NIF a successful failure

The National Ignition Facility (NIF)

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NIF - part of Lawrence Livermore National Laboratory

Output: 16 horsepower hours (per day)

The NIF is a marvel, the 'crown jewel' in laser technology

It is the most amazing achievement in optical technology ever imagined, a dream having become reality. It was designed to prove that laser-ignition of deuterium-tritium nuclear-fusion is possible, and that the fusion produces power. This proof has been achieved, and it proves, with the designed capacity of the facility realized, that laser-ignition fusion on the inertial confinement principle is not a practical option for power generation.

The current ignition capsule (hohlraum) design is rated at 13MJ of produced fusion power. It will likely be increased to 20 MJ with advanced designs. For the facility itself the baseline design allows for a maximum output of about 45 MJ of fusion energy release, due to the design limits of the target chamber. If the maximum limit was achieved, the result would nevertheless amount to a nearly 7-fold net energy loss.

A hohlraum design rated at 45 MJ (which is only theoretically possible, and would produce the maximum yield that the target chamber is designed for), would still produce only 12.5 kw/hr of thermal output energy, the amount that an average home furnace produces in 42 minutes (generated with a 100 kw/hrs input). In automotive terms, 45 MJ adds up to 16 horsepower hours. That's not exactly a gigantic power production, while the facility that is required to produce the 16 horsepower/hr fusion output, is truly gigantic, as is the input power to produce the fusion. The input power is so great (though concentrated into milliseconds) that the facility needs to cool for 24 hours before a repeat-ignition is possible. For practical power production 10 ignitions per second would be required.

It is unlikely that the large inefficiency in the system can be overcome, especially if one considers that a 3-fold energy-gain is required just to achieve break-even as the neutron-to-thermal-to-electric conversion is typically only 30% efficient. This means that at 21-fold increase in energy gain needs to be achieved beyond the maximum capacity that the facility is designed for, just to break even, together with 86,000-fold increase in the repetition rate. And to top it all off, the facility produces an extremely low power-flux density. With the current hohlraum design, rated at 13 MJ, a total of 3,000 such firings would be required to meet the monthly energy need of a single-family home (typically 13 GJ - 13,000 MJ), with the conversion inefficiently of 33% from neutron-to-thermal-to-electric-energy, included.

Thus, the path to a practical fusion-energy future is paved with a lot of science fiction dreams, in spite of the truly remarkable success that has been wrought to date. What the success proves more than anything else, is that a practical fusion-energy future lays evidently far beyond what can be realized, especially if one considers that the construction materials do not exist today that can withstand the produced high energy neutron flux and extreme temperatures for long periods, as would be required for an operating power plant.

Nevertheless, what has been achieved is truly a technological marvel, worth celebrating as an outstanding example of human ingenuity.

