Final Report

DOE Award DE-FG02-09ER46619

Recipient: University of New Mexico
1 University of New Mexico
Albuquerque, NM 87131-0001

Participating National Lab: Los Alamos National Laboratory

Project Title:
Development of Optimized Field-Reversed Configuration Plasma Formation Techniques for Magnetized Target Fusion

Approved Budget Amount: $356,514

Principal Investigator: Alan Lynn

Report Date: November 1, 2013

Period Covered by Report: 6-1-2011 to 8-14-2013

1 Abstract

The University of New Mexico (UNM) proposed a collaboration with Los Alamos National Laboratory (LANL) to develop and test methods for improved formation of field-reversed configuration (FRC) plasmas relevant to magnetized target fusion (MTF) energy research.

MTF is an innovative approach for a relatively fast and cheap path to the production of fusion energy that utilizes magnetic confinement to assist in the compression of a hot plasma to thermonuclear conditions by an external driver. LANL is currently pursing demonstration of the MTF concept via compression of an FRC plasma by a metal liner z-pinch in conjunction with the Air Force Research Laboratory in Albuquerque, NM.

A key physics issue for the FRC's ultimate success as an MTF target lies in the initial pre-ionization (PI) stage. The PI plasma sets the initial conditions from which the FRC is created. In particular, the PI formation process determines the amount of magnetic flux that can be trapped to form the FRC. A ringing theta pinch ionization (RTPI) technique, such as currently used by the FRX-L device at LANL, has the advantages of high ionization fraction, simplicity (since no additional coils are required), and does not require internal electrodes which can introduce impurities into the plasma. However RTPI has been shown to only trap ∼50% of the initial bias flux at best and imposes additional engineering constraints on the capacitor banks. The amount of trapped flux plays an important role in the FRC's final equilibrium, transport, and stability properties, and provides increased ohmic heating of the FRC through induced currents as the magnetic field decays. Increasing the trapped flux also provides the route to greatest potential gains in FRC lifetime, which is essential to provide enough time to translate and compress the FRC effectively.

In conjunction with LANL we initially planned to develop and test a microwave breakdown system to improve the initial PI plasma formation. The UNM team would design the microwave optics and oversee the fabrication and assembly of all components and assist with integration into the FRX-L machine control system. LANL would provide a preexisting 65 kW X-band microwave source and some associated waveguide hardware. Once constructed and installed, UNM would take the lead in operating the microwave breakdown system and conducting studies to optimize its use in FRC PI formation in close cooperation with the needs of the LANL MTF team.

In conjunction with our LANL collaborators, we decided after starting the project to switch from a microwave plasma breakdown approach to a plasma gun technology to use for enhanced plasma formation in the FRX-L field-reversed configuration experiment at LANL. Plasma guns would be able to provide significantly higher density plasma with greater control over its distribution in time and space within the experiment. This would allow greater control and fine-tuning of the PI plasma formed in the experiment. Multiple plasma guns would be employed to fill a Pyrex glass test chamber (built at UNM) with plasma which would then be characterized and optimized for the MTF effort.

2 Description of Accomplishments

A test chamber matching the key physical dimensions of the FRX-L vacuum chamber and including much better diagnostic access (Figure 5) compared to FRX-L was designed. The test chamber also has a magnetic field similar to the FRX-L experiment plasma formation region. The test chamber (including its vacuum system) has been designed, fabricated, and tested (Figures 1, 4). The magnetic field coils and power systems (Figures 2, 3) have also been designed, fabricated, and tested. The magnetic field has been verified to match the conditions in FRX-L. Design and testing of the triggering and control system for the experiment are complete .

Our LANL collaborators assembled the first plasma gun (Figure 6) and provided it to UNM along with a multi-port vacuum assembly to mount it (Figure 1). However, at that point the LANL FRX-L grant underwent a renewal. Under the renewed grant the original LANL principal investigator left the FRX-L project and the MTF efforts at LANL were reorganized to focus exclusively on supporting the MTF efforts at the Air Force Research Laboratory. The reorganized LANL MTF effort was no longer working on developing plasma guns for improving the plasma formation in FRC plasmas. The work on plasma formation techniques at UNM did not have and had never planned to have the manpower and resources to conduct the research without LANL involvement. Thus the UNM work on this effort was suspended at that point. It remains ready to resume should further support become available in the future.

