Is Low Power Warp Drive Possible?

Breaking the Space-Time Stiffness Barrier

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- 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, for example, that the speed of light can be slowed to 3 cm/sec keeping the magnetic response close to 1 with a non-propagating near-field low frequency negative dielectric response susceptibility. Therefore, since c scales as the inverse square root of the product of the electric and magnetic susceptibilites, yielding a dimensionless amplification of the repulsive anti-gravity field of perhaps as much as order of the cube of the electric susceptibility ~ 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.

Einstein's Gravity Field Equation

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

Maxwell's Unification

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

Constituitive Equations

$$\varepsilon = \varepsilon_{vac}\left(1+\chi_E\right)$$

$$\mu = \mu_{vac}\left(1+\chi_B\right)$$

Einstein’s Eq Inside Material

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

Electromagnetic Field Source Tensor

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

With Poynting vector for energy flow

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

Electromagnetic Field Stress Tensor

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

Nonlinear Material Electrodynamics

$$\chi_{E(B)} = \chi^{0}_{E(B)} + \chi^{\lambda\rho}_{E(B)} T^{EM}_{\lambda\rho} + \chi^{\lambda\rho\lambda'\rho'}_{E(B)} T^{EM}_{\lambda\rho} T^{EM}_{\lambda'\rho'} + \chi^{\lambda\rho\lambda'\rho'\lambda''\rho''}_{E(B)} T^{EM}_{\lambda\rho} T^{EM}_{\lambda'\rho'} T^{EM}_{\lambda'\rho'} + \ldots$$

Metamaterials

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

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

Near Fields

- 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.

Near Field Metamaterial Susceptibility

$$\tilde{\chi}\left(\omega,\vec{k}\right) \ll 0$$

$$\omega \to 0$$

$$\omega \neq c\left|\vec{k}\right|$$

Capacitor Filled With Metamaterial

$$T_{\sigma\nu}^{EM} \underset{\substack{B\to 0\\ \chi_B\to 0}}{\longrightarrow} \begin{pmatrix} -\frac{1}{2}\varepsilon_{vac}\left|\chi_E\right|E^2 & 0 \\ 0 & -\varepsilon_{vac}\left|\chi_E\right|E_iE_j-\frac{1}{2}\varepsilon_{vac}\left|\chi_E\right|E^2 \end{pmatrix}$$

Low Power Warping Space-Time

$$\begin{pmatrix} G_{00} & G_{0i} \\ G_{i0} & G_{ij} \end{pmatrix} + 8\pi\left(\varepsilon_{vac}\mu_{vac}\right)^2 \chi_E^2 G \begin{pmatrix} -\frac{1}{2}\varepsilon_{vac}\left|\chi_E\right|E^2 & 0 \\ 0 & -\varepsilon_{vac}\left|\chi_E\right|E_iE_j - \frac{1}{2}\varepsilon_{vac}\left|\chi_E\right|E^2 \end{pmatrix} \sim 0$$

Warp Drive Newtonian Limit

$$\nabla^2\phi - 4\pi G\left(\rho + 3\frac{p}{c^2}\right) \sim 0$$

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

Ultra-Low Power Warp Drive?

$$\frac{1}{c^2}\nabla^2\phi - e^{\kappa\chi_E^3(1+\chi_B)^2(\varepsilon_{vac}\mu_{vac})G\varepsilon_{vac}E^2}\, 12\pi\left(\varepsilon_{vac}\mu_{vac}\right)^2 \chi_E^3\left(1+\chi_B\right)^2 G\varepsilon_{vac}E^2 \overset{?}{\sim} 0$$

Energy is Conserved

$$U_i + W_{in} + Q_{in} = U_f + W_{out} + Q_{out}$$

$$U_i > 0$$

$$U_f < 0$$

$$W_{out} + Q_{out} > W_{in} + Q_{in} > 0$$

How Much Energy?

- 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 the cube of the susceptibility , 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 $(10^{14})^3$. Therefore, . Consequently, the required index of refraction in the non-radiatiive near field ELF range that scales as the reciprocal square root of the susceptibility is ~ 10^7 i.e., a metamaterial speed of light ~ 30 meters/sec.

Instant space communications using nonlocal quantum entanglement?

- Jacques Vallee emphasized the importance of trying to overcome the light barrier for star ship technology with quantum entanglement in the first meeting of the joint DARPA-NASA 100 Year Star Ship workshop in January 2011 in Marin County. MIT physics historian David Kaiser describes how this idea came about and objections to it in his book "How The Hippies Saved Physics" (W.W. Norton, New York, 2011). Mainstream opinion is that the direct use of quantum entanglement as a C^3 command, control, and communication channel without a light-speed limited signal "key" is fundamentally impossible because of the linearity of observable operators and the unitarity of quantum state time evolution between strong measurements.

My 1978 Concept Reborn?

