# Fundamental Theory and Improvements In the Electromagnetic Drive Using Stimulated Emissions[1]

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**Abstract:** The Wave Structure of Matter is used to describe the operation of the EM drive, with the thrust differential shown to be related to the square of the group velocity in the cavity, which is in turn found to be proportional to the inverse of the cosine of the taper angle of the cone-shaped cavity. Improvements in thrust are found by adding a gain medium to the cavity that will increase the number of photons through stimulated emissions.

The electromagnetic (EM) drive was first patented by Roger Shawyer[1]. The concept behind Shawyer's propulsion method is that a tapered (cone-shaped) resonant cavity with microwaves inserted at the larger end of the cavity will be in resonance (standing waves) at each end of the cavity but the larger and smaller ends of the cavity will have different group velocities for the microwaves in these sections (Figure 1).

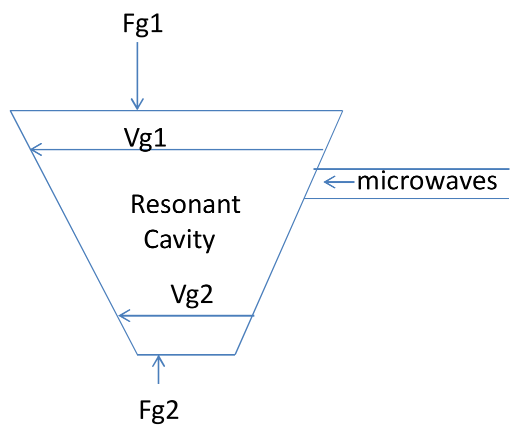


**Figure 1. Roger Shawyer's Thruster Concept**

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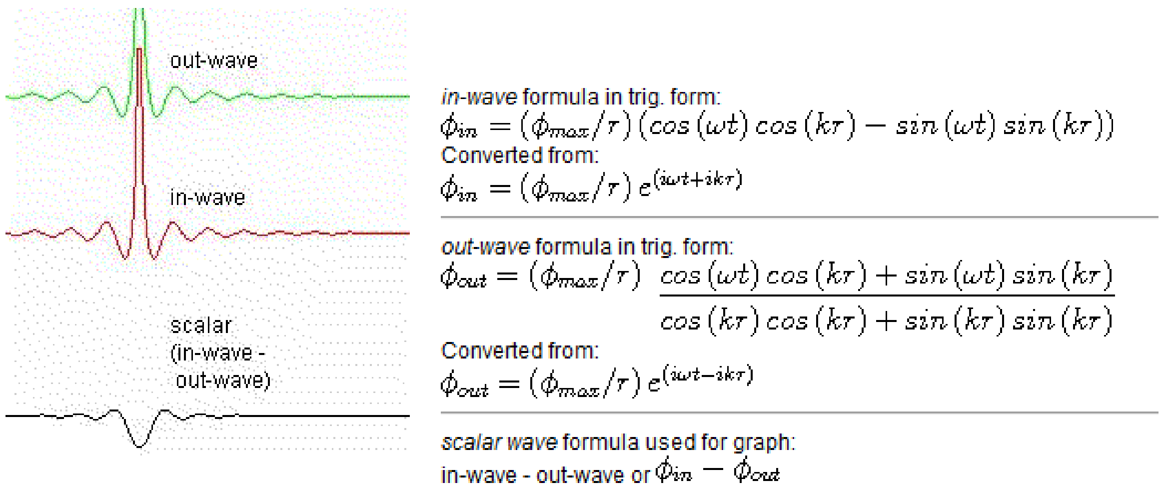
The difference in group velocity then produces a thrust based on the familiar Lorentz force equation **F** = q**v** X **B** where F is the Lorentz force produced by the difference in group velocity **v** between the microwaves in both ends of the chamber, **B** is the magnetic field in the chamber and q is the vacuum displacement charge associated with the presence of the electromagnetic waves. Although these equations as explained by Shawyer have been used to describe the force between a traditional moving charge relative to a magnetic field for years, a more satisfactory explanation of how the thrust is produced based on the interaction of resonating microwaves and the space time vacuum is desired.

One theory as to how this force is produced is provided by the Wave Structure of Matter (WSM), where particles in the vacuum are described by the interaction between incoming wavefronts and outgoing wavefronts. WSM describes a particle as a wave center where the incoming waves and outgoing waves meet, creating an energy density region of space that models the properties of particles such as spin and charge of stable particles and the transient decay of unstable particles such as mesons (Figure 2).




