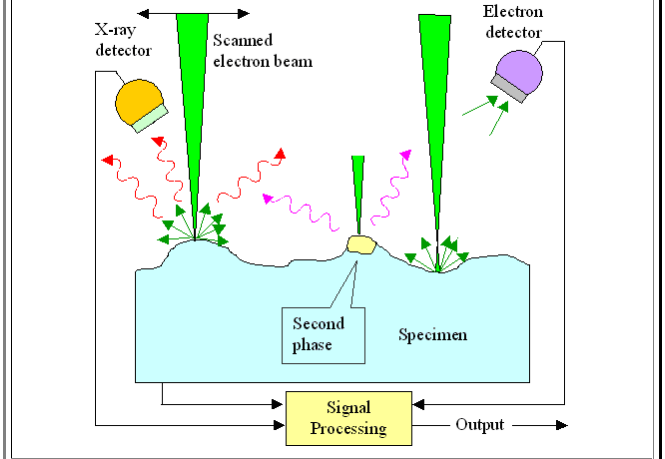
Science

2. Scanning Electron Microscope

- Scanning electron microscopes are simplicity itself - as long as you do it on paper. In reality a lot of involved components are needed that will not come all that cheap.
  - Here is a schematic drawing of the **basic principle**:



Principle of a scanning electron microscope (SEM)

- Let's go through what you need and how its done step by step.
  - First you need a high-intensity well-focussed *electron beam* with a (preferably adjustable) energy of a few 100 eV to 20 keV. Electron beams are not difficult to make as billions of old-fashioned TV picture tubes testify. However, it you want the beam to be focussed to a small "point", in the extreme less than a nanometer in diameter, things get more complex and far more expensive.
    The big catch, however, is that you can only work with electron beams in vacuum.
  - So electron beam, specimen, detectors and so on now go into a *vacuum vessel* with some load-lock to get specimens in and out. That never comes cheap and makes the SEM somewhat bulky.
  - Now you need a *specimen stage* on which you can place your specimen. You must be able to move that stage in all three directions (*x*, *y*, *z*) with considerable precision, and you want to tilt and / or rotate your specimen, too. That requires a complex piece of precision mechanics with remote controls for all those movements.
    If you want to extract a signal right from your specimen, for example some induced current, the stage must have implements for that.
  - After you positioned your specimen under the zero position of the electron beam, you now start to *scan the beam* across the specimen. That requires some magnetic or electrostatic "lenses" that can induce the electron beam to move in the required direction.
    You want to select in detail how that is done. The "magnification", after all, is directly given by the area you scan.
  - When an electron beam hits material, it will become absorbed within a few µm of the specimen. The energy deposited into that small specimen volume does a lot of "damage", leading to the emission of electrons and X-rays from the afflicted spot. That's what you *detect*.
    At the very minimum, every SEM has a "secondary" electron detector somewhere inside. Some of the electrons emitted from a pixel when it is hit by the passing electron beam will make it to this detector. How many electrons will be recorded depends on the particulars of the pixel, including its surface orientation relative to the detector. The image processor than adjusts the brightness on the screen for that pixel accordingly.
    There is no a depth-of -focus problem as in light microscopes at high magnifications, because the width of the beam hardly changes on wavy surfaces, as indicated in the figure above. That's why you get these three-dimensional looking pictures.
    Here is an example from science, and below is a SEM picture of that thing that is just now crawling up your leg.

A tiny little worm living way down in the ocean (Thank God)

Source: Philippe Crassous / FEI Company (www.fei.com)

- Many SEM's have more than one detector. Detecting the X-rays released *and* their energy is particular prominent because the energy indicates *directly* from which chemical element the signal was produced. Your SEM is now an *analytical tool* that gives you information about the local chemical composition of your sample. This is called **energy-dispersive X-ray spectroscopy** and abbreviated ***EDS*** or ***EDX***.
  Here is an example of what one can do with this.

Here is a picture of the SEM we use. It is a rather good one but not the very best. About half a million Euro will buy one.

. **Modern SEM from Carl Zeiss Corporation**

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