# Using Bose and Fermionic Condensate to Trigger Fusion Reaction

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## Abstract

Existing thermonuclear reactors are very complex, expensive, large, and heavy. During the past 30 years, innovations in mini and micro-thermonuclear reactors have been advanced by senior author of this paper. These innovations dramatically decrease the size, weight and cost of thermonuclear reactor and its installation, and can be a viable propulsion system and electric generator. The major obstacle in thermonuclear reactors is achieving the Lawson criterion, sufficient temperatures and pressure. This paper proposes that ignition can be achieved by a phenomenon called the bose condensate and the fermionic condensate; that when matter is cooled down to very low temperatures all the atoms behave as a single atom to some extent. This paper shall put forward the design and computations to demonstrate that it would be possible to achieve fission with only a microgram or even a nano-gram of uranium. This reaction can then effect fusion in a mini-thermocuclear reactor.

## Introduction

For the last sixty years, scientists conducted R&D of a thermonuclear reactor that promises a true revolution in the energy industry. *Fusion power* is useful energy generated by nuclear fusion reactions. In this kind of reaction two light atomic nuclei fuse together to form a heavier nucleus and release energy. An experimental reactor, ITER, [1] was designed to produce several times more fusion power than the power into the plasma over many minutes. Construction of the facility began in 2010, and the first plasma is expected in 2019. The problems with existing thermonuclear reactors is that they are very complex, expensive, large, and heavy.

*History of failed attempts to initiate thermonuclear fusion.* One of the earliest (in the late 1970's and early 1980's) serious attempts at an ICF design was *Shiva*, a 20-armed neodymium laser system built at the Lawrence Livermore National Laboratory (LLNL) [2] that started operation in 1978. Shiva was a "proof of concept" design, followed by the *NOVA* design with 10 times the power. [3] Funding for fusion research was severely constrained in the 80's, but NOVA nevertheless successfully gathered enough information for a next generation machine whose goal was ignition. Although net energy can be released even without ignition (the breakeven point), ignition is considered necessary for a *practical* power system. The resulting design, now known as the National Ignition Facility (NIF), [4] was completed a number of years ago at a cost of $3.5 billion. It is a huge lab, 10 stories high and bigger than a football field. Its massive building, heavily guarded and highly classified, stands on isolated ground inside the Lawrence Livermore National Laboratory. Their own staff is skeptical. "The scientific and technological progress in inertial confinement fusion has been substantial during the past decade. However, many of the technologies needed for an integrated inertial fusion energy system are still at an early stage of technological maturity," the committee said in a statement. "For all approaches to inertial fusion energy there remain critical scientific and engineering challenges."

Stephen Bodner, retired director of the laser-fusion program at the Naval Research Laboratory in Washington and a longtime public critic of the ignition project, said he was highly skeptical of the significance of the latest development. Bodner has advocated a completely different approach to creating the unimaginably high temperatures and pressures required for ~~achieving fusion. In April, 20~~12 their team of physicists and engineers said they fired an array of 192 laser beams, focused "in perfect unison," and created a single pulse of energy that for 23 billionths of a second generated a thousand times more power than the entire United States consumes in a single second. The experiment March 15 delivered to the center of the facility's target chamber 1.87 megajoules of ultraviolet light, amounting to 100 times more energy than any other laser system in the world. [5]

"Was it just a gimmick shot, achieved without any real progress ... and done only to demonstrate some sort of program progress?" he asked in an e-mail. "It appears that they are just floundering about as they try to solve the many basic problems with their ignition target design."

The other very expensive European failed attempt is HiPER (High Power laser Energy Research) [6] facility which has yet to demonstrate the scientific proof of principle, but claims that their facility will move from the scientific proof of principle stage to a commercial fusion reactor. Many scientists have long voiced doubts that the experiments could ever yield enough energy to achieve ignition, and it's still an open question whether thermonuclear reactions can ever be achieved in the laboratory. [7]

## Theory of Current Thermonuclear Reactor

It is not as easy as scientists previously thought. Fusion reactions require a very large amount of energy to initiate a reaction in order to overcome the so-called *Coulomb barrier* or *fusion barrier energy*. In stark contrast to attempts in deriving power from controlled fusion reactions in electrical power plants, fusion power has been demonstrated in various configurations of thermonuclear bombs. A modern thermonuclear weapon weighing little more than 2,400 pounds (1,100 kg) can produce an explosive force comparable to the detonation of more than 1.2 million tons (1.1 million tonnes) of TNT. Thus, even a small nuclear device no larger than traditional bombs can devastate an entire city by blast, fire and radiation. The **Teller–Ulam design** employs hydrogen fusion, though in most applications the bulk of its destructive energy comes from uranium fission, not hydrogen fusion. Today virtually all the nuclear weapons deployed by the five major nuclear-armed nations use the Teller–Ulam design. Its essential features, which officially remained secret for nearly three decades, are: 1) separation of stages into a triggering "primary" explosive and a much more powerful "secondary" explosive, 2) compression of the secondary by X-rays coming from nuclear fission in the primary, a process called the "radiation implosion" of the secondary, and 3) heating of the secondary, after cold compression, by a second fission explosion inside the secondary. For more than half a century, vast amount of power generated by these explosions has fired the imagination of scientists to harness this energy for electricity power generation.

In thirty years, scientists have increased the Lawson criterion of the ICF and tokamak installations by tens of times. It is the threshold of temperatures and pressure Lawson number –

lower the better. Unfortunately, all current and some new installations (ICF and totamak) have a Lawson criterion that is tens of times lower than is necessary (Figure 1).

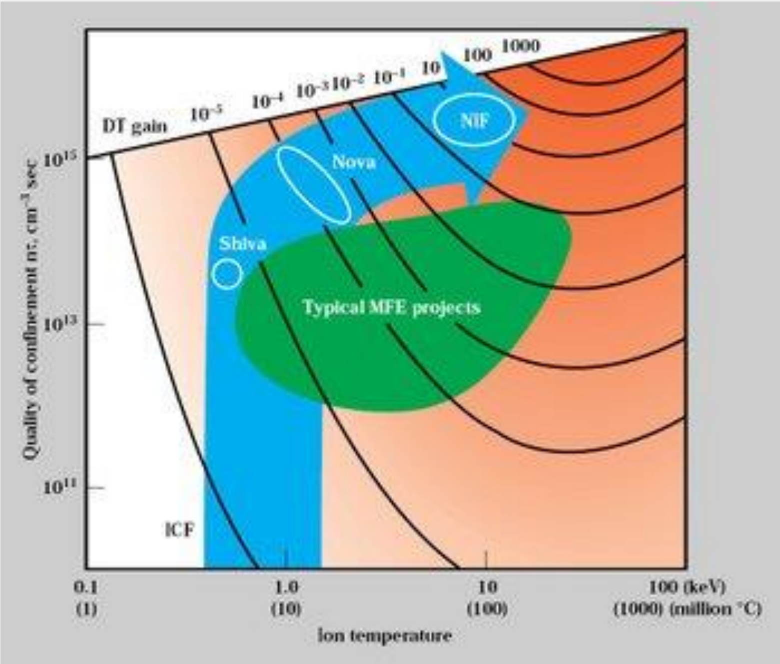


**Figure 1**. Parameter space occupied by inertial fusion energy and magnetic fusion energy devices. The regime allowing thermonuclear ignition with high gain lies near the upper right corner of the plot.

The key to practical fusion power is to select a fuel that requires the minimum amount of energy to start, that is, the lowest barrier energy. The best fuel from this standpoint is a one-to-one mix of deuterium and tritium; both are heavy isotopes of hydrogen. The D-T (Deuterium and Tritium) mix has a low barrier. In order to create the required conditions, the fuel must be heated to tens of millions of degrees, and/or must be compressed to immense pressures. To accomplish this, at present, D-T is used by two main methods of fusion: inertial confinement fusion (ICF) and magnetic confinement fusion (MCF)

*In inertial confinement fusion (ICF),* nuclear fusion reactions are initiated by heating and compressing a target. The target is a pellet that most often contains deuterium and tritium (often only micro or milligrams). Intense laser or ion beams are used for compression. The beams explosively detonate the outer layers of the target. That accelerates the underlying target layers inward, sending a shockwave into the center of pellet mass. If the shockwave is powerful enough and if the center has high enough density, some of the fuel will be heated enough to cause fusion reactions. In a target which has been heated and compressed to the point of thermonuclear ignition, energy can then heat surrounding fuel to cause it to fuse as well, potentially releasing tremendous amounts of energy.

*Magnetic confinement fusion (MCF).* Since plasmas are very good electrical conductors, magnetic fields can also confine fusion fuel. A variety of magnetic configurations can be used, the basic distinction being between magnetic mirror confinement and toroidal confinement, especially tokamaks and stellarators.

For the D-T reaction, the physical value is about

$$\begin{array}{l} L = n_e T\tau > (10^{14} \div 10^{15}) \quad \text{in} \quad \text{"cgs"} \quad \text{units} \\ \text{or} \quad L = nT\tau > (10^{20} \div 10^{21}) \quad \text{in} \quad \text{CI} \quad \text{units} \end{array}, \qquad (1)$$

where $T$ is temperature, [KeV], 1 eV = $1.16\times10^4$ °K; $n_e$ is matter density, [1/cm$^3$]; $n$ is matter density, [1/m$^3$]; $\tau$ is time, [s]. Last equation is in metric system. The thermonuclear reaction of $^2$H + $^3$D realizes if $L > 10^{20}$ in CI (meter, kilogram, second) units or $L > 10^{14}$ in 'cgs' (centimeter, gram, second) units. This number has not yet been achieved in any reactor, although the latest generations of machines have come close.

The Lawson criterion applies to inertial confinement fusion as well as to magnetic confinement fusion but is more usefully expressed in a different form. Whereas the energy confinement time in a magnetic system is very difficult to predict or even to establish empirically, in an inertial system it must be on the order of the time it takes sound waves to travel across the plasma:

$$\tau \approx \frac{R}{\sqrt{kT/m_i}} \qquad (2)$$

where $\tau$ is time, s; $R$ is distance, m; $k = 1.38 \cdot 10^{-23}$ $J/K$ is Boltzmann constant; $m_i$ is mass of ion, kg.

