Accelerating RHEED Analysis with FPGA-Optimized Neural Networks

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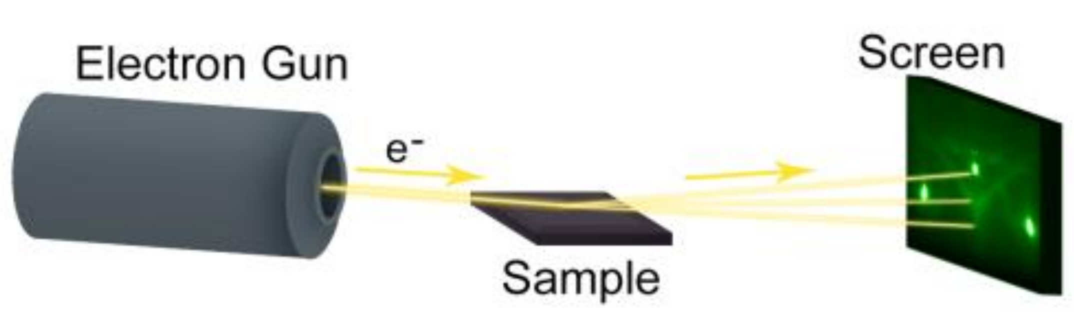
Introduction

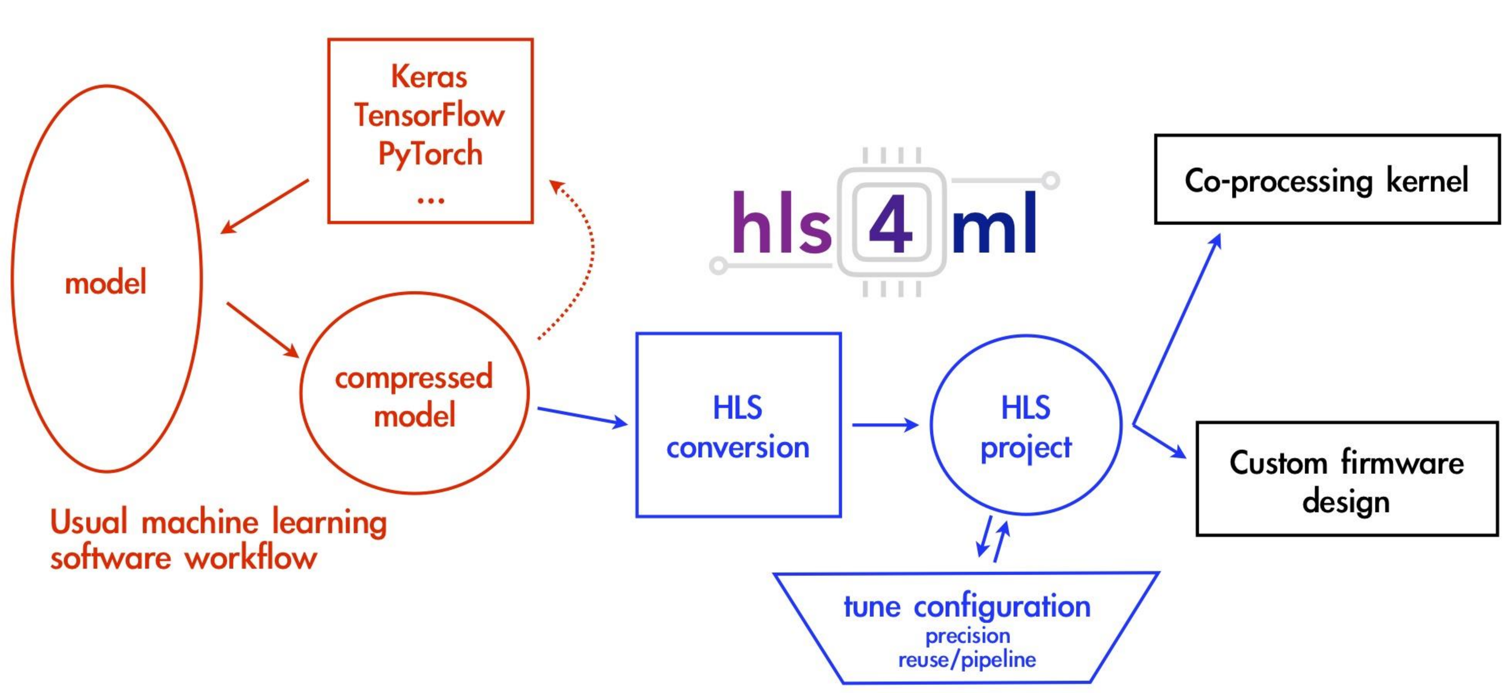
Reflection High Energy Electron Diffraction (RHEED) uses electron diffraction to monitor thin film growth and surface structure in real-time during deposition.



