Localized heating of Nd^{3+}- doped glasses using silica microspheres as focusing lenses

C. Pérez-Rodríguez[1], L. Labrador-Páez[1], I. R. Martín[1,2] and S. Ríos[3]

[1] Departamento de Física Fundamental y Experimental, Electrónica y Sistemas, Universidad de La Laguna, Av. Astrofísico Francisco Sánchez, s/n, E-38206 La Laguna, Tenerife, Spain

[2] MALTA Consolider Team, Instituto de Materiales y Nanotecnología (IMN), Universidad de La Laguna, Av. Astrofísico Francisco Sánchez, s/n, E-38206 La Laguna, Tenerife, Spain

[3] Departamento de Física Básica, Universidad de La Laguna, Av. Astrofísico Francisco Sánchez, s/n, E-38206 La Laguna, Tenerife, Spain

Abstract

The photonic nanojet that emerges from micrometric sized cylinders and spheres is a brand new subject of research that shows a high potential of application [1]. Basically it consists on a beam of high intensity and non-evanescent light with sub-diffraction waist that appears behind the mentioned systems under suitable illumination conditions.

In previous works [2,3] we have explored the light confinement capability of silica microspheres over rare earth doped glasses and its capability to produce upconversion. The combination of the focusing properties of the microspheres and the nonlinear dependence of the upconversion intensity yield spots as narrow as 238 nm. In this work we have employed an Nd^{3+} doped substrate that under excitation at 532 nm shows a two band spectrum in the 780-950 nm range. Due to the thermalization of the Nd^{3+} levels the ratio of the intensities of these two bands (see Fig. 1) is temperature dependent. A proper thermal calibration of this ratio is possible employing a dependence that follows a Boltzmann type population distribution. This method is known as Fluorescence Intensity Ratio [4,5]. Microspheres of 2, 7 and 25 µm diameter were sparse over the substrate in order to concentrate the 532 nm laser excitation. The thermal dependence of the Nd^{3+} spectra can be appreciated just by tuning up the power of the laser excitation. The aim of this research is to measure the Nd^{3+} thermalized spectra in the focal region of each microsphere and analyze its dependence with the sphere diameter. As can be seen in Fig. 1 the microsphere with 2 µm diameter produces a greater heating in the substrate. Therefore, the thermal variation in the focal region of a 2 µm diameter silica sphere over a glass substrate doped with Nd^{3+} ions produce an increment about 150 K (see Fig. 2).

Moreover we have performed Finite Differences Time Domain (FDTD) simulations of the electromagnetic field surrounding silica microspheres. The microspheres are in contact with the glass substrate with refractive index 1.525 under illumination at 532 nm in order to model our experimental conditions. These simulation results show a nanojet emerging from a microsphere and propagating in the bulk material with a jet width that increases with sphere diameter. This theoretical outcome led to infer that the confinement of excitation light in to the Nd^{3+} substrate is expected to be greater employing the smaller microspheres. Consequently, the greater heating in the substrate could be explained by the FDTD simulations.

References

[1] V. B. Alexander Heifetz, Soon-Cheol Kong, Alan V Sahakian, Allen Taflove, J Comput Theor Nanosci. **6**, (2009) 1979

[2] C. Pérez-Rodríguez, S. Ríos, I. R. Martín, L. L. Martín, P. Haro-González, D. Jaque, Opt. Express **21**, (2013) 10667

[3] C. Pérez-Rodríguez, S. Ríos, I. R. Martín, J. Opt. Soc. Am. B **30**, (2013)1392

[4] S. A. Wade, S. F. Collins, G. W. Baxter, J. App. Phys, 8 (2003) 4743

[5] C. Pérez-Rodríguez, L. L. Martín, S. F. León-Luis, I. R. Martín, K. K. Kumar, and C. K. Jayasankar, Sensors Actuators B Chem. **195**, (2014) 324

Figures

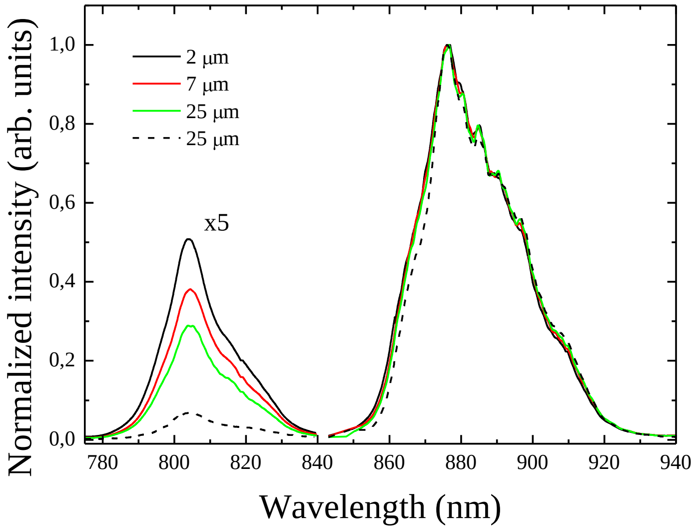

Fig. 1. Emission spectra obtained in the focal region emerging from different sized microspheres. The spectra shown in continuous lines were measured under excitation at 532 nm with 300 mW while the spectrum plotted with a dashed line was obtained with 12 mW.

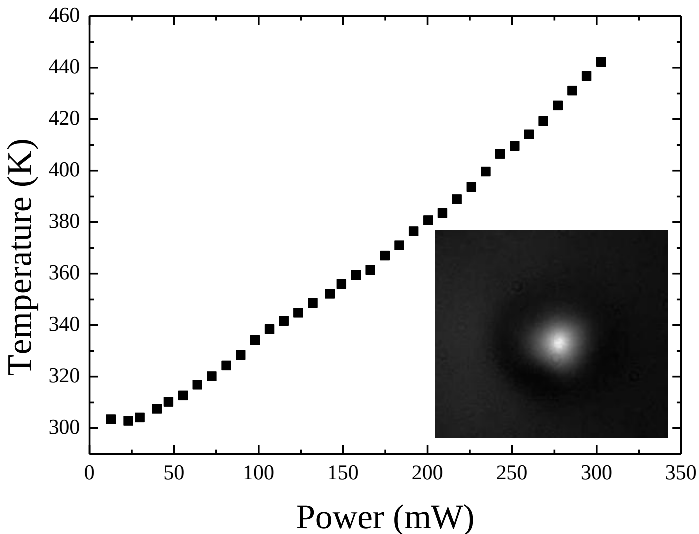

Fig. 2. Thermal variation in the focal region (shown in the inset) of a 2 μm diameter silica sphere over a glass substrate doped with Nd^{3+} ions.