Bubble Driven Fusion

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First Gate Energies

Abstract

Experimentally, heat and ^{4}He are sonofusion (SF) fusion products. SF boosts a naturally occurring phenomenon with cavitation-induced bubbles and their collapse to high energy densities. One unique fusion path to heat and ^{4}He is shown. What has been increasingly evident is that high-density experiments of ICF and astrophysical relations of fermions and bosons show a plausible path to SF products. SF focuses around implantation of nanometer jet volumes and picosecond time scales. Several high-density systems like those of WDS, MF, z-pinch systems, and ICF have influence over this model path.

Acronym list

BCS Bardeen, Cooper, Schrieffer; superconductivity theory
BDS Black dwarf star; an old and cool WDS
BEC Bose Einstein Condensate; follows Bose Einstein statistics
DOE Department of Energy
EM Electromagnetic
HDZP High density z-pinch using a deuterium frozen fiber and high current
ICF Inertial confined fusion; an approach to fusion via hot fusion
MF Muon fusion; a muon replaces an electron in D_2 and has a pseudo density of a WDS
MS Mass spectrum; helium measurement by DOE's Brian Olive
Qa Acoustic power input to piezo reactor in watts
Qi Total power input in watts
Qo The calorimetric measured heat out of reactor in watts
Qx Heat measured above that expected heat in watts
Rf The final transient cavitation bubble radius
Rmax Maximum transient cavitation bubble radius
SEM Scanning Electron Microscope
SF Sonofusion; fusion source from collapsing cavitation bubbles
SL Sonoluminescence; acoustic light emission from bubble collapse
TCB Transient cavitation bubble; a bubble with at least 3 watts of power/cm^2
WDS White dwarf star; a collapsed star no longer generating heat

Introduction

The experimental part of this paper draws from many years of compelling results pointing to fusion events in target foils produced by TCBs in D_2O. TCBs produce high-density plasma jets, which coincide with SL during the TCBs collapse process [1], where EM fields compress the jet's contents. SL is used to monitor SF experiments. Jets implant the target foil forming deuteron clusters. The transient deuteron clusters, with temperature and density consideration, are deuteron coherent BECs where the De Broglie wave exceeds the DD cluster spacing. The femtosecond endothermic recombination of the implanted free electrons with the surface deuterons of the cluster cools and compresses its contents. The implosion of the recombination shockwave creates enough contact time for DD fusion event(s) to occur. The expected gamma radiation is not found, as this expected product is replaced by heat. (The mechanism for the gamma is slower than the direct conversion fusion energy to heat. The single wave function involves all of the BEC cluster deuteron bosons.) The conversion of fusion energy to a lattice heat pulse is shown in the many SEM photos of target foil surface ejecta sites. In piezo systems that resonated at 20 and 40 KHz, ejecta were expelled into the circulating D_2O, where the fusion ^4He and heat were circulated and measured. The measurements of ^4He products, at 550 ppm were measured in a Department of Energy laboratory [2]. 1.6 MHz produce much smaller but more numerous jets with similar energy densities. Heat measurements showed Qx that increased with Qa. Qi was varied from 4 to 50 watts where Qx was 0 to 40 watts [3,4].

The fermion isotopes of hydrogen have a possibility to pair in crossover high-density environments forming a fermion boson, a behavior similar to Cooper pairing. Clusters and their recombination shockwave that will promote the fusion of pairs of hydrogen isotopes may behave in a mode parallel to DD fusion and heat.

The Transient Cavitation Bubble, TCB

A quick view of cavitation follows [1]. A sinusoidal wavelength defines the time for a generation of bubbles that cycle through a birth, growth, collapse, and jet formation modes as the D_2O prepares for its next bubble generation [5]. An oscillator drives a 1.6 MHz resonance system that produces millions of bubbles with an initial radius of around 0.4 microns. As the bubble expands in the low-pressure isothermal growth phase, it picks up D_2O mass from the bubble's interface. Crossing over into the positive pressure zone of the acoustic wave, the partially evacuated bubble reaches its Rmax of about 4 microns; then begins its rapid collapse. The bubble surface accelerates towards its center at Mach 4 velocity or greater [6]. In 0.1 microsecond the bubble's somewhat leaky adiabatic Rf of about 0.04 microns is reached. The 1 million-fold energy density increase is enough to dissociate some of the D_2O. Here two events occur: a burst of photons is emitted as SL and the plasma contents of the bubble are transferred to a jet where EM compression pressures squeeze the jet's contents [7]. See Figure 1-1. The jet — a high-density deuteron plasma — is confined by EM pressures [8]. The first step in producing heat and ^4He in SF is the TCB and jet system. Photos of cavitation jets will be found in reference [9].

