Inertial Beam Thermonuclear AB Reactor

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Abstract

Author offers a new impulse beam hole thermonuclear reactor. Reactor has the following features: one has a power high-current pulse ion accelerator using the thermonuclear fuel (for example, Deuterium) as ions. Accelerator focuses the ion beam into very small focus. The very small fuel capsule covered by shell from heavy and strong elements. The shell has a small hole for fuel beam from accelerator. The capsule contains a solid fuel (example, LiD). The theory and computation give conditions when will be ignition and developing the high intensity thermonuclear reaction. The suggested reactor is small, non-expensive and allows to make small engines.
Key word: Inertial Reactor, Impulse reactor, Beam reactor, Thermonuclear reactor, ICF reactor, AB reactor.

Introduction

The thermonuclear reaction depends from production three magnitudes: density (compression of fuel), temperature and time. At present time the scientists use two main methods for attempts to reach efficiency thermonuclear: Inertial Confinement Fusion (ICF) and Magnetic Confinement Fusion (MCF). In ICF the scientists use the high compression (by laser beam), but low time, in MCF they use low compression, but long time.

Both current main methods (ICF and MCF) are developed more 60 years by the thousands of scientists in all main countries. The governments spent the billions of dollars for their R&D (Research and Development) and are spending hundreds millions dollars every years. But optimist scientists only promise to reach the useful stable nuclear reaction throw 10 – 15 years (after 2018) and build the industrial electric station after the additional 5 – 10 years. The other scientists show: the price of the nuclear energy used tritium fuel (main fuel for current reactors is T+D) will be cost ten times more than the natural fuel using in present electric stations (tritium costs 30,000 $/gram, trend up 100,000 $/g).

Description of offered Reactor

The author offers the new reactor (method). Main idea is getting a high temperature by high-current impulse fuel ion focused accelerator and a special fuel capsule. The special fuel capsule has layer from the heavy elements, cover from strong material and the small hole for focused fuel ion beam. Reactor can easy to get the initial very high temperature up 30 keV (about 300 million K), has enough compression (up 600 - 1000 atm) of plasma and confinement (10^{-7} sec). One can work on cheap D+D nuclear fuel (1 gram of deuterium cost only 1$), is very cheap and has a small installation. The main test (getting the thermonuclear reaction) costs only some ten thousand dollars. If test will be successful, we can immediately design the engines for ships, trains, submarines, electric stations and propulsions for rockets.

Electric impulse ion beam hole method. Early author offered five the new methods (reflex, cumulative, impulse, ultra-cold, electric)[1 ÷ 6], which are cheaper by thousands of times, more efficiency and does not have many disadvantages of the laser and magnetic methods. In given article the author offers a version of the electric impulse ion beam hole reactor. Detailed consideration of advantages the new methods and computation proofs are in next paragraphs.

Outline of the new electric impulse ion hole reactors.

The offered version of the ion beam hole AB thermonuclear reactor is presented in figures 1 – 3.

The new thermonuclear reactor contains (fig.1): spherical strong body (diameter 0.3 – 3 m), high-current ion focusing accelerator, special fuel capsule and installation for delivery a fuel capsule into reactor body.

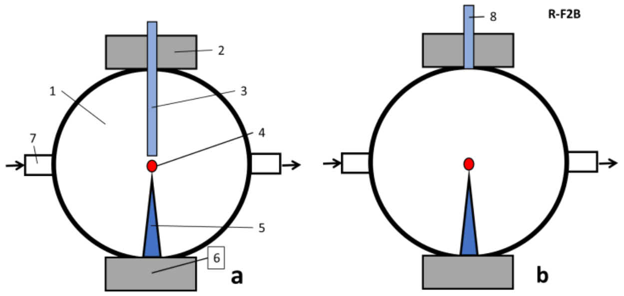

Fig. 1. Thermonuclear ion beam hole AB-reactor. *Notations*: **a** - reactor during the installation of the fuel capsule; **b** - reactor after installation of the fuel capsule. 1 – spherical reactor (diameter 0.3 – 3 m), 2 – installation, 3 - delivery rod in work position (installing of fuel capsule), 4 - fuel capsule, 5-6 – high-current ion focusing accelerator, 7 – ender for compression gas (air), 8 – delivery rod after in installation the fuel capsule.

