The Electron Gun its Saturation and Alignment—An Old Man's Saga

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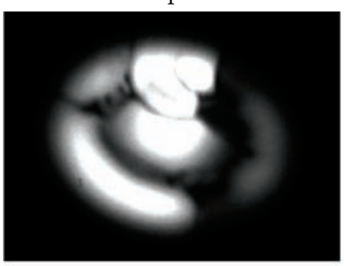
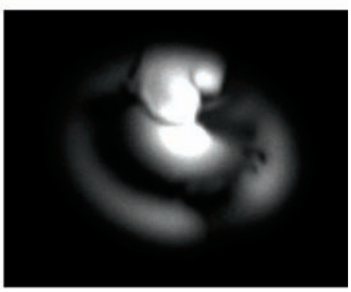
It was in October of 1964 when I first used a TEM, it was at the Siemens training school run by their agent Aeon Laboratories. A service engineer (we didn't call them technicians in those days), Robin Willis ran the course, five days for just alignment and cleaning! Robin, by the way, moved to University College London, Anatomy department and became the first person to publish on the tilting of biological samples. He actually invented tomography without knowing it! He used a fish tank within which he hung the negatives of his +60 to -60 tilt series. This procedure created a three dimensional image of the thin section, again I would guess, for the first time.

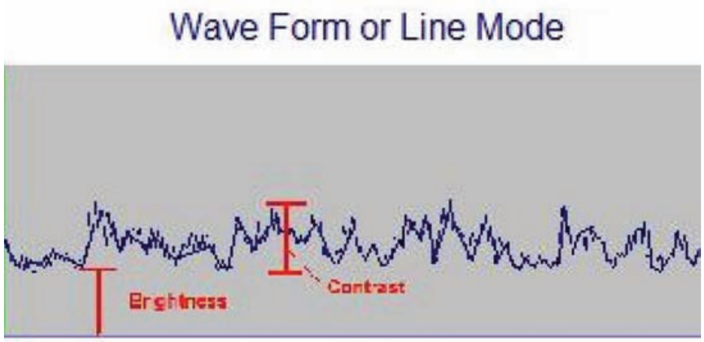
So how did we set about aligning a TEM in 1964? The procedure was to adjust the second condenser (brightness) to cross over when the image of the virtual source would be displayed. Heating the filament the operator could then see the spot and halo (known as a fried egg by some), balance the intensity in opposite quadrants with gun tilt (mechanical in those days), and centre the image with the gun alignment shift. Once aligned the operator would then heat the filament until the source formed a solid spot. This technique I would consider was the absolute standard method for the alignment and saturation of a gun up to the present day.

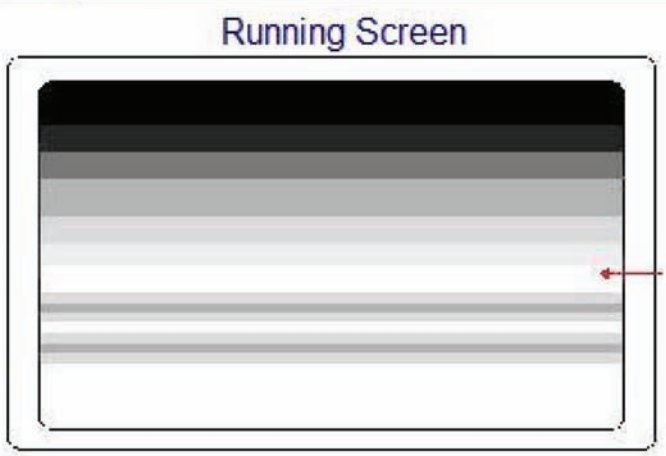
Through my career I did pick up other methods, for example heating the filament until the beam current meter (emission current) stopped rising, then watching the screen to find maximum brightness with the gun alignment controls. Not such a good method as the point where the meter stopped rising was open to a high degree of error and blown filaments!

