OnPoint User Manual

Model 400

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1 Regulatory compliance and safety considerations

IMPORTANT
It is your responsibility to ensure your safety and that of the people working around you. If the equipment is not used in the manner specified, the protection provided by the equipment may be impaired.

IMPORTANT

Before installing and operating this product, and to avoid the risk of injury and potential hazards, read and review the regulatory pamphlet and follow all safety instructions.

The OnPoint™ detector is intended for use in a closely temperature-controlled laboratory environment compatible with the use of an SEM. Please note that reducing temperature variations (including from exposure to direct sunlight) will improve the performance of both the OnPoint and the SEM.

1.1 User serviceability

The OnPoint detector is intended to be installed by a trained Gatan engineer, on a scanning electron microscope (SEM) which is already installed and functioning to the microscope manufacturer's specification.

This manual describes the functionality of the installed product and will help the user understand the product, gain optimum results, and reduce the risk of damage. It does not describe installation, service, or fault-finding tasks.

Please also reference the OnPoint Facilities Specification document.

IMPORTANT

Users should not attempt to service the equipment or perform maintenance tasks beyond those which are described in this manual. All servicing should be done by a Gatan trained or approved engineer.

2 System overview

The OnPoint is a high-speed, low-noise retractable backscattered electron detector (BSED) for the scanning electron microscope (SEM), optimized for the detection of low energy electrons.

The detector has a low profile, allowing for high-resolution imaging with a minimum working distance of less than 3 mm. Combined with its speed and near theoretical quantum efficiency at low energies, it is a powerful tool for imaging specimens at low accelerating voltages. It is particularly useful for collecting single or serial block-face images from resin embedded biological samples.

This overview chapter covers individual components of the OnPoint detector hardware and some background to their design and usage

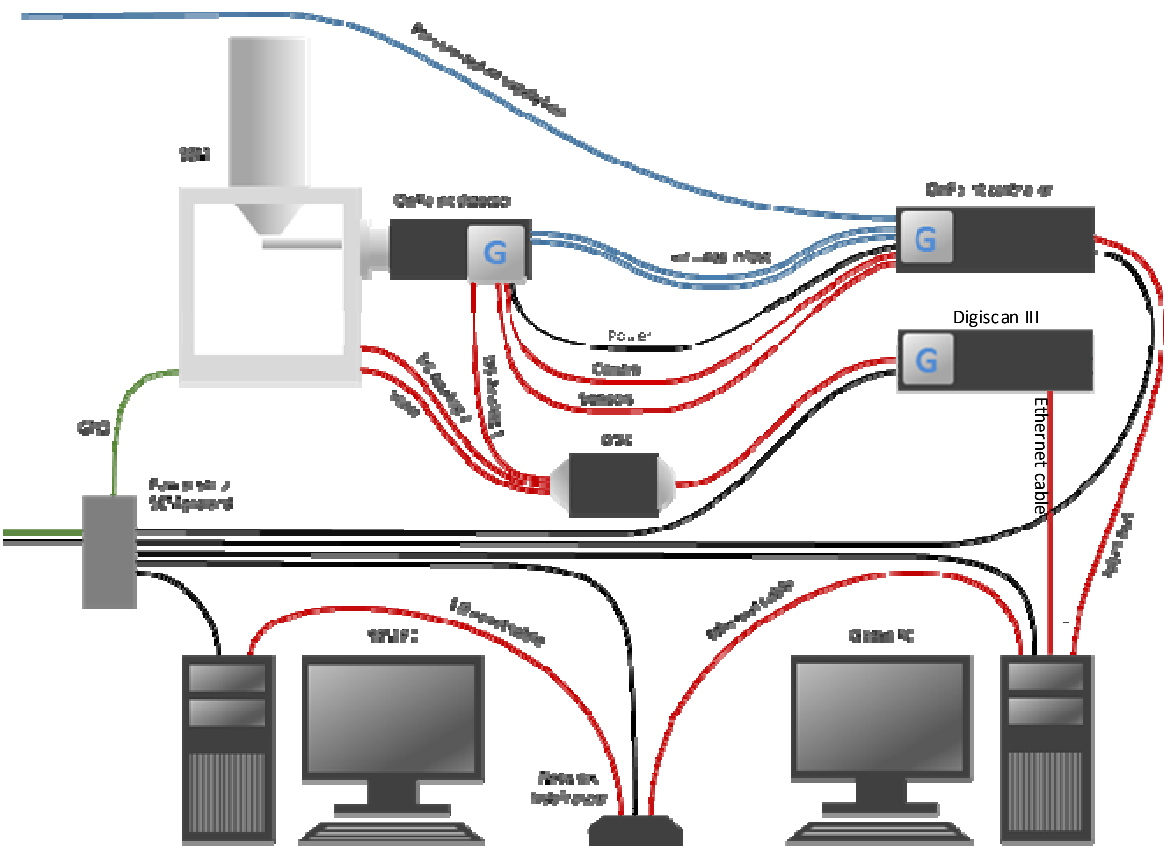

Figure 1: OnPoint detector interconnect diagram.

2.1 The SEM and imaging conditions

Most users will be familiar with the traditional operation of an SEM, where short working distances are required for the highest resolutions, especially when using low accelerating voltages. The OnPoint detector is designed to facilitate short working distances whilst still providing a high-collection efficiency and a large field of view, and can also fully retract from the chamber allowing full access and the use of other detectors. For an OnPoint detector acquisition, the Gatan system takes control of the SEM by scanning the electron beam, although the user is still free to use the SEM interface to adjust operating conditions.

2.2 The OnPoint detector

2.2.1 The retraction mechanism

The core of the OnPoint detector is a pneumatic retraction mechanism that mounts to a nominated free port on the SEM chamber. This drives an arm in and out of the chamber, positioning the BSED under the pole-piece when inserted, and retracting flush with the chamber wall when retracted.

The construction has been optimized to provide high positional stability, repeatability, and vibration isolation, whilst retaining easy X, Y, Z adjustment of the inserted detector position

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IMPORTANT

As with most detectors, if the user has adjusted the position of the BSED then care should be taken to ensure it has sufficient clearance to avoid damage when inserting.

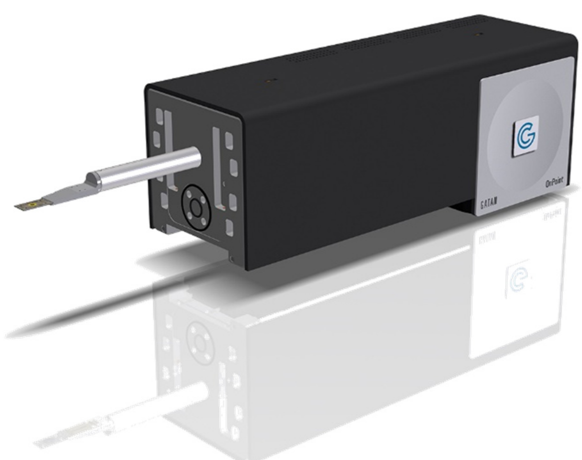


Figure 2: A rendering of the OnPoint detector on a benchtop.

