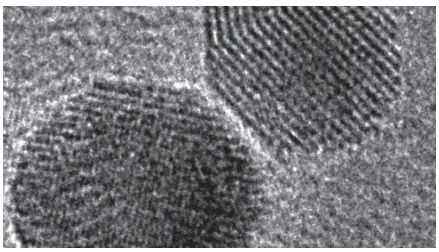
Application note

Sub-millisecond Time resolved TEM images of CeO_2 with Relativity™

In recent years, CMOS camera frame times have been reduced to tens of milliseconds; however, even faster imaging techniques are required for *in-situ* TEM observations to visualize dynamic specimen transformations. In this note, we report time-resolved TEM observations on the sub-millisecond order using the Relativity™ sub-framing system based on an electrostatic beam deflector manufactured by IDES. The Relativity™ system is installed beneath the projection lens of the microscope and rapidly electrostatically deflects the TEM image before it reaches the camera sensor. This allows the capture of multiple small sub-frame images within a single camera exposure, enabling recording at time scales shorter than the camera's native frame time, and the sequential reconstruction of the images.

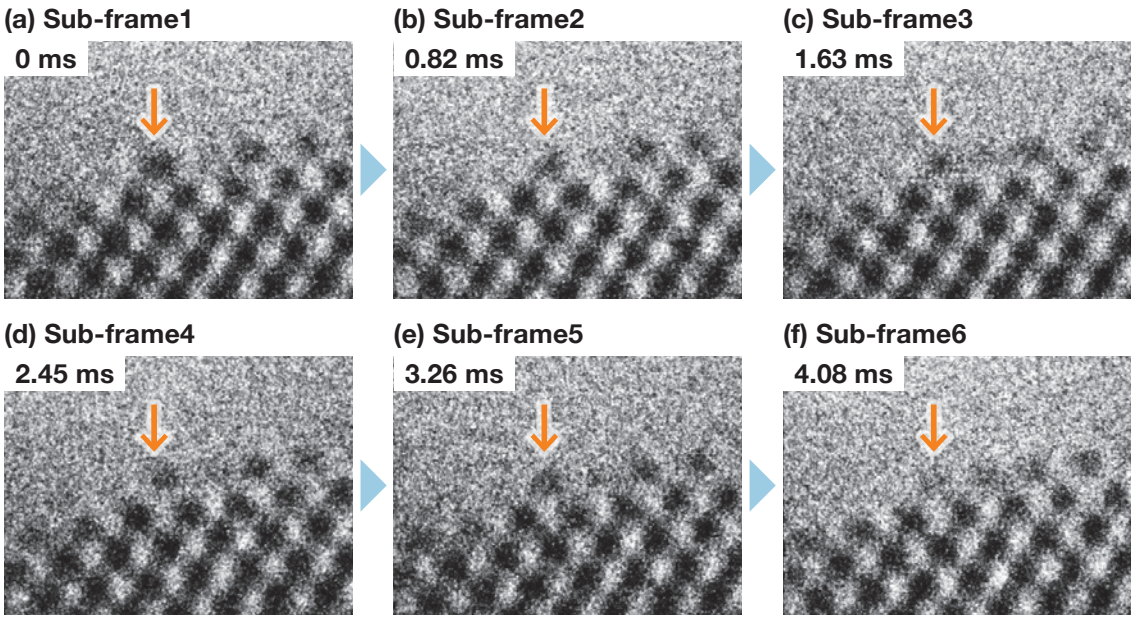
First, we compared a standard CMOS camera video at 25 fps (40 ms/frame) with a 500 fps (2 ms/frame, 488 × 272 per sub-frame) video acquired using the Relativity™ system with a 4 × 5 sub-frame setup. To facilitate direct comparison over the same field of view, a pseudo-25 fps video was generated by extracting one sub-frame every 25 sub-frames from the 500 fps video. Both videos were played back at ~1/8 speed (60 fps and 3 fps, respectively) to clearly show the dynamic behavior. The videos can be viewed via the QR codes below. The sample observed was Au nanoparticles.



