Sonoluminescence: microwaves and cold fusion

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Abstract Sonoluminescence (SL) observed in the cavitation of water is explained by the Planck theory of SL that treats the bubbles as miniature masers converting the velocity of bubble collapse to electromagnetic (EM) waves at microwave (MW) frequencies. The Planck theory of SL is consistent with historical experimental data that shows MW's concurrent with SL are produced in cavitation. As the bubbles collapse, MW's are absorbed and the Planck energy accumulates through the rotation quantum state of the bubble wall molecules. A MW photoelectric effect for accumulated MW photons is identified as a new SL parameter. During ultrasonic cavitation, cold fusion on average between the D's on colliding D_2O bubble wall molecules does not occur as the Planck energy is limited to about 2 keV, but a limited number of cold fusion events with a Planck energy in excess of 10keV are possible. However, high power microwaves (HPM) pulsed to less than ~1 ns appear to be a far more efficient way of creating cold fusion in D_2O than by ultrasonic cavitation.

Keywords Sonoluminescence, Maser, Cold fusion, Pulsed microwaves

1 Introduction

The Planck theory of SL[1−3] finds basis in quantum mechanics and does not rely on high bubble gas temperatures generated by compression heating or shock waves to explain optical SL radiation and is applicable even if the bubble gas temperatures remain near ambient during collapse.[1] The bubbles are treated[2] as miniature IRasers with standing waves at optical frequencies $f = c/\lambda$ in resonance with a characteristic bubble dimension δ, i.e., $\delta = \lambda/2$. The collapsing IRasers may be of any shape, including pancake and spherical geometries. Pancake bubble collapse occurs in multiple bubble SL where the collapse shape is not controlled; whereas the collapse shape is controlled to be spherical in single bubble SL. In the Planck theory of SL, a pancake and not a spherical collapse shape gives the optimum SL[2−3] and is consistent with SL spectra reported[4] that shows multiple bubble SL if normalized to the same background to be far more intense than single bubble SL. In this paper, a maser instead of an IRaser is used to describe the collapsing bubble because of the connection made between optical SL radiation and MW's.

2 Theoretical background

In the Planck theory of SL, MW's are created in a collapsing bubble of arbitrary geometry as opposite bubble walls close at the collapse velocity V_{collapse}. Electrical fields and currents are induced in clusters of bubble gas and H_2O molecules on opposing walls separated by the dimension δ as shown for a spherical bubble in Fig.1.

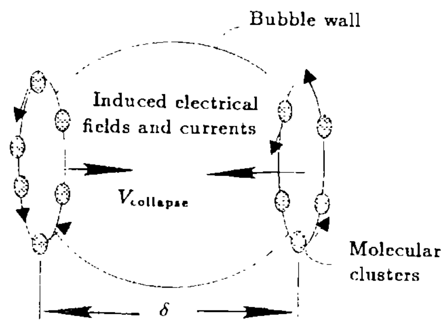

Fig.1 SL maser model

The MW's increase the Planck energy E of the bubble wall molecules by $\Delta E = h\Delta v$, where h is Planck's constant and Δv the change in frequency of the bubble wall molecules. If the SL fluid from IR to the UV is optically absorptive such that half wave boundary conditions for the optical radiation within the maser are satisfied at the walls, the Planck energy increment ΔE

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is required to be absorbed in a time Δt that is at least as fast as the period of the maser resonance frequency f, i.e., $\Delta t < 1/f \sim \lambda/c$. For example, the optical absorption of H_2O is significant everywhere except the VIS window. Indeed, the SL spectra[5] from cavitating bubbles in H_2O may only be measured from the optical radiation escaping through the VIS window of H_2O, i.e., half wave boundary conditions for optical radiation in H_2O are satisfied everywhere but at the VIS window.

