The Fork in the Road to Electric Power From Fusion

HB11 Energy

Peter Lobner, 1 February 2021

HB11 Energy was formed by Heinrich Hora in Sydney, Australia in September 2017 as a commercial spin-off from the University of New South Wales (UNSW). The HB11 Energy website is here: https://hb11.energy

HB11 Energy is developing a laser-driven hydrogen (proton) / boron-11 fusion machine that implements the following aneutronic p-B11 fusion reaction:

$$^{1}p + {}^{11}B \rightarrow 3\ {}^{4}He + 8.7\ MeV$$

Energy generated by fusion is carried off by three positively charged alpha particles, which creates an opportunity for direct conversion into electricity, with an efficiency of about 80%. Alternatively, fusion energy can be to converted to thermal energy for use in a conventional steam cycle power conversion system to produce electricity with a thermal cycle efficiency of 35 – 40%.

Relative to D-T fusion commonly employed in tokamaks like ITER, p-B11 fusion offers the following advantages:

- Does not generate neutrons, thereby reducing material and safety issues (i.e., neutron radiation streaming, material activation and radiation damage).
- Does not need or generate tritium for its fuel cycle, thereby eliminating the need for tritium breeding and tritium control systems.
- Fuel components (boron-11 and hydrogen) are commonplace, low-cost resources.

However, the p-B11 fusion reaction requires plasma temperatures more than ten times those of a D-T fusion reaction and the energy yield per fission is much lower for each p-B11 fusion than it is for D-T fusion. ITER will operate with D-T plasma temperatures of over 100 million °C. HB11 Energy's ultimate goal for p-B11 fusion is to reach plasma temperatures exceeding 3 billion °C.

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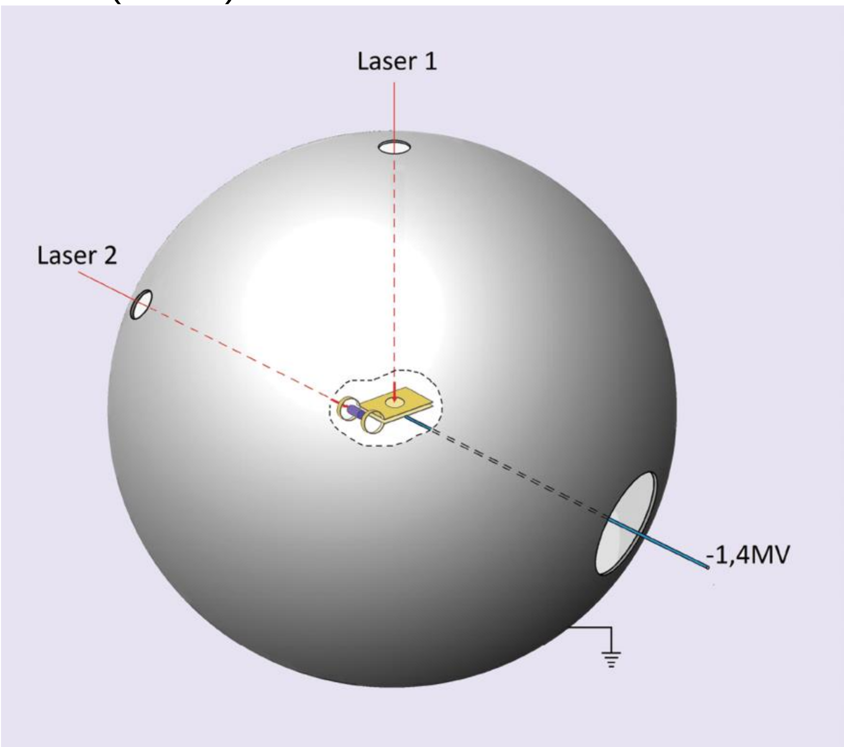
HB11's fusion reactor design was enabled by the development of the ultra-short (picosecond) pulsed CPA (Chirped Pulse Amplification) laser for which Arthur Ashkin, Donna Strickland, and Gérard Mourou were awarded the 2018 Nobel Prize in physics. With this type of laser, very high amounts of energy can be deposited on a target in an extraordinarily short period of time.

In 2010, a team led by Dr. Heinrich Hora described the use of picosecond (ps) laser pulses with power above a terawatt (TW) to ignite fusion by means of a hydrodynamic (non-thermal) process known as "plasma block ignition." In the 2010 paper, Hora's focus was on ignition of uncompressed solid state deuterium and tritium "for very high gain uncomplicated operation in power stations."

Hora developed the conceptual p-B11 fusion reactor design described in patent US10410752B2, "Method for Generating Electrical Energy by Laser-Based Nuclear Fusion and Laser Reactor," which was granted in 2018. You can read it here: https://patents.google.com/patent/US10410752B2/en

The general arrangement of the reactor system is shown in the following diagram. The reactor sphere has a radius of at least 1 meter (3.28 ft). The CPA lasers are outside of the sphere. A "Reaction Unit" holding the fuel target is located in the center of the reactor sphere and is electrically charged to -1.4 million volts relative to the wall of the sphere.

