OBSERVATION AND INVESTIGATION OF NUCLEAR FUSION AND SELF-INDUCED ELECTRIC DISCHARGES IN TURBULENT LIQUIDS

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The problems of stimulating and optimizing nuclear fusion using cavitation phenomena in different liquids are studied and discussed. The process of formation and mechanisms of excitation of directed laser-like beams in the volume of cavitating machine oil are studied. One of the analysed mechanisms of beam excitation is connected with stimulated nuclear reactions.

1. Introduction

The aim of this report is to present some preliminary results of experimental and theoretical investigations of the processes and phenomena connected with optimal fusion reactions in turbulent liquid targets.

It is well known that one of the most promising and ecologically safe types of fusion reactions is the $p + B^{11} \rightarrow 3He^4$ reaction with ΔE = 8.7 MeV energy release and without the creation of neutrons or formation of radioactive waste. For this reaction the optimal energy for interacting with moving protons is about $E_{pB,opt}$ = 675 KeV. In the usual uniform systems like cold or warm stationary plasma the probability of such a reaction is very low. This is the direct result of the high Coulomb potential barrier.

In our opinion one of the most promising methods for enhancing the probability of this reaction is connected with the use of turbulence and cavitation phenomena in the volume of a liquid (in this case, light water).

We believe that the same enhancement should generally take place for any type of fusion reactions with positive energy release, during the cavitation of bubbles in an appropriate liquid.

There are several theoretical models for such enhancement.

One of them ("coherent non-stationary interference model") is connected with the process of barrier-free fusion in the volume of a nonstationary (e.g. self-compressing) microcavity (e.g., [1-4]). In this model the latter process is possible for any over-threshold reaction with positive energy release.

Other ("direct") models are connected with both high impulse pressure and high temperature during collisions of atoms of the cavity walls during bubble collapse. In fact such models are connected with the microaccelerating (microhot) method of fusion using surface forces. We believe that these "direct" models are not able to ensure the necessary requirements for effective fusion because of the relatively low temperature (no more than 5 000 - 10 000 K in multibubble systems) and the relatively low pressure in a cavitation region [5]. It is also evident that tunneling quantum processes cannot provide a sufficient probability of nuclear transmutation.

2. Experimental setup

Schematic and general views of the installation for the production of controlled turbulence and formation of cavitation bubbles in the working chamber are presented in Figure 1.

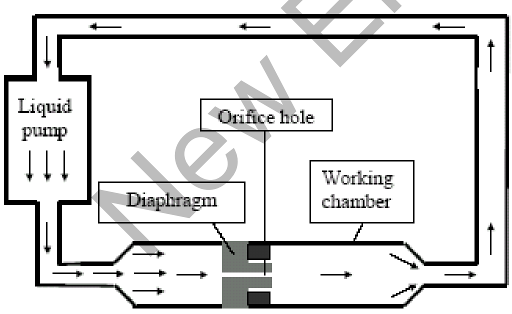


Figure 1. Scheme and general view of the experimental setup

The total volume of circulating liquid is 20 liters. The working chamber is made from plexiglas tube with diameter about 8 cm and length about 15 cm. The chamber wall is about 3 cm thick. A special insert (hermetic plastic plug) with an orifice hole is situated inside the working chamber. The diameter of the orifice hole is about 1 mm. In the experiments, different kinds of orifice hole with special variable profile and variable cross-section have been used. In these experiments two different liquids were investigated: machine oil and distilled light water.

3. Experiments and results of investigation of cavitation in pure machine oil

In the first case we have studied the optical and nuclear processes that take place during cavitation of machine oil. In this case different successive phenomena were observed as the pressure was increased. Several stages of the cavitation process were observed:

Stage 1. At low pressures (less than 20-30 atmospheres) and low velocity of machine oil (see Figure 2; flow is from left to right) the color of the moving liquid in the working chamber is tawny.

