High Isp Space Drive

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The following is an exploration of the theoretical feasibility of creating a space drive by manufacturing mass from the vacuum, accelerating it gaining momentum, annihilating it, absorbing the energy in photon form, and then reusing the energy. The surprising result is that the principle appears to be theoretically feasible.

It can erroneously be thought feasible to create particle pairs from the vacuum and to accelerate them and eject then from the rear of a ship as a reaction mass. This idea does not actually solve the reaction mass problem because the energy to create the pairs must be carried on the entire journey, and that energy is at least equal in mass to the pairs created. It is only the case that a (reaction mass free) inirtial drive can be obtained by this strategy if, as discussed in prior correspondence, pairs that are created by vacuum fluctuations can be accelerated for a duration within the limit to their lifetime imposed by the Heisenberg principle. The difficulty with this approach is creating a rich particle pair creating environment, and also with establishing sufficient field gradients to achieve net acceleration of the pairs within the limited separation of the particles achieved in their brief lifetimes and/or extending those lifetimes so as to obtain a greater separation.

The purpose here is to explore the possibility of creating electron-positron pairs, accelerating them toward the rear of the ship, but inside the ship, annihilating them, and then absorbing the energy at the rear of the ship and then conducting it back to the front of the ship to repeat the process. This method is of course impractical by today's standards, and far less attractive than vacuum created mass, if that were feasible, but if the subject method can be shown to be theoretically feasible, then that is a major step toward achieving a space drive. The infinite Isp space drive concept is advanced beyond the barrier of apparent physical impossibility to the realm of engineering.

Some starting point equations relating to photons and waves:

E = h nu (Planck) (1)

E = m c^2 (Einstein) (2)

lambda = c/nu (3)

p = E/c = (h)(nu)/c = h/lambda (4)

Assume the absorbing area (collector) at the rear of the ship is 100 percent efficient. If photons are absorbed at rate n photons per second for time t, then the total reaction force is given by:

F = (n p)/t (5)

and the power absorbed by the collector is given by:

P = (E n)/t (6)

It is of interest the amount of energy absorbed by the collector per unit of negative momentum transferred to the ship is obtained by substituting (4) into E/p:

$E/p = E/(E/c) = c$ (7)

Notice that the amount of energy per unit of momentum imparted to the collector is *independent of the wavelength* of the photons absorbed. In fact, it is independent of anything else, as it is constant. I suppose this is self evident, especially considering equation (4), but it is important to the basic issues at hand. As energy per photon goes up, so does momentum, and vice versa. They have a linear relationship.

To determine the power absorbed by the collector per photon unit of thrust we divide (6) by (5) to obtain:

$P/F = (n E)/(n p) = E/p$ (8)

but from (7) $E/p = c$, so:

$P/F = c$ (9)

and we immediately see:

$P = c F$ (10)

We know that one kg-force is equal to 9.807 newtons, or 9.807 kg-m/s^2. So we now see that to absorb the reverse thrust from the rear directed photons of any energy we need the collector to absorb a photonic power per kg of photon thrust of at least:

$P = (3x10^8 m/s)(9.807 kg-m/s^2) = 2.94x10^9 kg-m^2/s^3$ (11)

$P = 2.94x10^9$ watts (per kg-f thrust)   (12)

Unlike particles, the photons leave the annihilation source with constant velocity c, yet arrive at the collector at the same velocity c, regardless of the collector's velocity at the time of arrival. The photon arrives at the same velocity regardless of the energy cost of emitting it. It would appear on the surface, when looked at as a particle, to have the requisite characteristics for providing free energy. However, nature balances energy, even in the case of the photon, and even at low non-relativistic velocities. The energy balance is restored by nature via the red shift or blue shift, a result of the Doppler effect. The amount of change in wavelength of light, delta lambda, is dependent upon the ratio of Vr/c, where Vr is the recession speed of a departing object, or in our case the collector, relative to the light source. Note that the rate Vr is the rate at which the photon source departs from the collector. By using Vr as a departing velocity, the standard red shift formulas can be applied. However, a blue shift can be calculated simply by making Vr negative when the source and collector are approaching each other, as is typically the case for one of two photons of an annihilation pair.

