Quadrature Photonic Spatial Ising Machine

Wenjia Zhang (✉ wenjia.zhang@sjtu.edu.cn)

Shanghai Jiao Tong University

Wencheng Sun

Shanghai Jiao Tong University - Minhang Campus: Shanghai Jiao Tong University

Yuanyuan Liu

Shanghai Jiao Tong University - Minhang Campus: Shanghai Jiao Tong University

Qingwen Liu

Shanghai Jiao Tong University - Minhang Campus: Shanghai Jiao Tong University

Jiangbing Du

Shanghai Jiao Tong University - Minhang Campus: Shanghai Jiao Tong University

Zuyuan He

Shanghai Jiao Tong University - Minhang Campus: Shanghai Jiao Tong University

Research

Keywords: sing machine, optical computing, NP problem

Posted Date: June 16th, 2021

DOI: <https://doi.org/10.21203/rs.3.rs-611666/v1>

License: This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

The mining in physics and biology for accelerating the hardcore algorithm to solve non-deterministic polynomial (NP) hard problems has inspired a great amount of special-purpose machine models. Ising machine has become an efficient solver for various combinatorial optimization problems. As a computing accelerator, large-scale photonic spatial Ising machine have great advantages and potentials due to excellent scalability and compact system. However, current fundamental limitation of photonic spatial Ising machine is the configuration flexibility of problem implementation in the accelerator model. Arbitrary spin interaction is highly desired for solving various NP hard problems. Moreover, the absence of external magnetic field in the proposed photonic Ising machine will further narrow the freedom to map the optimization applications. In this paper, we propose a novel quadrature photonic spatial Ising machine to break through the limitation of photonic Ising accelerator by synchronous phase manipulation in two and three sections. Max-cut problem solution with graph order of 100 and density from 0.5 to 1 is experimentally demonstrated after almost 100 iterations. We derive and verify using simulation the solution for Max-cut problem with more than 1600 nodes and the system tolerance for light misalignment. Moreover, vertex cover problem, modeled as an Ising model with external magnetic field, has been successfully implemented to achieve the optimal solution. Our work suggests flexible problem solution by large-scale photonic spatial Ising machine.

Full Text

This preprint is available for [download as a PDF](#).

Figures

Figure 1

Please see the Manuscript file for the complete figure caption.

Figure 2

An example of spin interaction between quadrature spatial photonic Ising machine (Q-SIM) and original spatial photonic Ising machine (SIM). By introducing the relation matrix A that composed of half j and $-j$, the interaction values are able to change from non-negative to arbitrary values through tuning the light amplitude and relation matrix.

Figure 3

The physical property of spin glass system. (a) Magnetization of ground state versus negative interaction ratio. (b) Spatial intensity and relation matrix of the beam when negative interaction ratio is 0.3208. In the second section, negative and positive value corresponds to $-j$ and j respectively in relation matrix.

Figure 4

Solving Max-cut problem in arbitrary weight. (a) The cut value of a 100-order graph with graph density of 0.6. (b) The required iteration number when obtaining the Max-cut solution with various graph density and order. (c) The solution deviation compared to optimum. (d) Confidence interval of cut value by randomly generating 50 weighted 1600-nodes graphs.

Figure 5

Performance evaluation with light misalignment. (a) Error deviation of cut value after 76 iterations. (b) Illustration of light misalignment for quadrature modulation in two areas.

Figure 6

The 4-vertex cover problem. The probability distribution of spin configuration against a 4-vertex cover problem and the final result converges to $|\downarrow\uparrow\uparrow\uparrow\rangle$.

Figure 7

Lage-scale vertex cover problem. A 1600-vertex cover problem is simulated. The left and right phase map is the initial and final phase solution of our Ising machine.