Print - ISSN : 2319–9814
Online - ISSN : 2319–9822

Journal of
Space Exploration

WWW.MEHTAPRESS.COM

Full Paper

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Received: April 30, 2013
Accepted: June 24, 2013
Published: July 29, 2013

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Reducing fusion plasma confinement energy with specially conditioned electromagnetic fields

Abstract

A central fusion physics problem is strong repulsion between fusion fuel ions that must be overcome by strong confining fields that must drive ions close enough so their nuclear fusion can occur. The ions finally experience attraction when their separation becomes shorter than the short ranges of ion-attracting SU(3) strong nuclear fields, and ion fusion then occurs. In this respect, Barrett shows the possibility of conditioning ordinary U(1) electromagnetic (EM) fields with the same SU(2) and SU(3) Lie Symmetry as the SU(2) and SU(3) nuclear fields that accomplish hydrogen fusion in the Sun with less pressure and temperature than is required in fusion reactors on Earth. This has suggested the possibility of SU(2) and SU(3) EM fields causing terrestrial fusion less confinement energy than ordinary U(1) EM fields currently require for fusion. And, this possibility of SU(2) or SU(3) EM fields enabling terrestrial fusion with less confinement energy than U(1) EM fields currently require, is briefly explored for some promising nuclear fusion reactor designs.

Keywords

Coulomb repulsion; IEC fusion; SU(2) symmetry fields; SU(3) symmetry fields.

INTRODUCTION

Nuclear fusion of hydrogen occurs in our Sun because of charge-changing actions by SU(2) weak nuclear fields and ion-attracting actions by SU(3) strong nuclear fields. And accomplishing such relatively clean, safe fusion on Earth and in space was once believed Earth's best chance of meeting meet it's future terrestrial and space-flight needs. But, in space and on Earth a formidable fusion barrier must be overcome. This is enormous coulomb repulsion between fusion ions, which must be overcome by enormous levels of ion-compressing force by strong electrical or magnetic fields in fusion reactors. And so far, this formidable barrier has prevented any real success by any of the many nuclear fusion systems that have been proposed and built in the past 50 years.

The general historical trend in fusion energy development has been continual striving for more powerful fields for higher force for higher compression of fusion plasmas. Unfortunately, higher ion compressions tend to be accompanied by unexpected plasma behaviors or instabilities that negate some benefits of the increased input field power and force. So, progress is slow as unpleasant surprises usually accompany each increase in fusion power. Thus, national or international fusion research reactors (which receive most fusion funding) are now so large and expensive that many doubt that fusion can compete with renewable energies like solar and wind.

Short range, ion-attracting SU(3) strong nuclear fields can't cause ion fusions until the ions are driven close together by very strong electric (*E)*, or magnetic (*B*) or electromagnetic (EM) fields. Such strong *E* or B fields are not needed for hydrogen fusion in the Sun, even though pressures and temperatures in the Sun's core are too low for strongly-repelling hydrogen ions to be driven close enough together to be fused by ion attracting SU(3) nuclear fields. But quark-mutating actions in SU(2) weak nuclear fields convert some hydrogen protons into neutrons. So, strongly repelling proton-pairs transform into almost neutral proton-neutron pairs that are easily fused by ion-attracting SU(3) nuclear fields into deuterium ions. And these ions start a fusion chain of reactions that convert hydrogen into Helium 3 in the Sun and emit charged particles and solar radiation from its corona.

In this respect, Barrett[1] shows the possibility of transforming ordinary U(1) EM fields into EM fields with the same Lie Group symmetry as the SU(2) and SU(3) nuclear fields that enable successful nuclear fusion in the Sun. This led the Author, T. Barrett, G.Miley to explore the possibility of fusion ions possessing less charge differential or experiencing less repulsion if they are confined by higher symmetry SU(2) or SU(3) EM fields in fusion reactors[2]. And this would contrast with today's situation where ions possess more charge differential and experience more repulsion when confined by ordinary, lower symmetry U(1) EM fields in fusion reactors.

If SU(2) or SU(3) EM fields could reduce ion repulsion, less fusion reactor input power, mass, size and cost would be neded. In this respect[2], indicated the possibility of 10-15 fold reduction in input field power for fusion if SU(2) or SU(3) EM fields could significantly reduce fusion ion repulsion at separation distances 2-3 orders of magnitude longer than the 10^{-15} m distances needed for final ion fusion by SU(3) strong nuclear force. This follow-on paper continues exploring use of SU(2) and SU(3) EM fields to reduce fusion ion repulsion.

RESULTS AND DISCUSSION

SU(2) and SU(3) EM radiation fields

Ordinary electric (E) and magnetic (B) fields are usually described by vectors and Abelian algebra and they develop in space and time in accordance with the four Maxwell Equations formulated by Clerk Maxwell about 140 years ago. In the 1950's Feynman and others made Maxwell's EM theory compatible with quantum theory and special relativity. Quantum Electrodynamics was the result. It precisely predicts interactions between matter and radiation. But, Maxwell's classical theory and equations have been used, essentially unchanged, in the design of all electromagnetic devices since its inception. Maxwell theory describes electromagnetism in terms of: electric field strength (E), magnetic flux density (B), and total current density (J). Electric and magnetic fields develop and propagate in accordance with the 4 Maxwell Equations shown in TABLE 1. Its fields embody U(1) Lie Group symmetry, and E an B vector fields are sometimes defined mathematically in terms of non-physical potentials. They are usually called the magnetic vector potential (A) and electric scalar potential (φ).

