Nd^{3+}-doped polymer waveguide amplifiers and lasers

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Abstract: In Nd-complex-doped fluorinated polymer channel waveguides, internal net gain of 2.0 dB/cm at 873 nm and 5.7 dB/cm at 1064 nm is demonstrated. Continuous-wave lasing near 1060 nm is obtained with a slope efficiency of 2.15% and 1 mW of output power. Lasing was also achieved at 878 nm.

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Polymer materials are promising candidates for integrated optical waveguide devices due to their ease of fabrication, compatibility with other materials, and low optical loss in the near-infrared wavelength range. The latter property is especially attractive for the fabrication and functionality of waveguide amplifiers and lasers. However, up to now solid polymer lasers could be operated only in the pulsed regime. Incorporation of rare-earth ions into polymers for optical amplification is challenging due to the immiscibility of their salt precursors with organic solvents and luminescent quenching from C-H and O-H bonds in polymers. These problems can be overcome by encapsulating the rare-earth ions with organic fluorinated ligands to form stable complexes and doping these into a fluorinated polymer host.

We developed a polymer host material based on a cycloaliphatic diepoxy cured with a fluorinated dianhydride [1]. When activated with a Nd^{3+}-doped complex, luminescence quenching due to high-energy vibrations from O–H and C–H chemical bonds is avoided and the typical emission lines of the Nd^{3+} ion are detected. By spin-coating onto a thermally oxidized silicon wafer and photodefining a cycloaliphatic epoxy prepolymer, inverted channels in the low-refractive-index polymer were obtained. The Nd^{3+}-doped polymer material was then backfilled via spin-coating to obtain Nd^{3+}-doped channel waveguides. An additional cladding layer was spin-coated on top of the channels. Internal net gain at 865-930 nm and 1064 nm was demonstrated [2]. The small-signal gain measured in samples with a Nd^{3+} concentration of 1.0×10^{20} cm^{-3} was 2.0 dB/cm and 5.7 dB/cm at 873 nm and 1064 nm, respectively. By use of a rate-equation model, the internal net gain at these two wavelengths was calculated and the macroscopic parameter of energy-transfer upconversion as a function of Nd^{3+} concentration was derived.

Optimization of the fabrication procedure of both, host material and optical structure, lead to continuous-wave laser emission [3] from a channel waveguide near 1060 nm. Laser operation was confirmed by observing the relaxation oscillations as well as the longitudinal cavity modes in the laser spectrum. Laser emission was obtained above an absorbed pump threshold of 50 mW, with a slope efficiency of 2.15% and up to 1 mW of output power for 5% outcoupling [4]. Lasing was also achieved on the quasi-three-level 878-nm transition above a threshold of 74.5 mW [4]. A slope efficiency of 0.35% and an output power of 190 μW were obtained with 2.2% outcoupling. Long-term, stable cw laser operation over at least 2 h was demonstrated, indicating the durability of the polymer gain medium.

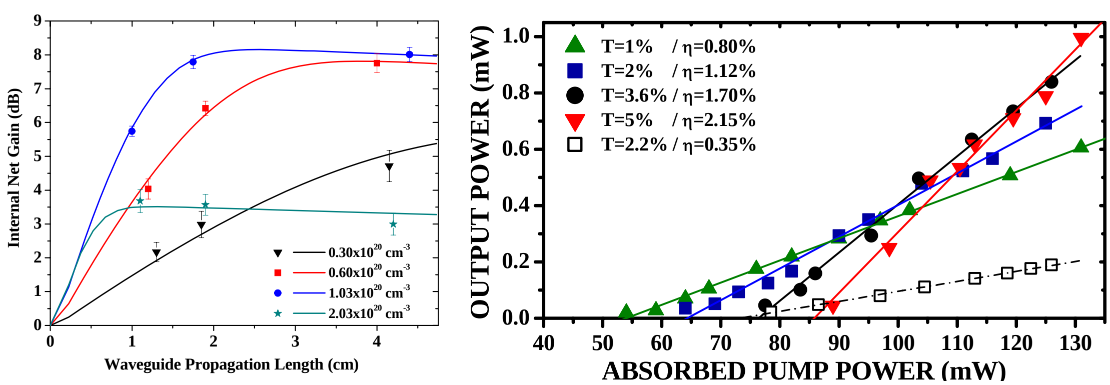

Fig. 1. (a) Measured (dots) and calculated (lines) internal net gain at 1064 nm versus propagation length for a launched pump power of 25 mW; (b) output power as a function of absorbed pump power for the four-level and quasi-three-level laser transitions at 1060.2 nm (solid symbols) and 878.0 nm (open symbols), respectively.

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References

[1] J. Yang, M. B. J. Diemeer, D. Geskus, G. Sengo, M. Pollnau, and A. Driessen, "Neodymium-complex-doped, photo-defined polymer channel waveguide amplifiers", Opt. Lett. **34**, 473-475 (2009).

[2] J. Yang, M. B. J. Diemeer, G. Sengo, M. Pollnau, and A. Driessen, "Nd-doped polymer waveguide amplifiers", IEEE J. Quantum Electron. **46**, 1043-1050 (2010).

[3] J. Yang, M. B. J. Diemeer, C. Grivas, G. Sengo, A. Driessen, and M. Pollnau, "Steady-state lasing in a solid polymer", Laser Phys. Lett., accepted (2010).

[4] C. Grivas, J. Yang, M. B. J. Diemeer, A. Driessen, and M. Pollnau, "Continuous-wave Nd-doped polymer laser", submitted (2010).