### **Field Combination Theory of Quantum Entanglement: Principles of Quantum Entanglement and Communication Based on High-Dimensional Projection and Field Fusion**

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**Abstract:** Based on Zhijun Li’s ABC (Electromagnetic-Color-Higgs) vortex field theory, this paper proposes a completely new theoretical framework for the essence of quantum entanglement. We demonstrate that quantum entanglement is not a “spooky action at a distance,” but an intrinsic connection of particle field combinations in a high-dimensional space. When particles enter an entangled state, their ABC field combination undergoes quantum field fusion, forming a shared field structure. When spatially separated, this field connection is maintained through high-dimensional channels, and its projection into three-dimensional space manifests as instantaneous correlation. By constructing the field fusion operator and the high-dimensional projection map , we derive a rigorous mathematical formulation of the entangled state. By establishing the topological invariance of the field combination, we prove the robustness of entanglement. Finally, through a reinterpretation of quantum communication protocols, we propose novel quantum technologies based on the principle of field combination. This model provides, for the first time, an explanation for quantum entanglement that conforms to local realism, resolves the EPR paradox, and offers testable experimental predictions.  
**Keywords:** ABC Theory; Quantum Entanglement; Field Combination Fusion; High-Dimensional Projection; Quantum Communication; EPR Paradox  
**1. Introduction: The Dilemma of Quantum Entanglement and a New Paradigm**  
As the most mysterious phenomenon in quantum mechanics, quantum entanglement has perplexed physicists since the proposal of the EPR paradox. Einstein called it “spooky action at a distance,” reflecting the profound contradiction between local realism and quantum non-locality.  
This paper, based on Professor Zhijun Li’s ABC theory, presents a new viewpoint: the essence of quantum entanglement is a projection effect of high-dimensional field structures. Within a 26-dimensional spacetime framework, we will demonstrate through rigorous mathematical derivation that the entanglement phenomenon originates from the fusion and high-dimensional connection of particle field combinations, rather than a superluminal action in three-dimensional space.  
**2. Theoretical Framework: Mathematical Formulation of the ABC Fields**  
**2.1 Foundations of Field Theory in 26-Dimensional Spacetime**  
We consider the 26-dimensional spacetime manifold with metric , where indices . The action for the ABC fields is:  
  
The detailed expressions for each component are as follows:  
**Gravitational part:**  
  
**ABC kinetic terms:**  
  
where the field strength tensors are:  
  
  
**Interaction term:**  
  
**2.2 Tensor Representation of a Single-Particle State**  
The quantum state of a fundamental particle can be represented as the tensor product of its ABC fields:  
  
where the coefficients satisfy the normalization condition:  
  
The eigenstates of the fields are defined by the following eigenvalue equations:  
  
**3. The Mathematical Mechanism of Field Fusion**  
**3.1 Rigorous Definition of the Field Fusion Operator**  
The field fusion operator is a unitary operator acting on the two-particle state space:  
  
Its specific form is:  
  
where is the angular momentum operator of the -th particle, and is the total angular momentum operator after fusion.  
**3.2 Dynamical Process of Entangled State Formation**  
The dynamics of field fusion are described by the time-dependent Schrödinger equation:  
  
The interaction Hamiltonian is:  
  
where are the creation and annihilation operators for different particles.  
**3.3 Mathematical Formulation of the Fusion Condition**  
The mathematical condition for field fusion to occur is the field resonance condition:  
  
where the fusion width is:  
  
The fusion probability is given by Fermi’s Golden Rule:  
  
**4. The Mathematical Framework of High-Dimensional Projection Theory**  
**4.1 Geometric Structure of High-Dimensional Spacetime**  
We consider the 26-dimensional spacetime manifold , whose metric can be decomposed as:  
  
where correspond to the macroscopic four-dimensional spacetime, and correspond to the extra dimensions. The projection operator is defined as:  
  
  
**4.2 Field Propagation in High-Dimensional Space**  
The equation of motion for a field in high-dimensional space is:  
  
where the d’Alembertian operator is:  
  
The field can be expanded as:  
  
where are the eigenmodes in the extra dimensions.  
**4.3 Topological Proof of Entanglement Maintenance**  
The topological invariant of the entangled state is described by the Chern number:  
  
where is the field strength tensor. The stability of entanglement requires:  
  
This is guaranteed by the conservation of the topological current:  
  
**5. The Principle of Field Combination in Quantum Communication**  
**5.1 Field-Theoretic Reconstruction of Quantum Teleportation**  
The three-step process of the standard teleportation protocol:  
1. **Entanglement Establishment:**   
2. **Bell Measurement:**   
3. **State Reconstruction:**   
In the field combination theory, this corresponds to:  
  
**5.2 Security Proof of Quantum Key Distribution**  
Security is based on the field no-cloning theorem:  
**Theorem:** There exists no unitary operator such that:  
  
for an arbitrary field state .  
**Proof:** Assume such a exists. Then:  
  
This requires or , which is a contradiction.  
**5.3 Gate Operations in Quantum Computing**  
Quantum gates based on field fusion:  
**Field-theoretic implementation of the CNOT gate:**  
  
**Hadamard gate:**  
  
**6. Experimental Verification and Predictions**  
**6.1 Testable Predictions**  
1. **Entanglement Length Threshold:** where is the mass difference and is the energy level difference.  
2. **Dimension-Dependent Entanglement Entropy:** where are dimension-related parameters.  
3. **Field Interference Pattern:** where the visibility contains dimensional information.  
**6.2 Reinterpretation of Existing Experiments**  
**Bell Inequality Tests:**  
Original formula:   
Prediction of the field combination theory:  
  
**Quantum Teleportation:**  
Success probability:  
  
The field combination theory gives a correction:  
  
**7. Comparison with Existing Theories**  
**7.1 Relationship with Standard Quantum Mechanics**  
**Wave Function Collapse:**  
Standard:   
Field Combination:   
**Entanglement Entropy:**  
Standard:   
Field Combination:   
**7.2 Relationship with String Theory**  
**Number of Dimensions:**  
String Theory: 10 or 26 dimensions  
Field Combination: 26 dimensions  
**Vibrational Modes:**  
String Theory: modes  
Field Combination: field excitations  
**8. Application Prospects**  
**8.1 New Schemes for Quantum Communication**  
**High-Dimensional Encoding:**  
Information capacity: where is the number of extra dimensions.  
**Error Correction:**  
Topologically protected qubits based on:  
  
**8.2 New Architectures for Quantum Computing**  
**Field Fusion Quantum Computer:**  
Logic gate fidelity:  
  
**Topological Quantum Computation:**  
Computational model based on anyons:  
  
**9. Conclusion and Outlook**  
This paper has established the field combination theory of quantum entanglement. The main conclusions are:  
1. **Mathematical Rigor:** A complete 26-dimensional field theory framework has been constructed.  
2. **Physical Intuition:** A local realist explanation for entanglement has been provided.  
3. **Experimental Testability:** Multiple testable predictions have been proposed.  
4. **Technological Applicability:** Novel quantum technology schemes have been inspired.  
**Future Research Directions:**  
1. Experimental verification of the high-dimensional field theory.  
2. Practical applications of field fusion technology.  
3. A unified theory with quantum gravity.  
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