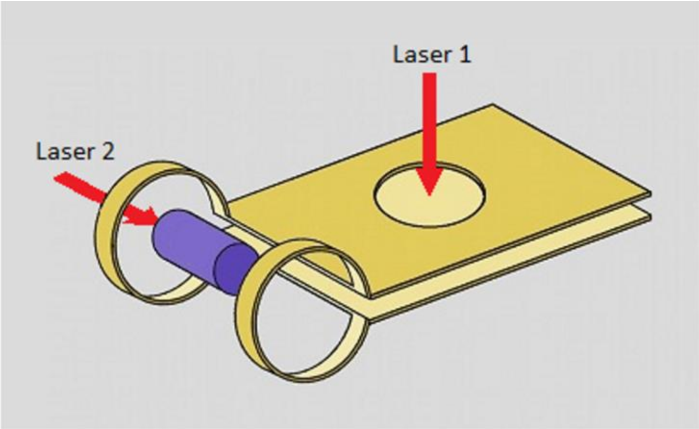


Source: Hora, et al. (2016)

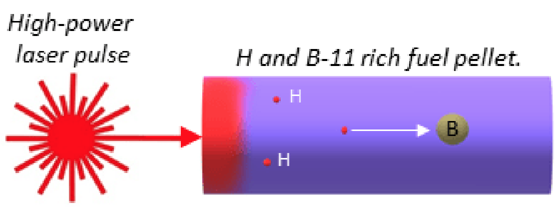
The cylindrical target (purple cylinder in the following diagram) with the HB11 fuel is co-axially located in a coil in a Reaction Unit held in the center of the reactor. Hora (2016) describes the ignition process:

> "Generation of a 10 kiloTesla magnetic field of about 2 ns duration in the coils by firing a >kilojoule nanosecond laser pulse 1 into the hole between the plates. The HB11 fusion fuel is a solid cylinder of 1 cm length and 1 mm radius coaxially located in the coils. The block-ignition of the fusion flame is produced by a ps-30 kJ laser pulse of 0.2 mm diameter for block ignition from laser 2."…." With avalanche reaction, the (fuel) cylinder…..is nearly completely reacting producing more than one gigajoule energy of alpha particles by the irradiated 30 kJ laser pulse 2."

With proper timing of the pulses from Lasers 1 and 2, the magnetic field created by Laser 1 traps the plasma created by Laser 2 within the cylindrical target, giving the accelerated hydrogen ions the highest probability of interacting with and fusing to a boron-11 atom.



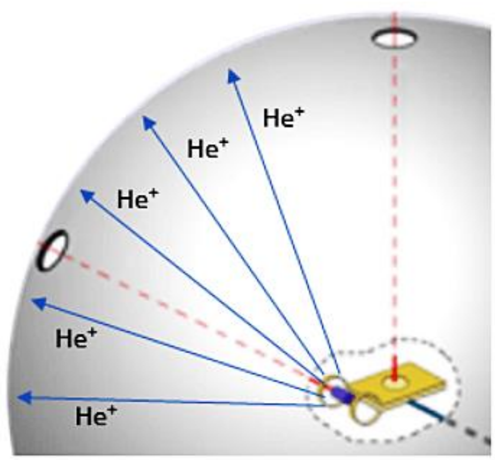
Details of the Reaction Unit. Source: Hora, et al. (2017)



Picosecond-30 kJ laser pulse accelerates hydrogen ions into boron-11 rich fuel, igniting p-B11 fusion. Source: HB11 Energy

HB11 Energy describes their process for direct energy conversion as follows:

> "The reactor is intended to achieve the direct conversion of nuclear energy into electricity without its conversion into heat. This is possible only if plasma discharge losses between the unit equipped with Faraday screening and the reactor wall (sphere) can be sufficiently reduced, eliminating any significant heating of the wall material. To achieve this, the reactor sphere will be charged at a potential of less than but close to 1.4 megavolts allowing it to slow the charged alpha particles before they contact the sphere. The alpha-particles will be neutralized on contact with the sphere allowing their charge to be captured as the source of electricity."



Alpha particles produced from p-B11 fusion are collected at the wall of the reactor sphere. Source: HB11 Energy

HB11 Energy estimates that igniting a 14-milligram hydrogen-boron target will produce about 0.3 MWh (about 1 Gigajoule) of energy. In comparison, a 42 US gallons barrel of oil yields about 1.7 MWh of energy

The shock produced by the fusion reaction corresponds to that of a 50 g chemical explosive. The small Reaction Unit is a single-use item, as it will be destroyed with each fusion reaction.

In an HB11 commercial fusion power plant, fusion pulses would be executed at one-second intervals. At that rate, a pulsed HB11 fusion reactor with direct energy conversion would have a generating capacity comparable to a 864 MWe conventional or nuclear power plant operating continuously.

In 2020, Warren McKenzie, Managing Director of HB11 Energy, reported that their approach to fusion power could be ready for operation by 2050. After recently securing international patents for their key technologies, HB11 is seeking investors to fund their next stage of development, which is to design, manufacture and test a proof-of-concept fusion reactor that can experimentally validate their claims for p-B11 fusion and direct energy conversion.

Funding

HB11 Energy's funding information is not available.

For more information

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- Jack Hare, "New calculations show proton-boron fusion is still difficult," Fusion and Things, 5 June 2019: http://fusionandthings.eu/2019/06/05/new-calculations-show-proton-boron-fusion-is-still-difficult/
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- Scarlett Evans, "HB11: the Australian start-up pursuing a new form of fusion," Power Technology, 14 May 2020: https://www.power-technology.com/features/hb11-the-australian-start-up-pursuing-a-new-form-of-fusion/

Patents

- Patent US10410752B2, "Method for Generating Electrical Energy by Laser-Based Nuclear Fusion and Laser Reactor," filed 5 December 2014, granted 10 September 2019, inventor Heinrich Hora, assigned to Ujk Management GmbH: https://patents.google.com/patent/US10410752B2/en