Bubble Fusion: Proof of Concept

Preliminary Report

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Abstract

I report on detection of neutrons coincident with cavitation of the low-vapor pressure mineral oil mixed with heavy water. The neutron flux is a definite indicator of nuclear reactions, although at this stage I cannot tell if the detected neutrons are of thermonuclear origin or result from spallation.

The detected neutron flux is 20 to 40 times in excess of background.The results are repeatable and reproducible.

In the short term I still need to do a bit more work before I can submit a paper for publication in a peer-reviewed scientific journal.

In the long run I intend to continue the research in order to determine if the neutrons are thermonuclear in origin and to gain a better understanding of the physics of the process.

Introduction

Inertially confined thermonuclear fusion in collapsing cavitation bubbles (aka bubble fusion) is deemed theoretically possible and has been discussed in peer-reviewed literature [1-3]. The idea is not controversial in itself as it is based on conventional physics that is well understood. Therefore USPTO had no problems awarding patents for bubble fusion, most notably to Flynn [4] and to Putterman [5].

Unfortunately, the experimental proof of bubble fusion until now remained elusive. The ground breaking work by Taleyarkhan [6] was contested by his peers [7], and eventually resulted in the ‘bubblegate’ controversy. To this day Taleyarkhan’s work was not replicated independently. The replication by Xu [8] was not deemed independent, and Taleyarkhan himself was not able to replicate his own results when he collaborated with Impulse Devices, Inc. (aka Burst Technologies), a now closed company that tried to pursue bubble fusion technology development commercially.

Therefore the question remains: while bubble fusion is theoretically possible, can it be realized experimentally? In this report I attempt to answer this question.

Experimental Setup

The experimental setup was assembled almost entirely out of inexpensive off-the-shelf components. The photo of the experimental setup is shown on Fig. 1 and the block diagram is given on Fig. 2.

