CEMENTED ACHROMATIC DOUBLETS

Cemented Achromatic Doublets offer greatly improved color correction to single BK7 components. In addition they have superior imaging performance even for monochromatic imagery.

Ideal conditions with slower doublets

Achromatic Doublets consist of two materials of differing dispersion characteristics. By combining a strong crown component with a weaker flint component of the opposite power, the chromatic aberration of the combination can be considerably reduced.

If the ratio of the lens powers of the crown and flint components are chosen to be the same as the ratio of their Abbe numbers or V–values for a particular spectral range, then the paraxial foci for the two extreme wavelengths will coincide.

For the achromats in this catalog the central design wavelength is 587.6nm (d line–yellow) with an achromatization target at 486.1nm (F line–blue) and 656.3nm (C line –red). Typical glass pairings will result in a crown component with approximately 2.5 times the power of the final doublet, and a flint component with approximately –1.5 times the power of the final doublet.

Secondary Spectrum

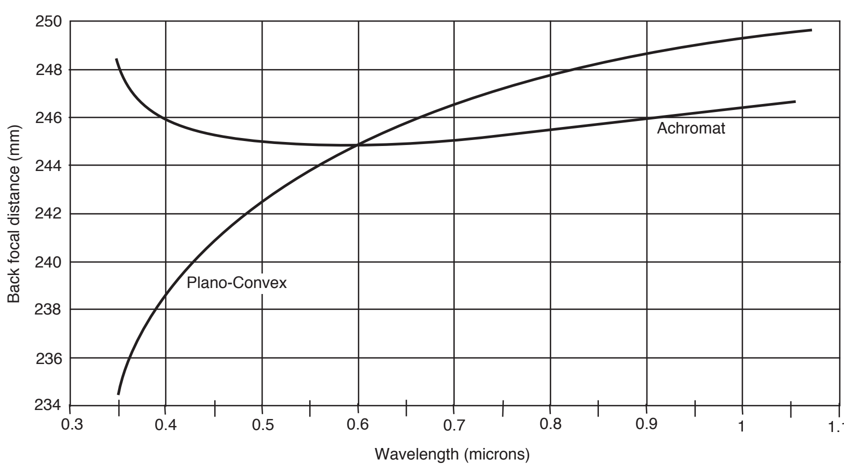
Because of a fundamental property of optical materials there is always a small residual difference between the green focus and the red/blue focus. This phenomenon is known as secondary spectrum. For a typical achromatic doublet this focal shift is 1/2000th of the focal length of the doublet. The focal excursions of an achromatic doublet and a BK7 singlet of equal focal length are plotted in the figure below. Over the visible region(480–650nm) of the spectrum the focal shift of an achromatic doublet is approximately 30 times smaller than for a BK7 singlet (Abbe number = 64). In most cases this is acceptably small compared with other remaining residual errors.

The exception, where it becomes the dominant aberration, is in long focal length lenses of low relative aperture e.g. collimator systems or refracting astronomical objectives. This type of lens is often hand– figured to give excellent correction of the monochromatic performance. In addition, for these cases, the cost/performance considerations are different, and more expensive materials and/or a three glass design can be used.

Each of the component parts of the doublet has spherical aberration which varies quadratically with lens bending. As always the positive crown component has undercorrected spherical aberration, while the negative flint component introduces a contribution of the opposite sign. The combination has a variation of spherical aberration which has a quadratic dependence on the shape factor of the doublet, but with greatly reduced magnitude compared with a single component of the same refracting power. Given a particular choice of crown component, it may be possible to choose a flint material which allows the overall spherical aberration to become slightly overcorrected for a range of lens bendings.

Considering the coma contribution of each of the components, one finds that they are of opposite sign and have a linear dependence on lens bending, as does the combination.

By choosing certain glass combinations it is possible to have simultaneously a high degree of correction of Spherical Aberration, Coma and Primary Color. Such a lens is aplanatic as well as achromatic.



Focus variation with wavelength
Achromat and BK7 singlet (f + 250mm)

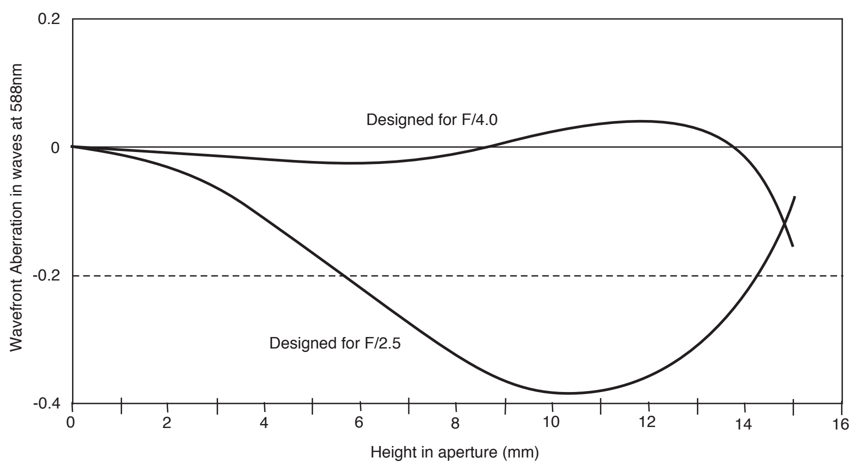
DOUBLETS

High Aperture Doublets and the Significance of Higher Order Aberrations.

As the relative aperture of a doublet is increased the higher order aberrations become significant. Unfortunately there are insufficient degrees of freedom to correct both the higher order aberration and the primary aberrations in a cemented doublet. Within the restrictions of the cemented doublet format the general procedure is to balance the unavoidable higher order aberrations with appropriate amounts of primary aberration.

The cemented surface introduces a large amount of overcorrection of the aberrations, by using high angles of incidence with a small difference in refractive index. This mechanism causes the higher order aberrations to be overcorrected in a standard doublet.

The optimum choice to improve the performance is to select undercorrected targets for the following aberrations - Primary Color, Primary Spherical Aberration and Primary Coma.



Doublets (EFL 120mm)
Used at aperture F/4.0

If a doublet designed for a high relative aperture is stopped down, then the image quality will improve. However the presence of the undercorrected primary aberrations, which it was necessary to introduce, will always make the performance inferior to that of a doublet which was designed for the target aperture. The effect is illustrated by the example of two Ealing doublets of focal length 120mm used at F/4.0, (see figure below.)

For the reasons outlined above, as a rule of thumb, (if the F/No is faster than F/5), it is usually advisable not to select a doublet which is excessively larger than required,

It is also worth noting that the monochromatic aberrations of faster doublets can be significantly improved if a doublet of around 1.5 times the required focal length is combined with a meniscus lens of the aplanatic type to give the desired total power.