Controlled Nuclear Fusion

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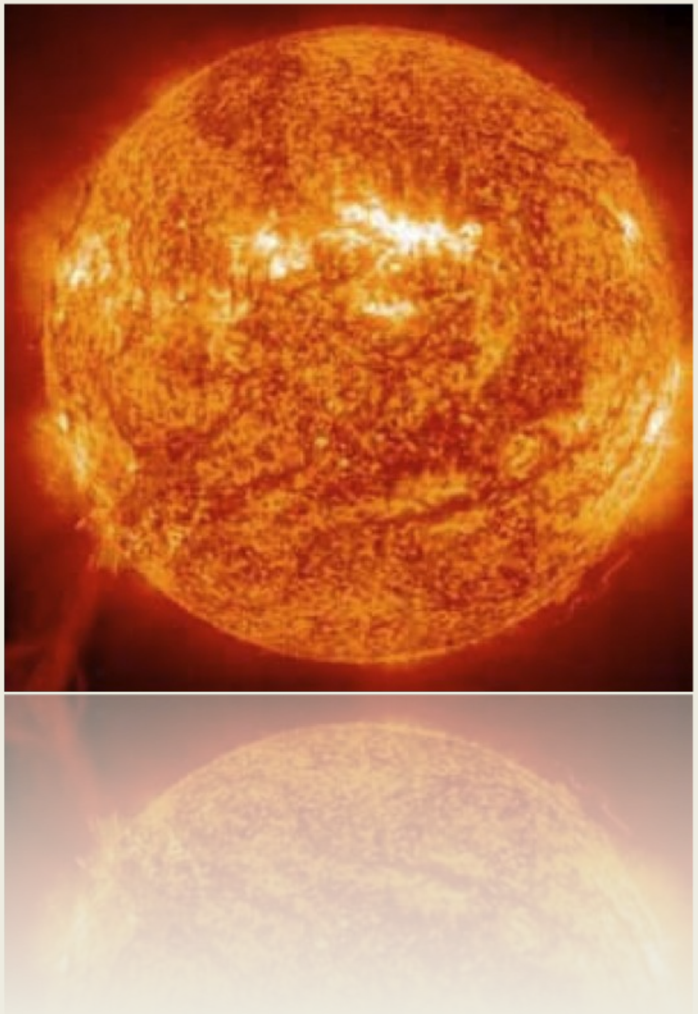
Nuclear Fusion

Thermonuclear fusion is the process by which nuclei of low atomic weight such as hydrogen combine to form nuclei of higher atomic weight such as helium. two isotopes of hydrogen, deuterium (composed of a hydrogen nucleus containing one neutrons and one proton) and tritium (a hydrogen nucleus containing two neutrons and one proton), provide the most energetically favorable fusion reactants. in the fusion process, some of the mass of the original nuclei is lost and transformed to energy in the form of high-energy particles. energy from fusion reactions is the most basic form of energy in the universe; our sun and all other stars produce energy through thermonuclear fusion reactions.

Nuclear Fusion Overview

- Two nuclei fuse together to form one larger nucleus
- Fusion occurs in the sun, supernovae

  explosion, and right after the big bang
- Occurs in the stars
- Initially, research failed
- Nuclear weapon research renewed interest

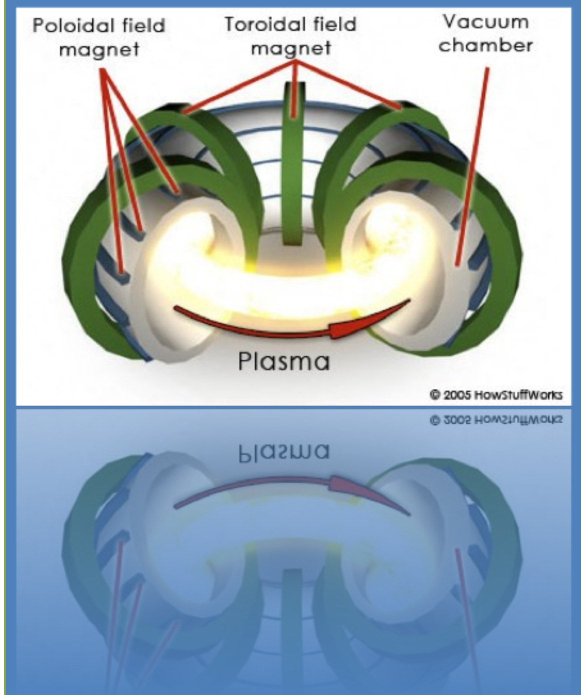


The Science of Nuclear Fusion

- Fusion in stars is mostly of hydrogen (H1 & H2)
  - Electrically charged hydrogen atoms repel each other.
  - The heat from stars speeds up hydrogen atoms
  - Nuclei move so fast, they push through the repulsive electric force
- Reaction creates radiant & thermal energy
- Controlled Fusion uses two main elements
  - Deuterium is found in sea water and can be extracted using sea water
  - Tritium can be made from lithium
- When the thermal energy output exceeds input, the equation is self-sustaining and called a thermonuclear reaction