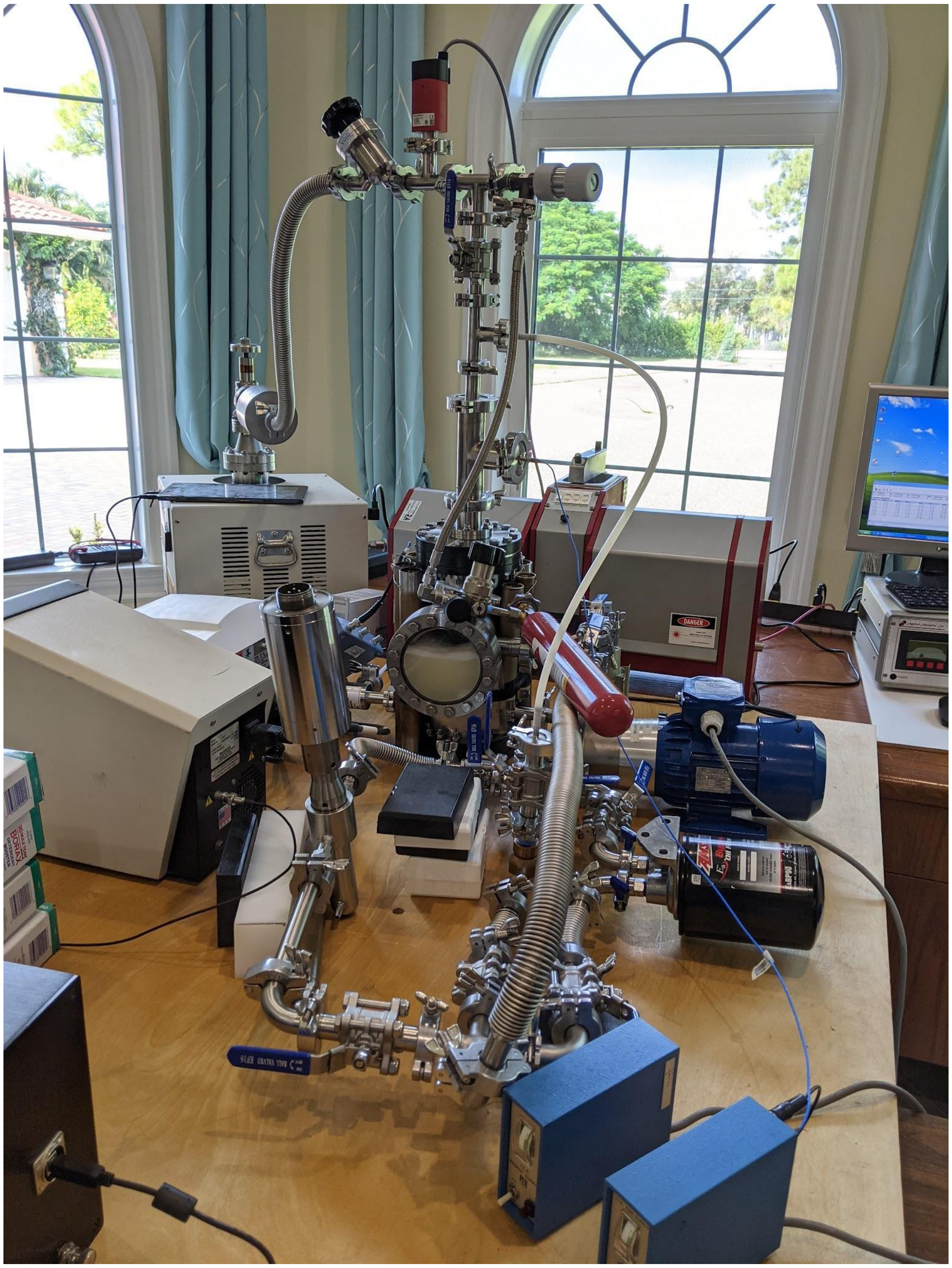


Fig. 1. The bubble fusion experimental setup.

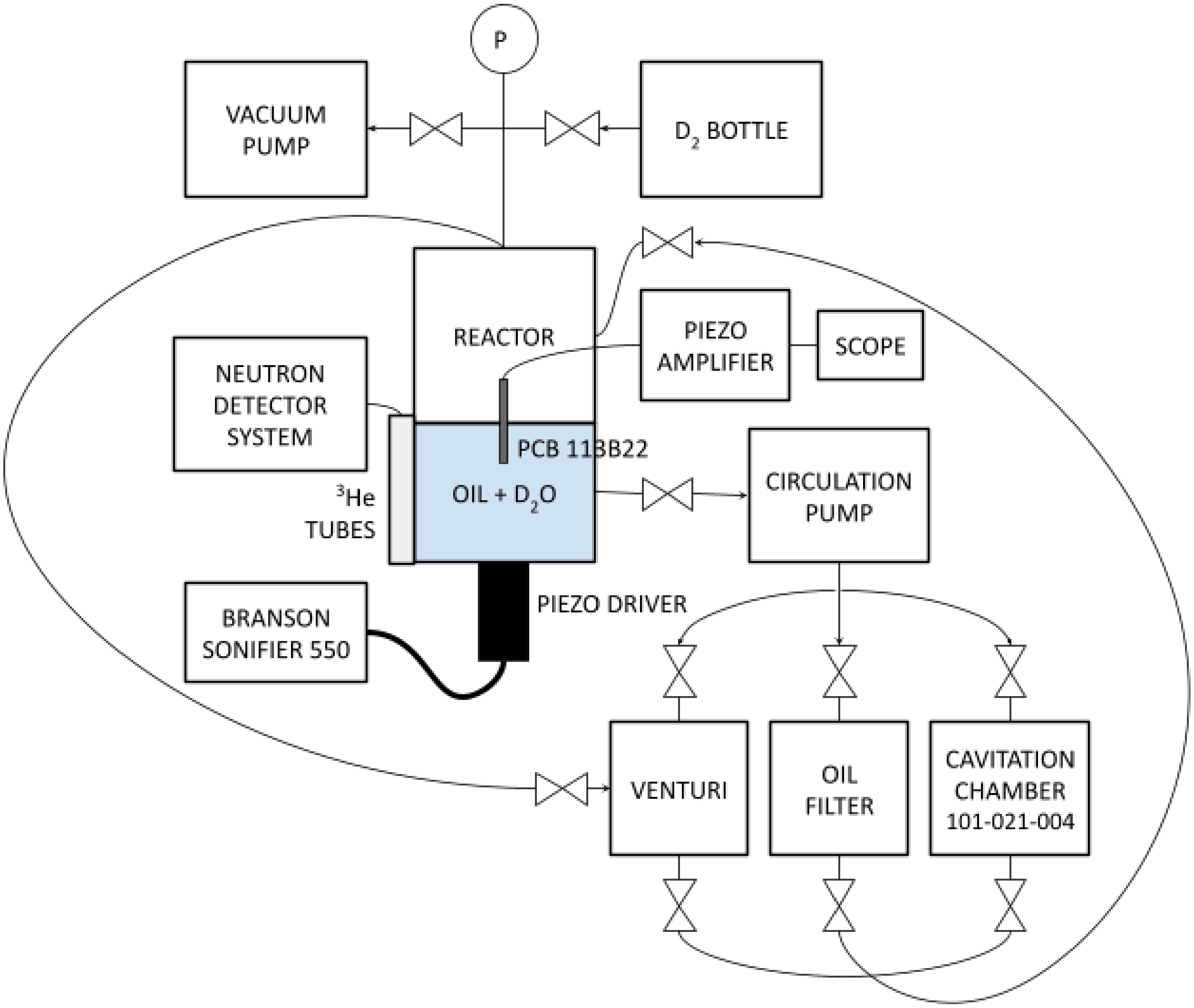


Fig. 2. The bubble fusion experimental setup diagram.

