Is Low Power Warp Drive Possible?

Breaking the Space-Time Stiffness Barrier

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Abstract

All conventional forms of spacecraft propulsion are unlikely to motivate large-scale private capital because the time scales for interstellar travel even to the nearest exo-planet are simply too long for practical commerce, the habitat problems are likely to be too difficult, and the cost in our declining world economy on the brink of financial if not environmental collapse in 2011 appear to be too great. Recent discoveries in the slowing of the speed of light in Bose-Einstein condensates and the negative electric permittivity and magnetic permeability in metamaterials suggests a low power speculative possibility for warp drive based on Einstein's orthodox field equation for gravity coupled to the electromagnetic field. Suppose we can slow down the speed of light to 3 cm/sec keeping the magnetic response χ_B close to 1 with an *anti-gravitating* non-propagating negative near field low frequency negative dielectric response susceptibility χ_E. Therefore, since c scales as the inverse square root of χ_E yielding a dimensionless amplification of the repulsive anti-gravity field of perhaps as much as order of the cube of $\chi_E \sim 10^{60}$. This would break the space-time stiffness barrier to low power warp-wormhole technology. This conjecture is entirely new and needs further investigation.

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1. The basic idea

Einstein's symmetric second rank classical tensor field equations for the curving of spacetime $G_{\sigma\nu}$ by stress-energy current densities $T_{\sigma\nu}$ of matter fields is

$$G_{\sigma\nu} + \frac{8\pi G}{c^4} T_{\sigma\nu} = 0 \tag{1.1}$$

Maxwell discovered the relation of light to electricity and magnetism

$$c^2 = \frac{1}{\varepsilon\mu} \tag{1.2}$$

where ε is the electrical permittivity and μ is the magnetic permeability. The speed of light appears to the fourth power in the denominator of the coupling constant between $G_{\mu\nu}$ and $T_{\mu\nu}$. The speed of light is taken to be the vacuum speed of light. What if the speed of light here were the speed in whatever medium is present while keeping the field equation generally covariant? This is the new empirically falsifiable conjecture of this paper.

"Virtual electron-positron pairs and virtual photons off-mass-shell inside the vacuum primarily determine the speed of light in the absence of electric 4-current densities from real on-mass-shell particles in the sense of quantum field theory. The "mass shell" is the pole of the single-particle Feynman propagator in the complex energy plane whose position depends on the momentum according to Einstein's special relativity for the frame-invariant rest mass m_0.

$$E^2 - (cp)^2 = (m_0 c^2)^2 \tag{1.3}$$

Virtual particles inside the vacuum are internal lines in the Feynman diagrams of the S-Matrix perturbation series. Real particles outside the vacuum are the external lines.

Maxwell's field equations in the interior of matter are formally covariant tensor equations under the Poincare group where the vacuum permittivity and permeability are simply renormalized to include the frame invariant "scalar" responses χ of the real interior electric 4-current densities j_σ as shown in (1.4) in the simplest case of an isotropic material to avoid unnecessary formal complications that would obscure the key physical idea.

$$\begin{aligned}\varepsilon &= \varepsilon_{vac}\left(1+\chi_E\right)\\ \mu &= \mu_{vac}\left(1+\chi_B\right)\end{aligned} \tag{1.4}$$

Assuming that the material responses are scalar invariants under the additional group of general coordinate transformations of general relativity [1], we can write Einstein's gravity field equations in the interior of materials as

$$G_{\sigma\nu} + 8\pi G\left(\varepsilon_{vac}\mu_{vac}\left(1+\chi_E\right)\left(1+\chi_B\right)\right)^2 T_{\sigma\nu}^{EM} = 0 \tag{1.5}$$

Where I have specialized the source tensor to the electromagnetic field.

