Advances in Aerospace Science and Technology, 2022, 7, 175-187
https://www.scirp.org/journal/aast
ISSN Online: 2473-6724
ISSN Print: 2473-6708

Fractal Laser Cone Structures Proposed to Confine Antimatter

Daniel Nelson Russell[1,2]

[1]Independent Physics Research & Consulting, Anchorage, USA
[2]Formerly, High-Temperature Superconductor Unit of Semiconductor Electrical Engineering Group, US Patent Office, Crystal City, USA
Email: dnrussellms@yahoo.com

How to cite this paper: Russell, D.N. (2022) Fractal Laser Cone Structures Proposed to Confine Antimatter. *Advances in Aerospace Science and Technology*, **7**, 175-187.
https://doi.org/10.4236/aast.2022.74011

Received: September 14, 2022
Accepted: November 13, 2022
Published: November 16, 2022

Abstract

Flat, straight sheets of paper, standing vertically on edge cannot support any load placed upon their top edge, but once formed into fractal tube conic sections, they have been measured to support up to 97.52 (± 2.27) kilograms (215 (± 5) pounds) of weight with strength-per-weight ratio up to 10,336 (± 240). So, strength has been discovered to be an emergent characteristic arising solely from addition of intelligent order. It is proposed to impose such intelligent order upon, preferably, at least 6 laser beams by focusing each of them to form cones of light, arranging the cones to form a wall of a larger fractal cone, and converging all of them to a common focal point inside a vacuum chamber to give them sufficient strength near this focal point to attract, hold, and move neutral antimatter, preferably anti-lithium. This opens the new field of structural engineering of light and re-defines the concept of strength. Means of cancelling out radiation pressure by reflection of laser beams back to the common focal point are proposed to enable laser confinement of particles having low polarizability, such as anti-hydrogen. Counter-circulation of light by reflection at grazing incidence is proposed as a means of returning escaping antimatter back to the common focal point containment area. Means are proposed to inject a stream of matter into the contained antimatter to create a matter-antimatter reactor and propulsion engine. Since anti-lithium is not available, yet, means are proposed to test these structures by confining ordinary lithium, instead, and by hitting it with antiprotons and/or positrons. Means are proposed to modulate the matter-antimatter reaction with information to create modulated gravitational waves for communication. The proposed structures would enable efficient, stable, safe confinement of antimatter, which would allow better study of antimatter, and make possible renewable, clean, safe, matter-antimatter reactor generators and propulsion engines, antimatter-assisted fusion reactors, and modulated gravitational wave generators.

Keywords

Antimatter Containment, Antimatter Confinement, Anti-Hydrogen, Anti-Lithium, Fractal Laser Cone, Modulated Gravitational Waves, Matter-Antimatter Reactor, Fractal Light Structures

1. Introduction

Reliable antimatter containment would enable practical use of antimatter fuel. 100% of antimatter fuel plus 100% of a matching amount of normal mass can all be safely converted into energy, compared with less than 0.7% of mass conversion via nuclear fusion. The ALPHA collaboration at CERN's Anti-proton Decelerator created and contained anti-hydrogen in a vacuum chamber for 1000 seconds, using a Minimum Magnetic Field Trap with complex magnetic fields and advanced cryogenic technology to slow down antimatter from drifting into container walls [1]. However, their vacuum container could not be moved and shipped with their antimatter cargo remaining intact, their cryogenic technology was very cumbersome and expensive, and very few atoms of anti-hydrogen could be contained and only for a very short time.

The present author, Russell, defined fractal tube reinforcements to be hollow tubes, having walls made of smaller hollow tubes, and so on, such that they have individual wall-thicknesses approaching zero, while the number of tubes goes up [2]. He has shown that a hollow central space surrounded by 6 tubes being fused to each other adds structure and strength, even though this central space has no mass, and that compression strength is inversely proportional to mass. The claims in patents by Russell, Shimoji and Russell, and further described in SAMPE technical conference paper by the present author, Russell, specify hollow tubes as small as nanotubes, having wall-thickness as small as one atom layer, as fundamental tubes to make fractal tube reinforcements [1] [3] [4] [5]. Rice University reports carbon nanotubes having walls one atom layer thick to be 100 times stronger than steel and only one-sixth the weight of steel [6]. That is 600 times the strength-per-weight ratio of steel.

