Electronic Supplementary Material (ESI) for Inorganic Chemistry Frontiers.

Supporting Information

Near-Infrared-Light-Mediated High-Throughput Information Encryption Based on Inkjet Printing of Upconversion Nanoparticles

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Experimental details

Chemicals: Holmium oxide (Ho_2O_3, 99.99%), erbium oxide (Er_2O_3, 99.99%), ytterbium oxide (Yb_2O_3, 99.99%), neodymium acetate (III) hydrate ($C_6H_9O_6Nd{\cdot}xH_2O$, 99.9%), trifluoroacetic acid (CF_3COOH, AR), sodium trifluoroacetate (CF_3COONa, 98%), oleic acid (OA) and 1-octadecene (ODE) were purchased from Aladdin. Yttrium oxide (Y_2O_3, 99.99%), acetic acid (CH_3COOH, AR), ethanol (AR), cyclohexane (AR), chloroform (AR), toluene (AR), sodium hydroxide (NaOH, AR), ammonium fluoride (NH_4F, AR) were purchased from Sinopharm Chemical Reagent Co. (China). Deionized (DI) water (resistivity ~ 18.25 MΩ) was used throughout the experiments.

Instruments: The morphologies of upconversion nanoparticles were measured with JEM-2100 transmission electron microscope (JEOL, Japan) with a working voltage of 200 kV. The crystal structures of upconversion nanoparticles were carried out with an X-ray diffractometer (Bruker, D8 Advance, Germany) with a Cu-Kα radiation (λ = 1.5406 Å). Fluorescence spectra of paper and luminescence spectra of upconversion nanoparticles were characterized on a fluorescence spectrometer (Hitachi, F-4600, Japan) equipped with a 980 nm CW laser and an 808 nm CW laser (Kai Site Electronic Technology Co., Ltd.). A

commercial ZF5 portable UV lamp was used to excite the commercial UV ink. The 980 nm CW laser and 808 nm CW laser were applied to excite UCNPs. The photographs of substrates and bright field pictures of UCNPs inks were recorded using a digital single-lens reflex camera (Nikon, D7100, Japan). The luminescence images of UCNPs inks were obtained on an in vivo imaging system (PE Spectrum & Quantum FX). An inkjet printer (HP Deskjet 1010) was employed in printing the UCNPs ink on paper.

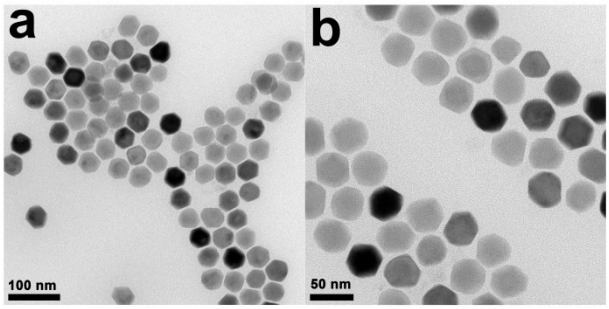

Fig. S1 TEM images of $NaYF_4$:20%Yb,2%Ho nanoparticles.

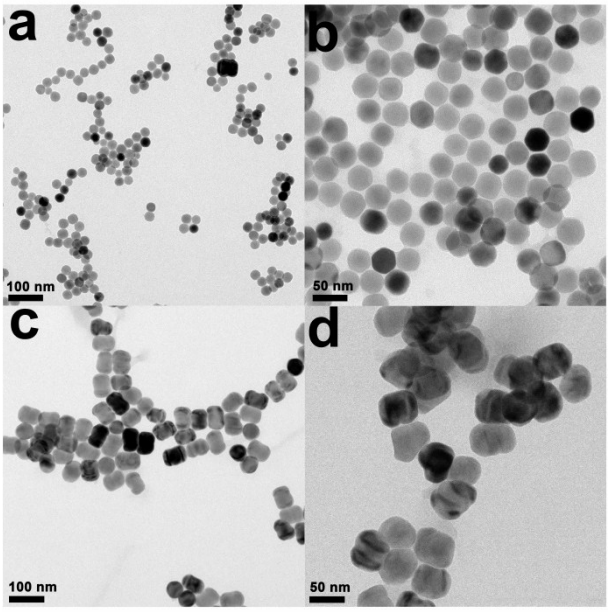

Fig. S2 TEM images of $NaYF_4$:18%Yb,2%Er core nanoparticles (a, b) and $NaYF_4$:Yb,Er@$NaYF_4$:Yb@$NaNdF_4$:Yb@$NaYF_4$:Yb core-shell nanoparticles (c, d).