$$T_{\sigma\nu}^{EM} = \begin{matrix} \frac{1}{2}\left(\varepsilon_{vac}\left(1+\chi_E\right)E^2 + \frac{B^2}{\mu_{vac}\left(1+\chi_B\right)}\right) & \vec{S}\sqrt{\varepsilon_{vac}\left(1+\chi_E\right)\mu_{vac}\left(1+\chi_B\right)} \\ \vec{S}\sqrt{\varepsilon_{vac}\left(1+\chi_E\right)\mu_{vac}\left(1+\chi_B\right)} & \Xi_{ij}^{EM} \end{matrix} \tag{1.6}$$

$$\vec{S} = \frac{\vec{E}\times\vec{B}}{\mu_{vac}\left(1+\chi_B\right)} \tag{1.7}$$

$$\Xi_{ij}^{EM} = \varepsilon_{vac}\left(1+\chi_E\right)E_iE_j + \frac{B_iB_j}{\mu_{vac}\left(1+\chi_B\right)} - \frac{1}{2}\left(\varepsilon_{vac}\left(1+\chi_E\right)E^2 + \frac{B^2}{\mu_{vac}\left(1+\chi_B\right)}\right)\delta_{ij} \tag{1.8}$$

The material response functions are an infinite series in the electromagnetic field source tensor, which in the strong field case add new nonlinearities to Einstein's gravity field equations.

$$\chi_{E(B)} = \chi_{E(B)}^{0} + \chi_{E(B)}^{\lambda\rho}T_{\lambda\rho}^{EM} + \chi_{E(B)}^{\lambda\rho\lambda'\rho'}T_{\lambda\rho}^{EM}T_{\lambda'\rho'}^{EM} + \chi_{E(B)}^{\lambda\rho\lambda'\rho'\lambda''\rho''}T_{\lambda\rho}^{EM}T_{\lambda'\rho'}^{EM}T_{\lambda'\rho'}^{EM} + \ldots \tag{1.9}$$

These new source nonlinearities will be ignored as no research has been done on them and are presented here perhaps for the first time in the history of physics. Indeed, the new way of looking at Einstein's equations inside of materials is usually ignored because for most materials, up until the last decade or so

$$\chi_{E(B)} << 1 \tag{1.10}$$

The experimental physics of Bose-Einstein condensates [2], metamaterials and other devices [3] that slow the speed of light down to a crawl has advanced so much that now

$$\chi_{E(B)} >> 1 \tag{1.11}$$

can be realistically considered.

Metamaterials are now being fabricated for on-mass-shell propagating far field micro-waves and light waves with only two transverse polarizations in which

$$\chi_{E(B)} < 0 \tag{1.12}$$

However, what is required for practical low power warp drive is not propagating radiation, but a new kind of metamaterial, filled with very low frequency off-mass-shell non-propagating near field virtual photons that are Bose-Einstein condensed into macro-quantum coherent Glauber states of sharp phase and uncertain number. It may be possible to generate them from the aforementioned strong EM field nonlinearities. Ideally, for example, the Fourier transforms of the material responses for the electric permittivity alone that is strongly negative for low frequencies as close to static as possible. Imagine such a longitudinally polarized non-propagating quasi-static near electric field in the hypothetical meta-material containing the virtual photon coherent Bose-Einstein condensate sandwiched between two parallel oppositely charged conducting plates – a new kind of electrical capacitor where

$$\begin{gathered}\tilde{\chi}_E\left(\omega,\vec{k}\right) << 0\\ \omega \sim 0\\ \omega \neq c\left|\vec{k}\right|\end{gathered} \tag{1.13}$$

The key point for warp drive is repulsive antigravity like the cosmological dark energy accelerating the expansion rate of our observable universe, that Einstein's field equation (1.1) together with WMAP and Type 1a supernovae z data say, is sandwiched between our Friedman-Walker-Robertson particle horizon and our future de Sitter event horizon. Our past particle horizon is the future light cone of the moment of inflation whose released energy made the hot Big Bang. Our future event horizon is the past light cone of our world line that we imaginatively stretch to infinite metric proper time that corresponds to a finite conformal clock time. We approach our future event horizon and recede from our past particle horizon.

