Optical properties of EDF codoped with Au nanoparticles

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Abstract

We report on the luminescent enhancement of the Er^{3+}-doped germano-silicate fibers by the incorporation of Au nanoparticles in the core of the fibers. The absorption peak appeared at 498.4nm was found due to the surface plasmon resonance of Au nanoparticles. The incorporated Au nanoparticles were found to be effective absorbents for hydroxyl groups to enhance the luminescence of Er^{3+} ions when pumped with the 980nm laser diode.

1. Introduction

The Er^{3+}-doped fiber amplifiers (EDFAs) have been extensively studied as key devices for wavelength division multiplexing (WDM) optical communication systems with the development of high-power semiconductor laser diodes (LD). The increase of concentration of doped Er^{3+} ions in the fiber core is an effective method to get higher amplification, whereas high concentration of Er^{3+} ions may lead to high resonant nonlinearity beyond our expectation when the EDF is pumped at 980nm [1-3]. Therefore, to use the modified chemical vapor deposition (MCVD) and solution doping processes to make EDF with low Er^{3+} concentration of ppm level but keep high efficient emission at the same time is more attractive than the traditional melting and sol-gel methods [4, 5]. The hydroxyl groups usually inevitably exist in silica-based or germano-silicate glass fibers. Since two vibrations of hydroxyl groups are enough to bridge the gap of about 6500cm^{-1} between the ground $^4I_{15/2}$ state to the first excited $^4I_{13/2}$ state of the Er^{3+}, the excited Er^{3+} efficiently transfers energy to the vibration of hydroxyl groups and relaxes nonradiatively [6].

In this study, we attempt to realize the enhancement of Er^{3+} luminescence by incorporation of Au nanoparticles in the germano-silicate fiber by use of conventional MCVD and solution doping processes. Through a series of experiments using Er^{3+} singly-doped, Au NPs singly-doped, and Au NPs/Er^{3+} co-doped fibers, we show that Au NPs are effective to enhance the luminescence of Er^{3+} ions by acting as the hydroxyl-group absorbents pumping with 980nm LD whereas are negative to decrease the luminescence of Er^{3+} by the surface plasmon resonance (SPR) absorption of Au NPs pumping with 488nm Argon-ion laser.

2. Experiment and results

Three fibers were tested in the investigation; the characteristics of each fiber are shown in Table I. The fibers were fabricated in house using the MCVD and solution doping processes. The concentrations listed in the table are nominal concentration and the solution doping time was fixed at 2 hours for all the fibers. To confirm the formation and existence of the Au NPs in the core of fiber, the cut-back method was used to measure the absorption spectra of the optical fibers. The core diameter and cut-off wavelength of the fibers listed in Table I allowed for single transverse mode operation at the communication window of 1550nm. The fibers were pumped with a 980nm LD and a 488nm Argon-ion laser, respectively.

Table I. Characteristics of the germano-silicate fiber used in the experiment

Sample	Doping Solution (Concentration)	Cut-Off Wavelength (nm)	Core Diameter (μm)
Au_Fiber	Au^{3+} (2.5mol%)	1350	8.44
EDF	Er^{3+} (0.1mol%)	1110	8.04
Au_EDF	Au^{3+} (1.0mol%) Er^{3+} (0.1mol%)	1250	8.04

Figure 1 compares the absorption spectra of Au_Fiber, EDF and Au_EDF. The absorption peak appeared at 498.4nm in Au_Fiber, which is due to the SPR absorption of the Au NPs embedded in the fiber core and is the evidence of the existence of Au NPs. As shown in Fig. 1, the absorption increases at short wavelength from 460nm to 560nm and decreases at long wavelength around hydroxyl absorption peak due to the incorporation of Au NPs.

By using different pumping sources such as 980nm LD and 488nm Argon-ion laser, we got opposite tendencies of the luminescence of Er^{3+} ions. From Fig. 2, we can see that the luminescence of Er^{3+} ions in Au_EDF decreased when

we pumped with 488nm Argon-ion laser whereas the gain of Au_EDF was enhanced when the pumping source was changed to 980nm LD.

