Ultrafast Mie Scattering in Sonoluminescence: An Experimental Proposal

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Sonoluminescence (SL) is the conversion of acoustic waves into light [1]. The standard experimental setup consists of a water flask in which a gas bubble is trapped using an acoustic field. Due to the action of the field the bubble undergoes rapid non-linear oscillations that result in a violent collapse phase. During this phase a hot spot is putatively formed reaching temperatures in the range of 10,000 to 100,000 K, giving rise to the emission of light. In its single bubble manifestation, the observed spectrum is continuous in the range of 200-600 nm, which is the transparency window of water. The duration of the emitted flash is of the order of 100 ps or less, and the intensity of the order of 1 mW. The intensity is strongly dependent on the doping of noble gases dissolved in water, and their molecular weights. In addition the intensity increases as the temperature of the water decreases. Several theories for the light emission mechanism have been proposed. For example, black body radiation, bremmstrahlung, vacuum radiation, proton tunneling, etc. However, up to date experiments do not allow to discern whether one of them is correct.

In a recent paper [2]we proposed an experimental procedure to investigate possible mechanisms for radiation emission in SL. Our analysis was based on Mie theory of differential light scattering (DLS) for coated spheres in an external medium. Depending on the physical mechanism responsible of SL the complex dielectric function $\epsilon(\omega)$ of the gas inside the bubble changes and this is manifested in the intensity of the scattered light. In a previous experimental work Vacca et al. [3] implemented a DLS approach capable in principle of retrieving information with pico-second resolution without the need for fast electronics to test the SL bubble collapse phase. Their formalism consists of comparing the intensity of scatter light from a bubble at differnt times.

The DLS approach along with a calculation of the changes of the dielectric function of the gas inside the bubble at different times, will enable us to determine wether the emission is due simply to black body radiation or if the gas can be ionized during the collapse as to create a plasma inside the bubble. To calculate the dielectric function of the gas during the collapse we may use of available experimental data depicting the evolution of the bubble radius as a function of time. In the case of an adiabatic compression we can calculate the changes in density and pressure and using a Claussius-Mossotti type relation ϵ as a function of time or radius can be calculated. For typical SL parameters, ϵ reaches a maximum value of about 1.7, close to the value of water. Thus, at the minimum radius the bubble will be transparent to the incomming radiation from an external source, and this could be detected within the DLS approach. On the other hand, if we assume that the colapse conditions are such that the gas gets ionized, the dielectric function will depend strongly on the frequency, the degree of ionization of the gas, its temperature etc. The plasma is created during the last moments of the collapse. Using Mie scattering experiments again within the DLS approach, the presence of the plasma could be detected as well as its spatial distribution if we perform scattering experiments with polarized light.

[1] B.P. Barber, R.A. Hiller, R. Loefstedt, S.J. Putterman, K.R. Weninger, *Phys. Rep.* **281** 65 (1997).

[2] C. Villarreal, R. Esquivel-Sirvent, R. Jauregui, *Phys. Rev. E* **61** 403 (2000).

[3] G. Vacca, R.D. Morgan and R.B. Laughlin, *Phys. Rev. E* **60** 6303R (1999).