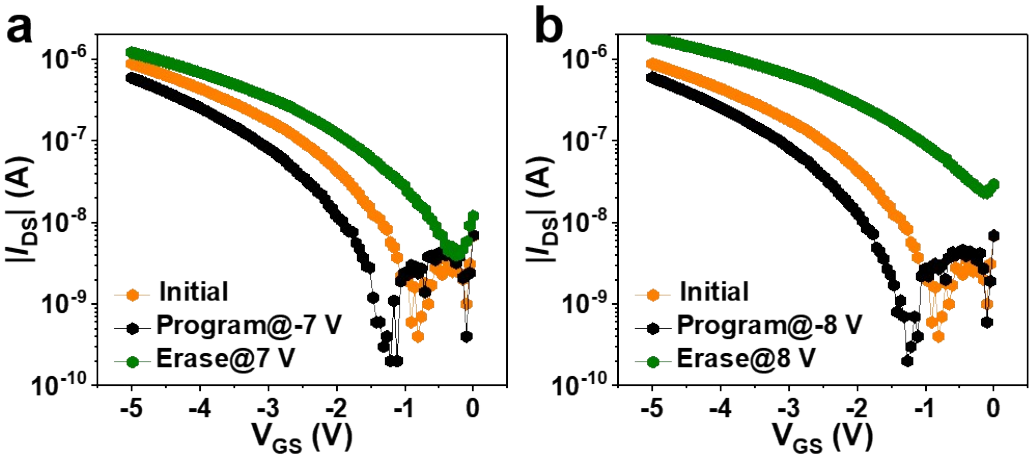

Fig. S4. The transfer curves of the memory device with doping concentration of 0.15 mg mL-1 under different programming voltage or erasing voltage (1 s; V_{DS} = -5V). (a) P: -7 V, E: +7 V; (b) P: -8 V, E: +8 V.

