The Fork in the Road to Electric Power From Fusion

First Light Fusion, Ltd.

Peter Lobner, 1 February 2021

First Light Fusion was formed in 2011 by Nicholas Hawker and Yiannis Ventikos as a commercial spinoff from Oxford University. In 2015, the firm established its own office in nearby Yarnton, Oxfordshire, UK. The firm mission statement is to “solve the problem of fusion power with the simplest machine possible.” This led the firm to develop pulsed “projectile fusion,” which is a form of inertial confinement fusion, for use in a near-term, low cost fusion power plant. The firm’s goals are to demonstrate "gain" (getting more energy out than went in, Q > 1.0) by about 2024, and build a first-of-a-kind electric power plant in the 2030s. More information is on the firm’s website here: https://firstlightfusion.com

Projectile fusion is a pulsed process in which an electromagnetic launcher, like a rail gun, accelerates a small copper projectile to hypersonic speed and impacts that projectile into a tiny, proprietary target containing deuterium and tritium (D-T) fuel. The impact shockwave rapidly heats the target to the conditions needed for fusion. A shockwave velocity of about 50 km/sec (112,000 mph) inside the target is necessary to achieve fusion. The magnetic field in the heart of the machine reaches about 1,000 Tesla during a shot. With D-T fusion, each target will release as much energy as a barrel of oil (42 US gallons of oil yields about 1.7 MWh of energy) by the following reaction.

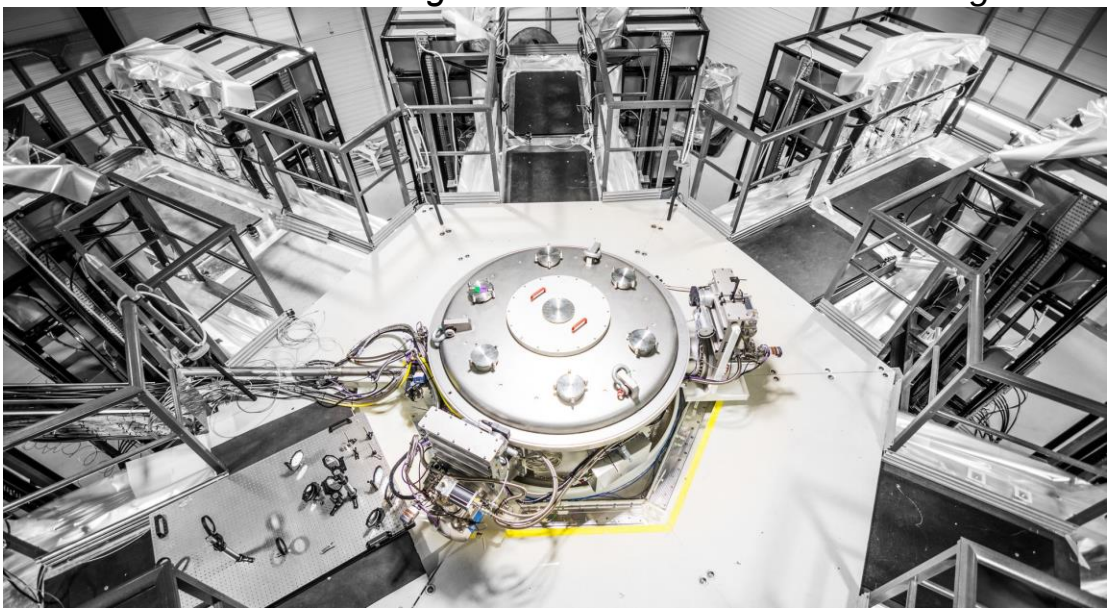
$$D + T \rightarrow He + n + 17.59\ MeV$$

About 80% of the energy generated from D-T fusion is in the form of energetic neutrons, which are absorbed in a liquid lithium blanket inside the vacuum vessel, which serves as a neutron shield to protect the steel vessel and as the primary coolant to remove heat from the fusion reactor.

