Anti-Stokes Green Emission of Er Doped Silica Fibers Excited by IR Laser

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ABSTRACT

In this paper we report the optical properties of Er-doped silica fibers. The fibers were produced from glasses obtained by sol-gel method. Luminescence spectra of Er^{+3} ion were measured in monolithic glass samples after excitation by a xenon lamp, as well as in the fiber after excitation by an IR 980 nm diode laser. It was found that under the IR excitation, a green emission at 540 nm was observed due to the up-conversion effect. This effect is associated with the aggregation of Er ions and constitues an important factor reducing the efficiency of 1.55 μm emission.

Keywords: sol-gel glass, Er ions, fiber

1. INTRODUCTION

Erbium-doped quartz glasses have recently become a subject of intensive investigation due to the possibility of applying them in telecommunication systems as materials for the production of fiber optical amplifiers. In the present work the properties of erbium doped glasses and fibers are presented. The quartz glass was obtained by the sol-gel method. This method offers the advantage of relatively simple production procedure of the vitreous material, which is moreover carried out at low temperatures.

2. EXPERIMENT

Sol-gel glasses were produced according to the prescription given in [1]. The sol-gel glasses contain usually an increased amount of OH^- groups which reduce the emission efficiency in the desired spectral range. A reduction in the concentration of hydroxyl ions in these glasses was done by thermal treatment of xerogel in the freon atmosphere. In order to obtain the reduction effect, xerogel was usually annealed at 1000°C in $C_2Cl_2F_3$ freon atmosphere for two hours. Some of the monolithic xerogel samples were impregnated with $ErCl_3 \cdot 6H_2O$ water solution in order to obtain erbium-ion-doped glass. The rods were formed from the glass obtained, from which the cores of PCS-type 200 μm dia. optical fibers were drawn.

Transmission and luminescence in erbium-ion-doped glasses was measured. The transmission characteristics of Er doped glass is shown in Fig. 1. The two most intensive peaks in the absorption spectrum at 380 nm and 520 nm are associated with Er^{+3} ion f-f transitions $^4I_{15/2} \rightarrow {}^2H_{11/2}$ and $^4I_{15/2} \rightarrow {}^4G_{11/2}$, respectively.

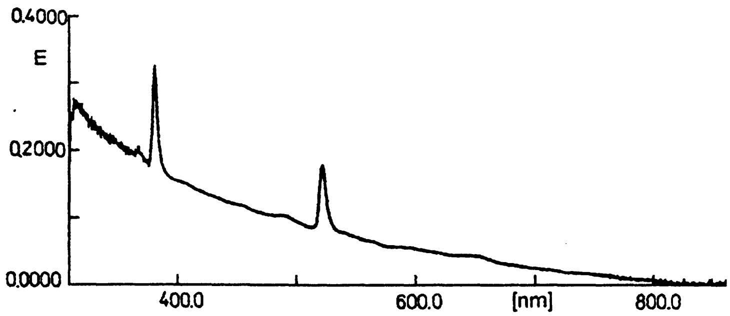

Fig. 1. Absorbance of Er doped quartz glass.

The emission spectrum of Er-doped quartz glass was excited by means of a xenon lamp. The luminescence observed in the range around 1.55 μm (see Fig. 2) is attributed to the $^4I_{13/2} \rightarrow {}^4I_{15/2}$ transition.

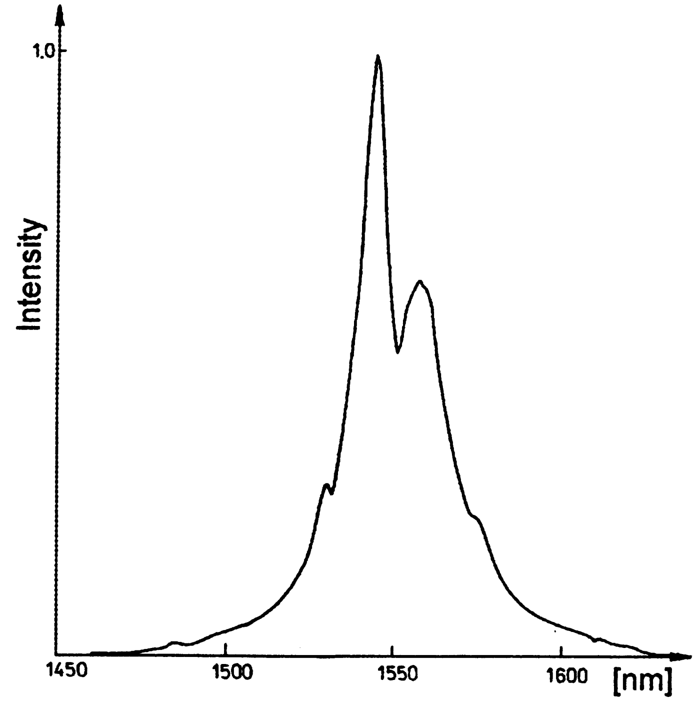

Fig. 2. Er^{+3} luminescence in quartz glass.

