Remote SEM revolutionised - imaging and teaching accessible to all

Dr Radka Gromnicova

As many laboratories had to shut down due to the COVID-19 outbreak, we all had to get used to the limitations of working from home. But imagine what it would be like to continue with your research or having your students carry on working on their projects – all remotely using real instruments...

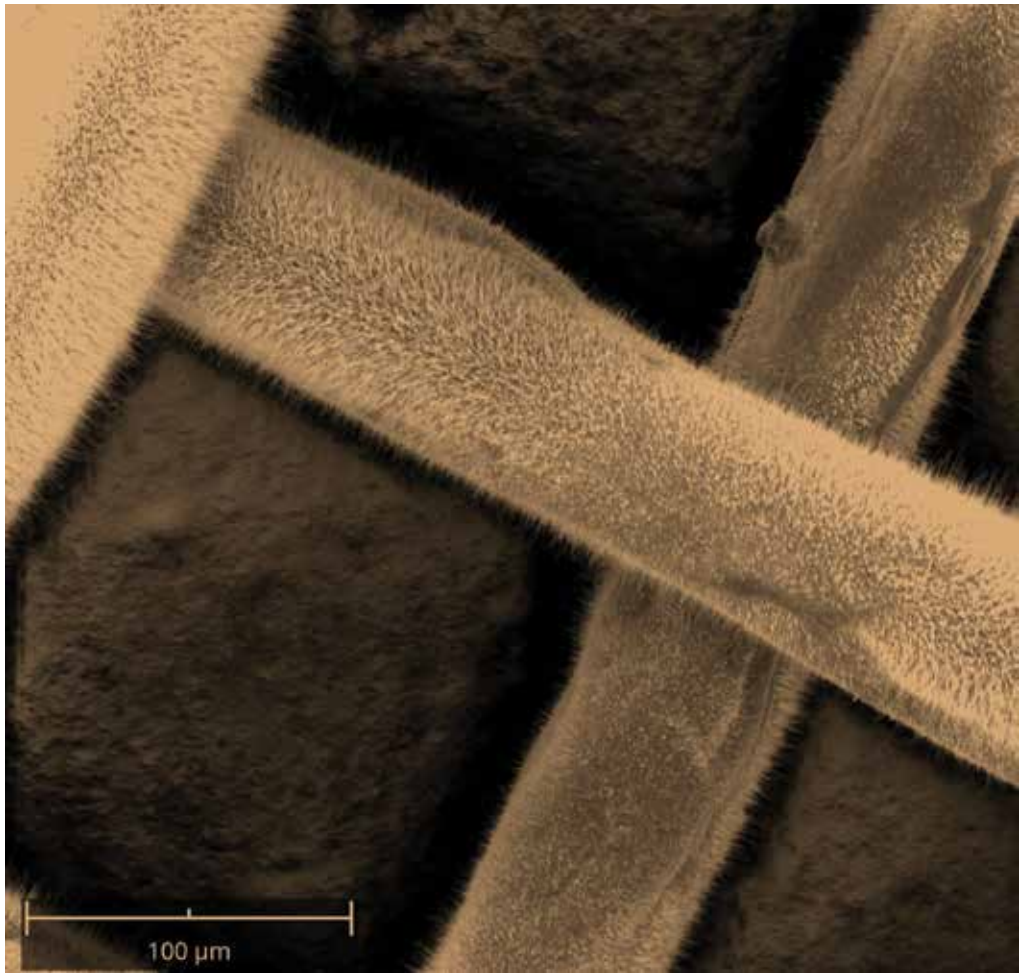

Figure 1: Whether it's cracks, failures, or micro-structures, the remote desktop SEM provides resolution down to 1 micron.

Sonia has a task ahead. She has to find 30 mini craters in a foil and measure their sizes, using a remote scanning electron microscope. She moves the stage and finds one. She clicks to autofocus and 'voila' – the crater appears in front of her. The crater she is looking at is a result of projectiles hitting a Stardust Collector.

Teaching reinvented

Sonia is one of the Open University's distance learning students using remote desktop SEM for her degree project. Unlike any other institution, the Open University has created a simple-to-use online web interface that operates their SEM instrument remotely. In that way, students from anywhere in the world, with little or no technical knowledge, can use SEM. And do it in their own time with no technical staff needed to assist them.

Geoff Austin, who maintains and develops the remote interface, says that the benefits to students are huge. "We have students from all over the world – one was on an oil rig and another one in New Zealand. Remote instruments allow them to take part using real samples and a real instrument, even though they cannot be physically present."