The relativistically adjusted Doppler frequency nu is given in terms of nu0, the frequency observed in the emitter's frame, by:

$$nu = nu0\ [(1-(Vr/c))/(1+(Vr/c))]^{(1/2)} \qquad (13)$$

which works for Vr positive (annihilation photon emitted toward back of ship) or negative (annihilation photon emitted toward back of ship.) Rearranging (3) gives:

$$nu = c/lambda \qquad (14)$$

and substituting into (13):

$$c/lambda = c/lambda0\ [(1-(Vr/c))/(1+(Vr/c))]^{(1/2)} \qquad (14)$$

$$lambda0 = lambda\ [(1-(Vr/c))/(1+(Vr/c))]^{(1/2)} \qquad (15)$$

Applying (4) and (13) we obtain the momentum applied to the collector in terms of the emission frequency nu0:

$$p = E/c = (h)(nu)/c \qquad (16)$$

$$p = nu0\ (h/c)\ [(1-(Vr/c))/(1+(Vr/c))]^{(1/2)} \qquad (17)$$

but, applying (1), (2) and (4), nu0 is a function of lepton rest mass:

$$E = M0\ c^2 = h\ nu0 \qquad (18)$$

$$nu0 = M0\ c^2/h \qquad (19)$$

and substitution (19) into (17)

$$p = M0\ c^2/h\ (h/c)\ [(1-(Vr/c))/(1+(Vr/c))]^{(1/2)} \qquad (20)$$

$$p = M0\ c\ [(1-(Vr/c))/(1+(Vr/c))]^{(1/2)} \qquad (21)$$

Let's now look at the overall momentum balance in a prospective drive. The full energy of the electron-positron rest mass plus the energy applied to accelerate the mass is delivered to the collector. This is good, because the ship loses no energy. Unfortunately, the momentum added to the photons due to the increased pair velocity toward the collector at the time of annihilation is also subtracted from the ship's momentum. Now to see if the net momentum adds to zero.

Suppose we want to produce a kg of thrust using particle pairs alone. Let's further assume the particles are accelerated to a speed of c/2, giving a gamma:

$$gamma = (1-(v^2/c^2))^{-1/2} = (1-((c/2)^2/c^2))^{(-1/2)} \qquad (23)$$

$= (1-(1/4))^{(-1/2)} = 1/.866 = 1.155$

The mass of an electron/positron prior to annihilation is thus:

$$Me = 1.155\ M0 = 1.052\times10^{-30}\ kg \quad (24)$$

and momentum Pe:

$$Pe = (c/2)\ Me = 1.577\times10^{-22}\ kg\text{-}m/s \quad (25)$$

and we want the force to be 1 kg-force, i.e. 9.807 kg-m/s^2:

$$Fe = (n\ Pe)/t = 9.807\ kg\text{-}m/s^2 \quad (26)$$

giving a particle flux n/t of:

$$n/t = (9.807\ kg\text{-}m/s^2)/(1.812\times10^{-22}\ kg\text{-}m/s) \quad (27)$$

$$= 6.22\times10^{22}\ particles/sec \quad (28)$$

$$= 3.11\times10^{22}\ pairs/sec \quad (29)$$

for a current in each beam of:

$$I_{beam} = (3.11\times10^{22}\ particles/sec)/(6.24\times10^{18}\ particles/coulomb) \quad (30)$$

$$= 4984\ amps$$

The electron kinetic energy is given by:

$$Ke = (1/2)\ Me\ v^2 = (1/2)\ (1.052\times10^{-30}\ kg)\ (c/2)^2 \quad (31)$$
$$= 2.95\times10^5\ eV$$

giving a beam power (for each particle type) of:

$$P_{beam} = (2.95\times10^5\ V)(4984\ amps) = 1.47\times10^9\ W \quad (32)$$

In addition, there is the 511 keV creation energy per particle, requiring at 100 percent creation efficiency an added power of

$$P_{pairs} = (5.11\times10^5\ V)(4984\ amps) = 2.55\times10^9\ W \quad (33)$$

and a total drive power of:

$$P\_drive = 2(1.47x10^9 W + 2.55x10^9 W) \quad (34)$$

$$= 8.04x10^9 W$$

to create the kg-f thrust. The photon counter-thust due to absorption of the twin beam annihilation energy might be thought to be given by (12) as:

$$P = 2.94x10^9 watts/kg-f \quad (12)$$

However, it should be noted that the photon energy resulting from the annihilation is assumed to be fully recovered and to be recycled. It is not beamed out the back, which is the assumption behind equation (12). Therefore the only item of concern with regard to theoretical feasibility is the amount of net momentum applied to the ship by the annihilation photons vs the momentum gained from accelerating the particles.

