Double pulse laser ablation in water: preparation and spectroscopic characterization of silver nanoparticles

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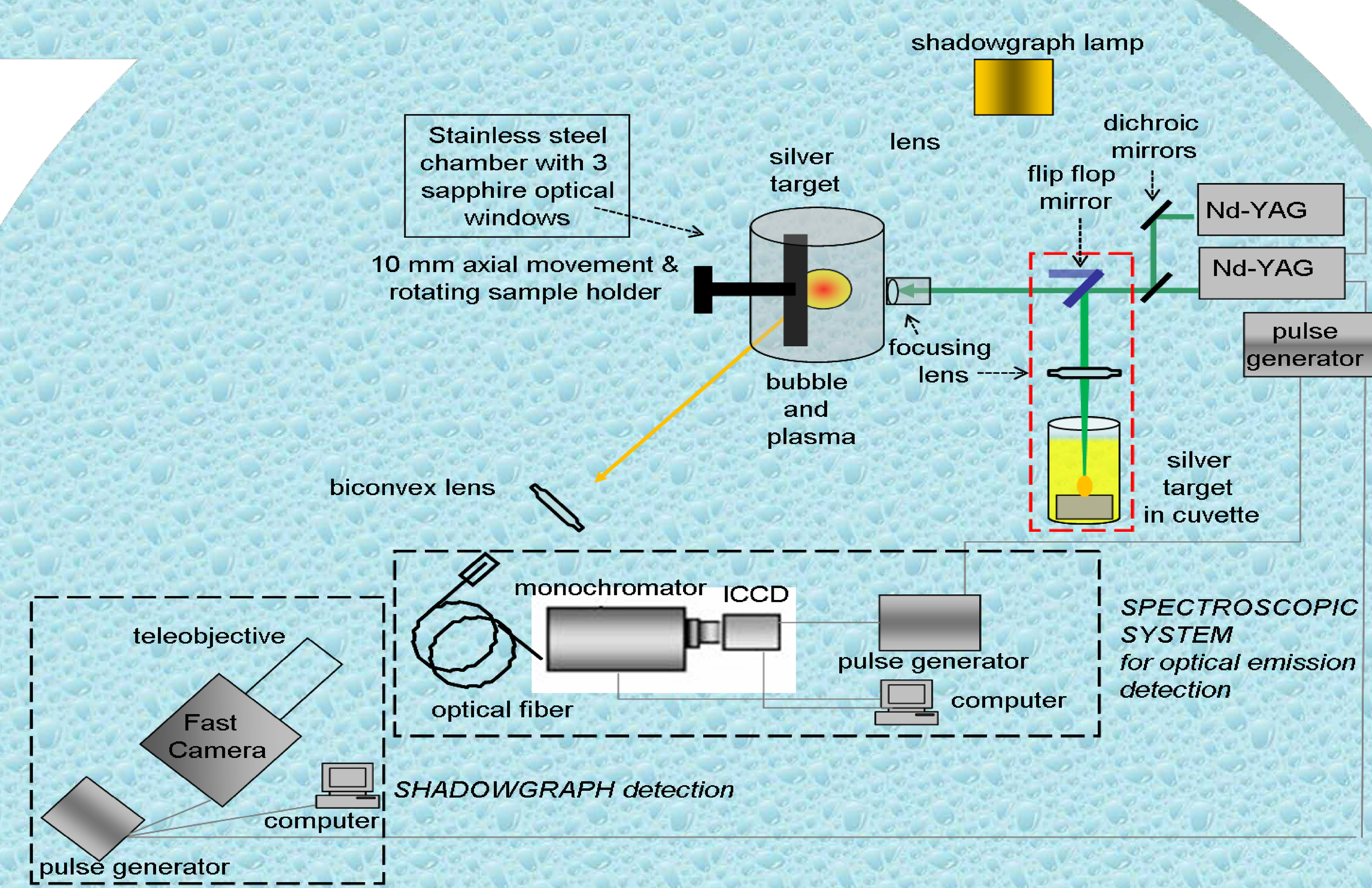
Abstract:

