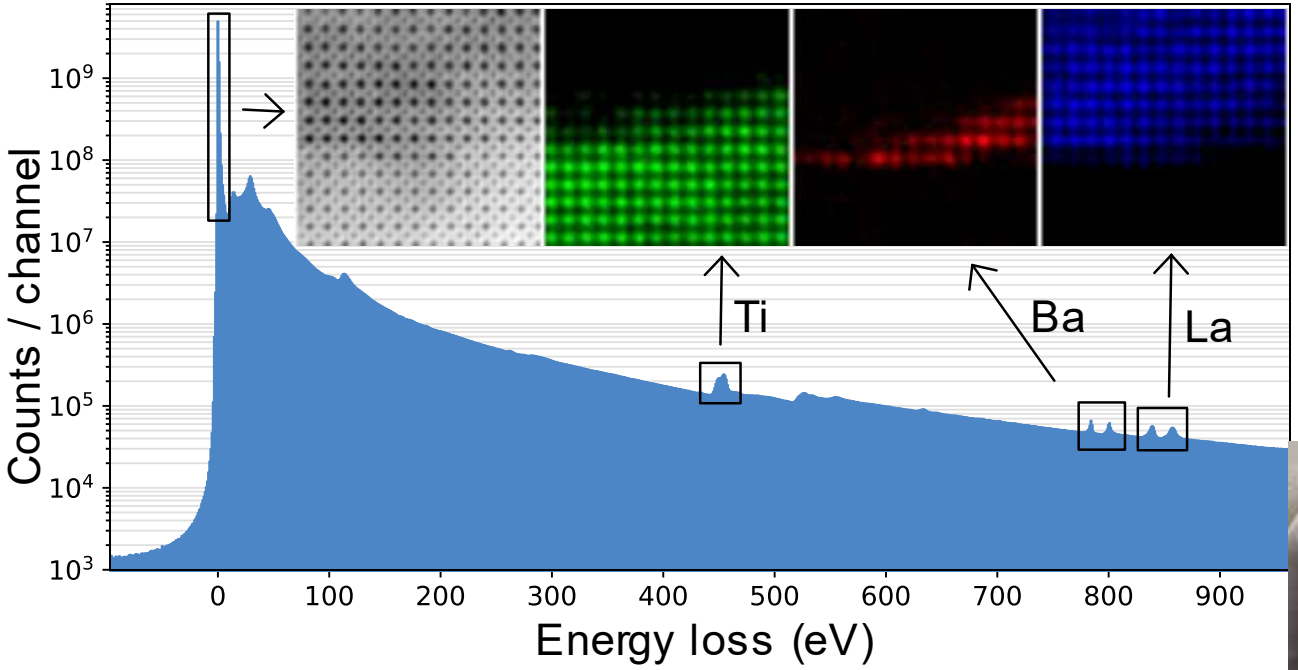
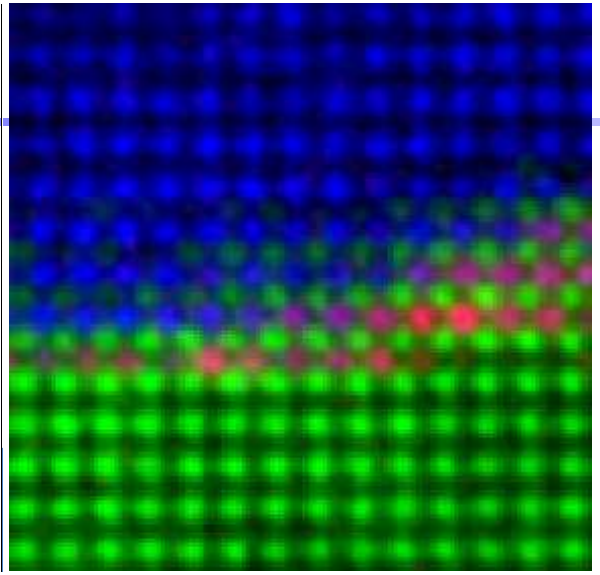
Multi-pass EELS spectrum imaging





32 separate SIs (8 sec each), aligned and summed (4.3 min total).

