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All papers have been peer-reviewed. This conference is focused on research activities on all areas of Optics, mainly in Latin-American and Iberic countries, but also in other countries all over the world as well. A specific session for Education in Optics is also included. The main interest of this conference is offering a general view of the present research activities and trends on Optics in the Latin-America area because all countries in the region with a significant activity in Optics were well represented, including senior and young researchers as well as graduated students talking about their PhD and MSc thesis work. Topics discussed included: atmospheric optics; color, vision and radiometry; diffractive optics; education for optics; guided optics; holography and interferometry; lasers and quantum optics; metamaterials; nonlinear optics; optical instruments; optical materials and applications; optical metrology; optical processing; optical spectroscopy; thin films.

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- vision and radiometry

Thermo-optical Properties of Nanofluids

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Abstract. In this work, we report thermo-optical properties of nanofluids. Spherical gold nanoparticles obtained by laser ablation in condensed media were characterized using thermal lens spectroscopy in SDS-water solution pumping at 532 nm with a 10 ns pulsed laser-Nd-YAG system. Nanoparticles obtained by laser ablation were stabilized in the time by surfactants (Sodium Dodecyl-Sulfate or SDS) in different molar concentrations. The morphology and size of the gold nanoparticles were determined by transmission electron microscopy (TEM). The plasmonic resonance bands in gold nanoparticles are responsible of the light optical absorption of this wavelength. The position of the absorption maximum and width band in the UV-Visible spectra is given by the morphological characteristics of these systems. The thermo-optical constant such as thermal diffusion, thermal conductivity and dn/dT are functions of nanoparticles sizes and dielectric constant of the media. The theoretical model existents do not describe completely this relations because is not possible separate the contributions due to nanoparticles size, factor form and dielectric constant. The thermal lens signal obtained is also dependent of nanoparticles sizes. This methodology can be used in order to evaluate nanofluids and characterizing nanoparticles in different media. These results are expected to have an impact in bioimaging, biosensors and other technological applications such as cooler system.

INTRODUCTION

The special interest in nanofluids thermal properties has been driven by their wide range of applications. The colloidal suspensions formed with nanoparticles and organic solvents can be used as antibacterial medical treatment [1],[2], photo-thermal therapy [3] and cooler systems [4] among others. These systems must be characterized in terms of particle morphology, size distribution, and colloidal stability using techniques such as UV-Visible, TEM and AFM. However, in order to determinate thermal properties of the nanofluids, thermo-optical techniques are required. Thermal lensing is widely used to determine the thermo-optical coefficients of materials. In a typical pump-probe mode-mismatched TL experiment, the pump beam is used to generate the temperature distribution in the sample, as a consequence that the sample has both linear and nonlinear absorption at the pump beam wavelength; distortions in the probe beam wave-front at the far field are induced. These distortions are used to calculate the TL signal as a function of the intensity pump beam by using the Fresnel diffraction approximation. For a nonlinear optical material that have linear and nonlinear absorption coefficients at the wavelength of the pump beam, according to the basic TPA process, the beam intensity changes along the propagation direction z-axis. We can calculate the TL signal, which is defined as the relative change of the transmission through the small aperture, for CW laser TL technique and it is viewed as the degree of mode-mismatching of the probe beam and excitation beam in the sample in z = 0 [5]:

$$TLS(0) = G\frac{8DA}{\kappa\lambda_p}\left(\frac{dn}{dT}\right)E \tag{1}$$

In this equation G is an experimental geometric factor given by

$$G = \frac{(e^2-1)w_p^2 z_1 z_c}{e^2(4w_0^2 w_p^2 z_c^2 + 4w_p^4 z_c^2 + w_0^4(z_1^2 + z_c^2))} \tag{2}$$

Where A is the absorbance of the sample, z is the spatial coordinate. w_0 is the waist beam, $w = w_0(2\ln 2)^{1/2}$, E is the energy of the pulse. κ is the thermal conductivity, D is the thermal diffusivity, dn/dT is the thermo-optic coefficient of the sample, λ_p is the wavelength of the probe beam and z_1 is the distance

