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OBSERVATION OF EFFECT OF MAGNETIC FIELD ON SYNCHRONOUS PICOSECONDS SONOLUMINESCENCE

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ABSTRACT

In present paper, we discuss about effect of magnetic, filed on working system of sonoluminiscence. Due to high concentration here generate flashes of light in a liquid when sonoluminescence is driven by a resonant sound field, the bursts can occurs in a continuously repeating. Then shock wave formed.

Key Words- Ultrasonic, Shock waves, Sonoluminescence, Equilibrium.

1. INTRODUCTION

Here we consider bursts in of on amplification of high energy. Now since the burst is continuously repeated so the shock wave formed which is useful for functioning of sonoluminescence. Such study presented by Saksena & Nyborg in absence of magnetic filed. We study same problem is presence of

magnetic field.

SONOLUMINESCENCE[1-13] is a non-equilibrium phenomenon in which the energy in a sound wave becomes highly concentrated so as to generate flashes of light in a liquid. We show here that these flashes, which comprise over 10 photons, are too fast to be resolved by the fastest photomultiplier tubes available. Furthermore, when sonoluminescence is driven by a resonant sound field, the bursts can occur in a continuously repeating, regular fashion. These precise 'clock-like emissions can continue for hours at drive frequencies ranging from audible to ultrasonic. These bursts represent an amplification of energy by eleven orders of magnitude.

Mathematical and Numerical Analysis

In a resonant sound field, sonoluminescence (SL) originates from the pressure antinode in a region less than 10 □m in. diameter and comes in repetitive bursts. Our measurements indicate that each of these bursts has a power greater than 1.0 mW and a duration less than 100 ps. By comparison, the Tastest visible transition ($3 \rightarrow 2$) of the hydrogen atom is over 100 times slower. The repetition rate for these bursts is the frequency, f_a, of the sound field. Typically, $f_a = 10^4$ cycles per second, which corresponds to an acoustic period of 100 us, so that the pulse width □t_{SL} is over 10 times smaller than the period of the sound field. A third important timescale is the wander in the difference in phase of the acoustic cycle at which consecutive bursts are emitted. □t_{SL}, which can be less than 200 ps. The light emission is visible to the unaided eye and appears blue. We therefore estimate its frequency, E_{photon}/h, to be 8.0×10^{14} Hz. This phenomenon is therefore characterized by a broad spectrum of times

$$E_{photon}/h >> 1/□□t_{SL} >> 1/□□t_{SL} >> f_a >> 1/T_M \quad ..... (1)$$

where T_M (modulation time) is the timescale, typically ~1 s, on which the intensity blinks on and off in certain regions of parameter space (regions of pressure and frequency).

Sonoluminescence was discovered over 50 years ago. In early studies of the effects of high-intensity sound fields on chemical reactions, it was found that H-O, was formed in water in the presence of cavitating bubbles". The quantum of energy needed to create peroxide from water is extremely large compared with the sound-field energies', and Mecke suggested that these quanta were sufficient to cause emission of visible light. This prediction was borne out by experiments' that refer to Mecke's otherwise unpublished work.

In the standard model for sonoluminescence[1.3], collapse of a bubble formed by cavitation occurs in a sufficiently spherical and adiabatic manner that the energy of collapse is delivered to a small number of molecules, which are thus excited or dissociated to the point at which they emit light (as chemiluminescence) when they recombine. The distribution, location and timing of cavitation have been largely unpredict able. Saksena and Nyborg have, however, observed SL in the absence of cavitation noise, and Crum and Reynolds have imaged a distribution of bubbles that also produced SL without cavitation noise. Recently Gaitan" and Crum" showed that single cavity could be driven hard enough to emit stable sonoluminescence. These experimental advances (along with our calculation of the energy amplification) motivated us to investigate the properties of controlled SL.

Our apparatus consists of spherical glass flasks filled with a 25% solution (by volume) of glycerine in water. A vacuum pump is used to degas the mixture, enabling us to reach the high- intensity sound field required for SLA radially polarized, hollow cylindrical piezoelectric drive is mounted on the Hask with its axis pointing to the centre of the sphere. This transducer is driven by the amplified signal from a waveform generator (HP3325A). Our investigations are limited to radially symmetric modes. A broad-band photomultiplier tube (PMT) is used to characterize the emitted pulses of light. Figure 1a shows the range of sound pressure amplitudes, at the centre of the flask. for which stable steady-state SL can be observed at different frequencies. The amplitudes were calibrated with a microphone (B&K 4138) held a few centimetres from the flask. From the radiated acoustic field, and the transmission coefficient, we determined the field in the fluid.