Following the above derivation of the limit on $n_e\tau_E$, we see that the product of the density and the radius must be greater than a value related to the minimum of $T^{3/2}/\langle\sigma v\rangle$ (here σ is Boltzmann constant, v is ion speed). This condition is traditionally expressed in terms of the mass density $\rho$: $\rho R > 1$ g/cm².

To satisfy this criterion at the density of solid D+T (0.2 g/cm³) would require implausibly large laser pulse energy. Assuming the energy required scales with the mass of the fusion plasma ($E_{laser} \sim \rho R^3 \sim \rho^{-2}$), compressing the fuel to $10^3$ or $10^4$ times solid density would reduce the energy required by a factor of $10^6$ or $10^8$, bringing it into a realistic range. With a compression by $10^3$, the compressed density will be 200 g/cm³, and the compressed radius can be as small as 0.05 mm. The radius of the fuel before compression would be 0.5 mm. The initial pellet will be perhaps twice as large since most of the mass will be ablated during the compression.

The fusion power density is a good figure of merit to determine the optimum temperature for magnetic confinement, but for inertial confinement the fractional burn-up of the fuel is probably more useful. The burn-up should be proportional to the specific reaction rate ($n^2\langle\sigma v\rangle$) times the confinement time (which scales as $T^{1/2}$) divided by the particle density $n$: burn-up fraction ~ $n^2\langle\sigma v\rangle\, T^{-1/2} / n \sim (nT)\, (\langle\sigma v\rangle/T^{3/2})$

Thus the optimum temperature for inertial confinement fusion is that which maximizes $\langle\sigma v\rangle/T^{3/2}$, which is slightly higher than the optimum temperature for magnetic confinement. Confinement refers to all the conditions necessary to keep plasma dense and hot long enough to undergo fusion:

- *Equilibrium:* There must be no net forces on any part of the plasma, otherwise it will rapidly disassemble. The exception, of course, is inertial confinement, where the relevant physics must occur faster than the disassembly time.

- *Stability:* The plasma must be so constructed that small deviations are restored to the initial state, otherwise some unavoidable disturbance will occur and grow exponentially until the plasma is destroyed.
- *Transport:* The loss of particles and heat in all channels must be sufficiently slow. The word "confinement" is often used in the restricted sense of "energy confinement".

To produce self-sustaining fusion, the energy released by the reaction (or at least a fraction of it) must be used to heat new reactant nuclei and keep them hot long enough that they also undergo fusion reactions. If more than about a milligram of fuel is used, the explosion would destroy the machine, so controlled thermonuclear fusion using inertial confinement causes tiny pellets of fuel to explode several times a second. To induce the explosion, the pellet must be compressed to about 30 times solid density with energetic beams. If the beams are focused directly on the pellet, it is called *direct drive*, which can in principle be very efficient, but in practice it is difficult to obtain the needed uniformity. An alternative approach is *indirect drive*, in which the beams heat a shell, and the shell radiates x-rays, which then implode the pellet. The beams are commonly laser beams, but heavy and light ion beams and electron beams have all been investigated and tried to one degree or another.

They rely on fuel pellets with a "perfect" shape in order to generate a symmetrical inward shock wave to produce the high-density plasma, and in practice these have proven difficult to produce.

In fusion research, achieving a fusion energy gain factor $Q = 1$ is called *breakeven* and is considered a significant although somewhat artificial milestone. *Ignition* refers to an infinite $Q$, that is, a self-sustaining plasma where the losses are made up for by fusion power without any external input. In a practical fusion reactor, some external power will always be required for things like current drive, refueling, profile control, and burn control. A value on the order of $Q = 20$ will be required if the plant is to deliver much more energy than it uses internally.

In a fusion power plant, the nuclear island section of a nuclear power plant where nuclear reactions happen, has a *plasma chamber* with an associated vacuum system, surrounded by a plasma-facing components (first wall and diverter) maintaining the vacuum boundary and absorbing the thermal radiation coming from the plasma, surrounded in turn by a blanket where the neutrons are absorbed to breed tritium and heat a working fluid that transfers the power to the balance of plant. If magnetic confinement is used, a *magnet* system, using primarily cryogenic superconducting magnets, is needed, and usually systems for heating and refueling the plasma and for driving current. In inertial confinement, a *driver* (laser or accelerator) and a focusing system are needed, as well as a means for forming and positioning the *pellets*.

## Methods in Current Reactors

In order to be useful as a source of energy, a fusion reaction must satisfy several criteria. It must:

- *be exothermic* - This may be obvious, but it limits the reactants to the low Z (number of protons) side of the curve of binding energy. It also makes helium $^4$He the most common product because of its extraordinarily tight binding, although $^3$He and $^3$H also show up.

- *involve low Z nuclei* - This is because the electrostatic repulsion must be overcome before the nuclei are close enough to fuse.
- *have two reactants* - At anything less than stellar densities, three body collisions are too improbable. It should be noted that in inertial confinement, both stellar densities and temperatures are exceeded to compensate for the shortcomings of the third parameter of the Lawson criterion, ICF's very short confinement time.
- *have two or more products* - This allows simultaneous conservation of energy and momentum without relying on the (weak!) electromagnetic force.
- *conserve both protons and neutrons* - The cross sections for the weak interaction are too small.

Few reactions meet these criteria. The following are those with the largest cross-sections:

**Table 1.** Suitable reactions for thermonuclear fusion

| | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| (1) | D | + | T | | | $^{4}He$ | (3.5 MeV) | + | | n | (14.1 MeV) | | | | | |
| (2i) | D | + | D | | | T | (1.01 MeV) | + | | p | (3.02 MeV) | | | | | *50%* |
| (2ii) | | | | | | $^{3}He$ | (0.82 MeV) | + | | n | (2.45 MeV) | | | | | *50%* |
| (3) | D | + | $^{3}He$ | | | $^{4}He$ | (3.6 MeV) | + | | p | (14.7 MeV) | | | | | |
| (4) | T | + | T | | | $^{4}He$ | | + | 2 | n | + 11.3 MeV | | | | | |
| (5) | $^{3}He$ | + | $^{3}He$ | | | $^{4}He$ | | + | 2 | p | + 12.9 MeV | | | | | |
| (6i) | $^{3}He$ | + | T | | | $^{4}He$ | | + | | p | | + | n | + 12.1 MeV | | *51%* |
| (6ii) | | | | | | $^{4}He$ | (4.8 MeV) | + | | D | (9.5 MeV) | | | | | *43%* |
| (6iii) | | | | | | $^{4}He$ | (0.5 MeV) | + | | n | (1.9 MeV) | + | p | (11.9 MeV) | | *6%* |
| (7) | D | + | $^{6}Li$ | | 2 | $^{4}He$ | + 22.4 MeV | | | | | | | | | |
| (8) | p | + | $^{6}Li$ | | | $^{4}He$ | (1.7 MeV) | + | | $^{3}He$ | (2.3 MeV) | | | | | |
| (9) | $^{3}He$ | + | $^{6}Li$ | | 2 | $^{4}He$ | | + | | p | + 16.9 MeV | | | | | |
| (10) | p | + | $^{11}B$ | | 3 | $^{4}He$ | + 8.7 MeV | | | | | | | | | |

p (protium), D (deuterium), and T (tritium) is shorthand notation for the main three isotopes of hydrogen.

For reactions with two products, the energy is divided between them in inverse proportion to their masses, as shown. In most reactions with three products, the distribution of energy varies. For reactions that can result in more than one set of products, the branching ratios are given.

Some reaction candidates can be eliminated at once. The D-$^{6}$Li reaction has no advantage compared to p-$^{11}$B because it is roughly as difficult to burn but produces substantially more neutrons through D-D side reactions. There is also a p-$^{7}$Li reaction, but the cross-section is far too low except possible for $T_i$ > 1 MeV, but at such high temperatures an endothermic, direct neutron-producing reaction also becomes very significant. Finally there is also a p-$^{9}$Be reaction, which is not only difficult to burn, but $^{9}$Be can be easily induced to split into two alphas and a neutron.

In addition to the fusion reactions, the following reactions with neutrons are important in order to "breed" tritium in "dry" fusion bombs and some proposed fusion reactors:

$n + {}^{6}Li \rightarrow T + {}^{4}He$,

$n + {}^{7}Li \rightarrow T + {}^{4}He + n$.

To evaluate the usefulness of these reactions, in addition to the reactants, the products, and the energy released, one needs to know something about the cross section. Any given fusion device will have a maximum plasma pressure that it can sustain, and an economical device will always operate near this maximum. Given this pressure, the largest fusion output is obtained when the temperature is selected so that $\langle\sigma v\rangle/T^2$ is a maximum. This is also the temperature at which the value of the triple product $nT\tau$ required for ignition is a minimum. This chosen optimum temperature and the value of $\langle\sigma v\rangle/T^2$ at that temperature is given for a few of these reactions in the following table 2.

**Table 2.** Optimum temperature and the value of $\langle\sigma v\rangle/T^2$ at that temperature

| fuel | $T$ [keV] | $\langle\sigma v\rangle/T^2$ [$m^3/s/keV^2$] |
|---|---|---|
| D-T | 13.6 | $1.24\times10^{-24}$ |
| D-D | 15 | $1.28\times10^{-26}$ |
| D-$^3$He | 58 | $2.24\times10^{-26}$ |
| p-$^6$Li | 66 | $1.46\times10^{-27}$ |
| p-$^{11}$B | 123 | $3.01\times10^{-27}$ |

Note that many of the reactions form chains. For instance, a reactor fueled with T and $^3$He will create some D, which is then possible to use in the D + $^3$He reaction if the energies are "right". An elegant idea is to combine the reactions (8) and (9). The $^3$He from reaction (8) can react with $^6$Li in reaction (9) before completely thermalizing. This produces an energetic proton which in turn undergoes reaction (8) before thermalizing. A detailed analysis shows that this idea will not really work well, but it is a good example of a case where the usual assumption of a Maxwellian plasma is not appropriate.

Any of the reactions above can, in principle, be the basis of fusion power production. In addition to the temperature and cross section discussed above, we must consider the total energy of the fusion products $E_{fus}$, the energy of the charged fusion products $E_{ch}$, and the atomic number $Z$ of the non-hydrogenic reactant.

