Can CDW physics explain ultra fast transitions, and current vs. applied electric field values seen in the laboratory?

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The tunneling Hamiltonian is a proven method to treat particle tunneling between different states represented as wavefunctions in many-body physics. Our problem is how to apply a wave functional formulation of tunneling Hamiltonians to a driven sine-Gordon system. We apply a generalization of the tunneling Hamiltonian to charge density wave (CDW) transport problems in which we consider tunneling between states that are wavefunctionals of a scalar quantum field. We present derived I-E curves that match Zenier curves used to fit data experimentally with wave-functionals congruent with the false vacuum hypothesis. The open question is whether the coefficients picked in both the wave-functionals and the magnitude of the coefficients of the driven sine Gordon physical system should be picked by topological charge arguments that in principle appear to assign values that have a tie in with the false vacuum hypothesis first presented by Sidney Coleman. Our supposition is that indeed this is useful and that the topological arguments give evidence as to a first order phase transition which gives credence to the observed and calculated I-E curve as evidence

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INTRODUCTION

This paper's main result has a very strong convergence with the slope of graphs of electron-positron pair production representations. The newly derived results include a threshold electric field explicitly as a starting point without an arbitrary cut off value for the start of the graphed results, thereby improving on both the Zener plots and Lin's generalization of Schwingers 1950 electron-positron nucleation values results for low dimensional systems. The similarities in plot behavior of the current values after the threshold electric field values argue in favor of the Bardeen pinning gap paradigm. We conclude with a discussion of how these results can be conceptually linked to a new scheme of exact evolution of the dynamics of quantum ϕ^4 field theory in 1+1 dimensions.

This leads to writing the new Gaussian wavefunctional to be looking like

$$\Psi \equiv \quad c \cdot \exp(-\alpha \cdot \int dx[\phi - \phi_C]^2) \tag{1}$$

Making this step from Eq. (1) to Eq. (2)involves recognizing, when we go to one-dimension, that we look at a washboard potential with pinning energy contribution from $D \cdot \omega_P^2$ in one- dimensional CDW systems

$$\frac{1}{2} \cdot D \cdot \omega_P^2 \cdot (1 - \cos\phi) \approx \frac{1}{2} \cdot D \cdot \omega_P^2 \cdot \left(\frac{\phi^2}{2} - \frac{\phi^4}{24} \right) \tag{2}$$

The fourth-order phase term is relatively small, so we look instead at contributions from the quadratic term and treat the fourth order term as a small perturbing contribution to get our one dimensional CDW potential, for lowest order, to roughly look like Eq. (2). In addition, we should note that the c is due to an error functional-norming procedure, discussed below; α is proportional to one over the length of distance between instaton centers. This leads to

$$c_1 \cdot \exp\left(-\alpha_1 \cdot \int d\tilde{x} \left[\phi_F \ \right]^2 \right) \cong \Psi_{initial} \tag{3}$$

As well as

$$c_2 \cdot \exp\left(-\alpha_2 \cdot \int d\tilde{x} \left[\phi_T \right]^2 \right) \cong \Psi_{final} \tag{4}$$

The tunneling Hamiltonian incorporates wavefunctionals whose Gaussian shape keeps much of the structure as represented by Fig. .Following the false vacuum hypothesis, we have a false vacuum phase value $\phi_F \equiv \langle \phi \rangle_1 \cong$ ***very small value***, as well as having in CDW, a final true vacuum $\phi_T \cong \phi_{2\pi} \equiv 2 \cdot \pi + \varepsilon^+$. This led to Gaussian wavefunctionals with a simplified structure. For experimental reasons, we need to have (if we set the charge equal to unity, dimensionally speaking)

$$\alpha \approx L^{-1} \equiv \Delta E_{gap} \equiv V_E(\phi_F) - V_E(\phi_T) \tag{5}$$

This is equivalent to the situation as represented by Fig. 1

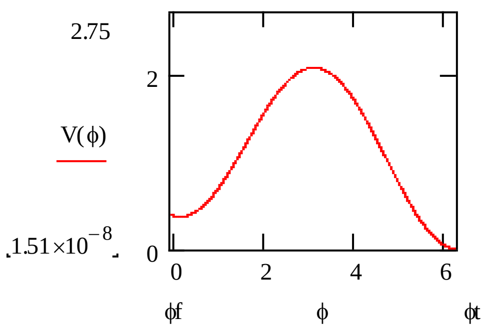

Fig 1*Fate of the false vacuum representation of what happens in CDW. This shows how we have a difference in energy between false and true vacuum values. This eventually leads to a current along the lines of*

$$I \propto \tilde{C}_1 \cdot \left[\cosh\left[\sqrt{\frac{2 \cdot E}{E_T \cdot c_V}} - \sqrt{\frac{E_T \cdot c_V}{E}} \right] \right] \cdot \exp\left(-\frac{E_T \cdot c_V}{E} \right) \tag{6}$$

The current expression is a great improvement upon the phenomenological Zener current expression, where G_P is the limiting Charge Density Wave (CDW) conductance.

$$I \propto G_P \cdot (E - E_T) \cdot \exp\left(-\frac{E_T}{E} \right) \ if \, E > E_T \tag{7}$$

$$0 \qquad\qquad otherwise$$

Fig. 4 illustrates to how the pinning gap calculation improve upon a phenomenological curve fitting result used to match experimental data. The most important feature here is that the theoretical equation takes care of the null values before thre threshold is reached by itself. I.e. we do not need to set it to zero as is done arbitrarily in Eqn (7).

