Magnetic Fusion Experiment
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Goals

Fusion: first and forever

The research we perform is dedicated to making fusion energy a safe reliable source of power for mankind. In pursuing this goal, other applications of the research, such as the development of space propulsion systems or of new materials processing techniques or of basic scientific methods, may well be found. This website describes both the fusion and non-fusion aspects of our research.

The fusion research focuses on the field-reversed configuration (FRC). This device has the potential to burn aneutronic fuels, reducing radioactive material inventory about a factor of 104 (per unit of power), compared to fission or D-T burning power plants. FRC power plants are expected to be relatively small, producing 0.1-1 MW each.

Both undergraduate and graduate students participate in MNX research in direct and essential ways. They bring energy, creativity, and new skills to bear on our challenging problems. Additionally, we collaborate extensively with plasma physicists at other laboratories, especially Los Alamos National Laboratory, the Redmond Plasma Physics Laboratory at the University of Washington, Fusion Physics and Technology, and NASA, bringing together a blend of talents and expertise.

If you have any questions, please contact us by e-mail, scohen@pppl.gov.

http://FusEdWeb.pppl.gov/
http://www.lanl.gov/external/science/subjects/physics/plasma.html
http://www.aa.washington.edu/AERP/RPPL/index.html
http://www.jsc.nasa.gov/Bios/htmlbios/chang.html

The MNX Research Program

Nozzle research

The US Department of Energy funds MNX research. We are currently in the second year of a three-year grant to perform experimental studies of rapid plasma cooling and the resulting recombination in the expansion zone of a nozzle whose shape is set by a magnetic field. The experiments are aimed at forming a supersonic neutral jet from a low-temperature, moderate-density, magnetized helium plasma. The phase transition from a magnetized plasma to a neutral gas is of fundamental interest, probing normal modes and irreversible processes of the system. Novel applications of such jets are possible in the fields of fusion power, space propulsion, materials processing, and lasing systems. Plasma detachment from the magnetic field lines is essential for space propulsion. Without this, the exhausted plasma would return to the spacecraft, reducing the thrust. Detachment of supersonic ions may be brought about by several processes, including both recombination and charge exchange of ions, or loss of magnetization.

The experiment will look for a double layer and steep electron temperature step in the nozzle throat and measure the charged and neutral particle temperatures and velocities in the expansion region. Double layers have special prominence in the field of astrophysics. Spectral emissivity measurements will yield the atomic-state distribution functions of the atoms and ions to quantify the recombination processes that have occurred.

Diagnostic development

To be added.

FRC Research

A proposal has been submitted to DOE to explore a solution to a long-standing fundamental problem in FRC physics: how to apply rotating magnetic fields (RMFs) so that the FRC's closed field-line structure is maintained. Our recent theoretical work predicts that odd-parity fields will preserve closure and will also heat electrons and ions to fusion-relevant energies, drive sustained currents, and stabilize the configuration. Having one system perform several functions provides a distinct technological advantage. RMFs have been used to produce plasmas, drive toroidal currents, and obtain field reversal. The standard RMF configuration, however, opens the FRC's field-line structure. Rotamak experiments have shown particle and energy losses near the ion-acoustic rate. This strongly motivates the study of field-closure-preserving RMF configurations and evaluation of their effects on particle confinement and heating. Recently, static odd-parity transverse fields have been predicted to preserve field closure in FRC's and odd-parity RMFs are predicted to heat electrons and ions by a hybrid of cyclotron resonance and stochastic mechanisms.

The proposed experimental program would study confinement, electron heating, and ion heating with up to 80 kW of odd-parity RMF power applied to a 3-cm radius, 30-cm long helium plasma column. Operation at high power/unit volume will yield plasma parameters above Te = 100 eV at ne = 5 x 1012 cm-3. Combined with a low neutral pressure and relatively remote walls, detrimental plasma-wall interactions and atomic physics effects would be minimized.

The MNX facility

The MNX facility produces a steady-state magnetized plasma column, about 3 cm in diameter and 100 cm long.

