# Experiment Brief

## Metro Camera

### Title

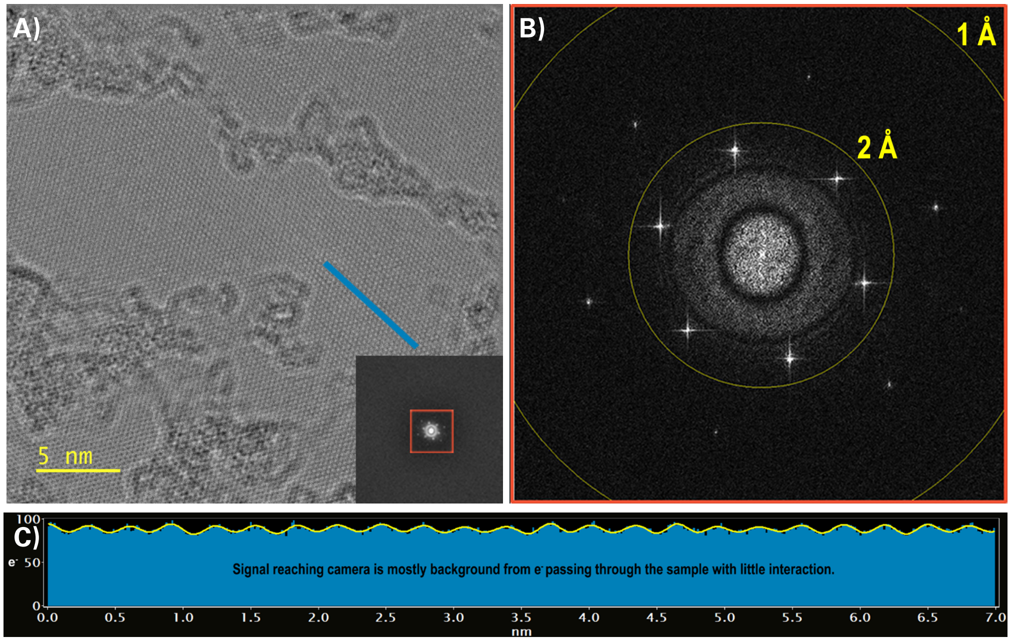
Imaging 2D materials at low kV with Metro

### Gatan Instrument Used

The Metro™ camera enables low-dose **imaging** and diffraction at **low kV via real-time electron counting** with a simple user interface.

### Background

2D materials like $MoS_2$ are increasingly studied for their unique and tunable properties. From single-atom vacancies to nanometer-scale pores, defects in 2D materials have facilitated a wide range of fundamental studies and applications related to DNA sequencing, protein sensing, water desalination, ion transport, etc. Observing defects in these materials at high resolution can provide insight into the origins of unique properties under real-world conditions and to engineer these defects for real-world applications.




### Materials and Methods

$MoS_2$ was grown via chemical vapor deposition (CVD) on silicon/silicon oxide substrates and transferred to a copper TEM grid via polymer wet transfer. The TEM used to capture the data was a JEOL F200 with a cold field emission gun operated at 80 kV. The Metro camera captured a 2.5 s image (Figure 1) with a dose rate of 2150 $e^-/Å^2/s$. The signal amplitude from the sample is <20% above the flat-field background, so only about 360 $e^-/Å^2/s$ contribute to the image contrast (Figure 1C). Live drift correction was applied by the camera during capture so that shifts were measured from around 100 frames before summing them to produce a single image.

**Figure 1.** A) Image of $MoS_2$ captured with the Metro camera using live drift correction. The far top and far right edges of the image fade to grey since only a few of the ~100 drift-corrected frames contained information from those regions. The inset shows the full FFT of the image. B) Small region at the center of the FFT showing two full sets of spacings are clearly resolved. C) Line profile from the location indicated in A, showing the small amplitude of the signal from the 2D sample above the flat-field background (<20%). The profile signal is averaged over a 10-pixel width. The yellow line shows the same profile from a band-pass filtered image.

### Summary


The Metro camera was used to capture this image at low kV, which helped to minimize damage to the 2D structure. Since the Metro counts each electron one by one, virtually all the background noise from the camera electronics is rejected. This is essential for a 2D material since most of the electrons pass through the sample with little interaction, contributing no useful contrast to the image, and shot noise dominates when the image is formed from too few electrons. This means that even a perfect camera that accurately measured every microscope electron would require a large number of electrons to generate an image with sufficient signal-to-noise. Here a decent signal-to-noise ratio per square angstrom (~8) is achieved, and a useful image is produced with minimal dose.


### Credit(s)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