Specification of the D-D reaction entails some difficulties, though. To begin with, one must average over the two branches (2) and (3). More difficult is to decide how to treat the T and $^3$He products. T burns so well in a deuterium plasma that it is almost impossible to extract from the plasma. The D-$^3$He reaction is optimized at a much higher temperature, so the burn-up at the optimum D-D temperature may be low, so it seems reasonable to assume the T but not the $^3$He gets burned up and adds its energy to the net reaction. Thus we will count the D-D fusion energy as $E_{fus} = (4.03+17.6+3.27)/2 = 12.5$ MeV and the energy in charged particles as $E_{ch} = (4.03+3.5+0.82)/2 = 4.2$ MeV.

Another unique aspect of the D-D reaction is that there is only one reactant, which must be taken into account when calculating the reaction rate.

With this choice, we tabulate parameters for four of the most important reactions (table 3).

**Table 3.** Parameters of the most important reactions

| Fuel | $Z$ | $E_{fus}$ [MeV] | $E_{ch}$ MeV] | Neutronicity |
|---|---|---|---|---|
| D-T | 1 | 17.6 | 3.5 | 0.80 |
| D-D | 1 | 12.5 | 4.2 | 0.66 |
| D-$^3$He | 2 | 18.3 | 18.3 | ~ 0.05 |
| p-$^{11}$B | 5 | 8.7 | 8.7 | ~ 0.001 |

The last column is the *neutronicity* of the reaction, the fraction of the fusion energy released as neutrons. This is an important indicator of the magnitude of the problems associated with neutrons like radiation damage, biological shielding, remote handling, and safety. For the first two reactions it is calculated as $(E_{fus}-E_{ch})/E_{fus}$. For the last two reactions, where this calculation would give zero, the values quoted are rough estimates based on side reactions that produce neutrons in a plasma in thermal equilibrium.

Of course, the reactants should also be mixed in the optimal proportions. This is the case when each reactant ion plus its associated electrons accounts for half the pressure. Assuming that the total pressure is fixed, this means that density of the non-hydrogenic ion is smaller than that of the hydrogenic ion by a factor $2/(Z+1)$. Therefore the rate for these reactions is reduced by the same factor, on top of any differences in the values of $\langle\sigma v\rangle/T^2$. On the other hand, because the D-D reaction has only one reactant, the rate is twice as high as if the fuel were divided between two hydrogenic species.

Thus, there is a "penalty" of (2/(Z+1)) for non-hydrogenic fuels arising from the fact that they require more electrons, which take up pressure without participating in the fusion reaction. There is, at the same time, a "bonus" of a factor 2 for D-D due to the fact that each ion can react with any of the other ions, not just a fraction of them. We can now compare these reactions in the following table 4.

**Table 4.** Comparison of reactions

| fuel | $\langle\sigma v\rangle/T^2$ | penalty/ bonus | reactivity | Lawson criterion | power density |
|---|---|---|---|---|---|
| D-T | $1.24\times10^{-24}$ | 1 | 1 | 1 | 1 |
| D-D | $1.28\times10^{-26}$ | 2 | 48 | 30 | 68 |
| D-$^3$He | $2.24\times10^{-26}$ | 2/3 | 83 | 16 | 80 |
| p-$^{11}$B | $3.01\times10^{-27}$ | 1/3 | 1240 | 500 | 2500 |

The maximum value of $\langle\sigma v\rangle/T^2$ is taken from a previous table. The "penalty/bonus" factor is that related to a non-hydrogenic reactant or a single-species reaction. The values in the column "reactivity" are found by dividing ($1.24\times10^{-24}$ by the product of the second and third columns. It indicates the factor by which the other reactions occur more slowly than the D-T reaction under comparable conditions. The column "Lawson criterion" weights these results with $E_{ch}$ and gives an indication of how much more difficult it is to achieve ignition with these reactions, relative to the difficulty for the D-T reaction. The last column is labeled "power density" and weights the practical reactivity with $E_{fus}$. It indicates how much lower the fusion power density of the other reactions is compared to the D-T reaction and can be considered a measure of the economic potential.

### Bremsstrahlung (Brake) Losses.

The phenomenon, Bremsstrahlung, was discovered by Nikola Tesla (1856-1943) during high frequency research he conducted between 1888 and 1897. This "braking radiation", is electromagnetic radiation produced by the acceleration of a charged particle, such as an electron, when deflected by another charged particle, such as an atomic nucleus. Bremsstrahlung is free-free radiation; radiation that arises as a result of a charged particle that is free both before and after the deflection (acceleration) that causes the emission. Strictly speaking, bremsstrahlung refers to any radiation due to the acceleration of a charged particle, which includes synchrotron radiation; however, it is frequently used (even when not speaking German) in the more literal and narrow sense of radiation from electrons stopping in matter.

**Table 5.** Rough optimum temperature and the power ratio of fusion and Bremsstrahlung radiation lost

| Fuel | $T_i$ (keV) | $P_{fusion}/P_{Bremsstrahlung}$ |
|---|---|---|
| D-T | 50 | 140 |
| D-D | 500 | 2.9 |
| D-$^3$He | 100 | 5.3 |
| $^3$He-$^3$He | 1000 | 0.72 |
| p-$^6$Li | 800 | 0.21 |
| p-$^{11}$B | 300 | 0.57 |

The ions undergoing fusion will essentially never occur alone but will be mixed with electrons that neutralize the ions' electrical charge and form a plasma. The electrons will generally have a temperature comparable to or greater than that of the ions, so they will collide with the ions and emit Bremsstrahlung. The Sun and stars are opaque to Bremsstrahlung, but essentially any terrestrial fusion reactor will be optically thin at relevant wavelengths. Bremsstrahlung is also difficult to reflect and difficult to convert directly to electricity, so the ratio of fusion power produced to Bremsstrahlung radiation lost is an important figure of merit. This ratio is generally maximized at a much higher temperature than that which maximizes the power density (see the previous subsection). The following table shows the rough optimum temperature and the power ratio at that temperature for several reactions.

The actual ratios of fusion to Bremsstrahlung power will likely be significantly lower for several reasons. For one, the calculation assumes that the energy of the fusion products is transmitted completely to the fuel ions, which then lose energy to the electrons by collisions, which in turn lose energy by Bremsstrahlung. However, because the fusion products move much faster than the fuel ions, they will give up a significant fraction of their energy directly to the electrons. Secondly, the plasma is assumed to be composed purely of fuel ions. In practice, there will be a significant proportion of impurity ions, which will lower the ratio. In particular, the fusion products themselves *must* remain in the plasma until they have given up their energy, and *will* remain some time after that in any proposed confinement scheme. Finally, all channels of energy loss other than Bremsstrahlung have been neglected. The last two factors are related. On theoretical and experimental grounds, particle and energy confinement seem to be closely related. In a confinement scheme that does a good job of retaining energy, fusion products will build up. If the fusion products are efficiently ejected, then energy confinement will be poor, too.

The temperatures maximizing the fusion power compared to the Bremsstrahlung are in every case higher than the temperature that maximizes the power density and minimizes the required value of the fusion triple product (Lawson criterion). This will not change the optimum operating point for D-T very much because the Bremsstrahlung fraction is low, but it will push the other fuels into regimes where the power density relative to D-T is even lower and the required confinement even more difficult to achieve. For D-D and D-$^3$He, Bremsstrahlung losses will be a serious, possibly prohibitive problem. For $^3$He-$^3$He, p-$^6$Li and p-$^{11}$B the Bremsstrahlung losses appear to make a fusion reactor using these fuels impossible.

In a plasma, the free electrons are constantly producing Bremsstrahlung in collisions with the ions. The power density of the Bremsstrahlung radiated is given by

$$P_{Br} = \frac{16\alpha^3 h^2}{\sqrt{3}\, m_e^{3/2}} n_e^2 T_e^{1/2} Z_{eff} \quad (3)$$

$T_e$ is the electron temperature, $\alpha$ is the fine structure constant, $h$ is Planck's constant, and the "effective" ion charge state $Z_{eff}$ is given by an average over the charge states of the ions:

$$Z_{eff} = \Sigma\, (Z^2 n_Z) / n_e \quad (4)$$

This formula is derived in "Basic Principles of Plasmas Physics: A Statistical Approach" by S. Ichimaru, p. 228. It applies for high enough $T_e$ that the electron deBroglie wavelength is longer than the classical Coulomb distance of closest approach. In practical units, this formula gives

$$PP_{Br} = (1.69\times10^{-32}\ /\mathrm{W\ cm^{-3}})\ (n_e/\mathrm{cm^{-3}})^2\ (T_e/\mathrm{eV})^{1/2}\ Z_{eff} =, \quad (5)$$

$$= (5.34\times10^{-37}\ /\mathrm{W\ m^{-3}})\ (n_e/\mathrm{m^{-3}})^2\ (T_e/\mathrm{keV})^{1/2}\ Z_{eff},$$

where Wcm$^{-3}$, cm$^{-3}$, eV, Wm$^{-3}$, m$^{-3}$, keV are units of corresponding magnitudes. For very high temperatures there are relativistic corrections to this formula, that is, additional terms of order $T_e/m_e c^2$.

## Bolonkin’s Thermonuclear Reactor

As early as 1983, Bolonkin [8] offered several innovations that he first suggested publicly for the AB multi-reflex engine, space propulsion, getting energy from plasma, etc. Over the years Bolonkin refined his design of mini and micro thermonuclear reactors for the production of electricity and for space craft propulsion. [9] [10] [11] [12] [13] [14] [15] [16]. Bolonkin’s books in which he detailed facets of is innovation include [17] [8] [18] [19] and book sections include [20]. These innovations are based on Bolonkin’s early patents [21] [22] [23]

[24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34]; classified report [35]; and papers presented in The World Space Congress [36] [37] [38] and International Astronautical Congress [39], and American Institute of Aeronautics and Astronautics Conference and Journal [40] [41]. The components of the devices proposed in this paper have been detailed in Bolonkin's previous papers. The configuration in the micro-thermonuclear AB- Reactor utilizes a very small fuel pellet that uses plasma confinement generated by multi-reflection of laser beam or its own magnetic field. The Lawson criterion increases by hundreds of times. Bolonkin also suggested a new method of heating the power- making fuel pellet by outer electric current as well as new direct method of transformation of ion kinetic energy into harvestable electricity. These offered innovations dramatically decrease the size, weight and cost of thermonuclear reactor, installation, propulsion system and electric generator.