The reactor was made out of 6” diameter stainless vacuum ConFlat tee fitted with a 6” glass view port (not shown). Several auxiliary ports were welded onto the tee.The bottom blank plate of the reactor was fitted with a threaded nipple for Branson Sonifier piezoelectric driver attachment. The top plate of the reactor was fitted with a manifold connecting the reactor to:

- the Varian Minuteman Turbo-V70LP dry vacuum pumping system (via the isolation valve);
- the Pfeiffer PCR280 capacitance vacuum gauge (connected to the Pfeiffer TPG362 gauge controller, not shown), and
- the deuterium lecture bottle (via the leak valve).

Additionally, the manifold was fitted with an electrical feedthrough to communicate with the PCB 113B22 piezoelectric acoustic transducer suspended inside the reactor, which was connected to the PCB 482A04 piezo amplifier and PicoScope 4262 USB oscilloscope.

Additionally the reactor was connected to the Veder VG 540.05 magnetic circulation pump (via the isolation valve), which could circulate the reactor oil through the following loops:

- the venturi nozzle (which was plumbed to draw gas from the reactor headspace);
- the Amsoil Ea 2-micron oil filter, and
- the Branson sealed atmospheric cavitation chamber p/n 101-021-004 (which was connected to the Fisher Scientific Dismembrator 500, not shown).

Neutron detector bank consisted of 6x LND 251106 ^{3}He proportional counter tubes and was situated in the back of the reactor. The bank was connected to the Automated Nuclear Lab system running PulseCounter Pro software, which powered the detectors and performed the detector signal acquisition and processing.

The reactor was also connected to the Sympatec HELOS Magic particle size analyzer (not shown) fitted with the R1/R3/R5 lenses and the Sucell flow cell. This system was used for bubble size distribution measurement. It was connected to the reactor via a separate loop containing two isolation valves and a small Iwaki magnetic gear pump for flow control.

Experimental Protocol

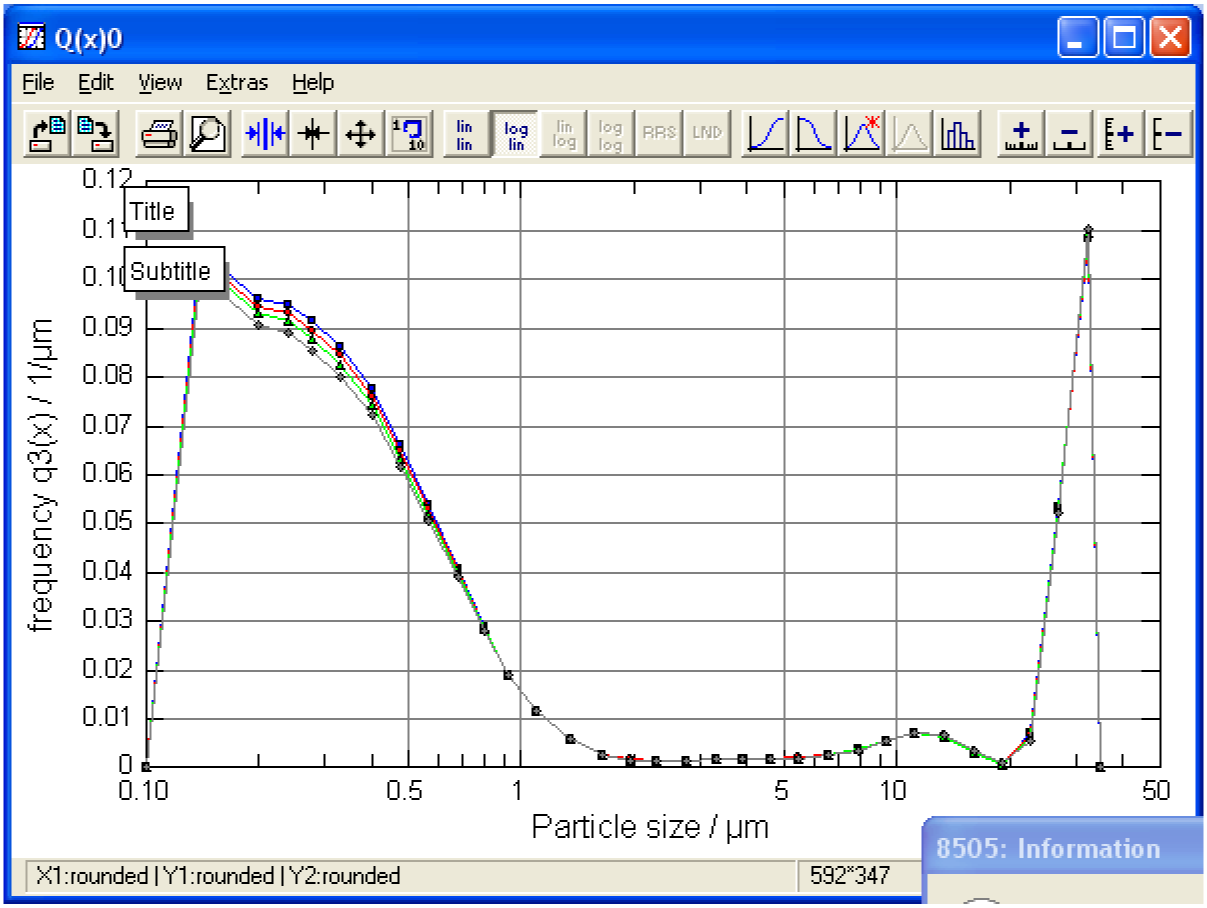
To prepare the system I open all isolation valves and evacuate the reactor together with all the plumbing to 1E-3 Torr to remove excess moisture and air. Then I isolate the circulation loop, admit air into the reactor and fill it with MultiTherm IG-4 oil. Then I proceed to slowly evacuate the reactor in order to degas the oil. The MultiTherm IG-4 is a low vapor pressure oil that can be evacuated to better than 1E-4 Torr. To speed up degassing I cavitate the oil using the Branson Sonifier.

