Startup Contest Application

International Conference on Electron, Ion, and Photon Beam Technology and Nanofabrication

1. Venture Name. PanoScientific, LLC.

2. Team Leader and Primary Contact Information.

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3. Additional Team Members.

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4. Describe the business opportunity.

Compressed Sensing (CS) in serial scanning instruments involves sampling a minority fraction (i.e., 20%) of the full pixel density while allowing a faithful reconstruction of the object. A number of requirements must be satisfied to achieve a faithful reconstruction. Among these requirements is a high degree of statistical randomness in the sparse sampling strategy. Executing a highly random, high speed, precise scan pattern has presented a barrier to implementing a practical CS Scan Generator (CSSG) for electron microscopy. An approach to overcome barriers to practical CS implementation in serial scanning electron microscope (SEM) or scanning transmission electron microscopes (STEM) was developed which integrates scan generator hardware specifically developed for CS, a novel and generalized CS sparse sampling strategy, and an ultra-fast reconstruction method, to form a complete CS system for electron microscopy. The system is also compatible with other serial scanning characterization techniques, such as AFM, EDS, Auger and even 3D sparse sampling applied to techniques such as laser scanning microscopy (LSM).

5. Describe your technological solution.

As mentioned, one of the common issues when designing a CS serial scan strategy is to mitigate effects tied to scan system dynamics [1]. To minimize hysteresis, slew and other scan distortions, CS scan matrices were explored which ensured predominantly smooth and largely continuous scan pattern properties. Space-filling curves (SFCs) represent a family of topological curves which possess such properties. It was found through simulated reconstruction that SFCs in general “worked”, but as a mathematical family are prone to non-idealities when applied directly as a CS sampling matrix. Namely, SFCs are pseudo random, which does not satisfy a highly statistically random sampling. SFCs are also discretized in degree of sparsity, as dictated by the order of the SFC and the pixel density.

The optimal patent-pending solution was to employ the SFC as a “slow” carrier signal modulated by a “fast” randomized perturbation signal. In this manner, by combining the "slow" continuous carrier and "fast" random modulation, a programmatic highly randomized pattern may be invoked with any fractional degree of sparsity and with a high geometrical degree of freedom (DOF) in 2D or 3D. The ratio of work performed by the carrier signal relative to the randomized modulated signal may be regulated to accommodate physical constraints of native hardware, such as amplifier circuits and scan coil response. The schema also does not generally require any beam blanking along the scan path! Fill blocks do not need to be orthogonal, square, or even Euclidean. A wide variety of SFCs may be applied with this system, including serpentine curves, spiral curves, Lissajous curves and other parametric curves. A module estimates resolution from the Fourier transform of the sparse data and the SNR from the Gaussian noise estimated from eigenvalues of the patch covariance. A second module measures and corrects scan distortions. A third module measures the point spread function and applies this kernel to correct beam distortions. See Figure 1 for examples of sparse sampling and reconstruction.

6. Who is your competition and what are your product differentiators?

A practical commercial product for generalized sparse sampling in a serial scanning electron or scanning ion microscope does not exist. Academic research conducted by various investigators has demonstrated varying degrees of success at producing sparse sampling schema and reconstructions. The randomness resulting from the degree of freedom enabled by this method has a distinct advantage over line-hopping methods applied to CS electron microscopy [2].

7. Describe the Market Opportunity. [Optional Section]

The high-end market is corrected STEM instruments, which are additionally limited by scan distortions. Cryo-STEM applications would benefit from higher acquisition speeds and lower dose. Initially, the system will be marketed to influential early adopters with high-end STEM systems conducting research in materials science and biological sciences.

8. Describe the Team. [Optional Section]

Our core team includes mature professionals with world class experience in high-resolution STEM, SEM and FIB-SEM. You can read about the PanoScientific team members at https://www.panoscientific.com/about-us/. This core team has partnered the capable scientists at Ion Innovations who have experience in algorithm development, electron and ion microscopy, and imaging science.

9. Describe any traction. [Optional Section]

A Beta platform has been delivered in October 2021to AFRL laboratory in Wright-Patterson Air Force Base. The system is currently being applied to increase through-put in verification and validation of critical semiconductor components.

