Si 基板上に Er 添加した希土類酸化膜導波路における光増幅

Optical Signal Enhancement in Er-incorporated Rare-Earth Oxide Waveguides on Si

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Single-crystal Er-incorporated rare-earth oxide (REO) thin films epitaxially grown on Si [1, 2] are a promising material platform for Si-based active photonic devices, due to its high material quality, high Er concentration and process compatibility with Si. Their optical properties have been investigated by several groups [3-6]. However, optical signal enhancement and/or amplification have not been demonstrated yet. In this work, we have fabricated low loss waveguides for REO thin films and, for the first time, observed signal enhancement upon optical pumping.

About 60-nm-thick $(Er_xGd_{1-x})_2O_3$ layer with x = ~5.7% was grown on (111) silicon-on-insulator substrate by molecular beam epitaxy. After that, 300-nm-thick SiN layer was deposited and patterned [7] to form a strip-loaded waveguide structure, without necessity of etching of REO, as shown in Fig. 1(a). The fundamental TM mode of the waveguide is well confined, as one can see in the electric field distribution shown in Fig. 1(b). To measure the optical gain, pump laser with a wavelength of 1462 nm and probe laser with tunable wavelengths were combined by a WDM coupler, and launched into the waveguide through a grating coupler. The probe laser was AC-modulated and the output was detected by a lock-in amplifier, so that the effect from amplified spontaneous emission could be eliminated. Figure 1(c) shows the output spectra of a waveguide with a width of 1.08 μm and a length of 1.2 mm, when the pump laser was turned on (with a power of ~230 mW prior to waveguide coupling) and off. It is clearly observed that the output around 1536 nm wavelength was increased upon pumping, demonstrating signal enhancement. The extracted spectrum of signal enhancement, which is defined by the ratio of waveguide output with and without pumping, is shown in Fig. 1(d). The peaks are consistent well with those of the light emission from the thin film, and maximum enhancement of ~16 dB/cm is achieved around 1536 nm. The results verify the feasibility of Er-incorporated REO thin films as active material for Si-based optical amplifiers and lasers, and we expect that net optical gain could be achieved through further material and device optimization.

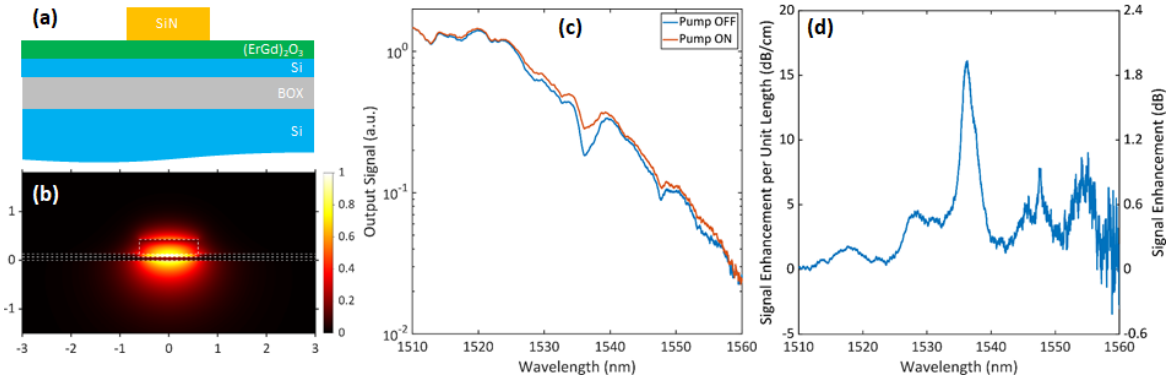

Fig. 1 (a) Cross-section schematic diagram, and (b) majority electrical field distribution of fundamental TM mode of $(ErGd)_2O_3$-based strip-loaded waveguide. (c) Output spectra of the waveguide with and without optical pumping. (d) Spectrum of signal enhancement of the probe light upon pumping.

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