

Enhanced Blue Emission in Au Nanoparticles/ Er-ions Doped Silica Glass Prepared with Sol-Gel Method

Vandana Ranga

Lecturer, Department of Physics, SPCGCA, India

ABSTRACT: Various glass doped with nano-scale particles (semiconductors, metals, or compounds) have received wide attention due to their unique property of resonant absorption. Recently, experimental studies show resonant absorption peak at 660 nm for the optical preform doped with Au nano particles and at 535 nm for Au nanoparticles doped in mesoporous silica. Wideband absorption due to Au nano particles in the visible wavelength region can be, possibly, used to alter optical characteristics of Er-ions in the silica glass host upon visible wavelength pumping. With this motivation, investigations have been carried out with the multicomponent alumino-silica glass incorporated with erbium ions and gold particles, fabricated using the sol-gel method.

KEYWORDS: sol-gel, nanoparticles, multicomponent, optical, silica

I. INTRODUCTION

The sol-gel technique was used to fabricate the multicomponent alumino-silica ($\text{Al}_2\text{O}_3\text{-SiO}_2$) glass with the molar ratio of Tetra ethyl ortho silicate (TEOS): ethanol : distilled water equal to 1:3.82:17.37 (TEOS is an acronym of tetra ethyl oxysilane). Appropriate molar quantities of $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$, $\text{ErCl}_3 \cdot 6\text{H}_2\text{O}$ (molar ratio 2:1) were dissolved in distilled water along with hydrochloric acid and aqueous ammonia to maintain the acidic pH. On solidification little pink-colored transparent glass samples were obtained which were further densified at 200 °C for 1 day. These samples were then inserted in the Au- HNO_3 solution (0.0025 Mole/liter) and kept inserted for 12 hours at 30 °C. The final transparent glass products were obtained with pink-yellow color and 1.1 mm thickness. Er-ions concentration was estimated to be 1.6×10^{26} ions/ m^3 . Using the same method and conditions, multicomponent silica glass containing only Er-ions was fabricated for the comparison.

II. EXPERIMENT

The sol-gel technique was used to fabricate the multicomponent alumino-silica ($\text{Al}_2\text{O}_3\text{-SiO}_2$) glass with the molar ratio of Tetra ethyl ortho silicate (TEOS): ethanol : distilled water equal to 1:3.82:17.37 (TEOS is an acronym of tetra ethyl oxysilane). Appropriate molar quantities of $\text{AlCl}_3 \cdot 6\text{H}_2\text{O}$, $\text{ErCl}_3 \cdot 6\text{H}_2\text{O}$ (molar ratio 2:1) were dissolved in distilled water along with hydrochloric acid and aqueous ammonia to maintain the acidic pH. On solidification little pink-colored transparent glass samples were obtained which were further densified at 200 °C for 1 day. These samples were then inserted in the Au- HNO_3 solution (0.0025 Mole/liter) and kept inserted for 12 hours at 30 °C. The final transparent glass products were obtained with pink-yellow color and 1.1 mm thickness. Er-ions concentration was estimated to be 1.6×10^{26} ions/ m^3 . Using the same method and conditions, multicomponent silica glass containing only Er-ions was fabricated for the comparison.

III. OBSERVATIONS AND RESULTS

Absorption spectra, an emission spectrum and TEM measurements of glass samples were measured at room temperature. The absorption spectra of the multicomponent alumino-silica glass samples were recorded using an ultra-violet-visible-infrared spectrophotometer and the results are shown in Figure 1, where the Au nanoparticles/Er-doped multicomponent alumino-silica glass shows an absorption peak at 534 nm, which is related to the absorption of Au nano particles. Similar absorption peak has been reported in the Au nanoparticles doped silica glass preform and fiber. The existence of Au particles can also be confirmed from the transmission electron microscopy (TEM) measurement for Au/Er-doped multicomponent alumino-silica glass samples Figure 2, which clearly shows Au nanoparticles of size around 2-5 nm. The absorption peaks related to the Er-ions doped multicomponent silica glass samples are also shown.

in Figure. 2, which are distinct from the Au nanoparticles related peak.