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between sample and aperture plane. The Rayleigh range ($\pi w_p^2/\lambda_p$) and the radius at the sample position of the probe beam are respectively denoted by z_c and w_p. We assume that the heat generation in liquid is instantaneous. This assumption is done due to that the duration time of the laser pulse (τ), which is in the nanosecond scale range, is much less than the characteristic relaxation time associated with photo-thermal effect ($t_c = w_0^2/4D$), that is in the milliseconds scale range. The rise in temperature of the medium is accompanied by a change in its refractive index ($\Delta n = (dn/dT)\Delta T$), which alters the propagation of the probe beam. From equation (1) is possible evaluate the dependence between *TLS* and *E* in an experiment called I-Scan[6]. The data provided in this experiment can be linearly fitting in order to obtain the slope, ζ defined by:

$$\zeta = G\frac{8DA}{\kappa\lambda_p}\left(\frac{dn}{dT}\right) \tag{3}$$

The values of ζ represent the global functional dependence between the thermo-optical parameters and the characteristics of nanofluids. The contributions of each parameter alone are very difficult to obtain because these quantities are related to each other.

EXPERIMENTAL DETAILS

The experimental setup is schematized in Figure 1. The experiments were performed with a Q-switched mode locked Nd:YAG laser (Continuum surelite) delivering 10 ns pulses at λ = 532 nm with a repetition rate of 10 Hz. A half-wave plate ($\lambda/2$) placed before a Glan polarizer (P), allows the adjustment of the total input energy. Control of the input pulse energy is achieved by means of a beam splitter (BS1) sending about 4% of the total beam on a photodiode (D1) connected to a two-channel digital oscilloscope. Using a positive lens (L) the beam is then focused to a spot of radius w_0 = 200 μm at the focal plane, corresponding to a Rayleigh length z_0 = 12 cm in the air. The probe beam is the light from 1-mW CW He-Ne laser (λ = 633 nm) and it passes through the sample (M), which is fixed at the waist of the excitation beam (z = 0). Samples consist in aqueous solutions of gold nanoparticles in sodium dodecyl sulfate (SDS), which have a concentration of surfactant between 10^{-5} to 10^{-3} M, contained in quartz cells of 1 cm path-lengths. A second beam splitter (BS2) directs the probe light onto the sample in the coaxial direction of the pump beam. The interference filter (F) cancels the pump light behind the sample-cell. The probe beam finally propagates into the detection system consisting of a small aperture, (d_0 = 1 mm), the photodiode (D2) and the digital oscilloscope. The absorption of the plasmonic resonance band [7] is measured using an ocean optics S2000 spectrometer.

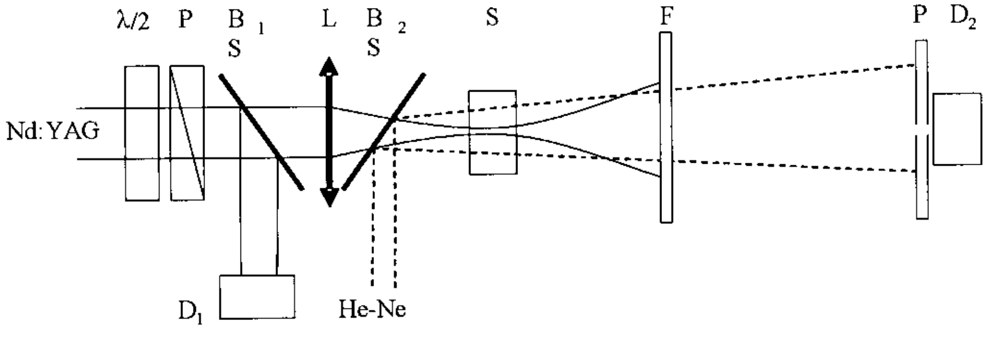

FIGURE 1. TL Experimental Setup

The samples were obtained by laser ablation in liquids [8]. The size and morphology of the gold nanoparticles were evaluated by transmission electron microscopy (TEM) using a JEOL JEM-550 TEM (Figure 2). The samples for TEM investigation were prepared by placing a drop of colloidal gold solution on colodion coated copper grids and evaporating it in air at room temperature.

