Towards Quantum Computing Enhanced Electron Microscopy

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Advanced imaging techniques such as microscopy have long been a foundation for scientific discovery, enabling the visualization and understanding of microscopic objects. The development of electron microscopy has overcome the resolution limit of optical microscopy, pushing the size of resolvable objects down to the nanoscale. Still, traditional electron microscopes rely on classical intensity measurements, absorbing electrons upon detection and thereby greatly limiting the way information can be extracted from them.
Quantum computing enhanced electron microscopy aims to supplement the classical detectors with the coherent interaction with a quantum computer consisting of a trapped ion lattice. We present a protocol that, by preparing the trapped ions in non-classical states of motion, realizes a conditional Pauli-X gate on the qubits, depending on the presence of a probe electron [1]. This leads to entanglement between the quantum computer and the state of the electron, which may be used to transfer information about a specimen to the quantum computer, allowing for coherent information processing and readout using arbitrary projective measurements. Multiple electrons can become entangled through their interaction with the quantum computer, enabling sensing schemes that go beyond the standard quantum limit and may pave the way to dose-efficient electron microscopy.

References

[1]: Elias Pescoller, Santiago Beltrán-Romero, Sebastian Egginger, Nicolas Jungwirth, Martino Zanetti, Dominik Hornof, Michael S. Seifner, Iva Březinová, Philipp Haslinger, Thomas Juffmann, Johannes Kofler, Philipp Schindler, and Dennis Rätzel. Coupling free electrons to a trapped-ion quantum computer. arXiv: 2601.11446 [quant-ph].

Acknowledgements

This research is funded in part by the Gordon and Betty Moore Foundation Grant GBMF12992, by the Austrian Science Fund (FWF) through Grant No. 10.55776/COE1, Y1121, P36041, P35953 and the FFG-project AQUTEM.

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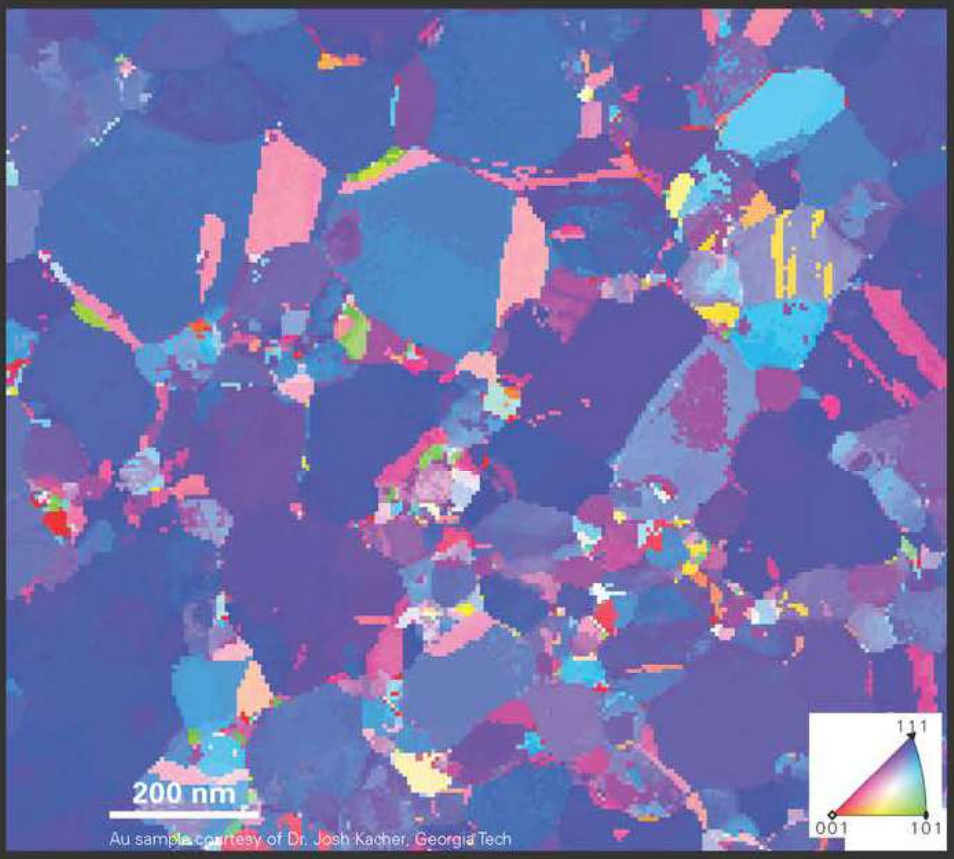

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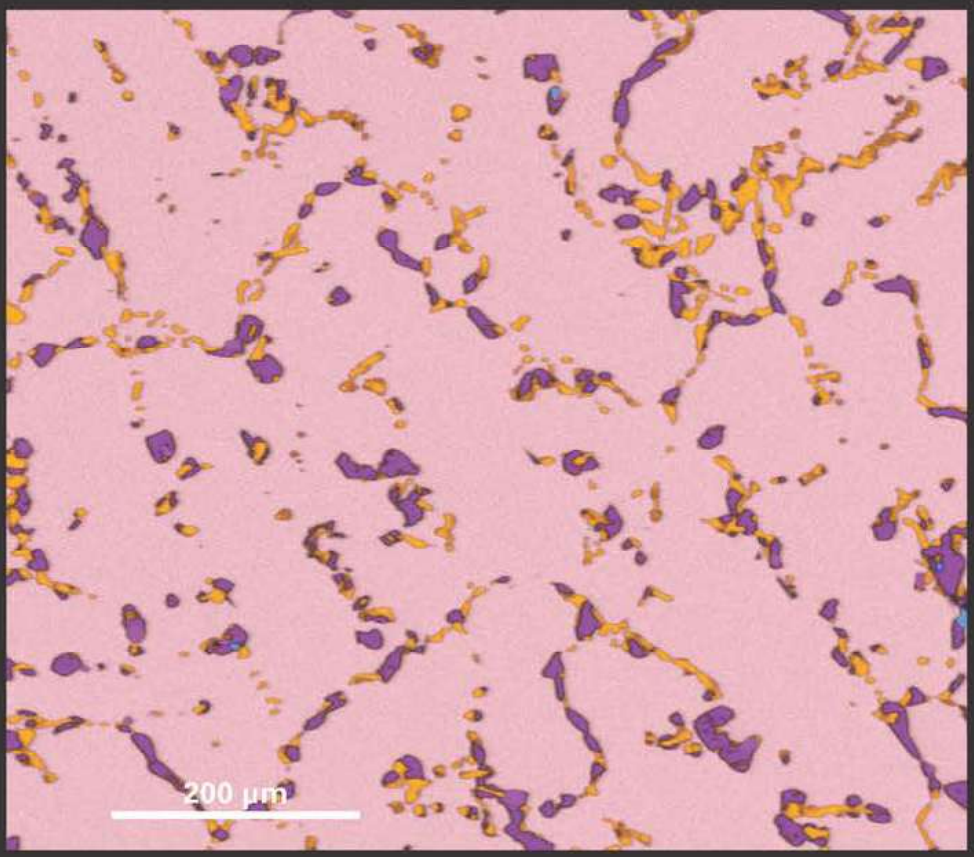

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