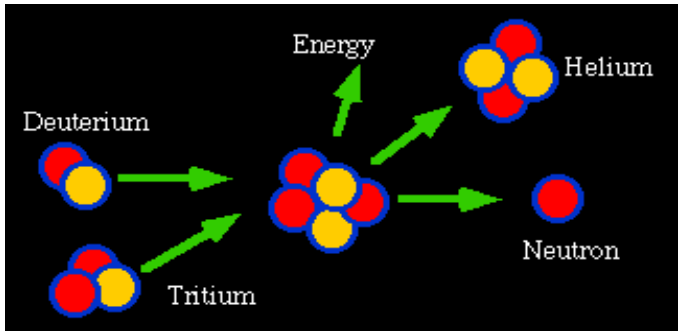
# Electro-magnetic Field Mapping of RF Heating Arrays

## What is Fusion?

Fusion, in general, is the process of combining the nuclei of light elements to form a heavier element. This is a nuclear reaction and results in large amounts of energy. Before this reaction can occur, nuclei must be able to collide. However, since both are positively charged, a natural repulsion, known as Coulomb Force, must be overcome. With enough kinetic energy, the repulsion may be overcome and the nuclei able to fuse together.

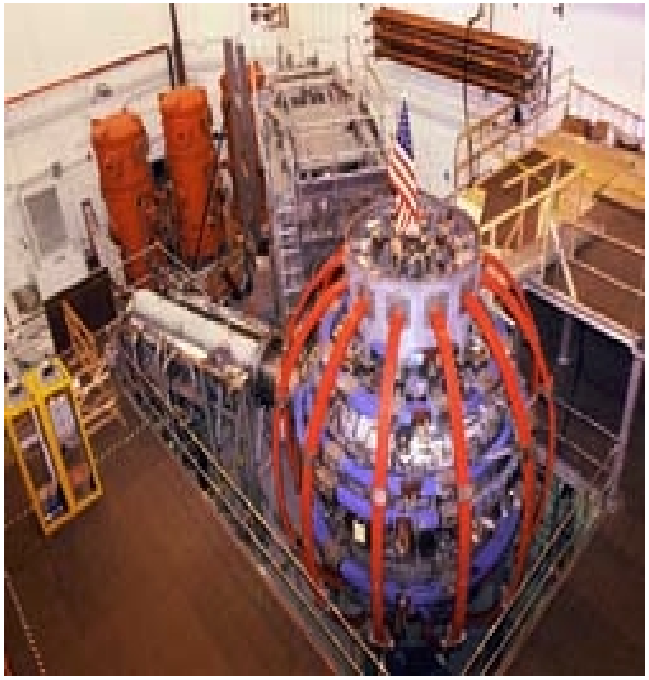



## How is all the Energy Confined?

One type of confinement is magnetic confinement with a tokamak. A tokamak is a toroidal plasma confinement device (tokamak, a contraction of the Russian words torodialnaya, kamera, magnitnaya, or toroidal chamber-magnetic). The plasma is confined here not by the material walls, which are not capable of handling the plasma s extreme temperatures (millions of degrees Celsius), but by magnetic fields.