Once I am able to achieve 1E-3 Torr or lower in the reactor I close the vacuum pump isolation valve and admit deuterium from the lecture bottle via the leak valve.

The create bubbles I have tried the following techniques:

- *Gas dissolution*: I wait for deuterium in the reactor headspace to dissolve in the oil forming nanobubbles; then by circulating the oil through the Sympatec HELOS / Sucell system I obtain a bubble size distribution, which in this case has a significant peak below 1 micron (the R1 lens cannot measure bubbles smaller than 100 nm) - Fig. 3;
- *Venturi*: I circulate the oil through the Venturi nozzle using the circulation pump (bypassing the cavitation chamber and the oil filter); the Venturi nozzle draws gas from the reactor headspace forming large quantities of bubbles of all sizes;
- *Sealed chamber cavitation*: to break down large bubbles I circulate the oil through the Branson sealed atmospheric cavitation chamber p/n 101-021-004 energized by the Fisher Scientific Sonic Dismembrator 500.

Once I am satisfied with the bubble size distribution (as measured by the Sympatec HELOS system) I proceed to cavitate the oil in the reactor. Throughout the process I capture neutron counts to contrast background counts to the counts obtained during cavitation.



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592*347

Fig. 3. Typical bubble size distribution resulting from gas dissolution.

Neutron Detection Methodology

In all of my experiments I employ ^{3}He-filled proportional counter tubes to detect neutrons. Initially I was using 6x SI-19N and 7x SNM-18 tubes arranged in a bank as shown on Fig. 4, which was mounted directly on the reactor.

Fig. 4. Closeup of the reactor lined with SI-19N neutron detectors.

I supply 1450V bias to the bank and connect the DC-filtered output al to a PicoScope 4262 USB oscilloscope. The PulseCounter software performs signal acquisition, logging and neutron counting. The neutron pulses reach up to 100 mV in amplitude. I have calibrate the detector using a Po-Be source. I also set up gamma rejection by ignoring pulses below 2 mV. As a result the bank was not producing excess counts when exposed to a 10 uCi ^{137}Cs source.

In recent experiments I switched to LND 251106 neutron detectors arranged in the bank of dix - Fig. 5.

Fig. 5. The bank of six LND 251106 neutron detectors.

I supply a 1350V bias to the bank and connect the DC-filtered detector output to a PicoScope 4262 USB oscilloscope. The PulseCounter software performs signal acquisition, logging and neutron counting. The neutron pulses reached up to 20 mV in amplitude. I calibrated the detector using a Po-Be source and obtained an excellent thermal neutron spectrum - Fig. 6.