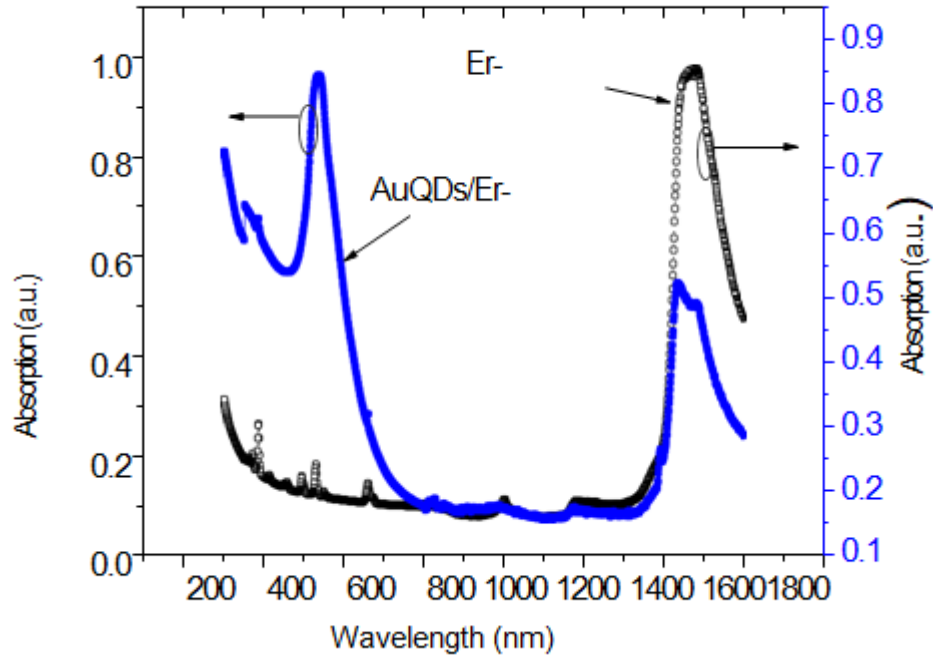


Figure 1: Absorption Spectra of Gold nanoparticles in erbium doped sample

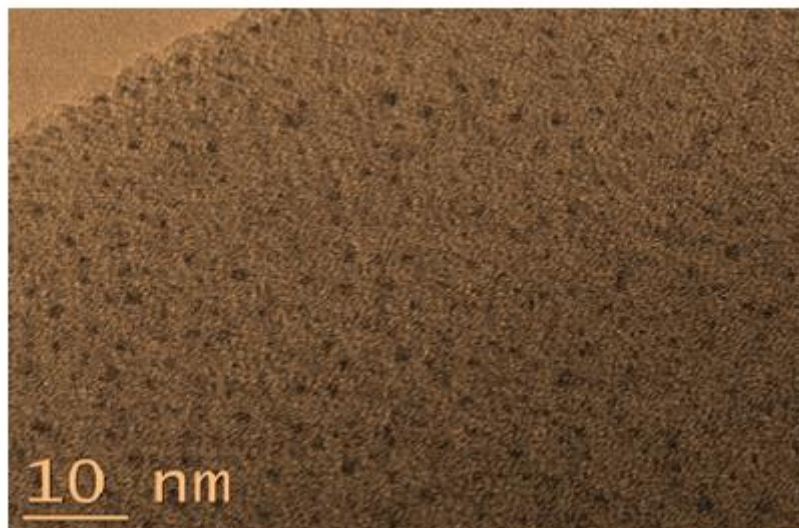


Figure 2 : TEM photographs of gold nanoparticles in silicate glass

