Inertial Electrostatic Confinement Fusion Reactor

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Purpose:

The purpose of this experiment was to demonstrate fusion by heating a deuterium plasma using an electric field.

Materials:

- 2 stage, 12 CFM, KF 40, 15 mtorr ultimate vacuum, 746 W mechanical pump
- 1200 l/s, ASA 400, KF 40, $5x10^{-6}$ mtorr, water cooled, 1,450 W diffusion pump
- 300 cc MT-705 diffusion pump oil
- 2’ KF 40 to KF 40 steel-reinforced PVC
- 8” CF, manual operation gate valve
- ASA 400 to 8” CF adapter
- Six way 6” CF cross with 6” diameter spherical body
- 8” CF to 6” CF adapter
- 4.5” CF, 45 kV 3A high voltage feedthrough
- (2X) 6” CF to 1.33” CF adapter
- 6” CF blank
- 6” CF borosilicate glass viewport
- Deuterium lecture bottle, 50 liters, 99.999% purity
- Gas regulator
- Needle valve
- Capillary tubing for deuterium transfer, 0.005” ID
- High vacuum gauge
- High voltage DC power supply, -40 kV 10 mA
- 200 kΩ 320 W wirewound ceramic high voltage ballast resistor
- 1.25” Diameter three-hoop spherical grid, made using 0.48 mm tungsten wire
- (3x) Voltmeter
- 40 kV High voltage probe
- Geiger counter
- BTI neutron bubble dosimeter 29 bubbles/mrem (zero gamma sensitivity)
- (3x) Camera capable of streaming a live video

Many small parts have been omitted from this list. (i.e. nuts, bolts, base materials…)

Procedure:

1. Depressurize the bubble dosimeter. After one hour, record the number of bubbles. This test establishes a control. Then reset the detector for the experimental test.
2. Depressurize the bubble detector and place it 6” from the center of the grid.
3. Turn on the mechanical pump, waiting until the pressure measured on the high vacuum gauge reads below 10 mtorr.
4. Initiate water flow to the diffusion pump and turn on its heater.
5. After the diffusion pump is operating at its peak performance and a vacuum of at least 10^{-5} torr is attained, deuterium can be admitted to the chamber.
6. Close the gate valve completely and barely turn the needle valve to admit a small flow of deuterium gas. As the pressure in the chamber rises, open the gate valve slightly in order to maintain a dynamic equilibrium at a pressure of 5 to 15 mtorr.
7. Ensure all radiation detection equipment is active and all personnel are cleared from the area.
8. From a distance of at least 30 feet, turn on the power supply.
9. Leave the power supply on for a duration of five minutes, constantly monitoring the deuterium plasma through the live camera feed.
10. Record the applied voltage and amperage throughout the test.
11. After the test is complete, ensure that the power supply is unplugged.
12. Count the bubbles generated in the neutron bubble dosimeter.
13. Turn off the diffusion pump, leaving the mechanical pump and water cooling system active.
14. After 10 minutes, the mechanical pump and water cooling system can be shut off.

Theory:

An inertial electrostatic confinement fusion reactor fuses deuterium nuclei using extreme temperatures. After the main chamber is refilled with deuterium, the inner grid is supplied with current from the power supply. The grid generates a large electric field, which ionizes the surrounding deuterium gas. Positively charged deuterons are then accelerated to the negatively charged grid. The temperature of this generated plasma exceeds several hundred million degrees Kelvin. The ions are confined to the cathode due to the strong electric field. Due to the shape of the grid, there are weak points in the electric field that allow plasma to escape the grid’s interior in the form of plasma beams. The positively charged deuterons approach each other at high velocities, pushing against the increasing coulomb repulsion force between them. The deuterons do not have enough energy to break the coulomb barrier, but occasionally meet by the means of quantum tunneling. When one deuteron tunnels to another, both particles are attracted due to strong force interactions that overpower the coulomb repulsion force. The deuterons oscillate at very high velocities until one loses energy either by emitting a fast neutron or a proton. This results in the synthesis of either a tritium atom plus a proton, which releases 4.03 MeV or a helium three atom plus a neutron, which releases 3.27 MeV. These two fusion reactions occur in equal proportions so it can be inferred that for every neutron produced by the fusion reactor, two fusions actually occurred.

Data:

Voltage: -30 kV

Current: 10 mA

Deuterium pressure: 5-15 mtorr (Cannot be accurately determined)

Duration of experimental test: $\frac{1}{12}$ hours

Duration of control test: 1 hour

Bubbles counted in experimental test: 5 bubbles

Bubbles counted in control test: 0 bubbles

BTI neutron bubble dosimeter sensitivity: 29 $\frac{\text{bubbles}}{\text{mrem}}$

Distance between detector and ideal neutron source: 15.24 cm

Calculations:

$$\Phi = \frac{\left(\frac{5}{29} \frac{\text{bubbles}}{\text{bubbles}/\text{mrem}}\right)\left(8 \frac{\text{neutrons}/\text{cm}^2}{\text{second}}\right)}{\frac{1}{12}\,\text{hours} \cdot 1\, \frac{\text{mrem}}{\text{hour}}} = 17\, \frac{\text{neutrons}/\text{cm}^2}{\text{second}}$$

$$\Phi \oint dA = 17\, \frac{\text{neutrons}/\text{cm}^2}{\text{second}} \cdot 4\pi(15.24\ cm)^2 \approx 50{,}000\, \frac{\text{neutrons}}{\text{second}} = 100{,}000\, \frac{\text{fusions}}{\text{second}}$$

Results:

Because the control test yielded no counts on the neutron dosimeter, the positive data recorded during the experimental test is a convincing indicator that fusion occurred. However, there might have been vibrations, temperature changes, or other poorly controlled variables that may have given false positive data in the detector. These are variables caused by the fusion reactor's operation. If hydrogen were used instead of deuterium there should be no neutrons produced, so any positive data during this control test will indicate a poorly controlled variable that has the capacity to produce bubbles in the detector. If no bubbles are generated in the detector during this test, the original experimental test's results will represent a stronger argument for fusion.