Inertial confinement fusion at the National Ignition Facility

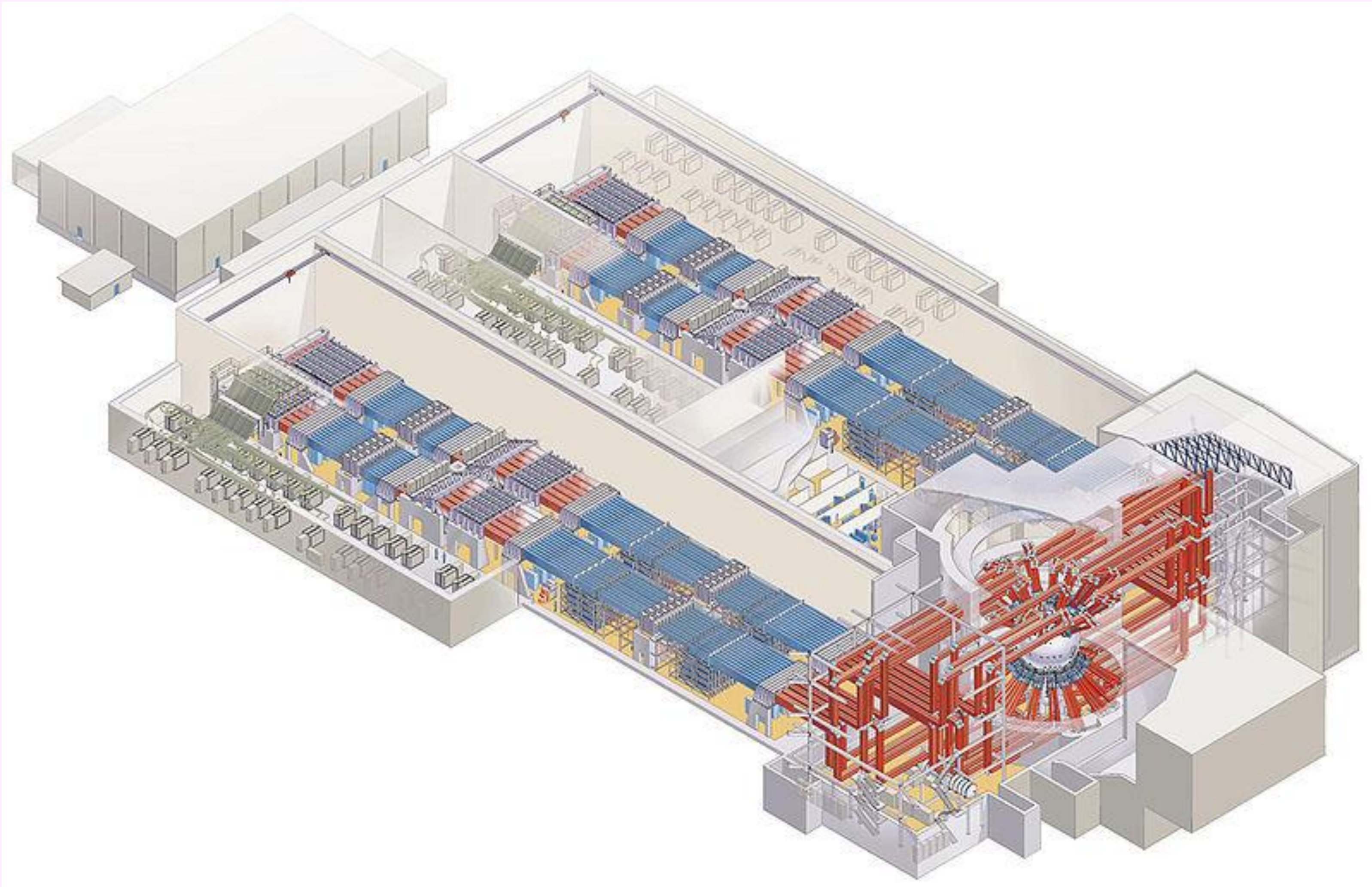
the 'crown jewel' of laser ignition

Instead of the fusion fuel being heated in a magnetically confined plasma, the alternate method for fusion ignition, at NIF laser-light is used to create a heat-shockwave that compresses a fuel capsule to an extremely high density whereby is atoms are beginning to fuse.

As with any other fusion experiment, here too, immense problems are standing in the way that are uniquely inherent in laser-powered fusion-ignition systems (inertial confinement). Nevertheless 'some' progress has been made on the road of demonstrating that fusion ignition is possible by simply compressing the fuel on the 'anvil' of immense power being applied to the fuel itself. The first laser-confined fusion ignition has been achieved, but this doesn't mean that a practical power plant is on the horizon, or will actually become possible.

To give you a sense of what "immense" power means, let me illustrate the process that is used. The process starts with the highest-power light source in existence, the xenon flash bulb where light-energy is created by electric arc confined in a gas plasma. A single one of these is so bright by itself that it could be seen from the moon. NIF employs some 8,000 of them, which together require nearly 400 MJ of electrical energy. Their light output is used to pump up 192 laser lines. The flash lamps that used for this purpose are the largest of this type ever produced. (Photo by the U.S. Department of Energy)

The flashbulbs are used in groups powered by capacitor banks in the rooms beside the laser bays. Their light is fed into large lasers lines where the light intensity is combined and amplified. The 192 lasers beams are then combined into groups of four, to form 48 beam lines (blue, below). In the beam lines the beams are focused and filtered and then sent on to the switch yard (red) where they are timed and guided to arrive all of them together from different directions, at the 30 foot wide target chamber - a sphere weighing 130 tons - where, before entering the chamber, each beam is focused by a high-precision final optics system.

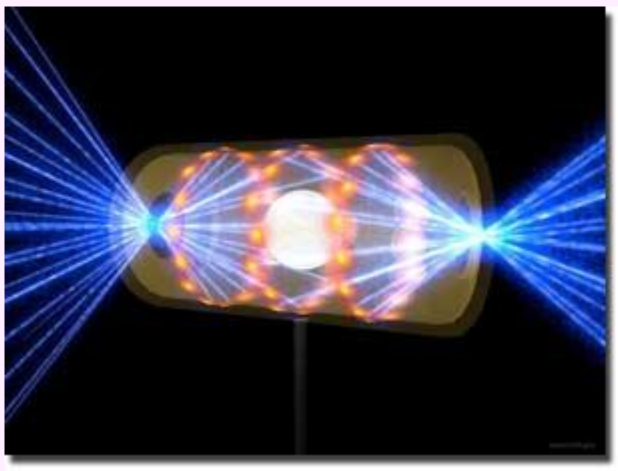


The NIF is a giant facility (which can been seen by scale of the people shown in it). It is three times larger than a football field. It is the most complex optical facility ever created. It is designed to produce altogether a 500 trillion-watt flash of light, precisely focused onto a target smaller than a pea, with the light arriving from 48 directions simultaneously, timed to within picoseconds.

