Application of Machine Learning to Accelerator Beam Transport Systems

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In recent years, the need for sustainability has driven efforts to improve energy efficiency and reduce operational workload in synchrotron light sources. For small-scale facilities like HiSOR at Hiroshima Synchrotron Radiation Center, which is being operated with a few staff members, automation of accelerator tuning is particularly crucial. The next-generation HiSOR-2 plans to introduce top-up operation [1], requiring stable injection efficiency over long periods, making automation indispensable.

This study focuses on the automatic tuning of beam transport systems using machine learning. Experiments were conducted at the Photon Factory (PF) at KEK to automate the beam injection process from the injector to the storage ring. We aimed to suppress stored beam oscillations and maximize injection efficiency using Bayesian optimization. Simulations compared two approaches: (1) minimizing the Courant-Snyder invariant and (2) minimizing orbit deviation at a specific point in the ring, with the latter chosen for experiments. The experimental results showed that automatic adjustment of the kicker magnet effectively suppressed stored beam oscillations. Additionally, tuning the kicker and septum magnets improved injection efficiency.

Furthermore, we explored the simultaneous optimization of oscillation suppression and injection efficiency. The results demonstrated that automatically adjusting multiple injection system parameters could enhance efficiency while minimizing oscillations. These findings contribute to the advancement of automation technology in small-scale synchrotron light sources, providing a foundation for future implementations, including in HiSOR-2. As synchrotron facilities increasingly require stable, efficient, and low-maintenance operations, these automation techniques are expected to play a crucial role in next-generation accelerator systems.

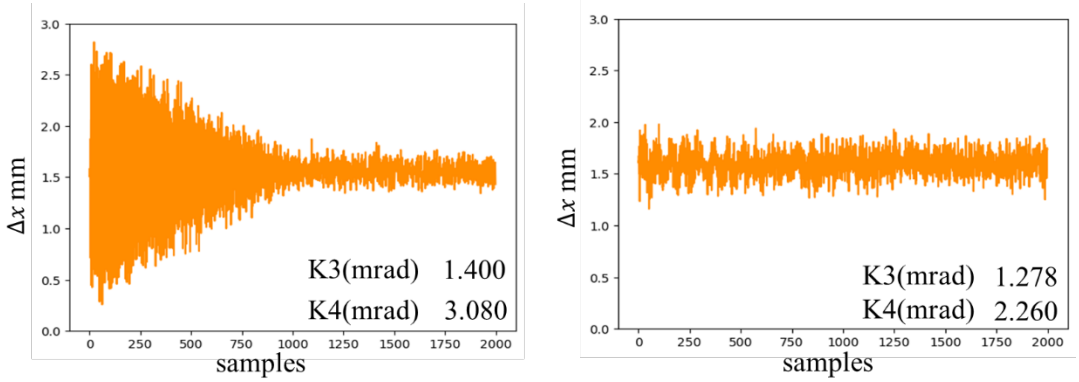

Figure 1: Changes in Electron Oscillations Before and After Optimization

REFERENCES

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