3 List of Papers

None

4 People on Project

1. Alan Lynn (Research Professor, partial support – 25% FTE)
2. Mark Gilmore (Professor, partial support – 18% FTE)
3. Ryan Clarke (graduate student, partial support – 37.5% FTE)
4. Yue Zhang (graduate student, partial support – 37.5% FTE)

5 List of Other Support

None

6 Cost Status

	Approved budget	**Actual costs**	**Unspent funds**
Faculty salaries	$114,128.00	$83,577.04	$30,550.97
Graduate salaries	$40,788.00	$65,667.01	($24,879.01)
Graduate tuition	$17,645.00	$14,130.22	$3,514.78
Fringe benefits	$37,184.00	$29,843.82	$7,340.18
Undergrad student salaries		$23,702.95	($23,702.95)
Materials & supplies	$27,079.00	$16,330.99	$10,748.01
Travel	$9,000.00	$1,475.94	$7,524.06
Publication costs	$2,250.00		$2,250.00
Contingency		$13,622.95	$(13,622.95)
F&A	$59,912.00	$59,355.07	$556.93
Capital Equipment	$9,350.00	$9,632.00	$(282.00)
Total direct & indirect	$317,336.00	$317,337.99	$(1.99)
Cost share	$39,178.00	$23,000.00	$16,178
Total costs	**$356,514.00**	**$340,337.99**	**$16,176.01**

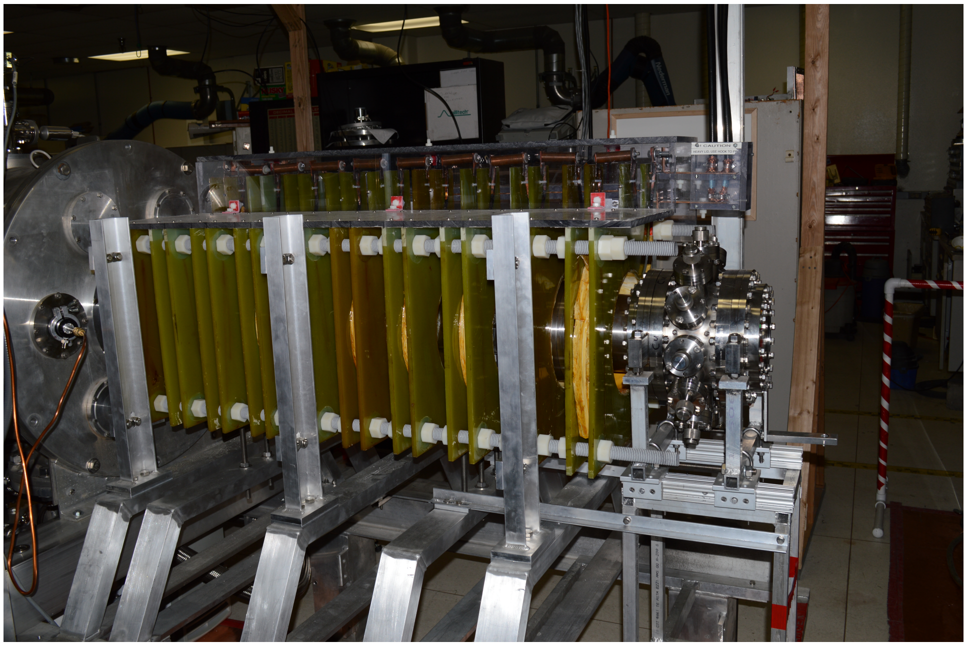

Figure 1: High magnetic field ($\sim$ 0.5 Tesla) solenoid with glass vacuum chamber inside (note LANL built multi-port plasma gun spool on right side of vessel)