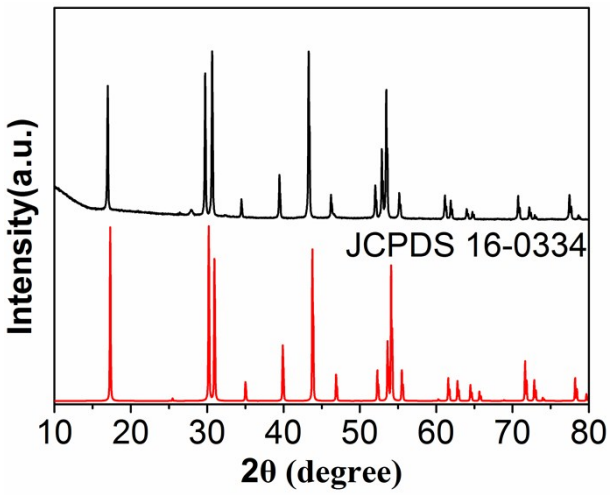

Fig. S3 XRD pattern of $NaYF_4$:20%Yb,2%Ho nanoparticles.

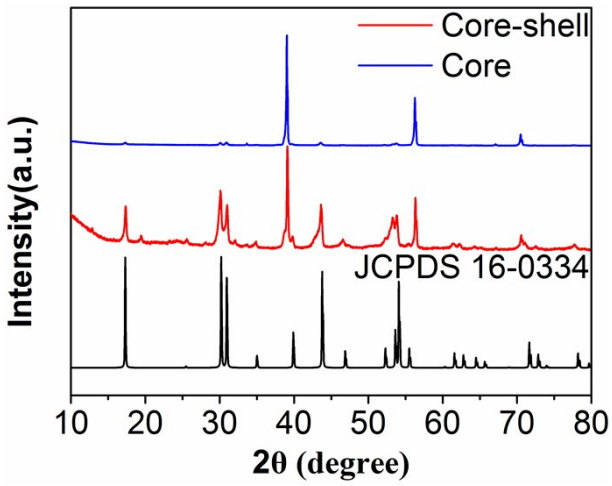

Fig. S4 XRD patterns $NaYF_4$:18%Yb,2%Er core nanoparticles and $NaYF_4$:Yb,Er@$NaYF_4$:Yb@$NaNdF_4$:Yb@$NaYF_4$:Yb core-shell nanoparticles.

Table S1. The concentration, dynamic viscosity and surface tension of the UCNPs-1 ink and UCNPs-2 ink.

Ink	Concentration (mg/mL)	Dynamic viscosity (mPs)	Surface tension (mN/m)
UCNPs-1 ink	0.6	2.008	11.72
UCNPs-2 ink	1.1	2.107	10.17

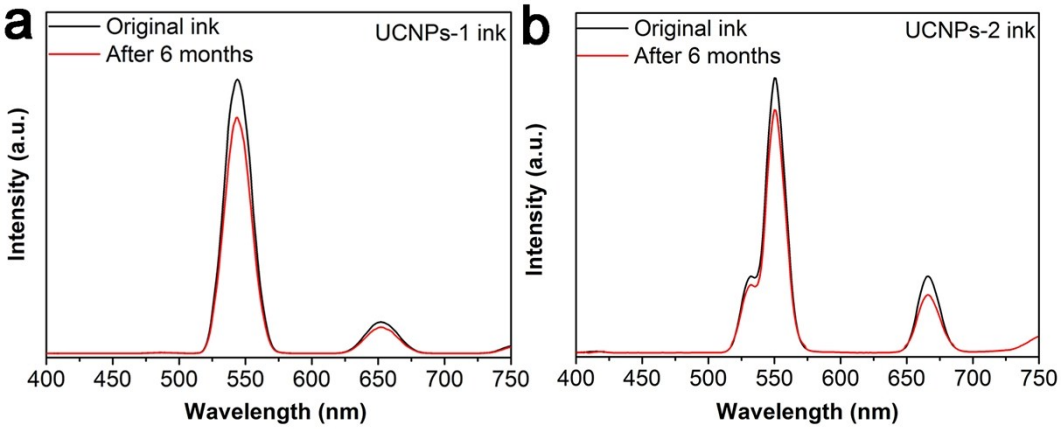

Fig. S5 Luminescence spectra of UCNPs-1 ink (a) and UCNPs-2 ink (b) before and after storage for 6 months.