The Open University is well known for its award winning remote OpenSTEM labs (Internet 1). They know what it takes to make a virtual instrument. However, making a virtual SEM and programming it would be almost as difficult as allowing students to analyse real samples remotely. Plus, academic degrees such as Engineering require students to participate in real study projects and operate real instruments. Master of Science degrees do not have such strict requirements, but students expect the same.

In fact, several research studies showed that students enjoy and learn better when using real samples and real instruments (Childers & Jones 2015). The feeling that they are controlling something in real time is crucial for their learning experience. it broadens their experience and increases further employability perspectives.

But remote SEM is not just limited to teaching. Research staff at the university have taken the opportunity to run their own experiments when free from their teaching duties.

Researchers in a rush (and not enough expertise) find it useful too

Unlike full-size SEM, desktop SEM is useful for quick analysis and for those researchers who don't have much experience with electron microscopy. The focusing is very easy, just turn a knob to focus, or use the built-in auto-focus feature.

Best of all, you save time. No alignment is necessary since the microscope has preset working conditions, and comes pre-aligned. The preset working conditions means the SEM is already aligned and calibrated. You insert the sample and you're ready to observe a focused live image a few minutes later.

Elemental composition analysis using EDS is just as simple as imaging. It takes short of 15 minutes to check the chemistry of your sample. And that includes inserting the sample and running a few EDS point analysis. Such a timescale is unheard of with a full-size SEM machine. EDS would take twice as long – at least 30 - 45 min from inserting the sample, depending on your expertise.

But using remote SEM goes beyond academia. Industrial and private customers can take advantage of analysing their samples from their offices and homes. The web interface makes using SEM very easy. Whether they are analysing crack distribution, failure in material or imaging fossils, the scope is limited only to the size of the sample (up to 100mm in length and 65mm in height) and resolution (down to 1 µm).

Web interface allowing anyone to operate SEM from anywhere

To create a simple, mobile-friendly web interface was revolutionary. Other institutions, like those in the US, have already been offering remote SEM to

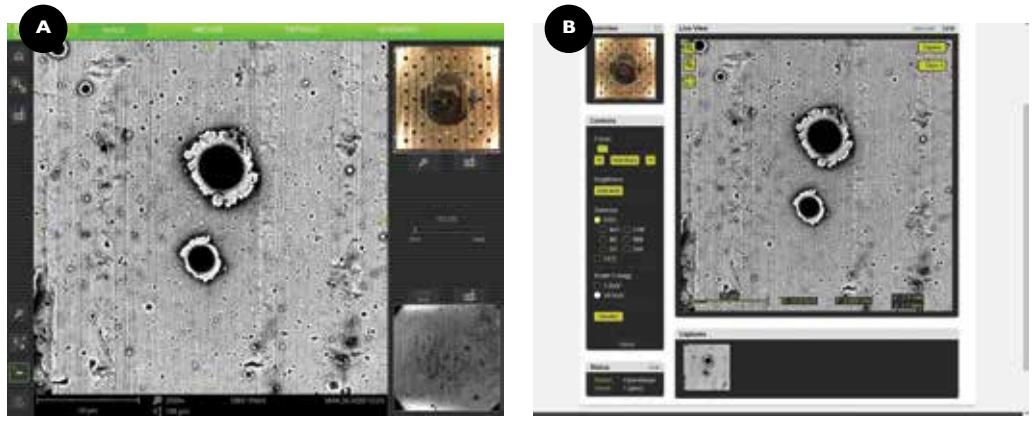

Figure 2: The Open University programmers have taken control of the manufacturer's software operating the microscope (A) and instead created user-friendly web interface (B). The image shows one of the craters from the Stardust Collector that were used for students' projects.

Figure 3: The compact stage of desktop SEM holds samples of up to 10 cm in length, by 10 cm width, by up to 6.5 cm depth.

students and researchers for a long time (Ashcroft et al., 2018; Huber et al., 2018) [Internet 2, 3]. However, users had to install a specific software on their PCs or remotely access the complex full-size software. As a consequence, technical support is needed to prevent ruining of the instrument by an unskilled student.

There is a learning curve in using any new software, as students have to learn how to control the instrument first.

On the other hand, Open University's web interface is super simple. You can grasp it within five minutes. Buttons like "Wake up" the instrument, "Auto-focus" and "Zoom" are self-explanatory. Students have quickly become familiar with the web interface, despite having a wide variety of backgrounds and experience. The SEM can be controlled from any web-enabled device, from anywhere in the world – not just restricted to a corporate network.

