e2v technologies

TECHNICAL NOTE ON FIBRE-OPTIC ARRAY COUPLING TO CHARGE COUPLED DEVICES

INTRODUCTION

There are two basic methods of coupling the light output from a phosphor onto a CCD:

1. A lens may be used, but this is often mechanically difficult to configure and has very low coupling efficiency (i.e. very little of the light emitted from the phosphor actually arrives at the CCD) unless a lens of very large aperture is used.
2. A fibre-optic array coupler may be used that can have the CCD attached to one end and the phosphor on the other. This generally gives improved coupling efficiency and is mechanically more robust, however considerable care is required in the coupling process to ensure that a reliable joint is obtained.

FIBRE-OPTIC ARRAYS

The fibre-optic array consists of 3 components (see figure) that are fused together to form a solid block: the core glass down which the required signal is transmitted, the cladding glass and the extra-mural absorber (ema). The exact mechanical arrangement within the fibre optic arrays will vary for different manufacturers.

The core glass consists of rods with a diameter typically in the range 4 to 12 µm with a refractive index of approximately 1.8. This is the glass down which the required signal is transmitted. These rods are usually hexagonal or square in cross section.

The cladding glass surrounds the core glass and has a refractive index of approximately 1.5. Hence, by Snell's law, any light within the core glass that strikes the interface between the core and cladding at an angle up to approximately 34° to the boundary (90 - arcsine (1.5/1.8)) will undergo total internal reflection. This means that most of the light incident on the core glass (at the top of the array) over the full 180° range of possible angles of incidence will be transmitted through the core as the maximum angle of refraction is that from light of grazing incidence which has a value arcsine (1/1.8) = 34°, i.e. the maximum angle for internal reflection. The numerical aperture (NA) is therefore 1.

The cladding glass is transparent and so light that enters the top of the array into the cladding glass would pass down through the fibre-optic array in an uncontrolled manner and emerge from the bottom in a position uncorrelated with its entry point. To avoid this unwanted transmission an absorbing dark glass (ema) is added in the cladding glass, with the position varying between manufacturers.

As only light that is incident on the core glass is transmitted through the fibre-optic array the transmission is less than 100%. Typical values achieved are in the range 40 to 75%.

Because the ema is only a very small percentage of the total glass used there is always some transmission of unwanted light and this will lead to a reduction in MTF (modulation transfer function).

FIBRE-OPTIC TAPERS

Fibre-optic arrays are made as straight bundles with unity magnification. After they have been made they can then be drawn out into tapers to give demagnification or magnification as required. Fibre-optic tapers are typically made with a magnification of up to 5:1. They are generally used as demagnifiers when coupling onto CCDs. If used as a demagnifier the taper has a transmission for a lambertian light source given by approximately:

$$T_X = \frac{A_O}{A_i} \times K$$

Where T_x is the transmission in photons in at the input to photons emitted

A_o is the output area of the optic

A_i is the input area of the optic

K is the open area ratio

Thus for example a 3:1 demagnifying fibre-optic taper with a 60% open area ratio will have approximately 7% transmission. This compares to less than 1% for an equivalent lens system.

The loss of transmission is due to the fact that the bending of the fibres causes some of the light at larger angles of incidence to break through into the cladding glass; this means that the NA is reduced below 1. Illuminating a taper with collimated light will result in much less loss of signal.

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COUPLING TO CCDs

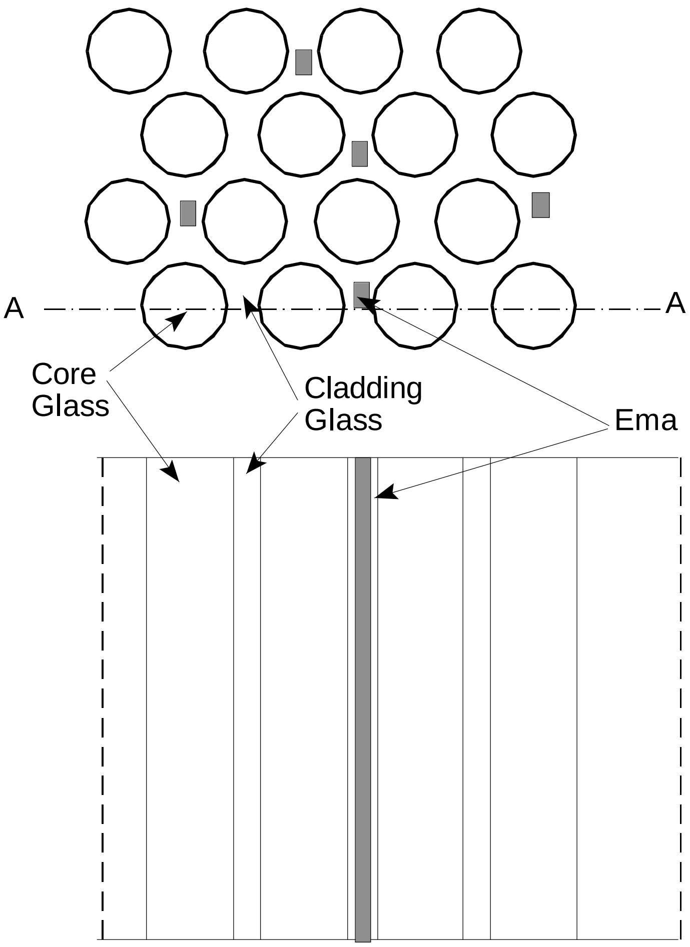
When coupling a fibre-optic array to a CCD there are many factors that are potential sources of problems:

The expansion coefficients of the CCD and fibre-optic array are considerably different which will cause the joint to be stressed as the assembly is heated or cooled. This means that it is important to minimise the stress in the joint at the temperature extremes to which the device will be subjected.

Coupling a glass surface onto a CCD is obviously a potential source of mechanical damage and considerable care and experience is required.

The thickness of the glue line must be well controlled in order to give a reliable joint whilst minimising the spreading of light within the glue joint. This requirement to control the thickness of the glue layer also means that it is important to control the flatness of both the fibre-optic and CCD.

e2v technologies has expended considerable time and resources in the investigation of different adhesives and bonding techniques and consequently the details of these are confidential. Proof of the quality of the bond has been carried out by temperature cycling and other environmental tests. Because of the complex nature of the joint between the fibre optic and CCD, e2v technologies recommends that requirements should always be discussed with e2v technologies representatives.



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