The total relativistic energy of any particle with momentum p is given by:

$$E^2 = E0^2 + (p\_particle*c)^2 \quad (35)$$

$$E = (E0^2 + (p\_particle*c)^2)^{(1/2)} \quad (36)$$

This is derived from the relativistic expression for mass. The same energy E embodied in photons corresponds to momentum by:

$$E = p\_photon*c \quad (37)$$

so:

$$p\_photon*c = (E0^2 + (p\_particle*c)^2)^{(1/2)} \quad (38)$$

$$(p\_photon)^2 * c^2 = E0^2 + (p\_particle*c)^2 \quad (39)$$

$$(p\_photon)^2 = (E0/c)^2 + (p\_particle)^2 \quad (40)$$

$$(p\_photon)^2 = (m0*c)^2 + (p\_particle)^2 \quad (41)$$

thus:

$$p\_photon > p\_particle \quad (42)$$

for equivalent energy expenditures! Again, this only applies to the case where all the photon energy is directed out of the back of the ship. However, when a pair annihilates, it projects one photon in one direction and another in the opposing direction. It is only the net change in momentum of the photons due to the blue shift provided by the velocity of the pair that gets applied to the ship. The component of the pair momentums directed laterally to the sides of the ship always net to zero.

The momentum imparted by accelerating a lepton to speed Vr

$$Pa = Vr * (gamma * M0) = gamma * (Vr)(0.511\ MeV) \qquad (43)$$

must be compared to Pd the Doppler adjusted momentum imparted by annihilation leptons given by (21):

$$Pd = M0\ c\ [(1-(Vr/c))/(1+(Vr/c))]^{(1/2)} + \qquad (44)$$

$$M0\ c\ [(1+(Vr/c))/(1-(Vr/c))]^{(1/2)}$$

$$Pd = M0\ c\ [[(1-(Vr/c))/(1+(Vr/c))]^{(1/2)} + \qquad (45)$$

$$[(1+(Vr/c))/(1-(Vr/c))]^{(1/2)}]$$

Therefore, the proportion of momentum thrust reduced by photon absorption is given by:

$$Pa/Pd = gamma * (Vr/c) * [[(1-(Vr/c))/(1+(Vr/c))]^{(1/2)} + \qquad (46)$$

$$[(1+(Vr/c))/(1-(Vr/c))]^{(1/2)}]$$

or, substituting u = Vr/c into (46):

$$Pa/Pd = (1-u^{2})^{-1/2} * u * [[(1-u)/(1+u)]^{(1/2)} + \qquad (47)$$

$$[(1+u)/(1-u)]^{(1/2)}]$$

In our sample case Vr = -c/2, so substituting -Vr/c = 1/2 into (46):

$$Pa/Pd = gamma * (-1/2) * [[(1+1/2))/(1-1/2))]^{(1/2)} + \qquad (48)$$

$$[(1-1/2)/(1+1/2)]^{(1/2)}]$$

$$Pa/Pd = (1-(1/4))^{(-1/2)} * (-1/2) * [[3]^{(1/2)} +[1/3]^{(1/2)}] \qquad (49)$$

$$= -4/3$$

This means 75 percent of the thrust gained by the acceleration is offset by the photon absorption, resulting in only .25 kg-f thrust in our example. If we proportionally adjust (by a factor of 4) the energy input, beam currents, wattages, etc., then a net of 1 kg-f results. Here are the characteristics of a ship with a (perfectly efficient) infinite Isp drive producing 1 kg-f thrust when using c/2 speed internal lepton beams:

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Design thrust:	1 kg-f
Gamma	1.155
Total pair flux:	1.244x10^23 pairs/sec
Current in each beam:	19,900 amps
Electron kinetic energy:	2.95x10^5 eV
Beam power (each beam):	5.88x10^9 W
Pair creation power:	1.02x10^10 W
Total drive power:	3.26x10^10 W

So where is an error made that permits violation of conservation of momentum? Possibly it is in the summing of two photon momentums assuming the annihilation only results in photons emitted in the longitudinal direction. An integration about all angles of emission is required. However, it appears that this would only serve to reduce the back trust from the photon absorption, and thus increase total net thrust.