Integrated optical waveguide amplifier

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Introduction

In the past we have made passive optical components like branching waveguides, couplers, Mach-Zehnder interferometers, power splitters and filters in silicon-oxynitride waveguiding films on silicon. The components were manufactured by the common processes of the Silicon technology and showed suitable characteristics and properties for many applications in integrated optics and optoelectronics [1]. However by this technology it is impossible to get active components for amplifying optical signals as they would be useful for example in optical senor chips.

The disadvantage of standard waveguiding glass films such as silica, silicon-nitride and silicon-oxynitride and also silicon is the lack of high efficient photo- and electroluminescence for active optical components, which is needed to emit and amplify optical radiation. One route to get efficient photo- and electroluminescence is the modification of glass films analog to the preparation of glasses for solid-state lasers and glasses for fiber lasers and amplifiers.

Optical amplifier design and preparation

In Fig. 1 a possible layout of a waveguide amplifier [2] shows the coupling region for the signal (S) and pump (P) power, the amplifying region with its restricted length (some tens to hundreds mm), which means a high length specific amplifying coefficient, and the decoupling region, where the optical power is split into the signal and the pump power.

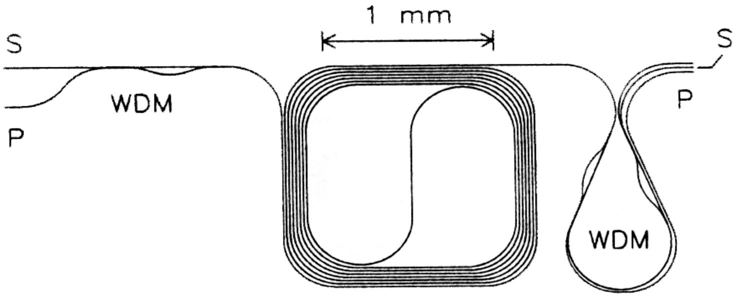

Fig. 1 Layout of a waveguide amplifier

Currently, we try to find a high amplifying film material and are focused on rare earth doped and modified waveguiding glasses. Interesting modifications of glasses such as silica or aluminium oxyde are possible by creating nanocrystals (nc's) of semiconductors, as for example made of silicon and germanium, in the material. This might allow efficient luminescence due to quantum size effects and specific interface conditions. By this type of material active photonic components such as laser could be possible, for details see [3].
For the telecom band around 1.5 µm silica films containing erbium (Er) and silicon nanocrystals (Si nc) with a diameter of a few nm were prepared and are under investigation, because a sensitizer – activator coupling between the erbium atoms and the Si nc's exist which leads to high amplification coefficients. The Er and Si contents in the glass films were prepared by ion implantation and rapid thermal annealing at the experimental Physics IV department at the University of Augsburg. To optimize such films for high optical amplification the energy coupling between the Si nc's and the Er atoms is of importance, which is shown at the diagram in Fig. 2 in a first model after [4]. The Si nc's absorb most of the photons of the pump source and transfer them with lower photon energy (800 nm) to the energy level $^4I_{9/2}$ of the Er atom which is here schematized by 5 energy levels, their state densities N_1 – N_5 and possible transitions (arrows). To get a high optical amplification coefficient at 1.5 µm, which is the energy level between $^4I_{13/2}$ and the ground state energy, the coupling between the Er atoms and Si nc must be high and therefore a high concentration of Er and Si in the same volume and diameters of 1 – 3 nm for the Si nc's is needed. Also the interface region surrounding the Si nc's has a high influence.
To determine the absorption lines of the material, we are measuring the transmission spectra with a spectrophotometer Lambda 900.