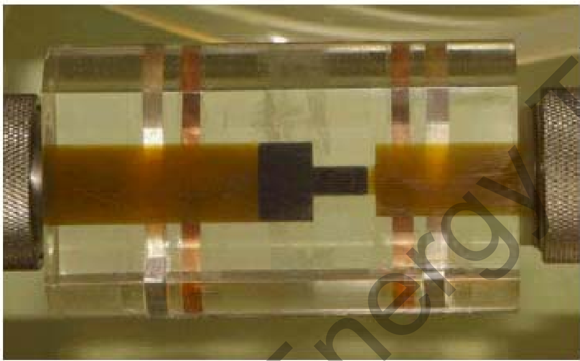


Figure 2. The view of the working chamber at very low pressure of machine oil

Stage 2. At a pressure of about 30 atmospheres the formation of cavitation bubbles in the volume behind the orifice hole begins. Behind the orifice hole turbulence is initiated, and large scale oil density fluctuations are observed.

Stage 3. At a pressure of about 40 atmospheres the average size of the fluctuations becomes small. In the space behind the orifice hole a translucent fog of small bubbles forms, giving it a milky appearance (see Fig.3).

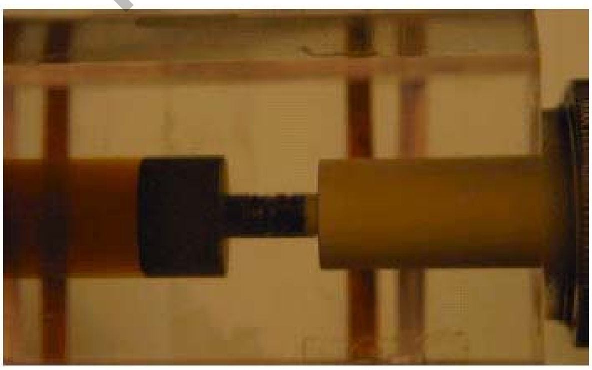
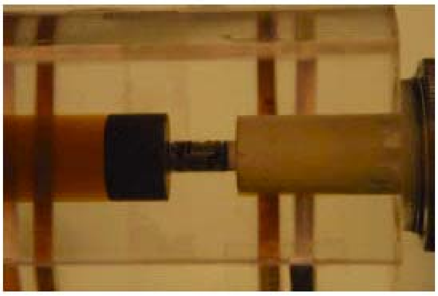


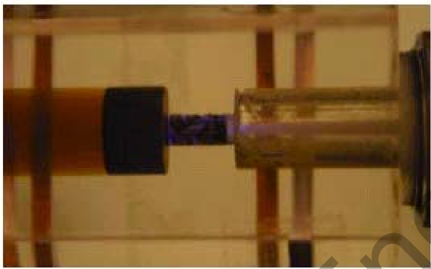
Figure 3. The view of the working chamber at low pressure of machine oil

Stage 4. At a pressure of about 60 atmospheres, a rapid increase in transparency of the turbulent oil takes place. As a result the chamber with cavitations downstream of the orifice hole becomes completely transparent. The steps of this process at increasing pressures *P* are presented in Figure 4.



P_1

P_2



P_3

Figure 4. Increasing of the caviting machine oil transparency in the working chamber at pressure increasing: $P_1 < P_2 < P_3$

At the latter stage, a small blue plasma jet appears in the cavitation zone. It forms in the region of turbulence and cavitations, immediately behind the orifice hole of the insert. This stationary plasma jet is about 2 mm long and about 2 mm in diameter.

Stage 5. With additionally increased pressure up to 70-80 atmospheres a directed bright light beam appears in the central part of working chamber (see Figure 5).

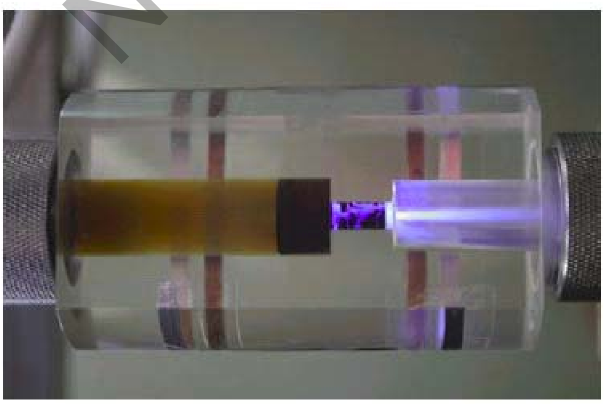


Figure 5. Generation of the directed bright light beam in the turbulent machine oil

The color of the beam is blue-white and is very bright. The diameter is about 6 mm.

The main question is - what is the nature and origin of the directed luminous beam?

