MAGNETIC FIELD PLASMA CONFINEMENT FOR COMPACT FUSION POWER

TECHNICAL FIELD

[1] This disclosure generally relates to fusion reactors and more specifically to magnetic field plasma confinement for compact fusion power.

BACKGROUND

[2] Fusion power is power that is generated by a nuclear fusion process in which two or more atomic nuclei collide at very high speed and join to form a new type of atomic nucleus. A fusion reactor is a device that produces fusion power by confining and controlling plasma. Typical fusion reactors are large, complex, and cannot be mounted on a vehicle.

SUMMARY OF PARTICULAR EMBODIMENTS

[2a] According to a first aspect of the present invention, there is provided a fusion reactor comprising:

an enclosure comprising:

a centerline running down a center axis of the enclosure;

a first end and a second end that is opposite from the first end; and

a midpoint that is substantially equidistant between the first and second ends of the enclosure;

two internal magnetic coils suspended within the enclosure and centered on the centerline, the two internal magnetic coils each having a toroidal shape, the two internal magnetic coils comprising:

a first internal magnetic coil located between the midpoint and first end of the enclosure; and

a second internal magnetic coil located between the midpoint and the second end of the enclosure;

wherein the two internal magnetic coils each have a radius configured to balance the relative field strength between a plurality of point cusps and a plurality of ring cusps, wherein the plurality ring cusps includes one or more first ring cusps located between the internal magnetic coils, a second ring cusp located between the first end and the first internal magnetic coil, and a third ring cusp located between the second end and the second internal magnetic coil;

a plurality of encapsulating magnetic coils centered on the centerline, the encapsulating magnetic coils having a larger diameter than the internal magnetic coils, the plurality of encapsulating magnetic coils comprising:

at least two first encapsulating magnetic coils located between the midpoint and the first end of the enclosure; and

at least two second encapsulating magnetic coils located between the midpoint and the second end of the enclosure;

a center magnetic coil centered on the centerline and located proximate to the midpoint of the enclosure; and

two mirror magnetic coils centered on the centerline and comprising:

a first mirror magnetic coil located proximate to the first end of the enclosure; and

a second mirror magnetic coil located proximate to the second end of the enclosure;

wherein the magnetic coils are operable, when supplied with electrical currents, to form magnetic fields for confining plasma within the enclosure; and

wherein the center magnetic coil is disposed outside the interior of the enclosure.

[2b] According to a second aspect of the present invention, there is provided a fusion reactor comprising:

an enclosure comprising:

a first end and a second end that is opposite from the first end; and

a midpoint that is substantially equidistant between the first and second ends of the enclosure;

two internal magnetic coils suspended within the enclosure, each internal magnetic coil positioned on an opposite side of the midpoint of the enclosure from the other internal magnetic coil, wherein the two internal magnetic coils each have a radius configured to balance the relative field strength between a plurality of point cusps and a plurality of ring cusps, wherein the plurality ring cusps includes one or more first ring cusps located between the two internal magnetic coils, a second ring cusp located between the first end and a respective internal magnetic coil of the two internal magnetic coils disposed closest to the first end, and a third ring cusp located between the second end and a respective internal magnetic coil of the two internal magnetic coils disposed closest to the second end;

a center magnetic coil located proximate to the midpoint of the enclosure, the center magnetic coil being coaxial with the internal magnetic coils;

one or more encapsulating magnetic coils positioned on each side of the midpoint of the enclosure, each encapsulating magnetic coil being coaxial with the internal magnetic coils; and

two mirror magnetic coils coaxial with the internal magnetic coils, each mirror magnetic coil positioned on

an opposite side of the midpoint of the enclosure from the other mirror magnetic coil;

wherein the magnetic coils are operable, when supplied with electrical currents, to form magnetic fields for confining plasma within the enclosure; and

wherein the center magnetic coil is disposed outside the interior of the enclosure.

