Enhanced up-conversion luminescence in a microtubular optical resonator

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The capability of trivalent rare earth ions (e.g. Er^{3+}or Yb^{3+}) to perform infrared-to-visible up-conversion (UC) fluorescence is attracting increasing attention because this effect can help optical absorption in the infrared spectra of solar radiation for energy conversion [1]. Strong UC efficiency can be realized in Er^{3+} doped powder as reported by various reviews[2, 3], but thin solid films with the same material deposited by e-beam present no or weak UC effect, which hampers its practical applications. In this work, we focus on fabricating thin solid films with UC effect and enhance the UC luminescence intensity by coupling Y_2O_3:Er^{3+}/Yb^{3+} fluorescence with optical resonance modes [4, 5] in microtubes [6].

Figure 1 (a) shows XRD patterns of Y_2O_3:Er^{3+}/Yb^{3+} powder and corresponding 100 nm-thick film. It can be seen that such film performs much poorer crystallinity than powder, which results in a weak UC fluorescence. Figure 1 (b) is the UC spectrum of Y_2O_3:Er^{3+}/Yb^{3+} film excited by 980 nm. Figure 1 (c) presents a SEM image of a microtube rolled-up by 100 nm-thick UC Y_2O_3: Er^{3+} / Yb^{3+} film. Pre-stressed Y_2O_3:Er^{3+}/Yb^{3+} film was deposited on the sacrificial layer (PMMA or photoresist), then selectively etch the sacrificial layer to release the stress and films self-roll into tubes. Figure 1 (d) displays the optical resonance mode (whisper-gallery mode (WGM)) of this microtube due to the confinement of light along tube walls (blue line in Figure 1d), which fits well with the simulation results by Mie scattering theory as shown by the red line in Figure 1 (d).

In conclusion, we have demonstrated a novel method to enhance the efficiency of UC fluorescence. Optical resonance mode in microtubes can lead a strong enhancement in the range from 500 nm to 900 nm, which coincidently overlaps with the luminescence of Y_2O_3:Er^{3+}/Yb^{3+}, and the strong coupling of this effect would result in a remarkable increase in UC intensity.

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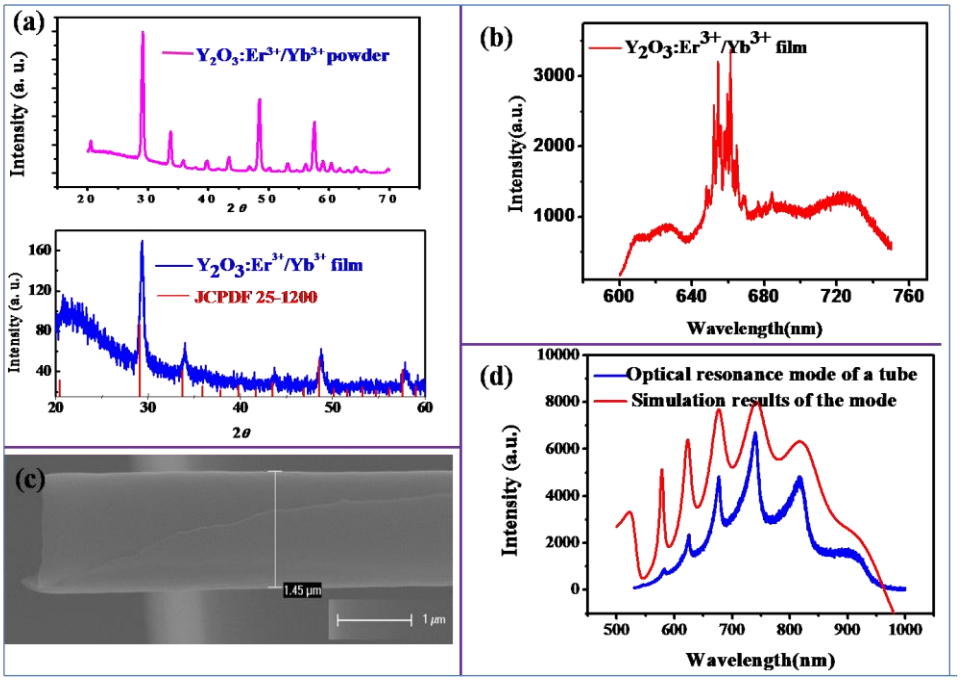

Figure 1 (a): XRD patterns of $Y_2O_3:Er^{3+}/Yb^{3+}$ powder and 100 nm-thick film. All the samples are annealed under 850 ^{o}C for 30min. *(b): UC spectrum of 100 nm-thick $Y_2O_3:Er^{3+}/Yb^{3+}$ film excited by 980 nm. (c): SEM image of a microtube.* The tube diameter is 1.45 μm. (d): *Optical resonance mode of the microtubes.* The blue line is the experimental result and the red one is the simulation result by Mie scattering theory, and the excited wavelength is 514 nm.

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