128 x 128 spectrum image (SI) of an STO / BTO / LMSO multilayer, 60kV, 20 pA, α/2 = 27 mrad, β/2 = 50 mrad, 1.04 eV / channel

DECTRIS detecting the future

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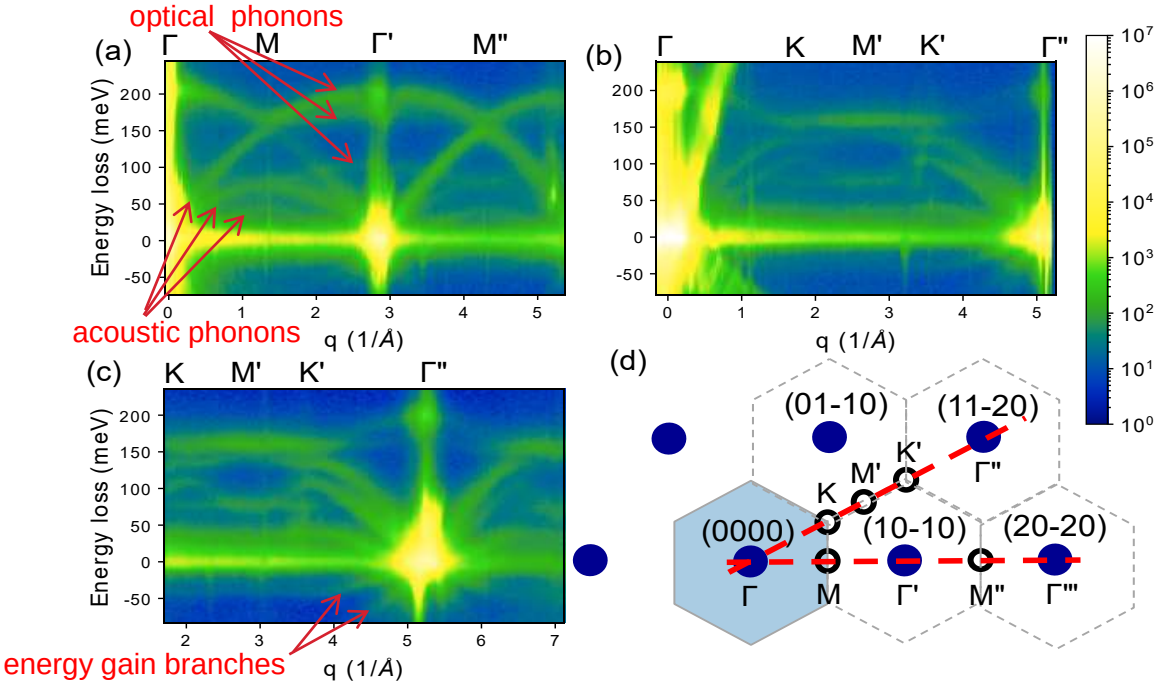
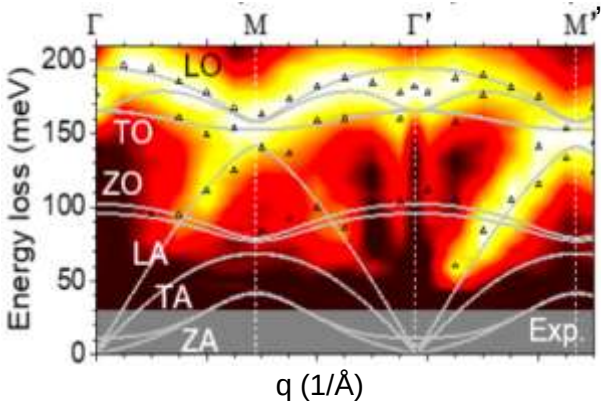
Efficient Energy-Momentum S(ω,q) in h-BN



Acoustic phonon branches start at ΔE=0 at q=0, optical branches at ΔE > 0.



