Photons as Ants: a Stigmergic Photonic Network

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Stigmergy is the cooperative behaviour of insects mediated by the environment, found for instance in the food searching activities of ants. The ant society communicates indirectly by marking routes with chemicals (pheromones), which attract other ants to tread the same route. Using stigmergy, the entire ant colony is finally able to find the optimal (shortest) path connecting the nest to the food.

We have previously shown how linear *cognitive photonic networks* can be used to implement non-Boolean analogue computing, including for instance the matrix inversion problem [1] or the search for the possible solution of nondeterministic polynomial (NP) problems [2]. Here we present an optical analogue to a stigmergic ant colony, where a non-linear telecom fibre network is used to implement the famous ant colony optimization (ACO) algorithm of finding the shortest route that connects two given points in a graph [3,4].

The classical two-layer double bridges experiment shown in Fig. 1(a) was mapped to a telecom fibre network as presented in Fig. 1(b). In our implementation, ants are represented by photons, food is mimicked by a 100% reflective mirror which provides feedback to progressively reinforce the path between the “food” and the “ant nest”, and pheromone is simulated by the nonlinear absorbing behaviour of erbium-doped fiber (EDF) segments with proper length. When laser pulses are injected into the network, the output waveform contains well-separated peaks that correspond to the four possible paths travelled by the photons. As shown in Fig. 1(c), the relative intensity of each of these output peaks is the same at low input power (pulse energy of 100 pW), but more and more energy concentrates into the shortest route (edge 1+3) at high input intensity (pulse energy of 500 pW). Fig. 1(d) shows that as input energy increases, optical energy progressively converges to the shortest route thanks to the increase of transmissivity of EDF segments into the shortest path. This behaviour is similar to plasticity of neuronal networks and proves that our stigmergic photonic network can effectively solve a complex optimization problem.

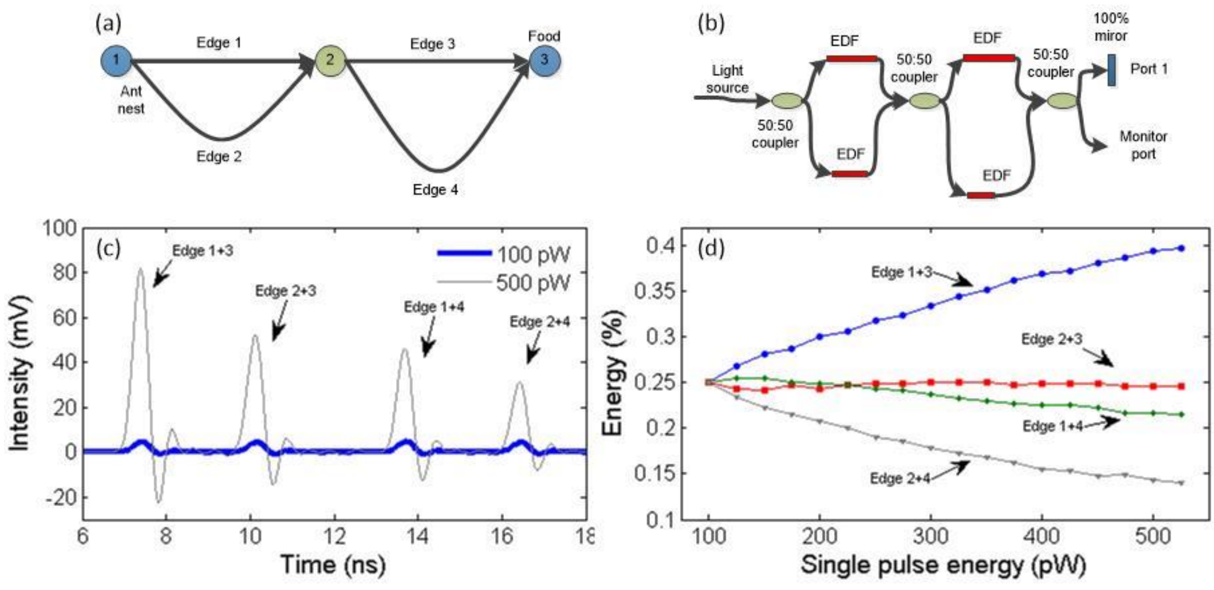

Fig. 1 (a) Topology and (b) optical network realization of a two-layer double bridges graph. (c) Output waveform measured for four different routes as single input pulse energy is 100 pW and 500 pW, respectively. (d) Relative energy distribution into the four possible routes, showing convergence of optical energy into the optimal path (edge 1+3, the shortest route connecting the “ant nest” and the “food”).

References

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