In 2006, Bolonkin researched the efficiency of these innovations for two types of the micro-thermonuclear reactors: multi-reflection reactor (ICF) and self-magnetic reactor (MCF). [42] In 2007, Bolonkin developed and researched mini-sized Micro- AB Thermonuclear Reactors for space propulsion and space power systems. [43] These small engines directly convert the high speed charged particles produced in the thermonuclear reactor into vehicle thrust or vehicle electricity with maximum efficiency. The simplest AB-thermonuclear propulsion offered allows spaceships to reach speeds of 20,000 - 50,000 km/s (1/6 of light speed) for fuel ratio 0.1 and produces a huge amount of useful electric energy.

In 2008, Bolonkin offered a new kind of thermonuclear reflect reactor. [44] The remarkable feature of this new reactor is a three net AB reflector, which confines the high temperature plasma. The plasma loses part of its energy when it contacts with the net but this loss can be compensated by an additional permanent plasma heating. When the plasma is rarefied (has a small density), the heat flow to the AB reflector is not large and the temperature in the triple reflector net is lower than 2000 - 3000 K. This offered AB-reactor has significantly less power than the currently contemplated power reactors with magnetic or inertial confinement (hundreds-thousands of kW, not millions of kW). The author has made a number of innovations in this reactor, researched its theory, developed methods of computation, made a sample computation of typical project. The main point of preference for the offered reactor is its' likely cheapness as a power source.

In 2013, Bolonkin proposed design for a mini thermonuclear reactor [45] which uses a method based upon a series of important innovations. A cumulative explosion presses a capsule with nuclear fuel up to 100 thousands of atmospheres, the explosive electric generator heats the capsule/pellet up to 100 million degrees and a special capsule and a special cover which keeps these pressure and temperature in capsule up to 0.001 sec. which is sufficient for Lawson criteria for ignition of thermonuclear fuel. The proposed A-B Reactor is different from present magnetic confinement reactor. That is smaller because AB-self-magnetic reactor works using a small fuel capsule and does not require laser confinement. In present-day MCF reactor, the rare fuel gas (D+T) fills all volume of large chamber. In AB-Reactor the fuel is placed into a small capsule under high pressure (or, as solid, liquid or frizzed fuel under conventional pressure). In this case the fuel density can reach $n = 10^{26}\quad 10^{27}$ 1/m$^3$ (or solid, liquid, frozen fuel may be inside conductive matter, $n = 10^{28}\quad 10^{29}$ 1/m$^3$). That is enough for thermonuclear ignition and keeping plasma under the radiation pressure and magnetic pressure. For current MCF the magnetic intensity is 5 T. For AB-Self-MCF the magnetic intensity may be about 10 T and more. For AB-reactor the shaper pressure is about $10^{10}\quad 10^{11}$ N/m$^2$ (0.1 – 1 million atm).

Major advantages of these reactors/bombs is its very low cost, dimension, weight and easy production, which does not require a complex industry. The same method may be used for thermonuclear engine for electric energy plants, ships, aircrafts, tracks and rockets.

While other proprietary methods to achieve ignition may be presented in future papers, this paper proposes that ignition can be achieved by a phenomena called the bose condensate and the fermionic condensate; that when matter is cooled down to very low temperatures all the atoms behave as a single atom to some extent. This paper shall put forward the design and computations to demonstrate that it would be possible to achieve fission with only a microgram or even a nano-gram of uranium.

**Theory of Bolonkin's 2013 mini thermonuclear: Estimations.**

The parameters of the offered installation may be estimated by the equation above and below.

1. Energy is needed for heating of plasma for nuclear reaction is computed by equation (1). For fuel D+T it is about $T_e$ = 0.34MeV. This energy nuclear has in temperature $T_k = 1.16 \cdot 10^4\ T_e = 4 \cdot 10^8$K. In reality this temperature is less in some times (see fig. 3).

2. Energy of nuclear explosion $E_n$ , [MeV]

$$E_n = (1/2) nVE_1 , \quad n = \frac{M}{(A_1 + A_2) m_p} , \tag{6}$$

where $n$ is number of nuclears into unit of volume, $m^{-3}$ or $cm^{-3}$ (for example, 1 $cm^3$ fuel mixture D+T contains about about $10^{21}$ nuclears in room temperature under 100 atm pressure); *V is* volume before nuclear reaction, $m^3$ or $cm^3$; $E_1$ is energy couples of nuclear in MeV. For example, couple nuclears D+T gives $E_1$ = 3.5+14.1 = 17.6 MeV energy (see. Table 1, line 1). It is in 52 times more than energy needs for reaction; $M$ is mass of the nuclear fuel in unit of volume, kg/$cm^3$ or kg/$m^3$ ; $A$ is number nucleons in reactants ($A$ = 2 for D, $A$ = 3 for T); $m_p = 1.67 \cdot 10^{-27}$ kg is mass of nucleon.

2. Maximal pressure and energy for high speed (6 km/s) detonation explosive (for example TNT):

$$p = E_s \gamma , \quad T = \frac{p\,v}{R_u} = \frac{pM}{\gamma R_u} , \quad R_u = \frac{8314.2}{\mu} , \tag{7}$$

*where p* is gas pressure N/$m^2$; $v$ is gas volume, $m^3$; $T$ is gas temperature, K; $M$ is explosive mass, kg; $E_s$ is specific energy of explosive, J/kg (for TNT $E_s$ = 5.4 MJ/kg); $\gamma$ is specific weight of explosive, kg/$m^3$; $R_u$ is heat constant, J/kg·K; $\mu$ is average molar weight (for $CO_2$ $\mu$ = 46, for $H_2O$ $\mu$ = 18; $w$ is outer work (energy of process, J). For example, TNT can produce in explosion p = $10^{10}$ N/$m^2$ = $10^5$ atm and temperature 20,000°K; E is energy, J; $\eta$ is coefficient efficiency.

3. For computation of explosion extension in the impulse electric generator may be used the equations of adiabatic process in gas:

$$p_1 v_1^k = p_2 v_2^k , \ \frac{p_1}{p_2} = \left(\frac{v_2}{v_1}\right)^k , \quad \frac{T_1}{T_2} = \left(\frac{v_2}{v_1}\right)^{k-1} = \left(\frac{p_1}{p_2}\right)^{\frac{k-1}{k}} , \quad E = pv , \quad \eta = \frac{E_0 - E}{E_0} ,$$

$$w=\frac{p_1v_1}{k-1}\left(1-\frac{T_2}{T_1}\right),\quad w=\frac{R_u}{k-1}(T_1-T_2),\quad w=\frac{R_u}{k-1}\left[1-\left(\frac{v_1}{v_2}\right)^{k-1}\right],\quad w=\frac{p_1v_1}{k-1}\left[1-\left(\frac{p_2}{p_1}\right)^{\frac{k-1}{k}}\right], \qquad (8)$$

where lower index "$_1$" means the first state of gas, "$_2$" means the second state of gas; $k \approx 1.4$ is adiabatic constant, for very high temperature k → 1.

4. Estimation the explosive electric generator:

$$\Phi = B_nS,\quad W=i(\Phi_1-\Phi_2)\ ,\quad E=-\frac{d\Phi}{dt}\ ,\quad i=\frac{E}{R}\ ,\quad R=\rho\frac{l}{s}\ ,\quad L=\mu_0\frac{N^2S_s}{l_s}\ ,\quad \frac{d}{dt}(Li)+iR=0\ , \qquad (9)$$

where Φ is magnetic flux throw area *S*, Wb; $B_n$ magnetic induction (intensity) perpendicular *S*, T; *W* is work of magnetic flow, J; *i* is electric current, A; *E* is electromotive force (voltage), V; R is electric resistance, Ω; *ρ* if specific electric resistance, for copper $\rho = 1.75.10^{-6}$ Ω·cm; *l* is length of wire, cm; *s* is cross-section of wire, cm$^2$; *L* is inductance of solenoid; $\mu_0 = 4\pi\cdot 10^{-7}$ is magnetic constant; *N* is number of coils in solenoid; $l_s$ is length of solenoid, m; $S_s$ is cross-section of solenoid, m$^2$; *t* is time, s.

5. Increasing and decreasing current in the electric circuit

$$For\ turnon\ \ i=\left(\frac{E}{R}\right)\left[1-\exp\left(-\frac{t}{T}\right)\right],\quad for turn\ of\quad fi=i_0\left(-\frac{t}{T}\right),\quad where\quad T=\frac{L}{R},\quad W=L\frac{i^2}{2}\ , \qquad (10)$$

where $i_o$ is initial current, A; W is work for state permanent current, J.

6. Ion collision rate and the mean free path

$$\nu_i = 4.8\cdot 10^{-8}Z^4\mu^{-1/2}n_i\ln\Lambda\cdot T_i^{-1/2},\quad l=\frac{V_i}{\nu_i}=2.04\cdot 10^{13}\frac{T_i^2}{Z^4n_i\ln\Lambda}\ , \qquad (11)$$

where lower index "$_i$" means ion.

7. Safety electric current in wire:

$$j=\left\{\frac{\gamma\left[C_{pm}\Delta T+\left(C_p\Delta T+r\right)m_w/m\right]}{\rho t}\right\}^{0.5}\ , \qquad (12)$$

where *j* is electric current density, A/m$^2$; *γ* – mass density of wire, for cupper γ = 8320 kg/m$^3$; $C_{pm}$ is heat capacity, for cupper $C_{pm}$ = 0.39 kJ/kg·K; *ρ* is electric resistance, for cupper $\rho$ = 1.75·10$^{-8}$ Ω·m; Δ*T* is safety temperature, K; $C_p$ is heat capacity of cooling liquid, for water $C_p$ = 4.19 kJ/kg; *r* is heat evaporation of the cooling liquid, for water *r* = 2260 kJ/kg·K; t is safety time, sec; $m_w/m$ is mass ratio of cooling liquid to wire mass. Example: for *t* = 0.003 sec, Δ*T* = 80 $^o$K, we get j = 3.26·10$^3$ A/mm$^2$ without cooling.

8. Estimation of neutron penetration:

$$l=1/n\sigma_n\ , \qquad (13)$$

where *l* is path of penetration, cm; *n* is density of material, cm$^{-3}$; *σ* is cross section area of nuclear, $\sigma_n \approx 10^{-24}$ cm$^2$.

9. Required thickness of the shell:

$$\delta = \frac{pd}{2\sigma} \quad , \tag{14}$$

where $p$ is pressure, N/m$^2$; $d$ is diameter of cylinder, m; $\sigma$ is safety tensile stress, N/m$^2$.