Silver nanoparticles **(Ag NPs)** have been generated by double pulse laser ablation in liquids **(DP-LAL)** from silver target submerged underwater at atmospheric pressure and room temperature by using second harmonic (532 nm) of two Nd:YAG lasers. The double- pulse (DP) technique offers a good control on the particle formation process and remarkabl enhancement in the production yield by selecting the appropriate interpulse delay **(I.D)** between laser pulses respect to single pulse method **(SP).** In dependence on the evolution time of the first laser produced bubble, the second laser pulse generates a different effect on the expansion of the second laser induced plasma **(LIP)** and on NPs generation. Different techniques have been used to study the plasma and the generated NPs : the optical emission spectroscopy **(OES)** has been used to study the plasma emission, shadowgraph image to monitor the cavitation bubble dynamics, and **UV-VIS** spectrometer as well as Dynamic Light Scattering **(DLS)** have been used for Ag NPs characterization

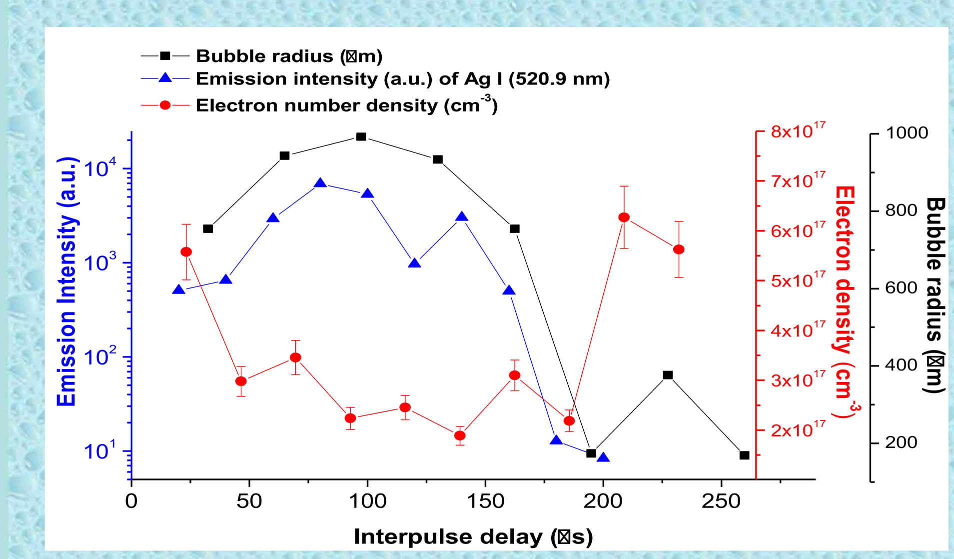
Experimental set-up



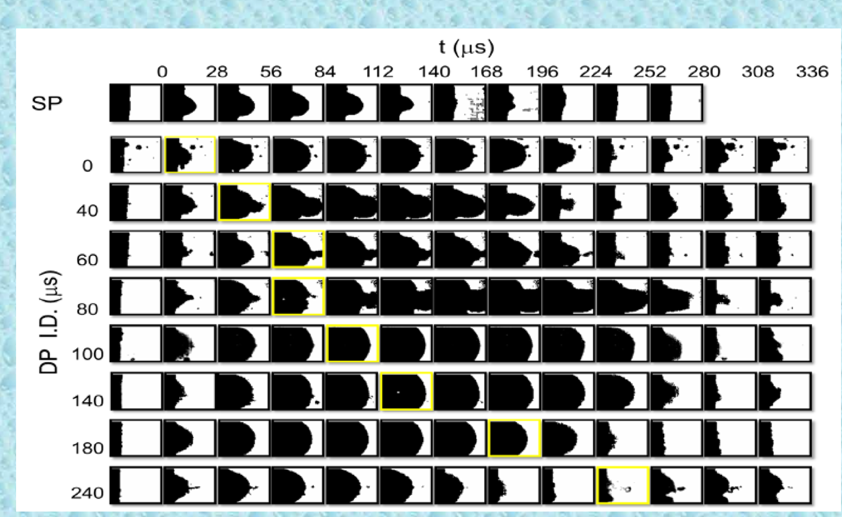
The dashed boxes show the two different detection systems used for the optical emission spectroscopy and shadowgraph measurements, and the cuvette for the realization of Ag colloidal solutions at controlled concentration

OES & Shadowgraph

By OES measurements it can be observed that the Ag I emission intensity follows the bubble dynamics, since different ablation yield at different interpulse delays are obtained, while the electron number density shows an inverse trend (with respect to the emission intensity) due to the pressure inside the bubble (higher in the early expansion and in the late collapse). In agreement with this OES results, the shadowgraph images show that for small bubble volumes, i.e. at the early expansion and late collapse stages, most of second laser pulse does not reach the target so the ablation rate is reduced while it becomes more efficient at the maximum bubble expansion where the NPs concentration is decreased