TABLE 1 : Maxwell's equations for U(1) symmetry electromagnetic vector fields

Gauss' Law	$\nabla \bullet \boldsymbol{E} = \boldsymbol{J}_0$
Ampere's Law	$\dfrac{\partial \boldsymbol{E}}{\partial t} - \nabla \times \boldsymbol{B} - \boldsymbol{J} = 0$
Coulomb's Law	$\nabla \bullet \boldsymbol{B} = 0$
Faraday's Law	$\nabla \times \boldsymbol{E} + \dfrac{\partial \boldsymbol{B}}{\partial t} = 0$

$$\boldsymbol{E} = -\frac{\partial A}{\partial t} - \nabla\phi, \quad \boldsymbol{B} = \nabla \times \boldsymbol{A}$$

Barrett[1] has used group and gauge theory and topology to develop SU(2) EM field theory, and TABLE 2 shows the Expanded Maxwell Equations associated with SU(2) EM fields. Ordinary U(1): J, E and B vector fields are transformed into SU(2): J, E and B tensor fields that are described by Non-abelian algebra, while the magnetic vector potential (which is non-physical in U(1) electromagnetism) is transformed into a physical A tensor field. And SU(2) EM, Maxwell Equations have additional terms that involve A tensor fields interacting with E and B tensor fields in various ways. SU(2) EM fields are not primordial and act over much longer distances than SU(2) nuclear fields do. Also, SU(2) EM fields are mediated by a single boson (a photon) while SU(2) nuclear fields are mediated by 3 bosons. On the other hand, mediating actions associated with the 3 different couplings of A, E, and B fields with each other (as is shown in the SU(2) Maxwell Equations of TABLE 2) may be somewhat analogous to mediating actions associated with the W^+, W^-, Z bosons of SU(2) nuclear fields.

TABLE 2 : Extended Maxwell's equations for SU(2) symmetry electromagnetic tensor fields

$\nabla \bullet \boldsymbol{E} = \boldsymbol{J}_0 - iq(\boldsymbol{A} \bullet \boldsymbol{E} - \boldsymbol{E} \bullet \boldsymbol{A})$
$\dfrac{\partial \boldsymbol{E}}{\partial t} - \nabla \times \boldsymbol{B} - \boldsymbol{J} + iq[\boldsymbol{A}_0, \boldsymbol{E}] - iq(\boldsymbol{A} \times \boldsymbol{B} - \boldsymbol{B} \times \boldsymbol{A}) = 0$
$\nabla \bullet \boldsymbol{B} + iq(\boldsymbol{A} \bullet \boldsymbol{B} - \boldsymbol{B} \bullet \boldsymbol{A}) = 0$
$\nabla \times \boldsymbol{E} + \dfrac{\partial \boldsymbol{B}}{\partial t} + iq[\boldsymbol{A}_0, \boldsymbol{B}] = iq(\boldsymbol{A} \times \boldsymbol{E} - \boldsymbol{E} \times \boldsymbol{A}) = 0$

Barrett has made a small start towards SU(3) electromagnetic field theory. SU(3) electromagnetic theory is, of course, more complex than SU(2) EM theory - with SU(3) EM fields embodying higher order tensors and higher order A, E, B couplings than SU(2) EM. But since SU(3) EM theory requires much more development, this paper focuses mainly on descriptions and hardware experiment possibilities for SU(2) EM radiation fields.

TABLE 2 shows SU(2) EM couplings between *A* and *E* and *A* and *B* fields that do not occur in ordinary U(1) EM. Thus, forces exerted on moving charged particles in an U(2) EM field can be different than forces on the particles when moving in an ordinary U(1) EM field. This is shown in TABLE 3 which is taken from[1]. Shown is Lorentz force exerted on a moving charged particle in an SU(2) *E* and SU(2) *B* tensor field - as compared to Lorentz force exerted on the particle in an ordinary U(1) *E* and *B* vector field. Here, U(1) Lorentz Force is described by *E* and *B* fields and *A* vector potentials; while SU(2) Lorentz force is described by E and B and A tensor fields. Differences in numbers of Lorentz Force terms and their different vector and tensor natures imply that an SU(2) EM field can exert a Lorentz force of different intensity and direction on moving fusion ions, compared to Lorentz Force exerted on the fusion ions by an ordinary U(1) EM field of equal strength.

Barrett[3] has identified one way of radiating SU(2) EM field energy. It is by flowing alternating current at radio frequencies through a toroid coil at one of the possible resonant frequencies that are possible for a given toroid and coil configuration. Figure 1 shows the two A field patterns that form about a transmitting toroid. They are viwed as two U(1) *A* vector potential patterns (φ_1 and φ_2) which overlap in polarity. A resonant frequency occurs when when the difference (φ_1-φ_2) in overlapping vector potential amplitude maximizes for the toroid at one of its alternating current frequencies. A single SU(2) tensor field forms about the toroid at this frequency. And, as indicated, many resonant frequencies are possible for the toroid and its coils in Figure 1.

