PSD v CCD

If you are facing the problem of finding the position of a lightspot on a detector surface there are essentially two ways to go: either you look at the whole picture and try to sort out what is a lightspot and where it is (the same procedure you use to find a needle in a haystack), or you use a device that only picks up light-spot positions and discards all other information (like using a magnet for finding the needle). The first approach describes the operation of a Charge Coupled Device (CCD) and the second a Position Sensing Detector (PSD).

Position Sensing Detectors (PSDs) and Charge Coupled Devices (CCDs) are really two different breeds of cat. Both have the ability to detect light but they do it in quite different ways. The PSD gives an output that is a function of the center of gravity of the total light quantity distribution on the active area. The CCD on the other hand detects the peak value of the light quantity distribution over the active area for each pixel and the values are put out sequentially.

The eternal question: Analog or Digital?
PSDs are purely analog devices and rely on a current generated by a photodiode divided in one or two resistive layers. This simple design gives the advantages of stabili-ty and reliability. The electronics needed for signal processing of the analog output are quite simple and can be imple-mented at low cost.

A CCD is basically an array of closely spaced MOS diodes. The light is recorded as an electric charge in each diode. Under the application of a proper sequence of clock voltage pulses the accumulated charges can be transferred in a controlled manner across the semiconductor surface to the output of the device. The much more complicated structure makes CCDs harder to manufacture and more prone to failures. The CCD gives a digital output.

Unsurpassed speed and resolution.
PSDs will measure the position of the centre of gravity of a light spot. That's about the only thing it can do, but it does it within nanoseconds with sub-nanometer resolution. Accuracy of about 0.1% is achievable and the dynamic light-range is over several decades. Using stored reference points as a look-up table can enhance this accuracy of the PSD by several decades. Usually the optical components used along with the sensor will add distortion, which can be incorporated into the look-up table and thus minimised.

As the PSD provides the position sensing in-formation through the diodes' photo response the device can be trea-ted as a normal large area photodiode using standard methods for signal processing such as using modulated light to avoid inter-ference from stray light.

A PSD can be manufactured to have any shape. Some odd examples are the helix, circular and spherical PSDs used for 2-D and 3-D angular measurements. For some appli-cations (for example surface inspection equipment) arrays of PSDs have been designed.

Taking the whole picture.

The CCD output contains information on the light quantity distribution all over the active area and thus describes a picture. A CCD is, for example, the normal choice for the picture-catching element in video cameras.

The CCD cannot measure the centre of gravity of a light spot without additional digital signal processing and thus this type of measurement will not be as readily available as it is in the PSD. Sampling and digitally processing all the pixels will add some time and make the CCD much slower than the PSD. On the other hand, all the pixels have a mask defined position so accuracy can be very high. However, in order to reach maximum accuracy and the highest resolution, interpolation between neighbouring pixels must take place. This further slows down the process. For light spots smaller than the distance between two adjacent pixels, interpolation is not possible and the signal is lost. This sets a lower limit for the spot size that can be used.

The dynamic range of a CCD is limited and sudden shift in light intensity can give rise to blooming. This can be overcome by using the CCD sibling: the CMOS arrays. These newly introduced devices overcome many of the CCDs weaknesses when it comes to dynamic range. An advantage of the CCD is that, like the human eye, it can store light received until there is time to measure it. This feature can come in handy when measuring minute light quantities.

Applications:

As can be seen from the above, the most straightforward and fastest way to measure the position of the centroid of a light spot is to use a PSD. In many applications this is exactly what is done. Examples are alignment systems where the position of a reference laser beam relative to the PSD is measured. Such systems are used for alignment of everything from bridges to optical systems. As PSDs can be made to operate at very low temperatures (liquid nitrogen), this alignment method has also been applied to infrared optics where the infrared radiation from the PSD must be kept to a minimum.

A weakness is that the PSD cannot differentiate between a direct beam and a reflected beam. It will just output the resulting centre of gravity from the two spots. Using a CCD in this application offers the possibility of differentiating between direct hits and reflections by evaluating the signal strength in the light spots. Of course this will add to the complexity of the system and further slow it down.

"King of Triangulation"

PSDs are widely used in displacement sensor systems using triangulation. Such a system can be made at a low cost using rather simple electronics. The downside is - unfortunately - that the condition of the surface being measured may cause considerable variations in measurement values. The texture of the surface, for example, may distort the shape of the light spot used for measurements. This will shift the centre of gravity of the light spot thus fooling the PSD. The CCD on the other hand detects the peak value and identifies this as the target position - uniformly and accurately.

Another problem is that dark surfaces, for example black rubber, have low reflectivity and a normal PSD may, unlike a CCD, encounter a low signal. To remedy this SiTek has developed a new family of sensitivity-enhanced PSDs. These devices are position-sensing phototransistors in contrast to the standard PSD which is based upon a photodiode. The phototransistor PSD shows an enhanced light sensitivity currently giving at least five times more photocurrent for the same light input. Light sensitivity is expected to increase further, in the near future, as the fabrication processes are perfected.

Using sophisticated signal processing such as optical filtering and synchronous detection together with a PSD may solve some "impossible" measurement tasks such as measuring the displacement of molten red hot iron or taking measurements inside the arc of a welding torch.

An area where the PSD will shine is where some sort of displacement needs to be monitored without contacting or loading the member moving. Examples are non-contact explosion-proof fuel level measurements, movement of membranes in microphones, loudspeakers and pressure-sensors or optical fibres moving in wind sensors or accelerometers. Here sub-nanometer resolution could be obtained using very simple analog circuitry.