Young *et al.* disclose total reflection of X-rays at grazing incidence and focusing by an ellipsoid reflector [7]. For X-ray, gamma radiation, and far UV light certain materials exhibit an index of refraction of less than one. This means that total external reflection at grazing incidence is possible with certain materials. Mallett calculates that a gravitational field arises, due to circulating electromagnetic radiation in a unidirectional ring laser, by solving linearized Einstein field equations [8]. This shows, theoretically, that gravitational strength arises by adding intelligent order to light by constraining and confining it in a ring laser.

Chu explains how neutral particles may be attracted, trapped, and manipulated with focused laser light having a power requirement of less than 1 Watt per laser [9]. Ashkin discloses that it is possible to optically cool atoms and to optically trap them at high densities [10]. Anti-hydrogen atoms have been shown to be laser-cooled [11]. Muir discloses a renewable supply of anti-protons trapped in the inner Van Allen radiation belt, which may be harvested [12]. American Physical Society reports that Marija Vranic used a row of 4 focused lasers to hold both electrons and positrons (antimatter), in place long enough to blast them repeatedly with powerful pulsed lasers to generate a cascade of pair production [13]. Although she proved that highly focused laser beams can confine antimatter for a short time, the laser beams were not arranged to create fractal light structures, and they only provided very short-term containment of antimatter.

Therefore, there is a need to create fractal containment structures made of light, rather than matter, to gather, manipulate, and transport antimatter, and which can contain antimatter safely for long-term storage.

2. Objectives

An objective of this proposed research is to introduce new fields of fractal light structural engineering, in general, and, in particular, fractal laser cone antimatter containment & propulsion engineering to stimulate development of fractal laser cone antimatter containment structures to gather, manipulate, transport, and safely contain antimatter for long-term storage, and to develop practical uses of antimatter for propulsion, power generation, antimatter research, and gravitational wave generation with a potential for communication. It is another objective to stimulate fundamental physics research in structures made of highly ordered light, and in their properties. It is another objective to stimulate development of antimatter chemistry to make new antimatter atoms and molecules.

3. Experimental Results: Basis for Proposed Structures

Straight, flat pieces of paper standing on edge have been observed to have no ability to support vertical load, placed upon their top edge, and to have compression strength-per-weight ratio equal to zero, and to collapse under their own weight. There are no units to this ratio, because compression strength or load is measured in pounds and the weight of the paper is also measured in pounds.

The same paper, as used above, formed into a hollow conic section 11.07 cm tall, 5.71 cm in diameter at is narrow end and 8.89 cm in diameter at its wider end, was measured to have vertical compression strength-per-weight ratio of 4400 (± 200).

A fractal tube conic section made of the same paper, as used above, 9.22 cm tall, 6.35 cm in diameter at its narrow end and 7.62 cm in diameter at its wider end, was built by placing ten smaller-diameter conic sections lengthwise to form the wall of the fractal tube conic section. This fractal tube conic section was measured to have compression strength-per-weight ratio of 5000 (± 250).

A double-layer fractal tube conic section made by rolling 2 flat sheets of paper, 8.56 cm tall, 6.50 cm in diameter at its narrow end and 8.89 cm at its wider end, was made with three circumferentially disposed flattened hollow tubes between the 2 layers of paper. This has been found to support 97.52 (± 2.27) kilograms ((215 (± 5) pounds), and to have compression strength-per-weight ratio of 10,336 (± 240).

All of the above conic sections were placed on a scale with their wider diameter ends down and with an increasing compression load placed on a flat board on top of their smaller diameter ends, until structural failure occurred. Strength against vertical loading weight was observed to be a new, emergent characteristic, arising solely from addition of intelligent order in forming the shapes of the paper, since no mass was added to the paper to form the conic sections. The increase in compression strength-per-weight ratio by the fractal tube conic sections, above that of simple conic sections, has been observed to arise from an addition of greater intelligent order only. The percent increase in compression strength-per-weight ratio in all cases above that of the straight flat pieces of paper has been observed, for all practical purposes, to be infinite or undefined.

