Resonant Electromagnetic Interaction in Low Energy Nuclear Reactions

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I Background about the importance of EMI in $d+d \rightarrow {}^4He+\gamma$

II What are EMI Resonant Interactions?

III EMI Resonant Interactions in Finite Crystals

IV Ground State-Excited (Ion Band) State EMI Resonant and Non-Resonant LENR

V EMI Resonant Interactions, Trapped Photons in SPAWAR Experiments: Some Predictions

Summary of Key Reasons why Electromagnetism is Important

- "Coulomb barrier" requires "static" Electromagnetic Interaction (EMI)

- In d+d→^{4}He+γ, EMI is not static; "Coulomb barrier" replaced by QED

- QED couples to all length scales

- Superficially, QED " not treated rigorously in Condensed Matter Physics." But, in fact, given appropriately interpreted pictures, this is not true.

- Missing ingredient in how Condensed Matter Physics (CMP) relates to CMNS:
  -Understanding "overlap" can occur without high energy particles.

- This happens all the time in CMP. How this happens not treated rigorously.

- Rigorous Statement Involves Many Particles and the fact that:
  -Many particles can act like a single particle/wave by moving precisely the same way;
  -Momentum can change abruptly, locally, without any particle acquiring high velocity

Concerning the Role of EMI Resonant Processes in LENR

- Giuliano Preparata suggested that the relationship between CF phenomena and mainstream nuclear physics, in general terms, is analogous to the relationship between radio engineering and the early physics of quantum mechanics.

- I sincerely believe, after many years, that, in essence, he certainly was right about this.

- But, as opposed to singling out the relationship between radio engineering and its relationship to early quantum mechanics, quite possibly simply because I am younger, I think a more appropriate analogy applies, involving the relationship between semi-conductor physics and post 1940 electrical engineers.