In Δt, the maser dimension δ decreases by $\Delta\delta \sim 2/V_{\mathrm{collapse}}\Delta t \sim 4V_{\mathrm{collapse}}\delta/c$ and the maser resonant frequency f increases by $\Delta f \sim c\Delta\delta/2\delta^2 \sim 4V_{\mathrm{collapse}}/\lambda$. However, maser wall boundary conditions require, $\Delta v = \Delta f$. Hence, the Planck energy E of the bubble wall molecules increases by the increment ΔE,

$$\Delta E = h\Delta v = \frac{4hV_{\mathrm{collapse}}}{\lambda} \tag{1}$$

In the Planck theory of SL, the MW's are created at the frequency Δv,

$$\Delta v = \frac{4V_{\mathrm{collapse}}}{\lambda} \tag{2}$$

Estimates of the Planck energy increment ΔE may be made by upper bounding the collapse velocity V_{collapse} by the sonic velocity of H_2O, i.e., V_{collapse} ~1460 m/s. As the maser collapses at optical wavelengths λ near 200 nm where H_2O is sufficiently UV absorptive such that half wave boundary conditions are satisfied, the Planck energy increments ΔE are approximately 120 μeV. Since the concurrent MW's are created at frequencies Δv near 30 GHz, the only quantum states of the bubble wall molecules that can be excited are the rotation states of molecules with high rotation inertia, e.g., the NaOH molecule[4] for SL in NaCl solutions. For SL in H_2O, the MW's may excite dimers[3] of H_2O molecules and excimers[5] of bubble gas and H_2O molecules, i.e. $m\mathrm{H_2O}\cdot n\mathrm{M}$, where M is a bubble gas molecule and m, n are integers. In the Planck theory of SL, the inert gases without rotation quantum states are not excited and may explain why the lines of the inert gases are not found in SL spectra.[5]

Assuming a continuous MW absorption spectrum, the Planck Energy E is pumped through the rotation state of bubble wall molecules at the rate $\mathrm{d}E/\mathrm{d}t$,

$$\frac{\mathrm{d}E}{\mathrm{d}t} \sim \frac{\Delta E}{\Delta t} \sim \frac{4hcV_{\mathrm{collapse}}}{\lambda^2} \tag{3}$$

In the Planck theory of SL, it is important that the lifetime Δt_{life} of ΔE be long relative to the absorption time Δt, i.e., $\Delta t_{\mathrm{life}} \gg \Delta t$ and thereby allow ΔE to successively accumulate to VIS-UV levels. From the Heisenberg uncertainty relation, $\Delta E\Delta t_{\mathrm{life}} \sim h$. For $\Delta E \sim 120\mu$eV, $\Delta t_{\mathrm{life}} \sim 35$ ps and is of the order of 50 to 150 ps SL pulse durations reported.[5]

The time $\Delta\tau$ for the maser to collapse from an IR wavelength λ_{IR} to a wavelength λ is, $\Delta\tau = (\lambda_{\mathrm{IR}} - \lambda)/4V_{\mathrm{collapse}}$. If $\Delta t_{\mathrm{life}} > \Delta\tau$, the Planck energy E accumulated in the bubble wall molecules over the time $\Delta\tau$ is,

$$E = \int_0^{\Delta\tau} \frac{\mathrm{d}E}{\mathrm{d}t}\mathrm{d}t = hc\int_\lambda^{\lambda_{\mathrm{IR}}} \frac{\mathrm{d}\lambda}{\lambda^2} = hc(\frac{1}{\lambda} - \frac{1}{\lambda_{\mathrm{IR}}}) \tag{4}$$

and is observed to be independent of V_{collapse}.

3 SL experimental data and discussion

EM radiation concurrent with optical radiation was observed over three decades ago in cavitation experiments[6] of a single bubble. Antenna and PMT test equipment were used to measure the peak intensity of EM and optical radiation. Concurrent time traces of EM and optical intensity show the EM radiation to slightly lead the optical radiation. If so, this is consistent with the Planck theory of SL that requires the accumulation of Planck energy increments ΔE prior to VIS-UV photon emission. The uncertain conclusion[6] that EM and optical radiations were emitted simultaneously was attributed to the limitation, mainly the bandwidth of the test instruments.