**<u>Figure 2. Wave Structure of Matter – Wave Center of a "Particle" (simulation from www.wsminfo.org)</u>**

The Wave Structure of Matter (WSM) describes particles as a wave center where an incoming and outgoing wave meet, creating a superposition of amplitudes that drop off in energy as we move away from the wave center. The "IN" waves arriving at a wave center are the thermalized mixing of multiple "OUT" waves from distant wave centers. The "OUT" waves result from a wave center are a result of the meeting of "IN" waves from all directions which experience a transformation and rotation at the wave center.

WSM also describes photons as the interaction of two wave centers - in this case, the wave centers are two electrons. The out waves that comprise one half of the electron from each wave center resonate with each other, producing a modulated wave that travels between one wave-center (the one at higher energy) to the other wave-center (the one with lower energy). In this model, the photon is the interaction between the out waves of two wave centers that are electrons. WSM describes a predetermined destination for the photon based on prior communication between the wave centers through their out waves, a concept which explains quantum entanglement and is similar to the theory proposed by John Wheeler and Richard Feynman known as Wheeler-Feynman absorber theory. The Wave Structure of Matter has also been shown to solve important problems such as the GZK limit (a modification to Special Relativity that preserves the observer reference frame results) [2].

Using this approach in understanding the photon, the resonating microwaves in the cavity can be seen as competing instances between two wave centers, one residing on opposite sides of the cavity for both the narrow and longer ends of the tapered profile. One side of the cavity (the longer-tapered side for instance) experiences a faster group (modulation) velocity than the other side and this results in a difference in energy between the out waves on both top and bottom of the cavity (Figure 3). This energy difference is an increase tension in the vacuum of space based on the out wave velocity through the classical wave equation,

$$\boldsymbol{velocity} = \sqrt{\frac{\boldsymbol{Force}}{\boldsymbol{\sigma}}} = \sqrt{\frac{\boldsymbol{kr}}{\boldsymbol{\sigma}}},$$

where *k* is the elasticity constant of the vacuum and is calculated as 7 x $10^{17}$ N/m as found from Table I in http://vixra.org/pdf/1002.0032v1.pdf , *r* is the distance force (tension) acts over and *σ* is the mass density of the vacuum [3,4]. The velocity of the standing out-waves are a result of the deformation of the vacuum (similar to how classical standing waves also deform an elastic material they are traveling in) and the difference in group velocity of the standing waves (due to the change in cavity shape) also results in a difference in the strain in the vacuum on each end of the cavity. This difference in strain can be equated to the difference in velocity as:

$$\mathrm{Vg1} - \mathrm{Vg2} = \sqrt{\frac{Force\_Vg1}{\sigma 1}} - \sqrt{\frac{Force\_Vg2}{\sigma 2}}, \qquad (1)$$

where $\sigma_1$ is the mass density (deformation of vacuum) in region 1 at the larger end of the chamber in Figure 1, and $\sigma_2$ is the mass density (deformation) of region

2 at the smaller end of the chamber in Figure 3. The mass-density changes between these regions because the group velocity of the waves are forced to change so that the continuity of the vacuum is preserved while maintaining the constraints of the dimensions of the cavity (similar to a Bernoulli foil on an airplane). Rearranging 1, ***the net thrust is then found to have a square-law dependence on the group-velocity***:

$$\mathbf{Fg1 - Fg2 =} \; \boldsymbol{\sigma_1 V_{g1}^2 - \sigma_2 V_{g2}^2} \qquad \mathbf{(2a)}$$

Where $\sigma_1$ and $\sigma_2$ are the local mass densities around points 1 and 2 in the tapered chamber and $V_{g1}$ and $V_{g2}$ are the group velocities at these same points. The parameter $\sigma$ in general can be related through a conversion constant *k* to the geometry (and *Q*) of the cavity as well as the power input (*P*):

$$\mathbf{Fg1 - Fg2 =} \; \boldsymbol{(V_{g1}^2 - V_{g2}^2)kPQ} \qquad \mathbf{(2b)}$$

As the group velocity is dependent upon geometry, we find that for a cone-shaped cavity the group velocity is proportional to the inverse of the cosine of the angle that is between the longitudinal section of the cavity and the taper of the cone:

$$\mathbf{Fg1 - Fg2 =} \; \boldsymbol{\frac{kPQ}{Cos(\emptyset)}} \qquad \mathbf{(2c)}$$

