Direct observation of electrons focusing with atom lens

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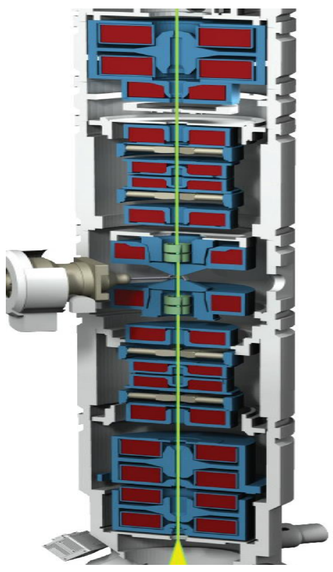
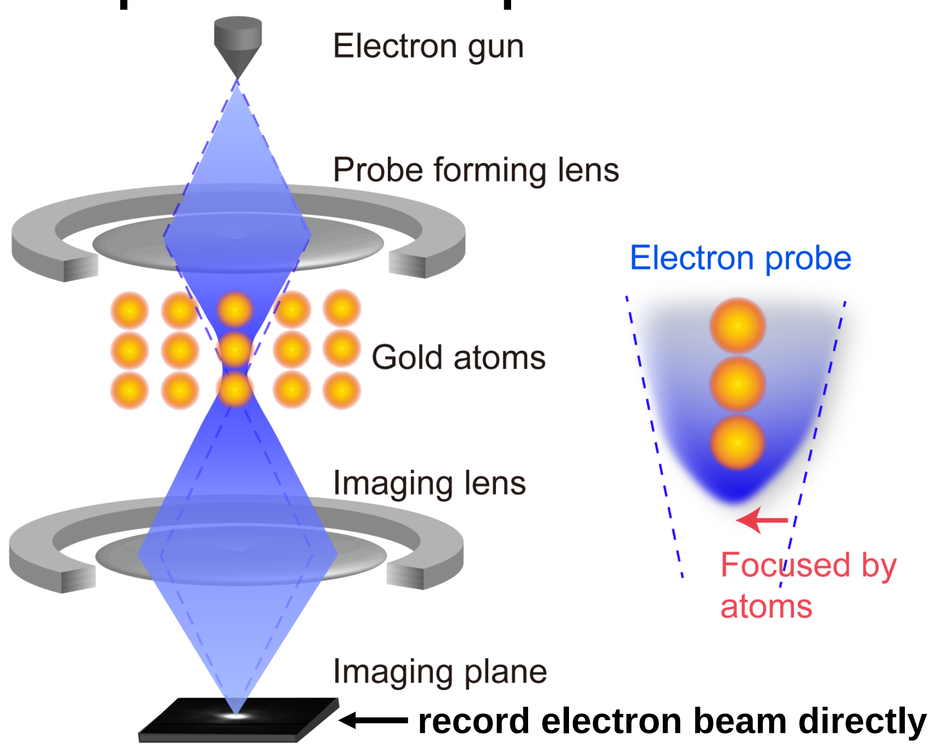
1. Motivation: demonstrate experimentally that atoms can act as lenses to focus high-energy electron beams (300kV)



① Scanning transmission electron microscopes (STEM) has sub-angstrom **resolution** which is further **limited** by higher order aberrations.
② Multistage magnetic lens system and aberration correction system make **STEM apparatus large** and **complex**.
③ Scientific researchers have proposed that a single or a column of heavy atoms can act as strong **atomic lens** to focus the electrons using atomic coulomb potential. But **no direct experiment** can prove that.

