Quantum self-oscillation with time-delay feedback

Y. Liu[a,b], W. J. Munro [c] and J. Twamley[a]

[a]*Quantum Machines Unit, Okinawa Institute of Science and Technology Graduate University, Okinawa 904-0495, Japan.*

[b]*Centre for Quantum Dynamics, Griffith University, Nathan, Queensland, Australia.*

[c]*NTT Basic Research Laboratories & NTT Research Center for Theoretical Quantum Physics, NTT Corporation, Kanagawa 243-0198, Japan*

One common method to generate precise clock signals is through the use of self-sustained oscillators (SSOs). These SSO clocks are used for time-keeping and frequency control in many classical applications [1]. Classical systems that exhibit self-sustained oscillations, such as the nonlinear van der Pol and Rayleigh oscillators, display limit cycles in phase space. However, the quantum versions of these nonlinear systems suffer from phase diffusion which leads to the smearing out of the quantum oscillator over the entire limit cycle in phase space seriously degrading the system's ability to perform as a clock [2]. Precise classical SSOs using **feedback however**, can yield high-precision SSOs with ultra-low phase noise [1]. In this work we explore quantum versions of such time delayed SSOs focused towards developing quantum clocks. Our photonic design of a linear quantum SSO is shown in Fig. 1(a). We use the quantum cascade formalism, where the current system is driven in a temporally directed fashion by its past dynamics (Fig. 1(b)) [3]. Contrary to all previously studied quantum SSOs we show that the linear delayed quantum self-sustained oscillator shows perfect oscillation without any phase noise or diffusion. It thus can behave as a perfectly synchronous quantum clock indefinitely.

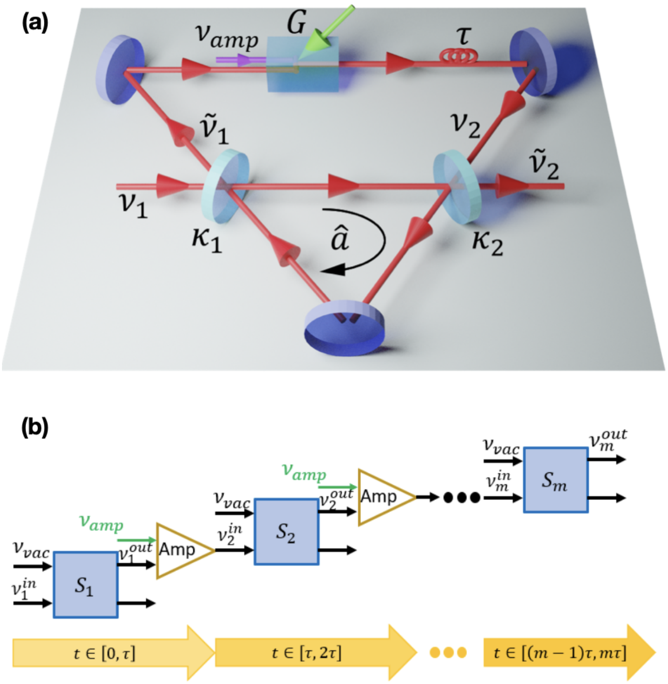

Figure 1: (a) A ring cavity is formed by two partially reflective mirrors and one fully reflective mirror which confines a circulating mode of light $\hat{a}$, one output is fed back to the cavity after amplification and delay. (b) Cascade chain of time-delayed feedback system.

[1] X. S. Yao and L. Maleki, IEEE J. Quantum Electron., **36**, 1, (2000).

[2] S. Walter, A. Nunnenkamp and C. Bruder, Phys. Rev. L **112**, 9, (2014).

[3] S. J. Whalen, A. L. Grimsmo and H. J. Carmichael, Quantum Sci. Technol., **2**, 4, (2017).