4. Proposed Fractal Laser Cone Antimatter Confinement

The above observed experimental results demonstrate that addition of intelligent order, alone, results in an emergent characteristic of strength, which does not require matter. The invention of fractal tube microengineering has demonstrated that structural strength may be obtained in a void having no mass and existing between fractal tubes, and that mass hinders strength, patented by the present author, Russell [2] [3] [4]. Based on this discovery, it is proposed to add intelligent order to light beams to form ordered fractal structures made of light, which, thereby, gain emergent structural strength sufficient to hold, gather, move, and manipulate particles, including antimatter atoms and molecules. Experiments by Marija Vranic, reported by American Physical Society, further support this proposal by demonstrating that four focused laser beams having no mass, and placed in a simple row, can hold positrons (antimatter) in place [13]. Constraining light to specific polarization and frequency, focusing it, arranging it into ordered fractal forms, and localizing it by restricting it from free propagation all add intelligent order, and holding strength to structures made of light. Since light has no mass, except for a small relativistic component, an emergent strength-to-weight ratio, due to addition of intelligent order, of structures made of light would be almost infinite. It is proposed that such intelligent order be imposed on at least 3 laser beams, and, preferably, on at least 6 laser beams, by focusing each of them to form laser cones by means of mechanically linked and controllable lenses, by arranging these laser cones to form the wall of a larger fractal hollow cone of laser light, and by converging all of the laser cones to a common focal point to form a fractal laser cone structure. The wall of this fractal laser cone should be made of a sufficient number of individual laser cones to have enough strength to gather and hold many particles, preferably neutral antimatter atoms and molecules, such as anti-lithium, anti-hydrogen, and anti-(lithium hydride), at or near its central focal point, within an evacuated vacuum chamber to form a fractal laser cone antimatter containment structure. Focused polarized laser light attracts and holds particles by inducing polarization on them. Anti-lithium and its hydride are proposed, as preferred antimatter, for long-term fractal laser cone confinement, when they become available, because anti-lithium has 36.5 times higher polarizability than anti-hydrogen, assuming polarizabilities are the same for antimatter as for matter. This assumption is reasonable in view of the confinement of positrons by focused lasers by Marija Vranic, reported by American Physical Society [13]. It is proposed that additional fractal laser cones be created with additional lenses and introduced into this vacuum chamber through windows or lenses, so that all of their focal points coincide at the common focal point of the above fractal laser cone. In a first proposed embodiment of this invention each of three fractal laser cones is shown in **Figure 1** to enter a vacuum chamber through a window, which may be a lens, along three mutually perpendicular directions to enable the common focal point to be adjusted in all three dimensions. Sets of 6 moveable and rotatable lenses are shown in both **Figure 1** and **Figure 2** to be attached to each moveable and rotatable truss ring located outside of the chamber to enable the common focal point of the laser beams to be fine-tuned and moved. Adjustment and coordinated movement of the moveable and rotatable external lenses, used to focus the laser beams, is proposed to enable gathering, movement, and manipulation of antimatter particles. Many laser beams may be made from one beam by beam-splitters having many outputs. **Figure 2** shows a second proposed embodiment of the invention in which each fractal laser cone, made of six focused laser cones each, enters through only one window in a spherical vacuum chamber. The wavelength of laser light should be chosen to avoid absorption peaks of particles to be confined, such as 656 nm, 486 nm, 434 nm, 410 nm, and many UV wavelengths for anti-hydrogen, and absorption peaks for anti-lithium, if that were chosen to be confined, for example, in order to minimize heating. Light intensity gradients produced by the highly focused laser beams would attract and gather particles toward higher light intensity by induced polarization near the common focal point, and contain them there. The spherical shape and high reflectivity of the internal surface of the chamber would reflect the laser light beams, after they diverge from the common focal point from the chamber wall back to the common focal point along their original paths. These reflected laser light beams would apply momentum and radiation pressure, opposite in direction to that of the initial laser beams, to cancel it out, and to slow down and cool antimatter particles near the common focal point. Alternatively, such cancellation of radiation pressure could be accomplished by introducing other laser beams through windows on opposite sides of the chamber. This would save a cost of the inside, highly-polished iridium mirror. But, that would require twice as many lasers and windows, as in the above proposed embodiments. It is especially important to cancel out laser radiation pressure on particles of low polarizabilities, because otherwise it would push and scatter particles to be confined, before the polarization gradient force could attract and hold them. The total power of the focused lasers, and their light-intensity gradients must yield sufficient attractive force to overcome diffusion, due to thermal agitation, also. Cryogenic cooling may be used for this, but it is cumbersome, costly, and it may restrict mobility of the containment means. Pulsing the laser beams would further minimize heating of confined particles. It is proposed that the fractal arrangement adds intelligent ordering to the laser light and, as follows from the above experimental results, would enable the laser beams to work together, so that each fractal laser cone would have greater holding strength and would hold more particles than the sum of the holding strengths of each of its lasers working separately. Since nobody knows how to make anti-lithium, yet, and since these proposed structures could confine matter, as well as antimatter, it is proposed that the above fractal laser cone structures be tested using ordinary lithium or the stable and more polar lithium hydride, as chosen particles for confinement.