# Computations

## List of Main Equations

Below are the main equations for estimation of benefits from the offered innovations.

*1. Energy, E, is needed for Thermonuclear Reaction*

$$F = k\frac{Q_1 Q_2}{r^2}, \quad E = \int_{r_0}^{\infty} F\,dr, \quad E = \frac{kZ_1Z_2e^2}{r_0}, \quad 1J = 0.625\cdot 10^{19}eV, \tag{15}$$
$$r_i = (1.2 \div 1.5)\cdot 10^{-15}\sqrt[3]{A}, \quad A = Z + N, \; r_0 = r_1 + r_2$$

where $k = 9\times10^9$ constant; $Z_1$, $Z_2$ are charge state of 1 and 2 particles respectively; $e = 1{,}6\times10^{-19}$ C is charge of electron; $r_o = r_1 + r_2$ is sum of radius of nuclear force, m; $A$ is number of element; $F$ is force, N; $E$ is energy, J; $Q$ is charge of particles.

For example, for reaction H+H (hydrogen, $Z_1 = Z_2 = 1$, $r_o \approx 2\times10^{-15}$ m) this energy is ≈ 0.7 MeV or 0.35 MeV for every particle. This energy nuclear has in temperature $T_k = 1.16{\cdot}10^4\ T_e = 4{\cdot}10^8$K. The real energy is about 30 times less because part of the particles has more average speed and there is a tunnel effect.

*2. Energy Needed for Ignition.* Figure 3 shows a magnitude $n\tau$ (analog of Lawson criterion) required for ignition.

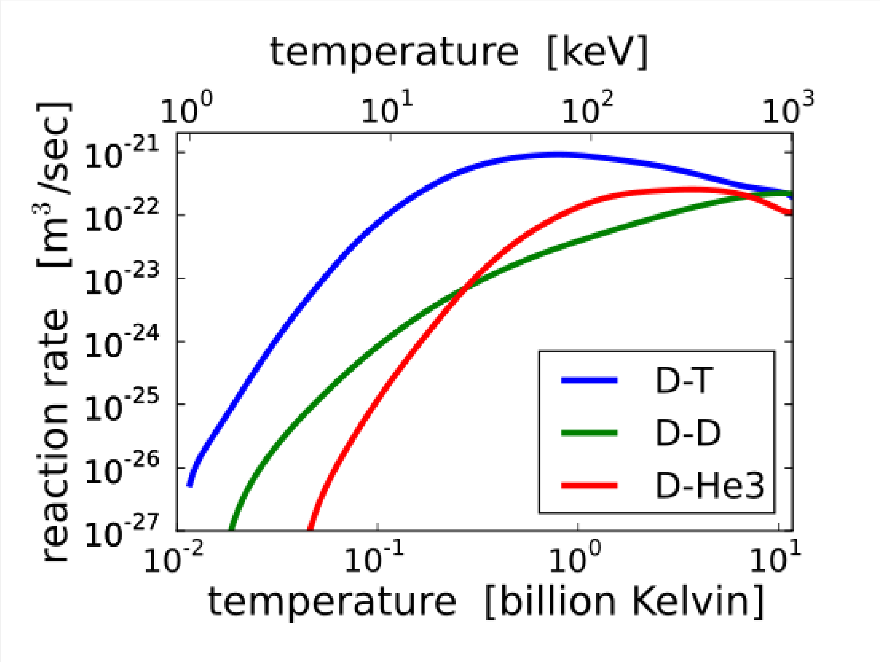


**Fig. 3.** Ration rate versus temperature in K.

3. *Radiation energy* from hot solid black body is (Stefan-Boltzmann Law):

$$E = \sigma T^4, \tag{16}$$

where $E$ is emitted energy, W/m$^2$; $\sigma$ = 5.67×10$^{-8}$ - Stefan-Boltzmann constant, W/m$^2$ $^o$K$^4$; $T$ is temperature in $^o$K.

4. *Wavelength* corresponded of maximum energy density (Wien's Law) is

$$\lambda_0 = \frac{b}{T}, \quad \omega = \frac{2\pi}{\lambda_0} \tag{17}$$

where $b$ = 2.8978×10$^{-3}$ is constant, m $^o$K; $T$ is temperature, $^o$K; $\omega$ is angle frequency of wave, rad/s.

5. *Pressure of light for Single Full Reflection* is

$$F = 2E/c, \tag{18}$$

where $F$ - pressure, N/m$^2$; $c$ = 3×10$^8$ is light speed, m/s, $E$ is radiation power, W/m$^2$. If plasma does not reflect radiation the pressure equals

$$F = E/c. \tag{19}$$

6. *Pressure for Plasma Multi-Reflection* [23-25] is

$$F = \frac{2E}{c}\left(\frac{2}{1-q}\right), \tag{20}$$

where $q$ is plasma reflection coefficient. For example, if $q$ = 0.98 the radiation pressure increases by 100 times.

We neglect losses of prism reflection.

*7. The Bremsstrahlung (Brake) Loss energy of plasma by radiation* is ($T > 10^6$ °K)

$$P_{Br} = 5.34\cdot 10^{-37} n_e^2 T^{0.5} Z_{eff}, \quad \text{where} \quad Z_{eff} = \sum (Z^2 n_z)/n_e \qquad (21)$$

where $P_{Br}$ is power of Bremsstrahlung radiation, W/m$^3$; $n_e$ is number of particles in m$^3$; $T$ is a plasma temperature, KeV; $Z$ is charge state; $Z_{\text{eff}}$ is cross-section coefficient for multi-charges ions. For reactions H+D, D+T the $Z_{\text{eff}}$ equals 1.

That loss may be very much. For some reaction they are more than useful nuclear energy and fusion nuclear reaction may be stopped. The Bremsstrahlung emission has continuous spectra.

*8. Electron Frequency in Plasma* is

$$\omega_{pe} = \left(\frac{4\pi n_e e^2}{m_e}\right)^{1/2}, \quad \text{or} \quad \omega_{pe} = 5.64\times 10^4 (n_e)^{1/2}$$
$$\text{in "cgs" units, or} \quad \omega_{pe} = 56.4(n)^{1/2} \quad \text{in CI units} \qquad (22)$$

where $\omega_{\text{pe}}$ is electron frequency, rad/s; $n_{\text{e}}$ is electron density, [1/cm$^3$]; $n$ is electron density, [1/m$^3$]; $m_{\text{e}} = 9.11\times 10^{-28}$ is mass of electron, g; $e = 1.6\times 10^{-19}$ is electron charge, C.

The plasma is reflected an electromagnet radiation if frequency of electromagnet radiation is less than electron frequency in plasma, $\omega < \omega_{\text{pe}}$. That reflectivity is high. For $T > 15\times 10^6$ °K it is more than silver and increases with plasma temperature as $T^{3/2}$. The frequency of laser beam and Bremsstrahlung emission are less than electron frequency in plasma.

*9. The Depth of Penetration of outer radiation into plasma* is

$$d_p = \frac{c}{\omega_{pe}} = 5.31\cdot 10^5 n_e^{-1/2} \text{ . [cm]} \qquad (23)$$

MEAUSRE OF OPACITY

For plasma density $n_e = 10^{22}$ 1/cm$^3$ $d_p = 5.31\times 10^{-6}$ cm.

*10. The Gas (Plasma) Dynamic Pressure, $p_k$*, is

$$p_k = nk(T_e + T_i) \quad \text{if} \quad T_e = T_k \quad \text{then} \quad p_k = 2nkT \qquad (24)$$

where $k = 1.38\times 10^{-23}$ is Boltzmann constant; $T_{\text{e}}$ is temperature of electrons, °K; $T_{\text{i}}$ is temperature of ions, °K.

These temperatures may be different; $n$ is ion density, 1/m$^3$; $p_k$ is plasma pressure, N/m$^2$.

*11. The gas pressure, $p$*, is

$$p = \frac{2}{3} nkT , \tag{25}$$

Here $n$ is gas density in $1/m^3$.

*12. The magnetic $p_m$ and electrostatic pressure, $p_s$,* are

$$p_m = \frac{B^2}{2\mu_0}, \quad p_s = \frac{1}{2}\varepsilon_0 E_S^2 \tag{26}$$

where $B$ is electromagnetic induction, Tesla; $\mu_0 = 4\pi\times10^{-7}$ electromagnetic constant; $\varepsilon_0 = 8.85\times10^{-12}$ , F/m, is electrostatic constant; $E_S$ is electrostatic intensity, V/m.

*13. Ion thermal velocity* is

$$v_{Ti} = \left(\frac{kT_i}{m_i}\right)^{1/2} = 9.79\times10^5 \mu^{-1/2} T_i^{1/2} \quad \text{cm/s} \ , \tag{27}$$

where $\mu = m_i / m_p$ , $m_i$ is mass of ion, kg; $m_p = 1.67\times10^{-27}$ is mass of proton, kg.

*14. Transverse Spitzer plasma resistivity*

$$\eta_\perp = 1.03\times10^{-2} Z \ln\Lambda T^{-3/2}, \quad \Omega \text{ cm} \quad \text{or} \quad \rho \approx \frac{0.1\text{Z}}{\text{T}^{3/2}} \quad \Omega\,\text{cm} \quad , \tag{28}$$

where ln $\Lambda = 5 \div 15 \approx 10$ is Coulomb logarithm, $Z$ is charge state.

*15. Reaction rates* $<\sigma v>$ (in $cm^3\ s^{-1}$) averaged over Mexwellian distributions for low energy ($T < 25$ keV) may be represented by

$$\begin{aligned} (\overline{\sigma v})_{DD} &= 2.33\times10^{-14} T^{-2/3} \exp(-18.76 T^{-1/3}) \quad \text{cm}^3\text{s}^{-1}, \\ (\overline{\sigma v})_{DT} &= 3.68\times10^{-12} T^{-2/3} \exp(-19.94 T^{-1/3}) \quad \text{cm}^3\text{s}^{-1}, \end{aligned} \tag{29}$$

where $T$ is measured in keV.

*16. The power density released in the form of charged particles* is

$$\begin{aligned} P_{DD} &= 3.3\times10^{-13} n_D^2 (\overline{\sigma v})_{DD} , \quad \text{W cm}^{-3} \\ P_{DT} &= 5.6\times10^{-13} n_D n_T (\overline{\sigma v})_{DT} , \quad \text{W cm}^{-3} \\ P_{DHe^3} &= 2.9\times10^{-12} n_D n_{He^3} (\overline{\sigma v})_{DHe^3} , \quad \text{W cm}^{-3} \end{aligned} \tag{30}$$

Here in $P_{DD}$ equation it is included D + T reaction.