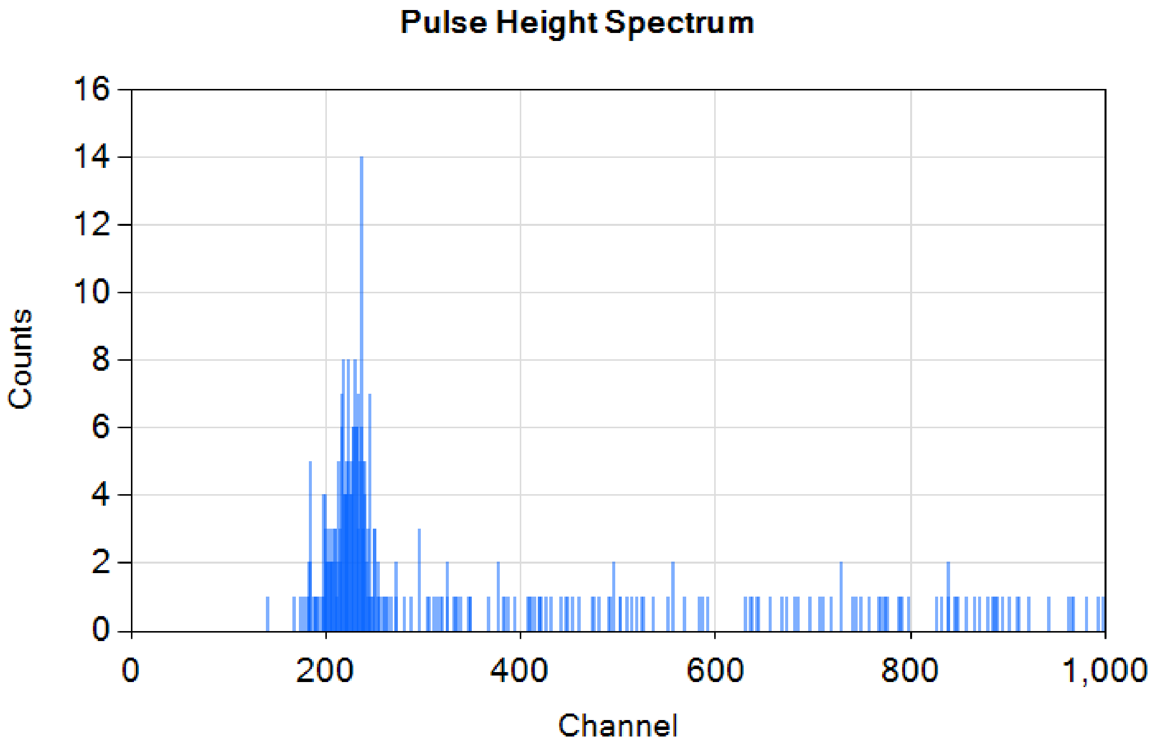

Fig. 6. The thermal neutron spectrum obtained using the bank of 6x LND 251106 detectors.

I set up gamma rejection by ignoring pulses below 2.5 mV. As a result the bank was not producing any excess counts when exposed to a 10 uCi ^{137}Cs source at point blank (hence no counts below channel 150 on Fig. 6).

To improve signal to noise ratio I shield the neutron detector bank from background neutrons by lining the reactor with the boxes of Borax - Fig. 7. As a result, the background counts declined to 0.01 CPS (0.6 CPM).

Fig. 7. The reactor shielded with the boxes of Borax.

Results

Numerous experiments with D_2 bubbles in oil did not produce notable above-background neutron counts. So, for a change I decided to pour some heavy water (deuterium oxide) straight into the reactor to see if a D_2O in oil emulsion would do anything interesting. And it did.

Almost immediately I started logging above-background neutron counts, when cavitation was turned on. While the excess counts were small, I have never seen such excess before. This prompted me to keep ‘tweaking’ the reactor operation in hope to increase the counts. The tweaking included:

- *varying the piezo acoustic drive power and duty cycle*: the Branson Sonifier could not sustain continuous operation (it was overloading), so I was using it in pulsed mode (0.02 second on / 0.02 second off), in which I could vary the acoustic power from 10 to 100% (in arbitrary units);

- *varying the headspace pressure*: I was pulling vacuum on the reactor to remove dissolved gasses from the emulsion; I did not want the dissolved gasses to dampen the intensity of cavitation; I experimented with the reactor pressures from 1E-3 to 760 Torr;

- *circulation:* occasionally I would circulate the emulsion through the venturi, through the filter, and through the sealed atmospheric cavitation chamber to create additional bubbles (venturi), to remove particulate matter (filter), or to make the emulsion even finer (cavitation chamber).

As a result of this ‘tweaking’ the counts did increase, although at this point I do not know which procedure contributed to the increase in the counts. At one point the counts exceeded 1,500 CPM, which was ~50 times higher than the background of ~30 CPM (measured using the SI-19N/SNM-18 detector bank without the Borax shielding). I could consistently reproduce these very high counts as I was operating the reactor on and off for several days. The headspace was deuterium at 760 Torr, and the Branson Sonifier was operating at 100% with 0.02 on / 0.02 off duty cycle.