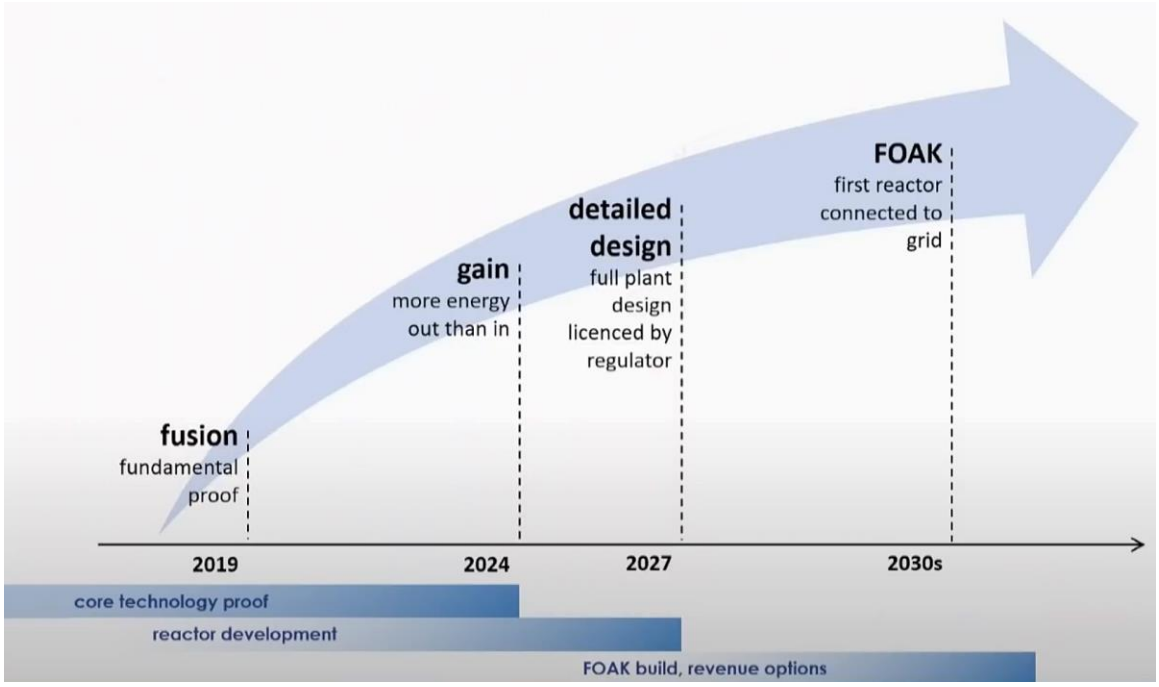
Since February 2019, First Light has been running their £3.6 million ($4.7 million) Machine 3 (M3), which they describe as the biggest pulsed power machine in the world dedicated to researching fusion energy. Machine 3 is capable of discharging up to 200,000 volts and

more than 14 million amperes of current within two microseconds; the equivalent of nearly 500 simultaneous lightning strikes. Machine 3 is designed to achieve a projectile velocity of about 20 km/s (48,000 mph) and their target is designed to form an impact shockwave that propagates at the higher velocities needed for fusion. The target design is the key to achieving fusion conditions.

Two views of First Light's Machine 3. Source: First Light



First Light expected to demonstrate D-T fusion reactions with M3 in 2019 and then 2020. As of January 2021, that demonstration has not yet occurred.



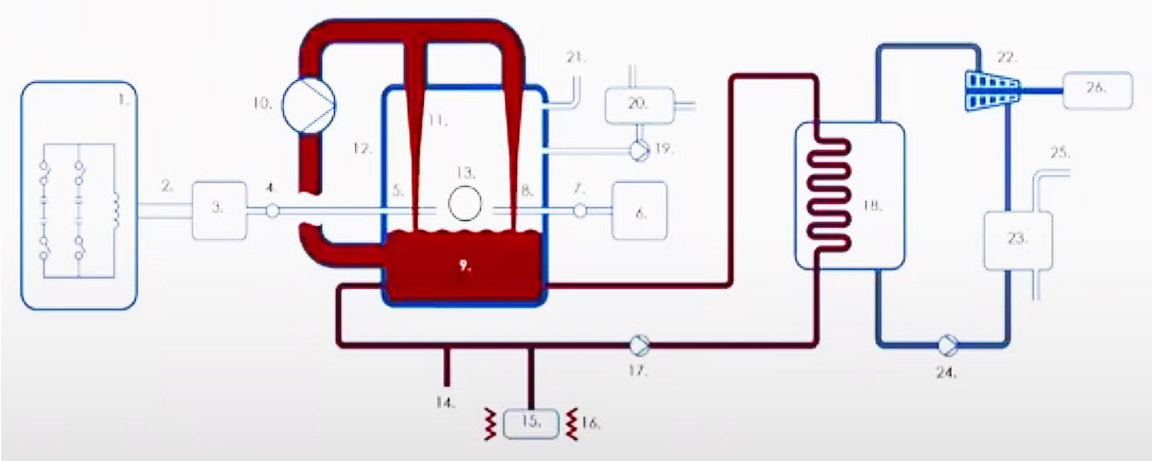
Source: Adapted from screenshot from 2019 First Light video

Beyond Machine 3, First Light plans to build another, larger machine before committing to the full power plant design.

