Silver Nanoparticles Dimensional Tailoring by Ultrashort Pulses Temporal Shaping

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Abstract: A study of particles sizes and size dispersion was carry carried out, showing that nanoparticles characteristics can be controlled by shaping ultrashort pulses. The absorbance spectrums show the increasing of particles size with pulse durations. The absorbance spectrum width increases with the pulse duration, showing the strong dependence of particles characteristics with the laser conditions.

1. Introduction

In recent years nanoparticles have been used in several applications. In this context, the nanoparticles production controlling its shape has fundamental importance for scientific and industrial applications where they are employed. To control these features is necessary to have control over the processes that create the particles. One method to control these physical processes is using an ultrashort pulsed laser with large bandwidth. This is due to the characteristics of this kind of equipment, related to extremely high peak powers and very short temporal durations, which allow performing experiments where high fluences are required, such as the generation of plasmas, materials processing, supercontinum generation, among others.

There are several ways to generate nanoparticles, among them, chemical processes using polymers. The characteristics of these materials have been motivated the search for new techniques that are less harmful to the environment, such as the use of natural polymers. This is the case of the plant Euphorbia milli latex, which was already demonstrated by us to be a viable polymer to assist the nanoparticles formation [1].

The objective of this work was to study the modification of the dimensional characteristics of silver nanoparticles present in a solution when they were exposed to ultrashort pulses with different temporal durations. This is the sequence of a work done by our group, in which the optimum conditions of pulse energy and irradiation time were determined to control the size, quantity and distribution of nanoparticles. In this previous work, nanoparticles previously created had their diameters halved to 10 nm when irradiated for 5 minutes by 300 µJ, 30 fs ultrashort pulses generated by a CPA Ti:Sapphire laser centered at 785 nm.

In the present study, the pulses temporal duration is changed by the control of the second order dispersion, thusmodifying the temporal energy distribution incident on the nanoparticles, controlling their sizes and shapes. The temporal pulse shaping is a technique to changethe pulse spectral profile, to control its temporal characteristics, since both spectral profile and profile in the time domain are related by Fourier Transforms.

These pulse shaping techniques have attracted great interest from the scientific community, since many physical processes induced by light can be studied and controlled by adaptive controlling of femtosecond pulses. The areas of applications of these techniques involve physics, chemistry, biology and engineering

2. Experimental Setup

The experiments were performed using ultrashort pulses from a commercial CPA laser (Odin, from Quantronix, seeded by a Mira-Seed, from Coherent), generating 650 µJ maximum energy pulses centered at 800 nm with 40 nm of bandwidth, at a 1 kHz repetition rate. To control the pulses duration through the introduction of second order phase components, an Acousto-optic Programmable Dispersive Filter (AOPDF) spectral pulse shaper (Dazzler, from Fastlite) was used, placed between the seeder and the amplifier.

3. Results

Figure 1 shows the measurements, in which the laser irradiation of the cuvettes with nanoparticules solution is shown. Is possible to observe the reddish color of the solution with silver nanoparticles, which have their sizes reduced, controlling the duration of the laser pulses used. $1cm^2$ cuvettes were used with 1.5 ml of silver nanoparticles. The irradiation lasted 10 minutes per sample for a total of 8 samples. Were used pulses with durations of 40 fs, 70 fs, 90 fs, 128 fs, 150 fs, 180 fs, 200 fs and 246 fs. The cuvettes were placed in a computer controlled translation stage for their displacement, once after being irradiated, the samples were moved horizontally to the measuring position, where they were aligned with fiber coupled halogen light source (Ocean Optics HL-2000) and a fiber spectrometer (Newport OSM 400 UV / VIS) for the acquisition of their absorption spectrum. These absorbance spectrum measurements are very important because of the strong surface plasmon resonances presents in the silver nanoparticles [2]. The particles sizes determine the particles potential, which the free electrons will oscillate collectively on the metallic particle surface, creating the cited resonances. The potential increase when the particles size grows, shifting the absorption to red wavelengths [3, 4].

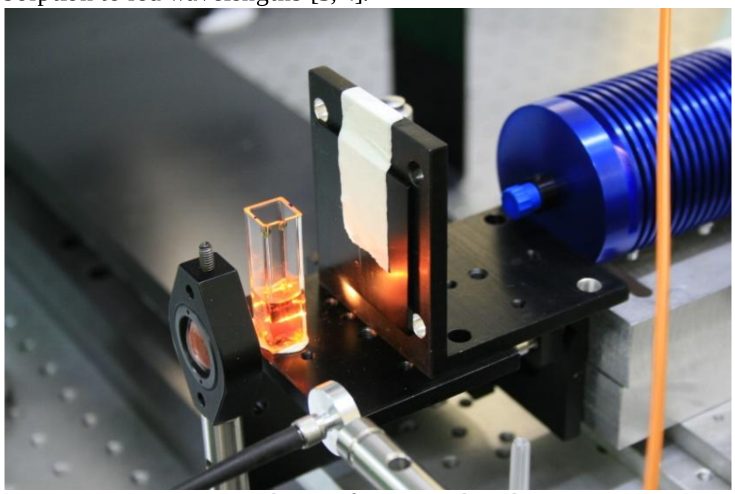

Figure 1 – Irradiation of nanoparticles solution.

The absorbance spectrum measurements are showed on the Figure 2.