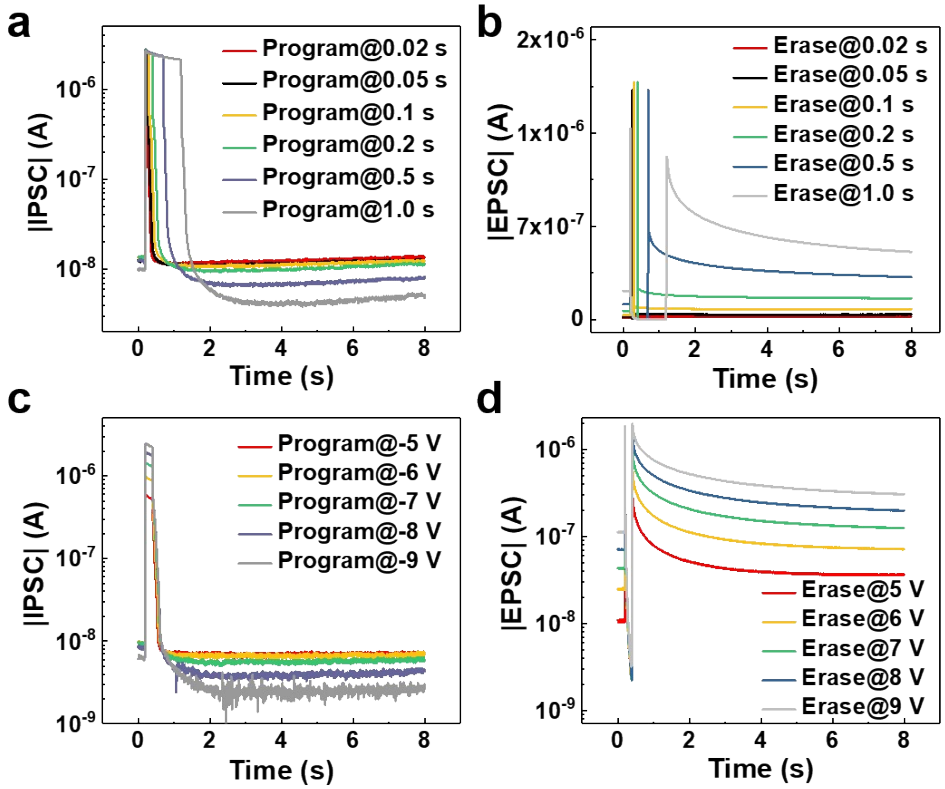

Fig. S5. The PSC generated by (a) programming operation (amplitude: -8 V, base voltage: -0.5 V, V_{DS} = -5 V) and (b) erasing operation (amplitude: 8 V, base voltage: -0.5 V, V_{DS} = -5 V) with diverse duration time from 0.02 to 1.0 s. The PSC generated by (c) programming operation and (d) erasing operation under the identical duration time (0.2 s) with diverse pulse amplitude from ± 5 V to ± 9 V.

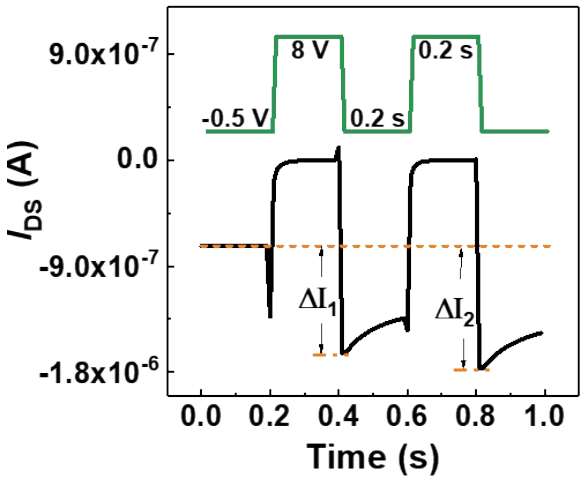

Fig. S6. The PPF behavior of UCNPs-based synaptic transistor triggered by a pair of presynaptic pulses (8 V, 0.2 s, interval: 0.2 s, base voltage: -0.5 V, V_{DS} = -5 V).

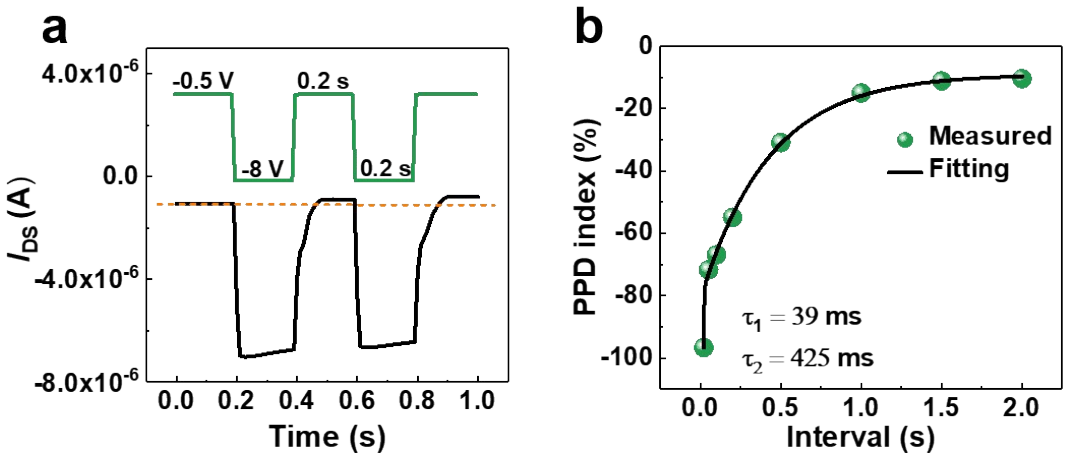

Fig. S7. (a) The PPF index under different time interval. (b) The PPD behavior of UCNPs-based synaptic transistor triggered by a pair of presynaptic pulses (-8 V, 0.2 s, interval: 0.2 s, base voltage: -0.5 V, V_{DS} = -5 V).