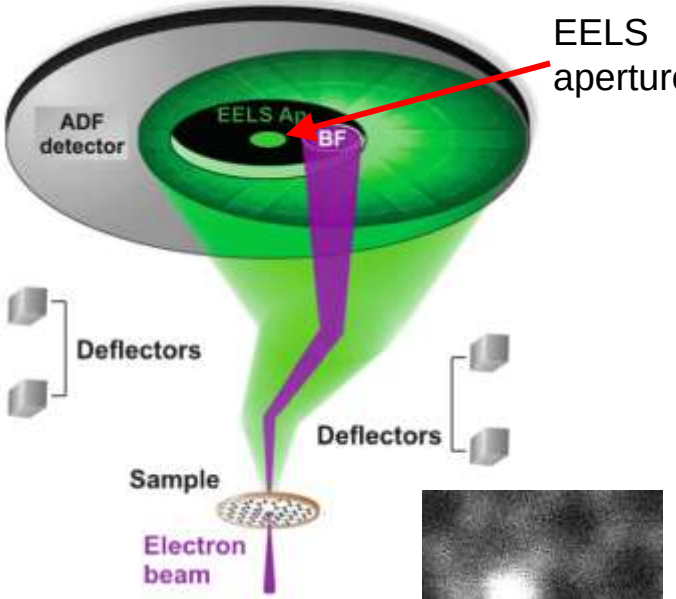
Experimental S(ω,q) data superposed on theoretical model. Serial acquisition: 8.3 hours total. *Senga, Suenaga et al., Nature **573** (2019) 247-250*

Momentum-resolved EELS is a powerful technique for solids in the EM.

S(ω,q) patterns acquired in parallel w. MACSTEM, in 16 min. (a, c) and 8 min. (b) acquisitions.

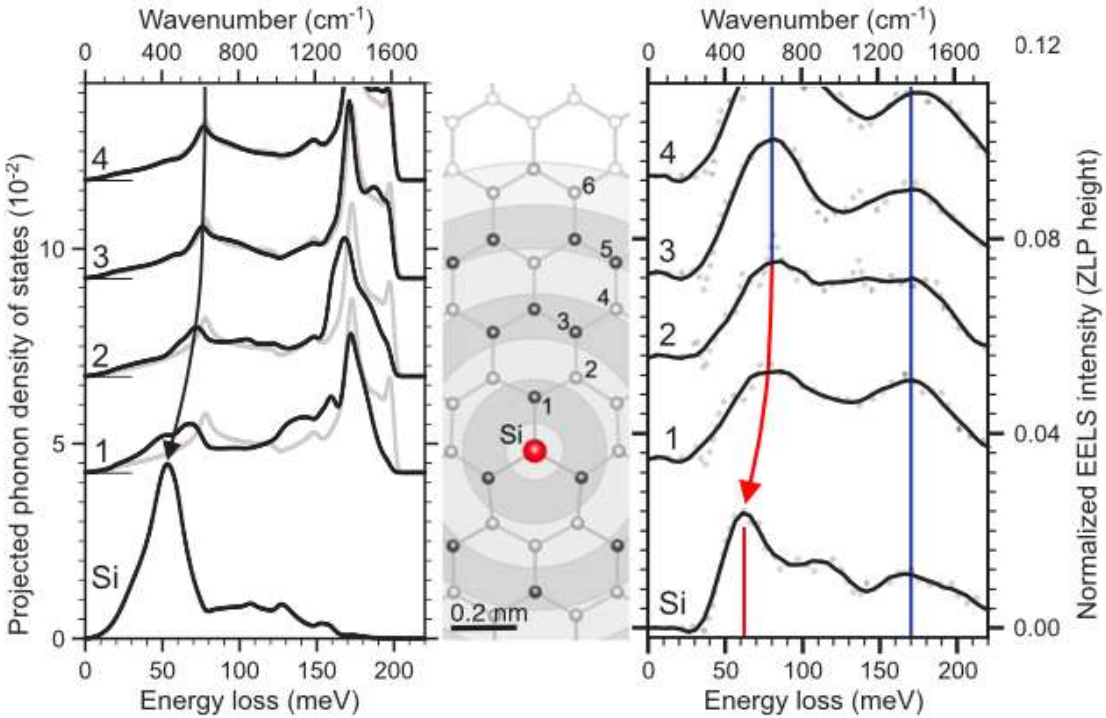
Plotkin-Swing et al., Ultramicr. in press..