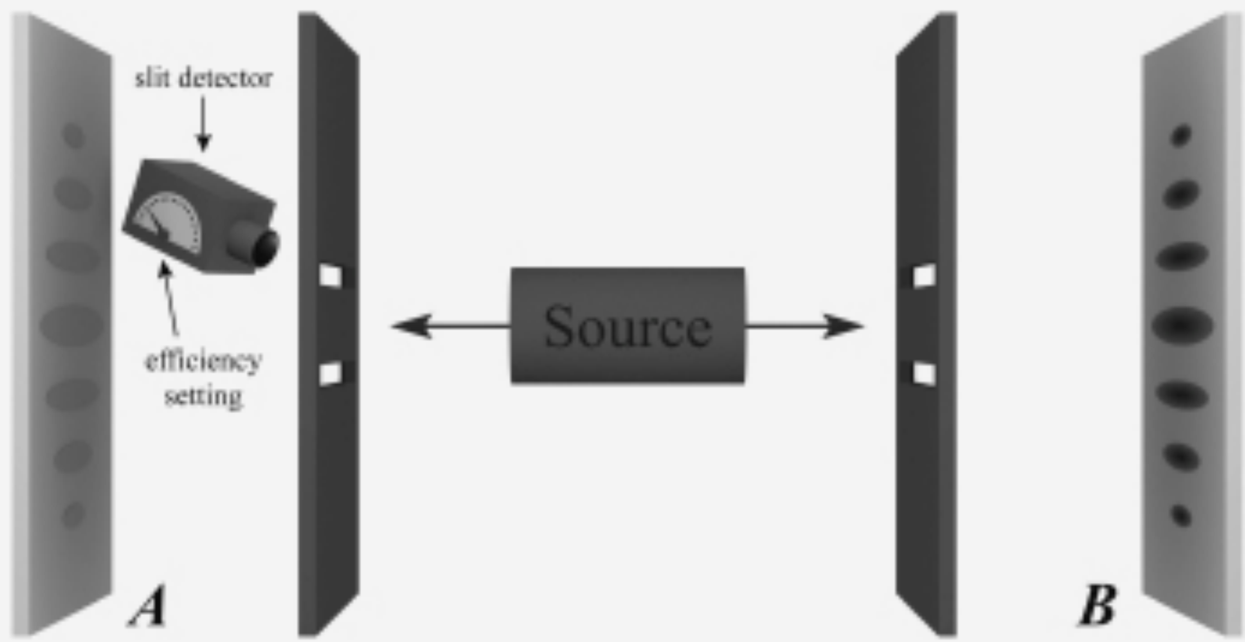

FIGURE 9.1. **Jack Sarfatti's design of a faster-than-light commu-**

Antony Valentini wrote

- *"It is argued that immense physical resources - for nonlocal communication, espionage, and exponentially-fast computation - are hidden from us by quantum noise, and that this noise is not fundamental but merely a property of an equilibrium state in which the universe happens to be at the present time. It is suggested that 'non-quantum' or nonequilibrium matter might exist today in the form of relic particles from the early universe. We describe how such matter could be detected and put to practical use. Nonequilibrium matter could be used to send instantaneous signals, to violate the uncertainty principle, to distinguish non-orthogonal quantum states without disturbing them, to eavesdrop on quantum key distribution, and to outpace quantum computation (solving NP-complete problems in polynomial time)."*

Coherent State Sender Entangled With A Single Qubit Receiver

$$|A,B\rangle = \frac{1}{\sqrt{2}}\left(|\alpha\rangle_A |0\rangle_B + |\beta\rangle_A |1\rangle_B\right)$$

$$\langle A,B|B,A\rangle = \frac{1}{2}\begin{pmatrix} \langle\alpha|\alpha\rangle_A \langle 0|0\rangle_B + \langle\beta|\beta\rangle_A \langle 1|1\rangle_B \\ +\langle\alpha|\beta\rangle_A \langle 0|1\rangle_B + \langle\beta|\alpha\rangle_A \langle 1|0\rangle_B \end{pmatrix}$$

$$= \frac{1}{2}\left(\langle\alpha|\alpha\rangle_A + \langle\beta|\beta\rangle_A\right) = 1$$

Nonorthogonal Sender Coherent States Give Signal Nonlocality

$$\langle \alpha | \beta \rangle = e^{-\frac{1}{2}\left(|\alpha|^2 + |\beta|^2 - 2\alpha^* \beta\right)} \neq \delta(\alpha - \beta)$$

Entangled Density Matrix

$$\rho_{AB} = |A,B\rangle\langle B,A| = \frac{1}{2}\begin{pmatrix} |\alpha\rangle_A|0\rangle_B\ {}_B\langle 0|\ {}_A\langle\alpha| + |\beta\rangle_A|1\rangle_B\ {}_B\langle 1|\ {}_A\langle\beta| \\ +|\alpha\rangle_A|0\rangle_B\ {}_B\langle 1|\ {}_A\langle\beta| + |\beta\rangle_A|1\rangle_B\ {}_B\langle 0|\ {}_A\langle\alpha| \end{pmatrix}$$

The Nonlocal Entanglement Signal

$$P(1)_B = Tr\left\{|1\rangle_{B\ B}\langle 1|\,\rho_{AB}\right\} = \frac{1}{2}\left(1 + \left|\langle \alpha|\beta\rangle\right|_A^2\right)$$

Violation of Born Probability Rule

$$P(0)_B = Tr\left\{|0\rangle_{B\ B}\langle 0|\,\rho_{AB}\right\} = \frac{1}{2}\left(1+\left|\langle\alpha|\beta\rangle\right|_A^2\right) = P(1)_B$$

$$P(0)_B + P(1)_B = 1+\left|\langle\alpha|\beta\rangle\right|_A^2 > 1$$