TABLE 3 : Lorentz forces acting on moving charged particles

U(1) Lorentz Force	$\mathscr{F} = e\mathbf{E} + ev \times \mathbf{B} = e\left(-\frac{\partial \mathbf{A}}{\partial t} - \nabla\phi\right) + ev \times \left((\nabla \times \mathbf{A})\right)$
SU(2) Lorentz Force	$\mathscr{F} = e\mathbf{E} + ev \times \mathbf{B} = e\left(-(\nabla \times \mathbf{A}) - \frac{\partial \mathbf{A}}{\partial t} - \nabla\phi\right) + ev \times \left((\nabla \times \mathbf{A}) - \frac{\partial \mathbf{A}}{\partial t} - \nabla\phi\right)$

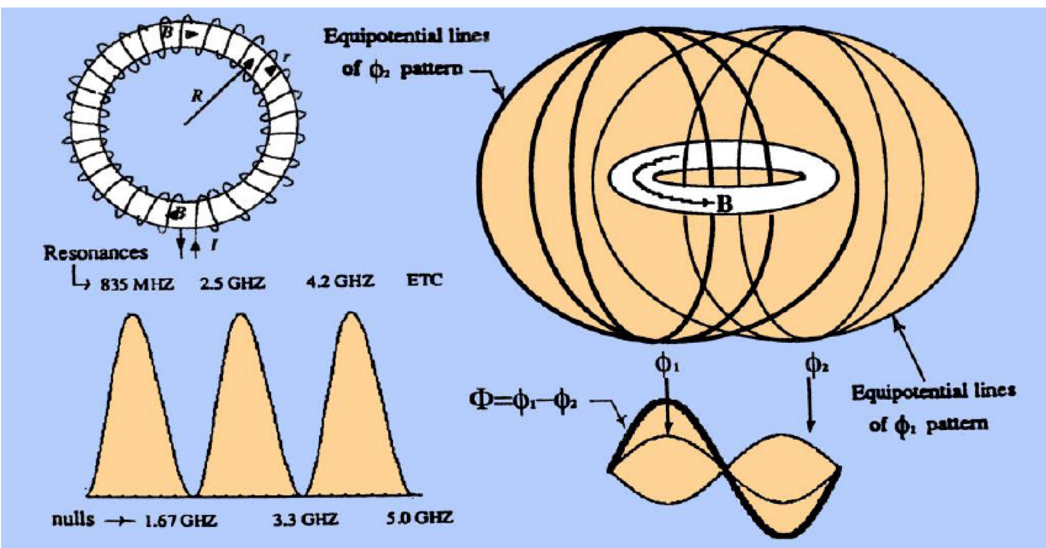

Figure 1 : A vector potential patterns generated by alternating current flow in toroid coils. Phase difference (φ_1-φ_2) of the patterns maximize when a "resonant" frequency is reached. Shown are 3 different resonant frequencies for a given toroid and coil geometry, and A slightly different SU(2) EM field will be emitted at each different resonant frequency.

Toroid testing at radio frequencies[4] was not exhaustive enough to conclusively prove that SU(2) EM fields were emitted at resonant frequencies But the measured resonant frequencies were in good agreement with those predicted from Barrett's SU(2) theory work. And, more intense and highly focused magnetic fields were always measured above and below surfaces of tested toroids when the toroids were radiatiting at a resonant frequency.

Barrett (1) has identified another way of generating SU(2) EM field energy. Description of this way is taken from pages 46 and 61 of[5]. It is shown in Figure 2, which uses a waveguide paradigm to show oscillating U(1) EM wave energy being transformed into SU(2)

EM wave energy by phase and polarization modulation. Here, input wave energy enters from left, is polarization-modulated, and is emitted as SU(2) wave energy to the right.

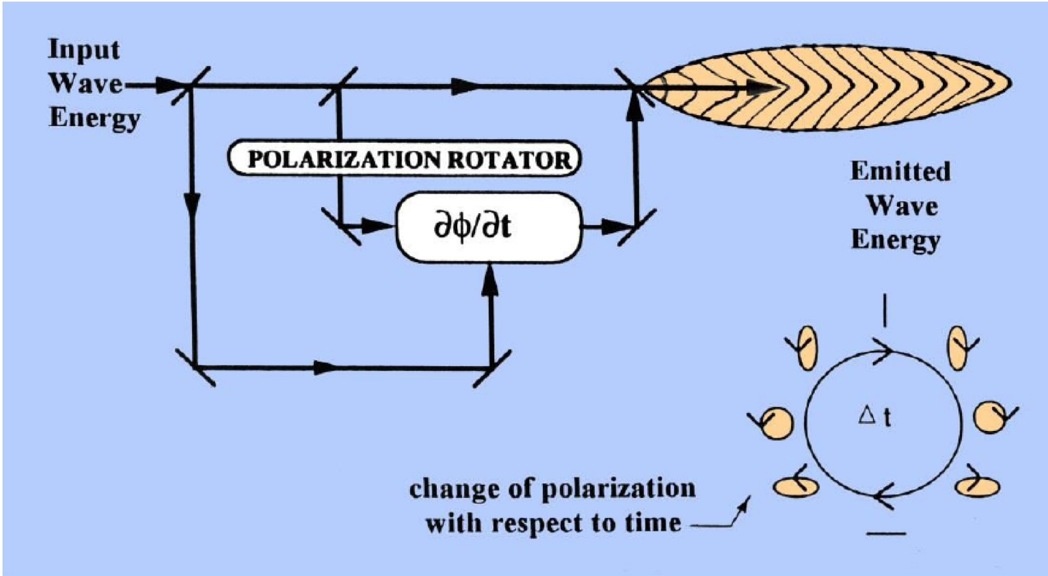

Figure 2 : Generation of polarization-modulated EM radiation

Figure 1 shows: part of the input wave energy unchanged; another part phase modulated ($\partial A/\partial t$) and combined with a part that passes through a "polarization rotator". This results in two orthogonally polarized waveforms (with one being the unchanged fraction of input wave energy. These phase modulated and polar-ization modulated waveforms are combined and emitted as a single beam of SU(2) EM radiation of continually varying polarization. Shown in the lower right of Figure 2 is polarization-modulated EM radiation swiftly sweeping through many polarizations (linear, elliptical, circular) during a cycle of polarization modulation.