When I examined the raw signal captured from the detector bank - Fig. 8 - I confirmed that the neutron pulses appeared genuine (negative spikes on the trace). The only noise that I could see was a small amount of EM interference coming from the Branson Sonifier, which was coincident with the cavitation events. The noise appeared as small batches of 1-2 mV oscillations following the 0.02s on / 0.02 off duty cycle. The noise amplitude was below the neutron detection threshold of -3 mV and thus did not create any false counts. The presence of the noise was fortuitous as it allowed relating neutron counts to cavitation: by far and large almost all neutron events are superimposed on top of the EM interference noise, which occurs only during cavitation, i.e. when the Branson power supply is energizing the piezoelectric driver.

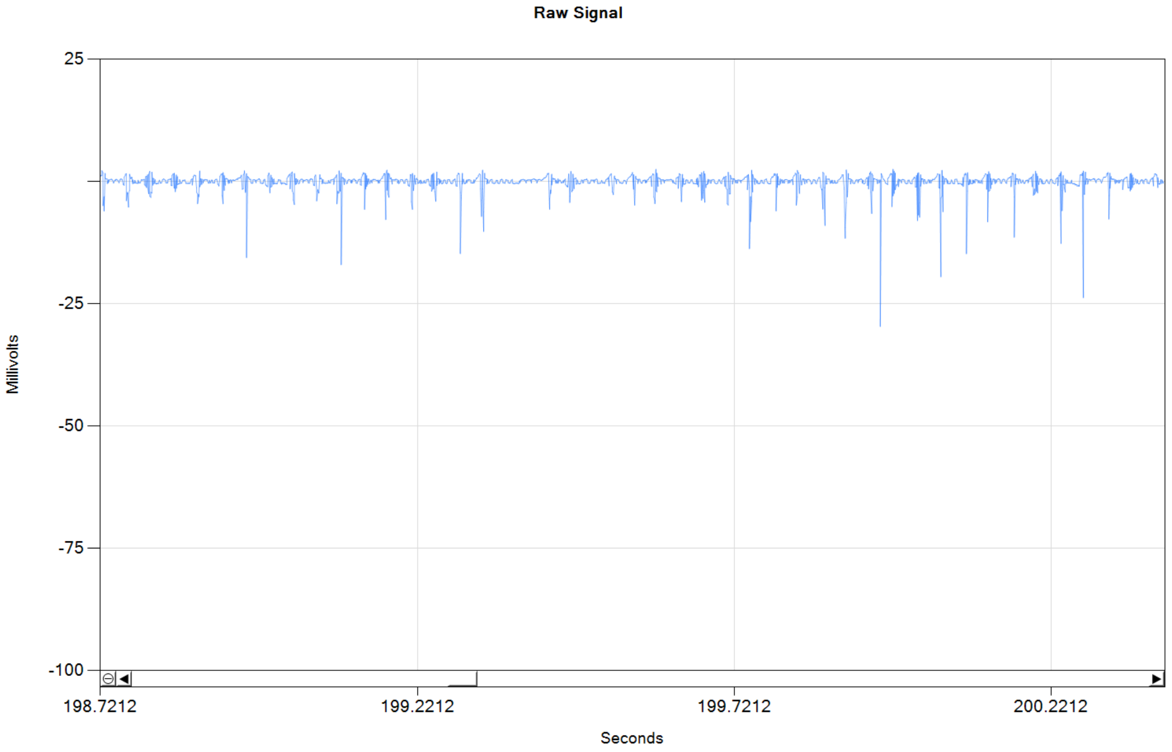

Fig. 8. Neutron events (negative spikes) coincident with the cavitation noise.

To rule out an unknown systematic error affecting the detector performance I removed the SI-19N/SNM-18 bank (Fig. 4) and replaced it with a new detector bank made out of 6x LND 251106 tubes (Fig. 5). I also drained the old oil from the reactor, poured new oil, and added ~1 ounce of D_2O. At this point the heavy water was not emulsified, but I expected it to emulsify with the onset of cavitation.

To improve the signal to noise ratio, I have backed the detector bank with a few boxes of Borax, which reduced average background counts from the bank mounted on the reactor to 0.01 CPS (0.6 CPM). I have collected background counts for 20 hours - Fig. 9 (blue bars); there were no counts above 0.03 CPS (1.8 CPM) in any of the background samples.

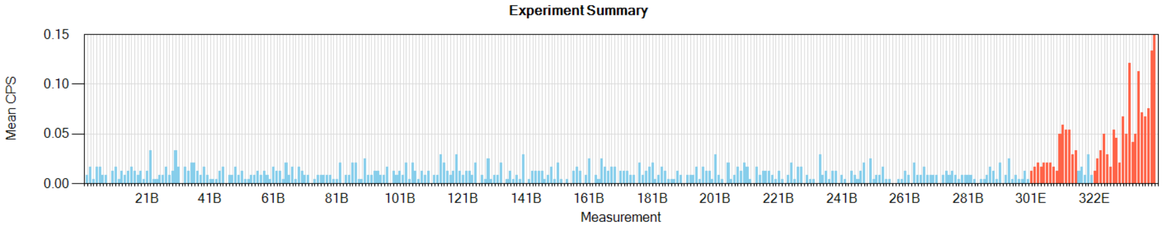

Fig. 9. Neutron counts during cavitation (red) compared to background counts (blue).