Moving on to SEM in the early 1970s I had to learn other alignment and saturation techniques. At that time the most popular procedure was to use the waveform, graph or line scan mode to visualise the point of maximum signal, at first saturation and then the gun alignments were adjusted. Some used a medium speed running scan, watching for the change in intensity to judge the saturation plateau and then the alignment. Then, as beam deflection coils were introduced into gun alignment, we suddenly had the option on the SEM of visualizing the virtual source again. Using almost the same techniques as for TEM, the gun could be aligned and saturated. However, this brought up an interesting series of points. Firstly, the maximum signal from a waveform set up was higher than from a virtual source set up. Secondly the best alignment from a waveform set up was not that which set the virtual source in the centre of the screen; why? I judged that a "perfect" alignment had to be achieved by collecting information from the specimen level under normal operating conditions. The virtual source alignments in a SEM do not use the instrument under normal operating conditions, in this case the gun coils are used to scan the beam thus forming the source image. Therefore, what we see is that alignment techniques that do not use normal operating conditions have a different centre. When you consider the way the instrument operates, switching lenses or deflection coils away from their normal mode, the alignments will change. Perform the simple test of changing scan speed and watch the image movement, even under normal operating conditions the alignment changes?









Even later in my career I started using a Faraday Cup to judge saturation. In this case, the beam is placed into a "black hole" and the current lost within the hole is metered. This technique is by far the best as the operator looks at numbers (nA), setting the saturation and alignment for the highest number. This is the best technique because we are all able to read numbers, when there are many differing judgements when screen brightness or wave form traces are being judged.

Now we move back to the TEM. On a recent course in Australia a regular attendant asked why we did not use the screen brightness meter to judge "Total Alignment" on a TEM. In this situation the TEM screen is used as our monitor in a similar way

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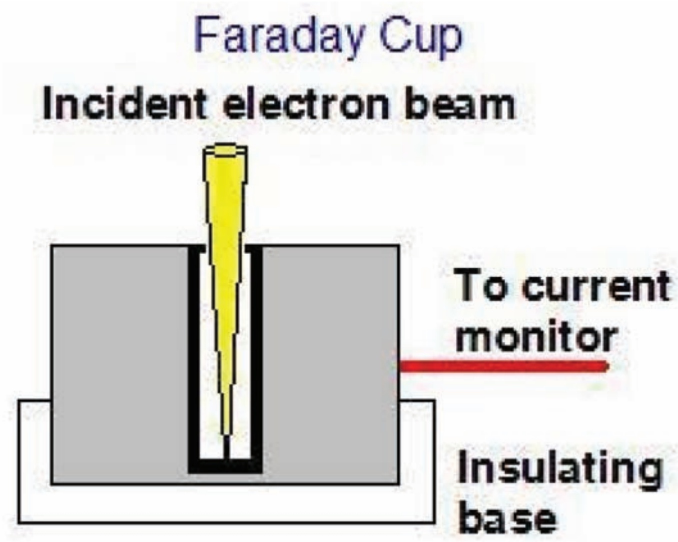
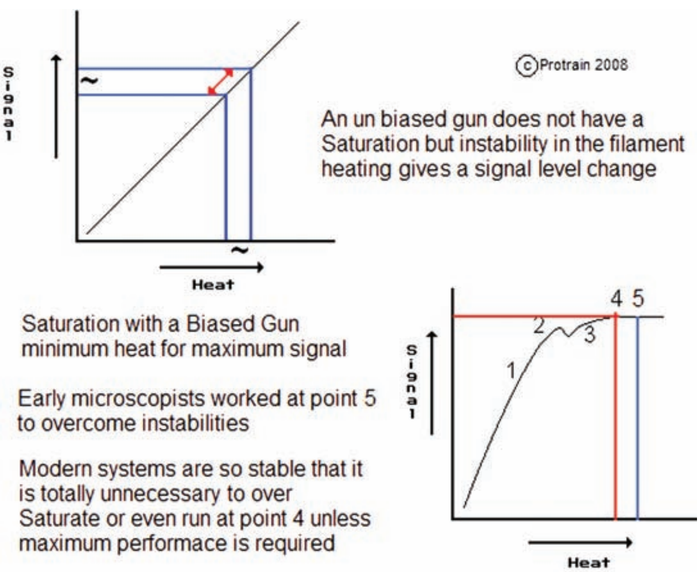
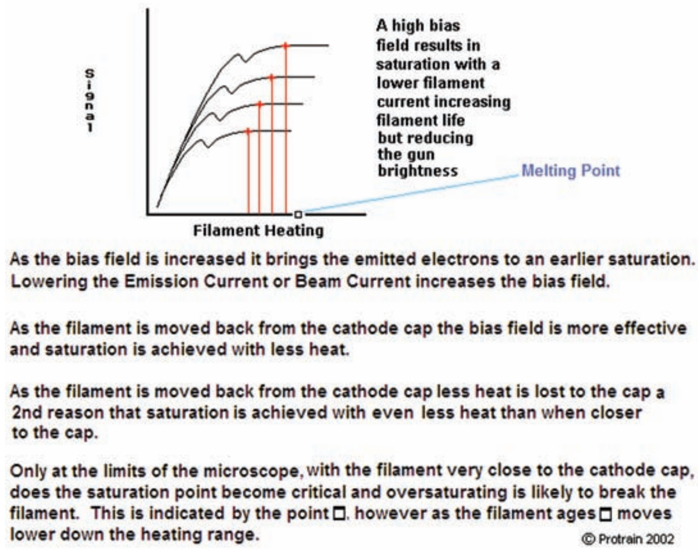


