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Dreaming of Schottky Spectra: Building World Models for LEIR robust automation

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Stripper foil degradation in the Low Energy Ion Ring (LEIR) causes beam distribution drift that progressively degrades performance during multi-turn stacking at flat bottom. World models have emerged as a promising approach for sample-efficient and robust agents, enabling them to improve their behavior by rolling out policies in learned environment models between real interactions, thereby reducing the need for expensive online exploration. In this work, a world model-based reinforcement learning approach is presented for autonomous compensation of foil aging effects in LEIR, extending previous reinforcement learning-based intensity optimization efforts. The agent observes the accelerator state through encoded Longitudinal Schottky spectra and Time-of-Flight (TOF) measurements—capturing the coupled dynamics of beam parameters affected by foil-induced distribution drift—and learns a compact latent representation via a trained world model. This learned representation allows the agent to plan actions through internal simulation, improving sample efficiency under the strict data and operation constraints of accelerator control. By controlling the RF ramping and debunching cavities, electron gun voltage, and cooler bump to maintain optimal phase space conditions, the agent adapts to aging-induced beam drift throughout the injection plateau. The stochasticity of the world model can be tuned through temperature scaling, enabling robust imaginary rollouts that prepare the agent for varying, unforeseen foil conditions. The resulting policy maintains beam intensity above nominal targets across repeated injection cycles despite progressive stripper foil aging, illustrating the potential of world model-based reinforcement learning for autonomous accelerator operation.

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