Designing a simple web-controlled system was not straight forward. Well before any microscope was chosen, the Open University software developers asked manufacturers a long series of questions about their controlling software and how it worked. Some software is more 'open' than others and makes it easier to allow third-party applications to control the microscope's hardware. The final choice of SEM came down to the software and manufacturer support as much as the hardware and final costs.

One also has to consider sharing a research-dedicated SEM with remote teaching. Researchers can get territorial about their time and access to the instrument and in the long run, this may cause problems. Ideally, a dedicated remote SEM is the answer, with occasional research projects taking place in the spare time between student teaching.

When it goes wrong...

Like with any machine and generally anything online, things may go wrong. Depending on the issue, it may take minutes or days to fix and get the instrument back online.

Any remote instrument can fail, and the Open University does not have a 24/7 technical support service. A failure after working hours when the technical team is not around means the issue has to wait until the next working day. This can be a drawback since the SEM is remotely available 24/7. The team tries its best to ensure it's working all the time, but it depends on the issue. A simple network or server restart does not take long to get it back online. However, if it is a technical issue with the microscope hardware or software, it can take up to three days for an engineer to come and fix it.

To tackle this problem, the Open University has a second remote SEM, so the bookings are moved to the spare instrument and/or extended to allow students to complete their work.

But it's not just the instrument downtime that can cause problems. Another is the quality of the sample itself. For example, square marks burnt by the electron beam on the sample surface imaged by previous students can give clues about locations where others need to look to complete their task.

Kevin Gowans, who is responsible for the remote SEM, says: "The samples have to be at the best quality before the start of the teaching module. Then, swap out for another sample as soon as possible. If samples are prepared properly, they should last a long time."

If it is remote – do you need to own one yourself?

Instead of developing a remote instrument of your own, consider partnering with those who have done all the hard work already [Internet 4]. An organisation can save the cost of purchase plus

Figure 4: Desktop scanning electron microscope is compact enough to be taken to events and demonstrations away from the campus.

developing the web interface and getting it online. Geoff notes that it takes "at least 12 months from developing and testing to be sure it's working".

How much would partnership cost though? Kevin says that partnership would include a year licence with a fixed fee (around £1,000) and usage would get charged depending on how many students or researchers are accessing it. Plus, it would also depend how much technical work is needed for preparing the samples and exchanging them.

In these days and age of Cloud-based systems and online platforms, sharing a remote SEM might be the future of teaching and research, industry and even private users. It is an economical solution for those who cannot afford the high purchase and development costs. Whether it is a busy institution juggling lots of students' projects or one that wouldn't get access to modern SEMs otherwise – remote instruments are the solution.

References:

Ashcroft, J. M.; Cakmak, A. O.; Blatti, J.; Bautista, E.; Wolf, V.; Monge, F.; Davis, D.; Arellano-Jimenez, M. J.; Tsui, R.; Hill, R.; Klejna, A.; Smith, J. S.; Glass, G.; Suchomski, T.; Schroeder, K. J.; Ehrmann, R. K. (2018) It's RAINing : Remotely Accessible Instruments in Nanotechnology to Promote Student Success. Current Issues in Emerging eLearning 4:1. Available at: https://scholarworks.umb.edu/ciee/vol4/iss1/4

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Huber, D., Scheltens, F., Williams, R., & McComb, D. (2018) Remote Operation: The Future of Education and Research in Electron Microscopy. *Microscopy Today, 26*(5), 26-33. doi:10.1017/S1551929518000871

Internet links:

Internet 1: www.stem.open.ac.uk/study/openstem-labs

Internet 2: www.cambridge.org/core/journals/microscopy-today/article/remote-operation-the-future-of-education-and-research-in-electron-microscopy/DD06F7C410725CA71E08052B98B280EF

Internet 3: www.nano4me.org/remoteaccess

Internet 4: www9.open.ac.uk/emsuite/facilities/instruments/phenom

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Originating from the Czech Republic, Radka came to the Open University to gain work experience, which lead to her PhD. Radka's biology-based PhD involved extensive use of transmission electron microscopes, which later allowed her to join newly forming team of electron microscopists at the Open University. The Electron Microscopy Suite, led by Dr Igor Kraev, is reaching out to other institutions and industry, helping them to get the analysis they need in short timescale and at a fair price.