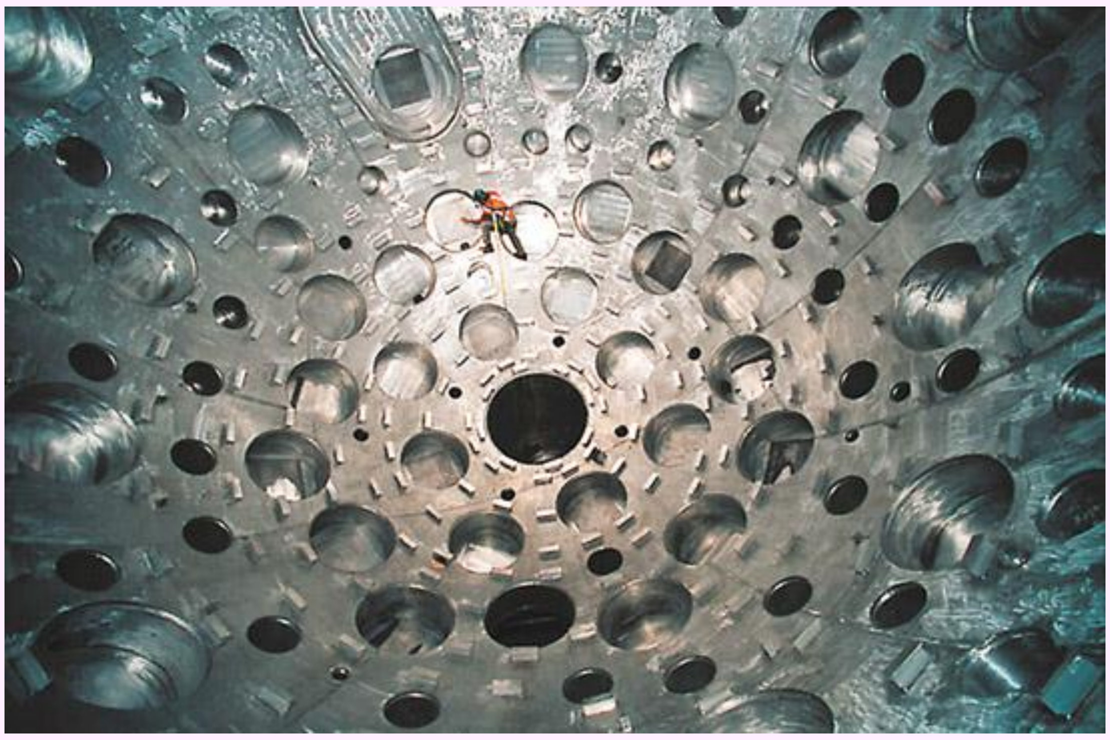
The fuel target is made up of a thin 2 mm wide shell of beryllium with a layer of solid deuterium-tritium deposited on its inner wall. The deposited fuel, weighing 0.238 mg, is frozen to minus 255 degrees Celsius,. The above photo (a mockup) indicates the size of the target capsule.

The target capsule itself is located inside a 10mm long gold-plated tube (hohlraum) the size of the tip of a finger. (See: http://fire.pppl.gov/fpa07_lindl_icf.pdf)

The 48 beams are focused to enter the hohlraum through a 2 mm hole on either end.



In the hohlraum the light is converted to x-rays that are able to couple with the exterior of the fuel capsule. The thereby absorbed energy is creating a shockwave that compresses the fuel to roughly 75 times the density of lead. It thereby causes a fusion explosion with an energy release up to 11 Kg of TNT (dynamite) exploding (one thousands of the energy of the Hiroshima bomb, but concentrated to occur within an extremely short timeframe). The resulting explosion takes place inside a 30 foot wide target chamber. - See the image below. Note the construction worker.



http://en.wikipedia.org/wiki/File:NIF_target_chamber.jpg

When the ignition is achieved (late in 2010), the 365 megajoules (MJ) of electrical energy that powers the over 8,000 flash bulbs by way of 216 giant capacitor banks, and whatever additional energy is required to amplify the laser light, is expected to produce about 13 to 20 MJ of fusion energy - effectively a 15-fold energy loss.
(for more, see: http://en.wikipedia.org/wiki/National_Ignition_Facility).