The experimental setup for the measurement of Er-doped fiber luminescence is depicted in Fig. 3. The luminescence in the Er-doped fiber was evoked by the radiation of a 980 nm 200 mW semiconductor laser. An Jobin-Yvon high-resolution grating monochromator TRW 1000 was used for the luminescence measurement.

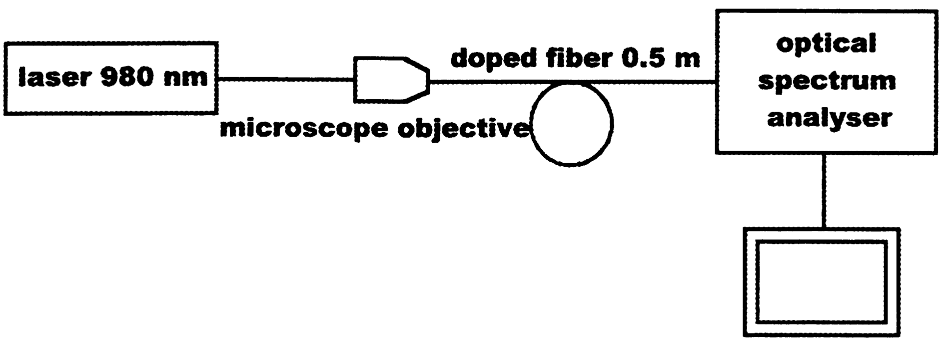

Fig. 3. Setup for measurement of luminescence in erbium-ion-doped fiber.

An emission spectrum of Er-doped quartz fiber was observed in the green range of spectrum (see Fig. 4). This emission is associated with the anti-Stokes emission due to the cooperative absorption of two ions Er^{3+} being in $^4I_{11/2}$ excited state. It may be schematically described by the following formula: $({}^4I_{11/2}, {}^4I_{11/2}) \rightarrow ({}^4F_{7/2}, {}^4I_{15/2})$.

The green emission occurs from the metastable levels $^4S_{3/2}$. The diagram of Er^{3+} energy levels is shown in Fig. 5. After exposing two Er ions occurring in the same state $^4I_{9/2}$ the energy is up-converted into the $^4F_{5/2}$ state and then after rapid multiphonon transition is relaxed into the metastable $^4S_{3/2}$ state which emits the intensive green emission. We did not observed an infrared emission in the 1,55 μm region corresponding to the $^4I_{13/2} \rightarrow {}^4I_{15/2}$ transition.

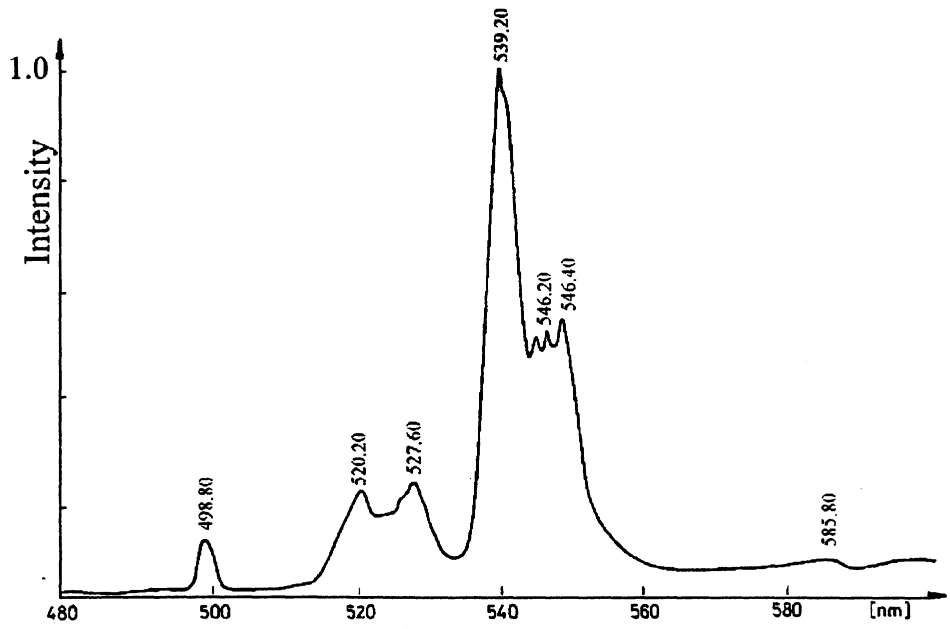

Fig. 4. Anti-Stokes Er^{+3}- emission a in quartz fiber, excited by 980 nm semiconductor laser.