1929	1939	1954	1976	1988	1993	2003
Prediction using e=mc2, that energy from fusion is possible	Quantitative theory explaining fusion.	ZETA	JET Project	Japanese Tokomak	Princeton Generates 10 megawatts of power (cold fusion)	ITER

Fusion Reactors



- Same reaction as nuclear bomb
- The reaction continually produces thermal energy
  - Used to boil water and make steam
  - 2H is removed from water through isotope separation
  - 3H is not found naturally
  - This can be done by surrounding the fusion chamber with lithium
- The reactor, like a star, has to heat itself to millions of degrees
  - Electric current passing through hydrogen fuel
- Net energy gain requires:
  - Highly compressed fuel
  - Very high heat reactor
  - Long enough for the reaction to occur
- If fuel touches the wall, it cools instantly
  - Fuel is held away from walls by electromagnetic force

Fusion Applications

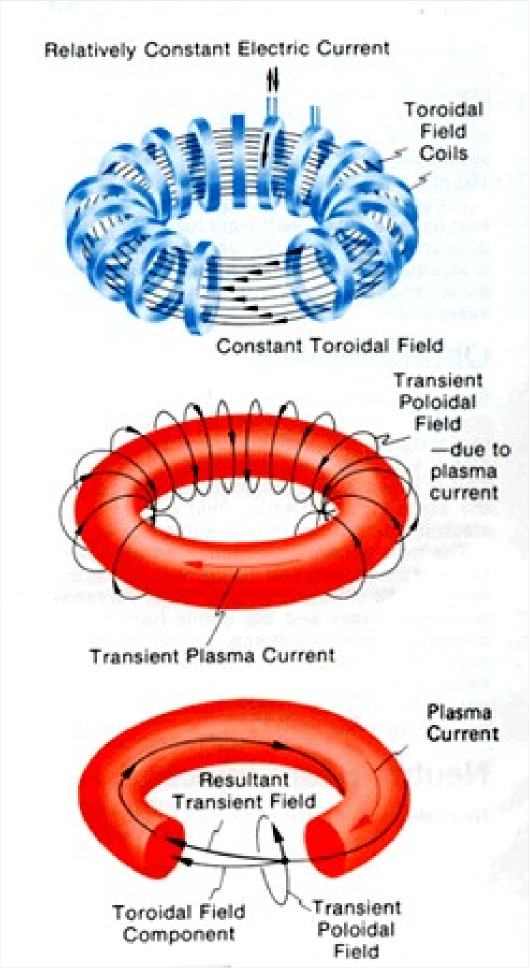
- Power Plants
  - 2 Liters of Water + 250 Grams of rock provide enough resources for a one energy supply of a European family
- Nuclear Weapons
  - 500 times more powerful then first fusion weapons
  - Different Process Then Power Generation

Challenges of Using Fusion

Fusion needs to be done at very high temperatures so that the elements become plasma.

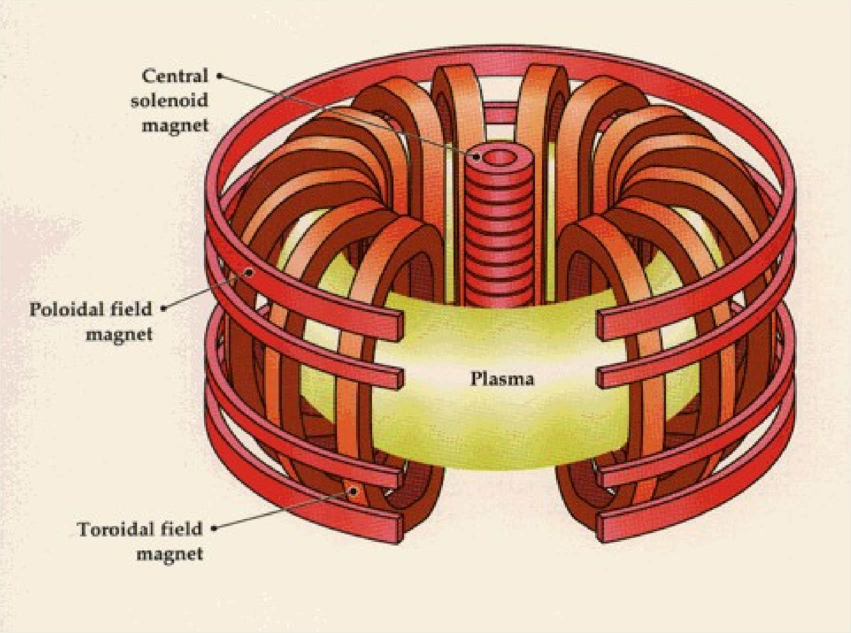
Containing Plasma

- Three ways to heat and restrain plasma
  - Gravity
  - Inertia
  - Magnetic



Tokomak Overview

Magnetic Plasma Containment



- Two superimposed magnetic fields enclose the plasma
  - Toroidal field generated by external coils
  - The field of a flow in the plasma

