THINKING IN DIFFERENT WAYS TO COMBINE FUSION WITH FISSION

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The common goal of CTR, but in particular of ICF, is low yield-high gain. Fission triggered large TN explosive devices meet the second but not he first of these conditions. These devices depend on the rare isotopes U235, Pu239, or U233, but for them the fusion energy output greatly exceeds the output from fission, limiting the fallout. In thinking about different ways to combine fusion with fission, there are three questions: 1. Are there ways where both conditions can be met, and where the fallout from fission is small? 2. Can the conditions be met without the use of U235, Pu239, or U233, but with U238, Th232, and perhaps with the fission of light nuclei like B10 or Li6, the latter having no fallout? 3. Are there concepts for MF, combining fusion with fission, without U235, Pu239 or U233? In my talk I will present reasons why under the above stated conditions two things seem to be possible: 1. The greatly facilitated fast ignition of thermonuclear microexplosions with a small amount of U238 or Th232. 2. The greatly enhanced pulsed MF burn aided by the fission of light nuclei such as B10, but also of the U238 and Th232 and with a neutron moderator. In either one of these cases the burn is "autocatalytic" in the sense that neutron-induced nuclear reactions in a halo surrounding the fusion plasma drive thermomagnetic currents compressing and increasing its neutron production rate.

The only way manmade nuclear fusion has been achieved is on a grand scale in large thermonuclear explosive devices triggered with a comparatively small amount of U235, PU239 or U233. One may therefore ask if there are shortcuts to controlled nuclear fusion, both inertial and magnetic, with the help of a likewise comparatively small amount of fission-reaction materials.

I first discuss this question for inertial confinement fusion. One of the more promising approaches there is "fast ignition". But this concept suffers not only from the required large compression of a solid DT target, by primarily from the need of a petawatt laser with an energy output of more than 100kJ, to create a hot spot in the compressed DT, launching from there a thermonuclear detonation wave.

A small amount of U238 or Th232 can make here a dramatic improvement. As explained in Fig. 1, a sphere containing DT surrounded by a shell of metallic U238 (Th232) is positioned at one end of a cylindrical thermonuclear microexplosion assembly. The DT inside the shell can be heated through an opening to thermonuclear temperatures by a laser or particle beam. The large temperature gradient in between the hot DT plasma and the cold U238 (Th232) shell surrounding the DT plasma generates near the DT – U238 interface currents by the thermomagnetic Nernst effect with magnetic fields large enough to entrap the α-particles from the DT fusion reaction in the DT plasma. In passing through the U238 (Th232) shell, some of the 14MeV DT fusion reaction neutrons make fast fission reactions in the shell heating it to high temperatures. If the thickness of the shell is properly chosen, the shell will implode onto the DT increasing the density and reaction rate of the DT plasma inside the shell, further accelerating the implosion of the shell and with it the DT thermonuclear reaction rate, in an "autocatalytic" fusion-fission-fusion reaction.

To set up the magnetic field by the currents of the thermomagnetic Nernst effect, a seed field is needed, which is amplified by the Nernst effect. From the fission assisted fusion hot spot thusly produced, a thermonuclear detonation wave is launched into a DT cylinder. There too, a metallic cylindrical shell surrounding the DT cylinder can set up a large magnetic field by the Nernst effect, making possible a magnetic field assisted thermonuclear detonation wave propagating down the cylinder. In addition, soft X-rays, released from both the hot spot and the rear of the detonation wave, can be utilized to compress the un-burnt DT ahead of the wave. Because the amount of U238 (Th232) needed to create the hot spot is small in comparison to the total amount of DT, the amount of the undesirable fission products is relatively small.

Next we turn to pulsed magnetic fusion, pulsed on a timescale of $\sim 10^{-3}$ s. Because there the fission of radiation-poor light nuclei like B^{10} is preferable with no fallout, the situation is even better. Ignoring the stability problem which can be avoided by choosing a field reversed theta pinch, the proposed idea can best be explained by the linear z-pinch discharge configuration. As shown in Fig. 2, a z-pinch discharge channel of radius $r = r_0$, is surrounded by a cylindrical high temperature corona shell of radius $r = R$, where $R >> r_0$. This shell is surrounded by a dense neutron moderator and reflector of thickness D. While in the core of radius $r = r_0$, a high plasma temperature is sustained by thermonuclear reactions, in the corona surrounding the core, the high temperature results from neutron-induced nuclear reactions by the neutrons released from the fusion plasma. The initially fast neutrons released by the fusion reactions must be slowed down, because only then is their nuclear reaction cross section sufficiently large. For the slowing down of the neutrons a dense hydrogen-rich substance, like water for example, can be used. In a homogeneous mixture with the light nuclei, a hydrogen rich dense medium would lower the temperature, too low for the generation of thermomagnetic currents. It is for this reason that the low density plasma made up of the light nuclei must be spatially separated from the dense neutron moderator. This can be done by placing the moderator in a cylindrical shell surrounding the plasma containing the light nuclei and where the thermomagnetic currents are induced.

The similarity with a heterogeneous nuclear reactor is striking. There the fast neutrons released in the fuel rods are slowed down in a moderator separated from the rods. Without such a separation a large fraction of the neutrons would be lost by resonance absorption in the rods, and thus lost to sustain the chain reaction. While in a fission reactor the separation makes possible a growing neutron chain reaction, it here makes possible the autocatalytic amplification of the thermomagnetic currents by an increase of the fusion reaction rate through a rise of the plasma pressure by the magnetic pressure of the thermomagnetic currents in the corona. This is expected to substantially increase the $n\tau$ product over its Lawson value.

