[0009] The systems and methods described herein advantageously provide: feedback control of the FRC plasma axial position by acting on the voltages applied to a set of external coils concentric with the plasma; feedback control of the FRC axial position using a non-linear control technique; and, feedback control of the FRC axial position independently of the stability properties of the plasma equilibrium. This is independence is advantageous because the equilibrium may have to transit between an axially stable and unstable equilibria on different phases of the FRC discharge, for instance if the axial instability scenario is temporarily lost and recovered during the plasma discharge.

[0010] The systems, methods, features and advantages of the example embodiments will be or will become apparent to one with skill in the art upon examination of the following figures and detailed description. It is intended that all such additional methods, features and advantages be included within this description, and be protected by the accompanying claims. It is also intended that the claims are not limited to require the details of the example embodiments.

[0010a] According to a first aspect, there is provided a method for generating and stabilizing a field reversed configuration (FRC) plasma, comprising the steps of: forming an FRC magnetic field about a rotating plasma in a confinement chamber to form an FRC plasma positioned along a longitudinal axis the confinement chamber adjacent a mid-plane of the confinement chamber, generating an applied magnetic field within the chamber with quasi-dc coils extending about the chamber, and stabilizing the FRC plasma in a radial direction normal to the longitudinal axis to position the FRC plasma axisymmetric about the longitudinal axis and in an axial direction along the longitudinal axis to position the FRC plasma symmetric about the mid-plane, wherein the step of stabilizing the FRC plasma in the radial direction includes tuning the applied magnetic field to induce radial stability and axial instability in the FRC plasma, wherein the step of stabilizing the FRC plasma in an axial direction includes creating first and second radial magnetic fields with first and second radial coils to interact with the FRC to induce axial stability in the FRC plasma.

[0010b] According to a second aspect, there is provided a system for generating and stabilizing a field reversed configuration (FRC) plasma comprising a confinement chamber, first and second diametrically opposed FRC formation sections coupled to the confinement chamber, the formation section comprising modularized formation systems for generating an FRC and translating the FRC toward a midplane of the confinement chamber, first and second divertors coupled to the first and second formation sections, first and second axial plasma guns operably coupled to the first and second divertors, the first and second formation sections and the confinement chamber, a plurality of neutral atom beam injectors coupled to the confinement chamber and oriented to inject neutral atom beams toward a mid-plane of the confinement chamber at an angle less than normal to a longitudinal

axis of the confinement chamber, a magnetic system comprising a plurality of quasi-dc coils positioned around the confinement chamber, the first and second formation sections, and the first and second divertors, first and second set of quasi-dc mirror coils positioned between the confinement chamber and the first and second formation sections, and first and second mirror plugs position between the first and second formation sections and the first and second divertors, a gettering system coupled to the confinement chamber and the first and second divertors, first and second set of radial magnetic field coils configured to generate first and second radial magnetic fields within chamber, and a control system operably coupled to the quasi-dc coils and the first and second radial magnetic field coils, the control system including a processor coupled to a non-transitory memory comprising a plurality of instruction that when executed causes the processor to tune the magnetic field generated by the plurality of quasi-dc coils and the first and second radial field coils, wherein the magnetic field generated by the plurality of quasi-dc coils is tuned to stabilize an FRC plasma in a radial direction normal to a longitudinal axis of the chamber to position the FRC plasma axisymmetric about the longitudinal axis and destabilize the FRC plasma in the axial direction along the longitudinal axis of the chamber, wherein the magnetic field generated by the first and second radial field coils is tuned to position the FRC plasma in an axial direction along the longitudinal axis to position the FRC plasma symmetric about the mid-plane.

BRIEF DESCRIPTION OF THE FIGURES

[0011] The accompanying drawings, which are included as part of the present specification, illustrate the presently example embodiments and, together with the general description given above and the detailed description of the example embodiments given below, serve to explain and teach the principles of the present invention.

[0012] **Figure 1** illustrates particle confinement in the present FRC system under a high performance FRC regime (HPF) versus under a conventional FRC regime (CR), and versus other conventional FRC experiments.

[0013] **Figure 2** illustrates the components of the present FRC system and the magnetic topology of an FRC producible in the present FRC system.

[0014] **Figure 3A** illustrates the basic layout of the present FRC system as viewed from the top, including the preferred arrangement of neutral beams, electrodes, plasma guns, mirror plugs and pellet injector.

[0015] **Figure 3B** illustrates the central confinement vessel as viewed from the top and showing the neutral beams arranged at an angle normal to the major axis of symmetry in the central confinement vessel.

[0016] **Figure 3C** illustrates the central confinement vessel as viewed from the top and showing the neutral beams arranged at an angle less than normal to the major axis of symmetry in the central confinement vessel and directed to inject particles toward the mid-plane of the central confinement vessel.

CLAIMS

What is claimed is:

1. A method for generating and stabilizing a field reversed configuration (FRC) plasma, comprising the steps of:

forming an FRC magnetic field about a rotating plasma in a confinement chamber to form an FRC plasma positioned along a longitudinal axis the confinement chamber adjacent a mid-plane of the confinement chamber,

generating an applied magnetic field within the chamber with quasi-dc coils extending about the chamber, and

stabilizing the FRC plasma in a radial direction normal to the longitudinal axis to position the FRC plasma axisymmetric about the longitudinal axis and in an axial direction along the longitudinal axis to position the FRC plasma symmetric about the mid-plane, wherein the step of stabilizing the FRC plasma in the radial direction includes tuning the applied magnetic field to induce radial stability and axial instability in the FRC plasma, wherein the step of stabilizing the FRC plasma in an axial direction includes creating first and second radial magnetic fields with first and second radial coils to interact with the FRC to induce axial stability in the FRC plasma.

