論文題目要旨

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論文題目: Robust Optimization of a Ring Cyclotron RF Cavity using an Ensemble Neural Network Surrogate (アンサンブルニューラルネットワークによるサロゲートモデルを用いたリングサイクロトロン RF 空洞のロバスト最適化)

論文要旨:
Cyclotrons are particle accelerators widely used in nuclear research, medicine, and industry. In a cyclotron, the radiofrequency (RF) cavity repeatedly accelerates the circulating beam, so its performance directly affects the achievable beam energy and intensity, RF power consumption, and operational reliability. Designing an RF cavity requires balancing several competing requirements, including acceleration efficiency, heat dissipation, peak surface fields, and resonant frequency. Exploring the best cavity shapes and quantifying their sensitivity to geometric uncertainty using full electromagnetic simulations are computationally expensive. This dissertation develops a neural-network surrogate that approximates the simulation results at a much lower computational cost, allowing large numbers of candidate designs to be evaluated rapidly. The framework is demonstrated through constrained multiobjective optimization of an RF cavity based on PSI's high-intensity ring cyclotron, followed by Monte Carlo propagation of stochastic geometric deformations. The optimization results show clear tradeoffs between efficiency and peak-field limitation, while the uncertainty quantification shows that optimal designs belonging to different optimal categories can differ in their sensitivity to shape uncertainty. These results demonstrate how neural networks can greatly reduce the cost of simulation-intensive RF cavity design while retaining sufficient accuracy for optimization and geometric robustness assessment.