The Highest Resolution Microscope, enabled by a new detector technology, reaches an ultimate resolution limit – the vibrations of atoms themselves

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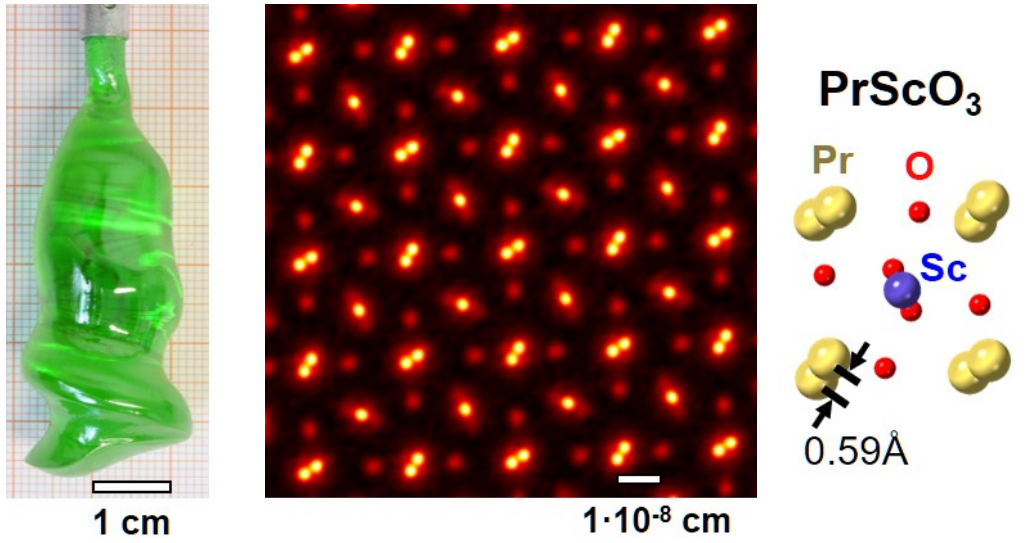
Electron microscopy is a widespread and often essential tool for structural and chemical analysis at the atomic level. Image resolution is dominated by the energy (or wavelength) of the electron beam and the quality of the lens. By combining our new design of electron microscope pixel array detector (EMPAD), which has the dynamic range to record the complete distribution of transmitted electrons at every beam position and a phase retrieval algorithm to process the data, PARADIM's in-house research team has increased the spatial resolution well beyond the traditional lens limitations, setting a world record in 2018 for the highest resolution microscope (0.39 Å Abbe resolution [1]) at the same dose and imaging conditions where conventional imaging modes reach only 0.98 Å. The EMPAD is the culmination of over a decade of detector development at Cornell, supported by NSF (through CHESS, CCMR), DOE, the WM Keck Foundation, and the Kavli Institute, and has been commercially licensed by ThermoFisher Scientific and is now manufactured and sold at scale.

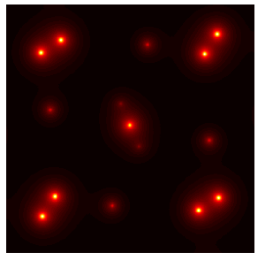
Our next-generation EMPAD prototype, with an order of magnitude increase in speed and data rate, has made it possible to image thicker samples at double the spatial resolution (<0.20 Å Abbe resolution), limited mainly by the random thermal motions of the atoms themselves [2]. **This new super-resolution imaging is available to PARADIM users** utilizing the new EMPAD detector in combination with multislice ptychography in (and only in) PARADIM's electron microscopy user facility.

[1] Y. Jiang *et al.*, *Nature* **559** (2018) 343–349;
[2] Z. Chen *et al.*, *Science* **372** (2021) 826-831.

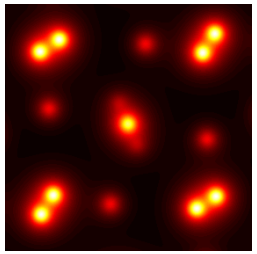
Highest resolution microscope image. Left a $PrScO_3$ crystal and microscope image zoomed in 100 million times.



Simulation of static atoms



Simulation with thermal vibrations



Experiment