Figure 3 from[1] shows swift, variegated change in E field amplitude and direction during a cycle of polarization-modulation. Similar B field change occurs 90 degrees to E field. Such rapid field variation cannot be approached with fixed linear, circular or elliptical polarization. The higher angular dynamics of such a polar-ization-modulated EM beam will exert different forces and moments on particles like electrons or fusion ions (as compared to lower angular dynamics of ordinary polarized beams). But ability of higher dynamics of polar- ization-modulated EM beams to modify ion charge distributions or ion repulsions has yet to be determined.

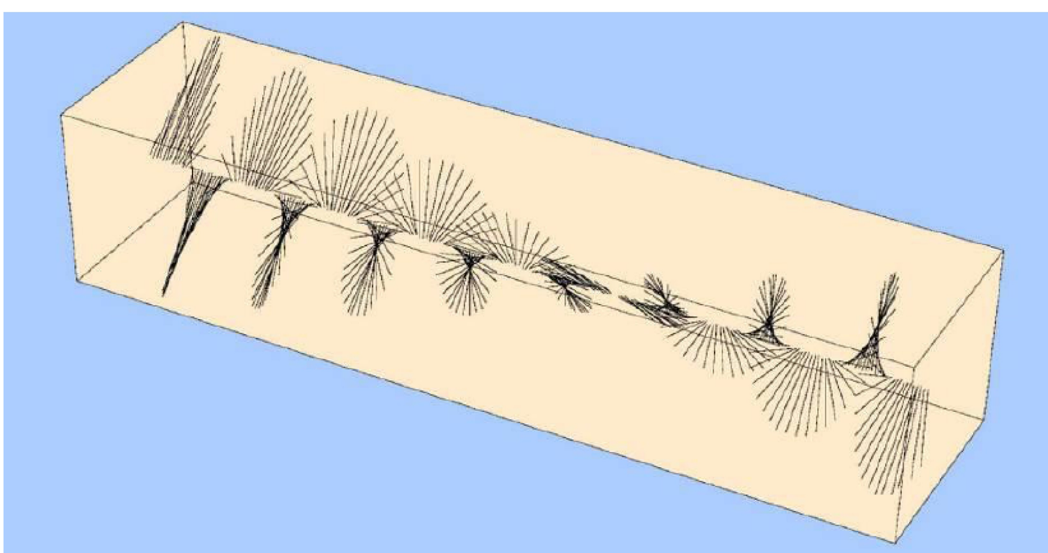

Figure 3 : Rapid change in E field configuration during 1 polarization-modulation cycle by an SU(2) beam.

Since ion-attracting SU(3) nuclear fields consummate every fusion reaction, ion-attracting SU(3) EM fields might be possible and reduce ion repulsion more than SU(2) EM fields. If so, Figure 4 from[5] shows an added modulation of polarization-modulated wave energy that may result in the emission of SU(3) EM wave energy.

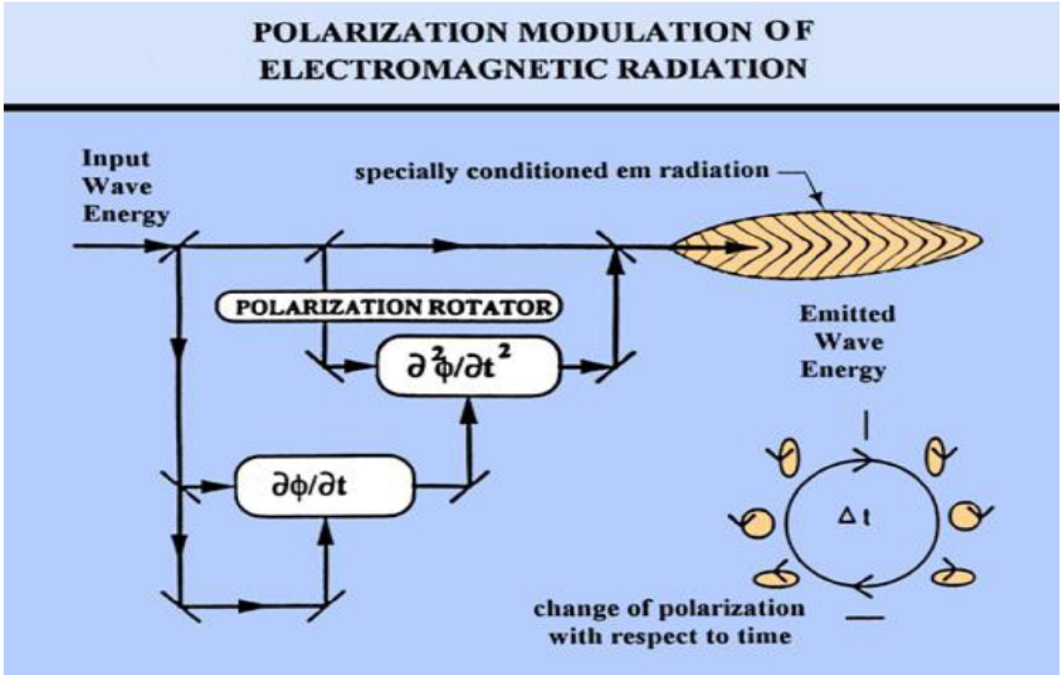

Figure 4 : Added phase modulation of EM wave energy that may result in emission of SU(3) EM wave energy

Developing SU(2) EM field theory to its present state has required much labor by a single individual (Barrett) and there are still SU(2) EM issues to be resolved. So, development of even more complex SU(3) EM field theory will surely require even greater effort. SU(3) EM Experimental challenges will also be encountered. For example, emission of the SU(2) polarization-modulated wave energy shown in Figure 1 requires a level of phase modulation that is believed achievable with current undulator or oscillator bandwidth state-of-the-art. But the additional wave modulation shown in Figure 4 indicates that a higher level of phase modulation would be required for emission of SU(3) polarization-modulated wave energy. Barrett[6] believes this higher level of phase modulation would require undulator or oscillator bandwidths in the 20-200 THz range. Such performance has not yet been achieved by any high-bandwidth device – even those in the highest performing FELs of today.