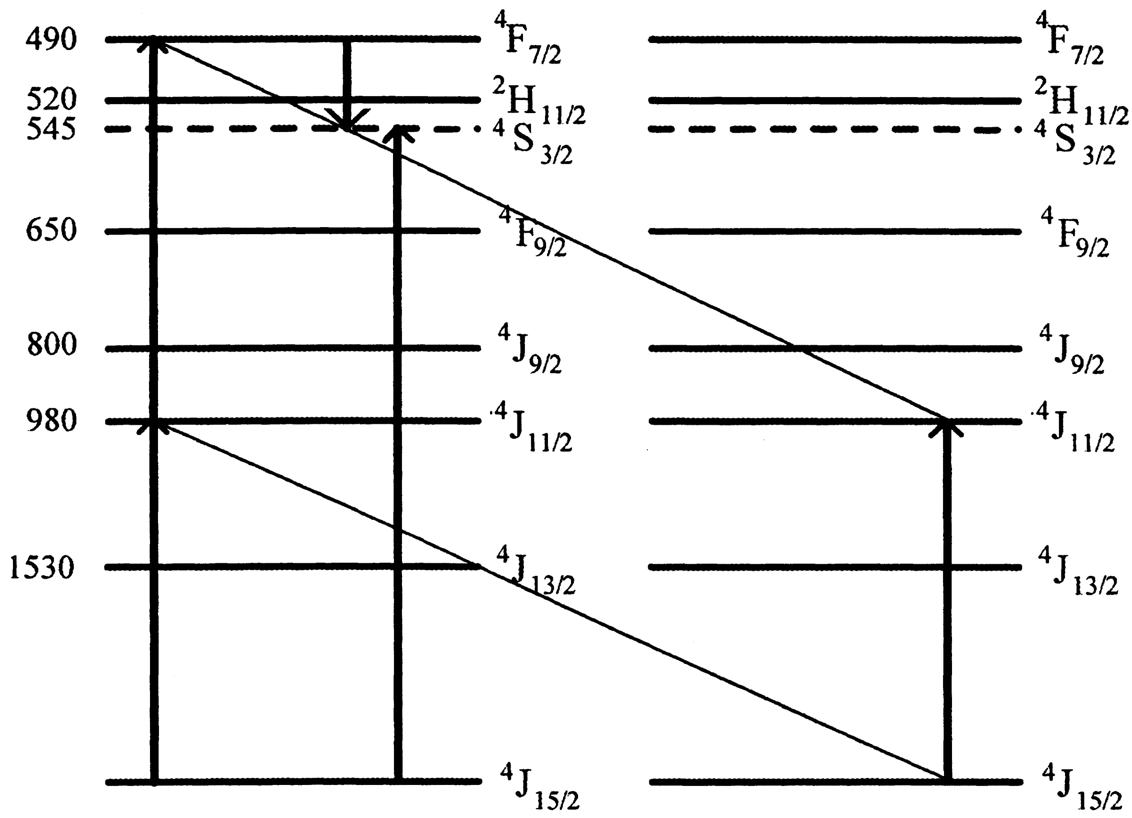

Fig. 5. Diagram of Er^{+3}- ion energy levels with anti-Stokes luminescence offensive transitions marked.

3. CONCLUSIONS

The phenomenon of up-conversion in the systems of rare earth ions resulting in the occurrence of anti-Stokes emission is well known. It was observed in numerous crystals and glasses [2].

The paper presents the anti-Stokes emission spectra of the Er-doped quartz fibers manufactured from sol-gel glass doped with erbium. An absence of Er emission in the desired spectral range 1550 nm is merely the result of imperfect command of sol-gel glass fiber production. It may be due to the clustering Er ions leading to decreasing IR emission and simultaneous occurrence of the up-converted green emission or too large radiationless relaxation of the $^4I_{13/2}$ state. Nevertheless, the sol-gel method of preparation of Er doped quartz glass seems extraordinarily promising as it provides a relatively simple technique of obtaining good-quality glass in low temperatures.

4. REFERENCES

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