An electron beam is directed at a surface, and the resulting diffraction pattern reveals information about the surface structure and crystalline quality.

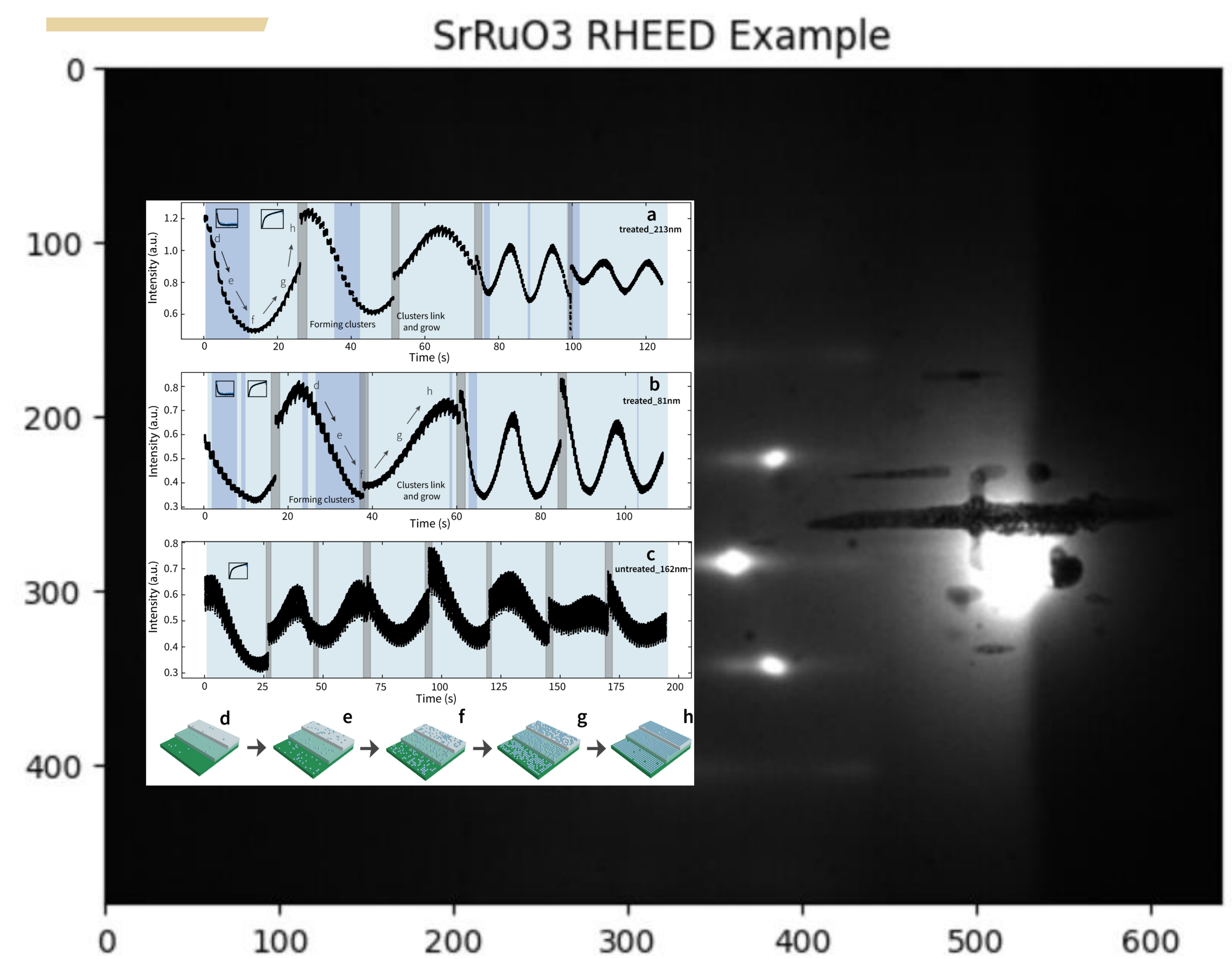
