

Novel Interactions of Dissipative Kerr Solitons in Nonlinear Cavity Networks

Joseph H. D. Munns^{1,2}, Ian A. Walmsley², Y. Henry Wen²

¹ Blackett Laboratory, Imperial College London, London, SW7 2AZ, UK

² Clarendon Laboratory, University of Oxford, Parks Road, OX1 3PU, UK

Kerr micro-resonator frequency combs exhibit a variety of nonlinear phenomena, most prominently the formation of dissipative Kerr solitons (DKSs). These solitons are critical for applications in frequency metrology, precision time-keeping and ultrashort pulse generation. Thus far all studies of DKSs have been limited to single cavities [1, 2] or two uncoupled cavities [3–5], though coupled dual microring resonators with the potential for generating DKS in both ring cavities have been demonstrated [6]. Inspired by multi-soliton interactions [7] and synchronization of coupled modelocked lasers [8], we numerically investigate the dynamics of DKSs in a network of coupled cavities. Given its scalable and phase sensitive nature such a system is expected to exhibit even richer nonlinear phenomena with the potential to enable new technologies.

Expanding on [9], we present a full mapping of interaction dynamics between two cavities, using simulation methods based on [10, 11]. We initially investigate the interaction regimes of two coupled cavities as a function of temporal shift and pump phase offset. We take a stable DKS solution to the Lugiato–Lefever equation as our initial state in each cavity and then turn on coupling to other sites within the network, and allow the system to evolve towards a new steady state. In tuning these parameters, we observe a transition between attractive, chasing, and repulsive interactions, shown in figures 1(c-e), respectively. In contrast to dissipative solitons in lasers and Kerr solitons in the same waveguide, Kerr solitons in separate cavities can exhibit repulsion even for solitons of the same polarity.

Additionally, we investigate the transport dynamics, when a single soliton is initialised on only one site of a larger lattice of degenerate cavities. Again, tuning the relative phase of the continuous-wave (CW) pump coupled to each cavity, we have observed “hopping” and “seeding” regimes, illustrated in figures 2 and 3 respectively: where the soliton can either hop between adjacent sites *conserving number*, or, seed a new soliton in the next-nearest neighboring site *without ever exciting the intermediate site*. In each of these cases, the direction of transport on the lattice is determined by the sign of the relative phase of the CW pump on each site.

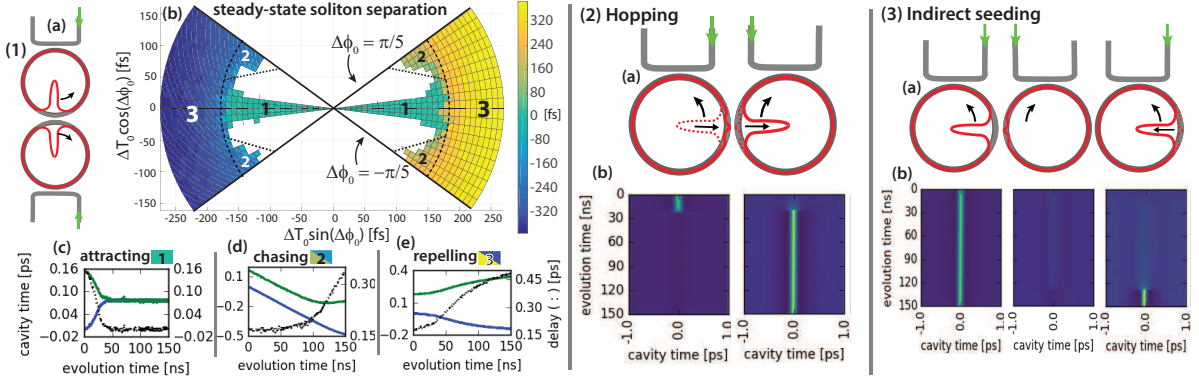


Fig. 1: Two-soliton interactions: (a) Schematic of single DKS in each cavity, (b) Final soliton separation (ΔT_s) as a function of initial delay (ΔT_0) and pump phase offset ($\Delta\phi_0$). Solid black lines indicate the simulated region, and white space within this corresponds to the death of one or both solitons. (c-e) Typical trajectories for the different regimes: 1. attraction, 2. chasing, and 3. repulsion. **Fig. 2:** Soliton hopping $|1_i 0_{i+1}\rangle \rightarrow |0_i 1_{i+1}\rangle$. (a) Schematic: dotted (solid) lines indicate initial (final) state. (b) Time evolution. **Fig. 3:** Indirect seeding of soliton between next-nearest neighbor cavities $|1_i 0_{i+1} 0_{i+2}\rangle \rightarrow |1_i 0_{i+1} 1_{i+2}\rangle$. Dotted (solid) lines indicate initial (final) state. (b) Time evolution.

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