Current Fusion Projects

ITER	Rochester Laser Lab for Energetics
ITER hopes to produce 500 Megawatts of electricity for approximately 1000 seconds by the fusion of 0.5 grams of a deuterium/tritium mixture.	The FSC for Extreme States of Matter is developing an understanding of how to create extreme states of matter using high-energy lasers and drivers

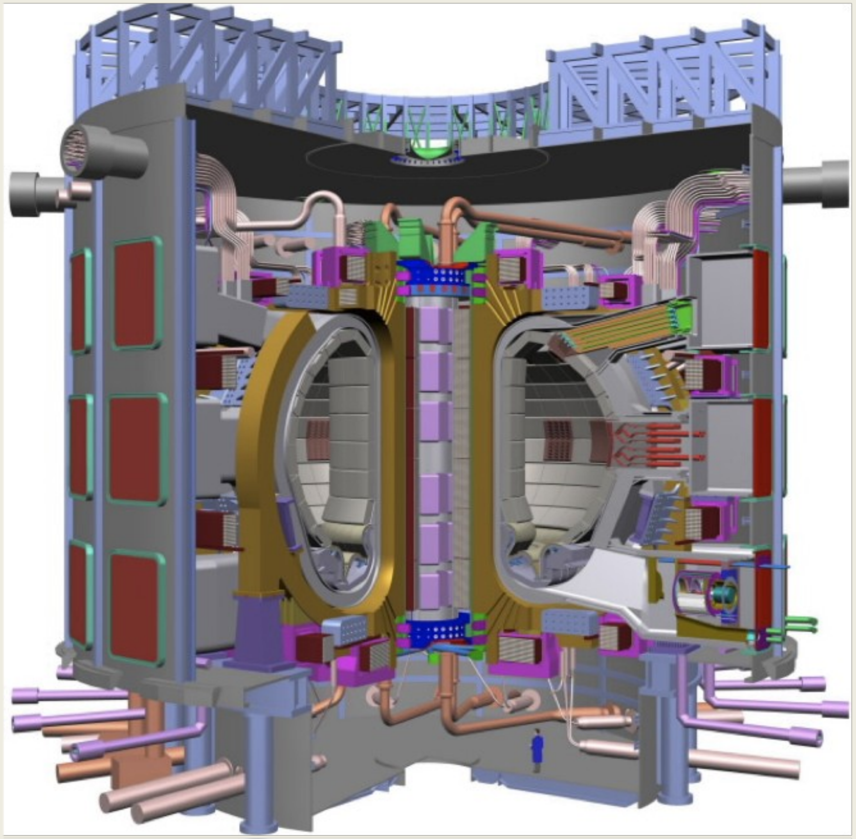
The ITER Project

- Originally an acronym for "International Thermonuclear Experimental Reactor"
- Located in Cadarache, in the South of France
- Countries: E.U., Japan, China, India, Korea, Russia, U.S.
- Construction Started 1999, First Plasma Planned for 2016

ITER: Goals of the Project

- Prolonged fusion power production in a deuterium-tritium plasma
- Scientific and technological feasibility of fusion power for peaceful purposes
  - Ignite a 'burning' (self sustaining) plasma

    http://www.hiper-laser.org/fusion
  - Develop technologies needed for future power plants



Rochester Laser Lab

- Only inertial confinement fusion (ICF) research lab of type in U.S.
- Supported by the National Nuclear Security
- Fast ignition/advanced fusion schemes are being investigated at LLE
- OMEGA laser (can create fusion)
- National Inertial Confinement Fusion Program
- http://www.hiper-laser.org/fus

Pros and Cons of Nuclear Fusion

Pros:

- Clean energy source that produces no greenhouse gases.
- Limitless amount of fuel available, deuterium and tritium easy to produce.
- Fusion, unlike fission, does not involve a chain reaction, so the process can be stopped eliminating the risk of a meltdown.
- Fusion does not produce nuclear waste, only the core of the reactor remains radioactive and only for 100 years.
- Fusion has the potential to fuel the entire world for relatively low costs compared to today's fuels.

Cons:

- Fusion can only occur at extremely high temperatures (10-15 million K) making it difficult to contain.
- The energy required to make fusion work could be greater than the output of energy by fusion itself.
- Current research and experimentation is going to cost billions of dollars, money that could be invested in renewable green fuels.
- Cold fusion may be the only way to make fusion efficient, and cold fusion has yet to been successfully developed.

Conclusion

- New energy sources are necessary
  - Oil reserves may run out in 50 to 100 years
  - Greenhouse emissions
- Short-term, nuclear fission is a better solution
  - Breeder reactors
- Long-run, fusion may be viable
  - Safe production of large amounts of energy