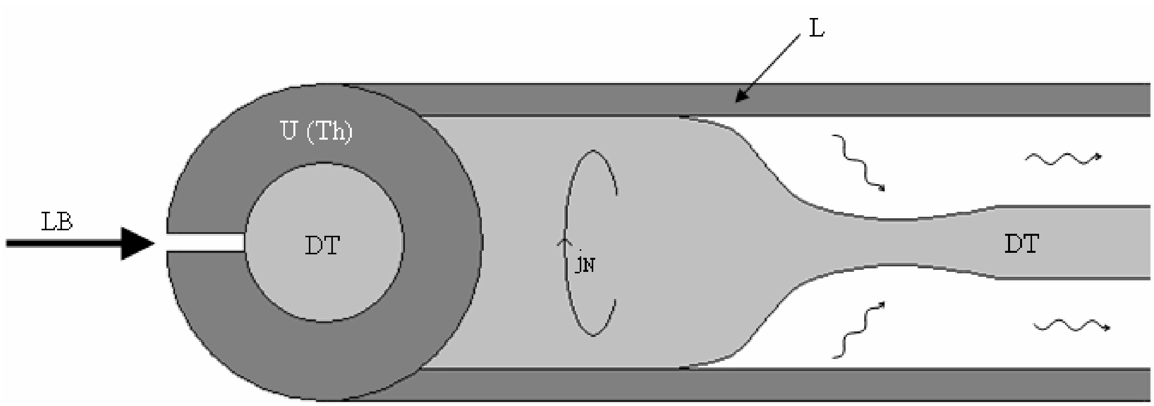

Fig. 1. Bombardment with a laser beam LB of a spherical solid DT target surrounded by a natural uranium (thorium) shell, with propagating burn into a DT cylinder inside a liner L

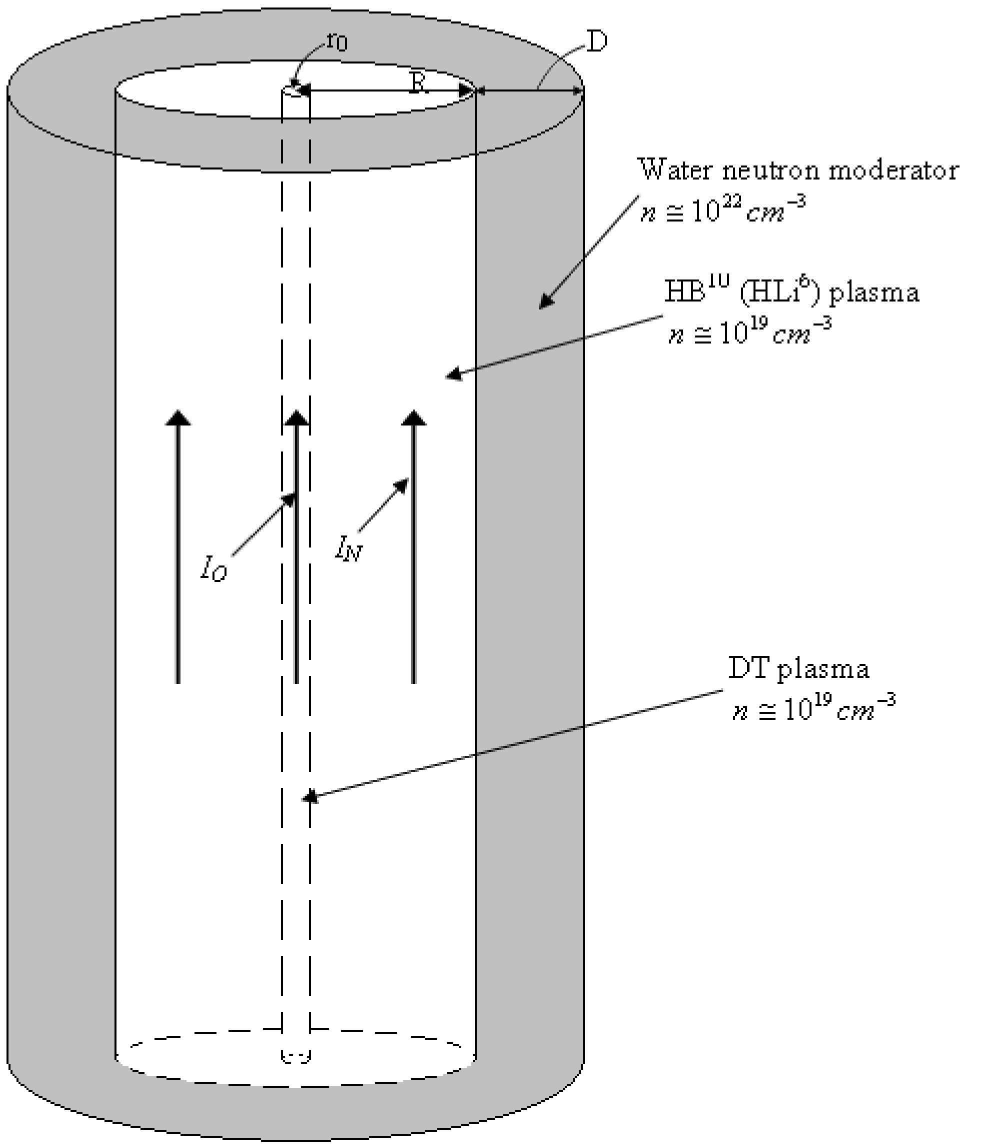

Fig. 2. z-pinch with Nernst current corona and neutron moderator