

A Tale of Two Times: Coupling Frequency and Polarization Clocks in a Page and Wootters Photonic Platform

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In the Page-Wootters mechanism, time is not a background parameter but emerges from the entanglement between a clock and a system. We propose a photonic platform in which two distinct degrees of freedom of a biphoton, frequency and polarization, act as two coupled clocks within the same closed system. The platform exploits a Sagnac source producing photon pairs hyperentangled in frequency and polarization. The coupling is realized in a 4f-line incorporating a spatial light modulator that imprints a frequency dependent phase on a single polarization component. As a consequence, the conditional evolution of the spectral clock depends on the polarization state, so that the dynamics read out from one clock is set by the configuration of the other. We present the theoretical framework linking the joint frequency-polarization state to a Page-Wootters conditional evolution, and we report initial measurements on the platform.