Improvements in both the laser system and the hohlraum design are expected to be possible that would improve the compression shockwave. An increase in fusion energy produced to 100 MJ is theoretically possible, but only as a theory. The current hohlraum design is rated at 13MJ. The NIF, the baseline design can handle about 45 MJ of fusion energy release, that is limited by the design limits of the target chamber. If the maximum limit was achieved, the result would nevertheless amount to a nearly 7-fold net energy loss.

see: http://www.slac.stanford.edu/econf/C011127/TUAI001.pdf
also: View Document of DOE amd OSTI
http://www.osti.gov/bridge/purl.cover.jsp;jsessionid=FB2EABB214F9DBA08760EAF2B833BF80?purl=/435064-dnjREm/webviewable/ -
DOE -US. Department of Energy Information Bridge: DOE Scientific and Technical Information // OSTI - Office of Scientific and Technical Informationhttps://lasers.llnl.gov/about/nif/
see: https://lasers.llnl.gov/about/nif/

and: Optimization of the holeraum - Energy and Work Converter

As stated earlier, it is unlikely that the large inefficiency in the system can be overcome, especially if one considers that a 3-fold gain is required just to achieve break-even (considering that the neutron-to-thermal-to-electric conversion is typically only 30% efficient). This means that at 21-fold increase in energy gain needs to be achieved to get to the break-even stage. This puts us far beyond what the facility is designed for.

Also the facility produces an extremely low power-flux density, considering that with the current hohlraum design, rated at 13 MJ, 3,000 ignitions would be required to meet the monthly energy need of a single-family home (typically 13 GJ - 13,000 MJ). At its maximum capacity, in automotive terms, the facility would produce a fusion energy output of 16 horsepower hours per day, since only one firing a day is possible. NIF expects to improve the cooling efficiency of the system for a possible 700 ignitions per year for a maximum outpu of 30 horsepower-hours per day, but this too, can hardly be counted as a gigantic power production, considering the enormous size of the facility.

While mankind is evidently miles away from constructing a viable fusion-power plant on the platform of the laser-confinement type, if it is indeed possible to do so, the main mission for the NIF is presently not the fusion-power project, but is to assure the viability of America's nuclear weapons stockpile. Fusion-power research appears to be a sideline project.

The inefficiency in the system was known before the first stone was laid for the facility. It was known that the maximum fusion power obtained, would not exceed 1/7th of the power needed to ignite the fusion. This is the parameter that the facility was designed for. However, the facility is an ideal tool for testing different fusion-fuel combinations and methods for laser ignition. The deuterium-tritium fuel, that is currently used, is made up of atoms that presents the least resistance to fusion, but as stated earlier, its output comes with a lot of problems attached. Theoretically a number of different fusion-fuel combinations are possible, that would not produce their fusion-energy in the form of highly destructive neutron bursts. They would produce atoms, protons, or ions, with a high kinetic energy instead that might be directly converted into electricity. These alternate fuels are called aneutronic fusion fuels. It has been proposed that such alternate fusion fuels "can be composed of light atomic nuclei like hydrogen, deuterium, tritium, helium, lithium, beryllium, boron, and their various isotopes. Some isotopes like hydrogen-1, helium-3, lithium-6, lithium-7 and boron-11 are of interest for aneutronic nuclear fusion (low neutron radiation hazards), for example:

$^{1}H + 2\ ^{6}Li \rightarrow\ ^{4}He + (^{3}He + ^{6}Li) \rightarrow 3\ ^{4}He + ^{1}H + 20.9$ MeV (153 TJ/kg ≈ 42 GWh/kg)
$^{1}H +\ ^{7}Li \rightarrow 2\ ^{4}He$ + 17.2 MeV (204 TJ/kg ≈ 56 GWh/kg)
$^{3}He +\ ^{3}He \rightarrow\ ^{4}He + 2\ ^{1}H$ + 12.9 MeV (205 TJ/kg ≈ 57 GWh/kg)
$^{1}H +\ ^{11}B \rightarrow 3\ ^{4}He$ + 8.7 MeV (66 TJ/kg ≈ 18 GWh/kg)

"Boron and helium-3 are special aneutronic fuels, because their primary reaction produces less than 0.1% of the total energy as fast neutrons, meaning that a minimum of radiation shielding is required, and the kinetic energy from fusion products is directly convertible into electricity with a high efficiency, more than 95%... Boron is available in the Earth's crust and helium-3 is available in the lunar regolith, both are relatively plentiful if compared to tritium."
(see: http://www.crossfirefusor.com/nuclear-fusion-reactor/overview.html)

Since the alternate fusion fuels require vastly greater energy as input The National Ignition Facility (NIF) might become upgraded in the years ahead to become sufficiently powerful to test some of the theoretically possible alternatives, although helium-3 fusion might not be achievable by the laser confinement method as the power that is required to overcome the larger coulomb barrier of helium 3 might not be attainable with laser ignition.

Do we have any hope left, for nuclear fusion power to ever become possible?

This is extremely unlikely. The problem here is not located in the inefficiency of the fusion system itself, but in the inefficiency of the driving system. The present world record for any type of produced fusion power still clocks in at only 10% of the power required to achieve the fusion. In most of the publicized cases the fusion gain is highly overrated, which is easily done by 'dishonest' accounting, omitting inconvenient factors.

- The fusion gain rating depends on what is measured

In rating the fusion energy gain, it all depends on what inputs one measures, and what is being ignored.