[1] Anderson, et al. "Sparse imaging for fast electron microscopy." *Computational Imaging X1. Proceedings of* SPI-*IS&T Electronic Imaging, SPIE*. Vol 8675 (2013).
[2] L. Kovarik, et al., "Implementing An Accurate And Rapid Sparse Sampling Approach For Low-Dose Atomic Resolution Stem Imaging", Appl. Phys. Lett. **109**, 164102 (2016); https://doi.org/10.1063/1.4965720.

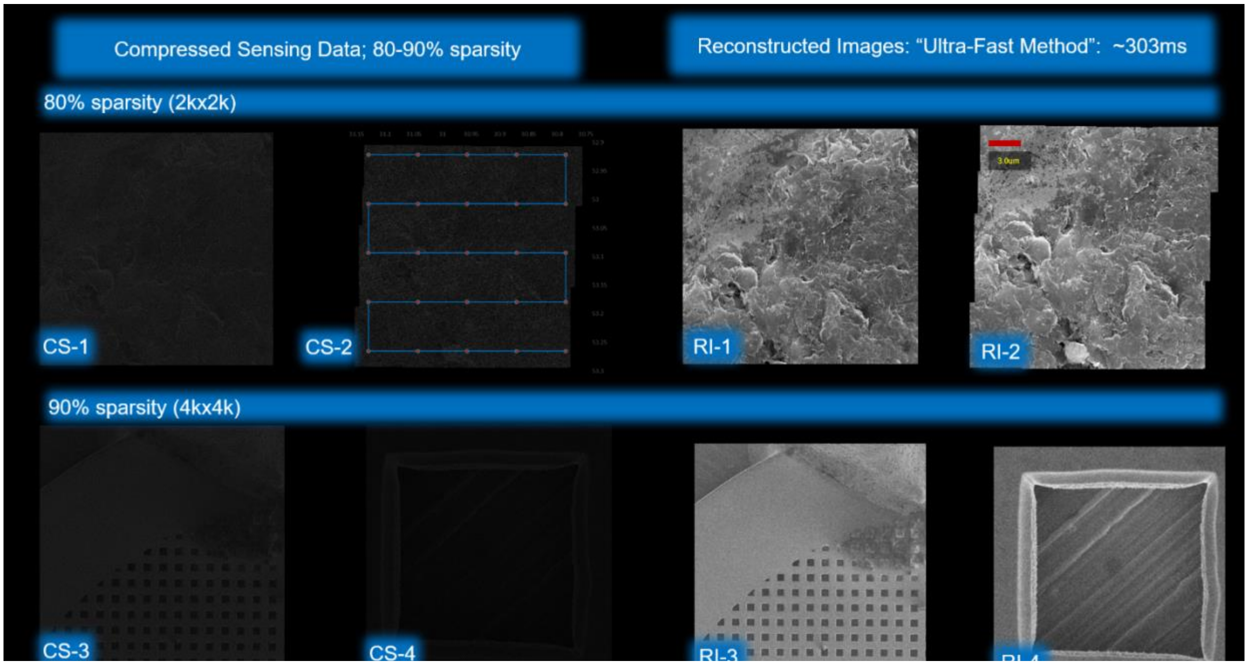

Figure 1. Compressively Sensed scanning electron microscope images are shown on the left (CS- #) and corresponding Reconstructed Images (RI-#) are shown on the right half of the graphic. Panels CS-1 through CS-4 a show a series of compressively sensed images. CS-1 and CS-2 were acquired at 80% sparsity in a 2Kx2K pixel array and CS-3 and CS-4 were acquired at 90% sparsity in a 4Kx4K array. It challenging to graphically display highly sparse sampled data, but features can be correlated to the reconstructed images RI-1 through RI-4 on the right side of the graphic. CS/RI-1 and CS/RI-2 are overlapping regions from a gold-on-carbon specimen acquired on a thermal emitter and Everhart-Thornley style secondary electron detector. CS-1 is 80% sparse, ~25um FOV and 12.2nm pixel size. CS-2 is an 80% sparse 5x5 serpentine montage, and the blue solid line and red dots representing the montage tile path are for visualization purposes only. Each montage tile is 6.1um FOV and 3.1nm pixel size. Comparing varying pixel size for the same sparsity in the ROI is a method to compare CS sampling parameters. CS-3 and CS-4 are 90% sparsity sampling images on a regular grid acquired on a Schottky field emitter platform using a through-lens detector. All scans shown were performed using a Hilbert style SFC.