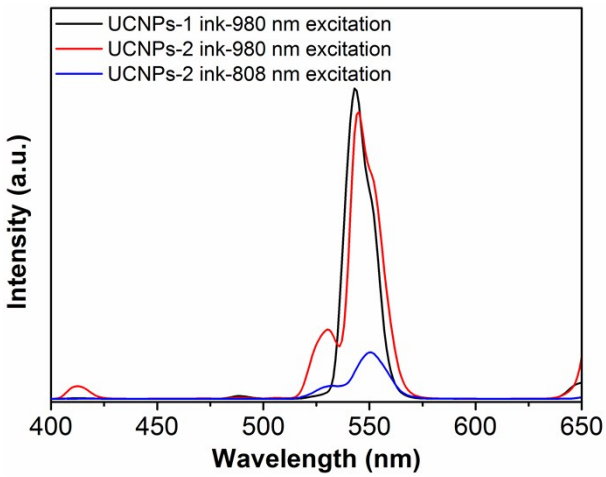

Fig. S6 Luminescence spectra of UCNPs-1 ink and UCNPs-2 ink under 980 nm excitation or 808 nm excitation.

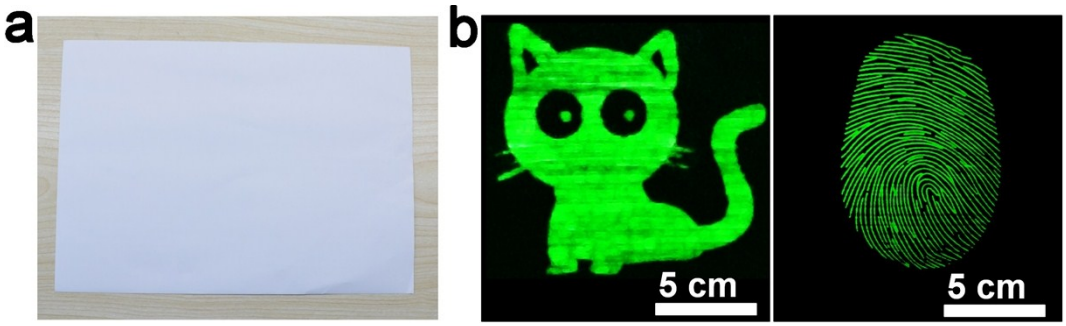

Fig. S7 (a) Image of the paper encrypted with UCNPs-2 ink under ambient light. b) Images of the paper encrypted with UCNPs-2 ink under 808 nm CW laser.

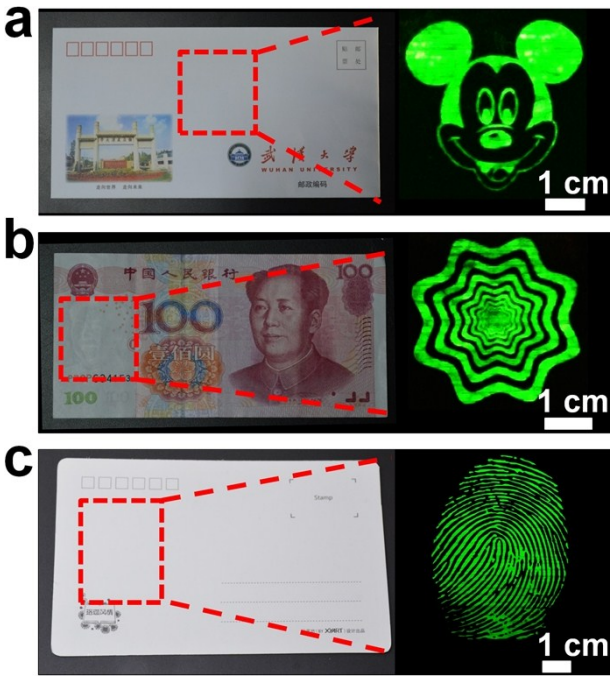

Fig. S8 Images of envelope (a), banknote (b) and postcard (c) encrypted with UCNPs-2 ink under 808 nm CW laser.