Use of SU(2) or SU(3) EM radiation fields in typical nuclear fusion systems

Reducing input power for fusion by use of SU(2) EM fields has been explored in most depth for "Inertial Electrostatic Confinement" (IEC) systems. The IEC system considered was pioneered by George Miley at the University of Illinois. Figure 5 shows an operating IEC system at the University of Illinois. It includes multiple ion beams (swiftly-moving streams of ions) converging toward the center of the IEC reactor. Ion beams are emitted from "ion guns" mounted on the reactor periphery. Ion inward motion is accelerated by a negatively-charged electrode (a spherical wire-woven 'grid') which allows positive-charge ions to freely pass through. And inside this grid, ions converge and criss-cross as thousands of ion fusions per second cause the bright central glow.

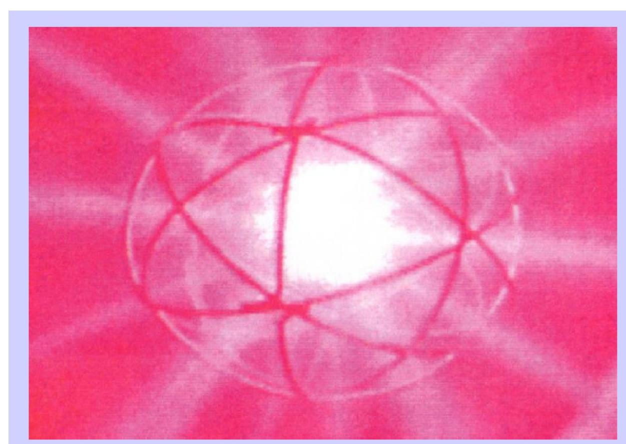

Figure 5 : IEC fusion reactor in operation at University of Illinois

Figure 6 shows one University of Illinois ion beam chamber (ion gun) connected to the IEC reactor. The ion gun contains an RF antenna which heats (ionizes) flowing fusion fuels with EM wave energy. For SU(2) EM testing, the ion-gun's fixed-polarization RF antenna would be replaced by a polarization-modulated RF antenna. Like the current RF antenna does, this RF antenna would create ions by ionizing fusion fuels with EM energy.

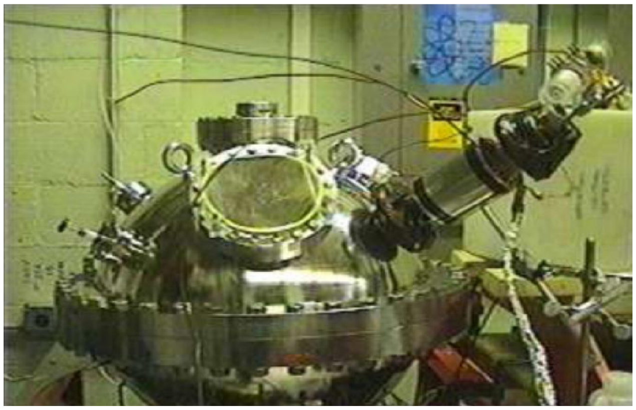

Figure 6 : Ion gun embodied in IEC reactor at University of Illinois

Figure 7 from[7] shows the currently used IEC ion gun. It contains: gaseous deuterium fuel; an electric power system; a "helicon" radio-frequency (RF) antenna whose EM energy intensely heats flowing fusion fuel to form fusion ions. The major ion gun change would be emission of polarization-modulated SU(2) RF wave energy instead of fixed-polarization U(1) RF wave energy for fuel heating and ionization. Fixed-polarization antenna elements would be replaced with orthogonally-polarized antenna elements. And the antenna elements would be driven with state-of-the-art phase modulators that Barrett[8] believes would be in the 10^{-12} to10^{-15} Hz range.

It is expected that emitted SU(2) or SU(3) wave energy would ionize fusion gases in ion guns with about the