Phonons *at* and *near* a single Si atom in graphene



EELS collection schematic

Si atom (HAADF image)



theory (graphene spectrum in grey) experiment

The phonon spectrum of a single Si atom, and modified phonons at nearby C atoms have been detected.

*Hage et al., Science **367** (2020) 1124–1127*

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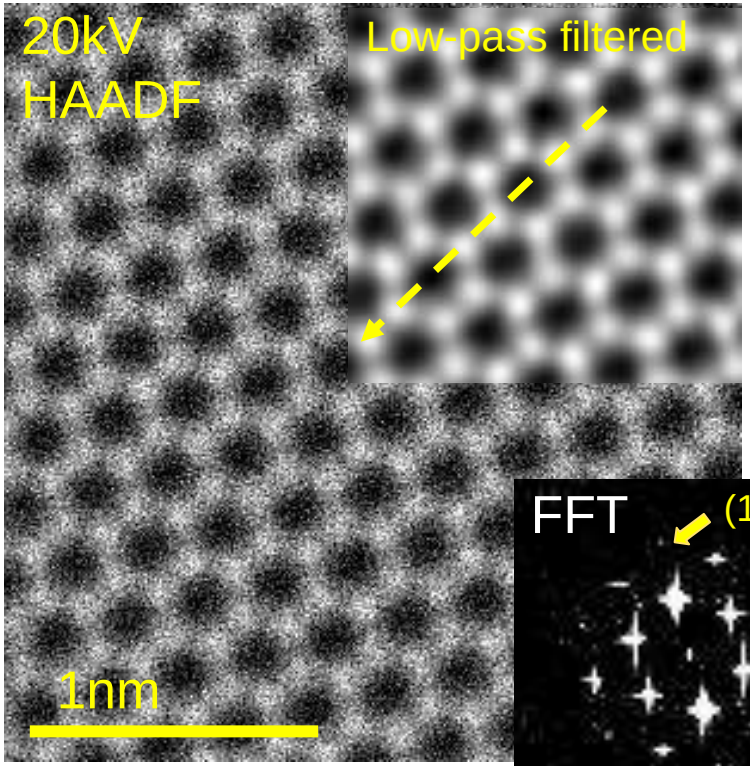
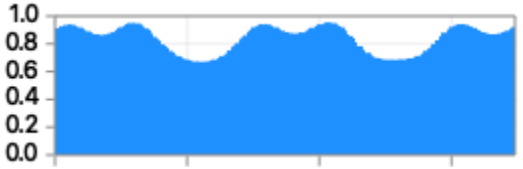
imaging and analysis at 20 kV





