

Nd-doped Polymer Waveguide Amplifiers at 850-930 nm

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Rare-earth-ion-doped polymer waveguide amplifiers [1-2] have been studied due to their potential use in integrated optical applications. Neodymium can be of great interest for high-speed amplifiers in optical interconnects, because it emits around 850-930 nm on the ${}^4F_{3/2} \rightarrow {}^4I_{9/2}$ ground-state transition. Polymers are promising host candidates in this application due to their low cost, ease of fabrication, and potential integration with polymer waveguides in integrated optical systems, e.g. optical backplanes. In this work, Nd³⁺-complex-doped polymer channel waveguide amplifiers have been realized and gain at 850-930 nm has been demonstrated.

Nd(TTA)₃phen-complex-doped 6-FDA/epoxy channel waveguides were fabricated [3]. A low-index cycloaliphatic epoxy prepolymer (code name CHEP) was spin-coated onto a thermally oxidized silicon wafer and photodefined to obtain inverted channels. The Nd-doped core material was then backfilled via spin-coating and 5×5 μm² channel waveguides were realized after thermal curing. Another CHEP layer was spin-coated onto the channels as an upper-cladding layer. Figure 1 shows the absorption and luminescence spectra of the Nd³⁺-doped channel waveguides. The propagation and absorption loss was determined with the cut-back method. After excitation at 740 nm by a Ti:Sapphire laser, the fluorescence spectrum around 830-950 nm was measured.

The small-signal gain was measured with a pump-probe method. An external cavity laser at 800 nm was used as the pump source. The signal source, a Ti:Sapphire laser with attenuated power, which was tuned from 850 to 930 nm, was modulated by a chopper. Pump and signal light were combined and coupled into and out of the waveguide via microscope objectives. The unabsorbed pump light was blocked by a high-pass filter. The signal light was measured by a germanium photodiode and amplified with a lock-in technique. The optical gain was determined by measuring the ratio of the transmitted signal intensities with pump on and off. By subtracting the waveguide propagation and absorption loss at the signal wavelength, the internal net gain was obtained.

Figure 2 displays the internal net gain spectrum at 850-930 nm. Waveguides with two Nd³⁺ concentrations were investigated. The sample lengths were ~1.7-1.8 cm. A wide gain bandwidth has been observed in both samples. The drop of gain around 870 nm is due to high absorption loss around this wavelength. Figure 3 shows the internal gain as a function of launched pump power at 800 nm. It increases with increasing pump power and saturates at high power. The saturation is due to ground-state bleaching and thermal effects that occur in the polymer material owing to partial conversion of the absorbed pump power into heat [4]. A maximum 5.3 dB/cm gain was observed at 850 nm in a 1.7-cm-long channel waveguide with a Nd³⁺ concentration of 1.03×10²⁰ cm⁻³.

Nd-complex-doped, polymer channel waveguides were realized on thermally oxidized silicon wafers by a simple fabrication procedure. Broadband optical gain was demonstrated at 850-930 nm. Internal net gain up to 5.3 dB/cm was obtained at 850 nm, which is very promising for optical amplification in optical backplanes. With this result a route toward low-cost integrated waveguide amplifiers for optical interconnects has been opened.

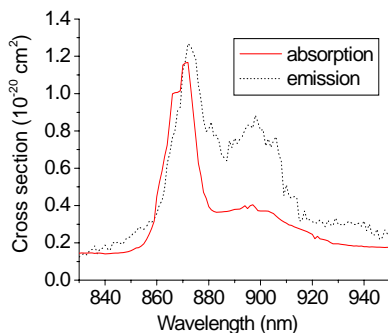


Fig. 1 Absorption and emission cross section spectrum of doped Nd³⁺ 6-FDA/epoxy.

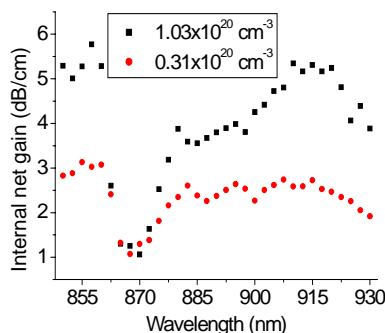


Fig. 2 Internal net gain spectrum of doped Nd³⁺ 6-FDA/epoxy at 850-930 nm for a launched pump power of 50 mW.

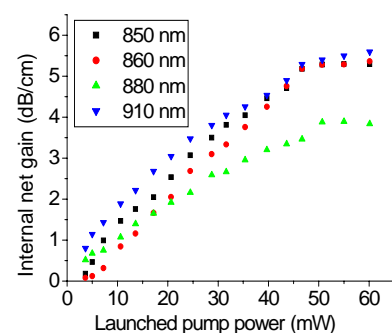


Fig. 3 Internal net gain at 850, 860, 880, and 910 nm vs. launched pump power for 1.03 × 10²⁰ cm⁻³ Nd conc..

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