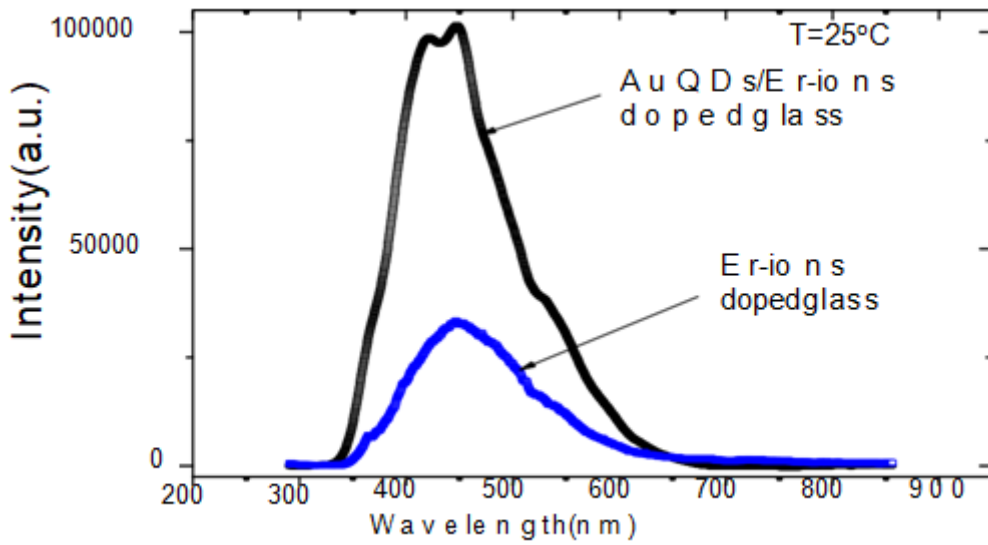
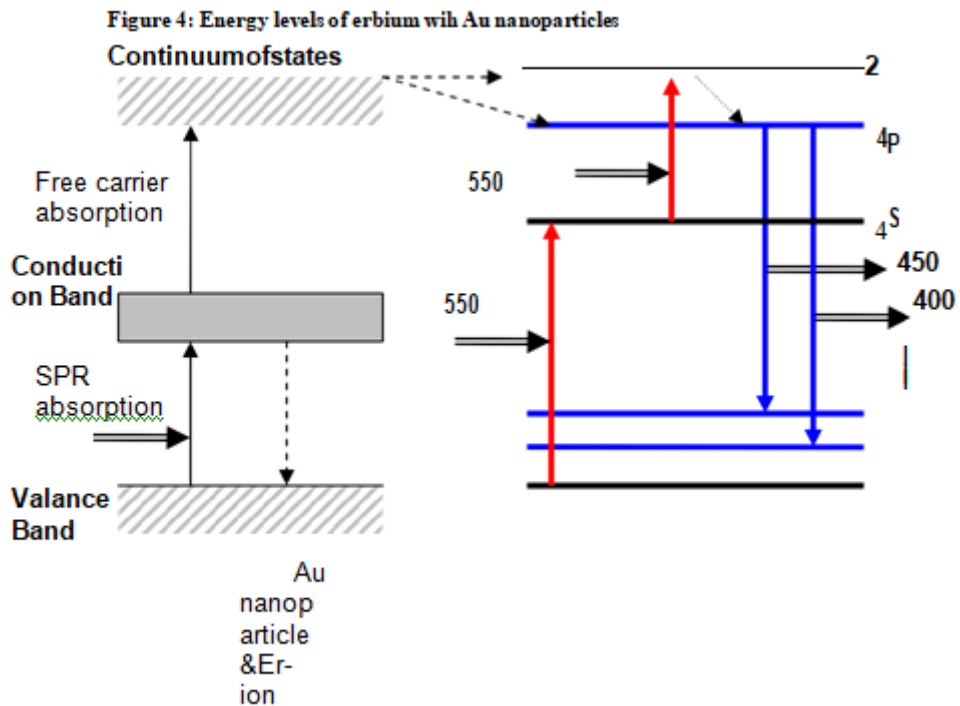


Figure 3: Emission spectra of gold nanoparticles in silicate glasses upon pumping with 550nm