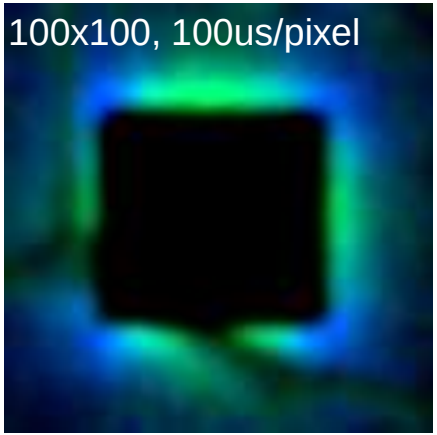
annular dark field (HAADF)

monochromated, δE ~ 100 meV

aligned sum of 60 frames

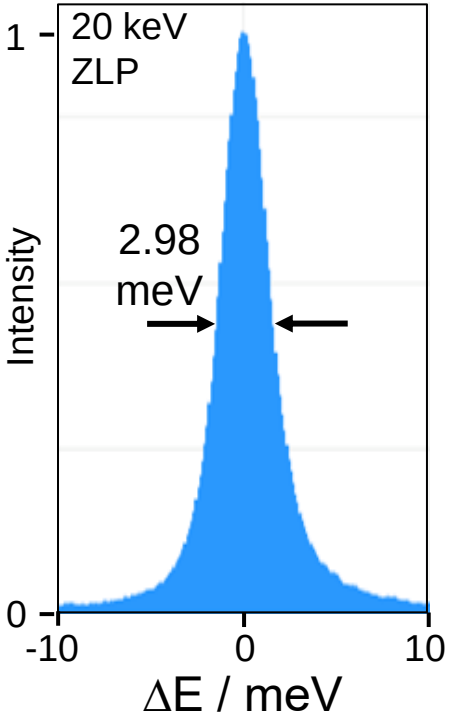
probe half-angle = 55mrad

***d*/λ = 12.7**

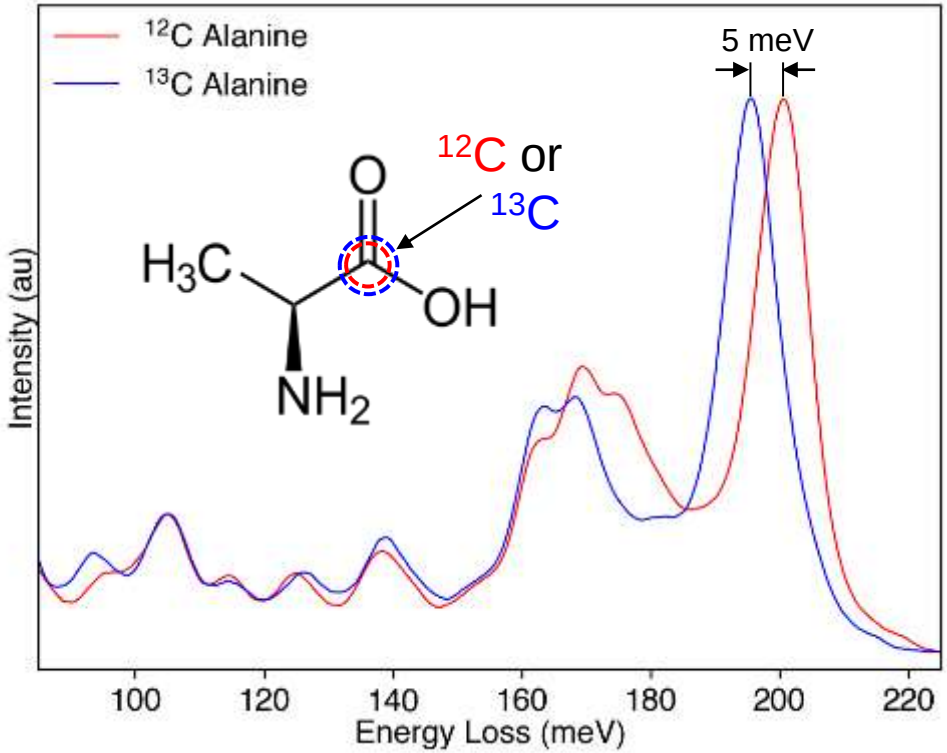


MgO phonons mapped

in one second



Detecting isotopic substitution in L- Alanine



Substituting ^{13}C for ^{12}C at indicated site lowers the C=O bond vibration energy by 5 meV and is readily detectable.