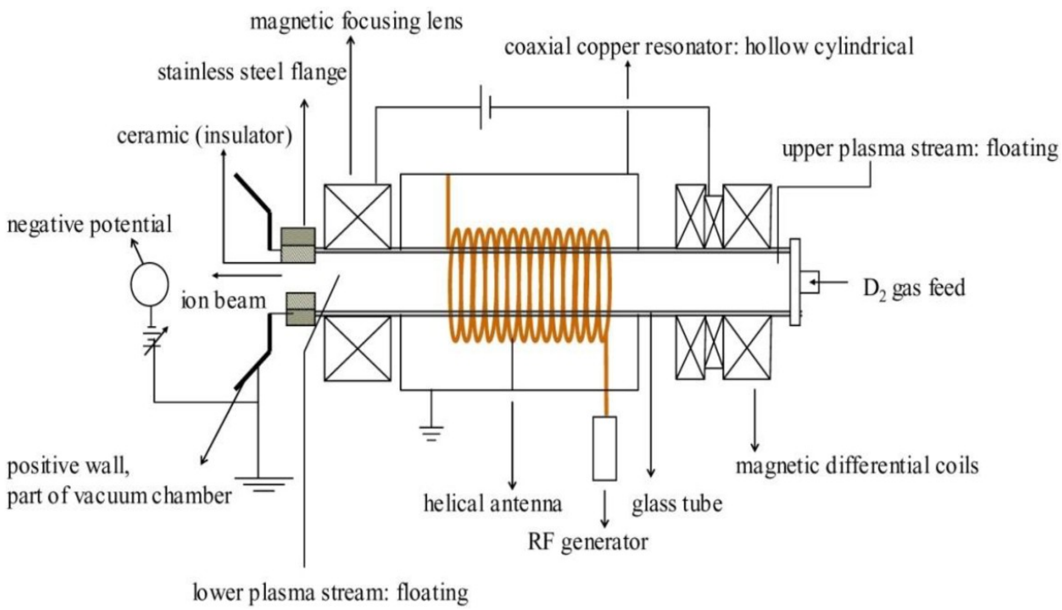

Figure 7 : Elements embodied in one of the ion guns used in the University of Illinois IEC reactor

same efficiency as currently emitted U(1) wave energy does. But energy intensity falls-off with distance, and it is not known how much this fall-off would affect SU(2) or SU(3) EM field ability for reducing fusion ion repulsion at the reactor center. So, more SU(2) EM energy than needed for gas ionization might be required.

A good location for deposition of more SU(2) EM wave energy may be inside the negatively-charged IEC grid – where ions are forced close together for fusion. Effective ion Irradiation in this region might require as many as 4 EM beams – with widths comparable to ion beam widths. Like ion beams, EM beams would mount on the reactor periphery and operate at high frequency to be narrow enough to avoid enlarging the IEC grid so both ion and EM beams could pass through. Many SU(2) EM beam concepts for irradiating fusion ions in central regions would have to be examined. One such EM beam concept could be like the undulator of a "Free Electron Laser (FEL) as shown in Figure 8. An undulator includes dipole magnets straddling a narrow beam of ions or electrons - a beam which is then transformed into a narrow beam of SU(2) or SU(3) EM radiation.

Undulator systems can radiate EM energy from either electron or ion beams. So, one possibility would be modifying an IEC ion gun so its emitted ions would enter a forward undulator section and be transformed into an SU(2) electromagnetic beam. Adding an undulator section to an ion gun may, of course, not be the best possible way to generate an SU(2) EM beam. But this might be the least expensive for early SU(2) testing.

APPLICATION OF SU(2) OR SU(3) EM FIELDS TO OTHER NUCLEAR FUSION SYSEEMS

Reducing input power for several other fusion systems have been very briefly explored. One is the EXL system by Robert Bussard[9]. It is shown on the right of Figure 9 and compared with Miley's IEC system (called IXL) on the left of Figure 9. In EXL, fusion ions are strongly-compressed togeather by a spherical distribution of electrons. The electron distribution itself is confined by inward-pushing magnetic fields formed from current flowing through the specially configured toroid coil shown in Figure 10. Therefore, highly-confined electrons strongly push fusion ions together in the reactor, where 10^9 fusions per second can occur.

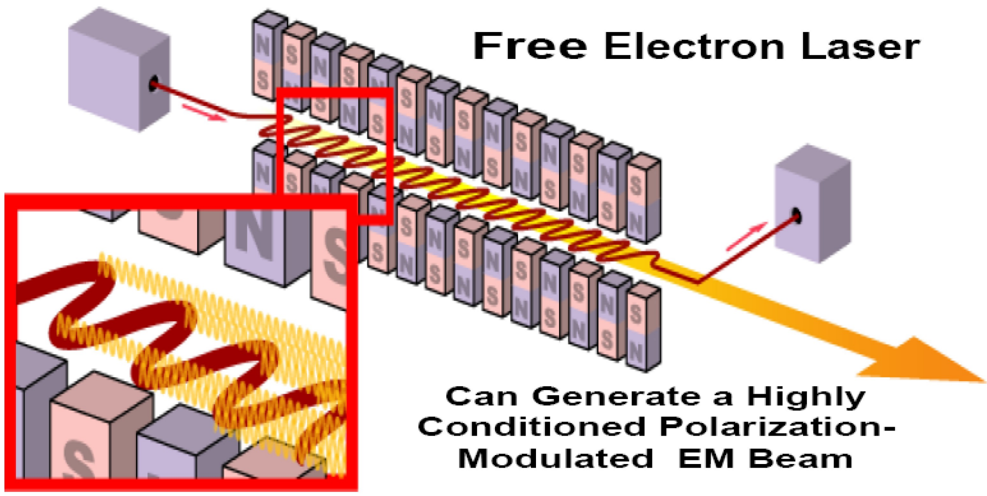

Figure 8 : Precise, highly modulatable electromagnetic beam formed by electron beam passing through dipole magnets.

