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Accelerating RHEED Analysis with FPGA-Optimized Neural Networks

Reflection High Energy Electron Diffraction (RHEED) is a technique for real-time monitoring of surface crystal structures during thin-film deposition. By directing a high-energy electron beam at a shallow angle onto a crystalline surface, RHEED produces diffraction patterns that reveal valuable information about both the bulk structure and the surface's atomic arrangement. The resulting patterns are used to infer the smoothness, crystallinity, and layer-by-layer deposition quality at sub-monolayer precision. However, traditional computational approaches struggle to keep up with the demand for high-speed analysis in dynamic deposition environments, where microsecond-level temporal resolution is critical.

This work presents a field programmable gate array (FPGA)-based neural network architecture that accelerates the analysis of RHEED diffraction patterns to microsecond speeds. The system is developed using the hls4ml tool and hls4ml optimization package, which streamlines the process of converting high-level neural network models into FPGA-optimized implementations. The use of an FPGA allows for extremely low latency and low power consumption during use. The neural network approach provides high robustness to noise unlike simpler computational methods, which is necessary due to high levels of interference during data collection.

Looking ahead, the ability to perform ultra-fast RHEED analysis opens new possibilities for real-time control during thin-film growth. With rapid analysis, it becomes feasible to implement immediate feedback loops that can adjust deposition parameters or trigger automatic shutdowns if crystal growth deviates from desired conditions. This would enable on-the-fly corrections, improving both the quality and consistency of thin films. Such advancements could lead to more efficient, autonomous systems for precise material fabrication, further expanding the potential applications of RHEED in industrial and research settings.

Focus areas

Author: WILKINSON, Matt (University of Washington)

Presenter: WILKINSON, Matt (University of Washington)