## Description of Innovation

## Design and Innovations

If instead of the reactions of a D + T reaction detailed above, this paper proposes achieving fission using bose condensate and fermionic condensate of $U^{233}$. To date the largest atom which was shown to be stable in a condensate is an isotope $Er^{168}$. As these are relatively newly researched areas, it will be delineated in some detail.

In quantum mechanics and particle physics, spin is an intrinsic form of angular momentum carried by elementary particles, composite particles (hadrons), and atomic nuclei. As the name suggests, spin was originally conceived as the rotation of a particle around some axis. This picture is correct so far as spin obeys the same mathematical laws as quantized angular momenta do. On the other hand, spin has some peculiar properties that distinguish it from orbital angular momenta:

- Spin quantum numbers may take half-integer values.
- Although the direction of its spin can be changed, an elementary particle cannot be made to spin faster or slower.
- The spin of a charged particle is associated with a magnetic dipole moment with a g-factor differing from 1. This could only occur classically if the internal charge of the particle were distributed differently from its mass.

The conventional definition of the spin quantum number, s, is s = n/2, where n can be any non-negative integer. Hence the allowed values of s are 0, 1/2, 1, 3/2, 2, etc. The value of s for an elementary particle depends only on the type of particle, and cannot be altered in any known way (in contrast to the spin direction described below). The spin angular momentum, S, of any physical system is quantized. The allowed values of S are:

$$S = \frac{h}{2\pi}\sqrt{s(s+1)} = \frac{h}{4\pi}\sqrt{n(n+2)}, \tag{31}$$

where h is the Planck constant. In contrast, orbital angular momentum can only take on integer values of s; i.e., even-numbered values of n.

### Fermions and bosons

Those particles with half-integer spins, such as 1/2, 3/2, 5/2, are known as fermions, while those particles with integer spins, such as 0, 1, 2, are known as bosons.

### Properties

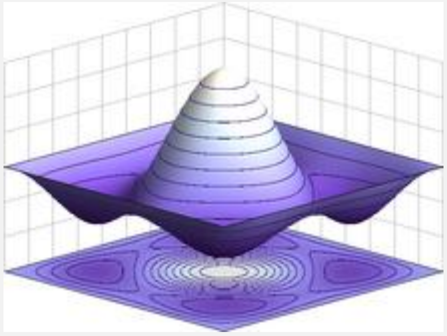

FIGURE 4: SYMMETRIC WAVEFUNCTION FOR A (BOSONIC) 2-PARTICLE STATE IN AN INFINITE SQUARE WELL POTENTIAL.

### Elementary bosons

All observed elementary particles are either fermions or bosons. The observed elementary bosons are all gauge bosons: photons, W and Z bosons, gluons, and the Higgs boson.

- Photons are the force carriers of the electromagnetic field.
- W and Z bosons are the force carriers which mediate the weak force.
- Gluons are the fundamental force carriers underlying the strong force.
- Higgs Bosons give other particles mass via the Higgs mechanism. Their existence was confirmed by CERN on 14 March 2013.

Finally, many approaches to quantum gravity postulate a force carrier for gravity, the graviton, which is a boson of spin plus or minus two.

### Composite bosons

Composite particles (such as hadrons, nuclei, and atoms) can be bosons or fermions depending on their constituents. More precisely, because of the relation between spin and statistics, a particle containing an even number of fermions is a boson, since it has integer spin.

Examples include the following:

- Any meson, since mesons contain one quark and one antiquark.
- The nucleus of a carbon-12 atom, which contains 6 protons and 6 neutrons.
- The helium-4 atom, consisting of 2 protons, 2 neutrons and 2 electrons.

The number of bosons within a composite particle made up of simple particles bound with a potential has no effect on whether it is a boson or a fermion.

### Bose condensate

A Bose–Einstein condensate (BEC) is a state of matter of a dilute gas of bosons cooled to temperatures very close to absolute zero (that is, very near 0 K or −273.15 °C[1]). Under such conditions, a large fraction of bosons occupy the lowest quantum state, at which point macroscopic quantum phenomena become apparent.

### Critical Temperature

This transition to BEC occurs below a critical temperature, which for a uniform three-dimensional gas consisting of non-interacting particles with no apparent internal degrees of freedom is given by:

$$T_c = \left(\frac{n}{\zeta(3/2)}\right)^{2/3} \frac{2\pi\hbar^2}{mk_B} \approx 3.3125\ \frac{\hbar^2 n^{2/3}}{mk_B} \tag{32}$$

where:

| | | |
|---|---|---|
| $T_c$ | is | the critical temperature, |
| $n$ | is | the particle density, |
| $m$ | is | the mass per boson, |
| $\hbar$ | is | the reduced Planck constant, |
| $k_B$ | is | the Boltzmann constant, and |
| $\zeta$ | is | the Riemann zeta function; $\zeta(3/2) \approx 2.6124$.[9] |

Interactions shift the value and the corrections can be calculated by mean-field theory

## Velocity-distribution data graph

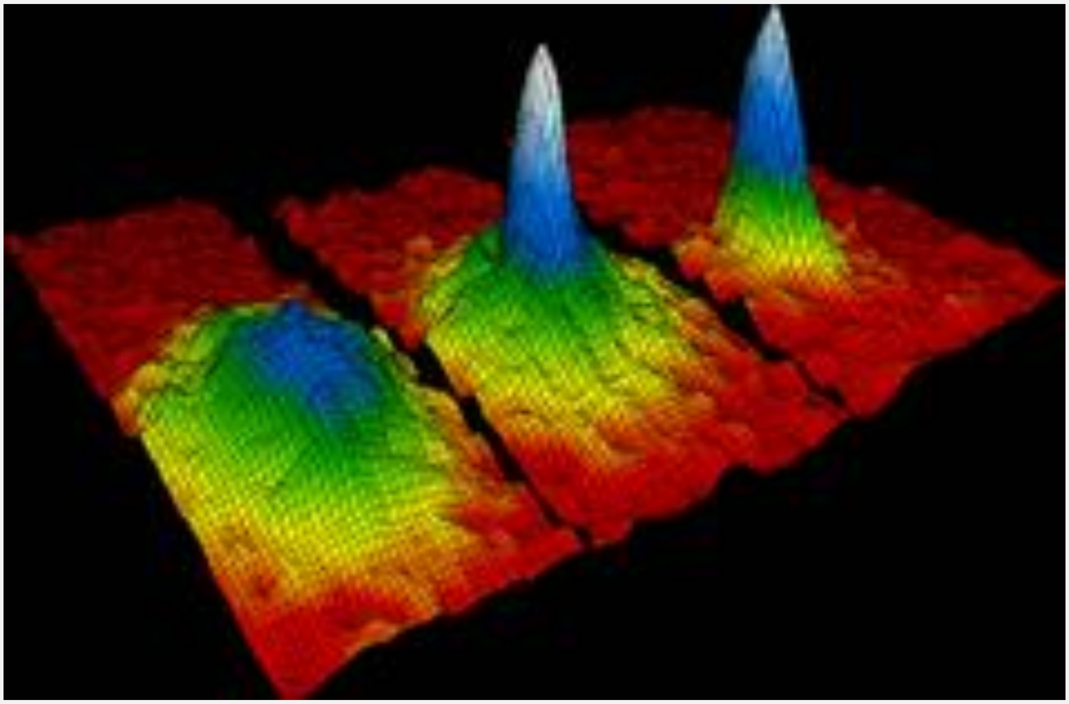

FIGURE 5: VELOCITY-DISTRIBUTION DATA (3 VIEWS) FOR A GAS OF RUBIDIUM ATOMS, CONFIRMING THE DISCOVERY OF A NEW PHASE OF MATTER, THE BOSE–EINSTEIN CONDENSATE. LEFT: JUST BEFORE THE APPEARANCE OF A BOSE–EINSTEIN CONDENSATE. CENTER: JUST AFTER THE APPEARANCE OF THE CONDENSATE. RIGHT: AFTER FURTHER EVAPORATION, LEAVING A SAMPLE OF NEARLY PURE CONDENSATE.

In the image above Fig. 5, the velocity-distribution data indicates the formation of a Bose–Einstein condensate out of a gas of rubidium atoms. The false colors indicate the number of atoms at each velocity, with red being the fewest and white being the most. The areas appearing white and light blue are at the lowest velocities. The peak is not infinitely narrow because of the Heisenberg uncertainty principle: spatially confined atoms have a minimum width velocity distribution. This width is given by the curvature of the magnetic potential in the given direction. More tightly confined directions have bigger widths in the ballistic velocity distribution. This anisotropy of the peak on the right is a purely quantum-mechanical effect and does not exist in the thermal distribution on the left.

### Quasiparticles

Bose–Einstein condensation also applies to quasiparticles in solids. Magnons, Excitons, and Polaritons have integer spin and form condensates.

- Magnons, electron spin waves, can be controlled by a magnetic field. Densities from the limit of a dilute gas to a strongly interacting Bose liquid are possible. Magnetic ordering is the analog of superfluidity. In 1999 condensation was demonstrated in antiferromagnetic TlCuCl3, at temperatures as large as 14 K. The high transition temperature (relative to atomic gases) is due to the magnons small mass (near an electron) and greater achievable density. In 2006, condensation in a ferromagnetic Yttrium-iron-garnet thin film was seen even at room temperature, with optical pumping.

- Excitons, electron-hole pairs, were predicted to condense at low temperature and high density by Boer et al. in 1961. Bilayer system experiments first demonstrated condensation in 2003, by Hall voltage disappearance.. Fast optical exciton creation was used to form condensates in sub-Kelvin Cu2O in 2005 on.
- Polariton condensation was detected in a 5K quantum well microcavity.

### Attractive interactions

Lithium condensates with attractive interactions could stably exist up to a critical atom number. Quench cooling the gas, the condensate grows, then subsequently collapse as the attraction overwhelmed the zero-point energy of the confining potential, in a burst reminiscent of a supernova, with an explosion preceded by an implosion.