[2c] According to a third aspect of the present invention, there is provided a fusion reactor comprising:

two internal magnetic coils suspended within an enclosure;

a center magnetic coil coaxial with the two internal magnetic coils and located proximate to a midpoint of the enclosure;

a plurality of encapsulating magnetic coils coaxial with the internal magnetic coils, the encapsulating magnetic coils being operable to preserve the magnetohydrodynamic (MHD) stability of the fusion reactor by maintaining a magnetic wall that prevents plasma within the enclosure from expanding; and

wherein the center magnetic coil is disposed outside the interior of the enclosure;

two mirror magnetic coil coaxial with the internal magnetic coils,

wherein the center magnetic coil and the encapsulating magnetic coils are external to the enclosure,

wherein the enclosure comprises a first end and a second end that is opposite from the first end; and

wherein the two internal magnetic coils suspended within the enclosure comprises:

a first internal magnetic coil located between the center magnetic coil and the first end of the enclosure; and

a second internal magnetic coil located between the center magnetic coil and the second end of the enclosure;

the plurality of encapsulating magnetic coils comprises:

a first set of two encapsulating magnetic coils located between the first internal magnetic coil and the first end of the enclosure; and

a second set of two encapsulating magnetic coils located between the second internal magnetic coil and the second end of the enclosure; and

the two mirror magnetic coils comprises:

a first mirror magnetic coil located proximate to the first end of the enclosure; and

a second mirror magnetic coil located proximate to the second end of the enclosure; and

wherein the two internal magnetic coils each have a radius configured to balance the relative field strength between a plurality of point cusps and a plurality of ring cusps, wherein the plurality ring cusps includes one or more first ring cusps located between the internal magnetic coils, a second ring cusp located between the first end and the first internal magnetic coil, and a third ring cusp located between the second end and the second internal magnetic coil.

[3] According to one embodiment, a fusion reactor includes two internal magnetic coils suspended within an enclosure, a center magnetic coil coaxial with the two internal magnetic coils and located proximate to a midpoint of the enclosure, a plurality of encapsulating magnetic coils coaxial with the internal magnetic coils, and two mirror magnetic coil coaxial with the internal magnetic coils. The encapsulating magnetic coils preserve the magnetohydrodynamic (MHD) stability of the fusion reactor by maintaining a magnetic wall that prevents plasma within the enclosure from expanding.

[4] Technical advantages of certain embodiments may include providing a compact fusion reactor that is less

WHAT IS CLAIMED IS:

1. A fusion reactor comprising:

an enclosure comprising:

a centerline running down a center axis of the enclosure;

a first end and a second end that is opposite from the first end; and

a midpoint that is substantially equidistant between the first and second ends of the enclosure;

two internal magnetic coils suspended within the enclosure and centered on the centerline, the two internal magnetic coils each having a toroidal shape, the two internal magnetic coils comprising:

a first internal magnetic coil located between the midpoint and first end of the enclosure; and

a second internal magnetic coil located between the midpoint and the second end of the enclosure;

wherein the two internal magnetic coils each have a radius configured to balance the relative field strength between a plurality of point cusps and a plurality of ring cusps, wherein the plurality ring cusps includes one or more first ring cusps located between the internal magnetic coils, a second ring cusp located between the first end and the first internal magnetic coil, and a third ring cusp located between the second end and the second internal magnetic coil;

a plurality of encapsulating magnetic coils centered on the centerline, the encapsulating magnetic coils having a larger diameter than the internal magnetic coils, the plurality of encapsulating magnetic coils comprising:

at least two first encapsulating magnetic coils located between the midpoint and the first end of the enclosure; and

at least two second encapsulating magnetic coils located between the midpoint and the second end of the enclosure;

a center magnetic coil centered on the centerline and located proximate to the midpoint of the enclosure; and

two mirror magnetic coils centered on the centerline and comprising:

a first mirror magnetic coil located proximate to the first end of the enclosure; and

a second mirror magnetic coil located proximate to the second end of the enclosure;

wherein the magnetic coils are operable, when supplied with electrical currents, to form magnetic fields for confining plasma within the enclosure; and

wherein the center magnetic coil is disposed outside the interior of the enclosure.