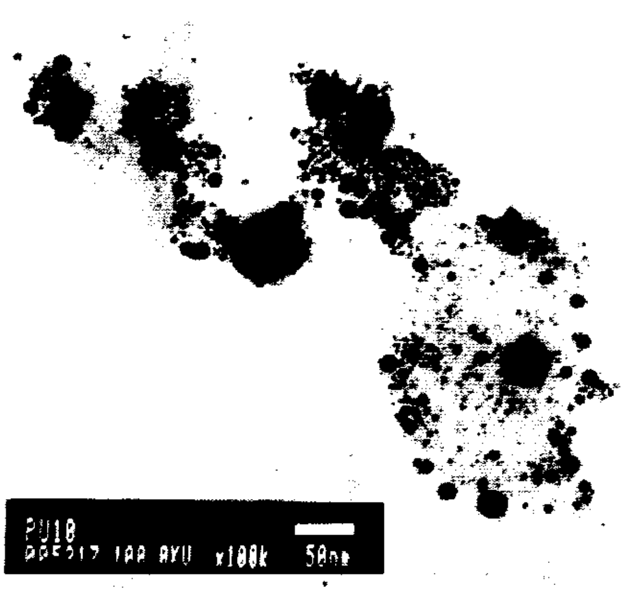

FIGURE 2. TEM micrographs of the gold nanoparticles produced by 532 nm laser ablation

RESULTS AND DISCUSSION

Figure 3 shows absorbance spectra as a result of plasmonic resonance of nanoparticles in aqueous solutions. Shapes of the bands suggest that the nanoparticles are spherical. The absorption maximum in this band is around of 520 nm. The slight landslide of the maximum obeys to the size nanoparticles variation.

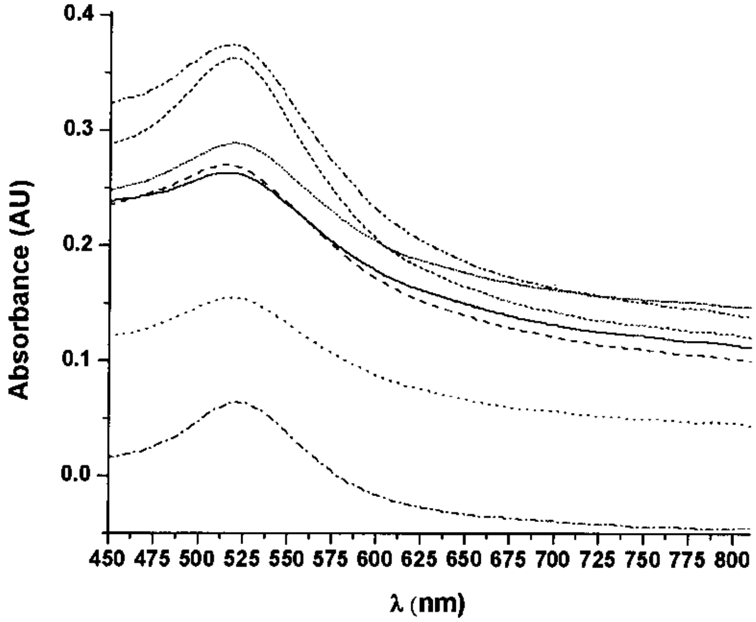

FIGURE 3. Absorption spectra of gold nanoparticles in Colloidals suspensions.

The temporal evolution of TLS is presented in figure 4. Analyzing the signal amplitude for different samples, we observe that TLS decrease with the increase of the mean nanoparticles size. We can neglect any thermal lens effect induced by pump beam on surfactant and solvent, because these do not have light absorption at this wavelength. I-scan experiment showed in figure 5, verified this tendency with the increase of the pump energy. The data for each sample can be fitting and is possible to obtain linear behavior such as predicted by equation 1. These results suggest that the termo-optical parameters are inversely proportional to nanoparticles size, $\zeta(d) \propto 1/d$.