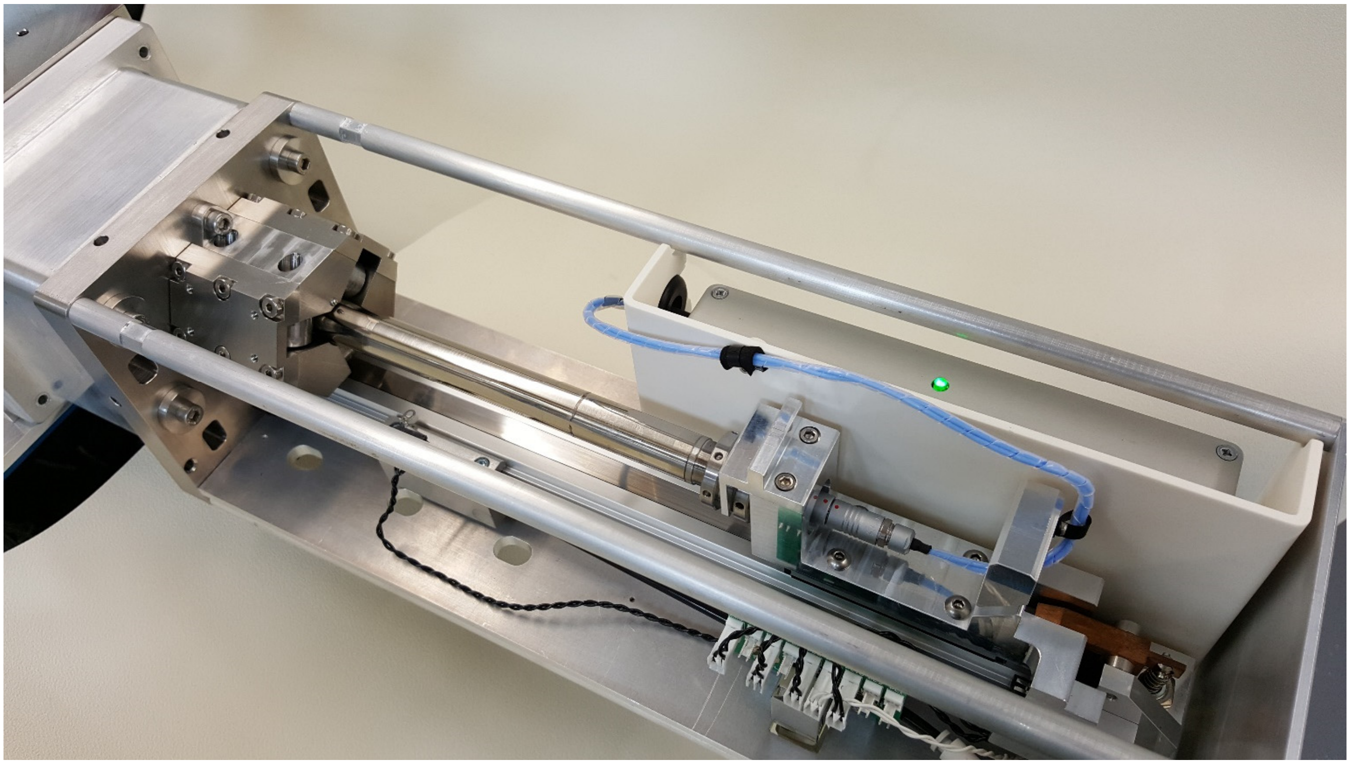


Figure 3: OnPoint detector with the cover removed, showing the retraction mechanism (part A), and the amplifier (part B), and the latch (part C).

The retraction mechanism is held in the fully retracted position using a catching latch (Figure 3: Part C), which is lifted by a solenoid during insertion. If the user wishes to manually insert the detector by an arbitrary amount (for example to gain easier access to the BSED), this is possible using the following procedure:

1. Remove the pneumatic air lines from the underside of the detector
2. Take any force off the latch by pulling back on the sled (Figure 3: Part A)
3. Depress the rear of the latch by hand (Figure 3: Part C)
4. Move the sled to the desired position. Take care if the chamber is under vacuum since the pressure differential can cause the detector to insert slowly

When moving the sled, you may notice some mechanical play between the sled and the sliding rod. This is by design to avoid coupling ambient vibrations to the BSED and is not a fault.

2.2.2 The amplifier

The signal from the BSED is routed through the retraction mechanism and plugs into the amplifier via a Fischer type connector. This transimpedence amplifier (Figure 3: Part B) has been optimized to provide both high gain (~1×10^9) and high speed (~2 MHz) – two features that are generally in conflict during amplifier design. It converts the current generated by the backscattered electrons into a voltage that is read by the DigiScan™ II.

The LED on the amplifier has the following states:

- Green – Unit powered and BSED signal is in range
- Red – Unit powered and BSED signal out of range. This does not indicate a fault
- Blue – Test wave for diagnostic purposes
- Purple – Test wave is on, but the BSED signal is out of range, and this does not indicate a fault

2.3 The OnPoint controller

The OnPoint controller contains electronics to control the amplifier, pneumatics, interlocks, and communication with the Gatan PC running DigitalMicrograph software. The unit is turned on by long-pressing the Gatan logo on the front (Figure 4: Part A), at which point the logo becomes continuously lit. A pulsating logo indicates that the controller is receiving mains power but has not been turned on. The controller must be on before DigitalMicrograph is started, otherwise, communications will not be established.

The internal pneumatics require an air or gas supply of any purity, in the pressure range 4 – 6 bar to function properly. Only a few cubic centimeters of gas are used for each retraction/ insertion – much less than venting an SEM chamber for example.

Figure 4: Front view of the OnPoint controller, showing the position of the ON switch/Gatan logo (part A).

The OnPoint controller provides the following interlocking capabilities:

- One output interlock signal

  This is a normally open (NO) circuit, which closes when fully retracted. This circuit can be used by third-party equipment that occupies the same space as the OnPoint retractable arm and BSED

- Two input interlock signals

  These sense a TTL signal and will only allow the OnPoint to insert on a voltage high (>3.3 V)

These interlocks can be enabled or disabled by a Gatan service engineer, but it is the responsibility of the third party to enable their equipment to work with the interlock signals provided.

2.4 The BSED

The BSED (Figure 5: Part A) is specially developed for demanding applications and consists of a silicon photodiode mounted on a rectangular ceramic substrate. It has a very high quantum efficiency for low energy incident electrons – a low accelerating voltage is often required when viewing surface details on a sample or when performing charge balance microscopy on an insulating specimen.

By default, the BSED is biased with a small DC voltage (typically 3 – 6 V). This alters the characteristics of the internal PN junction, reducing the amount of white noise (high-frequency thermal noise) in the image. This is most noticeable when using short pixel dwell times (<5 µs per pixel). For very long dwell times, the benefit of the bias will be less noticeable.