The phenomenon of SL involves an extraordinary degree of energy focusing. A typical SL sound field has a pressure swing p' of ~1 atm. which in water corresponds to a Mach number M of 10^{-5} (M=v'/u, where o' is the speed of the fluid motion. and u is the propagation speed of a sound wave). The energy density of the sound field is then U (1/2) p $(v')^2$ = 17.3 erg $cm)^{-3}$ (~1.08×10^{-11}eV per atom) where p is the-liquid density. As a photon must originate from a molecule, ion or atom and as a blue photon has an energy of –3eV, this phenomenon involves a focusing or amplification of about eleven orders of magnitude. The size of the spontaneous energy concentration that characterizes SL is so large that one must wonder about the limits of amplification that can be achieved with this type of non-equilibrium phenomenon.

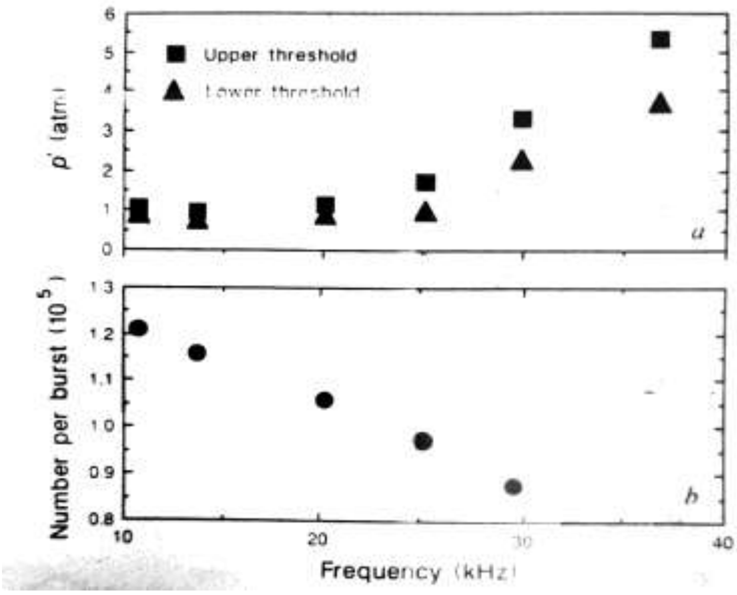

FIG. 1 a Phase plane for continuous single-bubble sonoluminescence. The 20-kHz data point agrees with the measurement of Gaitan. b. Photons per burst as a function of acoustic frequency: p' has been chosen to maximize the light output.

The accumulation of many bursts by a sampling oscilloscope leads to the solid curve in Fig. 2a. Note the 2.2-ns 'rise' time. Figure 2b shows a response curve obtained by using a 34-ps laser pulser as a light source. The two curves are virtually indistinguishable, suggesting that the width of the emission is substantially less than the limitations imposed by the PMT (rated at 2.2-ns rise time). Thus we attempted to determine the duration of the SL flashes with a microchannel-plate PMT (rise time rated as 240 ps). The response is shown in Fig. 2c and d for the SL and pulsed laser sources respectively. Again these responses are virtually identical. The difference between the observed rise time of 290 ps and the rated value is due to detection bandwidth and the variation in pulse heights recorded at the output of the PMT. (Details will be discussed elsewhere: B.P.B., R. Hiller, K. Arisaka, H. Fetterman & S.P., manuscript in preparation.) As Fig. 2d (and b) yields the response to a 8-function source, it can be used to devolve the response to SL: Fig. 2c (and a). We thus conclude that the (conservative) upper limit on □t_{SL} is 100 p Ops.

The number of photons in a single burst can be determined from the integrated charge output of the PMT, given by the area of the pulse divided by the resistance to ground of 50 through which it flows. Assuming that each electron is created by one photon, the total photon emission is then obtained by correcting for the gain (2×10^7 at 1 kV), the efficiency (electrons per incident photon; ~17%) and the solid angle subtended by the active element in the tube (1/1,290). The distribution of pulse heights is shown in Fig. 3a. To determine the characteristic shapes in Fig. 2, the trigger was set at a value V_0, above the peak height. Figure 1b shows the intensity of SL as a function of acoustic frequency, f. Figure 3b shows the increase in intensity as a function of the amplitude p' of the sound field at a frequency f_a =10.736 kHz.