Where Ø is the angle between the imaginary, horizontal axis of the cavity and the taper of the cone. The net force can also be equated to Hooke's law equation for an elastic medium:

$$\mathbf{Fg1 - Fg2 =} \; \boldsymbol{k(X_1 - X_2)} \qquad \mathbf{(2d)}$$

where *k* is as in equation 1 and $x_1$ and $x_2$ are the compression factors of the vacuum defined by:

$\sigma_1$ = Mass-Universe ($10^{53}$ Kg) / (Hubble Distance + $x_1$ ) (3)

$\sigma_2$ = Mass-Universe ($10^{53}$ Kg) / (Hubble Distance + $x_2$ ) (4)

Where the Hubble distance is 13.8 billion light years or $10^{26}$ meters and $x_1$ and $x_2$ are the compressional variations in the vacuum dues to the change in group velocity between waves each end of the cavity. The compression of space in the EM drive is a concept verified by the NASA's EagleWorks engineering division with the use of a warp interferometer, which they developed to verify a time delay (warp signature of the vacuum) inside the cavity of the EM drive [5].

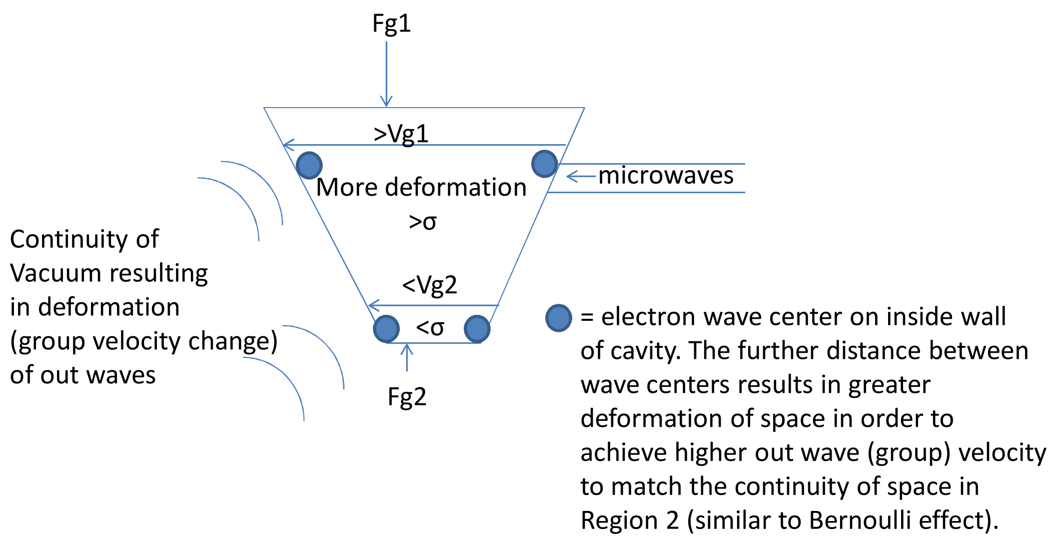



**Figure 3. Tension Created in The Vacuum By Constrained Wave Centers on Each Side of the Tapered Cavity and the Continuity of the Vacuum**

Based on the knowledge of the velocity of the out waves which are involved in producing the photons (through resonance between the "electrons" in the sides of the cavity) and an understanding that more photons results in an increase warp in the vacuum next to the walls of the cavity, a natural approach to increasing the overall thrust of the cavity is to increase the number of resonant photons in the cavity. One approach to increase the density of photons in the cavity is to increase the power of injected photons into the input port of the cavity as shown in Figure 1. The problem here is that a larger magnetron is required to increase the microwave power and the heavier magnetron offsets any gains in thrust obtained (as the thrust obviously has to act against the magnetron mass which is attached to the cavity).

Another new and novel approach is to use the concept of stimulated emission to produce more photons the cavity. As the cavity in Figure 1 is already resonant at a given microwave frequency, the reflects back and forth of photons in the cavity can produce more photons by filling the cavity with a gas such as Hydrogen or Ammonia, which will produced stimulated emissions of photons by raising electrons of the hydrogen gas into higher energy levels which then remits a photon of the same energy as the one used to stimulate the electron in the first place. This is the concept of a maser, first developed by Charles Townsend in the 1950s. By electrical stimulating the gas in the resonant cavity, photons are initially generated and with the right geometry, a stable resonator is created that will continue to produce photons in the cavity as long as electrical power is supplied to ignite the gas. The power supply does not increase in size, but it does produce significantly more power output than feeding more microwaves into the cavity with the use of a magnetron. The design concept is shown in Figure 4, with an external high-voltage electrical supply used to ignite the gas in the cavity.