It was not a directed light beam from the internal part of the hole because the initial diameter of the directed beam is 4 times greater than the diameter of the output aperture of the insert (orifice hole). It also was not equilibrium thermal radiation (sonoluminescence) from the region of cavitation. Several arguments support these conclusions:

Argument 1. The length (about 5-10 cm) and very narrow cylindrical form of the beam are sharply different from the dimensions and shape of the usual cavitation region (jet-like cone, sphere or short cylinder). This is supported by a simple calculation:

The processes of formation and collapse of bubbles take place immediately downstream of the transition zone at the exit of the orifice hole. The size of this transition zone approximately equals the diameter of the orifice hole (D = 1 to 1.3 mm).

It is well known (e.g., [6]) that the time for the collapse of cavitation bubbles with typical initial radius $R_0 \approx 5$ microns does not usually exceed $\tau_{max} \approx 20$ ns. Approximately the same amount of time is needed for formation of bubbles in the volume of moving liquid behind the orifice hole. It is also well known from hydrodynamic principles that the longitudinal velocity of moving fluid (moving bubbles) at $P \leq 100$ atmospheres does not exceed $v_{max} \approx 10^4$ to 10^5 cm/s. Hence the size of the cavitation region does not exceed $L_{max} \approx D + 2v_{max}\tau_{max} \approx 1$ to 1.3 mm. This is very small compared to the length of the observed directed beam (5-10 cm).

The angular properties of this directed light beam are similar to those of a laser beam.

Argument 2. The rather bright observed luminescence and rather high derived temperature (about 10^5 K) are comparable only to the intensity and temperature spectrum from sonoluminescence of single bubbles, and are the direct result of the spherical symmetry of the bubble at collapse. In the case of multibubble cavitation, the sonoluminescence spectrum indicates that the temperature inside a bubble at collapse is relatively low (2000-5000 K), and the intensity of the sonoluminescence is also low ("cold sonoluminescence") [7-9].

Argument 3. The intensity of sonoluminescence decreases strongly with increasing temperature of the cavitating liquid (e.g., at increasing temperature from 1^0 C up to 40^0 C the intensity decreases by 100 times [8]). But in our system the intensity of radiation does not depend on the temperature in the explored interval from 20^0C to 60^0C.

So, the observed phenomenon is not the usual kind of sonoluminescence.

There are reasons to believe that the intense directed beam could arise from one of three possible mechanisms:

1) Cherenkov emission of fast electrons;

2) single-pass laser generation at *UV*-, *VUV*- or soft *X*-ray wavelengths;

3) stimulated nuclear reactions in the volume of the directional turbulent oil jet, accompanied by spontaneous optical radiation.

We consider each of these mechanisms in more detail:

1) Using three different methods, we have studied the mechanism whereby Cherenkov radiation might be emitted by fast electrons when accelerated along the axis of the chamber to velocities $v > c/n(\omega)$ in the field of large separated charges.

- We used a ground connection to neutralize the separated volume charges in the chamber. This did not influence the directed properties or intensity of the laser-like beam.
- We measured the angular distribution of the directed beam and found that it differed from the distribution typical of Cherenkov radiation: $\sin\theta = c/n(\omega)v$.
- We investigated the action of an external transverse magnetic field on the direction and angular properties of the directed beam. The result was negative – a transverse magnetic field with magnitude 300 to 500 Oersted did not significantly influence the direction of the beam.

In view of these results, the directed beam is not believed to be connected with Cherenkov radiation.

2) The possible mechanism of single-pass induced laser generation is connected with the ionization and recombination of oil molecules in the cavitation region (similar to the processes in a gas-dynamic laser).

The first step would be intense ionization of the moving atoms and molecules. Formation of a moving hot plasma would then take place in the region of cavitation immediately downstream of the orifice hole. During the second step the process of recombination of moving atoms and molecules and the formation of inverted states in the active medium would contribute to self-cooling of the moving plasma farther downstream. Such a two-stage process could be steady and thus could lead to single-pass generation of a steady laser beam.

The central question is – what could be the pumping source for such a laser-like regime?

It is well known from fundamental laser and plasma physics that for pumping of a plasma laser (which is based on ionization and recombination) the temperature T of the active medium must be such that $k_B T \geq 5\varphi_i$.

