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Analog time machine in a photonic system

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Analogue physics is an interesting direction in modern Physics, based on the similarities of the mathematical models describing different systems. Such similarities were known for a very long time, the most famous example being the ubiquitous harmonic oscillator. However, the idea to use these similarities to study inaccessible systems and regimes in the lab has appeared relatively recently. The directions of research in analogue physics and associated effects include analogue gravity (Hawking emission), early Universe (Kibble-Zurek mechanism), high-energy physics (Klein tunnelling, Zitterbewegung), quantum simulations (Heisenberg model), and others.

In this work, we discuss a photonic model system for a “time machine” based on the paraxial beam approximation [1]. We show how the closed timelike curves [2] and the well-known grandfather paradox can be studied experimentally in this system and how Novikov’s self-consistency principle [3] is realized in quantum mechanics owing to Heisenberg’s uncertainty principle.

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[2] M. S. Morris et al, Phys. Rev. Lett. **61**, 1446 (1988).
[3] J. Friedman, Phys. Rev. D 42, 1915 (1990).