TEMPO

Trigger-event modulated probability observation, or Tempo, improves the amount of information obtained for a given electron dose.[1] The concept is simple, there is a large diminishing return on information as more electrons are detected from each point in a STEM scan. In the new TempoSTEM imaging mode, the electron beam is quickly turned off after a desired number of electrons are counted (typically 1 – 25) in each pixel, before being turned back on at the start of the next pixel time. Pixel intensity is defined by the time taken to detect the fixed number of electrons, as opposed to the number of electrons detected in a fixed time. While this distinction may seem small the implications for minimising specimen damage are substantial.

Advantages

- Compatible with existing analog STEM detectors and TTL driven beam blankers.
- Maximum information efficiency extracted from a minimum delivered electron dose.
- Flexibly balance dose or precision across full duty-cycle range via blanking trigger condition.

Specifications

	2 Channel	4 Channel
Pulse channels	2 in, 2 out	4 in, 4 out
Tempo outputs	2 (from single input)	
Tempo voltage	3.3 V or 5 V	
Tempo resolution	8 ns	
Pixel clock input	3.3V CMOS - 5V TTL compatible	
Blank signal output	3.3 V CMOS, 5 V TTL	
Connections	BNC	
Signal range	Max. ±10 V	
Signal resolution	14-bit	
Input impedence	50 Ω	
Sample rate	125 Msps (per channel)	
Pulse voltage	3.3 V CMOS, 5 V TTL	
Pulse frequency	Max. 62.5 MHz	
Power	5V barrel jack	
Control interface	RJ45 ethernet	

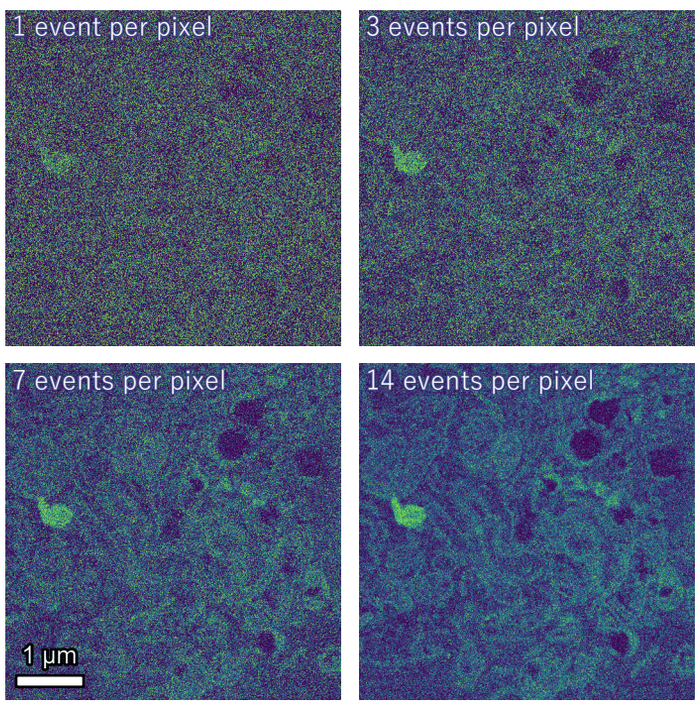

Figure 1 TempoSTEM images of human macrophage cells recorded with the beam blanker triggering after various event numbers. Contrast represents scattering-rate values. Sample credit: Alexandra Porter (ICL) and Karin Muller (U. Cambridge).

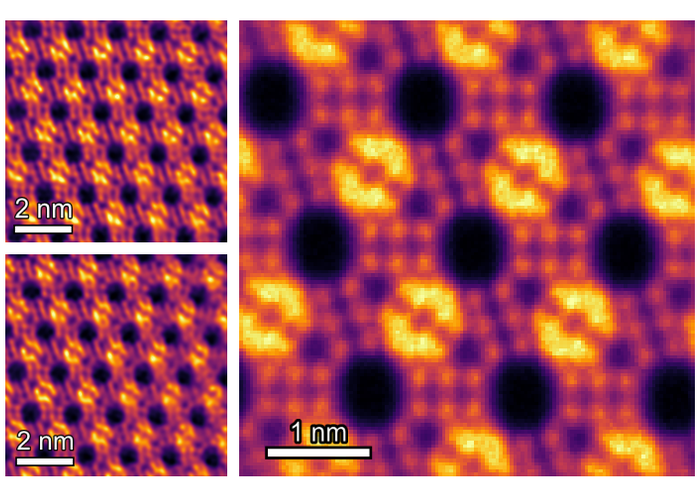

Figure 2 TempoSTEM imaging of FAU Y-type zeolite using 2 electrons per pixel. Top-left shows a first frame, bottom-left shows after 20 frames. The average dose per frame is 371 $e^{-}Å^{-2}$. Right shows a template matched image. Sample credit: JEOL Ltd..