Here φ_i is the ionization potential of the lasing atoms in the oil (φ_i = 11.2 to 14.5 eV for *C, H, O or N* atoms).

For a plasma laser generating blue or shorter wavelengths, the pumping source must have a temperature such that $k_B T \geq$ (0.5 to 1) KeV (i.e., $T \geq$ (0.5 to 1)x10^6 K).

Since the temperature in the centers of cavitation in a multibubble system is no more than (0.5 to 1)x10^4 K (e.g., [5]), a much more energetic pumping source is required to arise from the cavitation process. We believe that one possible source of energetic plasma for the hypothetical laser mechanism may be fusion reactions in bubbles in the cavitation region or the turbulent jet zone.

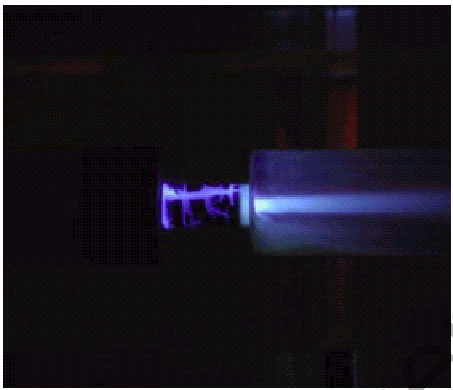
3) Nuclear processes would also be needed for the generation of spontaneous optical radiation in the directional turbulent oil jet.

In both cases 2 and 3 a source of nuclear energy would be necessary. There are many reactions that might occur in cavitating machine oil (e.g., carbon-nitrogen cycle). These reactions are being researched now and results will be reported in the future.

During steady operation of the chamber we also observed another phenomenon - formation of self-induced electric discharges (‘lightnings’) near the plasma jet (along the exterior surface of the insert). The average length of the lightnings was several cm. Such discharges are connected with ionization in the region near the orifice hole and the accompanying accumulation of free charges on the exterior surface of the insert. The typical frequency of such lightnings is several Hertz. Examples are presented in Figure 5.

Stage 6. At increasing pressures of up to 90-95 atmospheres the process of rapidly increasing intensity of the blue-white directed beam takes place. The frequency of lightnings also increases.

At this time, in the space upstream of the orifice hole, an additional short intense green jet appears (see Figure 6).



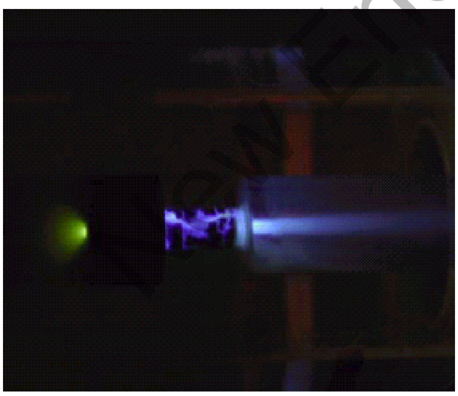


Figure 6. Three steps of the pressure-dependent process of back green jet formation in the working chamber at increasing of the liquid pressure.

The green jets are not in the region of turbulence and cavitation. The color of the oil in the area upstream of the orifice hole remains tawny and the motion of the liquid appears laminar. To stimulate the formation of the green jet we used a ground connection to neutralize separated volume charges in the chamber.

There are two possible mechanisms for formation of the green jet.

One mechanism is connected with possible action of a blue-white back-directed light beam to unexcited atoms of machine oil and corresponds to a usual luminescence.

The other mechanism is connected with microdischarges from the acute edges of the charged dielectric insert in the volume of the neutral liquid. The process of formation of a high charge on the insert is the result of friction with the water transiting through it. This mechanism is more likely because it would take place only in the presence of an additional ground connection for the liquid in the working chamber

4. Investigation of cavitation in distilled water

In the case of distilled water the properties of the cavitation region fundamentally differ from the case of machine oil. As before, there are several stages of the cavitation process.

In this case the intense laser-like directed beam was absent at any regime and any investigated pressure. The brightness of sonoluminescence in pure water at any pressure was likewise low. The formation of cavitation bubbles and their collapse at pressures near 30 to 40 atmospheres are shown in Figure 7.

Figure 7. Formation and collapse of cavitation bubbles in distilled water

At pressures above 50-60 atmospheres, weak sonoluminescence of cavitating bubbles takes place (see Figure 8).