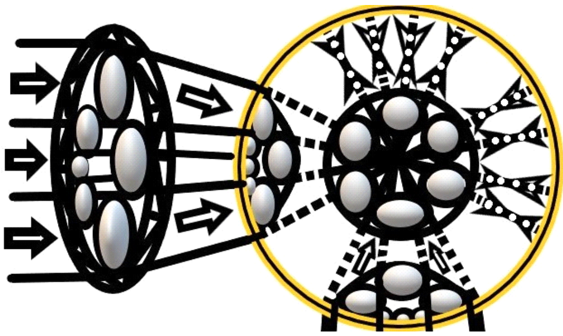

Figure 1. First embodiment of fractal laser cone chamber. Three proposed fractal laser cone antimatter containment structures are shown housed in a spherical, evacuated, vacuum chamber. The lines and arrows show laser beam paths. Each fractal laser cone structure is shown to be made of six hexagonally arranged laser light cones having a common focal point at the center of the chamber. Six windows, which are also lenses, are shown on the surface of the chamber to focus six laser light beams and transmit them into the chamber to create the laser light cones of each fractal laser cone structure. Six laser beams of a first fractal laser cone are shown to enter the chamber in a direction perpendicular to that of a second fractal laser cone, and six laser beams of a third fractal laser cone are shown to enter the chamber in a direction perpendicular to that of the other two. One window, which may be a lens, is shown in the chamber for each laser light beam to enter it. Internal and external surfaces of the chamber are shown by gold colored circle to be highly reflective, refractory layers, such as iridium coated molybdenum, which strengthen and support a middle layer shown by a black circle, which is an alpha particle source, such as UO_2. After each laser beam passes through the common focal point it is shown by dashed lines to diverge to the opposite wall of the chamber from where it entered it, from which it is shown by double arrows to be reflected back on itself along its original path to the common focal point. Six moveable, rotatable external lenses are shown to be attached to each moveable and rotatable reinforced truss ring to enable the common focal point to be fine-tuned and moved.

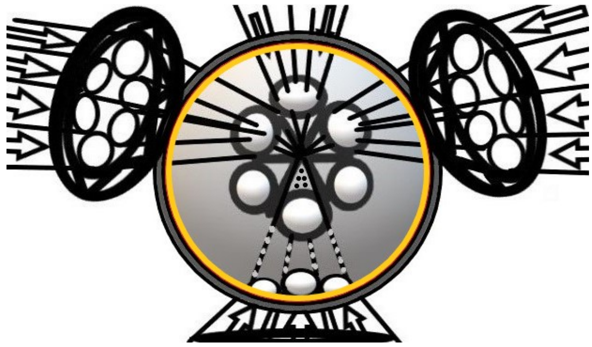

Figure 2. Second embodiment fractal laser cone chamber. Six laser beams, focused by six hexagonally disposed lenses, attached to a ring structure located external to a spherical vacuum chamber form each fractal laser cone structure. Arrows and lines indicate laser beam paths. Each fractal laser cone is shown to pass through one window in the chamber in a direction perpendicular to the surface of the spherical chamber toward a common focal point. All of the fractal laser cones merge at same common focal point to form fractal laser cone antimatter containment structures. Three windows shown at the bottom of the chamber are part of another set of six hexagonally disposed windows. The dashed lines from the bottom set indicate that laser light beams pass upward through the bottom of the chamber and converge to the common focal point. Each set of six fractal laser cone structures is shown to enter the chamber in a direction perpendicular to every other set of six fractal laser cone structures. The inside surface of the chamber, represented by a gold colored circle, is highly reflective at the laser wavelength and reflects the laser beams from the opposite wall from which they entered, after diverging from the common focal point, back along the original path of the laser beams. The external lenses and the external ring structures are each moveable and rotatable to enable the common focal point to be fine-tuned and moved.