Let's simplify (1.6) to the case $\vec{B} \to 0$

$$T_{\sigma\nu}^{EM} \underset{\vec{B}\to 0}{\longrightarrow} \begin{matrix} \frac{1}{2}\varepsilon_{vac}\left(1+\chi_E\right)E^2 & 0 \\ 0 & \varepsilon_{vac}\left(1+\chi_E\right)E_iE_j - \frac{1}{2}\varepsilon_{vac}\left(1+\chi_E\right)E^2\delta_{ij} \end{matrix} \tag{1.14}$$

When the response is strongly negative, we have

$$T_{\sigma\nu}^{EM} \underset{\vec{B}\to 0}{\longrightarrow} \begin{matrix} -\frac{1}{2}\varepsilon_{vac}\left|\chi_E\right|E^2 & 0 \\ 0 & -\varepsilon_{vac}\left|\chi_E\right|E_iE_j - \frac{1}{2}\varepsilon_{vac}\left|\chi_E\right|E^2\delta_{ij} \end{matrix} \tag{1.15}$$

Einstein's gravity field equation in this hypothetical desired limit is

$$\begin{pmatrix} G_{00} & G_{0i} \\ G_{io} & G_{ij} \end{pmatrix} + 8\pi\chi_E^2\left(1+\chi_B\right)^2 G \begin{pmatrix} -\frac{1}{2}\varepsilon_{vac}\left|\chi_E\right|E^2 & 0 \\ 0 & -\varepsilon_{vac}\left|\chi_E\right|E_iE_j - \frac{1}{2}\varepsilon_{vac}\left|\chi_E\right|E^2\delta_{ij} \end{pmatrix} \sim 0 \tag{1.16}$$

generating a universally quasi-static repulsive non-propagating confined gravity field.

The weak field Newtonian gravity limit gives an approximate Poisson equation

$$\nabla^2\phi \to 4\pi G\left(\rho + \frac{3p}{c^2}\right) \tag{1.17}$$

That in our case becomes

$$\nabla^2\phi - 12\pi\chi_E^3\left(1+\chi_B\right)^2 G\varepsilon_{vac}E^2 \sim 0 \tag{1.18}$$

In the linear regime of (1.9) suppose we can slow down the speed of light to 3 cm/sec keeping the magnetic response χ_B close to 1. Therefore, since c scales as the inverse square root of χ_E, we have a dimensionless amplification of the repulsive anti-gravity field of order 10^{60}. The nonlinear regime may improve on this linear result. This is uncharted territory since (1.9) is new to the literature.

For example, from (1.9) it may be possible to engineer a metamaterial described by

$$\nabla^2\phi - e^{\kappa\chi_E^3(1+\chi_B)^2 G\varepsilon_{vac}E^2} 12\pi\chi_E^3\left(1+\chi_B\right)^2 G\varepsilon_{vac}E^2 \sim 0 \qquad (1.19)$$

2. Energy Conservation

There is no problem with energy conservation.

$$\begin{aligned} &U_i + W_{in} = U_f + W\left(Q\right)_{out} \\ &U_i > 0 \\ &U_f < 0 \\ &W\left(Q\right)_{out} > W_{in} > 0 \end{aligned} \qquad (1.20)$$

The initial and final internal energies of the metamaterial's near electromagnetic fields are $U_{i(f)}$. The external work input done by system A in switching on the electromagnetic field is W_{in}. The work/heat output from the electromagnetic field-metamaterial on system B is $W(Q)_{out}$. We can arrange A = B with more work/heat output than input. Of course, the energy is coming from the meta-material so that the process is limited. Some kind of phase transition in the meta-material will be induced and the effect will saturate.

3. Energy Requirements

James Woodward [4] estimates a Jupiter mass scale 10^{27} kgm of total energy needed to engineer artificial warping of Einstein's metric field assuming the normal weak coupling of stress-energy current density to curvature. If we could cut that down by a factor of 10^{60} we would obviously be in good shape. We could even do with a lot less than that optimistic first estimate.

The mass of the Earth is ~ 10^{25} kgm (10^{42} Joules). Therefore, we would not need impractically large electric fields to neutralize the Earth's gravity around the ship if we could achieve large resonances in the low frequency dielectric susceptibility response functions of metamaterials. The amplification scales as χ_E^3, so if we only want to store say one Joule total in the slowly varying near electric fields of the metamaterial capacitor, we need a resonance of $-\left|\chi_E\right|^3 \sim 10^{42}$. Therefore, $\chi_E \sim -10^{14}$. Consequently, the required index of refraction in the non-radiative near field ELF range that scales as $\chi_E^{-1/2}$ is ~ 10^7 i.e., a metamaterial speed of light ~ 30 meters/sec.

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