The clock-like property of SL was investigated by triggering on one SL pulse and using a time delay ($1/f_a$) to acquire the next pulse. Because the scope produces an average of pulses, this procedure increased the rise time, but only by 50

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ps. There- fore, we conservatively estimate that the spread in time between successive pulses ($\square t_{SL}$ is the standard deviation of $T_n - T_{n-1}$ where T_n is the time of emission of the nth pulse of light) is less than 200 ps. The maximum drift in $T_n - n/f_a$, recorded over long times, is ±50 ns provided that the drive pressure and frequency are chosen to lie well within the limits for producing SL (Fig. 1a). Near the upper threshold for SL we have measured drifts of more than 1 □s. Gaitan' has also reported observing regions of parameter space where the phase 'jitter' is less than 1° of an acoustic cycle.

The quality factor Q for the acoustic resonances was deter- mined from the 'ring-down' time of the flask as measured by the microphone. At f_a = 25.257 kHz, Q was 1,200, which com- pares reasonably with the value that one would calculate if the losses were due to acoustic radiation damping at the surface of the flask; $Q_r = \square pu/(2pu)_E = 6\times10^3$. (Subscript g denotes room- temperature air surrounding the flask and unsubscripted quantities refer to the liquid.) This should in turn be compared with the quality factor that would apply if the acoustic damping were due only to shear (7) and bulk (5) viscosities of the fluid, $Q_t - u^2p / [2\square f_a (4\eta/3+\zeta)]$. For water, Q_t is ~1×10^7 at f_a = 10Hz. Use of Q_t leads to the acousto-optic conversion efficiency of ~10^{-5}, whereas use of Q_t would imply a conversion efficiency approaching 1%. It would thus be interesting to study SL at low f, and when the resonator is surrounded by a vacuum so that Q would be influenced by the emission of light and the dynamics of the bubble's motion. The transport properties of the bubble (cavity) will depend upon mass diffusion, thermal conduction to the surrounding liquid, acoustic radiation losses at its boundary and viscous losses. The conversion efficiency of 10^{-5} is similar to the fraction of an external macroscopic stress that is responsible for cumulative damage (fatigue) at the microscopic level in structures[12.13]. It would therefore be especially interesting to determine whether an increased Q will result in an increased acousto-optic conversion efficiency.

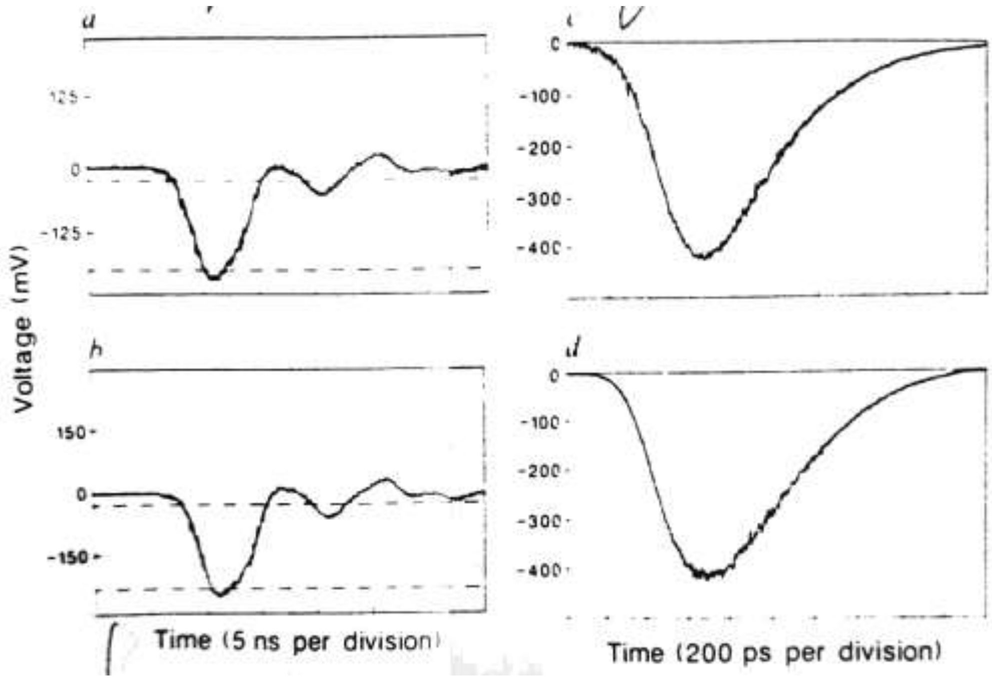

FIG. 2 The average of single-pulse outputs of the photomultiplier tube. a SL data as recorded by a conventional (R928) PMT: b, same as a but using a 34-ps laser pulser (Hamamatsu PLP-01) as the light source. a and b were obtained by running the PMT output into a digital sampling scope (HP 54201A). c and d Data for a microchannel-plate PMT (Hamamatsu R1564U) running into a 20-GHz digital sampling scope (Tektronix 11802). c is for the SL source, and d for the 34-ps laser pulser.