Other Fusion Systems

Other fusion systems exist. The first is Muon Fusion (MF), where a heavy muon replaces an electron in the D_2 molecule, shrinking its orbit to 1/207 of its normal orbit size. [10] In MF the two deuterium atoms of D_2 fuse at 100 K. The density or separation of the two deuterons is about the same as in a BDS environment. The gravitational forces present in a BDS would compress these boson deuterons to fusion densities in less than a picosecond. The BDS's high-density environment lacks internal radiation pressure, has no fuel for fusion, and is equivalent to the density of muon fusion systems. The second is the high density z-pinch (HDZP), a vacuum system that feeds a shaped high current pulse into a 50 micron frozen D_2 fiber. The magnetic pressures around the fiber are very similar to the EM pressures of the SF jet. The magnetic pressure squeezes the fiber's deuterons to the fusion point [11]. The third is the backlighting experiments performed by MIT and the University of Rochester where transient EM fields were measured in ICF systems using the plastic CR39 to establish deflection patterns of synchronized mono energetic protons. These fields were measured at 60 Tesla and 10^9 V/m. at densities of 300 gm/cc [12]. The fourth is the astrophysics of the BEC and the BCS systems. Information gathered from these systems gives substance to the formulation of a SF path to the fusion products heat and ^{4}He. From experiments, it is shown that DD fusion occurs via the cavitation bubble. So the objective is fitting the SF experimental work to extrapolated hot fusion systems into a coherent path.

Experimental Set-up

The objective is experimentally boosting the naturally occurring cavitation phenomenon to a controlled bubble system. Important parameters are controlled, creating the transient high-density, environment. A complex system is used to gather the data, but is not necessary for the devices operation. The cavitation device is energized by an ultrasound piezo, producing micron size bubbles in circulating D_2O. A pump circulates the D_2O through the SF device to a heat exchanger, a flow-meter, a bubbler and back to the pump [7].

The piezo device responds to its feedback oscillator that tracks the small changes of its resonance frequency due to the influence of small changes in temperature and pressure. This keeps the device well tuned to its resonant frequency. The adiabatic bubble collapse compresses and dissociates D_2O into its ions. For the 1.6 MHz system the measurement of SL photons were emitted and counted via a photomultiplier and counter system as they pass through the reactor window. SL is used as a tool for evaluating and maintaining control of the SF parameters; temperature, pressure, and acoustic input. The measurements were made in a light proof box where the air circulation keeps the box and the SF device at constant temperature. The photon background count was 200 photons/sec. The box contains the main components of the SF apparatus. The maximum photon count was near 2,000,000/sec. [3].

SF is a collection of billions of one cycle acoustic events that include the bubble's collapse, the transfer of the bubble's contents into a jet, the target foil Boson cluster and the fusion heat pulse. The jet is very small and contains high velocity sheath electrons. The 1.6 MHz jet has a volume $2x10^{-23}m^3$, 10 nm in diameter and 100 nm in length, with a lifetime of a picosecond. It is in the jet where the high densities are reached via z-pinch SF EM pressures producing very high-densities, 10^{27}D/cc, of very compressible bosons in the jet and cluster. The jet sheath electrons produce the EM compression pressures perpendicular to their Mach 20 velocity vector. The jet, located close to a 100 micron thick target foil, implants electrons and then deuterons into the foil lattice to form a cluster. See figure 1 - 1, 2. What is increasingly evident is that high-density experiments of ICF and the astrophysical relations of deuterons and electrons, bosons and fermions, add a great deal of reality to the picture of this transient jet and cluster [13].

The Path and Experimental Evidence

A connection between experimental evidence and transient high densities is shown. During the target implantation, electrons and deuterons, are momentarily separated as deuteron clusters and free electrons moving back to the cluster reacting with outer deuterons squeezing the cluster. The transient deuteron clusters are stabilized for a picosecond by their high-density (close packed structure), the de Broglie wave in the cluster producing a coherent BEC. See figure 1 - 3, 4.

In the closely packed cluster deuterons the shockwave initiates the ^{4}He fusion event. See figure 1 – 4, 5. The favored path produces heat and not gamma radiation [14]. The fusion heat pulse destroys the very high-density cluster and as the spherical heat pulse passes into the target foil lattice, it reaches the foil surface producing an ejecta site. See figure 1 – 6. The nm size ejecta sites are easily photographed using SEM analysis. In piezo systems that resonate at 20 KHz, the heat pulse's vaporous ejecta were expelled into the circulating D_2O, where the fusion products, ^{4}He and heat, are circulated and measured. This explains why little of the ^{4}He fusion product is found in exposed target foils.