Further work on attractive condensates had better control so they used naturally attracting atoms of rubidium-85 (having negative atom–atom scattering length). Through Feshbach resonance involving a sweep of the magnetic field causing spin flip collisions, they lowered the characteristic, discrete energies at which rubidium bonds, making their Rb-85 atoms repulsive and creating a stable condensate. The reversible flip from attraction to repulsion stems from quantum interference among wave-like condensate atoms. When the magnetic field strength was raised further, the condensate suddenly reverted to attraction, imploded and shrank beyond detection, then exploded, expelling about two-thirds of its 10,000 atoms. About half of the atoms in the condensate seemed to have disappeared from the experiment altogether, not seen in the cold remnant or expanding gas cloud. Under current atomic theory this characteristic of Bose–Einstein condensate could not be explained because the energy state of an atom near absolute zero should not be enough to cause an implosion; however, subsequent mean field theories have been proposed to explain it. Most likely they formed molecules of two rubidium atoms, energy gained by this bond imparts velocity sufficient to leave the trap without being detected.

### Current research

Bose–Einstein condensates composed of a wide range of isotopes have been produced. Cooling fermions to extremely low temperatures has created degenerate gases, subject to the Pauli Exclusion Principle. To exhibit Bose–Einstein condensation, the fermions must "pair up" to form bosonic compound particles (e.g. molecules or Cooper pairs). In 1999, Lene Hau and her associates slowed a beam of light to about 17 meters per second, using a superfluid. They have since made a group of condensate atoms recoil from a light pulse such that they recorded the light's phase and amplitude, recovered by a second nearby condensate, in what they term "slow-light-mediated atomic matter-wave amplification" using Bose–Einstein condensates.

### Isotopes

The effect has mainly been observed on alkaline atoms which have nuclear properties particularly suitable for working with traps. As of 2012, using ultra-low temperatures of $10^{-7}$ K or below, Bose–Einstein condensates had been obtained for a multitude of isotopes, mainly of alkaline, alkaline earth, and lanthanoid atoms ($^{7}$Li, $^{23}$Na, $^{39}$K, $^{41}$K, $^{85}$Rb, $^{87}$Rb, $^{133}$Cs, $^{52}$Cr, $^{40}$Ca, $^{84}$Sr, $^{86}$Sr, $^{88}$Sr, $^{174}$Yb, $^{164}$Dy, and $^{168}$Er ). Research was finally successful in hydrogen with aid of special methods. In contrast, the superfluid state of $^{4}$He below 2.17 K is not a good example, because the interaction between the atoms is too strong. Only 8% of atoms are in the ground state near absolute zero, rather than the 100% of a true condensate.[1]

## Fermionic condensate

A fermionic condensate is a superfluid phase formed by fermionic particles at low temperatures. It is closely related to the Bose–Einstein condensate, a superfluid phase formed by bosonic atoms under similar conditions. Unlike the Bose–Einstein condensates, fermionic condensates are formed using fermions instead of bosons. The earliest recognized fermionic condensate described the state of electrons in a superconductor; the physics of other examples including recent work with fermionic atoms is analogous. A chiral condensate is an example of a fermionic condensate that appears in theories of massless fermions with chiral symmetry breaking

### Superfluidity

Fermionic condensates are attained at temperatures lower than Bose–Einstein condensates. Fermionic condensates are a type of superfluid. As the name suggests, a superfluid possesses fluid properties similar to those possessed by ordinary liquids and gases, such as the lack of a definite shape and the ability to flow in response to applied forces. However, superfluids possess some properties that do not appear in ordinary matter. For instance, they can flow at low velocities without dissipating any energy—i.e. zero viscosity. At higher velocities, energy is dissipated by the formation of quantized vortices, which act as "holes" in the medium where superfluidity breaks down.

### Fermionic superfluids

It is far more difficult to produce a fermionic superfluid than a bosonic one, because the Pauli Exclusion Principle prohibits fermions from occupying the same quantum state. However, there is a well-known mechanism by which a superfluid may be formed from fermions. Below a certain temperature, electrons (which are fermions) can pair up to form bound pairs now known as Cooper pairs. As long as collisions with the ionic lattice of the solid do not supply enough energy to break the Cooper pairs, the electron fluid will be able to flow without dissipation. As a result, it becomes a superfluid, and the material through which it flows a superconductor.

### Creation of the first fermionic condensates

Jin 2003 managed to produce a condensate out of fermionic atoms for the first time. [46] The experiment involved 500,000 potassium-40 atoms cooled to a temperature of 5×10−8 K, subjected to a time-varying magnetic field.

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[1] Note: This should be explained in layman’s terms to be comprehensible. Does a fused atom in one quantum state remain after “defrosted”? Fusing different atoms to say make gold in condensate remains gold or comes apart when “defrosted”? In other words, if different atoms take the same space do they still keep their own identity or fuse giving a new meaning to cold fusion vs. super cold fusion. When this happens, is there the same energy exploded or is E near zero no this fusion will be without explosive force? What happens to gravitational pull? The denser the more gravitational pull. Any implications of this to theoretical temperature in a black hole?

## Innovation:

### Nuclear Reactions in Energy Charge

Bolonkin (2013) proposed a method for obtaining very cheap electric energy, liquid fuel, thermal energy, and cheap nuclear fuel using deuterium underground thermonuclear explosions. He shows the installation for generating energy is on the order of a thousand times cheaper than surface steel boiler designs offered by Russian scientists and safer because in case of any damage, the radiation is in a deep underground cavity.

In this design, the nuclear Energy charge contains the nuclear detonator, the deuterium as explosive and cheap Uranium-238 for production the nuclear fuel for next nuclear detonator and fuel for the nuclear electric stations and nuclear weapon. The main fuel is deuterium which is abundant in sea water. Its price is about $700/kg (2012). The fuel charge may also contain the cheap lithium and beryllium because they help to produce the energy and tritium – important and expensive fuel for thermonuclear reactors. Nuclear Reactors can use the isotopes Uranium- 233, 235, 238; isotopes Plutonium-239-242; isotopes Thorium: Th-232. [2]

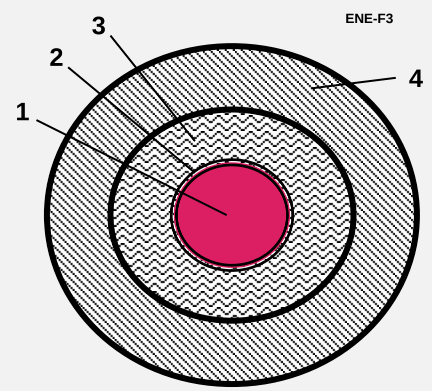


**Fig.8**. Energy charge. Notations: 1 – Nuclear charge/initiator (Uranium-233 or Plutonium-239); 2 – neutron reflector; 3 – deuterium; 4 – Uranium-238 or Thorium-232. Diameter is about 1 m, mass is about 1 ton.

The nuclear detonator 1 (fig.8) may use Uranium-233 or Plutonium-239.

For Uranium-233 reaction is

$$^{233}U + n \rightarrow X_1 + X_2 + \bar{\nu}_1 n + 200\ \text{MeV}\,, \qquad (33)$$

where $U$-233 is uranium, $n$ is neutron, $X_1$, $X_2$ are fission fragments, $\bar{\nu}_1$ is multiplication factor (one is ≈ 2.7 - 3 for $U$-233), MeV is unit of energy (1 MeV $=1.6\cdot 10^{-13}\ J$ ).

For Plutonium-239 the reaction is

[2] What is the cost of superfluid liquid helium? Is there a way to find out?

$$^{239}Pu + n \rightarrow X_3 + X_4 + \bar{\nu}_2 n + 200\ \text{MeV}\ , \qquad (34)$$

Where Pu-239 is plutonium; *n* is neutron, $X_3$, $X_4$ are fission fragments; $\bar{\nu}_2$ is multiplication factor (one is ≈ 3.5).

The high temperature produces the chain reactions in deuterium (layer 2 of fig.8.). We can succinctly write the thermonuclear reaction in deuterium as:

$$7D \rightarrow 2\ {}^4_2He + 3p + 3n \quad + 41 MeV\ , \qquad (35)$$

where *D* is deuterium; *p* is proton; *He*-4 is helium-4 (stable isotope)

The neutrons from (3) go to the layer 4 (fig.8). The layer 4 contains the cheap Uranium-238 or cheap Thorium-232. Protons convert them into very expensive Plutonium-239 or Uranium-233. Short (simplify) final reactions are:

$$^{238}U + n \rightarrow {}^{239}Pu\ , \quad {}^{232}Th + n \rightarrow {}^{233}U\ . \qquad (36)$$

As you see the cycle is closed-loop. Both products (Plutonium-239 and Uranium-233) may be used as nuclear fuel in production the very cheap energy for the new energy-charges (see equation (1)-(2)) or for thermonuclear weapon. We get several times more nuclear fuel in every cycle than spent in the energy-charge. The cost of U-238 and Th-232 is about 700$/kg (2012)[3] deuterium about 3500$/kg. The cost of Pu-239 and U-233 is about 60 Million $/kg in black market. The Russia offers the USA the price 16 Millions $/kg.[4]

This chain reaction may be presented as:

$$6\ {}^2_1D \rightarrow 2\ {}^4_2He + 2\ {}^4_2He + 2n \quad + 43.6 MeV\ . \qquad (37)$$

If we add the reaction $D + n \rightarrow p + 2n$ -2.2MeV, we receive the final reaction (3).

Neutrons are very useful for getting the nuclear fuel. For increasing the production of nuclear fuel we can add into the energy-charge the Berillium-9:

$$^9Be + n \rightarrow {}^8Be + 2n \rightarrow 2\ {}^4He + 2n\ . \qquad (38)$$

But for this reaction the energy of *n* must be more >1.85 MeV. For this the lithium also may be used. The list of possible reactions is in table 1 above.

**Critical mass of uranium depends upon its density**. That may be computed the equation:

$$M_c = \frac{4 \cdot 10^6}{\rho^2} \quad g^3 cm^{-6}\ , \qquad (39)$$

For $\rho$ = 20 g/cm$^3$ critical mass $M_c = 10\ kg$; for $\rho$ = 40 g/cm$^3$ critical mass $M_c = 2.5\ kg$; for $\rho$ = 80 g/cm$^3$ critical mass $M_c = 625\ g$. Using the neutron deflector significantly decreases the critical mass. If water neutron reflector is used, the critical mass of U-235 is 0.8 kg, of Pu-239 is 0.5 kg. In theory the Cf-251 has the minimal critical mass 10 grams.[5]

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[3] Please double check – perhaps U should be cheaper than Th

[4] please double check

[5] please check these numbers if still true

Because critical mass of uranium depends upon its density a bose condensate and fermionic condensate has greater density.

