

## Clear and Useful Aperture

Calculating the useful aperture of optical components

The clear aperture (CA) of a substrate is a key component of any optical specification. It specifies the area of the substrate surface over which the surface specifications are met.

The CA is usually represented as a percentage of the overall surface area. For example, for a substrate with 100mm diameter and 90% clear aperture, the clear aperture is a 90mm diameter central area.

Knowing the clear aperture of your substrate is essential when thinking of an optical design. If you were using a 5mm diameter beam and an optic with clear aperture of only 4mm, you would most likely not get good results.

If the beam you are using is going to be incident at  $0^\circ$ , it is easy to compare the beam diameter and the clear aperture and decide on a specification for the substrate. However, if a beam is incident on the optical component under an angle, as is often the case, a calculation has to be undertaken to ensure that beam diameter and optical components are compatible.

When a light beam passes through a substrate at a non-zero angle, it will come out at a different point along the diameter of the substrate (beam deviation), which will depend on the angle of incidence, the thickness of the substrate, and its refractive index. This may or may not be within the given clear aperture. If it is not within it, then the optic might not meet the required specification, and it will not function as intended.

The figure below clearly shows that when the substrate is used at an angle, the “useful” aperture is smaller than that of the same substrate used at  $0^\circ$ .

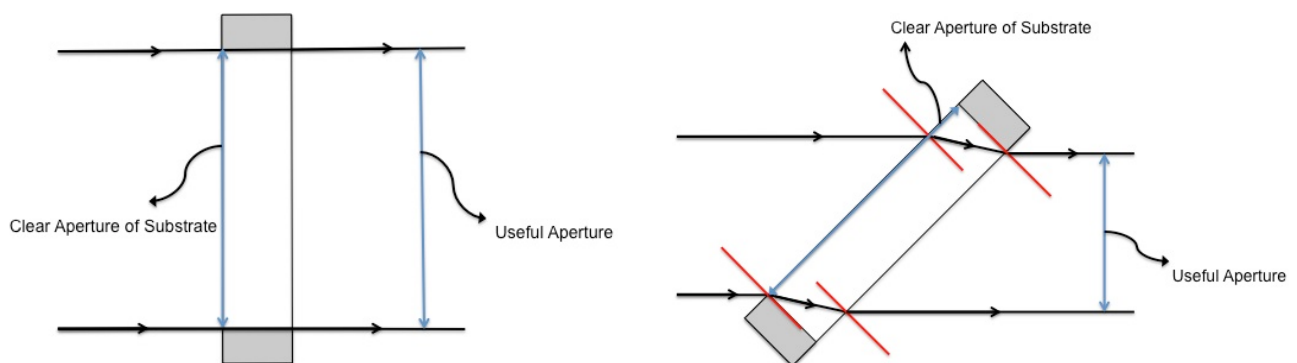


Figure: Diagram of light path through a substrate at  $0^\circ$ , and at  $45^\circ$ .

This needs to be taken into account when specifying optical components. The equation below calculates the useful aperture of the substrate :

$$UA = [d(CA) - (t * \tan(\Theta))] * \cos(\alpha) \quad \text{with } \Theta = \sin^{-1}((n_1/n_2) * \sin(\alpha))$$

(UA represents the useful aperture, CA the clear aperture, d the component diameter, t the component thickness and  $\alpha$  the angle of incidence of the beam)

Applying the formula to standard substrates and commonly used angles of incidence gives the data listed in the table below.

It is calculated for a clear aperture of 85% and substrate refractive index of 1.5. The refractive index varies with material and wavelength, so the useful aperture will have a slight wavelength dependence. We have developed a spreadsheet to calculate useful aperture to any specification, which will be available to use on our website.

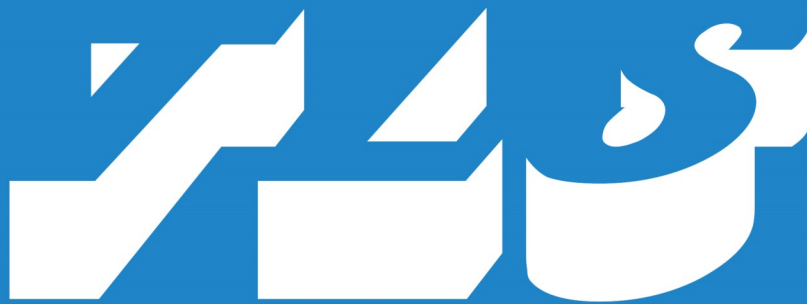
<b>Table of Common/useful angles - Clear aperture 85% (n=1.5)</b>			
<b>Diameter/mm</b>	<b>Thickness/mm</b>	<b>Angle of Incidence/°</b>	<b>Useful Aperture/mm</b>
25.4	6.35	45	12.87
		56	9.72
		72	5.06
50.8	9.52	45	26.93
		56	20.62
		72	10.93
76.2	12.70	45	41.00
		56	31.51
		72	16.80
101.6	12.70	45	56.27
		56	43.58
		72	23.47

If you are in doubt about how to specify your components, please do not hesitate to contact the MPO Team, we look forward to helping you.

#### References:

Handbook of Optical Systems Volume 5, H. Gross (ed.), Wiley-VCH Verlag GmbH & Co KG, 2012, ISBN 978-3-527-40381-3

Handbook of Chemistry and Physics, 60th Edition, CRC Press, Inc, Boca Raton, Florida 33431, 1979, ISBN-0-8493-0460-8



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