Erbium-Doped Waveguide Amplifiers

Personnel

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We have investigated the design of micron scale Er-doped waveguides to act as amplifiers for Si Microphotonics. From our analysis we have de-convoluted the competing processes in a waveguide amplifier's optical cavity as a series of length scales describing which amplifier operating regime (absorption, absorption saturation, small signal gain, and gain saturation) the waveguide is functioning in. Our analysis concluded it is possible to make a 3 dB/cm small signal gain amplifier within a 500×500 μm^2 area, doped with 2×10^{20} Er/cm^3 and pumped by a 1 µW power source for a waveguide with a core/cladding refractive index difference of $\Delta n=0.5$.

Design analysis was extended to study the possibility of adapting microring resonator structures as sub-lasing threshold amplifiers with an areal footprint of 100×100 μm^2. We conclude such structures are possible with quality factors of Q~10000 in a waveguide system with a core/cladding index difference of $\Delta n=0.5$.

Erbium oxide was evaluated as a materials system from which to make ultrahigh Er concentration micron-scale waveguide amplifiers. We discovered both the Er lifetime and up conversion coefficient change with erbium oxide crystal phase. The majority erbium oxide phase is BCC, and co-exists in heat-treated films with two metastable FCC and HCP phases. Our measurements of the up conversion coefficient conclude that this gain-limiting process affects erbium oxide performance severely. In a single-mode waveguide structure, 1 W of optical pump will be required to population invert sufficient Er atoms in order to achieve 3 dB/cm small signal gain.

We have now begun studying Er-doped silicon nitride as a feasible materials candidate for our micron-scale waveguide amplifier.