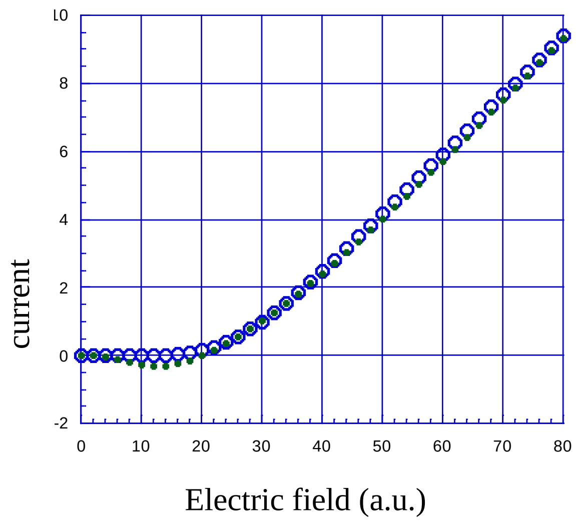

Fig 2*Experimental and theoretical predictions of current values versus applied electric field. The dots represent a Zenier curve fitting polynomial, whereas the blue circles are for the S-S' transport expression derived with a field theoretic version of a tunneling Hamiltonian.*

So then, we have $L \propto E^{-1}$.. When we consider a Zener diagram of CDW electrons with tunneling only happening when $e^{*} \cdot E \cdot L > \varepsilon_G$ where e^{*} is the effective charge of each condensed electron and ε_G being a pinning gap energy, we find , assuming that x is the de facto distance between an instanton pair and a measuring device.

In the current vs. applied electric field derivation results, we identify the $\Psi_i[\phi]$as the initial wave function at the left side of a barrier and $\Psi_f[\phi]$as the final wave function at the right side of a barrier.

$$\frac{L}{x} \cong c_v \cdot \frac{E_T}{E} \tag{8}$$

CONCLUSION- AND LINKAGE TO EXACT DYNAMICS OF ϕ^4 FIELD THEORY IN 1+1 DIMENSIONS

We restrict this analysis to ultra fast transitions of CDW; this is realistic and in sync with how the wavefunctionals used are formed in part by the fate of the false vacuum hypothesis.

A kink-anti kink structure so implied by the Gaussian wave functional is stated by Cooper, quoting Moncrief to have an evolution given by a sympletic evolution equation, as given below assuming an averaging procedure we can write as

$$y_i \sim \int_{V_i} dx \phi[x,t] / \Delta V_i \approx \text{average of } \phi[x,t] \text{ in a ball about } x_i \text{ of volume } \Delta V_i \tag{9}$$

And

$$\frac{dy_i}{dt} \equiv \pi_i[t] \tag{10}$$

And

$$\frac{d\pi_i}{dt} \equiv \frac{1}{a^2} \cdot [y_{i+1} + y_{i-1} - 2y_i] - \lambda y_i^3 + m^2 y_i = F[y_i] \tag{11}$$

This is assuming that we spatially discretize a Hamiltonian density via

$$\int dx \to a \cdot \sum_i \tag{12}$$

Following a field theory replacement of $\hat{x} \to \phi_{op}[x,t]$, and a discretized time structure given by $t = j \in$

This leads to the possibility of looking at a quantum foam evolution as given in **Fig 1** via the following sympletic structures , with i the 'spatial component along a chain' , and j the 'time component' along a chain. Eqn. (19e) and Eqn (19f) are materially no different than having energy course through a wave lattice as seen in ocean swells accommodating an energy pulse through the water.

$$y_i[j+1] = y_i[j] + \in \cdot \pi_i[j] + \frac{\in^2}{2} \cdot F(y_i[j]) \tag{13}$$

$$\pi_i[j+1] = \pi_i[j] + \frac{\in}{2} \cdot (F(y_i[j]) + F(y_{i+1}[j])) \tag{14}$$

A proper understanding of this evolution dynamic should permit a more mature quantum foam interpretation of false vacuum nucleation.

REFERENCES

(1) Unpublished notes by Dr. Fred Cooper and Dr. Barry Sneneider, written as of February 15, 2008, handed to the author. Contact fcooper@nsf.gov for copies

(2) V. Moncrief, Phys Rev D 28, 2485 (1983)

(3) **An Open question: Are topological arguments helpful in setting initial conditions for transport problems in condensed matter physics?**
A.W. Beckwith (Houston U. & Houston U., TcSAM) . Nov 2004. 17pp.
Published in **Mod.Phys.Lett.B20:233-243,2006**.
e-Print: **math-ph/0411031**

(4) **New soliton-anti soliton pair creation rate expression improving upon Zener curve fitting for I-E plots.**
A.W. Beckwith (Houston U., TcSAM) . Nov 2004. 24pp.
Published in **Mod.Phys.Lett.B20:849-861,2006**.
e-Print: **math-ph/0411**