The fuel capsule (fig.2) contains: the thermonuclear fuel in liquid, solid or a compressed gas form, layer from heavy elements (atom number A ≈ 200, for example, lead), and strong cover important for compressing gas fuel and heavy cover is important for increasing traction time. All have a spherical form. Capsule also has protrusion for mounting and fixing and small hole. Diameter of fuel is about 1 mm, cover in 2 -3 times more. Fuel has a groove for ion beam and can be separated by thin partition if we used a compressed gas fuel. This partition is destroyed by ion beam. The capsule is destroyed by thermonuclear explosion.

Small spherical thermonuclear capsule (other names: fuel cartridge, ampule, granule, beat, pellet) is shown in fig.2.

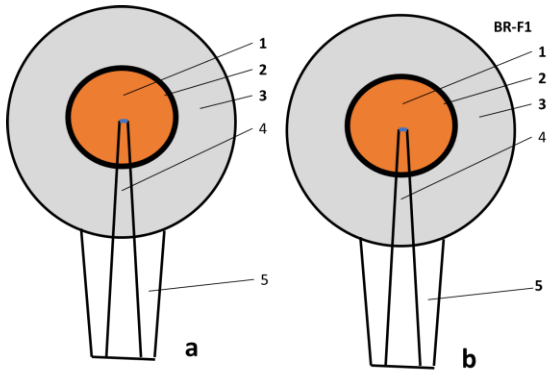

Fig.2. Fuel capsule for the offered ion hole reactor. **a**- forward view; **b** – side view. Notation: 1 – thermonuclear fuel, 2 – layer from heavy elements; 3 – strong cover, 4 – hole for ion beam, 5 - protrusion for mounting and fixing.

For fuel mass $M = 10^{-7}$ kg, the internal diameter is about 1 mm, pressure of gas fuel is up 600 ÷1000 atm.

The thermonuclear reactor is sphere of the diameter 0.3 – 3 m. (Fig.1). Reactor has two Version 1 - 2. In Version 1 the reactor has the additional installations for converting the nuclear energy into an electric, mechanical energy (MHG, turbine), in Version 2 the reactor converts by nozzle the thermonuclear energy in a rocket thrust (fig. 3).

The offered thermonuclear reactor works the next way (one example):

Version 1 for an electric or mechanic energy.

The internal volume of reactor is filled the atmospheric or compression air (enter 7 of Fig.1).

The fuel capsule (Fig.2) is installing by holder 3 (Fig.1) into reactor. Turn on the ion accelerator 6 (up 50 -100 kV, 30 – 60 kJ) (Fig 1). The ion (or neutral beam) from the accelerator are ionized the fuel molecules into capsule. In particular, they positive ionize and dissociate the fuel molecules (for example, D and T are contained into capsule). The positive ionized nucleus of the thermonuclear fuel (having small mass) are quick collectively accelerated by accelerator up very high temperature (up 30 – 60 keV), focused, neutralized by electron and collide with fuel nucleus into capsule. They ignite the thermonuclear reaction.

The cover from heavy molecules (nuclear mass A ≈ 200) reflect the light (A ≈ 2÷3) fuel nucleus and increase the fusion (reaction) time of the fuel nucleus. In results (as show computation) the fuel nucleus merge and produce a thermonuclear reaction. The thermonuclear reaction (explosive) heats the air into reactor body. For increasing the efficiency, work mass, decreasing explosive temperature and protection from neutrons, the liquid 7 (for example, water, fig.3a) may be injected into reactor.

After thermonuclear explosion the hot gas flow out into the magneto-hydrodynamic generator (MHG) 10 and produces electric energy or runs to the gas, steam turbine and produces a useful work (Fig. 3a). Or the hot compressed gas runs to rocket nozzle and produces the rocket trust (fig. 3b).