Switching the bias on and altering the magnitude affects the focus, and when operating at very low kV will

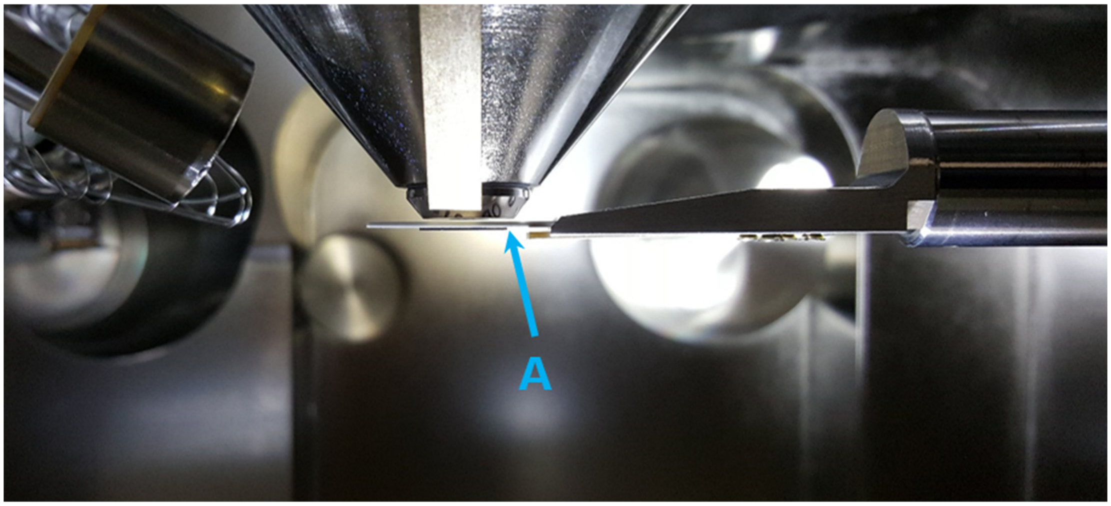


Figure 5: The BSED under the pole-piece, showing the position of the BSED (part A).

impact the working distance reported by the SEM. This is normal behavior which is a result of the altered field below the pole piece.

The BSED is connected to the amplifier electronics via the inside of the retractable arm. The BSED can be removed or replaced simply by sliding it in or out of its housing by hand.

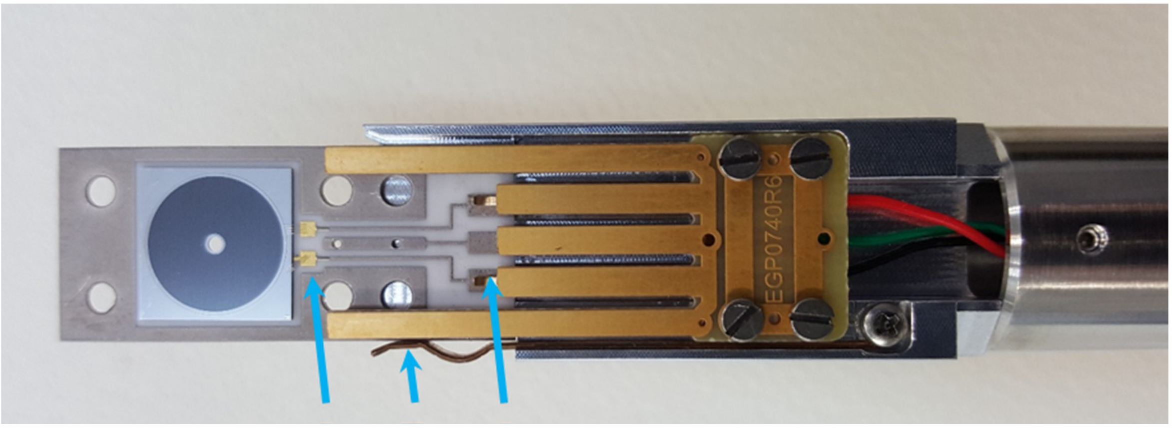


Figure 6: The BSED mounted in its holder at the end of the retractable arm. (A) shows bond wires, (B) shows the locating spring, (C) shows the electrical contacts.

2.4.1 Removing or swapping the BSED

To remove the BSED is just a matter of retracting the detector away from the pole-piece, carefully gripping it by the thin edges, and gently pulling it away from the arm. Avoid any twisting or bending action and avoid touching the active silicon photodiode area.

Putting a BSED back in is the reverse of this process. There are chamfered edges to the slot that the BSED slides into, but still, care should be taken to ensure it is in the right place and properly aligned with the slot before pushing. A weak spring (Figure 6: Part B) ensures the BSED always locates in the same place, so a small amount of force is needed to overcome this.

It is also important to make sure the BSED is fully inserted – the last millimeter of travel encounters some physical resistance from leaf-springs above the electrical contacts (Figure 6: Part C).

After installing the BSED, confirm the aluminum diode holder is not loose. A loose holder is likely to be out of alignment and could cause significant problems if not properly aligned and tightened. Contact Gatan Service for help in establishing alignment. The holder is mounted with an M2 set screw (Figure 6: Part D). It requires a 0.9mm hex wrench and should be tightened to a torque of 17 cNm.