The pulse width of 100ps or less is a striking result. It should be compared with previous estimates of 6 □s (ref. 14) and with the assertion that the cavitation hot spots have a lifetime of a few microseconds[15]. (Reports[16] of flash widths in the range of 10 ns were brought to our attention by a referee and will be discussed elsewhere; B.P.B. et al., manuscript in preparation.) The flash widths that we find are so short that one wonders whether some phenomenon stimulates the atoms to fire in unison. Known cooperative phenomena include laser action, super-radiance and super-fluorescence[17]. Any cooperative phenomenon underlying our observations must be of a spherical nature, however, because a randomly oriented dipole emission would lead to a broad spread in the distribution of pulse heights. According to Fig. 3a, no such broadening is seen. Nevertheless, it is reasonable to expect that some type of correlation characterizes the outgoing photons, because the spacing between light- emitting sources is much less than the wavelength of the emitted light.

To estimate this spacing we return to the standard model for SL and consider the radial oscillations of a bubble of radius R that is bounded by the maximum and minimum values R_{max} and R_{min}. The bubble's contents at the ambient radius R_0 have a temperature of 300 K and a pressure of 1 atm. As the bubble collapses from R_0 to R_{min} in it heats and compresses

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the enclosed gas according to the van der Waals adiabats where p is effective pressure, I' = C_p/C_v (=1.4 for air) is to be evaluated in the ideal gas limit and (4/3)□a^3 = nb is the van der Waals hard core (n is number of moles and b is the excluded volume which is 4×10^{-5} m^3 for air).Here $p^* = p + \frac{H^2}{2}$, H is magnetic pressure.

We estimated the maximum bubble radius to be ~75μm (in) a sound field of 1.4 atm) by visually comparing it with a 1-mm- diameter pipette introduced into the fluid. As an example, we take R_0 =20 μm, which implies that the bubble contains 8×10^{11} air molecules and that a ≈ 2.3 μm. During each burst, about one in every 10^7 bubble molecules radiates. As SL requires considerable heating of the contents of the bubble, we expect that $R_{min} \approx a$, which implies that R_{min} is about five times the wavelength of light, and the average spacing between emission sites is about one-eighth the wavelength of light. This estimate assumes that the emitters are evenly spaced throughout the volume of the bubble. Because □t_{SL} u $\leq$ 0.1a << a, the entire volume of the bubble may not be able to reach local thermodynamic equilibrium during the rapid adiabatic compression. In this case the hot spot would have thickness u□t_{SL}, and the spacing between emitters would be less than one-fiftieth of the wavelength of light.

It is also possible that the shortness of the light pulses arises from an extremely rapid cooling of the bubble after its oscillation passes through R_{min}, which we will call picosecond adiabatic cooling. A simulation of the Navier-Stokes equations for the above parameters yields R_{min} = a + 0.1 μm and a bounce time of 400 ps for temperature to decrease by 50% from its value at R_{min}. Details of this simulation will appear elsewhere (R. Löfstedt, B.P.B. and S.P., manuscript in preparation). The assumption that the bubble contains a conserved number of air molecules and is not a vaporous cavity can be tested by spectral analysis[19]. The pressure of electric field present the high concentration[20]. So we get major pressure effect which is much useful for clear picture study. The pressure effect in recenary for equilibrium of dubble[21].