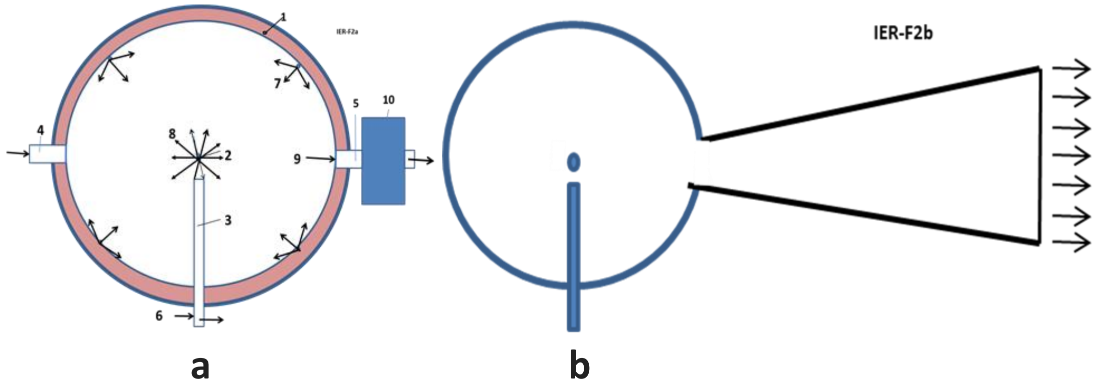

Fig.3. Final (industrial) work of Impulse Electric ion beam hole AB thermonuclear reactors. ***a***) Hot compressed gas from sphere runs to the magneto-hydrodynamic generator (MHG) 10 and produces electric energy or runs to gas turbine and produces a useful work (Fig. 3a). ***b***) Hot compressed gas runs to rocket nozzle and produces the rocket trust. *Notation*: 1- strong spherical (shell) of reactor, 2 -fuel capsule, 3 – holder for capsule, 4 – enter of compressed gas (air), 5-exit for hot gas, 6 – electricity, 7 – injection the cooling liquid (for example, water) (option); 8 – thermonuclear explosive of fuel pellet,9 – exit for explosive gas, 10 – MHG or gas (steam) turbine, 11 - exit of hot gas.

The main difference the offered electric reactor from the published cumulative reactors [2, 7] is type of explosive for getting the temperature, pressure and cumulative effect in fuel. On [2 - 4] author used the chemical explosive. The offered reactor uses the strong electric field for acceleration of nucleos, getting high temperature and cumulative effect. The electric method leads to practically unlimited cheap power. In [2, 4] the explosive is located into main spherical body 1 (fig.1) (or gun in [2]). In [4] version 1 (fig.2, [4]) the explosive 3 is small and located in the special fuel cartridge (fig.2, [6]). In current version no special compression explosive. The pressure and high temperature of the fuel are reached the high-current ion focusing accelerator. It is easier and it is more comfortable in using.

In the current cartridge version, the fuel pullet is filling by the compressed gas fuel (up 600÷1000 atmosphere or more). Reactor not has the explosive for an additional compressing of fuel. The fuel is compressed primary and heating only by strong ion focusing accelerator. The computation shows that is possible. We can also use the conventional pellet with frozen (gas) fuel, solid or liquid fuel.

AB Reactors are cooled using well-known methods between explosives or by an injection of water into sphere (fig. 3a).

Advantages of the suggested hole reactor in comparison with ICF Laser method.

The offered reactor and method have the following advantages in comparison with the conventional ICF laser reactor:

1. The high-current ion accelerator allows reaching the needed thermonuclear temperature.
2. Ion hole AB-reactors are cheaper by thousands of time because one does not have the gigantic very expensive laser or magnetic installations (see [1]-[6]).
3. They more efficiency because the laser installation converts only 1 - 2.5% the electric energy into the light beam. In suggested AB reactors, the all underused energy remains in the spherical reactor and utilized in MHG or turbine.

AB reactors cannot have coefficient *Q* (used energy) significantly less 1. Moreover, one has heat efficiency more than conventional heat engines because it has very high temperature and compression ratio. One can use as the conventional very high-power engine in civil and military transportation.

4. The offered very important innovation (accelerating of exhaust rocket gas) allows increasing the top speed of the exhaust mass up very high speed. This makes this method available for thermonuclear rockets.
5. Electric AB-reactors give temperature of the fuel much more than the current ICF laser installations.

