Improving the Success Rate of Coherent Ising Machine for Solving Optimization Problems through Gaussian Colored Noise

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Coherent Ising machine (CIM) is a typical gain-dissipative device which can speed up the solution of combinatorial optimization problems; thus, it has gained increasing research interests as a promising quantum analog annealer [1]. Different from many quantum annealers, quantum tunneling effect cannot be induced in a CIM, which indicates that it relies on the noise disturbance to escape the local energy minimum. However, in previous studies, only the Gaussian white noise was considered with discussing the influence of noise intensity on Ising machine. In addition to Gaussian white noise, noise in real-world devices has the same dispersion property as light, which can be utilized to modulate the dynamics of bifurcation systems [2].

In order to explore the conditions of improving the performance for CIM through modulating noise dispersion, the engineering method for generating Gaussian colored noise, which widely exists in real-world applications, is first simulated. According to the color of light with the same power spectral density, the color of a noise is defined. Then, we numerically build an opto-electronic feedback system based CIM as shown in Fig. 1, which can simulate arbitrary Ising Hamiltonian [3].

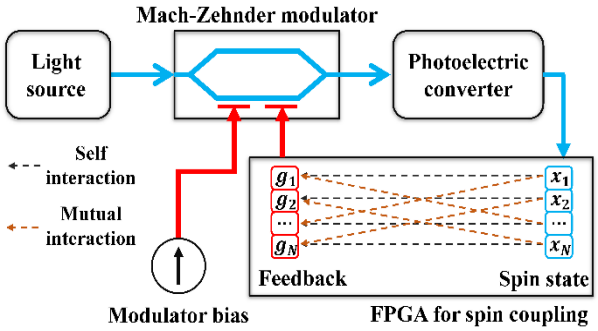

Figure 1 Schematic of opto-electronic feedback system based CIM.

In this work, by comparing the domain clustering dynamics, the random spin flip, which prevents the CIM from reaching the ground state, can be suppressed by the red and pink noise. In addition to the research on the dynamics, the CIMs with different colored noises is also benchmarked with three prevalent MAXCUT topologies, including the Moebius ladder (ML), random square lattice (RSL), and random Moebius ladder (RML). The results as shown in the Fig. 2 reveal that the blue and violet noise induce the same trend as the white noise [4]. In contrast, red and pink noise induce a bell-shaped trend, which can be regarded as the stochastic resonance effect, in RSL and RML. It thus evident that red noise can significantly improve the success rate of CIM in solving combinatorial optimization problems with random frustration. Because the dynamics of CIM is similar to other known gain-dissipative Ising machines [4], these conclusions can also be applied to other types of Ising machines.

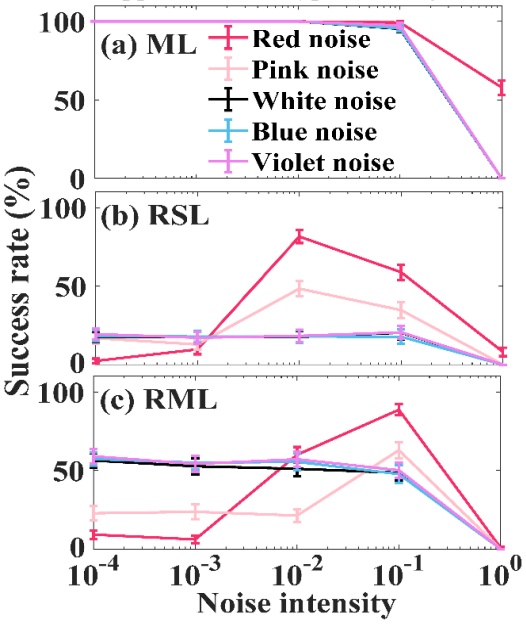

Figure 2 The success rates of CIMs with different colored noises versus noise intensity in solving (a) ML, (b) RSL, and (c)RML.

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Reference:

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[3] Böhm, Fabian, et al. Nature Communications 10.1 (2019): 1-9.
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