2. The method of claim 1 wherein the first and second radial magnetic fields interact with the FRC to axially move the FRC plasma to position the FRC plasma symmetric about the mid-plane.

3. The method of claim 2 wherein the first and second radial magnetic fields are antisymmetric about the mid-plane.

4. The method of claim 3 wherein the first and second radial magnetic fields are generated due to the currents induced in counter directions in the first and second radial coils positioned about the confinement chamber.

5. The method of claims 1 through 4 wherein the step of stabilizing the FRC plasma includes monitoring the position of the plasma.

6. The method of claim 5 wherein the step of monitoring the position of the plasma includes monitoring magnetic measurements associated with the FRC plasma.

7. The method of claims 5 through 6 further comprising the step of measuring the current in the first and second radial coils.

8. The method of claim 7 further comprising the step of monitoring the velocity of the FRC plasma.

9. The method of claims 1 through 8 further comprising maintaining the FRC at or about a constant value without decay by injecting beams of fast neutral atoms from neutral beam injectors into the FRC plasma at an angle towards the mid-plane of the confinement chamber and injecting a compact toroid plasma into the FRC.

10. The method of claim 9 further comprising the step of generating a mirror magnetic field within opposing ends of the chamber with quasi-dc mirror coils extending about the opposing ends of the chamber.

11. The method of claims 1 through 10 wherein the step of the forming the FRC includes forming a formation FRC in a formation section coupled to an end of the confinement chamber and accelerating the formation FRC towards the mid-plane of the chamber to form the FRC.

12. The method of claim 11 wherein the step of the forming the FRC includes forming a second formation FRC in a second formation section coupled to a second end of the confinement chamber and accelerating the second formation FRC towards the mid-plane of the chamber where the two formation FRCs merge to form the FRC.

13. The method of claims 9 and 10 wherein the step of forming the FRC includes one of forming a formation FRC while accelerating the formation FRC towards the mid-plane of the chamber and forming a formation FRC then accelerating the formation FRC towards the mid-plane of the chamber.

14. The method of claim 12 further comprising the step of guiding magnetic flux surfaces of the FRC into diverters coupled to the ends of the first and second formation sections.

15. The method of claims 1 through 14 further comprising the step of conditioning the internal surfaces of the chamber, formation sections, and diverters with a gettering system.

16. The method of claim 15 wherein the gettering system includes one of a Titanium deposition system and a Lithium deposition system.

17. The method of claims 1 through 15 further comprising the step of axially injecting plasma into the FRC from axially mounted plasma guns.

18. The method of claims 1 through 17 further comprising the step of controlling the radial electric field profile in an edge layer of the FRC.

19. The method of claim 18 wherein the step of controlling the radial electric field profile in an edge layer of the FRC includes applying a distribution of electric potential to a group of open flux surfaces of the FRC with biasing electrodes.

20. A system for generating and stabilizing a field reversed configuration (FRC) plasma comprising

a confinement chamber,

first and second diametrically opposed FRC formation sections coupled to the confinement chamber, the formation section comprising modularized formation systems for generating an FRC and translating the FRC toward a midplane of the confinement chamber,

first and second divertors coupled to the first and second formation sections,

first and second axial plasma guns operably coupled to the first and second divertors, the first and second formation sections and the confinement chamber,

a plurality of neutral atom beam injectors coupled to the confinement chamber and oriented to inject neutral atom beams toward a mid-plane of the confinement chamber at an angle less than normal to a longitudinal axis of the confinement chamber,

a magnetic system comprising a plurality of quasi-dc coils positioned around the confinement chamber, the first and second formation sections, and the first and second divertors, first and second set of quasi-dc mirror coils positioned between the confinement chamber and the first and second

formation sections, and first and second mirror plugs position between the first and second formation sections and the first and second divertors,

a gettering system coupled to the confinement chamber and the first and second divertors,

first and second set of radial magnetic field coils configured to generate first and second radial magnetic fields within chamber, and

a control system operably coupled to the quasi-dc coils and the first and second radial magnetic field coils, the control system including a processor coupled to a non-transitory memory comprising a plurality of instruction that when executed causes the processor to tune the magnetic field generated by the plurality of quasi-dc coils and the first and second radial field coils, wherein the magnetic field generated by the plurality of quasi-dc coils is tuned to stabilize an FRC plasma in a radial direction normal to a longitudinal axis of the chamber to position the FRC plasma axisymmetric about the longitudinal axis and destabilize the FRC plasma in the axial direction along the longitudinal axis of the chamber, wherein the magnetic field generated by the first and second radial field coils is tuned to position the FRC plasma in an axial direction along the longitudinal axis to position the FRC plasma symmetric about the mid-plane.

21. The system of claim 20 wherein the system is configured to generate an FRC and maintain the FRC at or about a constant value without decay while neutral atom beams are injected into the FRC.

22. The system of claim 20 wherein the first and second radial magnetic fields are antisymmetric about the mid-plane.