Demonstration of Net Gain at 1060 nm in a Nd-complex-doped, Photo-defined Polymer Channel Waveguide

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Rare-earth-ion-doped planar waveguide amplifiers are attractive, e.g., for high-speed data communication. Polymers are promising host candidates for these applications due to their low cost and simple processing technologies. In our work, an optical gain of 8.0 dB at a wavelength of 1060 nm was measured in a 5.6-cm-long Nd(TTA)$_3$phen-doped 6-FDA/epoxy photo-definable channel waveguide.

Polymers are usually poor host materials for luminescence emission from rare-earth ions due to the presence of high-energy vibrations from C-H and O-H chemical bonds. To suppress the luminescence quenching of rare-earth ions in polymer hosts they were encapsulated in fluorinated chelates in addition to doping them into a fluorinated polymer. The fluorinated neodymium complex, Nd(TTA)$_3$phen, was synthesized according to the procedure described in [1] and doped into the fluorinated host 6-FDA/epoxy.

By spin-coating and subsequently photodefining of a cycloaliphatic epoxy prepolymer (code name CHEP) [2, 3], inverted channels in the low-refractive-index CHEP polymer were obtained on a thermally oxidized silicon wafer. The core material, a Nd(TTA)$_3$phen doped 6-FDA/epoxy solution, was then backfilled via spin-coating twice and the 5×5 μm^2 Nd-complex-doped channel waveguides were realized after thermal curing. An additional 5-µm-thick CHEP layer was spin-coated on top of the channels as the upper cladding layer.

Figure 1 shows the photoluminescence spectrum of the Nd^{3+}-doped polymer. A Ti:Sapphire laser operating at a wavelength of 800 nm was used as the excitation source, and the fluorescence peak near 1060 nm due to the Nd^{3+} $^4F_{3/2}$-$^4I_{11/2}$ transition was observed. The luminescence lifetime was measured to be ~130 µs.

A pump-probe method was used for the small-signal-gain measurement. Pump light from a Ti:Sapphire laser at 800 nm and modulated signal light at 1060 nm were simultaneously coupled into the waveguide via a microscope objective. The signal light was collected and measured using a lock-in amplifier. The gain was determined by measuring the ratio of the amplifier output with pump on and off. By subtracting the waveguide loss at the signal wavelength, the net gain was calculated. Figure 2 shows the net gain as a function of pump power launched into the channel. A 5.6-cm-long channel waveguide with a concentration of 1.1×10^{19} Nd^{3+} ions/cm^3 was used in this experiment. A maximum net gain of 8.0 dB was observed upon pumping the sample with 173 mW of launched pump power.

In conclusion, optical amplification at 1060 nm was demonstrated in Nd(TTA)$_3$phen-doped 6-FDA/epoxy channel waveguides, which indicates that a Nd-complex-doped polymer waveguide is well suited for optical amplification and potentially lasing.

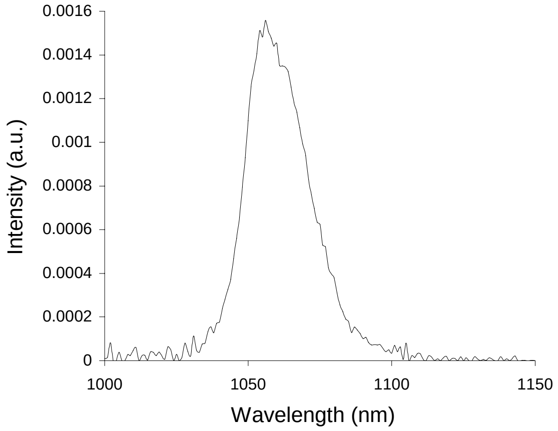

Fig. 1 Photoluminescence spectrum of Nd^{3+} doped 6-FDA/epoxy.

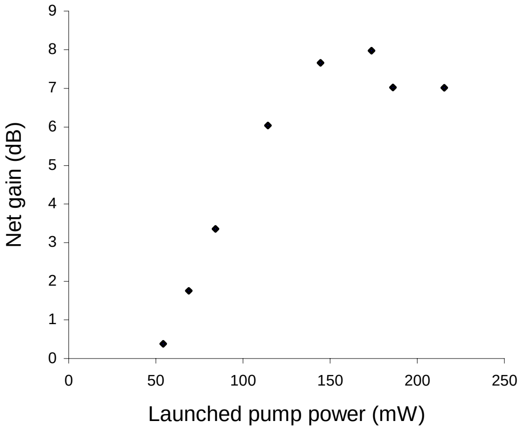

Fig. 2 Net gain at 1060 nm as a function of pump power at 800 nm.

References

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