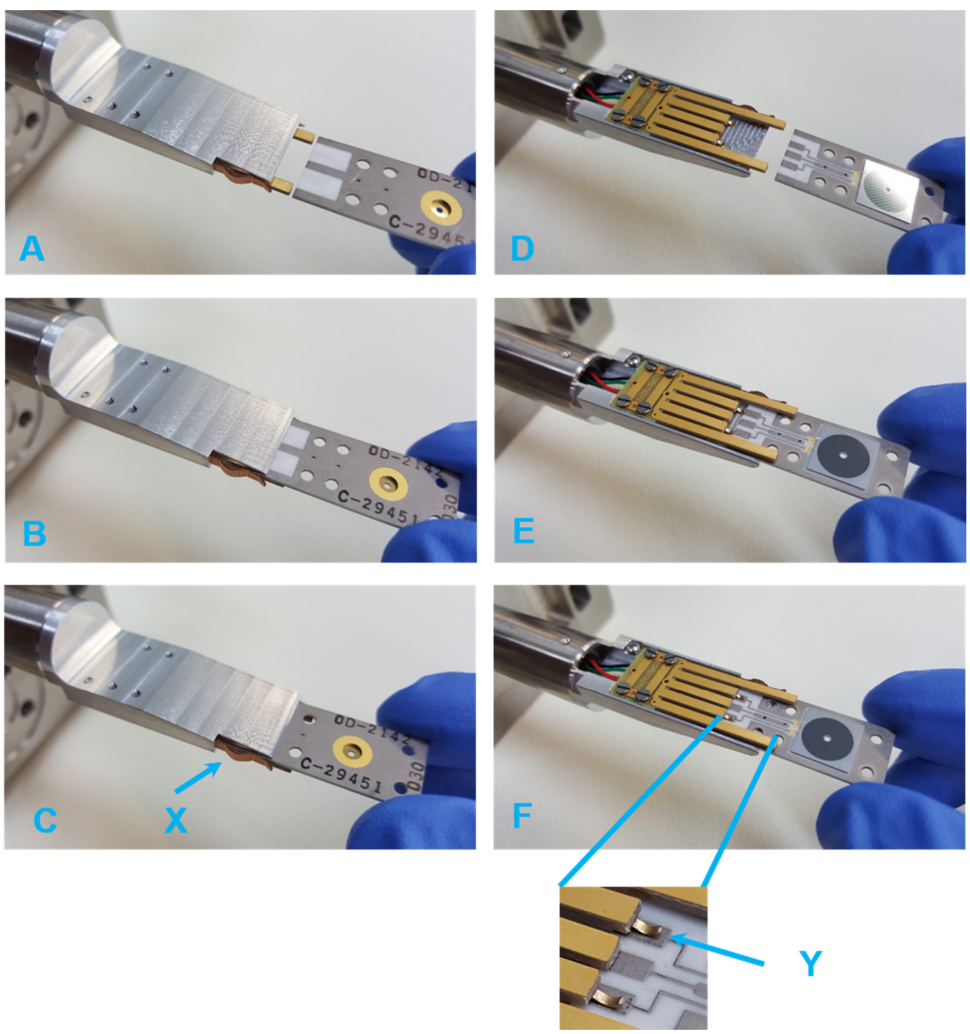


Figure 7: Stages of inserting the BSED. A, B, and C show view from above, D, E, and F show the view from below.

IMPORTANT

The detector substrate is a thin ceramic, which is fragile – take care not to knock or bend it.

Do not touch the silicon photodiode active area – only handle the ceramic substrate.

There are eight fine bond-wires (Figure 6: Part A) that connect to the detector surface - these are easily damaged, e.g., by a hair or loose glove. This will likely cause the detector to stop working.

The BSED is considered a consumable item and is not repaired by Gatan.

OnPoint systems are provided with a spare second BSED. The user can swap these when necessary and minimize downtime if replacing the original.

2.4.2 Practice alignment BSED

Figure 8: Practice alignment BSED part number 400.17060.

A single practice component, part number 400.17060 is also supplied as shown in Figure 8. This is made from aluminum rather than ceramic but is made to the same rectangular dimensions. It is, therefore, useful to help practice the insertion and removal, as well as the physical clearance when inserted. It has a smaller aperture in the same location as the aperture in the real BSED. This practice component can, therefore, be used for the alignment of the detector.

2.4.3 Maintenance of the BSED

The real BSEDs are very fragile components and cannot be treated with the same warranty conditions as the rest of the equipment. Therefore, it is exempt from extended warranties and is considered to be a consumable item.

If the detector exhibits low-frequency noise or banding which is visible under real imaging conditions (e.g., detector inserted, beam irradiating suitable specimen), then the detector may have sample debris or dust on the surface. In this case, the surface of the detector should be gently blown with a dry inert gas (e.g., dry nitrogen). Take care to avoid the use of compressed air containing propellant.

2.4.4 Aligning the BSED

As with any annular detector, it is important to have the BSED aperture in the center of the field of view – this is particularly important when recording a large field of view (FOV) at a small pixel size since the beam shape can become distorted close to the aperture edge. The position of the BSED aperture can be seen when imaging at low magnifications.

IMPORTANT

It is only valid to align the BSED if the SEM column is well aligned. If the SEM column is not well aligned at the current operating conditions, then even a BSED which is perfectly central under the pole-piece may appear off-center in the SEM image.

It is good practice to perform aperture alignment at a high accelerating voltage (e.g., >5 kV), to limit the effect of any SEM column misalignments.

If any adjustment is made to the Z position of the detector, use extreme caution when inserting. It is suggested that the detector be inserted manually first to confirm there are no clashes.

Use the following procedure to align the BSED with respect to the SEM zoom axis:

1. Remove the top cover from the OnPoint detector. This requires the cover thumbscrew to be loosened (Figure 9: Part C), and the cover slid back and up.
2. Make sure the BSED, or practice BSED is installed, and the retractable arm fully inserted into the chamber.
3. Acquire a low magnification image in which you can see the BSED aperture.
4. Eight bolts are holding the detector to the SEM interface flange – loosen the four cap-heads that are accessible (Figure 9: indicated by arrows, E). The other four tamper-proof screws will maintain sufficient contact to avoid breaking the vacuum.
5. To move the detector in the Y-axis, orthogonal to the direction of insertion, slacken both set screws shown as B and the opposite screw to B. Ascertain the direction of movement by tightening one of them while live imaging. Tighten whichever set screw is required whilst ensuring the opposite side is loose slack. Once the position is good, tighten both sides. Once the adjustment is complete, remember to tighten the cap head screws E once more. It is normal to see a slight lateral movement as one side is initially tightened before the other due to compression of the O-ring. To adjust the stopping point of the BSED in the X-axis, turn the wheel on the rear of the retraction arm (Figure 9: Part D).