The SEM photos show an uncountable number of ejecta sites. Several SEM photos of Pd foils have been analyzed by counting one square μ^2 areas of exposed target surfaces to find the distribution of the diameter sizes of ejecta sites. The plots of site diameters versus their number show a skewed distribution. Assuming that the depth of the ejecta site is the same as its diameter, the volume of the spherical heat pulse and ejecta relate to ejecta energy. A clear maximum for ejecta site diameter distribution was found to be near 100 nm. This falls off rapidly as the ejecta site diameter increases for multiple fusion events. Using these ejecta volumes and site diameters a conversion to about 20 +/- 10 Mev is the expected value for a single DD fusion event. The exposed target foils show surface distribution of ejecta sites in the form of permanent surface patterns of standing waves.

Gases from 20-KHz experiments were collected from directly over the SF reactor's circulating D_2O. This gas was expanded into 50 cc evacuated stainless steel cylinders for MS measurement, which was performed by Brian Oliver in a DOE laboratory specializing in helium MS analysis of the gas samples. The data from sample cylinder #3 measurement for ^{4}He, using three different small aliquots of gas from the sample cylinder, shows the average number of ^{4}He atoms that were in the sample cylinder to be 7463×10^{14} ^{4}He atoms of with a sigma of +/- 1. Only 50% of the gas in the experiment was collected in the sample cylinder. The remaining helium was equally distributed throughout the circulation volume. So the total ^{4}He was 1.5×10^{18} atoms. The calculated ^{4}He in the gas sample was 552 ppm, which is 100 times that found in atmospheric air. This experiment produced 80 watts with respect to helium production over a 19 hr. period. 64 watts of excess heat was measured by calorimetry. (B. Oliver's data is on DVD shown at ICCF-14 Wash. DC, 2008.)

The determination of excess heat was done using the D_2O flow-through calorimetric measurements of the 1.6 MHz piezo driven, low mass, 20 g device [15]. Measured the temperature of the D_2O flow into and out of the device, DT, and its flow rate in cc/s were measured, these two were multiplied together to give calories/s. This result is multiplied by

4.184 Joules/calorie to give Qo. Now, Qo was the sum of Qa and Qx. The efficiency of Qi was measured at 0.33 [2] so Qa = .33 Qi. Some of Qi powered a transformer and the 1.6 MHz oscillator. That is the basic calorimetry.

The experimental data for the 1.6 MHz device data is plotted in the web site www.sonofusionjets.com. [4] The series of runs is listed in the table shows increasing values of Qi, SL, and Qx. Qx reaching a maximum of 40 watts, with a Qa of 16.5 watts, and a Qi of 50 watts. A one second was the residence time for D_2O in the reactor volume and a flow rate of 1cc/sec. The external pressure was one atmosphere of argon. The SF device used a joule heater replacing Qa in the calibration mode. One must be careful to guard against radio-frequency interference during thermocouple measurements and heat lost via device's surface convection.

Summary

The robust 1.6 MHz SF device can be ganged together to make high energy-density systems of any size. SF can serve in the work place as space heating where about 0.3 of the grid power is used today. With future improvements it will be a self-supporting unit using thermoelectric devices to convert heat directly to electricity [2]. SF applied to space travel has the advantage of a high power/mass ratio. SF is a million times more mass efficient than hydrocarbon fuels or a $O_2 + H_2$ mix. This paper is about transient densities with parameter control of temperature, pressure, and acoustic input.