J. Hachtel et al.

*Science **363** (2019) 525–528*

Isotopic substitution can be used to study metabolic pathways in cells and whole organisms.

Nion Swift: open source, user-driven

Differential Phase Contrast in $DyScO_3$

Jordan Hachtel (ORNL): GetDPC

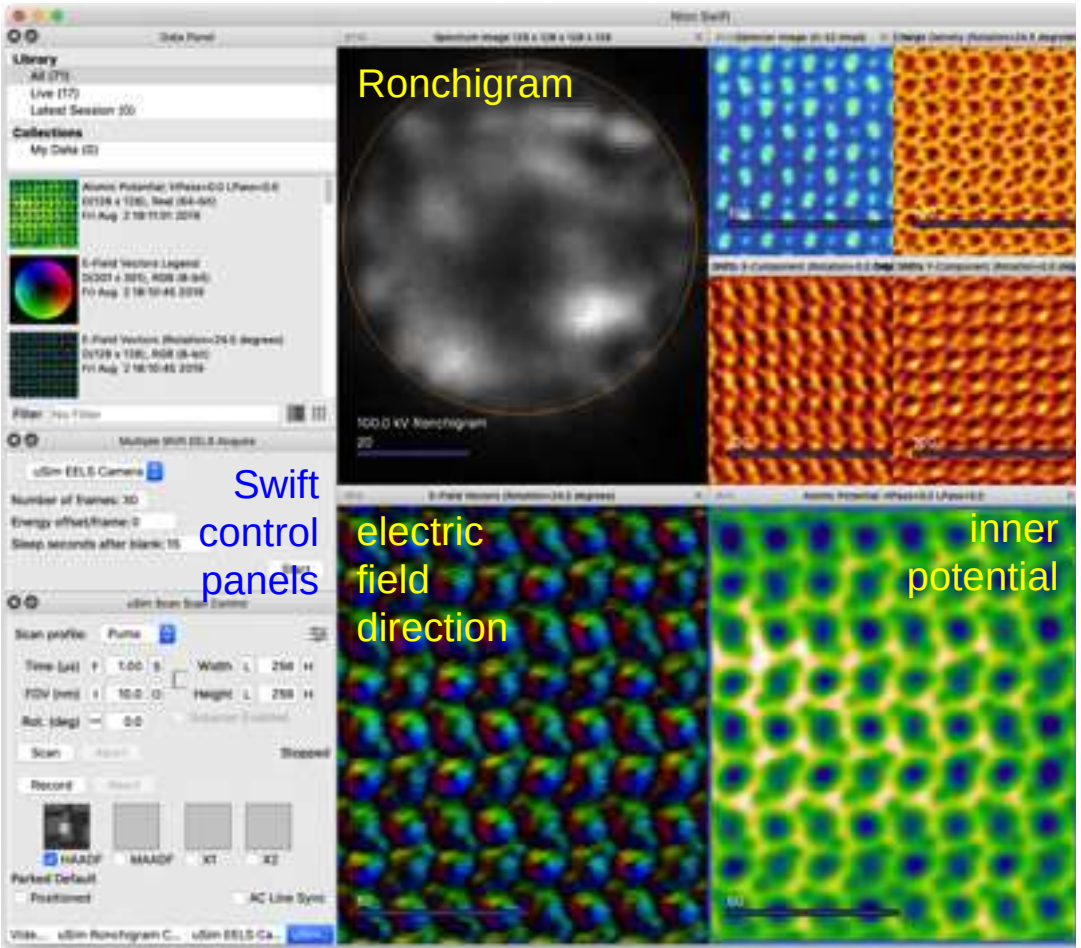
Uses 4D data set (Ronchigram at each point in a scan) acquired with Nion UltraSTEM SCMOS Ronchi camera.

