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Looperator – Nuclear Fusion Reactor with Spherical Magnetic Field – Harnessing Plasma Confinement in a Fusion Reactor

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Abstract

With its potential to provide clean, abundant energy under minimal environmental impact, thermo-nuclear fusion promises to revolutionize the energy sector. Today's thermonuclear fusion projects follow two types of reactors, Tokamak [1] and Stellarator [2]. Both are very promising, yet they present a few challenges to resolve to achieve long-term stable confinement. The present article describes the "Looperator" [3], a novel concept that lays ground to stable confinement of the reactor's plasma volume. It states that a spheric magnetic field combined with the intrinsic quantum mechanical properties of electrons and ions in its plasma eliminate fusion reactor instability due to harmonic motion of its constituting particles. The article describes a modular structure with a constellation of electromagnetic elements that generate the magnetic field creating a plasma volume with a double-helical shape. The fourfold reversal of particle spin within one revolution of the total plasma volume maintains electrons and ions tightly bound to their orbital trajectories. The total number gyration radii of the charged ions in motion around their respective magnetic field lines determines the total number of transformation spheres that exist within the given diameter of the tubular plasma volume.

This novel approach exploring quantum mechanical spin and angular momentum of particles within a spherical magnetic field promises a breakthrough in resolving plasma confinement limitations in fusion reactors. The reactor features a spherical magnetic field derived from the Poincaré group of the Lorentz transformation, translation and rotation, generating a double-helix configuration of the plasma volume.

Keywords: Fusion Reactor, Power Generation, Quantum Mechanics, Electromagnetism, Fluid Dynamics, Geometric Transformation, Poincaré Group.

State-of-the-Art

Today, Fusion reactors of types Tokamak as well as Stellarator present neoclassical tearing modes (turbulences) that constrain power generation continuity, leading to limited plasma confinement time forcing premature reactor shutdown [1, 2]. Multiple factors combined lead to harmful magneto-hydrodynamic turbulence in the plasma that is complex to control at macroscopic level. Scientists are seeking solutions to limit turbulence by applying AI methods, e.g., to model the complex MHD processes in the plasma to understand and gain control over the unwanted occurring modes [3, 4].

Structure of the "Looperator"

Figure 1 presents three views of the "Looperator" concept.

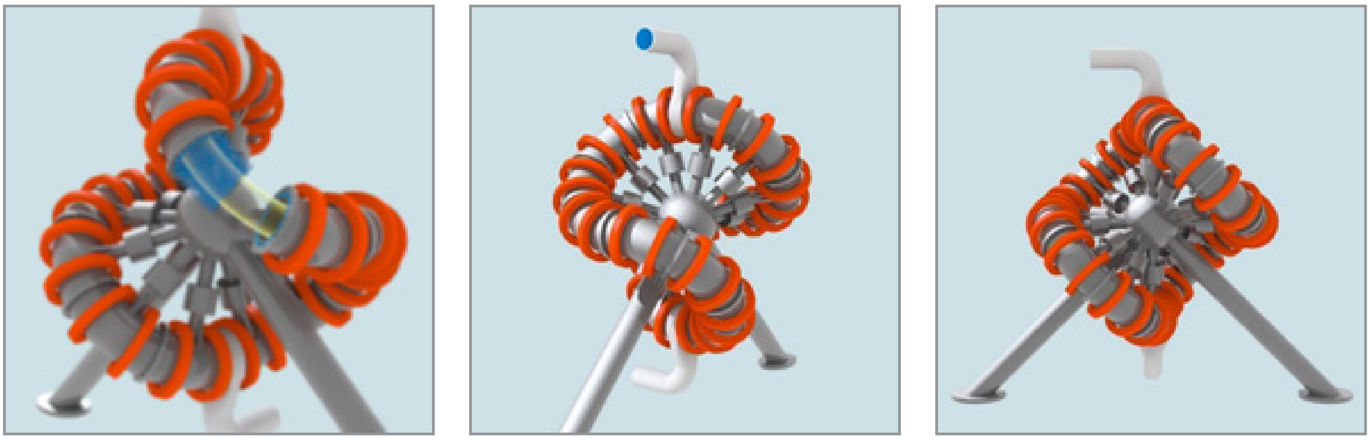

Figure 1: Schematic design structure of the "Looperator"

The core structure of the "Looperator" is a double helical tubular plasma vessel composed of four equally sized arcs, seamlessly connected to form an infinite loop.