Animation

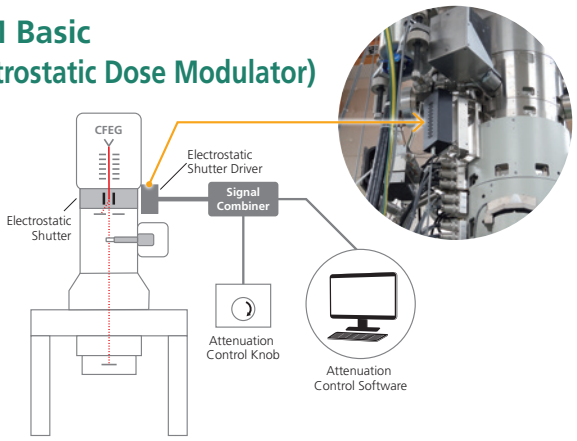
We also observed the time evolution of the (111) surface facets of CeO_2 nanoparticles [1] along the [1-10] incident direction. During a 40 ms exposure, the electron beam was sequentially deflected to record 49 images, yielding a temporal resolution of approximately 0.82 ms per TEM image. Figure 1 shows the third (1.63 ms) and eighth (5.71 ms) frames of the sequence. Atomic-column structure changes occurring within approximately 4 ms are clearly visualized. The actual video can be viewed via the QR code below, revealing single-atom fluctuations too fast for conventional frame rates to capture.

[1] CeO_2 nanoparticle specimen: Courtesy of Johnson Matthey (UK).



Animation

EDM Basic (Electrostatic Dose Modulator)



The Electrostatic Dose Modulator (EDM) is a fast beam blanking system with a pre-sample electrostatic deflector, including electronics and software control. With EDM, the 100,000x improvement in blanking speed immediately improves the clarity of data taken at fast exposure times. EDM can also attenuate electron illumination without affecting imaging conditions, giving TEM and STEM users exceptional control over the dose on their samples.

Programmable STEM with EDM Synchrony

The optional Synchrony upgrade takes EDM's timing and synchronization capabilities to the next level. Synchrony can coordinate with a STEM controller, tracking the probe beam location as it scans across the sample. EDM's lightning-fast electrostatic blanking turns the beam on for a specified time at each pixel, or keeps the beam blanked to completely exclude sensitive regions from dose.

Pulse System

PULSE turboTEM

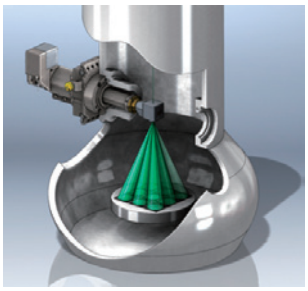
JEOL is pleased to offer Pulse for STEM. Pulse is a real time signal processor that enables digital imaging using standard analog STEM detectors. The device simply plugs in between your STEM detector and data acquisition system to deliver improved signal to noise ratios in your STEM images, particularly in low-dose or high-speed imaging modes.

TEMPO

TEMPO turboTEM

This is a completely new approach to STEM which inverts the typical approach to image formation by using the time required to reach a fixed number of electrons as the basis for pixel intensity rather than the number of electrons detected in a fixed amount of pixel dwell time. Once the desired number of electrons have been counted in a given pixel, the electron beam can then be rapidly blanked resulting in a significant reduction in overall dose applied to a specimen.

Relativity™ Electrostatic Subframing System



The IDES Relativity™ Electrostatic Subframing System multiplies the frame rate of cameras on JEOL TEMs. Microscopes equipped with Relativity™ achieve exceptional time resolution, data throughput, and advanced automation capabilities.

Luminary™ Micro Compact Specimen Photoexcitation System

Luminary™ Micro is a Compact Specimen Photoexcitation System (CPXS) for JEOL TEMs. With Luminary™ Micro, users can study laser-induced phenomena in situ using fast cameras. Combined with IDES/JEOL EDM fast shutter and/or Relativity™ subframing systems, Luminary™ Micro allows users to perform time-resolved studies using pump-probe methods on the microsecond time scale.

EM-IDES-005

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