that the Faraday Cup operates. Since the early 1970s all TEM have had an exposure meter which is usually sensing either a separate screen or the main screen's current flow to earth. So the "new" technique, for ever known as the "Naomi Technique," simply measures the intensity of the virtual source whilst saturation and alignment take place. One caution is to use a smaller condenser aperture than normal as you may well saturate the metering system even before the gun saturation is reached. Now that we have a perfect alignment procedure we are able to criticize what we have all, thousands of us, have been doing for the past 50 years! Once the Naomi technique has been performed going back to the source and de saturating we notice that the spot and halo are not in balance; interesting? Is the most important procedure the visual procedure or the screen sensing procedure; I go for the latter!

But let us discuss more about saturation of the gun and a feature that became essential for illumination stability. When electron optics was a new technique, there was an advance that made the instruments what they are today—the bias system. Before the bias system was introduced, there was not such a thing as saturation. The filament was heated to a temperature that gave



sufficient illumination for the task in hand but the images suffered from constant brightness change due to filament instability. The invention of a biased gun overcame this problem because under this regime the gun could be saturated. The bias circuit produced an electrical field that throttled down the cathode aperture. Once the aperture was full of electrons, no matter how much additional heat was applied to the filament, the signal level remained the same. Control of the bias level gave the operator the opportunity to adjust the point of saturation to the level of emission current desired for a particular project, but using point 5 on the plateau. Today the filament heating system is so stable that only at maximum performance is it worth while running on the plateau of the filament heating procedure.



For those who want more from their microscope, longer filament life or higher performance, the answer also lies in the gun set up. Moving the filament back from the cathode aperture effectively increases the bias field, which results in saturation being reached with a lower level of filament heating. The increase in filament life in this case is partly due to less tungsten evaporation taking place at these lower heat levels. Another advantage for the less experienced operator is that saturation for most of the filament's life will occur well away from the filaments melting point. Only near the end of the filament's life will saturation be near or at the melting point. The down side of this technique is a lower imaging intensity, which will most likely result in the operator working with poor beam coherence, thus slightly softer images may be produced.

High performance is most easily achieved by using smaller spot sizes in the condenser system and using a high degree of illumination over focus to improve coherence; unfortunately this technique requires a high emission current. If the higher emission current is achieved by backing off the bias field this produces a large virtual source which will be to the detriment of image quality. The perfect solution is to produce a high level of emission, filament forward, but with a high bias field which together will provide a better virtual source; more electrons in a smaller area.

The heart of any electron microscope is the electron gun, optimise it for your work no matter what is your application and you will be rewarded. ■