For example, the NIF facility can be said to achieve a more than 5-fold fusion power gain if one considers only the 4 MJ of light energy as input that comes out of the laser lines, which one then compares with the resulting 20 MJ fusion power output.

The problem with this kind of measurement is, that it ignores the fact that it takes 350 MJ of electrical energy to produce those 4 MJ of light energy in the beam lines.

But the fusion gain measurement can be further obscured, because the 4 MJ in laser light energy is converted to 1.8 MJ of UV light before it enters the target chamber, and is converted once more to a mere 900 KJ of x-ray energy in the hohlraum. So, what does one measure then?

The conversion to x-rays is needed, because nothing but x-rays can cause the high energy absorption (coupling) to happen that is needed for fusion to occur, which is the actual input to the fusion ignition. For this reason the fuel capsule has been constructed as a hollow shell to give it as large a surface area as possible in order to absorb the x-rays. For this reason, too, the fusion-fuel capsule is made of a material that readily absorbs x-ray energy. Once this absorption has occurred, in the end, only 140 KJ of energy is physically transferred to the fuel itself in the form of a heat-driven compression shockwave. Does one count this as the emery input? It is after all, this last bit of energy, those 140 KJ of energy, that gets coupled into the fuel, which then ignites the 20 MJ fusion burn. All the rest of the input is lost on the way. So, what does one measure if one talks about fusion energy gain?

For example, if the fusion energy is measured against the 4 MJ of light produced in beam lines, one can talk about a 5-fold energy gain.

If the fusion energy is measured against the 1.8 MJ of (UV) light energy that is sent to the target chamber, then one can speak about an 11-fold fusion-energy gain. This appears to be the typical standard for measuring fusion efficiency.

If however, one measures the fusion output against the 900 KJ of x-ray energy that is produced inside the hohlraum, then one can talk about a 22-fold energy gain.

Finally, if one measures the fusion output only against 140 KJ energy of the compression shockwave that acts on the fuel itself, then one can talk about a 142-fold energy gain.

On the other other hand, if one is honest and considers the entire process that takes 350 MJ of electric energy as input to power the process, then one faces a 15-fold energy loss.

This huge difference between the 142-fold fusion-energy gain and the 15-fold over-all loss, reflects the effective physical inefficiency of the entire operating system, that in a practical application, would have to be considered when judging the factors involved in an operational fusion power plant.

At present it takes enormous floods of energy to overcome the numerous natural barriers that the Universe has set up against nuclear fusion to happen. And this huge energy barrier is encountered already with the most-readily fusing fuel that exists, which is the D-T fuel, a 'dirty' fuel. The NIF research has proven beyond the shadow of a doubt that the wall of barriers that the Universe has created against fusion power is immensely formidable.

The "fast-ignition" HiPER fusion

Some attempts are being proposed in the UK, to overcome some of the inherent inefficiency problems experienced at NIF. For this a new experimental project has been designed, called HiPER - the proposed European High Power laser Energy Research facility. This proposed project is just as large in size as the NIF facility but aims to address some of the problems that stand in the way of a practical commercial fusion-power facility, and this on the platform of laser ignited fusion. While the goal appears noble, it displays the same quality of science-fiction unreality that is evident at the CERN project and may well be intended to consume talents and resources for an effort that is a dead-end effort from the start.

Let's explore the challenges and to potential for meeting them, which are all exciting, but appear fundamentally unattainable, especially the critical challenges.

- the OMEGA - type fusion

In order to overcome the inefficiency inherent in the design of the NIF, the HiPER project aims to use less powerful lasers, but in a two-stage ignition process, called the "fast ignition" process. In this process the first stage towards ignition will surface-heat a fuel pellet directly, causing not a shockwave but merely a 'moderate' thermal compression. Then a second and more powerful beam -- operating at a vastly larger energy density, but for a much shorter duration, typically 0.5 to 10 pico seconds, called the "peta watt" laser --, would penetrate the compressing plasma and in doing so create a plasma within the fuel that is expected to release a shower of electrons that in turn would start the fusion process. The penetration of the compression plasma can be accomplished by placing a gold cone funnel on one side of the fusion pellet for the penetration by the peta laser. A second method that is also considered for fast-ignition fusion is to simply overpower the compression plasma and cause a spot-burn at the surface to start the ignition process. The principle has been demonstrated at the OMEGA facility at The Laboratory for Laser Energetics (LLE) of the University of Rochester. The experiment has produced a 0.01 fusion gain by this methode (a world record).

The process is deemed to be 15 times more efficient (though not enough). But will it work at all on a larger scale? It may be just another dream. A potentially practical process has not been demonstrated, and cannot be demonstrated for another 15 years or more, until the HiPER facility has been completed.
(See: http://en.wikipedia.org/wiki/HiPER)

The efficiency of the light source is also expected to be increased by HiPER. Since recent advances in light emitting diode systems (LED) now achieve the most efficient conversion of electricity to light for which a 15-fold efficiency gain is expected for the light source.