## Discussion

The thrust of this paper was advancing a mathematical model more in theoretical physics than experimental physics. There are however a number of empirical questions that require answers to complete this theoretical model.

Since critical mass of uranium depends upon its density, assuming even small Uranium condensate can be routinely achieved; there are two empirical questions.

1. Does one neutron fission one U atom or the entire condensate? Theoretically, it is expected that surface layers would evaporate forming opacity globe around core condensate but remaining core --if belief correct-- should fission as one.[6] If antimatter particles sufficient to annihilate just one U nucleus directed to core condensate--will just one be annihilated or entire core condensate? If entire core condensate is annihilated, then contemporary views on the nature of matter is incomplete leaving the question: How deep does entangled state go?

   Tests of this theoretical problem can be divided into tests of multiple sub-problems:

Firstly, assuming that one neutron hitting a fissionable condensation transition (Bose, Fermionic or other condensate) will result in EVERY nucleus in the condensate simultaneously firing; then using neutron bombardment can test the problem of the right kind of quantumly entangled state for a given very small and dense unit of fissionable material to be able to reach a very high power density upon neutron penetration as they have a superimposed quantum state. [47]

It is known that Bose-Einstein condensation can occur in quasiparticles and can be expected to obey Bose-Einstein statistics like traditional particles; to form when low temperatures cause nearly all particles to occupy the lowest quantum state; and occur in ultracold gases and materials. The calculations that lead to the conclusion that the lower masses of material quasiparticles relative to atoms lead to higher BEC temperatures is as follows:

An ideal Bose gas has a phase transitions when inter-particle spacing approaches the thermal wavelength: $k_B T = \hbar^2 n^{2/3}/M$. The critical concentration is: $N \propto (T/2\pi)^3 \mu^{1/2} P/\nu \hbar^3$, leading to a critical temperature: $T_c < 32\pi^3 \hbar^6 V u_0 P^2$. The particles obey the Bose-Einstein distribution and all occupy the ground state: $n(S) = (e^{(Es-u)/kT} - 1)^{-1}$. The bose gas can be considered in a harmonic trap, $V(r) = M\omega^2/2$, with the ground state occupancy fraction as a function of temperature: $f(0) = N_0(t)/N = 1 - (T/T_c)^3$. In 1998, Fetter [48] further detailed expected properties of bose concentrate quasi-particles which lends support to the notion that destruction of one BEC quasiparticle would destroy the others in the same quantum space.

[6] Unknown how thick the opacity globe is – if the outer layer is too big and actual net reaction (core) is too small then the efficiency is too small to pay

But would it really be a Bose or, Fermionic condensate or some other form is for example the superimposition in a Tonks-Girardeau gas?

A **Tonks–Girardeau gas** [49] is a Bose gas in which the repulsive interactions between bosonic particles confined to one dimension predominate so that strictly speaking this is not a Bose–Einstein condensate as it does not demonstrate any of the characteristics, such as off diagonal long range order or a unitary two body correlation function, even in a thermodynamic limit and as such cannot be described by a macroscopically occupied orbital (order parameter) in the Gross Pitaevskii formulation.

A row of bosons all confined to a one-dimensional line cannot pass each other and therefore cannot exchange places. Because the particles cannot exchange places, one might expect their behavior to be fermionic, but it turns out that their behavior differs from that of fermions in several important ways: the particles can all occupy the same momentum state which corresponds to neither Bose–Einstein nor Fermi–Dirac statistics. The fermionic exchange rule implies more than the exclusion of two particles from the same point: in addition, the momentum of two identical fermions can never be the same, wherever they are located. Mathematically, there is an exact one-to-one mapping of impenetrable bosons (in a one-dimensional system) onto a system of fermions that do not interact at all. Tonks–Girardeau gas coincide with quantum Nonlinear Schrödinger equation for infinite repulsion, which can be efficiently analyzed by Quantum inverse scattering method.

Or would this be Super Tonks-Girardeau gas?

**Super Tonks–Girardeau gas** [50] represents an excited quantum gas phase with strong attractive interactions in a one-dimensional spatial geometry. Usually, strongly attractive quantum gases are expected to form dense particle clusters and lose all gas-like properties. This lowest gas-like state should be stable and show new quantum mechanical properties. Particles in a Super Tonks gas should be strongly correlated and show long range order with a Luttinger Liquid parameter $K<1$. Since each particle occupies a certain volume, the gas properties are similar to a classical gas of hard rods. Despite the mutual attraction, the single particle wave functions separate and the bosons behave similar to fermions with repulsive, long range interaction. To prepare the Super Tonks–Girardeau phase it is necessary to increase the repulsive interaction strength all the way through the Tonks–Girardeau regime up to infinity. Sudden switching from infinitely strong repulsive to infinitely attractive interactions stabilizes the gas against collapse and connects the ground state of the Tonks gas to the excited state of the Super Tonks gas.[7]

## 2) The problem of the cryogenic requirement for the fuze.

It is also not necessarily so that the production of a condensate requires cryogenic temperatures. Using optical pumping, condensation in a ferromagnetic Yttrium-iron-garnet thin

[7] For targeting purposes, one can speculate if this acts like a long chain – almost like an ab matter chain of particles – if rigid is it a perfect target in the long axis. Could it have applications to build an AB matter chain. Is the ideal geometry a condensate ball for ease of targeting followed by super tonks–girardeau gas which catalysises – consider combination of bose and super tonks–girardeau gas

film was produced even at room temperature. [51] But even if near zero Kelvin temperatures are required for this condensate in order to effect fission, this does NOT stop practical design

## 3) The problem of a portable mechanism to produce a condensate state

The problem of achieving a portable mechanism to produce a condensate state is another problem. If you can induce a working condensate fuze in a national lab like facility a few minutes away and a few kilometers away from point of use, some mechanism needs to be found to contain and maintain the fuze for use in the fusion device. The practical equivalent be achieved in something analogous to a specialized design of quantum dot. In a **quantum dot** [52], its excitons are confined in all three spatial dimensions. The exciton confinement energy can be modeled using the particle in the box. The electron and the hole can be seen as hydrogen in the Bohr model with the hydrogen nucleus replaced by the hole of positive charge and negative electron mass. Then the energy levels of the exciton can be represented as the solution to the particle in a box at the ground level (n = 1) with the mass replaced by the reduced mass. Thus by varying the size of the quantum dot, the confinement energy of the exciton can be controlled. Quantum dot bound exciton energy is determined by the Coulomb attraction between the negatively charged electron and the positively charged hole.. When the size of the semiconductor crystal is smaller than the Exciton Bohr radius, the Coulomb interaction must be modified to fit the situation. Being zero-dimensional, quantum dots have a sharper density of states than higher-dimensional structures. Hy*pothetical designs exist for such a portable device* [53] [54] [55].

## 4. The problem of achieving a large amount of condensate.

One would assume that *Fuse needs in some grams of condensate. How to get, save, use it?* but in fact far fewer than grams, or even micrograms might be enough to ignite a properly designed special trigger mechanism. The key property is the energy density and sharpness of the power spike. Assuming that even very small fusion ignition conditions are achieved (and the leakage from a tiny fusion ignition is not too great) there are various design possibilities to scale up the spark to ignite kiloton yields (and from there, much more)

Related question? The mass of all the rubidium atoms in the largest condensate to date is how much? [56]

***1 mol of rubidium is 85.468 grams.***
***1 mol is 6.022x10^23 atoms.***

Therefore, 1 atom of rubidium is 1.419x10^(-22) grams.

Even allowing say 10000 rubidium atoms as the largest condensate to date that is a millionth of a nanogram, or a billionth of a microgram. But if this idea is not nonsense that could be an advantage not a disadvantage (a feature not a bug) because fission product contamination would be utterly negligible--if reliable fusion could be achieved and scaled up.

## 5. The problem of achieving the right species of fissionable material feed.

Even strange isotopes like Plutonium 240 might be good 'starter' fission fuel because there is no pre-detonation problem at this scale. I am assuming U 235 because easily turned to gas as UF6 but that is only assumption. The Uranium may need to be elemental.

## 6. The problem of achieving scale up from reliable tiny fission detonation/fusion ignition.

An **ideal gas** is a theoretical gas composed of many randomly moving point particles that do not interact except when they collide elastically. At normal conditions such as standard temperature and pressure, most real gases behave qualitatively like an ideal gas. The ideal gas model tends to fail at lower temperatures or higher pressures, when intermolecular forces and molecular size become important. As the temperature approaches zero, the entropy approaches negative infinity, in contradiction to the third law of thermodynamics. In the above "ideal" development, there is a critical point, not at absolute zero, at which the argument of the logarithm becomes unity, and the entropy becomes zero. This is unphysical.

### Ideal Bose and Fermi gases

An ideal gas of bosons (e.g. a photon gas) will be governed by Bose–Einstein statistics and the distribution of energy will be in the form of a Bose–Einstein distribution. An ideal gas of fermions will be governed by Fermi–Dirac statistics and the distribution of energy will be in the form of a Fermi–Dirac distribution. [57]

### Ideal Bose equation of state

The equation of state for an ideal Bose gas [58] is

$$pV_m = RT\,\frac{\mathrm{Li}_{\alpha+1}(z)}{\zeta(\alpha)}\left(\frac{T}{T_c}\right)^{\alpha}$$

where α is an exponent specific to the system (e.g. in the absence of a potential field, α=3/2), $z$ is $\exp(\mu/kT)$ where $\mu$ is the chemical potential, Li is the polylogarithm, ζ is the Riemann zeta function, and $T_c$ is the critical temperature at which a Bose–Einstein condensate begins to form.

## Conclusion

The major obstacle in thermonuclear reactors is achieving the Lawson criterion, sufficient temperatures and pressure. During the past 30 years, innovations in mini and micro-thermonuclear reactors have been advanced by senior author of this paper. This paper proposes that ignition can be achieved by a phenomenon called the bose condensate and the fermionic condensate; that when matter is cooled down to very low temperatures all the atoms behave as a single atom to some extent. This paper put forward the design and computations to demonstrate that it would be possible to achieve fission with only a microgram or even a nano-gram of uranium. This reaction can then effect fusion in the Bolonkin micro-thermocuclear reactor.

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