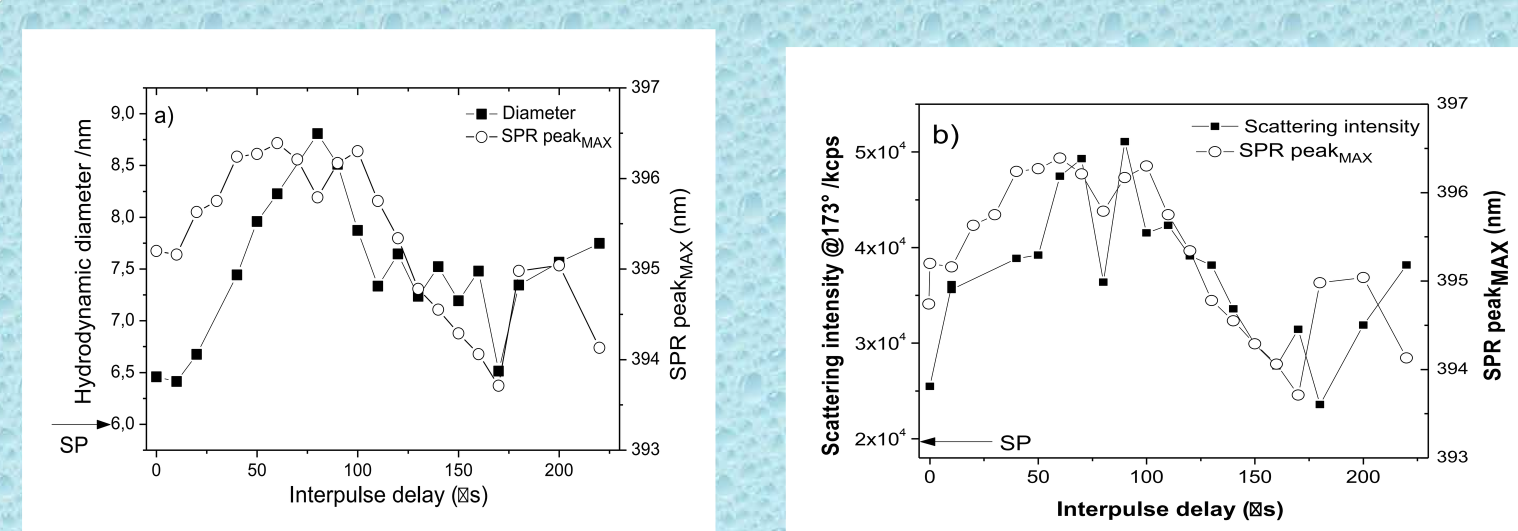


OES measurement of plasma emission produced by the second laser pulse during a DP experiment on Ag target in water



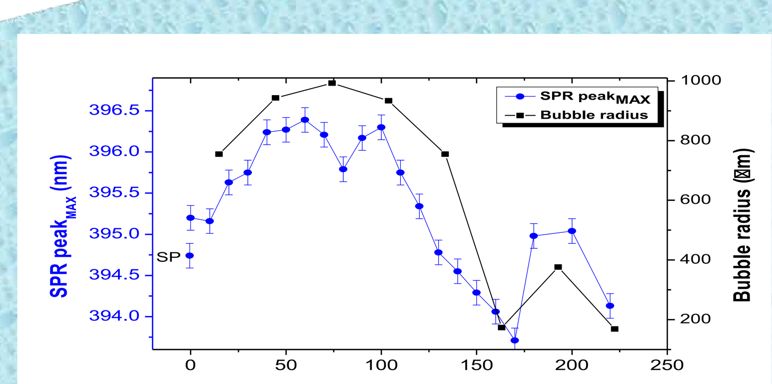
Time-resolved shadowgraph images of bubbles induced by double laser pulses on Ag target in water. The image with yellow square represents the incoming time of the second pulse.