6. The compression has longer time (up to $10^{-6} – 10^{-7}$ s) than a laser beam pressing ($10^{-9} – 10^{-12}$ s), because molar mass ($\mu \approx 200$) of heavy molecules (cover of capsule in fig.2) is many times (50 ÷ 100) heavier than fuel molar mass (μ = 2 ÷ 3).
   This pressure is supported by shock wave coming from moving gas and pinch effect. This pressure increases the temperature, compressing and probability of thermonuclear reaction.
7. The heavy mass of the cover of capsule (fig.2) (having high nuclear numbers Z ≈ 80 and A ≈ 200) not allow the nuclear particles easily to fly apart. That increases the reaction time and reactor efficiency.
8. The suggested AB-thermonuclear reactor is small (diameter about 0.5÷3 m or less up 0.3 m), light (mass is about some tons or less up 100 kg) and may be used in the transport vehicles and aviation.
9. The water may protect the material of the sphere from neutrons.
10. It is possible (see computations) the efficiency of AB reactors will be enough for using as fuel only the deuterium (or others) which is cheaper then tritium in thousands of times (One gram of tritium costs about 30,000 US dollars. One gram of deuterium costs 1$) (see Estimations of a fuel cost).
11. The offered hole AB reactor has high temperature. That allows to use the fuels do not give many neutrons and gamma radiation. These fuels are safety for humanity and installations.
12. Offered reactor may be used for syntheses elements.

Theory, estimation and computation of hole AB-reactor

Let us to estimate the need parameters of ion beam (jet) the ion accelerator. As thermonuclear fuel we take the ^{6}LiD (deuterate of lithium). That is the solid crystals having the melting temperature 692 °C. We will only consider the thermonuclear reaction D+D because the probability reactions Li+D and Li+Li are small. That reaction is:

$$D+D \rightarrow T(1.01)+p(3.02) \quad 50\% \qquad (1)$$
$$D+D \rightarrow {}^3He(0.82)+n(2.4) \quad 50\%$$

Here are: D=^{2}H is deuterium, T=^{3}H is tritium, ^{3}He is helium, p is proton, n is neutron, numbers into brackets are million electron volts. The full average energy is E_1 = 3.62 MeV. The energy into capsule (without neutron) is E_2 = 2.42 MeV. Using LiD in solid form, we can escape the pressing of fuel in gas form.

Let us take the fuel mass into capsule M = 10^{-7}kg. Number N of nuclear into capsule is

$$N = \frac{M}{\mu m_p} = \frac{10^{-7}}{8 \cdot 1.67 \cdot 10^{-27}} = 7.6 \cdot 10^{18} \qquad (2)$$

where N = number of fuel nuclear into capsule; M = mass of fuel, kg; m_p=1.67·10^{-27} is mass of nucleon (proton) [kg]. μ = 6+2=8 is molar mass of fuel *LiD*. Half of N is nuclear D and another half is nuclear of Li. For reaction D+D the other half D and an ignited energy must delivery the ion beam from accelerator. If ignition temperature is E_o = 10 keV (, the request heat energy of beam is

$$E = 1.5 \cdot N \cdot E_o = 1.5 \cdot 7.6 \cdot 10^{18} \cdot 10^4 = 1.14 \cdot 10^{23} eV = 1.14 \cdot 10^{23} \cdot 1.6 \cdot 10^{-19} \approx 18\, kJ \quad . \qquad (3)$$

The full thermonuclear energy of fuel D+D is

$$E = N \cdot E_1 = 0.5 \cdot 7.6 \cdot 10^{18} \cdot 3.62 \cdot 10^6 = 1.38 \cdot 10^{25} eV = 1.38 \cdot 10^{25} \cdot 1.6 \cdot 10^{-19} \approx 2.21\, MJ \,, \qquad (4)$$

The full thermonuclear energy of fuel D+D into capsule (without neutron) is

$$E = N \cdot E_2 = 0.5 \cdot 7.6 \cdot 10^{18} \cdot 2.42 \cdot 10^6 = 0.92 \cdot 10^{25} eV = 0.92 \cdot 10^{25} \cdot 1.6 \cdot 10^{-19} \approx 1.47\, MJ \,, \qquad (5)$$

Easy to calculate the size of spherical capsule for fuel M = 10^{-4} g, having specific mass γ = 0.82 g/cm^3. They are: volume $v = M/\gamma$ =1.22·10^{-4} cm^3, diameter D = 6.16·10^{-2} cm; gross section S = 3·10^{-3} cm^2.

