[Invited Talk]

Coherent Ising machine based on a laser network

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Abstract—We propose a new type of computing scheme to solve 3D Ising models based on a laser network.

1. Introduction

Optimization problems are well known computationally hard problems in our modern life such as weather forecast, protein holding problems, stock price prediction, traveling salesman problems, and so on. Even supercomputer cannot solve those problems exactly because the required computational time scales exponentially as the growth of their problem size. Those optimization problems are classified into as NP-complete/hard problems. The quantum computing is one of the possibilities to solve those computationally hard problems efficiently. Recently new type of quantum computing called as quantum annealing machine has gotten a lot of attention recently.

2. Mapping Ising models onto a laser network

Our goal is to implement the Ising models with a Zeeman term in an injection-locked laser network. The Ising Hamiltonian with a Zeeman term is described as follows:

$$H = \sum_{i<j}^{M} J_{ij}\sigma_{iz}\sigma_{jz} + \sum_{i}^{M} \lambda_i \sigma_{iz} \qquad (1)$$

In this Hamiltonian, σ_{iz} describes an Ising spin, i.e., spin projection onto the z-axis. J_{ij} is the interaction coefficient between spin i and spin j, and λ_i is a supplemental Zeeman (external field) term. The injection-locked laser network proposed in our previous paper can find the ground state of the Hamiltonian, Eq. (1) through a laser phase transition. A photon in the lasing mode is not localized in any specific slave laser but its wavefunction is coherently spread over all slave lasers as partial waves. At the end of the computation, the phase configuration of such partial waves is expected to represent the ground state $\{\sigma_{iz}, i = 1 \sim M\}$.

We recently proposed a coherent Ising machine to solve NP-hard 3D Ising models efficiently using a laser network which could be implemented by semiconductor lasers [1, 2] , optical parametric oscillators[3] or fiber mode locked lasers. By implementing Ising spins with the phases of optical pulses oscillating in a fiber cavity with the OPO time domain multiplexing method, the system size with $M \sim 5000$ will be achieved, The algorithm of coherent computer is quite new and different from existing quantum computing or quantum annealing, based on the minimum gain principle of a laser network. We can also implement the many body Ising spin interaction with the measurement feedback scheme so that mathematically hard problems such 3-SAT, Grover algorithm and factoring. The numerical results we performed so far reasonably suggest the effective computational power of the proposed a coherent Ising machine.

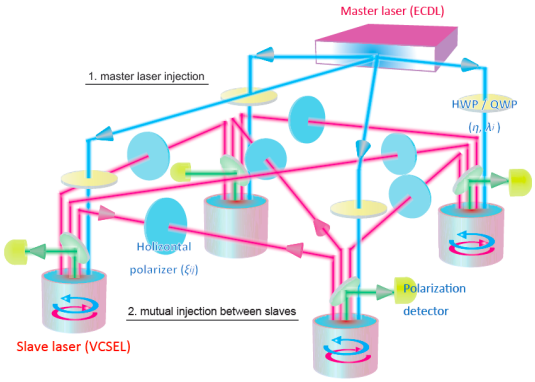

Figure 1: A schematic of an injection-locked laser system for finding the ground state of an Ising model [1]. A master laser output is equally split into M paths and injected into M slave lasers via an optical isolator.

References

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[3] Z. Wang, A. Marandi, K. Wen, R. L. Byer, and Y. Yamamoto, "A Coherent Ising Machine Based On Degenerate Optical Parametric Oscillators," Phys. Rev. A 88, 063853 (2013)