- Regardless, in both analogies, EMI resonance (which is at the heart of what both of us have been suggesting) is essential in most (if not all) CF phenomena.
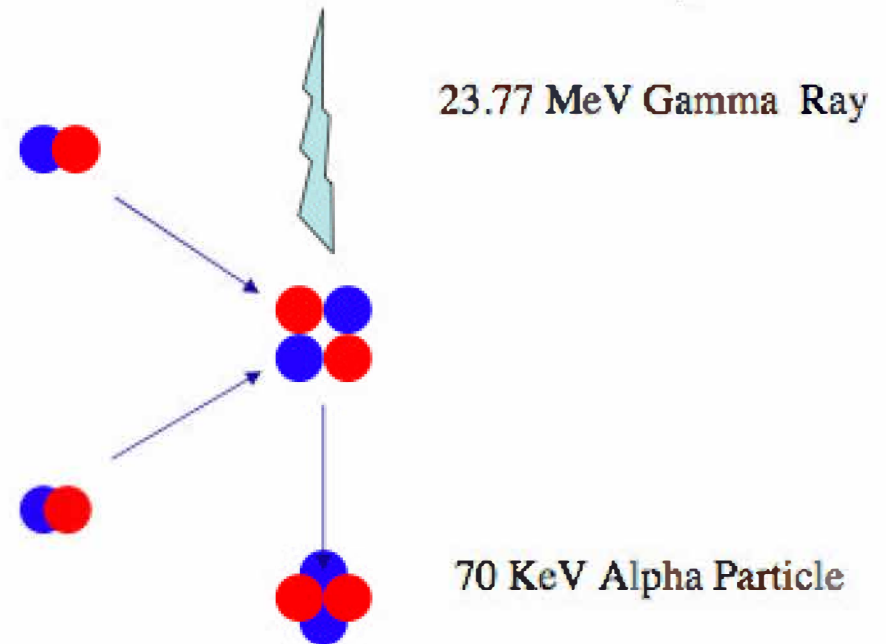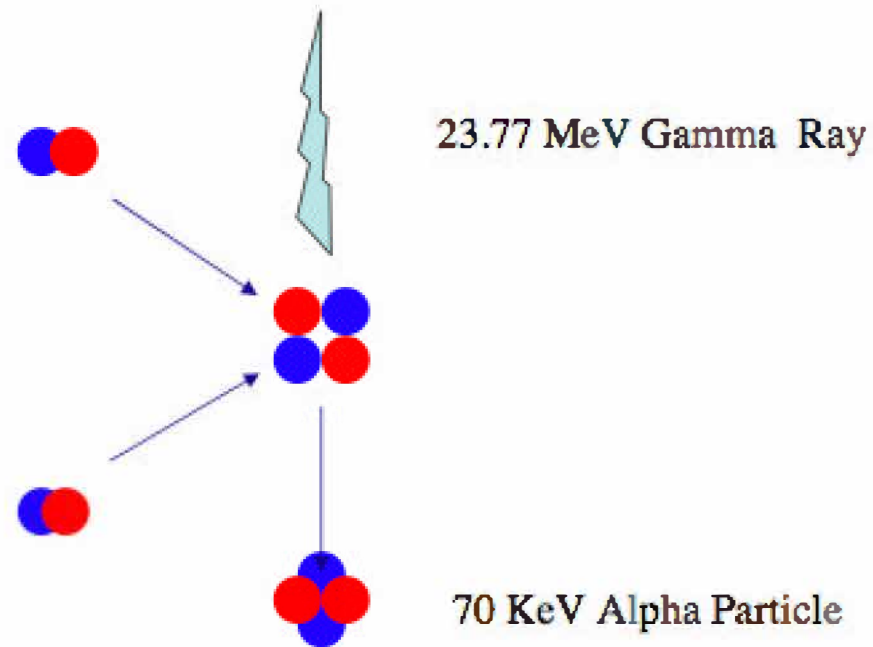
Facts About Conventional Fusion
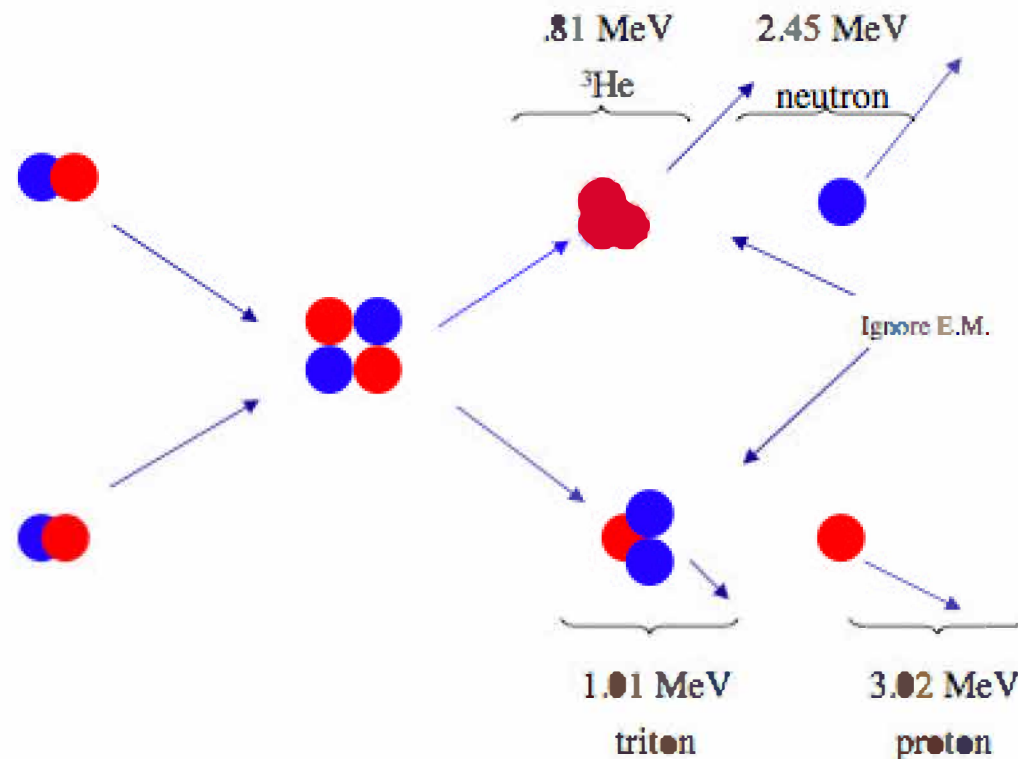
EMI can be ignored. Static, Coulomb Barrier applies.