2. The fusion reactor of Claim 1, wherein the electrical currents supplied to the magnetic coils comprise:

a plurality of first electrical currents flowing in a first direction through the plurality of encapsulating magnetic coils, the center magnetic coil, and the two mirror magnetic coils; and

a plurality of second electrical currents flowing in a second direction that is opposite from the first direction through the two internal magnetic coils.

3. The fusion reactor of Claim 1, wherein the plurality of encapsulating magnetic coils are operable to preserve the magnetohydrodynamic (MHD) stability of the fusion reactor by maintaining a magnetic wall that prevents the plasma from expanding.

4. The fusion reactor of Claim 1, wherein the enclosure comprises an outer blanket and an inner blanket, the outer blanket comprising steel or iron and the inner blanket comprising beryllium or a mixture of lithium fluoride (LiF) and beryllium fluoride (BeF2)(FLiBe).

5. The fusion reactor of Claim 1, wherein each of the two internal magnetic coils comprises:

a core comprising a plurality of coil windings;

an inner shield surrounding the core;

a protective layer surrounding the inner shield; and

an outer shield surrounding the protective layer.

6. A fusion reactor comprising:

an enclosure comprising:

a first end and a second end that is opposite from the first end; and

a midpoint that is substantially equidistant between the first and second ends of the enclosure;

two internal magnetic coils suspended within the enclosure, each internal magnetic coil positioned on an opposite side of the midpoint of the enclosure from the other internal magnetic coil, wherein the two internal magnetic coils each have a radius configured to balance the relative field strength between a plurality of point cusps and a plurality of ring cusps, wherein the plurality ring cusps includes one or more first ring cusps located between the two internal magnetic coils, a second ring cusp located between the first end and a respective internal magnetic coil of the two internal magnetic coils disposed closest to the first end, and a third ring cusp located between the second end and a respective internal magnetic coil of the two internal magnetic coils disposed closest to the second end;

a center magnetic coil located proximate to the midpoint of the enclosure, the center magnetic coil being coaxial with the internal magnetic coils;

one or more encapsulating magnetic coils positioned on each side of the midpoint of the enclosure, each encapsulating magnetic coil being coaxial with the internal magnetic coils; and

two mirror magnetic coils coaxial with the internal magnetic coils, each mirror magnetic coil positioned on an opposite side of the midpoint of the enclosure from the other mirror magnetic coil;

wherein the magnetic coils are operable, when supplied with electrical currents, to form magnetic fields for confining plasma within the enclosure; and

wherein the center magnetic coil is disposed outside the interior of the enclosure.

7. The fusion reactor of Claim 6, wherein:

the two internal magnetic coils comprises:

a first internal magnetic coil located between the center magnetic coil and the first end of the enclosure; and

a second internal magnetic coil located between the center magnetic coil and the second end of the enclosure;

the one or more encapsulating magnetic coils positioned on each side of the midpoint of the enclosure comprises:

a first set of two encapsulating magnetic coils located between the first internal magnetic coil and the first end of the enclosure; and

a second set of two encapsulating magnetic coils located between the second internal magnetic coil and the second end of the enclosure; and

the two mirror magnetic coils comprises:

a first mirror magnetic coil located proximate to the first end of the enclosure; and

a second mirror magnetic coil located proximate to the second end of the enclosure.

8. The fusion reactor of Claim 6, wherein:

the two internal magnetic coils each comprises a toroidal shape; and

the encapsulating magnetic coils comprise a substantially square cross section.

9. The fusion reactor of Claim 6, wherein the enclosure comprises an outer blanket and an inner blanket, the outer blanket comprising steel or iron and the inner blanket comprising beryllium or a mixture of lithium fluoride (LiF) and beryllium fluoride (BeF2)(FLiBe).

10. The fusion reactor of Claim 6, wherein each of the two internal magnetic coils comprises:

a core comprising a plurality of coil windings;

an inner shield surrounding the core;

a protective layer surrounding the inner shield; and

an outer shield surrounding the protective layer.

11. The fusion reactor of Claim 6, wherein the electrical currents supplied to the magnetic coils comprise:

a plurality of first electrical currents flowing in a first direction through the encapsulating magnetic coils and the two mirror magnetic coils; and

a plurality of second electrical currents flowing in a second direction that is opposite from the first direction through the two internal magnetic coils.