A hollow sphere made of a highly reflective material for ultraviolet (UV) and X-ray light, such as uranium dioxide (UO_2) disposed between 2 layers of molybdenum alloy with a thin iridium alloy coating on the internal surface of the sphere and another thin coating of iridium alloy on the external surface, is proposed to form the wall of a proposed evacuated vacuum chamber (**Figure 1**). Rutile (TiO_2) is proposed for the windows and lenses, because its index of refraction, like that of UO_2, is also less than one for some X-ray and UV light, but much greater than one for visible light, and because it also has a high melting point of 1843˚C. Alternatively, diamond windows and lenses may be used, if higher operating temperature and durability are required. Windows in the chamber wall should be installed flush with an internal surface of the chamber to allow grazing incidence reflection. These materials reflect ultraviolet or X-ray light, which is proposed to be introduced into the chamber in opposite directions at grazing incidence (less than 3 degrees from the surface) along its internal surface to create counter-circulating light. This light should be collimated, but it does not need to be laser light. This grazing incidence reflection is called, total external reflection, if an index of refraction is less than one. This counter-circulating light may be injected into the chamber via optical fibers, for example, through small ports or windows in the chamber wall. A frequency should be chosen for this light, so that an index of refraction for the chosen material is as small a fraction of one as possible for UV or X-ray light, and an inside reflective surface of the chamber should be ultra-smooth and highly polished, so that this light would reflect at grazing incidence at such frequency to allow it to circulate inside the chamber. This counter-circulating light would cancel out radiation momentum and pressure in circumferential directions, so that a net radiation pressure would be applied only radially toward the central focal point on anti-matter particles, which have escaped from the central confinement area. This would prevent antimatter from escaping by returning it to the confinement area, where the focused laser gradient forces would attract and hold it near the common focal point. Intelligent order would be added to such counter-circulating light by restricting it from free propagation, and by constraining it to propagate along the internal surface of the proposed chamber, and this would give additional strength to the light. The larger the chamber, the greater would be the efficiency of grazing incidence reflection of light. Sandberg *et al*. reported UO_2 to be more reflective than all known reflectors for light of wavelength from 5 nm to 9 nm [14]. So, the dioxide of uranium-238 is recommended, as a material inside the chamber wall, to reflect X-ray light at grazing incidence, and to absorb annihilation gamma rays and X-rays, as shielding. This dioxide of uranium, layered on both sides by molybdenum alloy coated with iridium alloy, as proposed above, would absorb both alpha-particle and weak gamma radiation from uranium-238, and the molybdenum layers would strengthen the chamber against brittleness. The iridium coated molybdenum may also serve to transfer heat to heat exchangers, and to reflect both sunlight, and laser beams from laser weapons, off of the chamber. The minimum thickness of these layers would be dictated by the amount of shielding required, the size of the chamber, and the strength required. Alternatively, the UO_2 layer is proposed to be reinforced internally with at least one layer of carbon fiber open-mesh cloth to strengthen it against brittleness and crack-progression. This could, reduce its density and weight by half. The open-mesh carbon fiber reinforcement cloth is proposed, in future, be made of continuous carbon nanofibers, when such cloth becomes available, to further increase its strength, and to reduce thickness, density and weight of the chamber. Shimoji and Russell invented "Laser fabrication of continuous nanofibers", which could be developed to make open-mesh, carbon, nanofiber reinforcement cloth up to 600 times stronger per unit weight than steel [5].

5. Proposed Applications

It is proposed that such laser containment means be located outside of the atmosphere in the vacuum of space, shielded from sunlight, and that one end of the chamber be open to the vacuum of space. It is well-known and established that a focal point of laser light can be moved by moving and adjusting the lenses that create the focal point. A focal distance of the converging laser beams is proposed to be able to be moved by moving the lenses, such that the common focal point of the fractal laser cones, containing the antimatter, may be moved outside of such an open-ended chamber. In this way rotation of the lenses or of the entire chamber would transport confined antimatter particles as fast as the focal point could be moved with laser-point accuracy onto a target through the vacuum of space. Alternatively, this means may be used, in reverse, to bring antimatter particles from outside, to inside the chamber for reliable, long-term storage.