IV. PHOTOLUMINESCENCE RESULTS

When Au nanoparticles/Er-doped and only Er-doped multicomponent glass samples were pumped with 550 nm Ar-ion laser, very interesting photoluminescence properties were obtained. Er-doped sample showed frequency upconversion, where emission at 450 nm was observed. The absorption and emission in the Er-ion doped glass can be attributed to transitions: $^4I_{15/2} \rightarrow ^4S_{3/2}$, $^4S_{3/2} \rightarrow ^2G_{9/2}$, and $^4P_{3/2} \rightarrow ^4I_{13/2}$ (and $^4P_{3/2} \rightarrow ^4I_{11/2}$). With regards to the Er-ions doped in the multicomponent silica glass, the energy levels were recognized as per Carnall convention. Similar $^4P_{3/2}$ initiated emission has been reported for the zirconium-barium-lanthanum-aluminum-sodium-fluoride (ZBLAN) glass fiber where violet and blue emissions were obtained upon pumping with 650 nm. When Au nanoparticles/Er-doped multicomponent glass was pumped with 550 nm, it showed similar emission, but its magnitude was enhanced by about 2.5 times as compared to that of Er-doped multicomponent glass sample. This enhancement in the photoluminescence can be attributed to the existence of Au nanoparticles in the Er-doped multicomponent glass. In earlier report, Au nanoparticles doped glass samples and fibers have shown very high resonant nonlinearity upon pumping at the resonant absorption wavelength. The reason for it has been stated to be free carrier absorption. Similar energy levels can be considered for the Au nanoparticles in our discussion. As shown in Figure 1, the absorption peak for the Au nanoparticles/Er-doped glass sample was at 534 nm, and the pumping wavelength matched the resonant absorption band of Au nanoparticles. The intraband transition or free carrier absorption of photon at the resonant frequency will cause the excitation of electrons to the higher level and possibly energy transfer has taken place to the nearby Er-ion causing the energy level transitions $^4P_{3/2} \rightarrow ^4I_{13/2}$ to generate emission at 450 nm as shown in Figure 3 and Figure 4

V. CONCLUSIONS

Au nanoparticles/Er-doped and only Er-doped multicomponent silica glass samples were prepared and studied for emission upon pumping with a visible wavelength in the vicinity of resonant absorption of Au nanoparticles. The resonant absorption band was peaked at 534 nm for Au nanoparticles and the Au nanoparticles/Er-ions doped sample showed nearly 2.5 times enhancement in the emission at 450 nm upon pumping with 550 nm. Absorption spectra of Au nanoparticles/Er-ions doped multicomponent silica glass and Er-doped multicomponent silica glass. A distinct absorption peak at around 534 nm has been obtained related to the Au nanoparticles in the glass.

REFERENCES

1. *Spectroscopic signature of three year aged erbium doped silicates*. Vandana Ranga, R.K.Khanna, H.N.Acharya and A.K.Ranga. Hamirpur. 2009. Proc. National conference on recent advances in condensed matter physics.
2. *Rare- earth doped glasses for photonics*. Vandana Ranga, R.K.Khanna, H.N.Acharya and A.K.Ranga. Sagar . 2009. Proc. National Symposium on Advances in laser and Spectroscopy (NSLS).
3. *Raman Spectroscopy of Aged rare-earth doped glasses*. Vandana Ranga, R.K.Khanna, B.B.Nayak, H.N.Acharya and A.K.Ranga. Trivandrum 2008. Proc. International conference on perspectives of vibrational spectroscopy (ICOPVS).
4. *Raman Spectroscopy of aged rare-earth doped glasses*. Vandana Ranga, R.K.Khanna, H.N.Acharya and A.K.Ranga. Shimla 2009. Proc. International Conference on Multifunctional oxide materials.
5. *Raman spectra of aged erbium doped silicate xerogels*. Vandana Ranga, R.K.Khanna, H.N.Acharya and A.K.Ranga. Singapore 2009. Proc. ICMAT-2009 & IUMRS-ICA2009.