12. The fusion reactor of Claim 6, wherein the encapsulating magnetic coils are external to the enclosure.

13. A fusion reactor comprising:

two internal magnetic coils suspended within an enclosure;

a center magnetic coil coaxial with the two internal magnetic coils and located proximate to a midpoint of the enclosure;

a plurality of encapsulating magnetic coils coaxial with the internal magnetic coils, the encapsulating magnetic coils

being operable to preserve the magnetohydrodynamic (MHD) stability of the fusion reactor by maintaining a magnetic wall that prevents plasma within the enclosure from expanding; and

wherein the center magnetic coil is disposed outside the interior of the enclosure;

two mirror magnetic coil coaxial with the internal magnetic coils,

wherein the center magnetic coil and the encapsulating magnetic coils are external to the enclosure,

wherein the enclosure comprises a first end and a second end that is opposite from the first end; and

wherein the two internal magnetic coils suspended within the enclosure comprises:

a first internal magnetic coil located between the center magnetic coil and the first end of the enclosure; and

a second internal magnetic coil located between the center magnetic coil and the second end of the enclosure;

the plurality of encapsulating magnetic coils comprises:

a first set of two encapsulating magnetic coils located between the first internal magnetic coil and the first end of the enclosure; and

a second set of two encapsulating magnetic coils located between the second internal magnetic coil and the second end of the enclosure; and

the two mirror magnetic coils comprises:

a first mirror magnetic coil located proximate to the first end of the enclosure; and

a second mirror magnetic coil located proximate to the second end of the enclosure; and

wherein the two internal magnetic coils each have a radius configured to balance the relative field strength between a plurality of point cusps and a plurality of ring cusps, wherein the plurality ring cusps includes one or more first ring cusps located between the internal magnetic coils, a second ring cusp located

between the first end and the first internal magnetic coil, and a third ring cusp located between the second end and the second internal magnetic coil.

14. The fusion reactor of Claim 13, wherein the magnetic coils are operable, when supplied with electrical currents, to form magnetic fields for confining plasma within the enclosure, the electrical currents comprising:

a plurality of first electrical currents flowing in a first direction through the encapsulating magnetic coils, the center magnetic coil, and the two mirror magnetic coils; and

a plurality of second electrical currents flowing in a second direction that is opposite from the first direction through the two internal magnetic coils.

15. The fusion reactor of Claim 13, wherein:

the two internal magnetic coils each comprises a toroidal shape; and

the plurality of encapsulating magnetic coils each comprises a substantially square cross section.

16. The fusion reactor of Claim 13, wherein the enclosure comprises an outer blanket and an inner blanket, the outer blanket comprising steel or iron and the inner blanket comprising beryllium or a mixture of lithium fluoride (LiF) and beryllium fluoride (BeF2)(FLiBe).

17. The fusion reactor of Claim 13, wherein each of the two internal magnetic coils comprises:

a core comprising a plurality of coil windings;

an inner shield surrounding the core;

a protective layer surrounding the inner shield; and

an outer shield surrounding the protective layer.

18. The fusion reactor of Claim 1, wherein the two internal magnetic coils are surrounded by, and shielded from, the plasma and suspended within the enclosure by at least one support.

19. The fusion reactor of Claim 6, wherein the two internal magnetic coils are surrounded by, and shielded from, the plasma and suspended within the enclosure by at least one support.

20. The fusion reactor of Claim 13, wherein a direction of current in the center magnetic coil, the plurality of encapsulating magnetic coils, and the two mirror magnetic coils is the same and wherein a direction of current in the two internal magnetic coils is opposite the direction of current in center magnetic coil, the plurality of encapsulating magnetic coils, and the two mirror magnetic coils.

21. The fusion reactor of Claim 13, wherein the two internal magnetic coils are surrounded by, and shielded from, the plasma and suspended within the enclosure by at least one support.

22. The fusion reactor of Claim 13, wherein the two mirror magnetic coils comprise first and second mirror magnetic coils disposed on opposite sides of the center magnetic coil.