At NIF, the big inefficiency is in the light production that employs 8000 giant xenon flash lamps. Considering that 350 MJ of electrical energy is needed at NIF to produce the 1.8 MJ of UV light energy that is transmitted into the target chamber, the efficiency of the system reaches barely above the 1% mark. HiPER intents to achieve a 10% to 15% efficiency. Whether this can actually be achieved remains to be seen. The dream may yet come true.

With the two factors of increased efficiency combined, a more than 200-fold increase in power-gain is expected. The actual fusion energy produced, per ignition, is expected to be the same as for NIF, ranging at about 20 MJ per burn. This all means that NIF's 17-fold net power-loss can be turned into an overall 12 to 15 fold power gain.

However, for this gain to be realized in a practical power plant, a rapid fire process must now be developed. In a 1 GW power plant the ignition process would have to be repeated 6 to 10 times per second. For this to be possible, a diode-laser system is now being developed that produces less heat and might enable a fusion repetition rate of 10 times per second, provided that the dream comes true. And that's a big if, considering the power level that is needed on a sustained basis.

At the fifth International Conference on Inertial Fusion Sciences and Applications (IFSA2007) an international demonstration plant was proposed: The International Laboratory Inertial Fusion Test facility (i-LIFT) operating at 100-kJ with 1-Hz implosion rate and another 100-kJ laser system, operating at 1-Hz for the ignition heating, which together would generate 10-MW of thermal power at an energy gain of 50. Of the thermal output, 40% of the energy would be converted to electricity by a power generator. A half of the electricity, 2 MW, would be used to drive the laser with 10% efficiency, and another half (2 MW) would be transferred to the grid. It is expected that the power and stability of such an experimental reactor would be comparable to those of a typical wind power machine. Nevertheless, the net electrical power production would be a landmark achievement in fusion energy development. If enough funding is given for it, power generation could be expected with this type of demonstration plant by 2030.
See: http://www.iop.org/EJ/article/1742-6596/112/1/012002/jpconf8_112_012002.pdf)

Of course, the biggest and most 'impossible' exotic problem for this principle is that the fusion pellet injection into the target chamber has to be absolutely precise, so that the tiny fusion target of two tenth of a milligram in weight, after possibly a 15-foot injection trajectory, becomes positioned at the exact center of the laser system's focal point and with the extreme accuracy that is required for radial compression, and all this at precisely the time when the lasers are fired. This super-precise kinetic positioning also needs to be achieved in rapid succession up to ten times a second, and all this in an extremely volatile high-energy environment of a fusion flux chamber that is powered by continuous nuclear explosions.

This all adds up to a daunting engineering task that makes fairy tales seem rational, but which may never be achieved in the real world. At NIF and other experiments the fusion target is always statically positioned and aligned with extreme precision. This type of precision has never been achieved in flight with a tiny mass of a fraction of a milligram and in a volatile environment. This inherent demand that is fundamental to the entire process puts the project into the realm of miracles and evidently far out of reach for practical power generation.

Furthermore, it is uncertain whether a target chamber can be built that is capable of extracting multi-megawatts ow power on a continuous basis and carry that heat out of the target chamber for power production, while at the same time protecting the facility from the 100-fold stronger neutron flux of the D-T fusion reactions. And the final challenge is to place sufficient quantities of lithium close enough to the neutron stream to enable the production of tritium from the neutron flux, with which to produce more fuel for the reactor.

The most optimistic estimate that has been tabled recently is that a 100 - 200 MW demonstration plant might be possible by 2035 with the development of a new generation of high gain target designs.
(see: http://j-parc.jp/Transmutation/ws/pdfen/3-3_Mima.pdf)

Since the HiPER fusion project, and other similar projects, have so many basic characteristics in common with the Large Hadron Collider of CERN, one one wonders if this direction of high-energy research has been intentionally initiated as just another dead-end effort along the Wellsian/Fabian road of keeping science tied into knots and thereby ineffective for the common benefit of mankind. This possibility needs to be considered, especially in the light of the high cost and complexity of producing the D-T fuel for the rector, and the cost-efficiency of the total system in comparison with the readily available thorium fission power systems that produce the same energy output per ton of fuel in radically smaller, simpler, less expensive, and already designed reactors, and for which a couple of million tons of fuel are easily accessible with vastly more available, while for the fusion system the fuels are extremely difficult to produce.

The final question: Would fusion power be worth the effort, considering the fuel cost, should the fusion process ever become possible?

Per ton, the current nuclear fusion fuel, a deuterium/tritium combination, contains 5 times the energy per kilogram than uranium 235 (481 TJ of energy per kilogram for D-T, versus 82 TJ of energy for uranium) This is not a huge difference. The small advantage that the fusion fuel offers is more than used up by the inherent inefficiency of the fusion power process in which the fusion 'explosion' blows the fuel apart before all of it is used up.