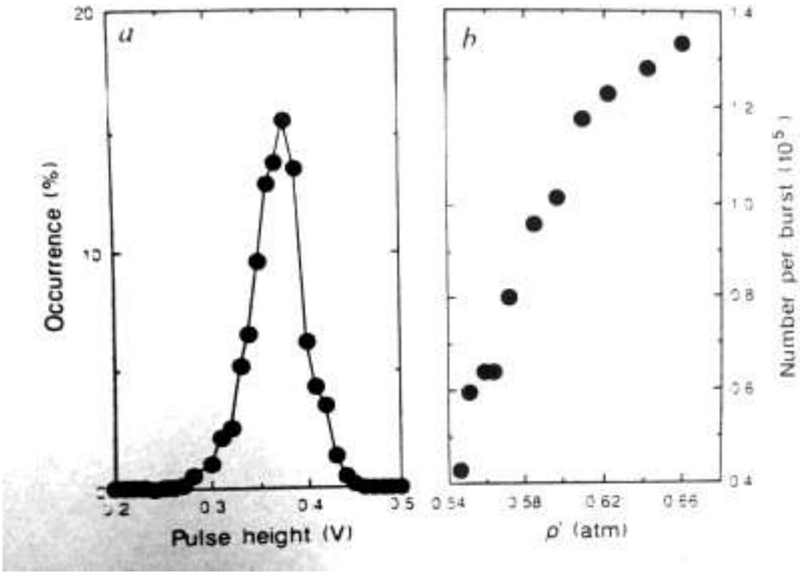

FIG. 3 a Pulse height distribution. A pulse height of 0.1V represents 1.1×10^4 photons emitted. f_a = 20.193 kHz. b. Photons per burst as a function of acoustic pressure amplitude. f_a = 10.736 kHz.

2. RESULT

The phenomenon of sonoluminescence represents a failure of the Navier-Stokes equations in a situation where one would normally expect them to apply. The Mach number of the imposed sound field here is much less than one and the wavelength of the sound is very large compared with the microscopic mean free path, yet light is produced, and is emitted, furthermore, in a clock-like manner.

This phenomenon arises from the highly nonlinear oscillation of a bubble which at large R is an ideal gas and at small R is a liquid or solid (or possibly a plasma). The acceleration at R_{min} is 10 times as large as the acceleration at R These oscillations involve the transfer and focusing of energy from macroscopic scales down to the molecular, atomic or even electronic degrees of freedom.

The huge, spontaneous (non-equilibrium) amplification factors discussed above are noteworthy in that they are controllable and reproducible. In this respect, stable synchronous SL differs from other phenomena (such as dust explosions, ball lightning and highly speculative conditions for nuclear fusion) that also require large spontaneous energy concentrations. If we could understand the mechanism behind synchronous SL, we might see a way to achieve large but 0 controllable energy concentrations more generally.

3. REFERENCES

[1] Walton, A.J. & Reynolds, G.T. Adv. Phys. 33. 595-660 (1984).

[2] Verral, R.E. & Sehgal, C. Sonoluminesence in Sonochemistry its Chemical & Physical Biological Effects (ed. Sunlick, K.S.) (VCK, New York 1988).

[3] Sunlick, K Science 247, 1439-1445 (1990).

[4] Frenzel. H. & Schinsten, H.Z. Phys. Chem. B27, 421-424 (1934).

[5] Richards, W.T. Loomis, A.L.J. Am. Chm. Soc. 49, 3086-3100 (1927)

[6] Schmitt, F.O., Johnson, C.H. & Olson, A.R.J. Am. Chm. Soc. 51, 370-375 (1927)

[7] Beuthe, H.Z.Phy. 163, 161-171 (1932)

[8] Saksena, T.K. & Nybory, W.L. Chem., Phys. 53, 1772-1733 (1970).

[9] Crum. L.A. & Reynolds, G.T.J. account Soc, Am 78, 137-139 (1985)

[10] Gaitan, D.F. thesis Univ. of Minisippi (1990).

[11] Gaitan, D.F. & Crum, L.A. Proc Joint ASME-JSME. Fluid Engng. Conf. Micro Fluid Mechanics (ASME, New York, in the prem) : J. account Soc. Am. Suppl. 1.87.5141 (1990)

[12] Halford, G.R. thesis Univ. of Illionis (1996).

[13] Erber, T. & Guralnick, S.A. Ann. Phys. 18L, 25-53 (1988).

[14] Margulis, M.A. Ultrasonics 23, 157-168 (1985).

[15] Sunslick, K.J. account soc. am.89, 51885 (1991).

[16] Kurochkin, A.K. Smordov, E.A. Valitov, R.V. & Margylis, M.A. Russ. J. Phys. Chem 60, 731-734 (1986). Zh Fiz Khim 60, 1234-1238 (1986) .

[17] Dick, R.H. Phys. Rev. 93, 99-110 (1954).

[18] Bonifacio, R. & Lugiato, L.A. Phys. All, 1507-1521 (1975).

[19] Suslick, K.S. Mature 330, 553-555 (1987).

[20] Srivastava, N. and Ray, A.K. IRJMETS Vol 06, In 07, 1719-1724 (2024).

[21] Ray. A.K. and Shukla R.N. IJSR, Vol 12 In 08, 779-781 (2024).