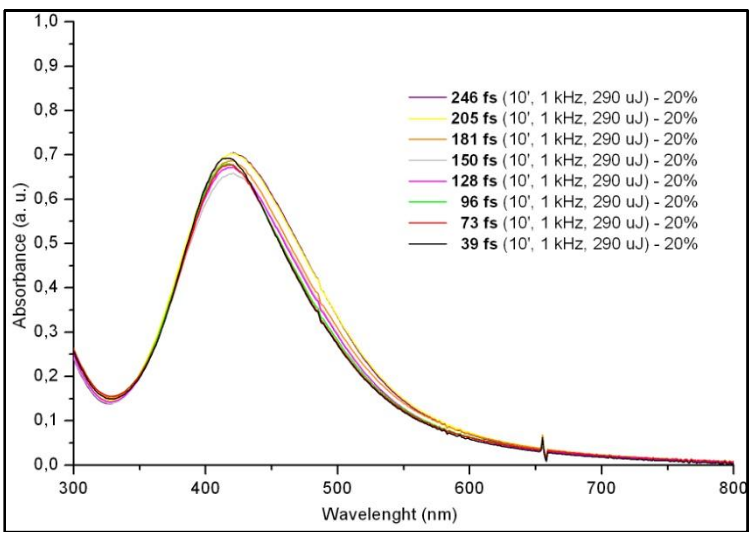

Figure 2 – Absorbance spectrum for the diferent pulse durations.

Figure 3 shows the results obtained for the position of the absorption peaks of the samples as a function of the temporal duration of the laser pulses. It is possible to observe a decrease in the peak position as the pulses duration shortens. It is therefore the reduction in size of silver nanoparticles with the shortening of the pulses used for irradiation.

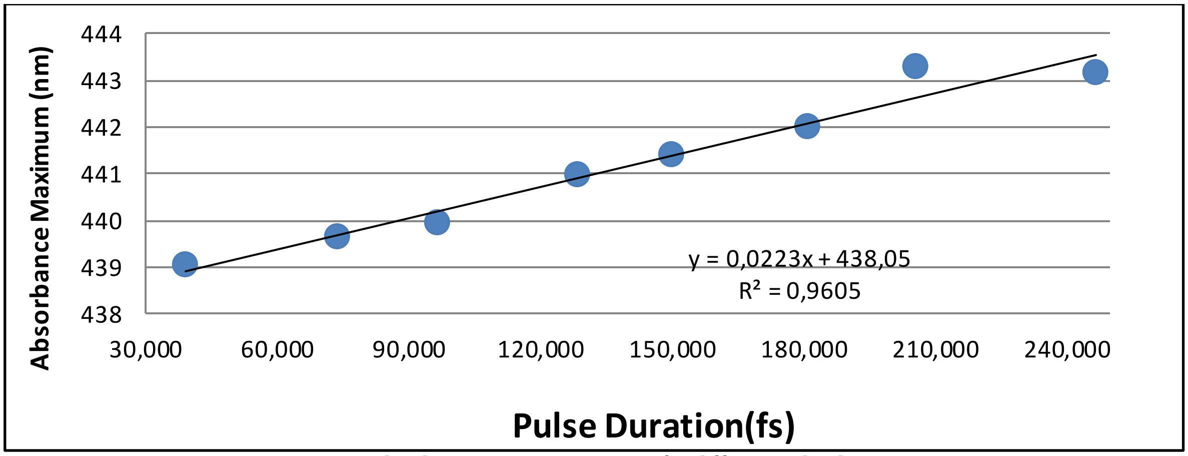

Figure 3 – Absorbance maximum position for different pulse duration.

Figure 4 shows the width of the absorption peak as function of pulses durations. There is an growing in the peak width with the pulses duration increase, showing sharpening of the nanoparticles size distribution with the pulses duration decreasing.

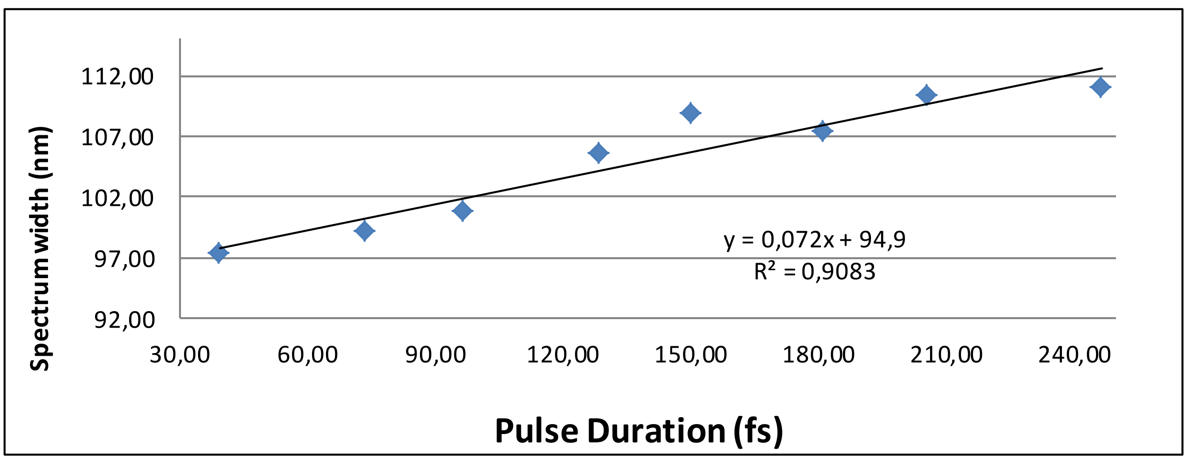

Figure 4 – Absorbance spectrum width for different pulse durations.

3. Conclusions

The results show that it is possible to control the characteristics of the silver nanoparticles by spectrum conformation of the laser pulses used for the irradiation of the samples. This control can be tailored by changing phases of higher order dispersion in the future experiments.

3. Acknowledgements

The authors tanks Fapesp, CNpq, Capes, CLA and Unifesp for the structure and financial support.

4. References

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