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Spinning in a Bottle: Centrifugal Mirror Achieves Long Pulse, Stable Discharges

With steady state superconducting magnets and constant power input, the Centrifugal Mirror Fusion Experiment demonstrates stable operation of scalable fusion energy concept.

ATLANTA—Fusion, the combining of light elements into heavier ones resulting in a release of energy, has long been sought after as an energy source due to its energy density, abundance of fuel, and lack of long-lived radioactive waste products. One concept to generate energy from fusion is the magnetic mirror. Magnetic mirrors use circular electromagnets to create a cylindrical magnetic "bottle" that traps charged particles (a plasma). Strong magnetic fields on either end of the bottle prevent most particles from escaping as they bounce between these strong fields. If the plasma is heated to high enough temperatures, the particles undergo nuclear fusion, releasing enormous amount of energy in the process. However, simple mirrors are known to be unstable and lose all the confined energy when approaching the temperatures required for nuclear fusion.

The centrifugal mirror improves on the simple magnetic mirror by spinning the plasma around the linear axis at supersonic speeds to stabilize it and heat it. The centrifugal mirror is an attractive concept to produce commercial fusion energy because of its compact form and engineering simplicity, compared to the more complex toroidal (donut-shaped) confinement concepts such as tokamaks and stellarators. Centrifugal mirrors are scalable and are ideal candidates to provide energy in modular systems with power outputs anywhere between 1 and 100 megawatts, which could provide uninterrupted

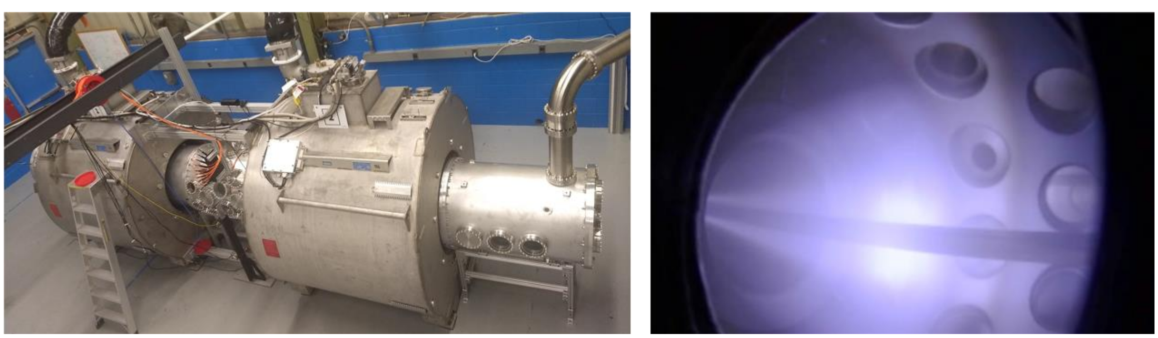

Figure 1. Left: The Centrifugal Mirror Fusion Experiment at the University of Maryland; the superconducting magnets, seen in the image with the long cylindrical chamber through them, are arranged symmetrically to create the trapping field for high-temperature plasmas. Right: A view of the plasma between the two magnets as it heats up due to the imposed rotation around the center conductor. As the plasma heats up, the images become dimmer for the cameras to capture.

power and help increase the resiliency of electrical systems in data centers, industrial parks, or entire cities with no greenhouse gas emissions.

The Centrifugal Mirror Fusion Experiment, CMFX, located at the University of Maryland and supported by the Advanced Research Projects Agency for Energy (ARPA-E), is the first centrifugal mirror that uses superconducting coils to ever be experimentally tested (Figure 1). The experiment has been in operation since 2022, but has just recently achieved the important milestone of demonstrating stable, steady discharges of up to 10 seconds, limited only by the heating of components that are not actively cooled.

Previous centrifugal mirror experiments had only operated for a few milliseconds or less. From past experiments it was well known that centrifugal mirrors tend to become over dense, which then leads to instabilities that limit temperature and confinement times of the plasma. By carefully controlling the particle inventory even before it is turned to a plasma, the CMFX team has managed to keep density within the predicted limits of the experiment, allowing plasma to be stably confined for long periods of time. To maintain the supersonic rotation, an electrical voltage is applied perpendicular to the magnetic field, with the resistance along this path easily measured and predicted to increase as the plasma heats up.

What is remarkable about the latest experiments is that the plasma resistance increases to be thousands of times higher than it would be in cold magnetized plasmas without rotation, a clear indication of stable plasma heating and confinement. Future experiments in CMFX are planned to achieve even higher rotation velocities, as well as higher heat and particle densities.

The experiment is now producing small amounts of fusion reactions that are used as an additional diagnostic to validate the centrifugal mirror models. The latest results will allow the Maryland researchers to design and build the next generation machine as part of a commercial startup, the Terra Fusion Energy Corporation. This venture aims to demonstrate net energy gain from fusion in a modular centrifugal mirror system, and commercially deploy these systems in partnership with other research groups and national laboratories, as well as local and regional energy providers.

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Abstract

NP12.00132	Steady operation of the Centrifugal Mirror Fusion Experiment with a High Voltage DC Power Supply
Session	NP12: Poster Session V Fundamental Plasma Physics III: waves, self-organization Fundamental Plasma Physics IV: turbulence, reconnection, non-neutral/antimatter High Field Tokamaks

Mirrors
9:30 AM–12:30 PM, Wednesday, October 9, 2024
Room: Hyatt Regency Grand Hall West