Design of coaxial coils using hybrid machine learning

J. Chen[1], Z. L. Wu[1], G. Z. Bao[2], L. Q. Chen[1], and W. P. Zhang[234]

[1] State Key Laboratory of Precision Spectroscopy, Quantum Institute for Light and Atom, Department of Physics, East China Normal University, Shanghai, People's Republic of China

[2]School of Physics and Astronomy, and Tsung-Dao Lee Institute, Shanghai Jiao Tong University, Shanghai, People's Republic of China

[3]Collaborative Innovation Center of Extreme Optics, Shanxi University, Taiyuan, Shanxi, People's Republic of China

[4]Shanghai Research Center for Quantum Sciences, Shanghai, People's Republic of China

A coil system to generate a uniform field is urgently needed in quantum experiments. However, general coil configurations based on the analytical method have not considered practical restrictions, such as the region for coil placement due to holes in the center of the magnetic shield, which could not be directly applied in most of the quantum experiments. In this paper, we develop a coil design method for quantum experiments using hybrid machine learning. The algorithm part consists of a machine learner based on an artificial neural network and a differential evolution (DE) learner. The cooperation of both learners demonstrates its higher efficiency than a single DE learner and robustness in the coil optimization problem compared with analytical proposals. With the help of a DE learner, in numerical simulation, a machine learner can successfully design coaxial coil systems that generate fields whose relative inhomogeneity in a 25 mm-long central region is ~ 10^{-6} under constraints. In addition, for experiments, a coil system with 0.069% inhomogeneity of the field, designed by a machine learner, is constructed, which is mainly limited by machining the precision of the circuit board. Benefiting from machine learning's high-dimension optimization capabilities, our coil design method is convenient and has potential for various quantum experiments.

References

[1] Rev. Sci. Instrum. **92**, 045103 (2021);