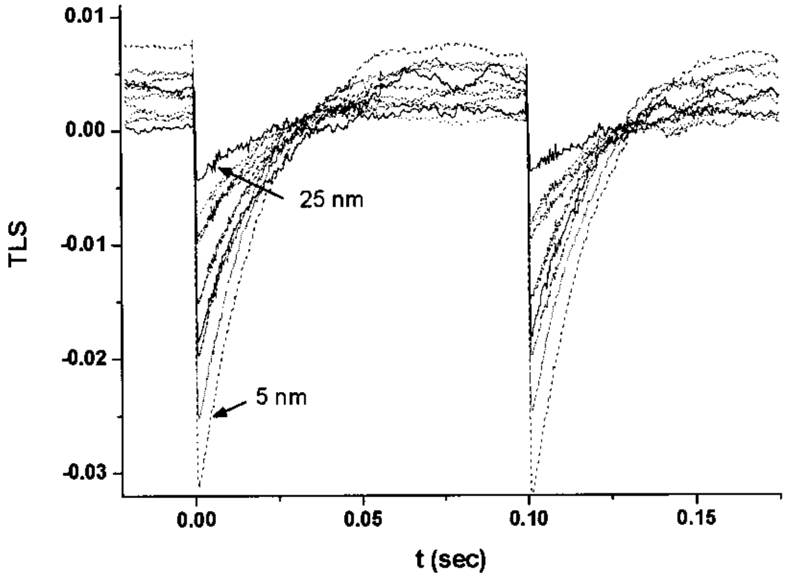

FIGURE 4. Thermal lens signal of nanofluids.

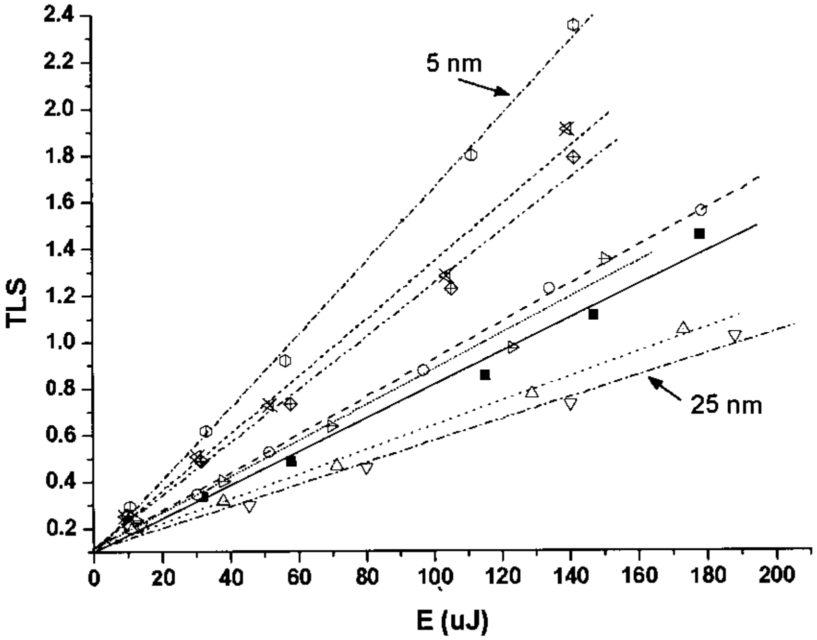

FIGURE 5. Variation of Thermal lens signal with pump laser energy (I-Scan) for gold nanoparticles with different mean sizes

Suspensions of colloidal gold nanoparticles can produce change in heat flux in liquids. Interaction between radiation and these systems is determinate by its size and morphology. This dependence produce changes in thermo-optical parameters such as thermal conductivity and thermal diffusivity. In addition, high energy laser radiation can induce fragmentation [9], changing the properties of heat transfer in nanofluids. I-scan experiment is an interesting alternative for the measurement of termo-optical properties with high sensitivity. Experiments are under going in order to demonstrate this important application of the proposed method.

CONCLUSIONS

We have described a new approach based on the TL and I-scan techniques for the determination of thermo-optical properties of nanofluids. Using this method, we have performed a comparison for different nanometer-size gold nanoparticles. These results show that thermo-optical properties of nanofluids changing significantly with the size of gold nanoparticles in colloidal liquids systems. An increase of the thermo-optical parameters with the decrease of the mean size of nanoparticles can be hoped. We propose that to change the thermal properties of liquids is possible using high energy laser radiation, in order to induce fragmentation and to modify nanoparticles system and properties of heat transfer in nanofluids, and these systems have therefore been suggested as potential "intelligent coolants".

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