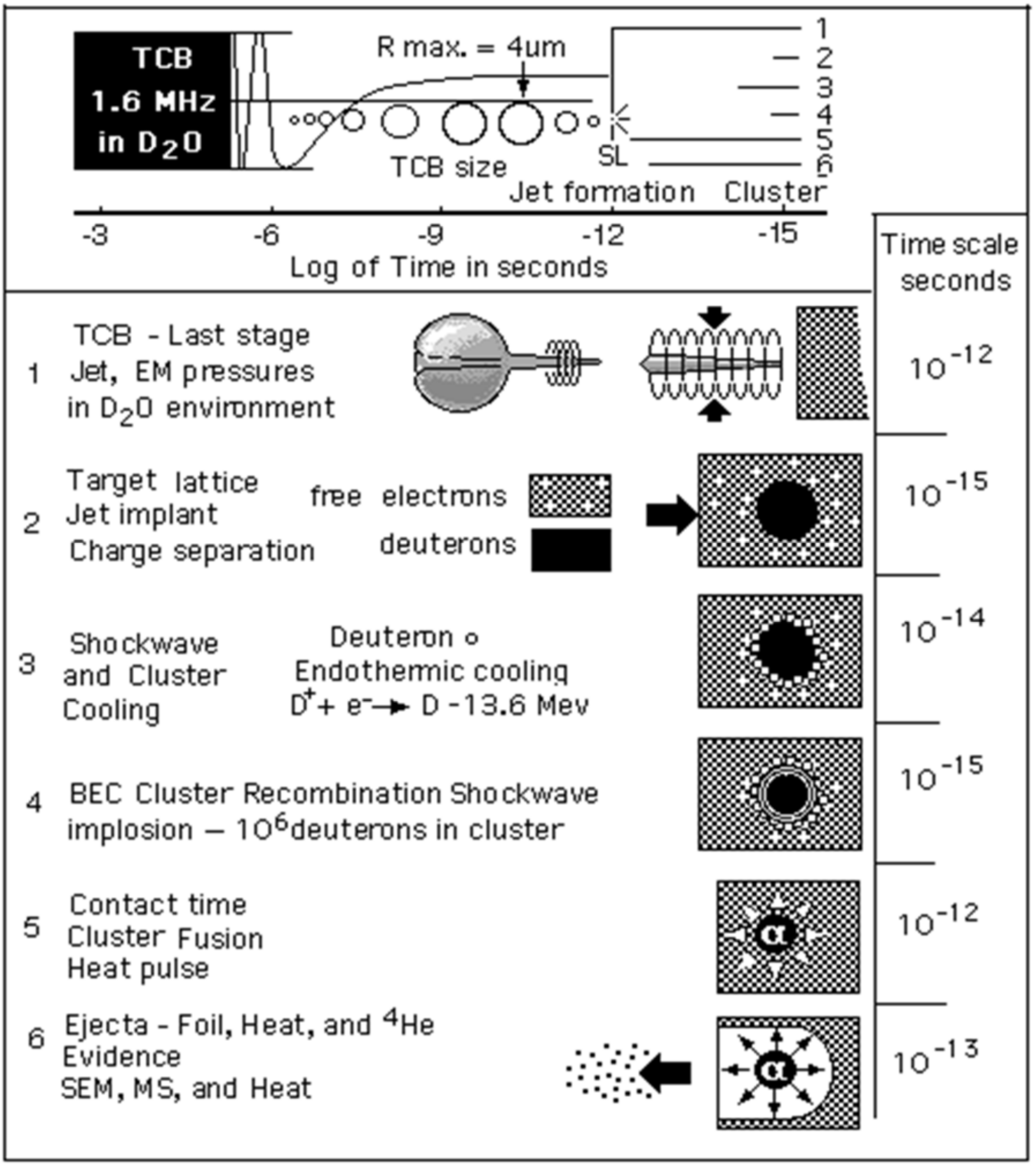

Figure 1. Six steps to SF.

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References

1. M. P. Brenner, S. Hilgenfeldt, D. Lohse, Rev. Mod. Phys., vol 74, No 2, 425-484, (2002).
2. B. Oliver, Report, DOE lab. at Rockwell International, CA 91309, 642/NAO2 (1994).
3. R. Stringham, ICCF11 Proc., J. Biberian Ed. Marseilles, France, 238, 31, (Oct.-5 Nov.'04)
4. Web site, www.sonofusionjets.com - one page, (2006)
5. R. Stringham, IEEE US Symp. Proc.; Sendai, Japan; 98CH36102; Vol. 2, 1107, (1998).
6. K. R. Weninger, P. G. Evans, and S. J. Putterman, Phys. Rev. E., 61(2), 3, 2000.
7. R. Stringham, ICCF-10 Proceedings, Poster, P. Haglestein, S. Chubb ed. Boston, USA, LANL-CANR web library, (2003).
8. R. Stringham, ICCF 9 Proceedings, Ed Zing Z. Li, Beijing, China, p 323, May 19-24, (2002)
9. Y. Tomita, A. Shima; Acoustica, 71,161, (1990). and M. P. Felix, A. T. Ellis, Appl. Phys. Lett., 19, 484, (1971), and W. Lautterborn, H. Bolle, J. Fluid Mech., 72, 391 (1975).
10. W. Alvarez, et al, Catalysis Nuclear Reactions by μ Mesons, Phys. Rev.; 105 1127, (1957).
11. M. A. Liberman, J. S. De Groot, A. Toor, R. B. Spielman; Physics of High-Density Z-Pinch Plasmas; Springer-Verlag NY, QC718.5.P45P48, 1998, pages 37 and 238-241
12. R. D. Petrasso, et al, Science, 319: 1223-1225, (29 Feb. 2008)
13. R. Stringham, ACS book to be published, (2008-9).
14. S. Chubb, T Chubb, P. Hagelstein, Y. Kim and others who have presented theories on why gammas are not present, most recently at the Proceedings of ICCF 12, A. Takahashi ed. Yokohama, Japan, Nov. – Dec. 2, 2005
15. R. Stringham, ICCF-10 Proceedings, P. Haglestein, S. Chubb ed. Boston, (Aug 2003)