Key Limitation of "Conventional" Nuclear Fusion Theory

23.77 MeV Gamma Ray

- "Secret, 'Rare' Reaction": $d+d \rightarrow {}^4He + \gamma$

- Common assumption: energy release too large

70 KeV Alpha Particle

- Assumption is not right. Reaction is Rare because:

  * Reaction involves EMI

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Additional Facts About Additional Reaction

23.77 MeV Gamma Ray

70 KeV Alpha Particle

- Rate of "Secret Reaction" is 10^7 smaller than other reactions

- Not cited in conventional fusion literature for this reason

- d+d $\longrightarrow$ ^{4}He + γ is rare, but reverse reaction ^{4}He + γ $\longrightarrow$ d+d is well-known

- ^{4}He + γ $\longrightarrow$ d+d teaches us that: In d+d $\longrightarrow$ ^{4}He + γ,
  - ❖ Simplified Coulomb Barrier tunnelling does not apply.
  - ❖ Far from reaction, EMI required: d+d must be prepared appropriately

Historical Note about Importance of EMI in LENR

- Preparata and Schwinger did not know about

$$^4He + \gamma \rightarrow d+d$$
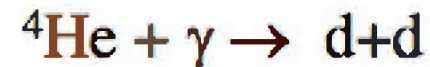
- Both believed EMI was important, either implicitly (in the case of Schwinger) or explicitly (in the case of Preparata)

Wrong Intuitive Picture has resulted from not Including EMI in d+d→^{4}He+γ

- Because all d-d fusion reactions conserve isospin, it has been widely assumed that the dynamics is driven by the strong force interaction (SFI), NOT electromagnetic interaction (EMI)

- Major source of confusion is the assumption that the strong force dictates both the dynamics and the available energy states and transitions

- True for the conventional reactions but not for d+d→^{4}He+γ

- Thus, most nuclear physicists assume: 1. EMI is static; 2. Dominant reactions have smallest changes in incident kinetic energy (T); and (because of 2), d+d →^{4}He+γ suppressed.

Further Implications of $^4He + \gamma \rightarrow d+d$
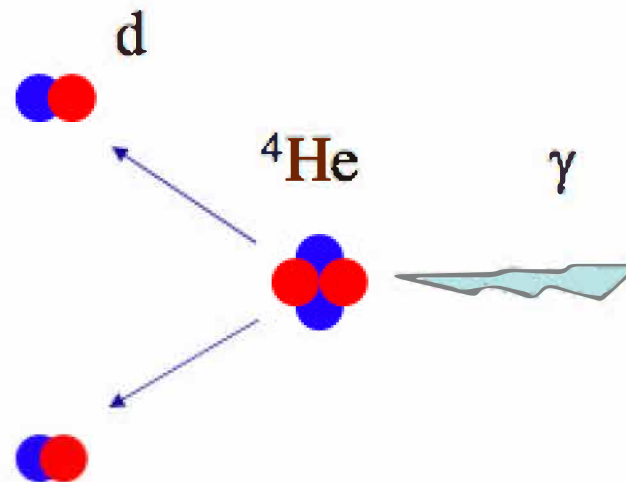
- Coulomb Barrier does not apply-- more general QED Barrier required

  * Strong Force determines energy levels, not dynamics

  * Far from location of reaction, d+d has spin=0, angular momentum = $2\hbar$

- Time Reversal invariance→ Also true for $d+d \rightarrow {}^4He$

- QED effects can become important: mv=p-e/cA (mv ≠ p)

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What are EMI Resonant Interactions?

Simple Example: Radio Transmission and Reception

Oscillating Current J(λ)

λ / 2

J(λ)

λ / 2

J(λ)

λ

Transmitter

λ / 2

J(λ)

