Supplementary Information:

Experimental details:

Here we present detailed supplementary information about spectral properties of our RE-doped ZBLAN material (absorption and up-conversion processes) and experimental setups. First of all, optical absorption spectrum of ZBLAN sample was measured by an ultraviolet-visible-infrared (UV-VIS-IR) spectrophotometer Perkin-Elmer Lambda 9 with a resolution of 0.5 nm. This absorption spectra of our glass triply doped with 3.5 Yb^{3+}, 0.5 Er^{3+} and 0.5 of Tm^{3+} ions (in mol%) is shown in Fig. S1, where assignation to transitions from the ground to excited states for the Er^{3+}, Tm^{3+} and Yb^{3+} ions, has been labelled. Optical absorption is clearly dominated by large cross-section of Yb^{3+} ions at around 980 nm corresponding to the $^2F_{7/2} \rightarrow {}^2F_{5/2}$ transition (see energy level diagrams of Fig. S2), resonant with many inexpensive laser diodes and acting as an efficient sensitizing infrared antenna for activation of luminescence of Er^{3+} and Tm^{3+} ions by energy transfer processes.

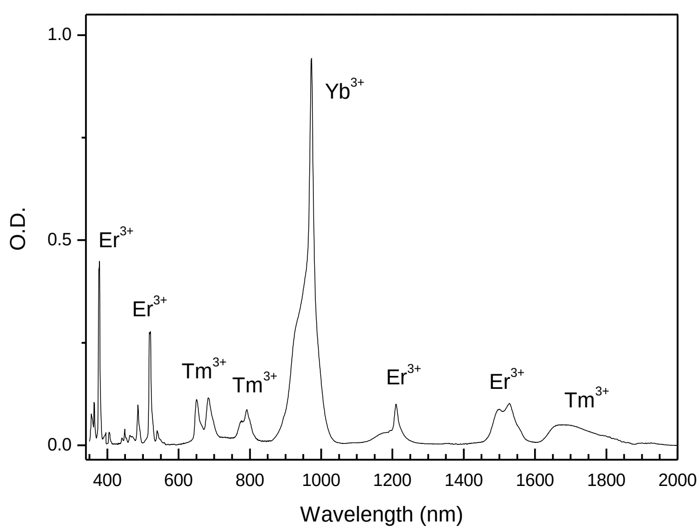

Fig. S1. Absorption spectra of a ZrF_4–BaF_2–LaF_3–AlF_3–NaF glass triply doped with 3.5 Yb^{3+}, 0.5 Er^{3+} and 0.5 of Tm^{3+} ions (in mol%) in the near-IR and visible range clearly dominated by large cross-section of Yb^{3+} ions acting as sensitizing infrared antenna.

Secondly the 980 nm pump mainly excites Yb^{3+} ions, and also Er^{3+} ions, as seen on energy levels of Fig. S2. Then, high efficient energy transfer processes from Yb^{3+} to Er^{3+} and Tm^{3+} ions take place, giving rise to the observed visible and UV emissions through well-known reported up-conversion mechanisms as schematically depicted in Fig. S2.

Electronic Supplementary Material (ESI) for RSC Advances
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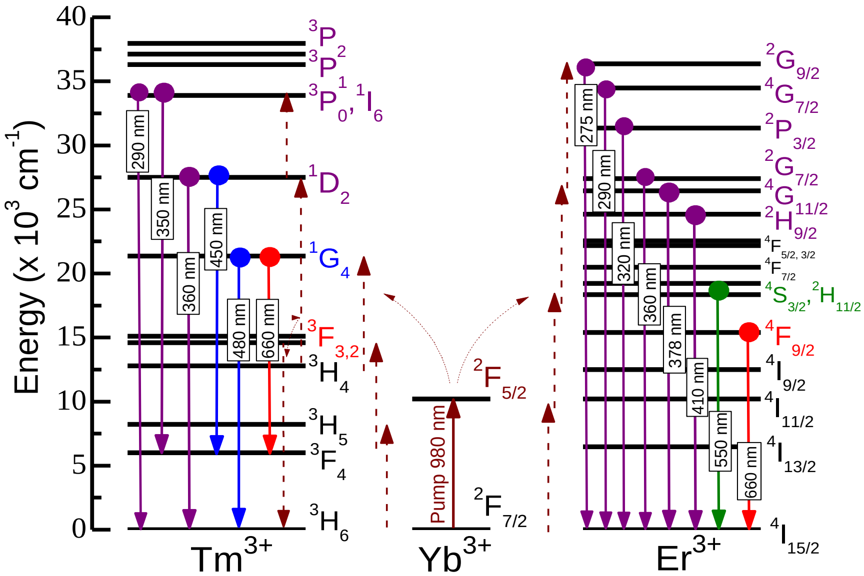

Fig. S2. Energy level diagram of Yb^{3+}, Tm^{3+} and Er^{3+} ions. Up-conversion mechanisms, pumping and main emission transitions are arrowed and labelled with corresponding wavelengths. Yb^{3+} sensitizing infrared antenna mainly absorbs the 980 nm pump, giving rise to UV-VIS up-conversion emissions after suitable efficient energy transfer processes to Tm^{3+} and Er^{3+} ions.