The color of the low intensity sonoluminescence is blue, and is located on the left side of the photo. The size of sonoluminescence area is about 1-2 mm. The luminescence in the central and right-hand parts of the photo is the result of the scattering of light in pure turbulent water. The intensity of radiation weakly depends on the pressure in the interval 60 to 90 atmospheres and decreases with the increase of the water temperature. According to all the tests that were discussed above it is the usual multibubble sonoluminescence.

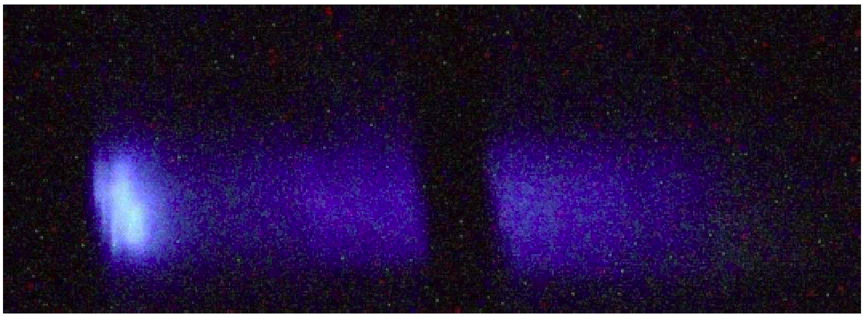


Figure 8. Sonoluminescence in distilled water

The spectrum of hydrogen from this sonoluminescence area was investigated. Spectra of the two most intense lines are shown on Figure 9.

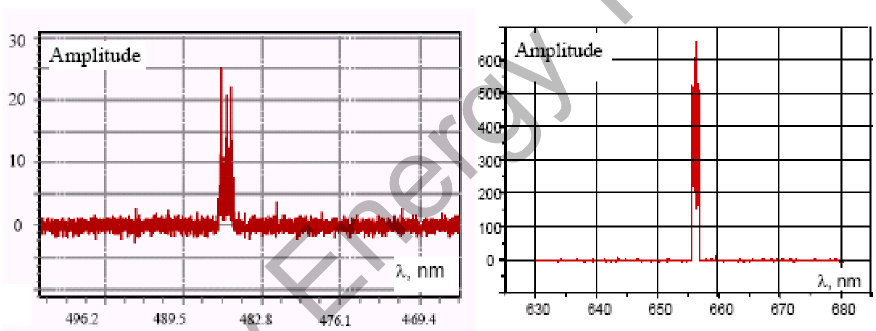


Figure 9. Spectra of two measured lines of hydrogen radiation of the sonoluminescence area

By analyzing the relative intensities of the two lines with wavelengths $\lambda = 656.28$ nm and $\lambda = 486.13$ nm (550 - 600 *au* and 15 - 20 *au respectively*), the temperature of the luminescing centers was calculated to be $T \approx 3000$ K. This is a temperature typical of multibubble sonoluminescence.

Additional studies

Additional physical and nuclear tests on cavitating machine oil and distilled water have also been carried out.

The possibility of the realization of one of the most optimal fusion reactions: $p + B^{11} \rightarrow 3\ He^4$ for these liquids was investigated. The process of He^4 creation was investigated by the analysis of the optical spectrum of luminescence of the stationary plasma jet and identification of *He* spectral lines in real time. One of the main problems of identifying such reactions is connected with the search for an optimal method of controlled B^{11} isotope insertion in the cavitation zone. Experiments have shown that uncontrolled insertion of ions of B^{11} isotope as an admixture leads to suppression of the sonoluminescence.

The possibility of the realization of reactions of the carbon-nitrogen cycle in moving turbulent machine oil was also investigated.

These processes were studied using various nuclear and spectral methods, including correlation analysis of the radiations from the luminescence region.

In several cases the generation of directed intense hard *X*-ray (or gamma-ray) beams was detected outside the working chamber with cavitating machine oil or distillated water. This hard irradiation was detected using *X*-ray photographic plates that were isolated in black paper and fixed on the external surface of the plexiglas working chamber.

Initial calorimetric tests have shown that the final (output) thermal energy of hot circulating machine oil in some cases exceeds the input electrical energy used for liquid pumping.

These results, including studies of nuclear transmutation and energy release, will be reported in the near future following additional research.

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