λ / 2

J(λ)
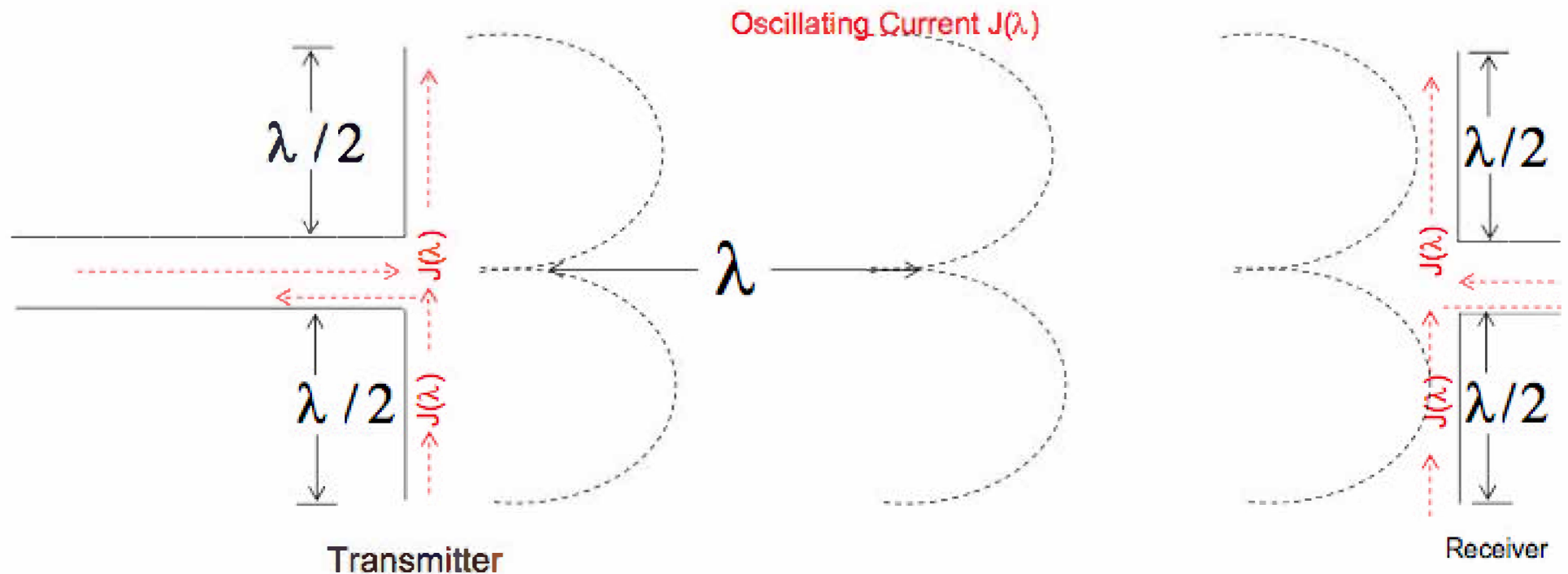
Receiver

- Simple Example of Resonance occurs through a matching condition: Transmitter (dipole) Antenna and Receiver (dipole) Antenna apertures match each   other and the wavelength of the signal.

EMI Resonant Interactions in Finite Solids

- Scattering Theory for Photons (Bragg Scattering):

$$w \equiv w(k) = c \times k = w(k + g) = c \times |k + g|$$

– Boundary Conditions Satisfied at Boundaries of Solid

- Multiple Scattering Theory for Charged Particles:

$$\varepsilon \equiv \varepsilon(k) = \varepsilon(k + g)$$

- Wave vectors (k) and reciprocal lattice vectors g minimize outside coupling

- Flux of each kind of particle is conserved

- Ground State and Lowest Lying Excited States couple only through rigid translations that do not alter separations between particles

- Then, semi-classical theory of transport applies

Kinematics of Ground State-Excited (Ion Band) States

- In a finite lattice, when E is constant, or varies slowly, in the reference of an observer, outside the lattice, initially

  -Ground state (GS) and low-lying excited state band
   energies evolve in time,

  $$\varepsilon(k(t)) = \varepsilon(k(0) + eEt),$$

  provided |eEt| does not cross a "zone boundary" (e.g., in 1-dimension, |eEt|<π/a)

  - Each time |eEt| crosses the first, second, third,…, zone boundary, a resonant condition takes place in which momentum is transferred to the center of mass. In one dimension,

  $$v_{CM} -> v_{CM} \pm \frac{2\pi n}{a} \qquad \longrightarrow \qquad \text{Bloch Oscillations}$$

- Momentum can be "stored": When available momentum is large enough, nuclear reactions can take place

Resonant LENR and Stopped Photons

- This last picture occurs when E is normal to the surface and constant

- When a second E or B field is applied parallel to the surface, new physical effects can occur:
  - in the reference frame that is stationary with respect to the center-of-mass of the lattice,

$$\frac{\hbar dk}{dt} = 0 = e\vec{E} + e\frac{\nabla\varepsilon(k)}{\hbar c} \times \vec{B},$$

$$\frac{\partial E_x}{\partial t} = -\nabla_{k_z}\varepsilon(k)\frac{\partial E_x}{\hbar \partial z},$$

  - This last equation has exponentially growing and decaying solutions, which can explain the emission of high energy particles in the SPAWAR experiments.

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Summary

- I have reviewed the basic ideas behind resonant EMI can take place in finite solids has been reviewed.

- These ideas not only provide a basis for conventional band theory but explain how through finite size effects, it is possible to create many of the kinds of effects envisioned by Giuliano Preparata.

- The underlying formalism predicts that the orientation of the external fields, that are applied in the SPAWAR protocol, has direct bearing on the emission of high energy particles. It also implies that nano-scale particles, of a particular size, provide an optimal environment for initiating LENR in the PdD system.