At NIF the fuel capsule typically contains 0.238 mg of fuel for an expected energy yield of 20 MJ, which will likely be achieved. This, however, adds up to only 17% of the energy contained in the fuel being produced. The rest of the fuel is lost as a result of the ignition process. At this rate of low efficiency the fusion fuel output is roughly equal to the fission fuel output in a thorium fueled nuclear-fission reactor. At today's best rate, a ton of either fuel is required of (D-T fuel for fusion, or thorium for fission) to power a 1 GW reactor for a year. The difference is, that of the thorium fission fuel, two million tons are readily available in known deposits, while the D-T fusion fuel does not exist at all in any useful quantities, and requires expensive and cumbersome processes for it to be produced.

The D-T fuel is made up of two parts. The deuterium (D) portion of the fuel is a 'heavy' isotope of hydrogen. It exists plentifully on the Earth. It is found in large quantities in seawater. However, it is highly diluted there. In the oceans, 'heavy hydrogen' (D) amounts to a mere 0.015 percent of the hydrogen of the water molecules. Deuterium is 'heavy' hydrogen, because it has a neutron attached to its nucleus. The presence of 'heavy' hydrogen produces 'heavy' water. At the best current technologies 340,000 tons of seawater are required for the extraction of a single ton of heavy water, from which the deuterium can be extracted. Since the hydrogen (deuterium) component of 'heavy' water makes up only 20% of the weight of heavy water, five tons of heavy water are required to produce a ton of deuterium. (In the D-T fusion fuel, 40% is deuterium). In other words, it takes the processing of 680,000 tons of water (and desalination if seawater is used) to produce the deuterium for a single ton of fusion fuel. The fuel production on this scale adds up to a rather expensive and energy intensive process, considering that 1 ton of D-T fuel is required to power a 1 GW reactor for one year.

Between 1979 and 1997 Canada had operated the world's largest heavy water plant, the Bruce Plant located at Douglas Point in Bruce County on Lake Huron, where it had access to the waters of the Great Lakes. The heavy water plant was a part of an integrated complex of 8 CANDU nuclear reactors that supplied the plant's process heat and electrical power. The giant heavy water plant had produced 700 tons of heavy water per year, (containing 140 tons of deuterium, enough for 350 tons of D-T fuel, or half the amount needed to power the USA for a year with nuclear fusion reactors). The Bruce heavy water plant was shut down in 1997 because of environmental concerns, since it utilized the Girdler process that involves large amounts of hydrogen sulfide. After the shutdown, the plant was gradually dismantled and the site cleared. Atomic Energy of Canada Limited (AECL) is currently researching other more efficient and environmentally benign processes for creating heavy water. The production of heavy water is nevertheless essential for the future of the CANDU reactors since heavy water represents about 20% of the capital cost of a CANDU reactor system. The case of Canada is mentioned here as an indicator of the high production cost of the D-T fusion-reactor fuel. It may well be less expensive to import the fusion fuel from the moon, should helium-3 fusion, and indeed nuclear fusion power in general, ever become commercially feasible.
(see: http://en.wikipedia.org/wiki/Heavy_water)

Heavy waters is currently used in CANDU reactors for its excellent efficiency in moderating the neutron propagation without absorbing the neutrons themselves. (See table)

The other component of the fusion fuel is tritium. It is extremely rare on Earth. It takes a million tons of seawater to extract a single ton of tritium from it. Tritium can also be produced in nuclear reactors by irradiating lithium with neutrons. This too, is a slow process. Since 1996 only a quarter ton of tritium has been produced worldwide. The production has been largely shut down under the nuclear weapons control treaty. Tritium (T) is an even 'heavier' isotope of hydrogen, which is also slightly radioactive and has a half-life of only 12 years. Tritium is currently the key-critical element in the D-T fusion fuel. It is difficult to produce since ts nucleus contains one proton and two (unnatural) attached neutrons. (Normally, hydrogen contains no neutrons.)

Thus, the D-T fuel is rather costly to produce. To help the production process of the tritium for the fuel, it is envisioned that commercial fusion reactors will be designed in a manner that some of their fusion-derived neutrons will strike lithium, which thereby breeds tritium, in order that the tritium can subsequently be extracted to produce more fuel. This adds another level of complexity to the fusion reactor design and operation.

Helium-3 is not the savior of fusion-power on Earth!