Presents a UI in Nion Swift, processing is done in Python

Developed in Jupyter Notebook and Nion Swift

Available on GitHub
https://github.com/hachteja/GetDPC

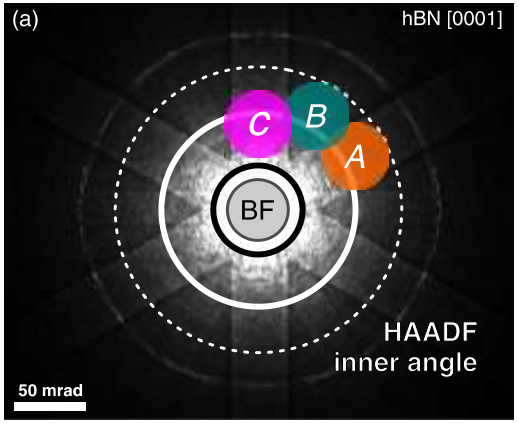
Developing their own code and integrating it tightly into microscope operation is available to all Nion users.



Impact signal images BN at ~2 Å res.

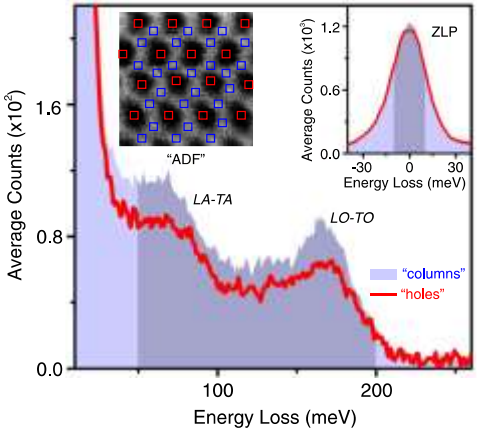
By selecting the impact signal with a collection aperture in the diffraction plane, spatial res. is greatly enhanced.

placement of EELS collection aperture to achieve q-selection



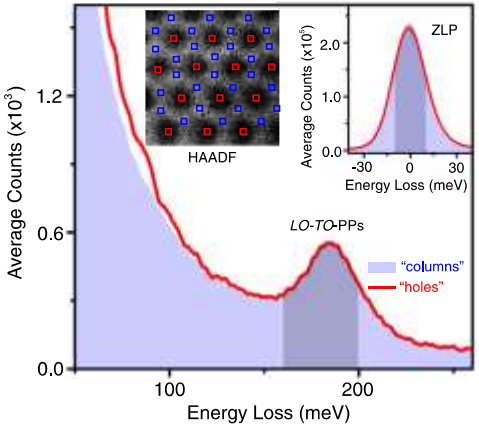
*Hage et al., PRL **122** (2019)*

EELS aperture position: C



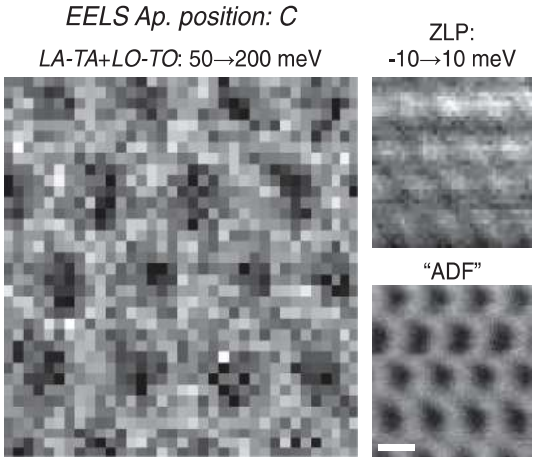
phonon spectrum for large q

EELS aperture position: BF



phonon spectrum for small q

Images of selected momentum and energy transfers



Atomic-resolution imaging with phonons has been demonstrated, but not yet fully optimized.

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