When I started cavitation, the counts started climbing and initially reached 0.05 CPS (3 CPM) and then exceeded 0.20 CPS (12 CPM) - Fig. 9 (red bars). When I stopped cavitation the counts returned to the baseline. The calculated P-value was well below 0.000.

I have repeated this experiment several times by draining the oil, adding fresh oil, degassing, and adding ~1 oz of D_2O, which I proceeded to emulsify. During cavitation I maintained headspace pressure on the order of 1-10 Torr removing excess deuterium oxide vapor. Every time neutron counts during cavitation were climbing and reaching 0.20-0.40 CPS (12 - 24 CPM) - Fig. 10, which was 20 to 40 times above the background of 0.01 CPS (0.6 CPM).

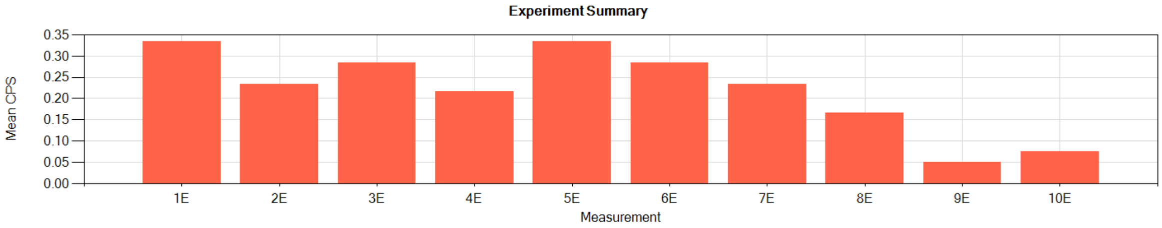

Fig. 10. Neutron counts during cavitation, sample #2.

A typical acoustic trace captured using a PCB 113B22 transducer is shown on Fig. 11.

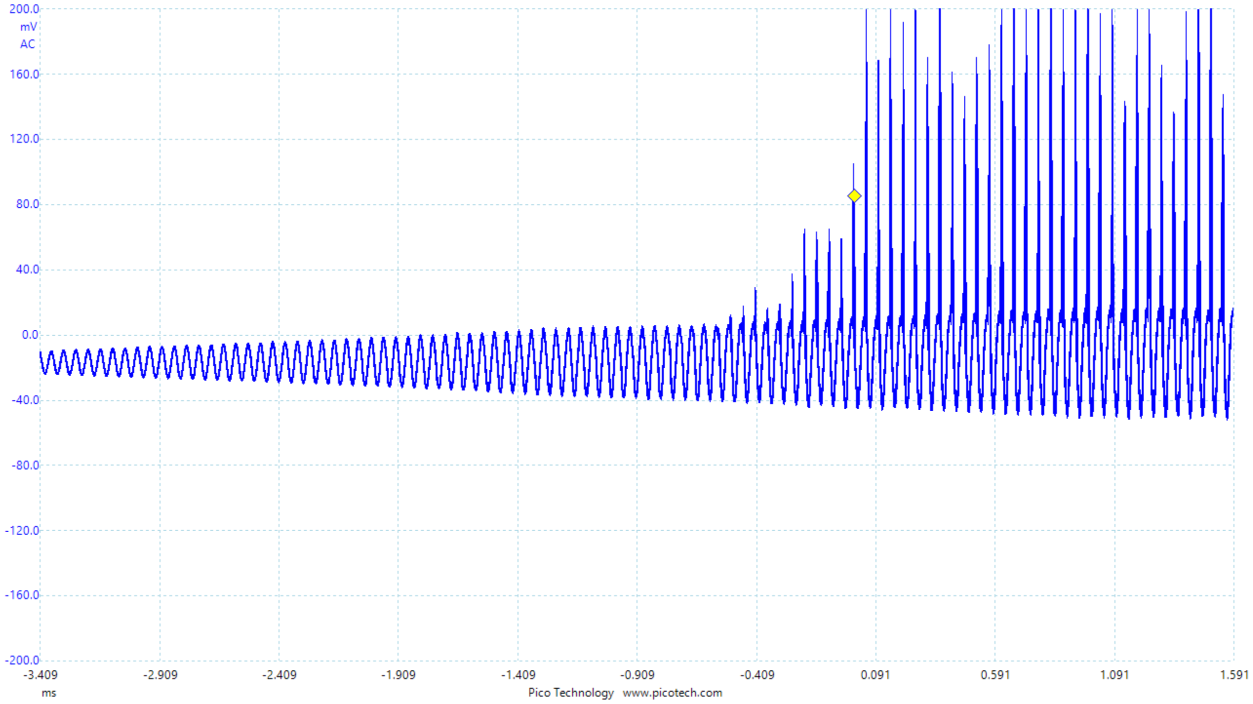

Fig. 11. A typical acoustic signal from the reactor: 1 mV = 1 psi, f = 20 kHz.