It is proposed that a stream of matter, such as alpha-particles, protons, hydrogen or helium, be injected into the laser containment chamber to merge with confined antimatter, such as anti-lithium, to react with it to produce both energy and propulsion. If the middle layer of the chamber wall is UO_2, then it is proposed to direct a stream of alpha particles into the focal point confinement area by opening a door or shutter in the internal iridium coated molybdenum layer to expose the UO_2, which always naturally emits alpha particles. Other alpha particle sources, such as americium-241, or proton emitters may be added, as inclusions within the UO_2 layer, behind such a shutter to increase the number of particles emitted per unit time. This would allow matter insertion, without a need to open the vacuum chamber, and it would enable the above chamber to become a matter-antimatter reactor. In order to use this reactor, as a propulsion engine, it is necessary to maximize production of particles with kinetic energy for thrust by only merging dissimilar masses. For example, anti-lithium is proposed to be merged with alpha particles, protons, hydrogen, or helium. In another example, anti-hydrogen is proposed to be merged with alpha particles, helium, or lithium. Since alpha particles and protons are charged, it would be easy to direct a stream of them toward the focal point using magnetic and electric fields. A nozzle in the chamber would be open to the vacuum of space, to direct an exhaust of high-energy, sub-atomic particles. Since anti-lithium is not available, yet, it is proposed that such reactors and propulsion engine prototypes be tested by confining ordinary lithium or its stable hydride, instead of antimatter, by these proposed structures, and by directing a stream of anti-protons and/or positrons at this confined matter target.

Based on the well-known discovery that gravitational waves are created by matter that is suddenly accelerated to the speed of light and transformed into light and removed from the matter component of our Universe by collisions of 2 or more black holes or by collisions of neutron stars with black holes by the Laser Interferometer Gravitational Wave Observatory (LIGO), it is hypothesized that matter-antimatter annihilation events also produce gravitational waves by suddenly warping or perturbing a local curvature of spacetime. This is further supported and predicted by the General Theory of Relativity of Albert Einstein. So, it is proposed that a collision frequency of matter particles with confined antimatter particles inside the above proposed antimatter containment chamber be modulated with information. This may be done, either by moving the matter stream directing means or by moving a location of the common focal point, relative to the matter stream trajectory, so that modulated matter-antimatter annihilations and, thereby, modulated gravitational waves would be created. This would enable matter-antimatter reactor engines to generate modulated gravitational waves capable of transmission of communications and data. An advantage of using modulated gravitational waves for communication is that they are believed to travel, uncorrupted, through stars, planets, moons, rocks, ice, and dust. So, there would be no dead-zones for spacecraft, where communications are blocked. Future, planned, space-based, orbiting laser interferometer gravitational wave detectors may be sensitive enough to detect and interpret such gravitational wave communication. Such detection of modulated gravitational waves is proposed as a means to search for advanced civilizations in the Universe.

6. Discussion

Anti-protons have been harvested by the Payload Antimatter Matter Exploration and Light Nuclei Astrophysics satellite (PAMELA), launched in 2006, from the innermost Van Allen radiation belt. They could be harvested by the above proposed means in greater amounts from such belts around Jupiter and Saturn, because they have larger magnetic fields and radiation belts. Planets of other star systems having even larger magnetic fields would probably store much higher concentrations of antimatter in their radiation belts. Positrons can be made efficiently, already, or they could be harvested from outer Van Allen belts. A cloud of positrons could be deployed in front of a scoop to decelerate fast anti-protons in inner Van Allen radiation belts. Some of those positrons would merge with anti-protons and create anti-hydrogen, which also could be captured and confined by the above proposed means. Anti-lithium would be much easier to confine than anti-hydrogen, once we figure out how to make it efficiently from these building blocks, due to its 36.5 times higher polarizability. It also, potentially, would yield 7 times as much energy per atom as anti-hydrogen, upon annihilation, because it has that much more mass. For these reasons both anti-lithium and anti-(lithium hydride) would be well worth making, and this may be quite profitable. Anti-lithium may be made by merging 3 anti-protons and 4 anti-neutrons with 3 positrons. This may be considered a cold fusion, if these particles are fused in thin, single-file streams of particles. Then, one may chemically add an anti-proton merged with a positron to this to create anti-(lithium hydride). This would open a new field of antimatter chemistry. Both of these antimatter fuels would yield a lot of thrust in a reaction with alpha particles, protons, hydrogen, or helium, for example, because their annihilation products would include subatomic particles with great kinetic energy, some of which would, in-turn, react to produce more subatomic particles with great kinetic energy.

