

APPLICATION NOTE

Aplanatic Meniscus Glass Lenses

Meniscus lenses can be shaped so that no additional spherical aberration or coma is introduced into the system. This shape is called the aplanatic form. It is possible to achieve aplanatic form only when the lens operates at magnification numerically equal to the reciprocal of the material index of refraction. Referring to the drawing, third-order optics show that a positive aplanatic meniscus lens has a front radius given by

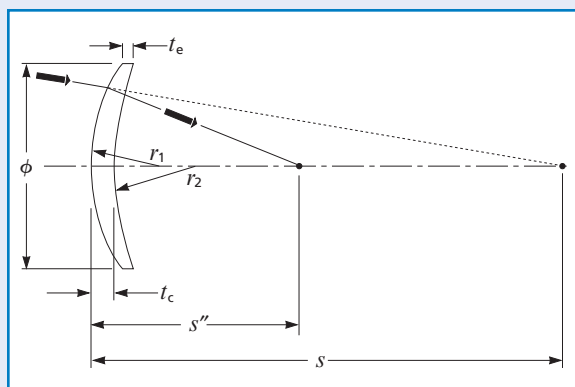
$$r_1 = \frac{s}{n-1}$$

where

$$\text{magnification} = -\frac{1}{n} = \frac{s''}{s} \text{ or } s'' = -\frac{s}{n}$$

The second radius of a positive aplanatic meniscus is given by

$$r_2 = s'' - t_c$$



Aplanatic meniscus lens with index of refraction n

Thus, the second radius is concentric with the image point. In the negative aplanatic meniscus, the first radius is concentric with the (virtual) object, so

$$r_1 = s$$

and

$$r_2 = \frac{n(s-t)}{n+1}$$

The aplanatic lens form, although very useful because of its aberration properties, must be used under specific magnification and object distance conditions to realize its fullest advantages. In general, it would be more useful to have a meniscus lens that would perform satisfactorily over a wide object distance or magnification range. For a general form meniscus lens, third-order aberration theory states that total transverse spherical aberration (TSA) of the meniscus and preceding element is

$$\text{TSA} = \text{TSA}_0 \left(\frac{s''}{s} \right) + \text{TSA}_m$$

where TSA_0 is the original system transverse spherical aberration, and TSA_m is the meniscus lens transverse spherical aberration. In a positive meniscus lens, original system transverse spherical aberration is actually reduced by a factor equal to the meniscus element magnification. Since system focal length is shortened by this same amount, angular aberration of the system is unchanged. The total system spherical aberration is only increased by the amount TSA_m . Thus, a positive meniscus can be used to shorten focal length and lower the f-number of a system without adding much aberration if TSA_m is small. Of course, in the aplanatic meniscus, the term TSA_m is equal to zero.

In the negative meniscus lens, original system aberration is increased by an amount equal to magnification. Since system focal length also increases by the same factor, there is again no change in angular resolution.