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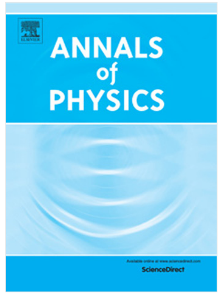

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Retrieving the lost fermionic entanglement by partial measurement in noninertial frames

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The initial entanglement shared between inertial and accelerated observers degrades due to the influence of the Unruh effect. Here, we show that the Unruh effect can be completely eliminated by the technique of partial measurement. The lost entanglement could be entirely retrieved or even amplified, which is dependent on whether the optimal strength of reversed measurement is *state-independent* or *state-dependent*. Our work provides a novel and unexpected method to recover the lost entanglement under Unruh decoherence and exhibits the ability of partial measurement as an important technique in relativistic quantum information.

Keywords: fermionic entanglement, partial measurement, Unruh effect

I. INTRODUCTION

Relativistic quantum information [1], a combination of relativity theory and quantum information, is a rapidly developing new field of physics. It aims to blend together the concepts from relativity and quantum information, and understand them from each other's perspective. The latest research shows that a deeper comprehension of the quantum entanglement (or quantum correlations) in a relativistic frame is not only of interest to quantum information processing [2, 3], but also plays a crucial role in understanding black hole thermodynamics [4, 5] and information paradox of black holes [6–11]. Another exciting development in this field is that several quantum information experiments, such as the quantum communications between the Earth and satellites, are already approaching relativistic regimes [12–16].

In relativistic quantum information, one of the most distinguished topic is how the entanglement and entanglement-involved quantum information protocols are affected by Unruh-Hawking effects [6, 17]. There are many literatures showing that entanglement is dependent on the observer's motion [18–29]. When one of the partners of an entangled system undergoes uniform acceleration, the initial entanglement between the partners is degraded. The degradation of entanglement inevitably reduces the confidence of entanglement-based quantum information tasks (e.g., quantum teleportation [30–32]). This phenomenon is directly related to the Unruh effect and usually known as Unruh decoherence. Particularly, the results show significant differences between bosonic and fermionic fields: the bosonic field entanglement vanishes asymptotically at the infinite acceleration limit while the fermionic field entanglement is found never to be completely destroyed. This notable difference is usually attributed to the fermionic/bosonic statistics [20]. Although it was widely believed that the Unruh effect can only cause the degradation of entanglement shared between an inertial and an accelerated observer, the realistic results are more subtle. Montero and Martín-Martínez found that beyond the single-mode approximation (SMA) and for some particular initial states, net entanglement between inertial and accelerated observers could be created by the Unruh effect [33]. However, the created entanglement is rather limit and makes little contribution to relativistic quantum information processing. Note that the aforementioned discussions are restricted to consider the entanglement degradation in noninertial frames, while limited attention is paid to the protection or retrieval of the lost entanglement against Unruh decoherence.

In this paper, we propose a scheme to retrieve the lost fermionic entanglement by partial measurement in noninertial frames. Partial measurement (or weak measurement in some references [34–36]) is associated with the positive-operator valued measure (POVM). By "partial", we mean that the wave-function doesn't completely collapse under this type of measurement. Hence, when needed, the initial state could be restored with some operations. In non-relativistic quantum information, partial measurement has been extensively demonstrated to protect the quantum entanglement from amplitude damping decoherence (energy relaxation from the excited state of a two-level system to its ground state) both theoretically [37–39] and experimentally [40–43]. The key idea of these proposals for entanglement protection is based on the fact that partial measurement is not completely destructive and can be reversed by a series of operations named as partial measurement reversal with a certain probability. Here, we borrow this technique from quantum information and show that the lost fermionic entanglement could be retrieved from Unruh decoherence by utilizing partial measurement. Our proposal is

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