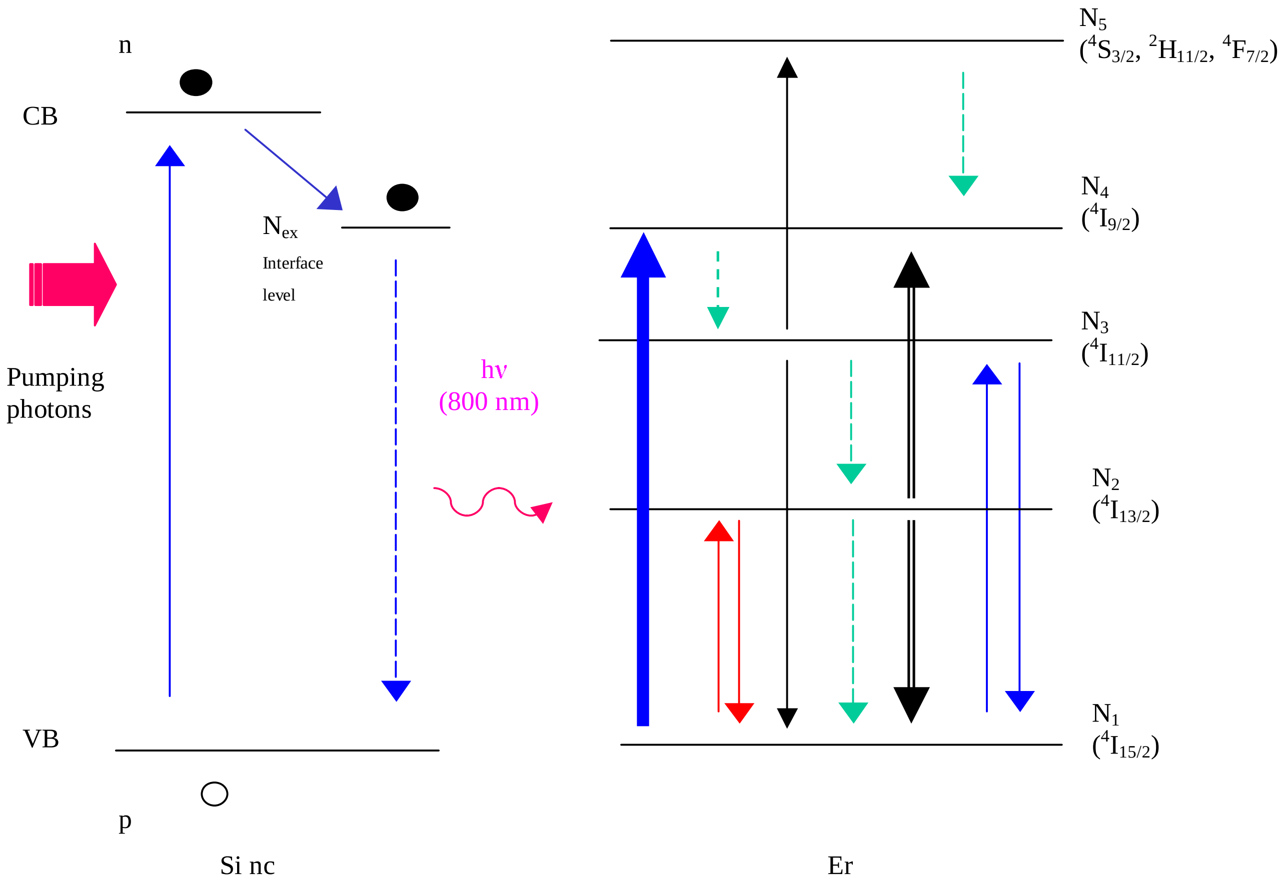

FIG. 2 Energy level diagram of the Si nc - Erbium energy transfer

Conclusion and outlook

We prepared Silica films with Er and Si nc's by ion implantation and RTA for optical amplification. Measurements of the optical absorption of films are under investigation and will be followed by measurements of luminescence spectra. Later on we will characterize complete waveguide amplifiers.

Acknowledgements

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References

[1] **Schauwecker, B.; Arnold, M.; Przyrembel, G.; Kuhlow, B.; Radehaus, C.:** "Optical waveguide components with high refractive index difference in silicon-oxynitride for application in integrated optoelectronics", Opt. Eng. 41(1), p. 237, 2002.

[2] **Wächtler, T.:** "Conception of an integrated optical waveguide amplifier", Project report, TU Chemnitz 2002.

[3] **Pavesi, L.:** "Will silicon be the photonic material of the third millenium?", J. Phys.: Condens. Matter 15, p. R1169, 2003.

[4] **Pacifici, D.; Franzo, G.; Priolo, F.; Dal Negro, L.: "**Modeling and perspectives of the Si nanocrystals–Er interaction for optical amplification", Physical Review B 67, p. 245301-1, 2003.