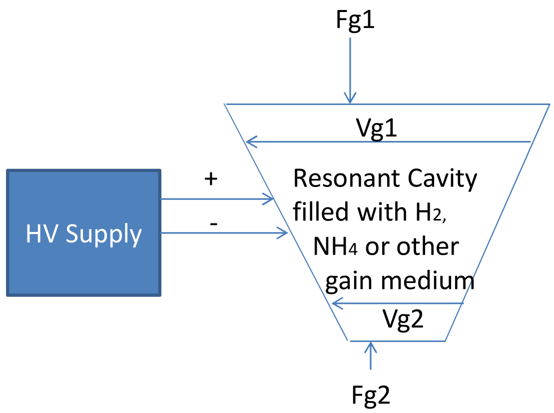



**Figure 4. Increased Photon Density and Thrust With the Conversion of the Cavity to a MASER**

The increase in photons which each pass of the microwaves increases and before long, the microwave power and coherence of the standing waves is much higher than it was at startup of the electrical supply. The issue of maintaining a stable resonator for this cavity is one that can be solved by placing appropriate dielectrics in the right place for a cavity of specific dimensions so that reflected waves are of the correct phase for reinforcement, creating a balanced resonator that also produces a thrust differential across the cavity.

The same concept should hold true for light waves – with the design of a tapered laser cavity producing a differential thrust (Figure 5). For the case of both the laser and microwave thruster, the cavity is designed to keep the energy inside of it to maximize thrust. For a laser, this would seem to suggest the best approach is to make both mirrors of the resonator 100% reflective and to use electrical pumping as optical pumping requires an optical input port from light may be able to escape. Optical pumping at a lower wavelength will result in higher wavelength emissions and the transparency of the optical resonator cavity to certain wavelengths which also blocks the higher wavelengths could still facilitate optical pumping of the medium, however. An ideal electrically-pumped gas laser for testing the thrust cavity may be a $CO_2$ laser where both Brewster windows are 100% reflective.

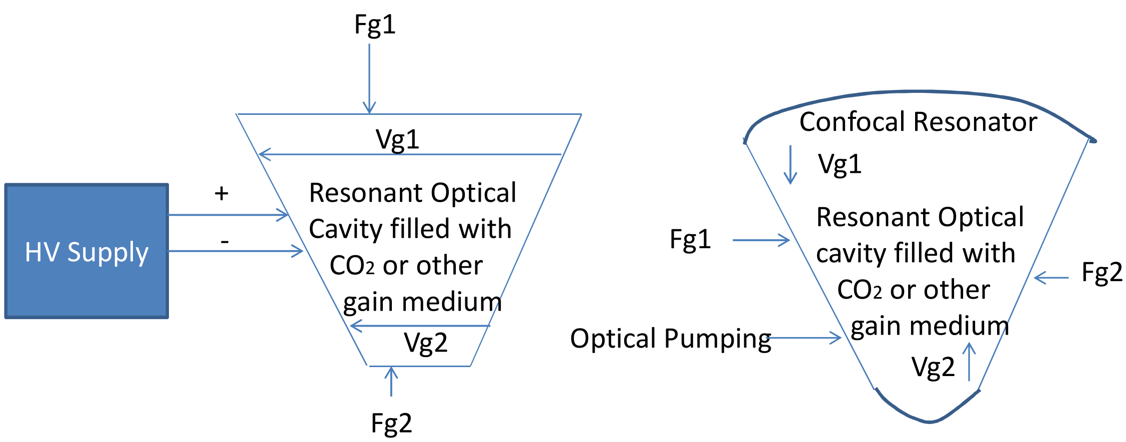



**Figure 5. Increased Photon Density and Thrust Using an Electrical or Optically pumped LASER**

The use of two mirrors of different sizes for each end in a confocal resonator configuration may be used to produce a differential group velocity in the medium, resulting in differential thrust. However, the loss of energy based on the size of the mirrors may need to be mitigated by changing the focal lengths of each mirror so as to produce an optimally stable resonator. Another possibility is a hemispherical resonator where one focal length of a plane mirror is at infinity and the focal length of the opposing mirror is the length of the optical cavity. In any case, by changing geometry of the cavity so it is not laterally symmetrical but the resonator geometry is stable, a differential group velocity can be achieved.

The use of stimulated emissions for improving EM drive thrust is a compelling approach to increasing the efficiency of the EM drive without adding mass that counters the thrust.

This paper is dedicated to Thomas Odom, who I am indebted to for his inspiration and imagination.

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