Atom interferometers, instead of laser interferometers, may greatly increase a sensitivity of gravitational wave detectors. Ground-based, laser interferometer gravitational wave detectors suffer from too many kinds of noise and are not sensitive enough to detect the proposed gravitational waves for communication, especially at lower frequencies. Atomic clocks would be better suited and more sensitive for detecting such gravitational waves, because they do not depend on movement and are not so affected by vibrational noise. Instead, they work by measuring time-dilations and time-contractions created by them. So, an atomic clock gravitational wave observatory is suggested to be created by placing an array of six atomic clocks on Earth, spaced 9656 kilometers (6000 miles) apart from each other, and one on Mars. If sufficiently sensitive, gravitational wave detectors are created, this would make possible the proposed gravitational wave communication and data transmission. If the speed of gravitational waves is found to be greater than the speed of light, then this would be another advantage to using this medium to transmit communication. Although most people believe, from indirect evidence, that gravitational waves travel at the speed of light, the present author, Russell, explained that their speed has never been directly measured, and his theoretical argument concluded that their speed is undefined [15]. Spacetime is observed to expand at a speed proportional to distance with no known upper limit, having Hubble's proportionality constant of 82.4 km/sec/megaparsec (±10%). Gravity, according to the General Theory of Relativity, defines the geometry and curvature of spacetime, and gravitational waves are perturbations or ripples in the definition and curvature of all dimensions of spacetime. So, gravitational wave speed, should have no upper limit, and is undefined. Since gravitational waves exactly follow the curvature of spacetime, unlike light, which is only slightly affected by gravity, a path-length of travel for gravitational waves would be longer than that for light from the same source. So, both gamma-ray bursts and gravitational waves could not have arrived on Earth at the same time from the same gravitationally collapsing source, contrary to what is widely believed to be evidence that both types of waves travel at the speed of light. It is, therefore, proposed that the speed of gravitational waves be directly measured by comparing the time of arrival on Earth of gravitational waves generated by solar flare explosions with the exact time of optical observation of those solar flare explosions by both laser interferometer and by the above proposed atomic clock gravitational wave observatories. Since our Sun is 8 light-minutes away, the observatories must be recording data at least 8 minutes prior to optical observation of these solar flare explosions to test, objectively, whether gravitational waves travel faster than light-speed, and to directly measure their speed, taking into account their distinct path-lengths along curved spacetime. More such experiments were proposed by the present author in [15]. The above atomic clock gravitational wave observatory is proposed as a means to detect advanced civilizations using modulated gravitational wave communication.

7. Conclusions

Since ordering sheets of paper, without adding more mass, results in strength/weight ratio to support structural load to go from zero to 10,336, which is essentially an infinite percent increase, this discovery makes it reasonable, in view of the cited references, to apply these results to light beams to make highly ordered fractal laser cone structures having sufficient strength to gather and contain antimatter for long-term storage and for further research of its nature, which have not been possible before. The highly ordered, fractal laser cones of light would add intelligent order to chosen confined particles, as well as to the light, by causing them to share wave-functions, as a Bose-Einstein condensate. The fractal arrangement of many individual cones of highly-focused laser light to form larger cones of laser light would add more strength and attractive force to hold particles, based on these experimental results and on the referenced patents by the present author, than if all of the lasers were randomly arranged or linearly arranged or anything that has been tried, before.

Since either matter or antimatter may be held and manipulated by fractal laser cone structures, further research is suggested to yield biological and medical applications of these fractal laser cone structures to place medicines or chemicals into tissues with atomic-scale accuracy, and to destroy unwanted tissues and tumors, for example. Moving the fractal laser common focal point could be used to project antimatter, as fast as the focal point could be moved, from orbit onto a target, such an asteroid, to apply an acceleration to it to alter its trajectory or to destroy it. This could also be applied to asteroid mining operations to move a valuable asteroid to a Lagrange point orbit nearer the Earth or Moon, for example, to enable more efficient mining. Further research is suggested to determine the limitations to both velocity and acceleration at which antimatter could be projected by moving the common focal point of fractal focused laser beams. The fractal laser common focal point could be used in another practical application, as an antimatter chemistry tool to combine antimatter particles of various kinds to make new antimatter atoms and molecules, and to study their characteristics. Ordinary matter, such as large, unstable, radioactive atoms, could also be held and studied safely by this method.