The tubular plasma vessel consists of a set of identical vessel modules with circular or oval cross-section. These modules together form the containment around the central magnetic field line, with each module positioned between an inner and outer radius of the spherical magnetic field. The modules are joined to form four arc-shaped sections. The double-helix configuration ensures that the plasma volume follows the shape of the plasma vessel, maintaining a distance from the inner shell.

Helmholtz coils are positioned along the plasma vessel and are spaced radially and longitudinally by sector angles. The central magnetic field line is surrounded by several concentric layers of eccentric magnetic field lines, each defined by analogous vertices and connection points. Once the plasma is ignited, the electrons and protons of deuterium and tritium begin to separate from each other, driven by the Lorentz force generated by the Helmholtz coils. This force controls both the magneto-hydro-dynamic flow and the orientation of the angular momentum axis of the particles, and its plane.

The two periods of the ring oscillation are divided into two distinct phases by a zero line between opposing connection points of the central magnetic field line. This separation results in different layer-specific frequencies for the ring oscillations. The frequency band varies from tens of Hz on the exterior of the plasma volume to several kHz near the central magnetic field.

With the quantum mechanically effective induction system, the fusion reactor can achieve stable plasma confinement with charged particles (quantum number 1/2) traveling along magnetic field lines. The plasma vessel diameter required for ignition can be as small as 0.30 to 0.40 meters, enabling the development of compact fusion reactors.

Function of the "Looperator"

Figure 2 a) and b) present schematically a few lines visualizing the orbital paths of particles along one magnetic layer.

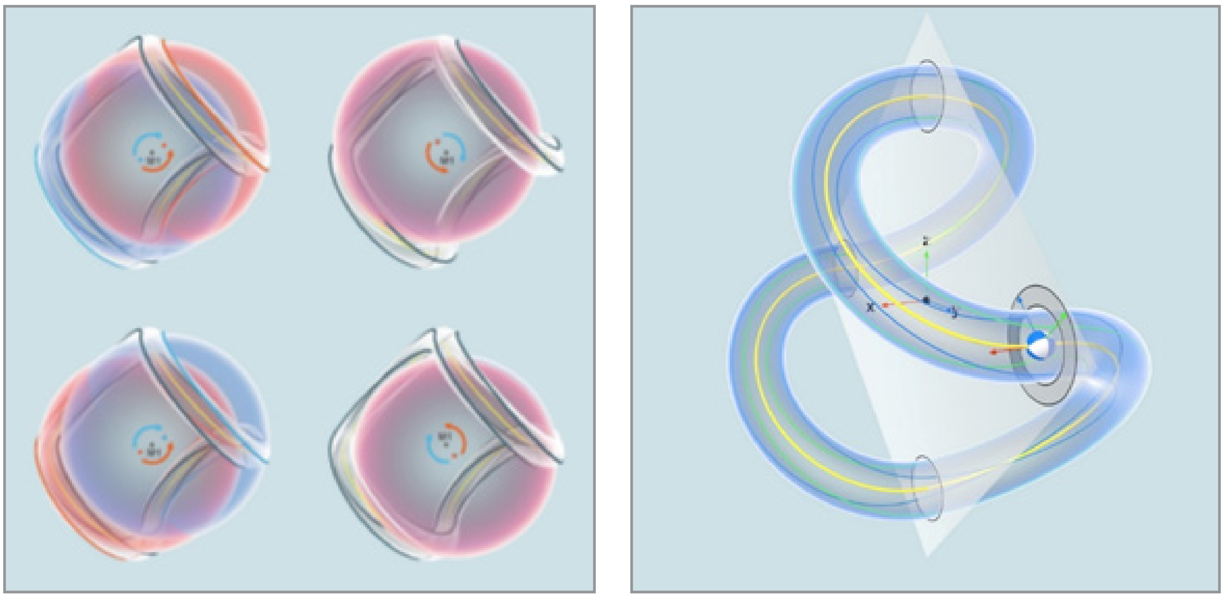

Figure 2: a) and b). Schematic view of magnetic field lines of the "Looperator".