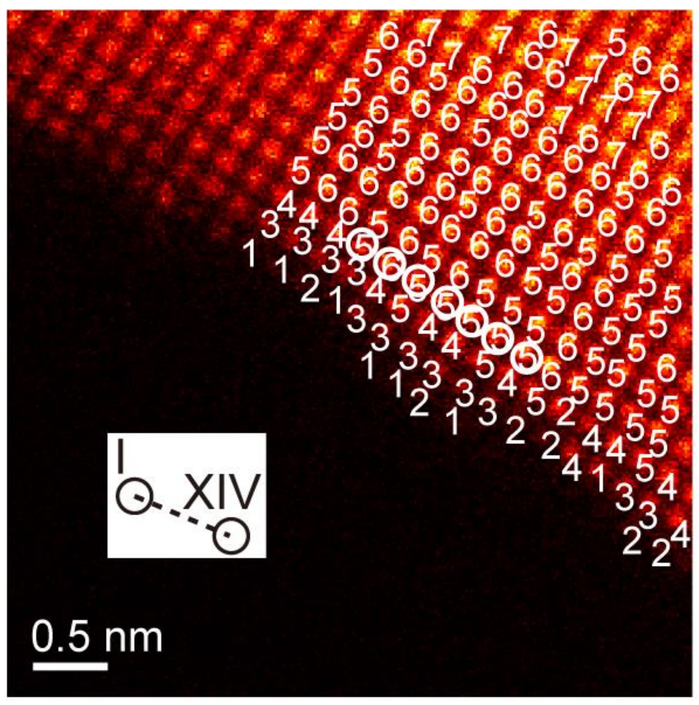
References: [1] Ultramicroscopy(1997). 68,135. [2] J. Phys. D (1998).31,1548.

2. Experimental setup: Confocal mode

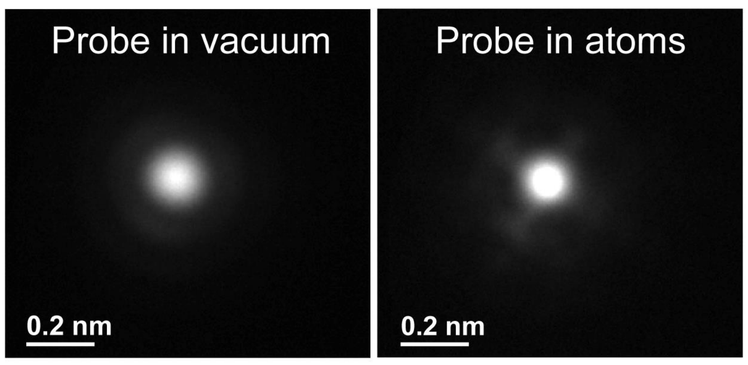


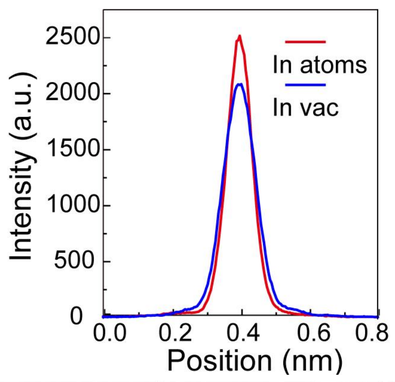
3. Experiments: use electron probe to scan Au foil and record beams in imaging plane

