Concentration Dependence of Optical Gain in Yb^{3+}-doped Potassium Double Tungstate Channel Waveguides

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Yb^{3+}-doped potassium double tungstates exhibit an excellent gain performance [1]. Liquid-phase epitaxy of $KGd_xLu_yYb_{1-x-y}(WO_4)_2$ layers onto undoped $KY(WO_4)_2$ substrates allows one to independently design active doping level and refractive index [2,3]. The highest Yb^{3+} concentration enabling lattice matching between layer and substrate leads to the composition $KGd_{0.465}Lu_{0.000}Yb_{0.535}(WO_4)_2$. In Fig. 1(a), lifetime measurements (red) and correction [4] of radiation reabsorption (blue) show that energy migration among Yb^{3+} ions and subsequent energy transfer to impurities or cooperative upconversion diminishes the lifetime from ~270 µs to slightly less than 200 µs at 47.5% Yb^{3+} concentration. This small amount of quenching does not affect the gain significantly. We fabricated channel waveguides with Yb^{3+} concentrations of 15%, 20%, and 47.5%, and pump-probe measurements provided a gain of 280 dB/cm, 430 dB/cm, and 935 dB/cm, respectively, at the peak wavelength of 980.6 nm, see Fig. 1(b). Besides, we grew thin films with 47.5% and 57.5%, beyond the lattice-matching limit of 53.5%, and perpendicular gain measurements indicate a gain of 1028 dB/cm [1] and 1050 dB/cm [5], respectively. In all waveguides, a gain bandwidth of 55 nm from 977–1032 nm was measured, see Fig. 1(c), equaling 16.3 THz spectral bandwidth, providing 150 dB/cm gain for 47.5% Yb^{3+} concentration (red arrow).

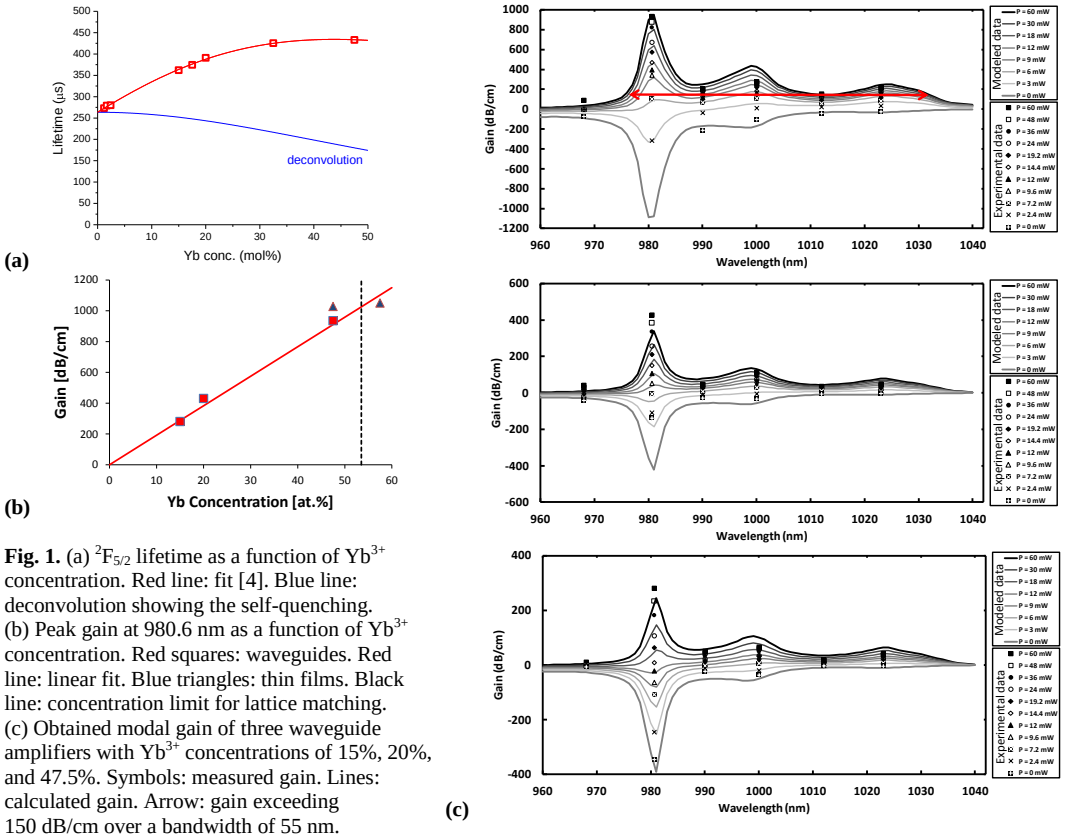

Fig. 1. (a) $^2F_{5/2}$ lifetime as a function of Yb^{3+} concentration. Red line: fit [4]. Blue line: deconvolution showing the self-quenching. (b) Peak gain at 980.6 nm as a function of Yb^{3+} concentration. Red squares: waveguides. Red line: linear fit. Blue triangles: thin films. Black line: concentration limit for lattice matching. (c) Obtained modal gain of three waveguide amplifiers with Yb^{3+} concentrations of 15%, 20%, and 47.5%. Symbols: measured gain. Lines: calculated gain. Arrow: gain exceeding 150 dB/cm over a bandwidth of 55 nm.

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