We take the hole diameter d = 0.1D =0.616·10^{-2} cm.

Let us to estimate the parameters of accelerated D jet from ion accelerator. The need mass of jet is m = 0.25M = 0.25·10^{-7} kg. The speed of jet accelerated up E_o = 18 kJ is:

$$E_o = \frac{mV^2}{2}; \quad V = \left(\frac{2E_o}{m}\right)^{0.5} = 1.2 \cdot 10^6\ m/s \qquad (6)$$

Electric charge Q and electric current I of D jet for impulse time t = 10^{-9} sec are:

$$Q = Ne = 3.75 \cdot 10^{18} \cdot 1.6 \cdot 10^{-19} = 0.6\ \text{C}, \quad I = Q/t = 0.6/10^{-9} = 600\ \text{MA}. \qquad (7)$$

If the impulse time t – 10^{-8} sec., the impulse current will be I = 60 MA.

The length of jet for impulse $t = 10^{-9}$ sec is

$$L = V \cdot t = 1.2 \cdot 10^{6} \cdot 10^{-9} = 1.2 \cdot 10^{-3} \text{ m} \qquad (8)$$

Assume, the focused diameter of ion jet equals the diameter of hole into capsule $d = 2r = 0.1D = 0.616 \cdot 10^{-2}$ cm.

Let us estimate the negative electric pressure and positive magnetic pressure of jet at hole.

The linear electric charge is $\tau = Q/L = 0.6/1.2 \cdot 10^{-3} = 500$ C/m. Electric intensity is

$$E = k\frac{2\tau}{r} = 9 \cdot 10^{9}\frac{2 \cdot 500}{3.08 \cdot 10^{-5}} = 2.92 \cdot 10^{7} \; N/C \; or \; V/m, \qquad (9)$$

The magnetic intencity is

$$H = \frac{I}{2\pi r} = \frac{6 \cdot 10^{8}}{2 \cdot 3.14 \cdot 3.08 \cdot 10^{-5}} = 3.1 \cdot 10^{12} \text{ A/m} \qquad (10)$$

Positive magnetic and negative electric pressure at focused jet are

$$p_m = \frac{\mu_o H^2}{2} = \frac{4\pi 10^{-7}(3.1 \cdot 10^{12})^2}{2} = 3.02 \cdot 10^{18}\frac{N}{m^2} \approx 3 \cdot 10^{13} \text{ atm.},$$
$$p_e = \frac{\varepsilon_o E^2}{2} = \frac{8.85 \cdot (2.92 \cdot 10^{7})^2}{2} = 3.31 \cdot 10^{15}\frac{N}{m^2} = 3.3 \cdot 10^{10} \text{ atm.} \qquad (11)$$

As you see, the positive magnetic pressure is significantly more then negative electric pressure.
We can decrease the pressure, if we add in jet after focusing the electrons.

Discussion

The offered beam AB reactor requests a high-current ion accelerator, having the energy 30 ÷ 100 kJ, voltage about 50 kV and the impulse time about 2 ÷ 3 ns. At present time the ion accelerators widely are used in technology, in coating

, the introduction of elements, the production of chips and electronics. Especially the get big R&D in Program SDI (Strategic Defense Initiative). Charged particle beams diverge rapidly due to mutual repulsion, so neutral particle beams are more commonly proposed. A neutral-particle-beam weapon ionizes atoms by either stripping an electron off of each atom, or by allowing each atom to capture an extra electron. The charged particles are then accelerated, and neutralized again by adding or removing electrons afterwards.

SDI got a beam (ions) up 1 gigajoule of kinetic energy and ion speed closed to the light speed. Our requests are in thousand time less.

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