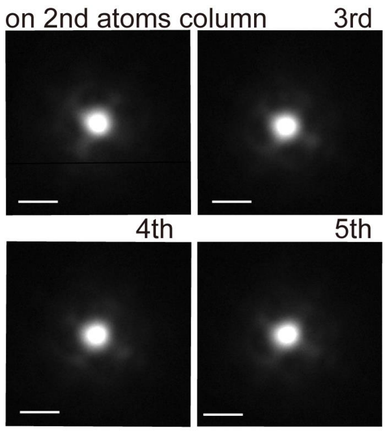
Counting the number of Au atoms

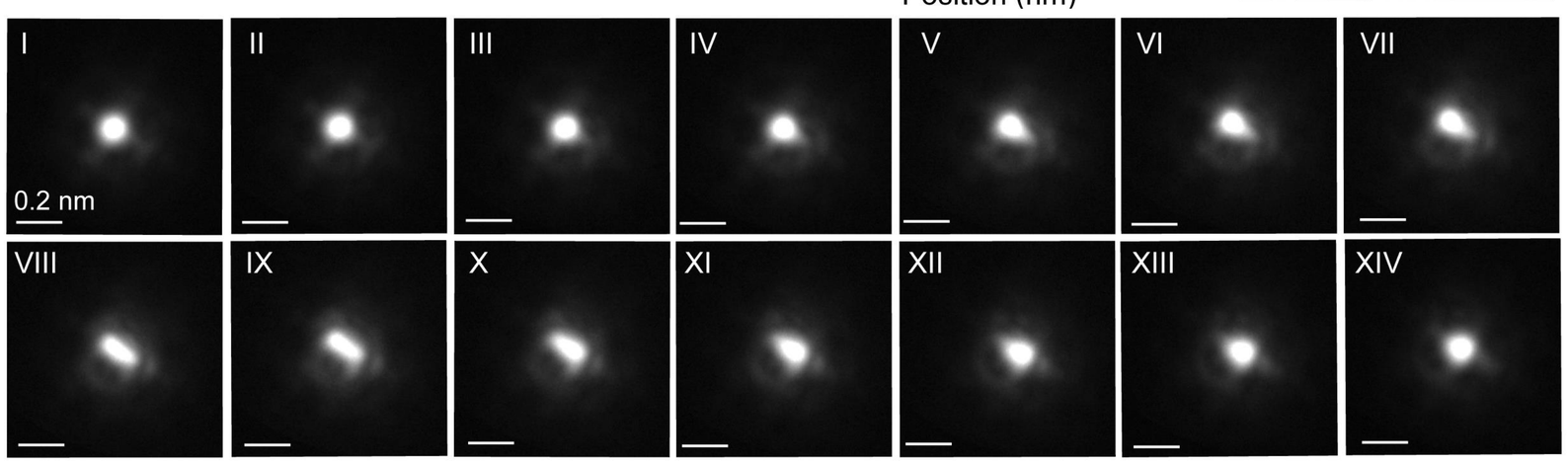


Fractional intensity = $\frac{H-J_{vac}}{J_{det}-J_{vac}}$

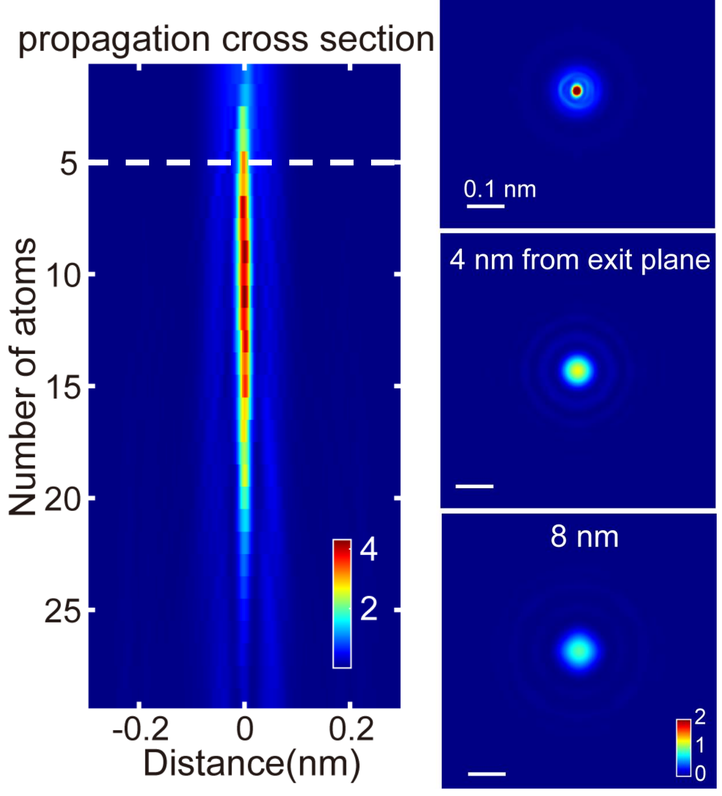


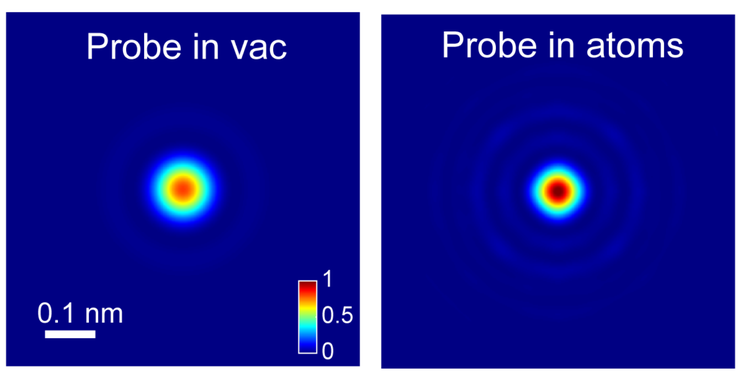


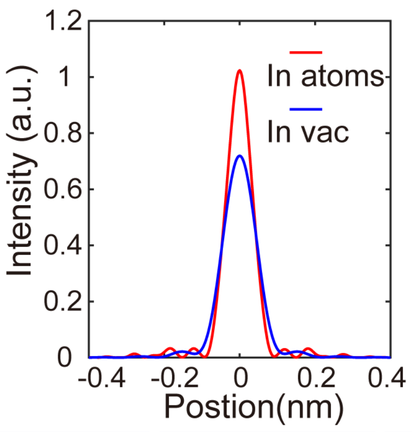


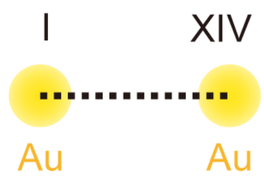


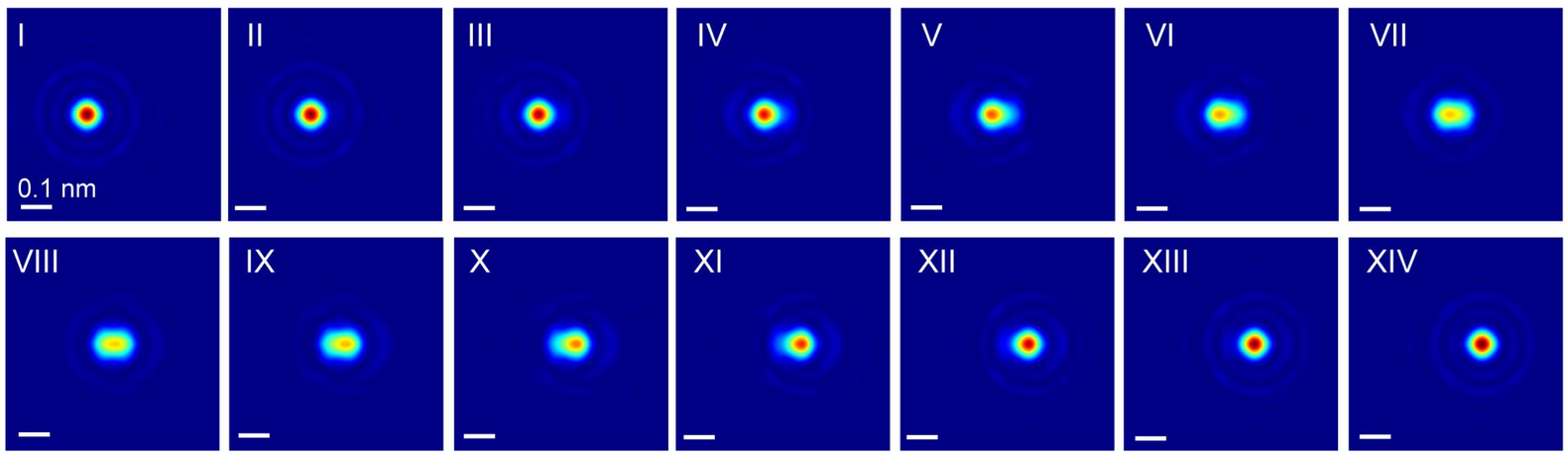
4. Simulations











5. Highlights:

① The **first** experiment directly observed that a row of gold atoms could act as a strong **atomic lens** to focus electrons.
② Open a new path for **breaking the diffraction limitation** of electron imaging with near-field optics, which is expected to achieve higher EM resolution and new ultra-small TEM in the future.
③ Provide direct insight into the **interaction** between **electrons** and **atoms**.