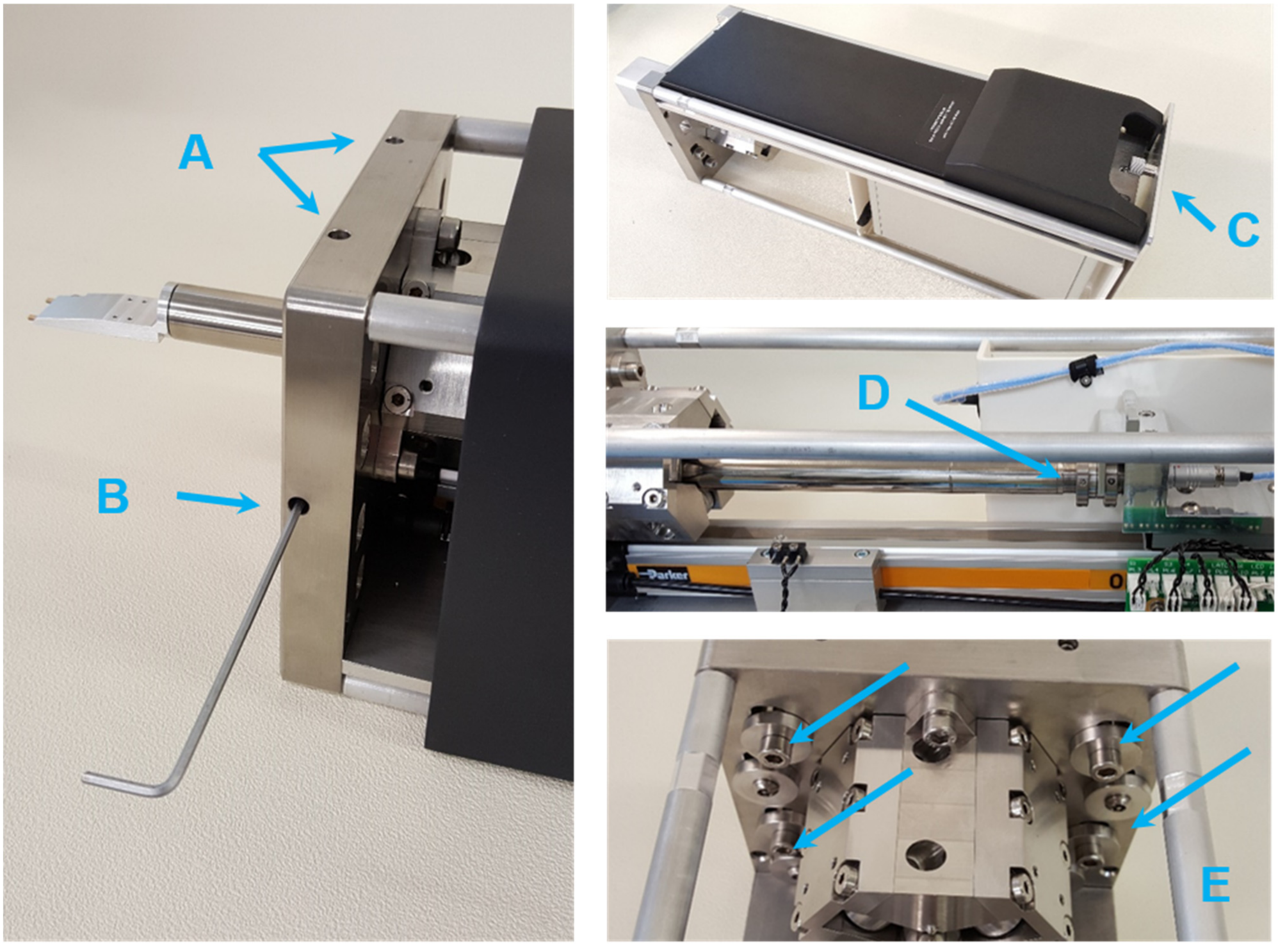


Figure 9: Left – The chamber-end of the OnPoint detector with the top cover slightly pulled back. (A) shows the Z adjust screws, (B) shows the Y adjust screws.

Upper-right - The underside of the OnPoint detector. (C) shows the thumbscrew which releases the top cover (top cover not present in this image).

Center-right – Side view of the OnPoint detector with the top cover removed. (D) shows the X-stop adjustment wheel.

Lower-right – The chamber-end of the OnPoint detector, with the top cover removed. Arrows indicate user-accessible bolts.

2.5 DigiScan III

DigiScan forms the backbone of many analytical tools for scanning transmission electron microscopy (STEM) and SEM applications. In the context of the OnPoint detector, it controls the scanning of the electron beam in the SEM and simultaneously acquires the resulting low noise image. Image bit depth can be 1, 2, or 4 bytes/pixel. A frame size of up to 32k x 24k pixels is supported, with dwell times from 400 ns to 400 ms per pixel.

Figure 10: DigiScan III system.

2.6 OnPoint PC

The PC for the OnPoint detector must be a 64bit windows system with DigitalMicrograph® (DM) software installed as part of Gatan Microscopy Suite® (GMS) 3. Both the Gatan PC and the SEM PC must have one free Ethernet port to establish communication. Communication with OnPoint requires one USB port, whilst communication with DigiScan requires one Ethernet port.

The exact specification will depend on whether the OnPoint detector is being used on its own or with other Gatan products.

3 Software functionality

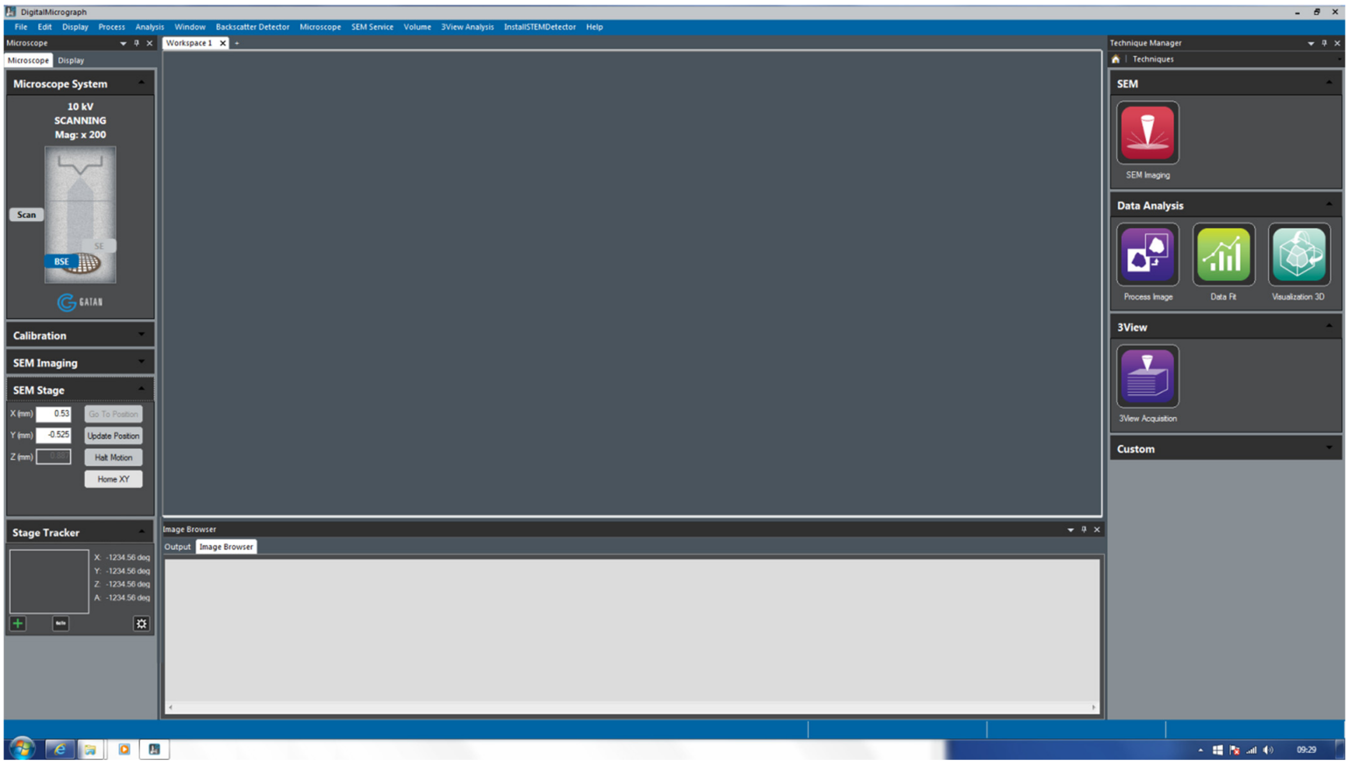


Figure 11: Overview of Gatan's DigitalMicrograph interface in GMS 3.

3.1 OnPoint detector specific hardware control

The OnPoint is designed to be controlled using the DM software running on a dedicated PC.

The following sections explain the controls required for the operation of the OnPoint detector and are listed in the order they are seen in DM’s interface.

All dialogs or windows discussed below can be found through the menu *Window* > *Floating windows*, if they are not already present.