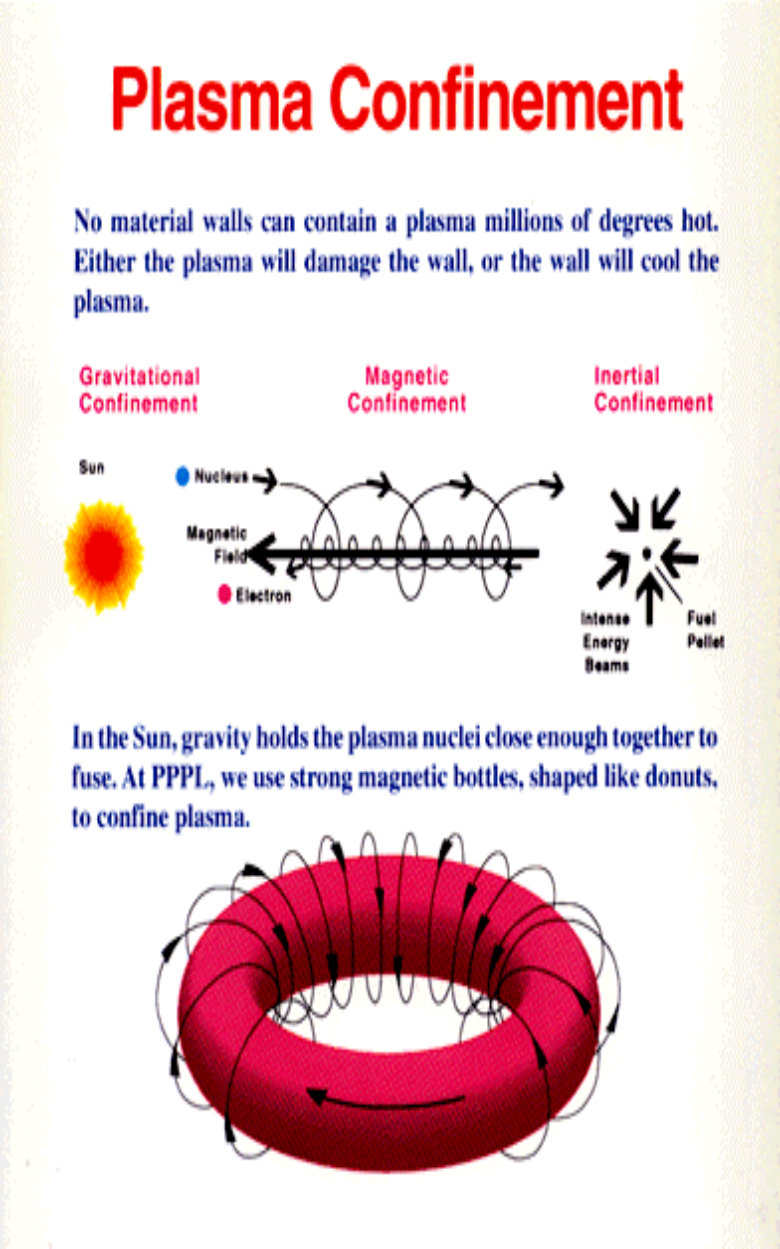
**National Spherical Torus Experiment (NSTX):**

The National Spherical Torus Experiment (NSTX) is constructed by the Princeton Plasma Physics Laboratory (PPPL) in collaboration with ORNL, Columbia University, and the University of Washington at Seattle. NSTX is an example of tokamak shaped like a sphere with a hole through the center rather than the conventional donut shaped tokamak. The new style enables the tokamak to confine a higher plasma pressure for a given magnetic field strength. Since the net power is proportional to the square of the plasma pressure, the use of the spherically shaped plasmas could result in a smaller, more economic reactor. NSTX is a proof-of-principle experiment therefore using deuterium plasmas rather than a plasma comprised of equal parts of deuterium and tritium (radioactive), the fuel mix likely to be used in commercial fusion power reactors. If successful, NSTX will be followed by similar devices, eventually including a demonstration power reactor, burning deuterium-tritium fuel.



**Electro-magnetic Waves and Radio Frequency:**

The magnetic fields in a tokamak are produced by a combination of currents flowing in the external magnetic coils and currents flowing within the plasma itself. Radio frequencies (rf) are used as one way of powering the plasma by both heating the plasma and driving the required internal currents. Rf produces toroidal currents by direct momentum transfer from waves to particles, moving the plasma at a velocity nearly matching the phase velocity of the wave. Fortunately, NSTX has the ability to produce a high bootstrap electric current. This self-driven internal current would significantly reduce the power required by the external currents from the antenna to heat and confine the plasma.



## Motivation Behind EM Field Mapping

Understanding the field characteristics near the antenna gives insight on how to better couple to propagating waves in the plasma. To better understand these characteristics, we have scanned the surface of an NSTX antenna array with Faraday shields fixed with a normal horizontal geometry and the same array with Faraday shields with a thirty degree tilted geometry. Since Faraday shields are used to control the orientation of the EM fields, a considerable directional change with respect to the horizontal shields is expected. Measurements of these fields with different Faraday shield geometries aid scientists in optimizing the characteristics of the launched waves.

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**Conclusion:**

- assembled apparatus
- mapping the b-field shows the finite wavelength affect along the current strap
    - field strength is maximum near ground where currents are greatest
    - currents become a minimum a quarter wavelength from ground
    - phase velocity of the strap can be determined by the field pattern (roughly 1/2 speed of sound)
- tilting the Faraday shield reduces the magnitude of the horizontal b-field component, but not its pattern
- tilting the Faraday shield introduces a vertical component to the magnetic field

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