The spherical magnetic field provides a spherical model for electromagnetically induced ring oscillations within concentric magnetic field layers, which enables stable dynamic equilibrium and long-term plasma confinement of electrons and ions in the plasma vessel of the fusion reactor.

Lorentz transformation, translation, and rotation form a Poincaré group describing a spherical model that defines the motion regime.

Quantum dynamics of fermions, electrons and ions, lead to the harmonic motion of the particles within the plasma volume under the influence of the magnetic field.

Geometric analysis shows that within each concentric magnetic field layer of the tubular plasma volume, particles with a spin quantum number of 1/2 exhibit uniform orbital motion around transformation spheres of a single radius.

Magnetic field lines in the "Looperator" maintain a uniform length and lie on the surface of a corresponding transformation sphere with constant radius around a central point in the fusion reactor. The transformation spheres align with the properties defined by the Poincaré group, which governs the symmetries of spacetime in relativistic mechanics. This uniform spherical arrangement is the key distinction from the toroidal shapes of tokamaks and stellarators, where magnetic field lines are confined within doughnut-shaped or twisted geometries, leading to potential instabilities and voids.

Hence, the embodiment of the Poincaré group in the transformation spheres demonstrates the deeper connection between the magnetic field lines of the "Looperator" and the symmetries of general relativity. The Poincaré group, which includes rotations, translations, and Lorentz transformations, encapsulates all possible transformations in relativistic mechanics, reinforcing the spherical geometry of the magnetic field lines as an optimal configuration for maintaining equilibrium in the high-energy environment of a fusion reactor.

Equilibrium of Plasma and Stability

Figure 3 a) and b) visualize the angular rotation of the momentum exercised on the electrons and ions in their motion along the magnetic field lines.