Goal

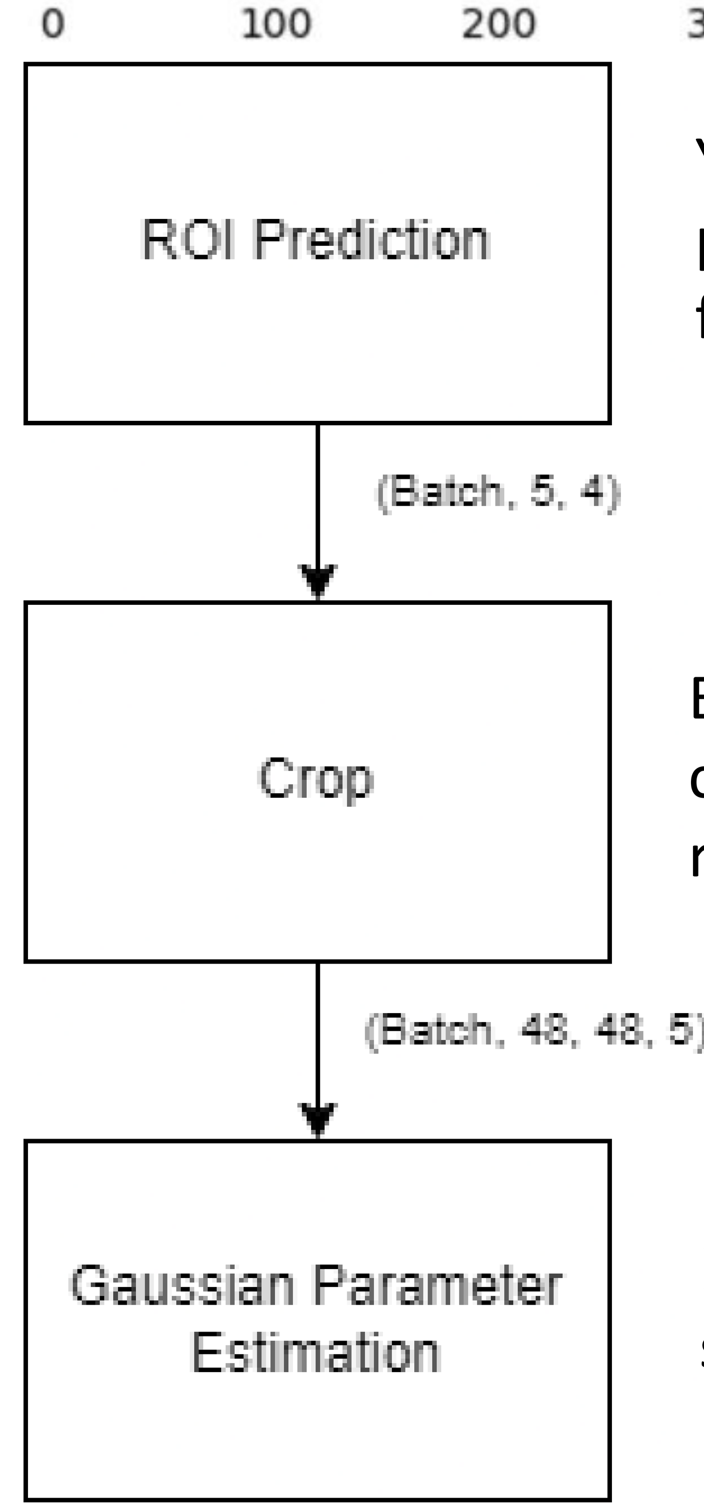
Deploy a machine learning based RHEED analysis on an FPGA using HLS4ML to provide real time insights and lower costs.