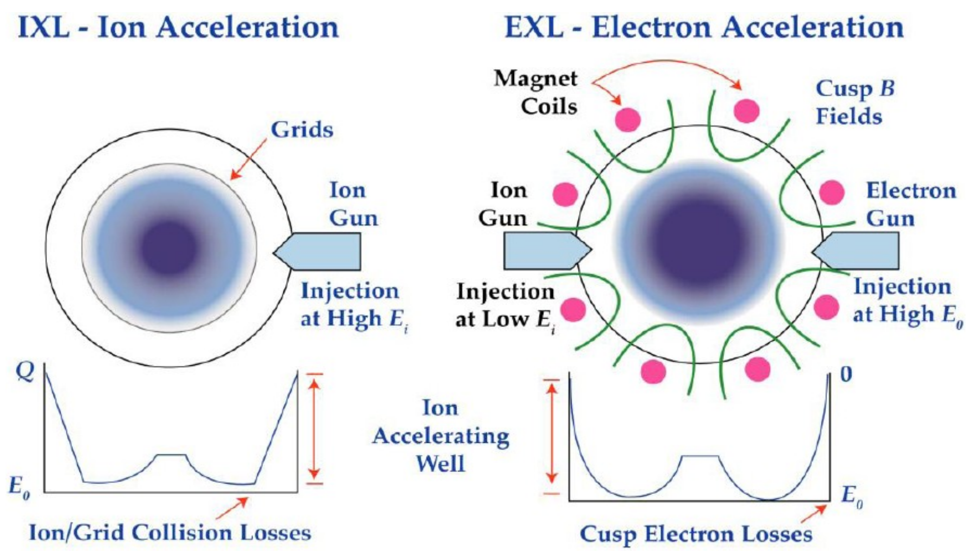

Figure 9 : Comparison of George Miley's IX fusion reactor with Robert Bussard's EXL reactor

Figure 10 : Toroidal coil geometry for EXL electron-confining magnetic field

Details of Bussard's toroid coil design and field pattern aren't known. But it is conceivable that Barrett's idea of emitting SU(2) magnetic field energy from a toroid at resonant frequencies (Figure 1) might enhance the efficiency of Bussard's electron-confining toroidal magnetic field. Also, Bussard's EXL uses an ion gun and accomplishes fusion in a reactor's center like Miley's IEC. But fusion ions tend to be surrounded by confining electrons in an EXL. So, more knowledge on how electron and ion patterns and distributions evolve in EXL reactors is needed to identify an effective possibility for depositing SU(2) or SU(3) EM energy within them.

Reducing input power for a "Focus Fusion" (FF) system by Lawrenceville Plasma Physics Inc has also been considered.. It is a variant of a fusion device called "Dense Plasma Focus" (DPF) studied by the US Air Force for fusion propulsion in the 1980's. Figure 11 from[10] shows one DPF system developed by the Air Force in the 2002-2004 time period. Here, gaseous fusion fuel is ionized by strong electrical discharges and a formed plasma sheath is accelerated between cylindrical electrodes. At the cylinder's open end, the sheath reverses direction and enormously intense, ion-confining magnetic fields form in a narrow pinch region, where fusion occurs. And, Figure 12 shows a 6 nanosecond exposure of a DPF test by Professor Nardi at Stevens Institute.

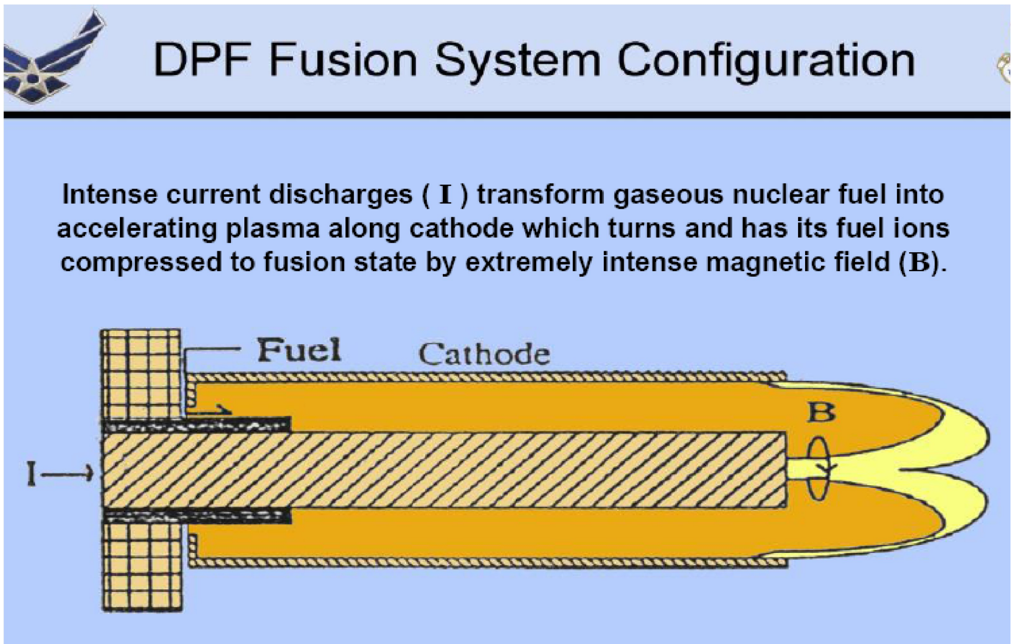

Figure 11 : Dense plasma focus fusion propulsion for flight

Dense Plasma Focus (DPF) Fusion Tests by Nardie etal. at Stevens Institute in the 1980's

Figure 12 : Dense plasma focus (DPF) testing at Stevens institute

The Lawrenceville Plasma Physics Inc. website describes significant advancement in DPF-FF state-of-art with their Focus Fusion designs – with plasmoid densities of $8x10^{19}$ ions per cm^3 quoted. As with Bussard's EXL system, detailed FF information is needed before any SU(2) ; SU(3) EM benefits could be claimed. But, it is known that accelerating-turning-compressing of DPF or FF fusion plasmas are strongly influenced by Lorentz Forces, which would be different for SU(2) *A, E and B* fields. SU(2) Lorentz force calculations could ascertain if SU(2) EM Lorentz force could considerably influence the accelerating-turning-compressing of FF plasmas.

