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Probing Terrestrial Relic Neutrino Charge with Mach-Zehnder Interferometer

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We propose a novel mechanism to detect terrestrial cosmic neutrino background's (CNB) limit of electric charge by employing Mach-Zehnder interferometer with asymmetrical arm placement –one at the Earth's surface and the other is placed underground. Assuming that relic neutrinos possess a small but nonzero charge, their coherent forward scattering with photons induces measurable phase shift in a laser beam. From the terrestrial CNB overdensity resulting from weak interaction induced by neutrino-antineutrino asymmetry near the surface of the earth, we formulate the quantum interaction Hamiltonian and analyze the induced phase shift under realistic interferometric constraints. The projected sensitivity reaches of our setup are evaluated under three operation regimes: the standard quantum limit (SQL), the Heisenberg limit, and the super-Heisenberg limit. For neutrino masses mν = 0.05 eV, our scheme can probe fractional electric charges εν as small as 9.3×10−11, 1.6×10−16, and 2.9×10−22, respectively. The proposed interferometric strategy surpasses existing laboratory bounds and even astrophysical constraints when operating in the Heisenberg or super-Heisenberg mode.

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