Since all atomic nuclei, regardless of their makeup, repel one another, because of the positive electric charge of their protons, it has been discovered that at high enough temperatures and pressures, they can be 'forced' together to such close distances that their electrical repulsion (called the Coulomb force) is overcome and the nuclei collide. At this point the strong nuclear force becomes the dominant force and binds the colliding nuclei to form a heavier atom. Now, with the tritium nucleus containing two (additional) neutrons, while having the same electric charge as the nucleus of ordinary hydrogen, the electrostatic repulsive force is more easily overcome, as the tritium offers a two-fold mass advantage. This happens, because the (additional) neutrons in the tritium nucleus, which do NOT add to the repulsive force, do however increase the ability to break through the coulomb barrier to access the attractive strong-nuclear force that initiates the fusion. As a result, the tritium atoms do more easily fuse with other light atoms, especially with deuterium that has also an extra neutron. This basic characteristic makes the D-T fusion fuel the most-readily-fusing fuel that is known to exist.

With helium-3 the situation is reversed. The helium-3 isotope has two protons and only one neutron. This means that the repulsive electric force that must be overpowered is twice as strong per mass as in the D-T fuel. This doubly-strong Coulomb force, which must be overcome for fusion to happen, requires a significantly greater energy input than is necessary with D-T fusion. It is unlikely that a magnetic confinement reactor (such as ITER), which is already stressed to the limit, can be up-scaled for the energy input that is needed for helium-3 fusion, and then produce power past the break-even point. Those requirements put practical fusion power from helium-3 via magnetic confinement fusion far out of reach, and more so by laser confinement methods.

Nor is it likely that the NIF laser fusion facility, (that actually has not yet achieved D-T fusion at all, but will likely do so in the future), will achieve the large needed increase in power input to overcome the large Coulomb barrier of helium-3. As I said earlier, the only reactor that has demonstrated helium-3 fusion, to my knowledge, is an electrostatic confinement reactor designed by Professor Kulcinski, a member of the NASA Advisory Council. This reactor requires a 1,000,000-fold greater energy input than the fusion gives back. Professor Kulcinski's design uses "an electrostatic field to contain the plasma, instead of an electromagnetic field. His current reactor contains spherical plasma roughly ten centimeters in diameter. It can produce a sustained fusion with 200 million reactions per second producing about one milliwatt of power while consuming about one kilowatt of power to run the reactor. The output is nuclear power without radioactive waste or neutron caused radiation." (see: A fascinating hour with Gerald Kulcinski)

The inverse ratio of the number of neutrons to protons in the helium-3 atom (in comparison with tritium, hydrogen-3), makes fusion extremely hard to achieve. The current hoopla over helium-3 fusion appears to be just another global-warming type scientific hoax on the Paolo-Sarpi platform of driving scientific development into a dead-end ally, intended to block the potential for real power development.

Helium-3 fusion appears to be possible only in the vacuum of space and by the same principle by which helium-3 is created in the first place, the principle of kinetic fusion, and for kinetic fusion-energy output such as is useful for space propulsion. On earth efficient kinetic fusion is inhibited by air molecules getting in the way. No natural principle exists for nuclear fusion to happen in a planetary environment.

The principle for nuclear-fusion power is entropic and therefore not natural as a power resource

In the Universe nuclear fusion is a building process, and not a consuming process, such as the fusion-sun is deemed to run on, that is deemed self-consuming. The lack of a fundamental principle for it in the Universe, and even need for it, may be the chief reason why nuclear-fusion energy production is failing in principle. The Universe does not employ processes that are entropic in principle, since the Universe itself is anti-entropic in nature.

It needs to be repeated here that the fusion-power concept is built on the assumption that every sun in the Universe is powered by nuclear fusion, whereby the Universe is deemed self-consuming and winding down, rather than being self-developing and expanding in every respect. Since no evidence exists that supports the assumption of universal entropy, the nuclear-fusion-power concept that is built on the assumption of natural entropy is built on a false premise, and becomes becomes an unnatural pursuit that is inherently bound to fail.

Helium-3 fusion, on the other hand, would constitute a natural type of fusion, a kinetic fusion. Kinetic fusion is the type of fusion that the Universe operates at the surface of the Sun, which is powered by galactic plasma electricity. Helium-3 is an incomplete product resulting from kinetic fusion. It results from excessive energy input during the creating fusion process, which through nuclear fission can be regained, like the electricity in a charged battery can be utilized. All so-called nuclear fusion-power, no matter by what method it is realized, is actually power derived from an associated nuclear-fission process. One of the atoms of the D-T fuel fissions in order to supply the proton that the other atom lacks. The neutron release (with a high kinetic energy) results from this fission. With helium-3 fusion the process is similar. Its energy is derived from nuclear fission.

The utilization of the kinetic fusion that is a building process on the surface of the Sun can also be applied in space if the kinetic process can be duplicated. The utilization of this process would then not mimic a primary entropic process, but merely constitute a secondary, completing, or correcting, process. The resulting kinetic product itself, would then become useful in the space environment in which it occurs naturally, as for space travel propulsion. Electrically driven kinetic fusion is naturally occurring. It happens on every sun in the process of producing larger atoms, and not primarily for power production that results merely as an insignificant side-effect in the over-all scheme of creative fusion.

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