Reliable, safe, and practical containment of antimatter by fractal optical containment would make possible clean, safe, renewable energy by matter-antimatter reactors, and by antimatter-assisted fusion reactors. Matter-antimatter reactor engines would produce at least ten million times more efficient propulsion than chemical rocket engines. The use of the same fractal laser cone structures for antimatter containment, propulsion, and communication would allow creation of spacecraft with such efficient and powerful thrust and communications, so as to enable travel to distant star systems.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] The ALPHA Collaboration (2011) Confinement of Antihydrogen for 1,000 Seconds. *Nature Physics*, **7**, 558-564. https://doi.org/10.1038/nphys2025

[2] Russell, D.N. (2000) Fractal Tube Reinforcement Microengineering. In: Adams, P.J., Elsworth, S.A., Petkauskos, M.J. and Walton, T.C., eds., *Revolutionary Materials: Technology and Economics*, *Society for the Advancement of Material and Process Engineering* (*SAMPE*), Diamond Bar, CA, USA, 224-230. https://books.google.com/books?id=T6_zuebS25kC&pg=PA224&lpg=PA224&dq=Russell+SAMPE+32+technical+conference+Fractal+microengineering&source=bl&ots=qhXB-1zo9V&sig=ACfU3U0YsiaisaJ2uOhrJP6Beo8QCQ30YQ&hl=en&sa=X&ved=2ahUKEwjQsIvvrYDqAhWCvJ4KHSaWAvMQ6AEwAHoECAoQAQ#v=onepage&q=Russell%20SAMPE%2032%20technical%20

[3] Russell, D.N. (1998) Fractal Tube Reinforcement. US Patent No. 5707724. https://patents.google.com/patent/US5707724A/en

[4] Russell, D.N. (1999) Process of Making Fractal Tubes. US Patent No. 5928450. https://patents.google.com/patent/US5928450A/en

[5] Shimoji, Y. and Russell, D.N. (2005) Laser Fabrication of Continuous Nanofibers. US Patent Appl. No. 2005/0255033 A1. https://patents.google.com/patent/US20050255033

[6] Rice University (2013) New Nanotube Fibers Have Unmatched Combination of Strength, Conductivity, Flexibility (w/video). https://phys.org/news/2013-01-nanotube-fibers-unmatched-combination-strength.html

[7] Young, J.F, Macklin, J.J., and Harris, S.E. (1987) Grazing-Incidence Ellipsoidal Reflector for Longitudinally Pumping Short-Wavelength Lasers. *Optics Letters*, **12**, 90-92. https://doi.org/10.1364/ol.12.000090

[8] Mallett, R.L. (2000) Weak Gravitational Field of the Electromagnetic Radiation in a Ring Laser, *Physics Letters A,* **269**, 214-217. https://doi.org/10.1016/s0375-9601(00)00260-7

[9] Chu, S. (2008) Laser Trapping of Neutral Particles. Scientific American. https://www.scientificamerican.com/article/steven-chu-laser-trapping-of-neutral/

[10] Ashkin, A. (1997) Optical Trapping and Manipulation of Neutral Particles Using Lasers. *Proceedings of the National Academy of Sciences of the United States of America*, **94**, 4853-4860. https://doi.org/10.1073/pnas.94.10.4853

[11] Baker, C.J., et al. (2021) Laser Cooling of Antihydrogen Atoms. *Nature*, **592**, 35-42. https://doi.org/10.1038/s41586-021-03289-6

[12] Muir, H. (2011) Antiprotons Trapped Around Earth. *New Scientist*, **211**, 16 p. https://doi.org/10.1016/s0262-4079(11)61878-2

[13] American Physical Society (2018) Laser Blasting Antimatter into Existence. EurekaAlert! https://www.eurekalert.org/pub_releases/2018-11/aps-lba110218.php

[14] Sandberg, R.L., Allred, D.D., Bissell, L.J., Johnson, J.E. and Turley, R.S. (2004) Uranium Oxide as a Highly Reflective Coating from 100-400 eV. *AIP Conference Proceedings*, **705**, 796-799. https://doi.org/10.1063/1.1757916

[15] Russell, D.N. (2018) Gravitational Wave Speed: Undefined. Experiments Proposed. *Research Ideas and Outcomes*, **4**, e25606. https://doi.org/10.3897/rio.4.e25606