For the SL fluids: H_2O, 2 mol/L NaCl solution, and alcohol, the peak EM and optical intensity data[6] as a function of collapse velocity are constructed and shown here in Fig.2.

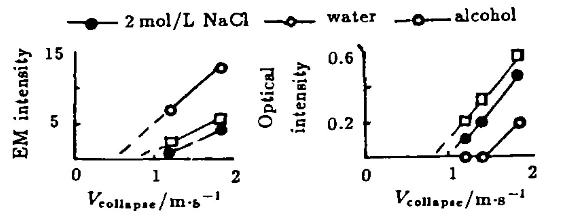

Fig.2 EM and optical intensities vs $V_{collapse}$

The peak EM and optical intensities are observed to approximately linear with $V_{collapse}$. This is consistent with Planck theory of SL, i.e., $\Delta\upsilon \propto V_{collapse}$ and $\Delta E \propto V_{collapse}$. Further, the slopes of EM and optical intensities are a measure of Planck's constant h and are approximately the same for the SL fluids so as to also be consistent with the Planck theory of SL. Still further, a threshold velocity V_{thresh} for both EM and optical radiation occurs below which radiation is not observed. This threshold behavior is similar to the VIS-UV photoelectric effect where free electrons are created if VIS-UV photons of a sufficiently high Planck energy irradiate a solid surface. But work W is required to overcome the electron binding energy. In the VIS-UV photoelectric effect, the energy E_{elect} of the free electron, $E_{elect} = h\upsilon - W$, i.e., a threshold frequency $\upsilon_{thresh} \sim W/h$ must be exceeded to create free electrons, where W is the work function. In contrast, the Planck energy of MW photons is far too small to directly create electrons from the liquid maser wall comprising SL fluid and bubble gas molecules. However, as the Planck energy accumulates MW photons to VIS-UV levels during bubble collapse, free electrons may be created as in the VIS-UV photoelectric effect. In the Planck theory of SL, the creation of free electrons from the accumulated MW photons is herein defined as the MW photoelectric effect.

4 Extensions to cold fusion

4.1 Ultrasonic cavitation

The development of the Planck theory of SL for cold fusion in ultrasonic cavitation began[1] with treating the bubbles in multiple bubble SL as pancake collapse geometries with standing wave boundary conditions assured by the reflectivity of the bubble walls. If $mfp > R$ after bubble expansion(here mfp is the mean free path of the bubble molecules, R bubble radius), the bubble gas molecules are on the walls after bubble expansion and photon eission instead of a temperature increase was predicted during bubble collapse. Subsequently, the Planck theory of SL related the pancake collapse shape to an IRaser[8] and cold fusion by IR enhancement if the vibration modes of the H_2O molecule could be excited with a HF laser. Next, the Planck theory of SL was extended[9] to an IRaser creating cold fusion neutrons. High IR absorptivity was used to more properly quantify the reflectivity of the bubble wall molecules. A Planck energy of about 2 keV in a D_2O liquid was predicted, but UV laser enhancement was proposed to reach the 10 keV necessary for cold fusion. However, both IR and UV laser enhancements[8,9] rely on the accumulation of IR or UV photons. But ΔE of IR and UV photons at wavelengths of 1250 and 270 nm is about 1 to 6 eV, and as shown by the Heisenberg relation these photons are short lived, $\Delta t_{life} \sim 1$ to 3 fs. Hence, an accumulation of Planck energy to the 10 keV levels necessary for cold fusion in the ultrasonic cavitation of D_2O is not likely with either IR or UV laser enhancement.