First Light is working with the engineering firm Mott MacDonald on a design concept for a small commercial power reactor operating at one shot per minute and generating 150 MWe. The shot rate was reduced from one shot every five seconds after recent analysis predicted a higher fusion energy yield for each shot. A conventional steam cycle secondary plant will be used to generate electric power. This plant will be designed for baseload operations.

The “primary” system resembles a pool-type reactor with a large pool of liquid lithium (9) inside the vacuum vessel (12). The liquid lithium serves as both the primary coolant and the neutron shield for the vacuum vessel. The hot liquid lithium is pumped (17) through a closed loop fluid system to a heat exchanger (18) where heat is transferred to a conventional steam and power conversion system and then returned to the vacuum vessel. Steam produced on the

secondary side of the heat exchanger (18) drives a steam turbine generator (22, 26) to produce electric power. Turbine exhaust steam is condensed (23) in the closed-loop secondary system and the water is pumped (24) back to the heat exchanger. You can see this flow path in the following diagram.



First Light fusion power plant heat transfer & power conversion systems. Source: Screenshot from 2019 First Light video

A cylindrical liquid lithium neutron shield is created by pumping (10) liquid lithium from the pool (9) to a flow distribution header above the reaction chamber (13). The liquid lithium flows back to the pool as a cylindrical “waterfall” (11) surrounding the reaction chamber and protecting the vacuum vessel from neutron radiation damage.

First Light’s goals are to start detailed design in 2027 and have a fusion plant delivering power to the grid by the early 2030s. First Light CEO Nicholas Hawker estimated that, “Designs with LCOE (levelized cost of electricity) as low as $25/MWh are found with optimistic but not obviously unrealistic inputs.” This is less than the LCOE from fission power plants and wind turbine generators.

First Light’s business model includes selling fuel targets to the power plant operators for the life of the power plant, similar to the way many fission reactor vendors continue to sell the fuel needed for their reactors.

Rendering of a coastal site for a First Light fusion power plant. Source: First Light.

Funding

First Light Fusion has been funded largely from institutional and private investors.

- July 2011: $1.2 million from IP Group plc and ParkWalk Investors.
- August 2015: $29.8 million from IP Group plc, Invesco Asset Management Ltd., and Sandaire Investment Office.
- December 2020: $25 million from existing and new investors, including Oxford Sciences Innovation (OSI), IP Group plc, Invesco, University of Oxford Endowment, Technikos and Hostplus.

For more information

- “First Light Fusion's Machine 3 Fully Operational,” CISION PR Newswire, 12 February 2019: https://www.prnewswire.com/news-releases/first-light-fusions-machine-3-fully-operational-300793982.html
- Mike Brown, “Inside First Light Fusion’s Fight to Solve Clean Energy and Save the Planet,” Inverse, 7 November 2019: https://www.inverse.com/innovation/60746-inside-first-light-fusion-s-fight-to-solve-clean-energy-and-save-the-planet
- Clive Cookson, “Two British companies confident of nuclear fusion breakthrough,” Financial Times, 27 December 2019: https://www.ft.com/content/a8d0a7e4-20e3-11ea-b8a1-584213ee7b2b
- Nicholas Hawker, “A simplified economic model for inertial fusion,” Philosophical Transactions of the Royal Society, 12 October 2020: https://royalsocietypublishing.org/doi/10.1098/rsta.2020.0053
- “First Light Fusion raises $25 million,” CISION PR Newswire, 23 December 2020: https://www.prnewswire.com/news-releases/first-light-fusion-raises-25-million-301198006.html

Videos

- Video, “ECO19 Berlin: Nicholas Hawker First Light Fusion,” ecosummitTV, 21 May 2019: https://www.youtube.com/watch?v=suAelXzEYjs
- Video, “First Light Fusion: The Future of Electricity Generation and a Clean Base Load?” Fully Charged, 17 September 2019: https://www.youtube.com/watch?v=M1RsHQCMRTw

Patents

- WO2011/138622A1, “Localized energy concentration,” inventors N. Hawker & Y. Ventikos, assigned to ISIS Innovations Ltd.: https://patents.google.com/patent/WO2011138622A1/en?oq=Nicholas+Hawker

- US9620247B2, “Energy focusing,” inventors N. Hawker & Y. Ventikos, assigned to Oxford University Innovation Ltd.: https://patents.google.com/patent/US9620247?oq=Nicholas+Hawker
- US9704603B2, “High velocity droplet impacts,” inventors N. Hawker & Y. Ventikos, assigned to Oxford University Innovation Ltd.: https://patents.google.com/patent/US9704603?oq=Nicholas+Hawker