Figure 2: Capacitor bank for driving solenoid magnet

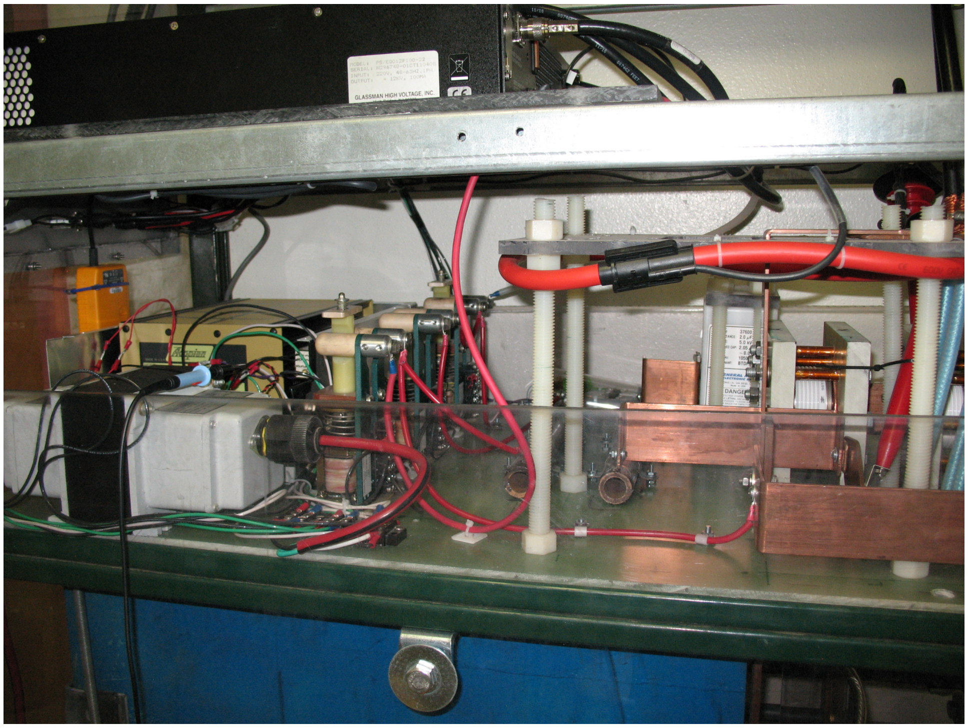

Figure 3: Control and monitoring circuit for solenoid magnet system

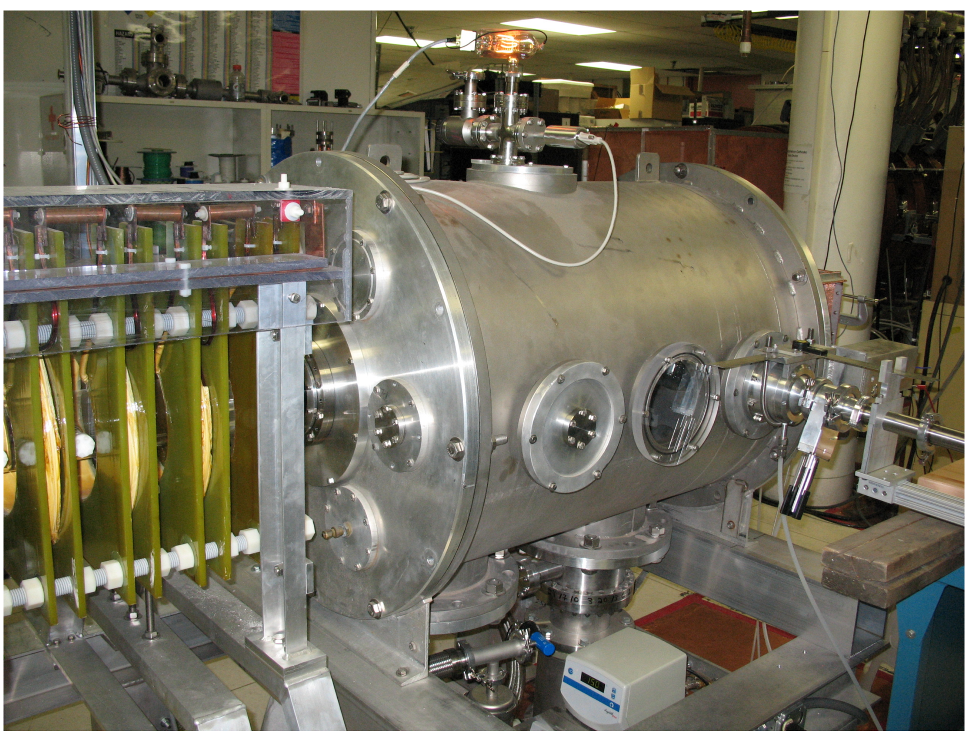

Figure 4: Plasma expansion tank downstream from plasma guns (note Langmuir probe installed on right ready for plasma measurements)

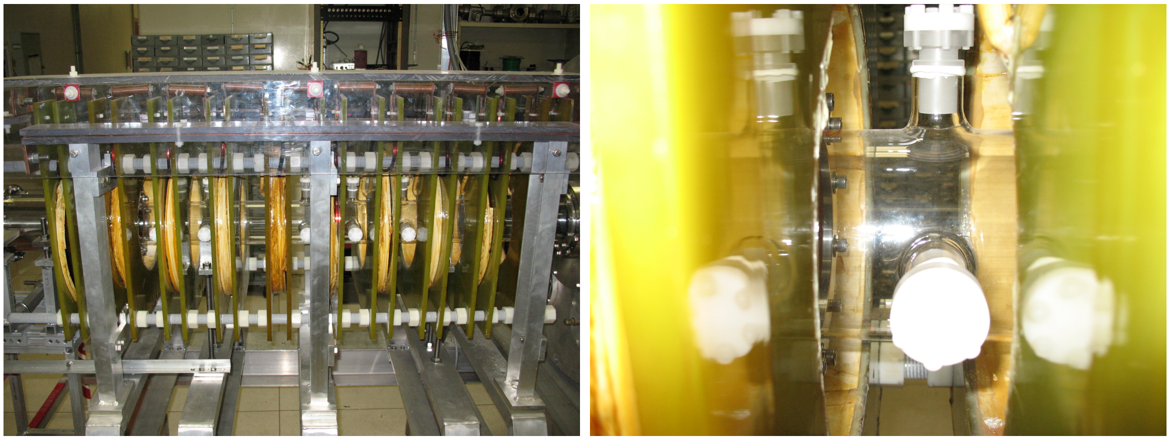

Figure 5: Diagnostic ports on glass vessel (close-up on right); this test stand has 14 diagnostic ports allowing direct vacuum access to the plasma along it's length compared to none on FRX-L

Figure 6: Plasma gun in-vessel component received from LANL