In contrast to IR and UV photons, the MW photons are relatively long lived, i.e., at 30 GHz, $\Delta E \sim 120\mu$eV and $\Delta t_{life} \sim 35$ ps. The accumulated MW Planck energy E is, $E = N\Delta E$, where N is the number of absorptions. Now, $N = \Delta t_{life}/\Delta t$ and $\Delta E \Delta t_{life} \sim h$. Hence, $E = h/\Delta t \sim hc/2\delta$, so the accumulated energy E does not depend on the size of the Planck energy increment ΔE or the corresponding life Δt_{life}. Instead, only the final spacing δ between the bubble wall molecules is important. Taking the final spacing as the average cubical distance between D_2O molecules in the liquid state $\delta_c \sim 0.31$ nm, the accumulated Planck energy E is limited[9] to about 2 keV during bubble collapse. Hence, MW enhancement to the 10 keV necessary for cold fusion is also not likely in ultrasonic cavitation.

The Planck energy limitation of about 2 keV during bubble collapse in D_2O is based on the spacing δ between the D's on colliding bubble wall D_2O molecules to be the average spacing δ_c between D_2O molecules at liquid density. But, a normal distribution of spacings δ between D's as the walls collide would suggest that at least a few may briefly come close enough to exceed a Planck energy of 10 keV. Under these conditions, the Planck theory of SL suggests a limited number of cold fusion events during bubble collapse are likely during ultrasonic cavitation.

4.2 Pulsed microwaves

The Planck theory of SL suggests that a way of creating cold fusion is to irradiate clusters of D_2O molecules with pulsed High Power Microwaves (HPM). However, at 1.35 GHz, pulse durations of about 740 ps are required. Currently, klystrons are capable[10] of maximum pulse powers of 10~100 MW, but pulse durations are limited[11] to about 16 ns at repetition rates of 10 Hz. For the purposes here, a 1.35 GHz MW source capable of generating 740 ps pulses of 5.6 μeV MW photons at a repetition rate of 100 Hz is assumed. About 1.8×10^9 MW photons are required to achieve the 10 keV for cold fusion per D_2O molecule and the MW power is about 2.1 μW per D_2O molecule. A 1 mm diameter hollow glass sphere filled with a D_2O vapor at 20°C to a pressure of 1 mm Hg contains about 1.7×10^{13} D_2O vapor molecules. If the sphere is cryogenically frozen, crystals of D_2O molecular clusters may be formed. If the sphere is irradiated with about a 35.7 MW source of 26 mJ in a 740 ps pulse, cold fusion may be achieved. Assuming 2.45 MeV gain per D_2O molecule, the total fusion energy (alphas+neutrons) created is about 6.7 J. If the MW source is pulsed at 100 Hz, the steady fusion power is about 670 W. Hence, pulsed MW's are a far more efficient way of creating cold fusion of D_2O than by ultrasonic cavitation.

5 Conclusions

The Planck theory of SL finds basis in quantum mechanics and asserts single and multiple bubble SL is a conversion of bubble collapse velocity to MW's that are absorbed by the rotation states of clusters of bubble wall molecules and accumulates to VIS-UV levels. A MW photoelectric effect and collapse velocity thresholds for EM and optical radiation are identified as new SL parameters. Hence, SL radiation in the VIS-UV to about 6 eV may be simulated and collapse velocity thresholds studied by irradiating clusters of bubble gas and H_2O molecules with pulsed MW.

On average, cold fusion during ultrasonic cavitation is not expected as the Planck energy of bubble collapse is limited to 2 keV. But a limited number of cold fusion events are possible as the Planck energy of the D's in the colliding D_2O molecules exceed 10 keV. Cold fusion during ultrasonic cavitation is not expected to be significantly enhanced by pulsed MW, IR, or UV lasers.

Cold fusion with pulsed HPM appears to be more easily achieved than by ultrasonic cavitation. Research of MW sources at about 1.35 GHz with pulse durations less than ~1 ns and repetition rates of 10000 Hz is suggested.

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