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2.8µm emission of Er-doped CaF_2 planar waveguides fabricated by molecular beam epitaxy

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We report the fabrication of erbium doped calcium fluoride thin film optical waveguides by molecular beam epitaxy and the luminescence study of the 2.8µm emission from a guide with an erbium concentration of 13 at. % under pumping at 980nm.

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The wavelength range near 3μm has many applications in medical processes due to an overlap with the absorption spectrum of water. Emission of the Er^{3+} ion near 2.8μm, which operates on the transition from $^4I_{11/2}$ to $^4I_{13/2}$ is especially promising as it can be pumped by either 800nm GaAlAs or 980nm InGaAlAs diodes, paving the way for a compact device with low electrical energy consumption.

Optical waveguides of laser gain media are highly desirable because large inversion densities can be obtained for relatively low pump powers due to the confinement of light to small dimension over longer lengths as compared to bulk materials. Molecular beam epitaxy (MBE) provides the ability to grow high quality material with a very high thickness precision, to make controlled (abrupt or gradual) composition changes, to grow multilayer stacks, and to control separately the concentration of the doping impurities, which could facilitate an optimized waveguide structure. Recently, we have shown that molecular beam epitaxy is very suitable for the growth of rare-earth doped CaF_2 active waveguides on CaF_2 substrates[1]. The thermodynamical conditions imposed during MBE growth (low temperature and growth rate) favorably modify the incorporation of rare-earth ions compared to other high-temperature growth techniques used for insulating bulk materials. As a consequence, it is possible to significantly increasing the doping level of an active impurity without any degradation of the crystal quality of the layers. Moreover, the incorporation of rare-earth ions in CaF_2 favorably modifies the index of refraction of the layer giving rise to the formation of a planar optical waveguide with a step-like refractive index profile.

The CaF_2 matrix is a good candidate for efficient 2.8μm emission : a high doping level of Er^{3+} ions can be obtained and, owing to a small phonon energy, the ratio of upper-state to lower-state lifetime is very favorable compared to an oxide matrix. Here we report 2.8μm room temperature guided luminescence of CaF_2 waveguides doped with 13 at % of Erbium. Besides this emission, three others were also observed : the well-known 1.5μm emission, and two emissions peaking at 1.7μm and 2μm due to upconversion processes. We have measured the lifetime of the initial ($^4I_{11/2}$) and terminal ($^4I_{13/2}$) laser states of the 2.8μm transition at room temperature. The values obtained are promising compared to bulk fluoride materials like $LiYF_4$ or BaY_2F_8 where laser emission has already been demonstrated[2].

Results dealing with the waveguiding properties of our layers, such as refractive index characterization and loss measurements, will also be reported.

1- E. Daran and al., J. Appl. Phys. **81** (2), 1997
2- T. Jensen and al. , Optics Letters **21** (8), 1996