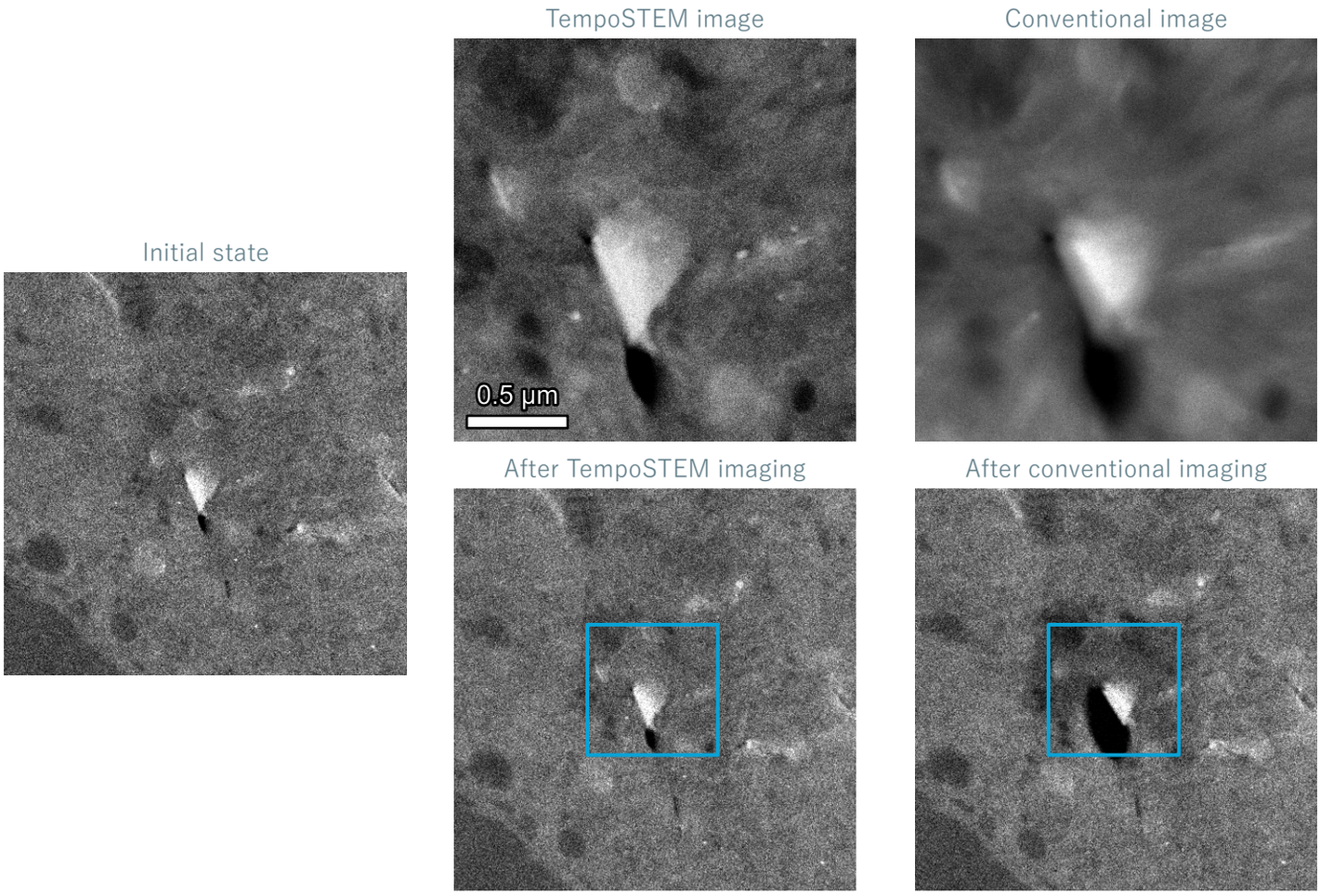

Figure 3 Example of reduced damage to a human macrophage sample when using TempoSTEM to image versus conventional STEM. After TempoSTEM imaging (using 3 electrons per pixel, 10 averaged frames) the initial state is preserved. During and after conventional imaging (10 averages frames) the sample displays significant damage and distortions. Sample credit: Alexandra Porter (ICL) and Karin Muller (U. Cambridge).

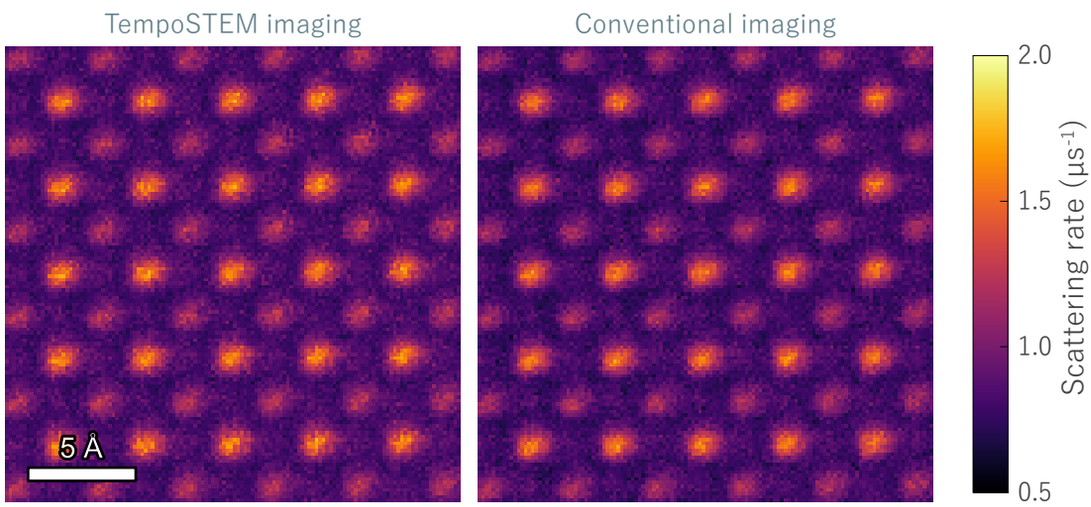

Figure 4 Comparison of the image contrast between TempoSTEM and conventional STEM imaging of $SrTiO_3$. Both images are shown in units of events per microsecond. The quantitative information offered by TempoSTEM is identical to conventional approaches. TempoSTEM image shows 210 electrons per pixel, conventional image uses approximately equivalent total average dose. Sample credit: JEOL Ltd..

[1] J.J.P. Peters, B.W. Reed, Y. Jimbo, *et al.*, Event-responsive scanning transmission electron microscopy, Science **385** (2024) 549-553