3.1.1 SEM control window

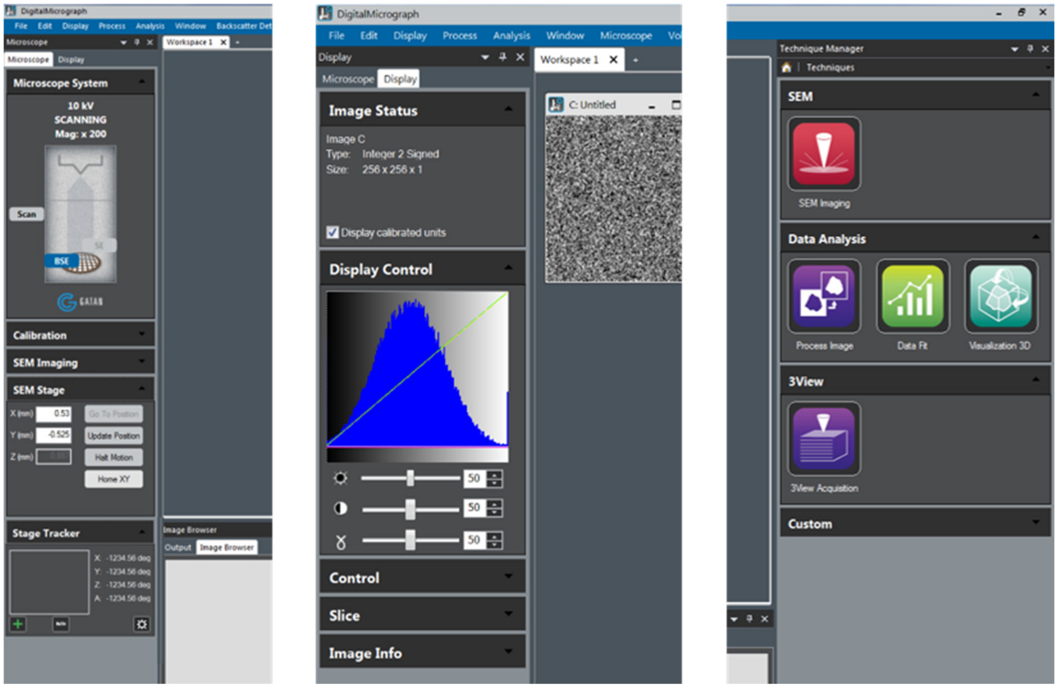


Figure 12: Left – SEM control options. Middle – Image display options. Right – the Technique Manager.

SEM control window

Sub-section	Control	Description
Microscope system	BSE	Right-click on the BSE for options to insert and retract detector, and for additional settings.
	Scan	Clicking this causes the system to start scanning using the default detector.
	SE	Clicking this causes the system to start scanning using the SE detector if present.
SEM stage	X, Y, Z, tilt, rotation	These fields allow the user to specify where the stage should move to. The types of movement allowed will vary depending on which stage the system is connected to.
Stage Tracker	Plus (+)	Clicking the plus button allows the user to record the current stage position, for revisiting later.
	GoTo	Allows the user to directly specify any stage coordinates.

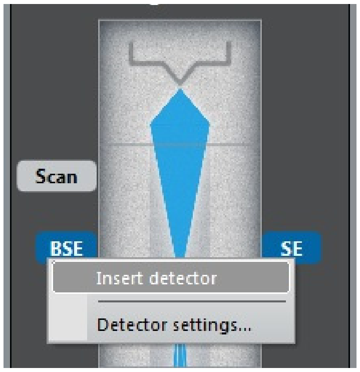


Figure 13: Right-click on BSE button to insert/retract detector or open new BSED settings window.

The boxes on the right can be edited and control the step size for the toggle buttons. In addition to the toggle

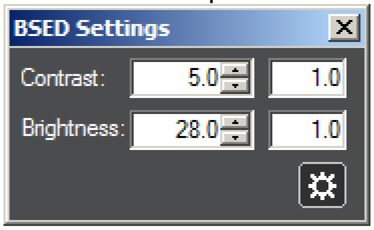


Figure 14: BSED Contrast Brightness settings window.

buttons, if the user places the mouse cursor in the setting window, then the mouse wheel can be used to increase or decrease the value.

Pressing the cogs wheel opens the BSE bias window.

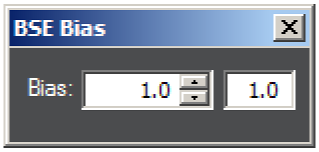


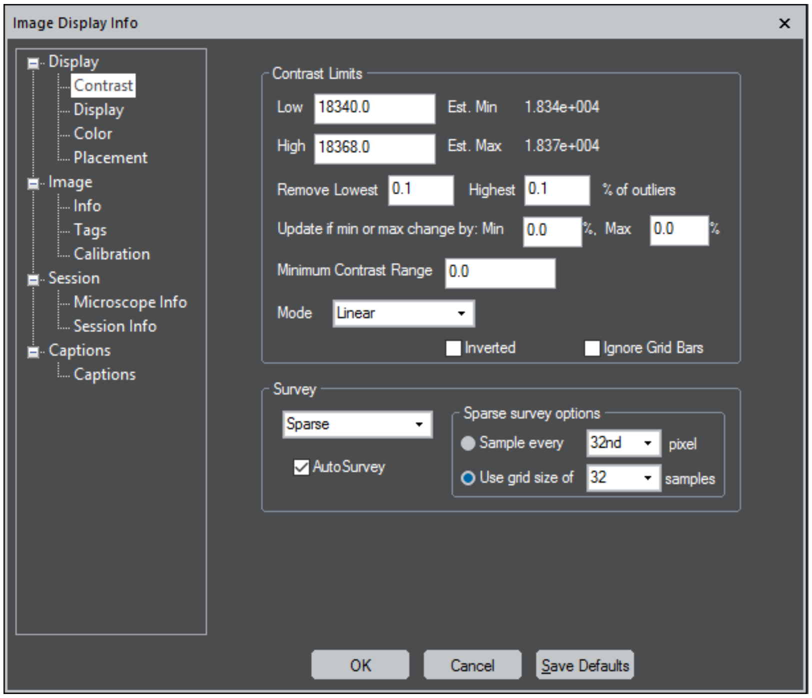
Figure 14: Bias adjustment.

Entering a value of 0 bias turns the bias off. There is no on/off status switch for the diode bias. Users should not normally need to adjust the setting unless attempting to diagnose problems.

Image display options

<table>
<tr><th>Sub-section</th><th>Control</th><th>Description</th></tr>
<tr><td></td><td>
</td><td>The Histogram and display sliders are two useful standard tools within DigitalMicrograph. The histogram shows the proportion of each grey level present in the front-most image window. The green represents the look-up table used for displaying the data.

A useful feature is the ability to reset the dynamic range of the grey levels by dragging a region of interest across the histogram.

Manually selecting the display range in this manner will disable the image AutoSurvey – this can be reinstated by double-clicking the gradient bar under the histogram</td></tr>
<tr><td></td><td>
</td><td>The Image Display Info panel can be invoked by right-clicking on an image and contains a submenu of options to control how the image is shown on-screen. Note that none of these options will change the raw image data.