[1]

Method





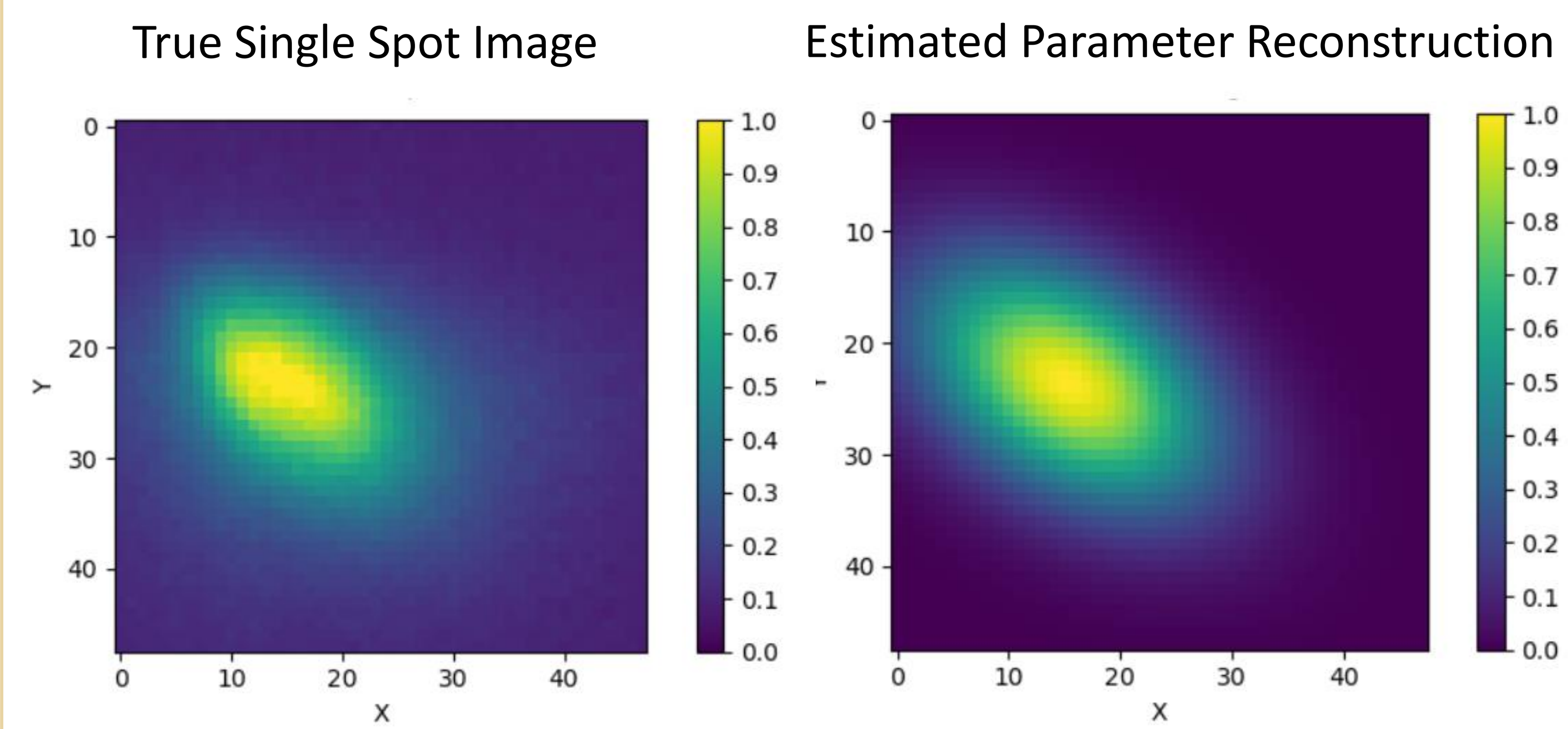
YOLO-style CNN to predict bounding boxes for spots

Either in hardware or a custom Keras layer to lower resources used

Run the crops through the same set of layers

Gaussian Parameter Estimation

Spots are modeled as gaussians by predicting μx, μy, σx^2, σy^2, and θ with a CNN



Training loss of 0.0005566 when comparing the original image to a reconstructed image with a MSE loss

Next Steps

> Train a unified python model (Keras crop) and test the accuracy and resource usage against the two separate model approach (hardware crop)
> Design a system to provide real-time control feedback to the deposition

References

[1] J. Duarte et al 2018 JINST 13 P07027

NSF: MRI: Development of Heterogeneous Edge Computing Platform for Real-Time Scientific Machine Learning (2215789)
NSF: MRI: Development of a Platform for Accessible Data-Intensive Science and Engineering (2320600)
DOE: Real-time Data Reduction Codesign at the Extreme Edge for Science
ARL: Collaborative for Hierarchical Agile and Responsive Materials (CHARM) (W911NF-19-2-0119)

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