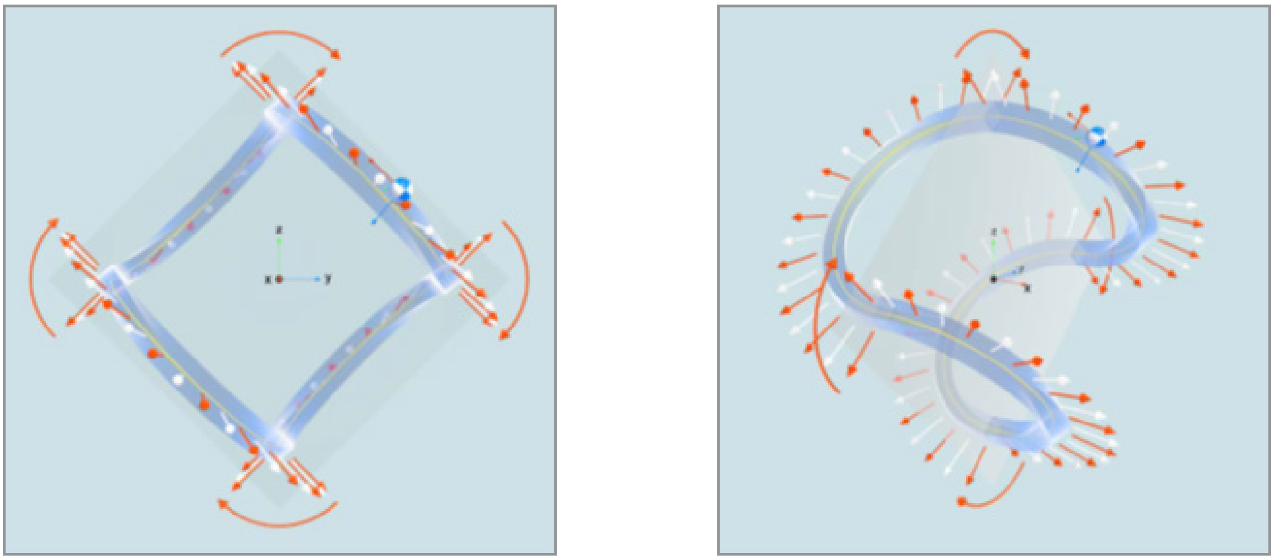

Figure 3: a) and b). Angular momentum shifts at double helix vertices visualized.

By the fourfold $\pi/2$ rotation of the momentum within one revolution at the intersections of the arcs building the double helix the total plasma is subject to the twisting motion stabilizing it and preventing harmful turbulences.

The hypothesis suggests that the equilibrium of angular momentum for rotating particles is governed by the configuration of four equal semi-circular arcs of the central magnetic field line, arranged symmetrically with equal radius around the center of the fusion reactor. In the plasma state, the charged particles undergo a quantum mechanical process in which the direction of rotation reverses four times between the connecting points of the central magnetic field line. This fourfold reversal results in an angular sum of 720 degrees, which ensures the orbital stability of the particles the two halves of a period of the ring oscillation. The torques exerted on the particles cancel each other out, leading to a balanced system. The particles complete one full rotation around their own angular momentum axis, resulting in an angular sum of 360 degrees.

Thus, the equilibrium of the magnetic forces within the plasma volume is achieved through the utilization of the particles' intrinsic spin. The formation of destructive turbulence, which arises from the gyral drift of electrons and ions, is prevented by altering the direction of spin four times within one orbital revolution. This spin reversal occurs within fractions of a femtosecond, effectively preventing uncontrolled gyral drifts caused by spin-induced precession.

By implementing this quantum mechanical control mechanism, the twisting of the magnetic field lines is facilitated, allowing the particles to return to their original spin state along paths of equal length in both halves of the mirror-symmetric endless loops. The necessary magnetic field is generated by the Helmholtz coils, which produce a central magnetic field line surrounded by a multitude of eccentric magnetic field lines. Due to the equilibrium of the Lorentz forces induced by the Helmholtz coils in the mirror-image halves of the double helix, the eccentric magnetic field lines spontaneously wrap around the central magnetic field line in multiple layers, forming endless loops. This occurs naturally, without the need for additional intervention, in contrast to current experimental setups that require extra coils for plasma twisting or other manipulations.

The two halves of the endless loops are of equal length, with charged particles orbiting their respective midpoints in the individual layers of the plasma volume along identical path lengths. The Helmholtz coils, arranged concentrically at regular intervals around the central magnetic field line and following the course of a double helix, enclose the plasma vessel. This arrangement facilitates the generation of spherical ring oscillations within the plasma volume.

Main Characteristics of the "Looperator":

Scalability Through Modular Structural Design

The plasma vessel of the "Looperator" consists of identical concentric modules fixed together to form four arc-shaped units joined at four intersections. A structure of beams mounted on a stable foundation supports the plasma vessel. Fuel injection and slag evacuation systems are placed at locations with minimum impact on the equilibrium of the plasma. Heating and cooling systems are integrated in their respective modules ensuring ease of maintenance.

Track Fidelity and Equilibrium Through Spin Rotation

Harmonic spin rotation at arc intersections ensures minimization of particle drift and leads to long-term plasma equilibrium.

Energy Exchange Through Conduction

Energy extraction through heat exchanger integrated in the plasma vessel wall with connection to steam turbines for electric power generation.

Conclusion

In the above article we highlighted the major limitation of state-of-the-art fusion reactors of type Tokamak and Stellarator. We presented a novel fusion reactor structure and particle modulation concept that minimizes particles drift thus eliminating unwanted turbulences in the plasma. We state that the "Looperator" concept will lead to stable confinement of plasma in future fusion reactors inviting scientists and engineers to practical exploration and validation [5, 6].

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