The most commonly used feature is the AutoSurvey tick box. When turned on, the image pixels are surveyed in the defined manner to calculate the displayed intensity range.

When not active, the display range is controlled from the histogram/display control windows only.</td></tr>
</table>

3.1.2 Technique Manager

Technique Manager

Control	Description
SEM	This button brings up all the DigiScan options related to image acquisition
Data Analysis	Users can perform basic processing on their images, such as filters, convolutions, and alignments
Other	The availability of options in the techniques manager window will depend on whether the OnPoint system is licensed for use with other Gatan products

Image acquisition

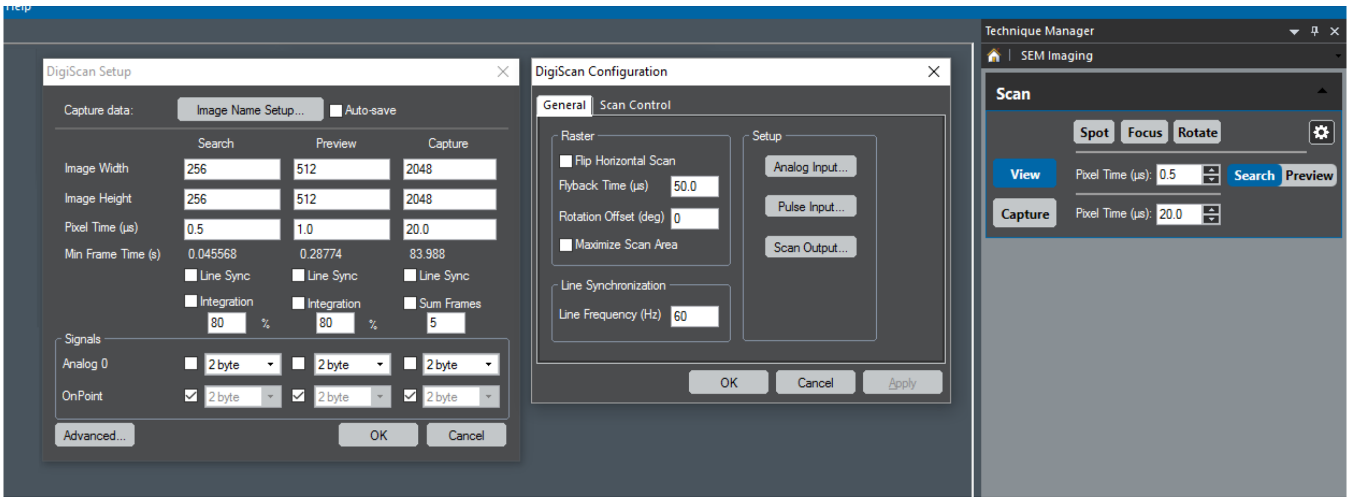
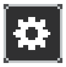


Figure 15: DigiScan control window (right). The tools button allows access to the two advanced configuration windows (middle and right).

DigiScan control window

Control	Description
Search/Preview	This switch toggles the behavior of the View button such that it will initiate either a search or preview image, the parameters of which are found in the DigiScan Setup dialog.
View	Initiates a continuous live image using either the search or preview parameters, depending on the state of the Search/Preview switch.
Capture	This records a single image using the parameters specified in the DigiScan Setup dialog. When the acquisition is complete, this image is moved to a new workspace.

	The tools button opens the DigiScan Setup Dialog shown below for configuring the Search, Preview, and Record Settings.
Line synch	The line sync option can be used if there is noticeable mains interference on your image, in which case the DigiScan will wait until the start of the next mains cycle before starting the line scan. This way, any artifacts caused by mains interference will appear as vertical stripes on the image, rather than an arbitrary angle.
Sum frames	The sum and integrate options can be used to help mitigate the effects of sample charging by reducing localized charge build-up. This is only recommended for conditions where the size of any drift (from sample or beam) is significantly less than a single pixel.

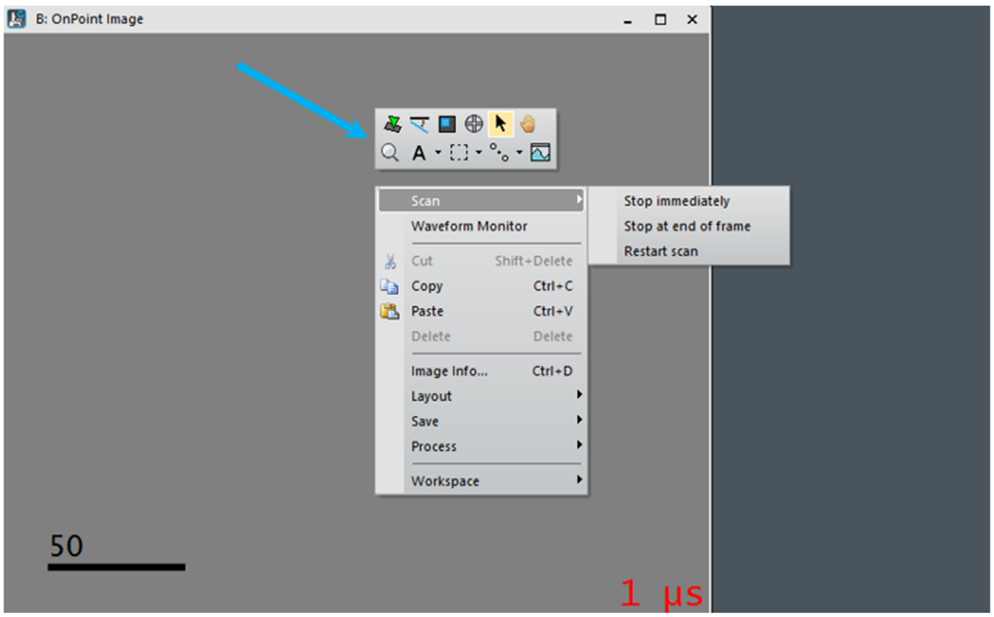
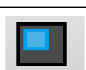


Figure 16: Image context window, indicated by the arrow. Right-clicking on an image will bring up the context menu.

Image context menu

Control	Description
Waveform Monitor	This option activates a red line profile of the signal intensity across the bottom half of the DigiScan image window. This is a useful feature to monitor the incoming signal like an oscilloscope, giving a quick indication of the strength and offset of the BSED signal – which is otherwise hidden by the auto-survey function.
 Click to center	Click on an area of the sample to move it to the center of the image window (the stage moves to position it in the zoom axis of the SEM)
	This tool initiates the focus loupe. Specify a region of interest on your image, and it will begin a fast scan to aid focus or wobbler adjustment

	This tool places the beam in a location defined by crosshairs on the DigiScan image, which can be positioned by the user. Note that leaving the beam in one place can damage the sample over time, particularly resin embedded biological samples.

3.2 Reviewing and post-processing data

Post-processing can be performed using both online and offline PCs. For larger and more numerous images it is beneficial it is to have a large amount of RAM in the Gatan PC. Some data manipulation and rendering tools may be best performed by third-party software, and for this reason, DigitalMicrograph allows the user to export 3D data in a flexible manner.