SOME IDEAS ON THEORETICAL AND THEORETICAL RESEARCH WORK

As previously mentioned, Dr Terence Barrett (though his consulting company "BSEI" has developed SU(2) EM radiation field theory sufficiently for numerical studies to be performed and SU(2) EM field generators to be designed, and this has enabled preliminary experiments to be performed with encouraging results. But some unresolved SU(2) EM field issues remain. Furthermore, theory development for SU(3) EM fields, which may be even more promising then SU(2) EM fields for reducing fusion input energy, will require much more effort than a lone person can accomplish in spare time. Thus, it is believed important that academic institutions be involved in advancing SU(2) electromagnetism and starting SU(3) electromagnetism development.

SU(2) and SU(3) theoretical work would require an estimated 3 year level of effort at fairly modest cost with university faculty, graduate students, computing facilities and some consulting help. Work would enable code development for numerical modeling of SU(2) EM processes associated with fluid and plasma dynamics involved in typical power and propulsion systems. Research would also begin to lay down foundations of SU(3) EM field theory, with consulting help from people like Dr Barrett.

Two experimental options are possible for relatively quick and inexpensive testing to confirm or refute the possibility of SU(2) EM fields modifying coulomb repulsions. One possibility is: (a) use of an available IEC reactor and ion gun system at one of several universities that possess IEC fusion systems; and (b) modification of the helicon RF antenna of an IEC gun to emit SU(2) EM wave energy. Then, measured IEC fusion intensity with U(1) EM discharges from existing fixed-polarization RF antennas can be compared with measured IEC fusion intensity with SU(2) EM discharges from a modified ion gun with polarization-modulated RF antenna.

The other possibility is use of less expensive non-nuclear plasmas formed by RF discharges in gases like Argon or Xenon. Such tests can be done in plasma chambers with helicon RF antennas to heat (ionize) their gases. These RF antennas are very similar to RF antennas in University of Illinois IEC ion guns. Figure 13 shows such a chamber. It has a helicon RF antenna, and is located at the Australian National University (ANU).

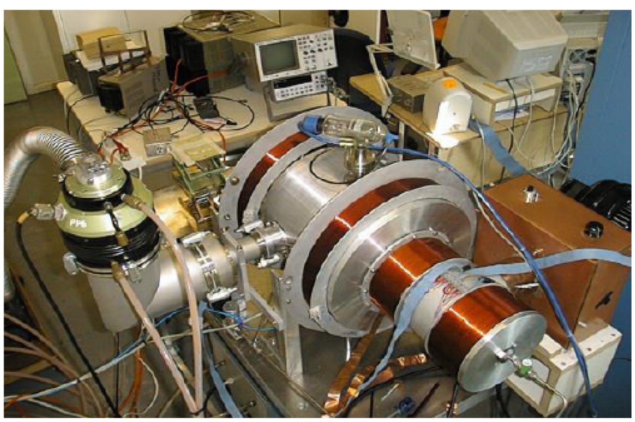

Figure 13 : Chamber with a Helicon RF plasma generating system at the Australian National University

Just as small differences in fusions for U(1) and SU(2) RF discharges must be detected in IEC reactors, so small differences in ion and electron behaviors would have to be detected in plasma chambers for U(1) and SU(2) RF discharges. This is possible in the ANU chamber. For it incorporates an innovative "movable energy analyzer" that allows plasma properties to be accurately and rapidly mapped throughout the entire chamber.

As with theory, a concurrent 3 year level of effort is recommended for experiment work. It is admitted that this theory and experiment work is exploratory. Hence, it is somewhat "high risk" in that specific accomplish-ments or success cannot be assured. But, at the very least, advances in EM field theory will be made, new plasma physics will be learned, and the experiments will significantly extend plasma physics state-of-the-art.

CONCLUSIONS

T.W.Barrett, has derived EM fields with the same SU(2) and SU(3) Lie Group symmetry as the SU(2) weak and SU(3) strong nuclear fields that bring about hydrogen fusion in the Sun with less confinement power and temperature than is required in terrestrial fusion reactors. And it is suggested that the *A, E,* and *B* tensor field couplings embodied in SU(2) and SU(3) electromagnetism could conceivably modify charge distributions in fusion ions and repulsive forces between them. This reconstituting of fusion ions into higher symmetry form – which removes stronger ion repulsion present at lower U(1) symmetry state - would reduce confining power and temperature needed for terrestrial fusion. And this would be somewhat like what SU(2) and SU(3) nuclear fields do in modifying charges and repulsions of hydrogen ions in the Sun's core to bring about efficient solar fusion.

Reducing needed input power for fusion with SU(2) or SU(3) EM energy has been explored. One possibility is depositing such EM energy into gaseous fusion fuels - to transform them into ions whose lessened repulsion would require less confining force for their fusion. Another is irradiating ions in fusion regions with charge-changing or repulsion-reducing SU(2) or SU(3) EM field energy, to lessen needed confining force for their fusion. Finally, SU(3) EM may be more promising than SU(2) EM, but it needs more development. Initial theoretical SU(2) and SU(3) EM research would require: about three years at relatively modest cost at an interested university. A concurrent three year SU(2) experimental effort at a university reactor or plasma facility is also recommended. This theoretical and experimental research would be high-payoff if successful. But, at the very least, it would greatly advance electromagnetic field theory and plasma physics state-of-art.

ACKNOWLEDGEMENTS

I would like to acknowledge the extensive, pioneering work of Dr. Terence Barrett, who is the originator and developer of the advanced electromagnetic field theory described in this paper. I am also grateful to

Dr. Barrett for many stimulating discussions on theoretical and experimental issues associated with his work. I also want to acknowledge all the nuclear fusion knowledge I have had the privilege of gaining from Professor George H. Miley on our many collaborations on Inertial Electrostatic Confinement and Dense Plasma Focus fusion systems – collaborations based on Professor Miley's very innovative and groundbreaking fusion energy work.

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