ANDOR
an Oxford Instruments company

Indirect Detection

Understand indirect detection CCDs

With energies of >~22 keV, the CCD is no longer able to directly detect the incident photons. This means a transducer needs to be introduced into the system to convert the incident photons to photons, which are again visible to the detector.

'Two Step' Detection
Thge first step in this 'two step' detection is a material, commonly a scintillator, to convert the incident X-ray's photons into visible wavelength photons, which can then be directly detected by the CCD in the second step. These 'converter' materials comprise of an extensive range of options of both phosphors and scintillators, selection depends on the specific requirement for detection, for example energy range, spatial resolution etc.

As is shown in the sensor range diagram, this method of detection is the only option once the energies of X-ray photons (>20 keV) are to be detected as the CCD is no longer able to absorb the photons within the depletion zone. The requirement to convert the incident photon has some key disadvantages, primarily the actual conversion process is very inefficient. Also, as the incident photon is no longer directly detected there is no longer the ability to correlate the number of electrons to the incident energies. There has been a series of evolutions of design and in the components, which has improved the detection of signal.

Methods of **Indirect Detection**

Phosphor
The sensor is coated with a phosphor, for example Gadolinium Oxysulphide (Gd2O2S:Tb) often referred to as GADOX, also known as P43. This phosphor absorbs X-ray photons and emits visible photons predominately at 545 nm (2.28 eV), and has approximately a 15% conversion efficiency, i.e. 15% of the absorbed X-ray photon energy is converted into visible photons. However, only a fraction of these generated photons will reach the detector as they are emitted in all directions. This illustrates the inefficency of the conversion process with both signal and spatial resolution, as the secondary emission will effectively spread from the generation point. Increasing the depth of the scintillator, or phosphor, relates to the energy range that it will be able to absorb and convert, however the thicker it becomes, there is an equivalent reduction in the spatial resolution, so again a balance must be found.

Fiber Faceplate and Scintillator/Phosphor
The next development was to place fiber-optic, coated or bonded to a scintillator. This effectively acts to maintain spatial resolution as it channels the light via the individual fibers onto the sensor, reducing the spread of the light from the generation point. The introduction of the fiber-optic has other important advantages, the fiber can be extruded to form a taper, this increases the area that can be imaged, albeit with a demagnification of the image. It can also offer protection to the sensor from the harder X-rays, which are in themselves damaging to the silicon structure of the CCD.

Lens Based Systems
There has been a growing interest in the use of lens-based camera systems to image scintillator screens. The method is popular as the active area of the scintillator can be very large, 50 cm2 and larger. With the camera protected from the direct path of the damaging hard X-ray, even neutron and gamma sources can be used in this method. From a camera position this is also a simpler and easier method as there is no need to modify or change the standard camera which allows for a quick and easy replacement or upgrade.

Each of these versions have their associated adavantages and disadvantages, however some simple rules can be applied:-

- The more components in the optical path the less the transmission
- Higher Spatial resolution requires the light to be channelled or focussed
- If imaging greater than 5x sensor area a lens system is required
- If the distance from scintillator >10's cm, a lens is required

There are further variations on these basic types of indirect detection. At Andor we have cameras in all versions and we use a dedicated team to design and build these bespoke systems. The design process looks at the requirements and matches the variety of components options, such as fiber and scintillator, to produce a final quality Andor product. Contact your local sales representative. For details of our CSR (Customer Special Request) process, see page 20 where we can deliver an Andor quality camera for your specific requirement.