*Note: When opening files, you need to specify the file type from the drop-down menu (e.g., *.dm4) to see files of that type.*

3.3 Optimizing experimental variables

This topic is much more detailed than can be fully presented herein. This is a brief overview to act as a starting point for those who are less familiar.

The fundamental SEM variables are:

- Accelerating voltage (kV)
- Spot size/probe current: width of the electron beam as it hits the sample
- Chamber gas and pressure or high vacuum conditions
- Focus
- Astigmatism
- SEM Magnification

If the SEM column benefits from a degaussing procedure, remember to do this once the kV and spot size has been fixed.

The relevant OnPoint variables are:

- Contrast (gain)

  This is software controlled and takes effect part way through the signal amplification hardware. This should generally be kept as high as possible without saturating the signal at the DigiScan input (e.g., when viewing the waveform monitor, the red line should remain comfortably within bounds). For applications such as SBFSEM on biological samples (e.g., using 3View) the contrast can be set at 100, exceptions being when there is a very high backscattered signal.

- Brightness (offset)

  This is an offset introduced alongside the signal from the BSED at the start of the signal amplification, to cancel out the small leakage current caused by reverse biasing the BSED. This is adjusted to ensure the signal entering the electronics is in the correct range before amplification.

The common configuration is to have the Contrast set to a maximum AND the brightness adjusted such that the entire signal is in range (see Figure 17: waveform monitor). Only scale back the contrast if the signal is too large. This maximizes the number of bits over which the incoming signal is digitized, preventing unnecessary information loss and slightly improving the signal to noise (SNR)

The main DigiScan variables are:

- X and Y pixel dimensions (For a given magnification this affects the pixel density and hence dose per unit area on the specimen)
- Pixel dwell time

3.3.1 High DigiScan pixel density settings

DigitalMicrograph can be configured for DigiScan to record images with high pixel density, and the OnPoint system is optimized to allow scanning at the maximum scan speed of the DigiScan. For one signal input acquisition, this is 0.5 μs. For a dual signal input, the shorted pixel dwell time is 0.9 μs.

The flyback time is configurable in DigiScan settings and is normally set at installation so that there are no image artifacts on the left-hand side of an image where the scan starts.

A filtered DigiScan cable may be employed to allow DigiScan to drive the SEM at the highest possible pixel densities and fastest scanning speeds. In this case, the flyback time will normally be increased as set up at installation. However, the flyback time which is implemented is limited by internal settings which are a function of the time it takes to perform a single sweep across one image.

A system optimized for fast, high pixel density images using a filtered cable will not allow fast imaging at the lowest pixel density settings without some artifacts. These distortions become evident when using 1uS dwell times and shorter, and pixel densities less than ~500 across. These distortions are not present for larger pixel densities or longer dwell times.

In this case, if a fast acquisition is required for small areas, for example for focusing, then it is better to choose a non-square region of interest, where the X dimension (image width) is longer than the Y dimension (image height).

3.3.2 Autofocus

GMS 3 provides an automatic focus/astigmatism correction function. The pixel density and dwell time for the routine are taken from the DigiScan Preview settings. It is essential that DigiScan Preview settings are configured to give an appropriate scan speed and dwell time otherwise the Autofocus routine may fail, take too much time, or lead to too much dose on the specimen. Only the BSED/OnPoint (second input) should be ticked in Preview. Otherwise, DigiScan will attempt to Autofocus on the wrong signal.

For a system with a filtered DigiScan cable, please ensure that the Preview settings are optimized within the limitations placed by the flyback time and aspect ratio.

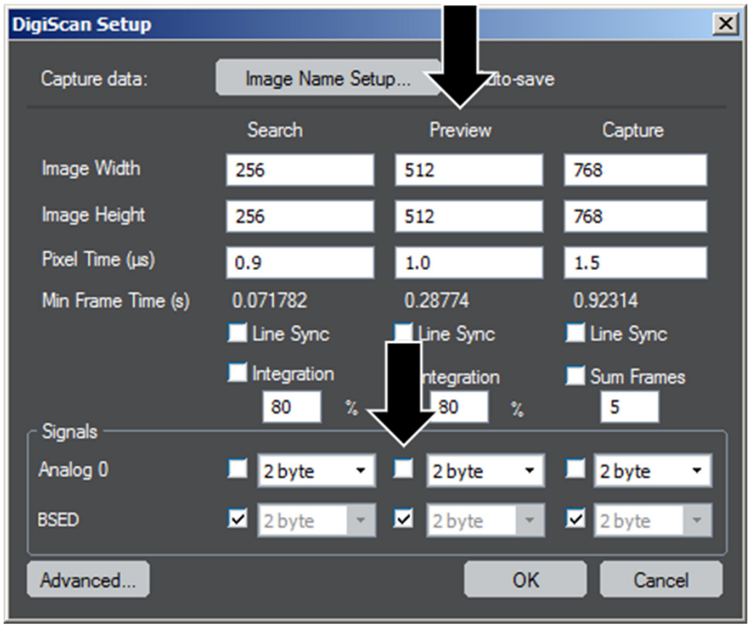


Figure 17: DigiScan Preview settings configure the Autofocus routine.

As is the case when optimizing focus by eye, the image needs to contain sufficient features, and these should have no strong spatial correlation for the astigmatism to be correctly measured.

Users may find it helpful to adjust focus and astigmatism using the live Fast Fourier transform (FFT) option within DigitalMicrograph. To use this, a user normally chooses to image a suitable field of view at a size of 256 x 256 or 512 x 512 (pixels) and observes the live FFT whilst adjusting the focus and astigmatism.

It is worth remembering that the interaction volume of the electrons increases with accelerating voltage, with the effect being stronger for materials of low atomic mass. This means that low beam energies are required to study features on the surface of a sample, avoiding the information being mixed with that from below the surface.

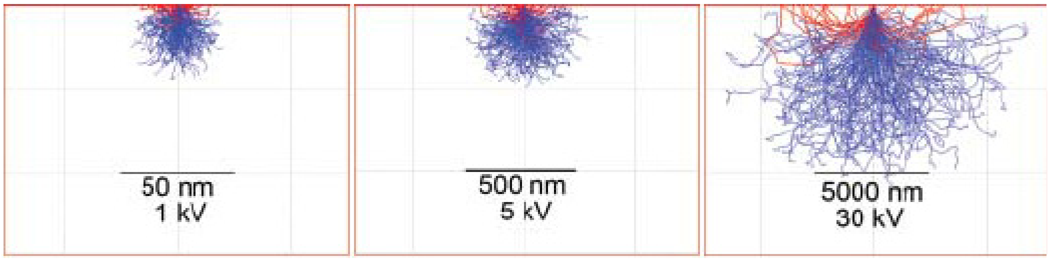


Figure 18: Example interaction volume for electrons entering a low-Z material.

4 Consumables and options

Gatan provides a list of consumables with the standard system. Please contact Gatan or your distributor for more information

Gatan part number	Description
400.SNSR.1	Replacement OnPoint BSED