A 20 kHz sinusoidal drive is evident on the trace. But curiously there are many immense pressure spikes of hitherto unknown origin. These spikes sometimes saturate the transducer and peak 15 V (15,000 psi). The intense cavitation in the emulsion must be creating these strong pressure spikes, which have a distinct audible sound. In fact the glass viewport of the reactor eventually cracked and I had to replace it with a metal blank.

Also, I have noticed unusual behavior of neutron counts, which I recorded when I was using oil, contaminated with ~1 gram TiD powder. When I cavitated the oil with the TiD powder suspended in it, the neutron counts were rising, but when I turned the cavitation off they did not return to the baseline immediately, but rather did so gradually - Fig. 12.

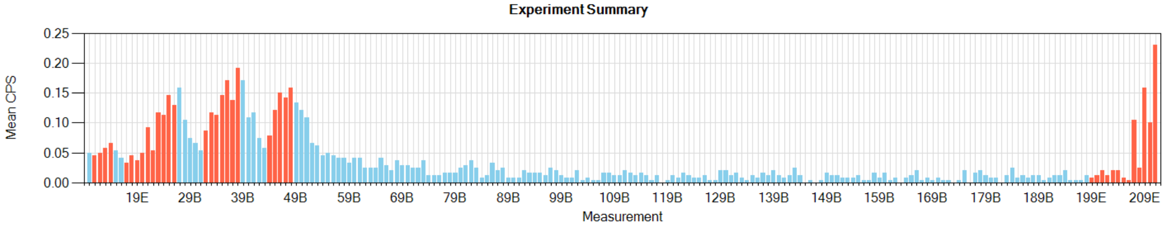

Fig. 12. Neutron counts during cavitation (red) compared to background (blue).

I have repeated this experiment several times and every time I saw the gradual increase followed by the gradual decline of the counts. Eventually the counts would return to the baseline and stay at the background level. But if I resume cavitation, the process begins again: counts gradually rise, and when I stop cavitation they gradually decline.

Such unusual behavior of neutron counts defies a simple explanation. However, more research is necessary in order to claim evidence of ‘new physics’.

Outlook

Clearly, more work is necessary in order to understand the physics of the process and to develop a mathematical model that would permit engineering a reactor capable of producing useful power.

To meet this objective the following next steps are necessary:

1. *Secondary means of neutron flux confirmation:* it is prudent to confirm the neutron flux using a different detection technique. I am considering using a $Cs_2{}^6LiYCl_6$ scintillator (such as CapeSym MacroPixel nEL-14x25c-SiPM-T). I also consider indium foil activation with subsequent counting using an HPGe system. I do not think that BubbleTech detectors are appropriate due to their sensitivity to acoustic and mechanical vibrations.

2. *Increasing the neutron flux* will help with the secondary means of confirmation (especially with the indium activation study) as well as with developing understanding of the physics of the process.

3. *A light water control* experiment must be conducted; the expectation is that a light water emulsion should not produce an above-background neutron flux.

4. *Tritium detection* is necessary to confirm the thermonuclear origin of the detected neutrons (this effort is currently underway).

5. *X-ray and gamma spectra* must be acquired.

6. *Overlay neutron events on acoustic trace*: are neutrons produced by the massive pressure spikes evident on the acoustic trace?

7. *Using ^{3}He*: ^{3}He+D fusion reaction has a higher cross section than DD fusion at certain energies. Will adding ^{3}He to the reactor headspace increase neutron flux?

8. *Using tritium*: DT fusion has the highest cross section; adding tritium to the reactor must boost fusion yield and therefore increase neutron counts.

Conclusion

I have registered a significant neutron flux coincident with cavitation of deuterium oxide mixed with low vapor pressure oil. The detected neutron flux is 20-40 times above the background. The results are repeatable and reproducible.

At this stage I do not have enough data to determine if neutrons are of thermonuclear origin or arise from some other nuclear process such as spallation.

The observed neutron flux has a puzzling characteristic when a TiD powder is added to the heavy water emulsion: neutron counts rise during cavitation, but when the cavitation is turned off the counts do not instantly return to the baseline but rather take several minutes to gradually decline. This unusual behavior must be studied further to determine if a conventional explanation could be found or if this is evidence of ‘new physics’.

References

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