Finally up-conversion measurements were carried out with a continuous wave laser diode at 980 nm with a power up to 300 mW, collimated using a 4X micro-objective, with a focal length of 4.51 mm and 0.55 of numerical aperture, which allows obtaining the power density of about 20 W/cm^2 at the sample surface, as achieved by the authors in previous published works *(32)*. Detection was obtained through a 0.25 m monochromator equipped with a photomultiplier. The full luminescence spectra have been measured using visible photomultiplier and InGaAs near-infrared detectors, which have overlapping spectral sensitivity ranges, to cover the spectral range from 300 to 1600 nm taking into account their respective spectral response function. The high quantum yield of up-conversion luminescence in these HREE-doped fluoride glasses is confirmed also in Fig. S3. When calculating the ratio of total energy flux in up-conversion emission bands (in the 275-850 nm range) to resonant and infrared emission located at 980 and 1500 nm, respectively. In this area calculation, the number of photons emitted in each up-conversion band corresponding to 2-, 3- and 4-photon up-conversion processes was multiplied by factor of 2, 3 and 4 respectively, as it can be seen in the paper of Suyver et al. (31), to appreciate the fact that in these processes absorption of multiple infrared photons are involved. Thus, the overall up-conversion efficiency is estimated to be at around 46% through this comparative area calculation. This efficiency represents the fraction of all NIR photons absorbed by the material that contribute to the up-conversion emission.

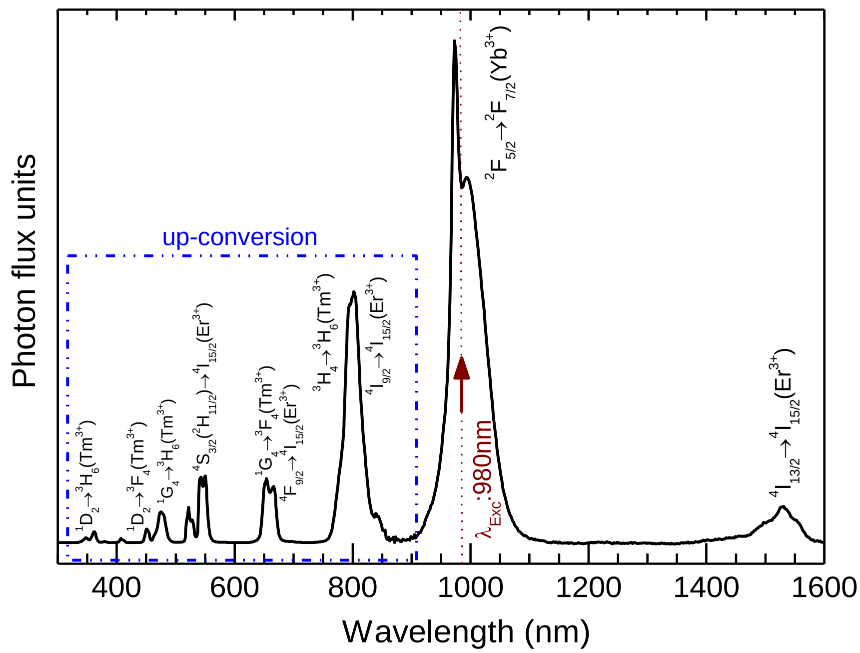

Fig. S3. Full UV-VIS-NIR emission spectrum of the 3.5 Yb^{3+}-0.5 Er^{3+}-0.5Tm^{3+} (in mol%) triply doped ZrF_4–BaF_2–LaF_3–AlF_3–NaF glass glass under 980 nm excitation at 300 mW in photon flux units to calculate up-conversion efficiency. The area below upconversion bands are estimated to be at around 46% of the total emission after multiplication by the corresponding number of infrared photons involved.

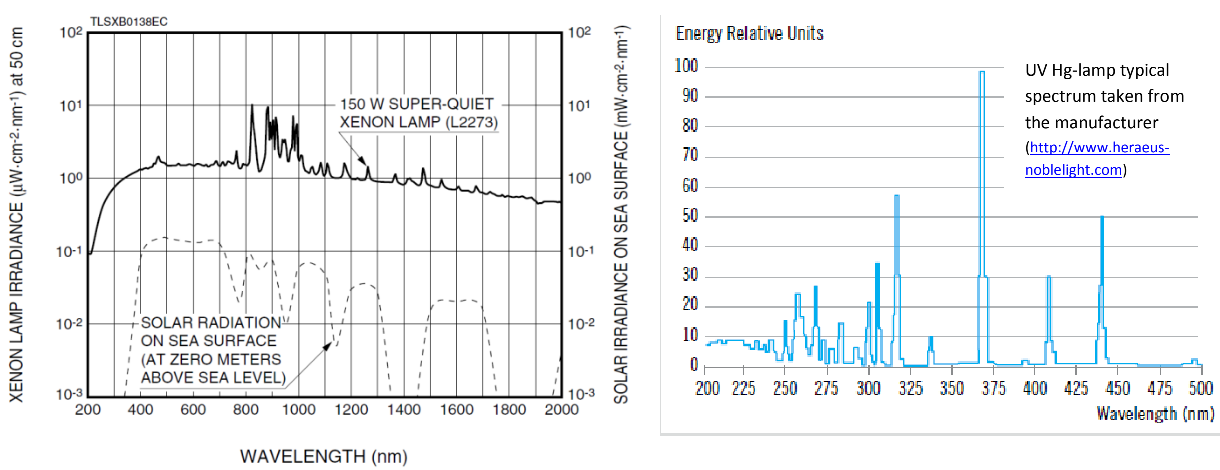

Fig. S4. Typical spectral irradiance of both Xe-lamp (left), and Hg UV-lamp (right) taken from their corresponding technical specification sheets provided by the manufacturer. The Xe gas emits a "white light" at a high colour temperature of 6000K which covers a broad continuous spectrum from the ultraviolet to infrared region.