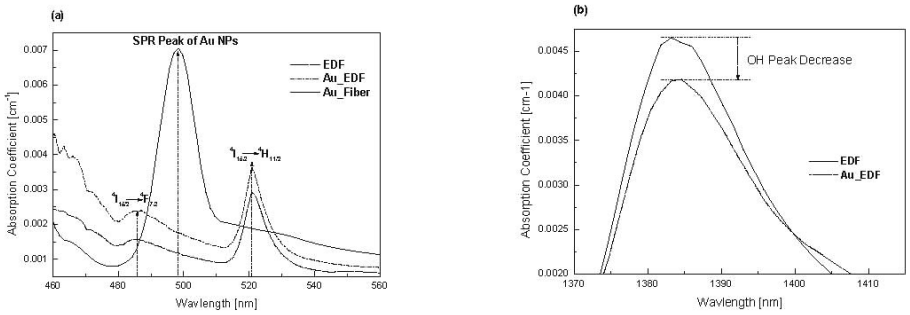

Fig.1. The absorption contrast among the EDF, Au_EDF and Au_Fiber:

(a) the short wavelength from 460nm to 560nm; (b) the long wavelength from 1370nm to 1410nm.

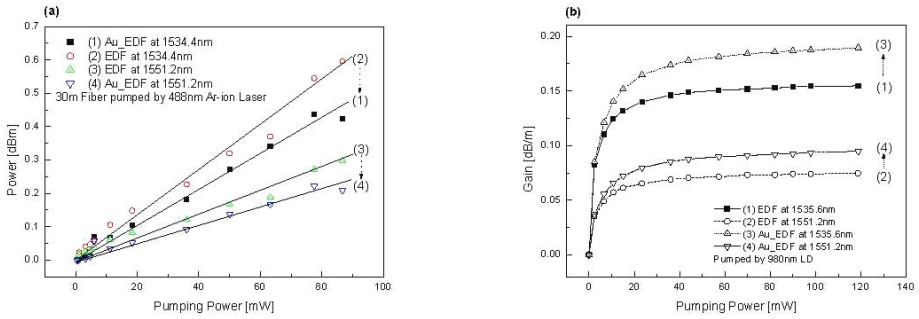

Fig.2. Opposite tendencies of the effect of Au NPs on the luminescence of Er^{3+}

pumping with 488nm Argon-ion laser (a) and 980nm laser diode (b), respectively

3. Conclusion

In summary, we successfully made EDF co-doped with Au nanoparticles. Au NPs were found to be effective chemical absorbent for hydroxyl groups by increasing the number of hydroxyl-group-free Er^{3+} ions and consequently enhancing the luminescence of Er^{3+} ions upon pumping with the 980nm LD. Due to the SPR phenomena originating from the free electron interband transition and the photoexcited hot electrons of Au NPs, the opposite and negative effects also turned up when the pumping source was changed to 488nm Argon-ion laser.

References

[1] P. L. Chu, in Proceedings of *Laser and Electro-Optics Society Annual Meeting* (LEOS' 97 10th Annual Meeting, Academic, San Francisco, CA Technical meeting), pp. 371-372, 1997.

[2] R. A. Betts, T. Tjugiato, Y. L. Xue and P. L. Chu, *IEEE J. Quantum. Electron.*, vol. 27, pp. 908-913, 1991.

[3] J. W. Arkwright, P. Elango and G. R. Atkins, *J. Lightw. Tech.*, vol. 16, 798-806, 1998.

[4] H. Dislich, *J. Non-Cryst. Solids*, vol. 73, issue 1-3, pp. 599-612, Aug. 1985.

[5] H. Kozuka and S. Sakka, *Chem. Mater.*, vol. 5, no.2, 99. 222-228, 1993.

[6] C. Coutier, W. Meffer, P. Jenouvrier, J. Fick, M. Audier, R. Rimet, B. Jacquier, and M. Langlet, *Thin Solid Flims*, vol. 392, pp.40-49, Jan. 2001.