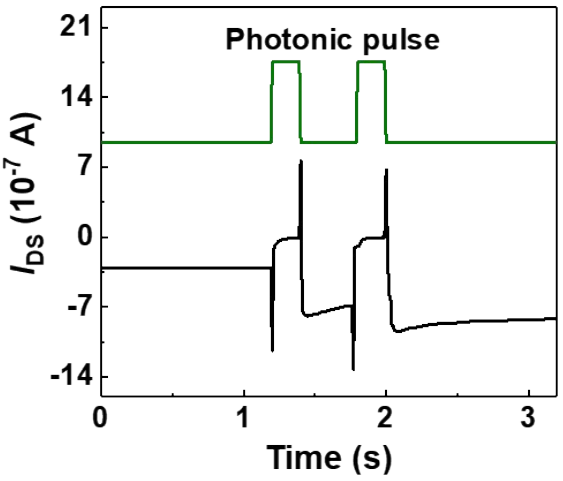

Fig. S8. The EPSC achieved by two successive light pulses.

Table S1. Summary of Previously Reported Flash Memory Performance.[a]

semiconductor layer	tunneling dielectric layer	charge trapping layer	blocking dielectric layer	initial threshold voltage (V)	operating voltage (V)	memory window (V)	I_{on} (A)	I_{off} (A)	I_{on}/I_{off}	P/E cycle	ref
BPE-PTCDI	no	PCBM:N(PTPMA)3	SiO_2 (100nm)	~4	50	~30	10^{-6}	10^{-9}	$\sim10^{3}$	200	1
pentacene	PS	graphene quantum dots	SiO_2 (100nm)	~1	60	~35	10^{-4}	10^{-10}	$\sim10^{6}$	100	2
NDI2OD-T2	no	PS:[P3HT:PCBM]	PMMA (280nm)	~4	50	~3.5	10^{-7}	10^{-9}	$\sim10^{2}$	500	3
NDI2OD-T2	no	PS:Tips-Pen	PMMA (320nm)	ND	55	~10	10^{-6}	10^{-8}	$\sim10^{2}$	500	4
pentacene	no	PaMS/HfO_2	Al_2O_3 (20nm)	ND	11	1.5	10^{-5}	10^{-10}	$\sim10^{5}$	2000	5
C60	pV3D3	Al	pEGDMA	~2	15	8	10^{-6}	10^{-10}	$\sim10^{4}$	1000	6
pentacene	no	PS/DPP	SiO_2 (300nm)	~8	100	~30	10^{-4}	10^{-10}	$\sim10^{6}$	ND	7
TPA-CN-TPE	no	TPA-CN-TPE	SiO_2 (300nm)	~40	100	42	10^{-5}	10^{-9}	$\sim10^{4}$	ND	8
P(NDI2OD-T2)	PMMA	PS-b-PPP	PMMA (400nm)	~11	60	26.7	10^{-6}	10^{-8}	$\sim10^{2}$	500	9

pentacene	pV3D3	p(BDDA-co-HEA)	pBDDA (19nm)	~2	16	~3.3	10^{-7}	10^{-11}	~10^{4}	1000	10
P3HT	no	BCP/$MAPbBr_3$	SiO_2 (100nm)	~8	60	ND	10^{-7}	10^{-10}	~10^{3}	ND	11
IGZO	Al_2O_3	ZnO	Al_2O_3 (35nm)	~1	12	7.1	10^{-5}	10^{-11}	~10^{6}	1000	12
ITZO	no	SiO_x	SiO_2 (20nm)	0.15	13	3.73	10^{-6}	10^{-13}	~10^{7}	ND	13
IGZO	Al_2O_3	IGZO	Al_2O_3 (35nm)	~1	15	3.16	10^{-5}	10^{-11}	~10^{6}	ND	14
IGZO	Al_2O_3	ZAO	Al_2O_3 (60nm)	0.1	10	5.74	10^{-6}	10^{-10}	~10^{4}	ND	15
pentacene	no	UCNPs	Al_2O_3 (30nm)	~2	8	~2.1	10^{-6}	10^{-9}	~10^{3}	500	this work

[a]ND, no data.

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