Photo, through a 12 cm diameter window, of an argon plasma in the main section of MNX. The plasma diameter is about 3 cm.

The plasma species may be readily changed; the inert gases are the most commonly used. A plasma density up to 1014 cm-3 and a maximum temperature of about 7 eV (~80,000 K) have been acheived. If proposed fusion experiments in the field-reversed configuration (FRC) are successful, the temperature should reach over 100 eV.

The MNX is the fourth use of the same experimental equipment over a 25-year period. The magnet coils were first used for basic plasma studies of lower-hybrid wave propagation and parametric instabilities. The second use was for spacecraft-glow research. It was then used for studies of detached plasmas relevant to tokamak divertors. The MNX is now used to study expansion of plasmas through strong gradients in magnetic fields. This is called the magnetic nozzle.

The magnetic nozzle is predicted to accelerate the plasma to supersonic speeds. Whether this happened is a primary goal of the research and is especially important to space propulsion applications.

Photo of an argon plasma exhausting through the nozzle of the MNX facility. The plasma is inside a barely visible glass tube.

The MNX axial magnetic field is provided by a Helmholtz pair of 22 water-cooled coils, which provide an axial field up to 3.5 kG. A single magnetic nozzle coil is located coaxial with one of the Helmholtz coils. It can be run to 2.5 kG in steady state, or pulsed to 25 kG for 30 ms. A 1 kW helicon RF system, operating at 27 MHz, is used to create steady-state plasmas.

Schematic of the MNX facility.

MNX has the following diagnostic systems operating:
RF power measurements (1 –10 kW)
Scanning Langmuir probes
Multi-chord visible spectrometer with iCCD camera detector
LIF system (FP&T) for Ti measurement and turbulence studies
MSE diagnostic (FP&T)
MNX has the following diagnostics available for installation:
UV normal-incidence spectrometer
30 GHz microwave interferometer

Publications

"Experimental observations of steep temperature gradients in dense magnetized plasmas," G. Chiu and S.A, Cohen, Phys. Rev. Lett. 76 (1996) 1248.

"Comparisons of experimental measurements and two-dimensional plasma-fluid numerical simulations of a magnetized plasma column" G. S. Chiu and S.A. Cohen. Phys. Plasmas 3, 4250 (1996).

"Arc Jets for divertor component testing," S.A. Cohen, J. Balboni,and T. Munsat, to appear in J. Nucl. Mater. 241-43, 483 (1997).

"Helium ash removal from a tokamak plasma using radio frequency heating and ripple trapping," C.S. Chang, S.A. Cohen, R. Majeski, M. Redi, and S. Zweben, Comments on Plasma Physics 18, (1997) 235.

"Plasma-neutral interaction in thermally collapsed plasma," Jaeyoung Park, T.K. Bennett, M.J. Goeckner, and S.A. Cohen, J. Nucl. Mater. 241-243, 489 (1997).

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"A wave-heated magnetically confined plasma thruster for space propulsion," S.A. Cohen and M.A. Paluszek, Launchspace, (1998) 46.

"Hollow cathode magnetron," Z. Wang and S.A. Cohen, J. Vac. Sci. and Technol. A17, 77 (1999).

"Geometrical aspects of a hollow-cathode planar magnetron," Z. Wang and S.A. Cohen, Phys. Plasmas 6, 1655 (1999).

"Nitrogen atom energy distribution in a hollow-cathode sputtering magnetron," Z. Wang, S.A. Cohen, D.N. Ruzic, and M. Goeckner, Phys Rev E 61, 1904 (2000).

"Fusion concept exploration experiments at PPPL," S. Zweben, S. Cohen, H. Ji, R. Kaita, R. Majeski, and M. Yamada, to appear.

"Maintaining the closed magetic field configuration of a field-reversed configuration with the addition of static transverse magnetic fields," S.A. Cohen and R.D. Milroy, Phys. Plasmas 7, (2000).