DLS

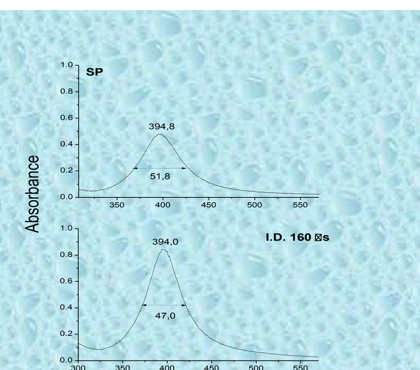


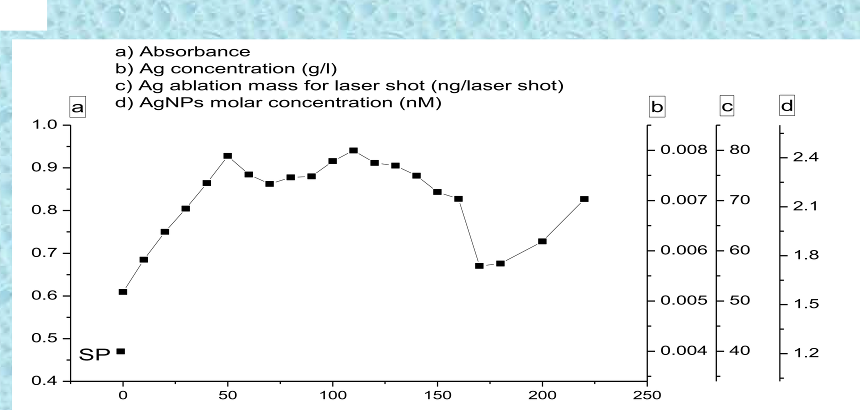
DLS shows that the average size of Ag NPs is between 6 to 10 nm. The AgNPs SPR maximum peaks and the Ag NPs hydrodynamic diameters measured with DLS follow the same trend when they are plotted as function of the interpulse delay: the smaller particles are produced in the early expansion and late collapse stage of cavitation bubble.

UV-Vis spectroscopy



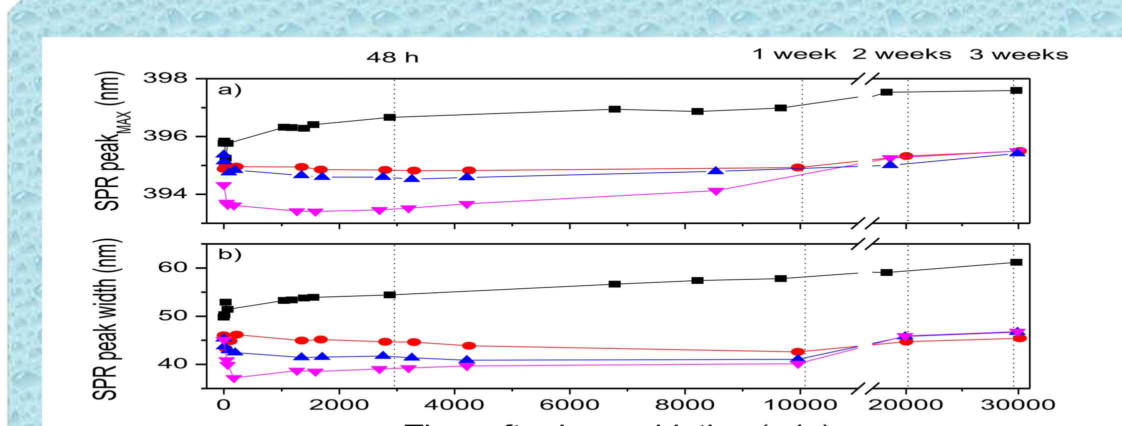
From the result of SPR peak vs I.D. and considering the proportionality of the SPR wavelength with the NP size, smaller NPs are obtained at interpulse delay times corresponding to the early expansion and late collapse of the cavitation bubble.





SP-LAL has different behaviour at the same experimental conditions of DP-LAL. The Ag NPs prepared with SP-LAL show smaller SPR wavelength than those prepared with DP-LAL. But in terms of yield (i.e. solution concentration) the AgNPs produced by DP-LAL show higher concentration (3 times at the maximum of bubble expansion).

Stability of AgNPs



a) SPR peak wavelength and b) SPR peak width of AgNPs solutions obtained by □ SP and DP-LAL at three representative interpulse delays □ 10 µs, □ 80 µs and □ 160 µs respectively, as functions of time after laser ablation

Both colloidal solution (by SP-LAL and DP-LAL) show an acceptable stability when SPR peak wavelengths and peak width are monitored through 3 weeks as function of time after ablation.

Acknowledgements

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