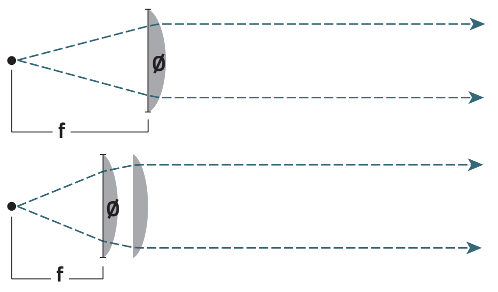
# Choosing the right condenser




Our condensing optics vary in material and number of lenses, in their spherical aberration and the radiant flux present at the output. The light gathering capability is described by the F/number. As a first approximation the F/number of a lens is given by the ratio of focal length to diameter. The rule of thumb is: the smaller the F/number, the more light can be collected and collimated by a condenser.

**F/number and beam quality**

Unfortunately the reduction of the F/number leads to an increase of the aberration of the optics. Though a lens with a lower F/number collects much more light, the parallelism of the collimated beam is of poorer quality. Even with a point source, the collimated beam has diverging rays far from the collimated ideal. No optical system can focus a poor- quality beam to a good image of the source. Which means: although the beam of a condenser with a lower F/number collects more intensity than one with a higher F/number, it is not possible to focus the highly intensive beam on a small spot. So for all applications where image quality or spot size are important, a condenser with a higher F/number will give better results.

The practical limit for the F/number of spherical lenses depends on the application. For high-performance imaging the limit is about F/4. In practice F/numbers of F/2 – F/1 have proven to be a good compromise for arc lamps. The lens must have an adequate radius of curvature and the correct side (plane) has to be turned to the light source. Planoconvex condensers have very poor aberration performance if not mounted correctly.

**Spectral transmittance**

The spectral transmittance of arc and halogen lamps is limited by the quartz material of the envelope. The substrate material of a condenser also has a limited spectral transmittance. The UV transmittance of condensers is especially important, if you don't want to further reduce the limited transmission of the lamp due to the envelope material. The UV transmittance of quartz depends very much on the quality of the material and on cumulative exposure to short wavelength radiation (solarization < 260 nm). Our condensers are made from selected synthetic silica for best ultraviolet transmittance. Depending on the application it may also be preferable to limit the emission of the light source by using a particular substrate material. It is for example possible to block UV transmittance with a glass condenser.

**Thermal stress**

The refractive index and therefore the focal length are temperature dependent. However, with high-power light sources, the risk of lens breakage due to thermal stress is a problem. The inner lens of a condenser is always very close to the lamp and absorbs the IR and UV radiation. The resulting thermal stress and thermal shock at power-up can cause the lens to break. For this reason, optics closest to the condenser in our high-power lamp housings are always made of quartz. Quartz has a significantly higher thermal resistance than glass.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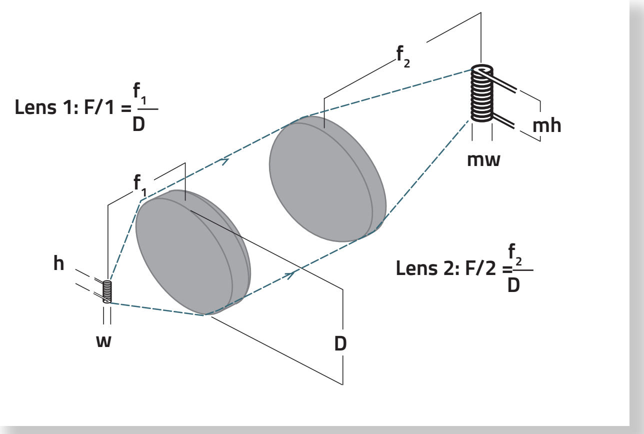
## Divergence and spot size

Real radiant sources are no infinite point sources, but have finite extent. The figure shows the geometry of collecting and imaging a real source.

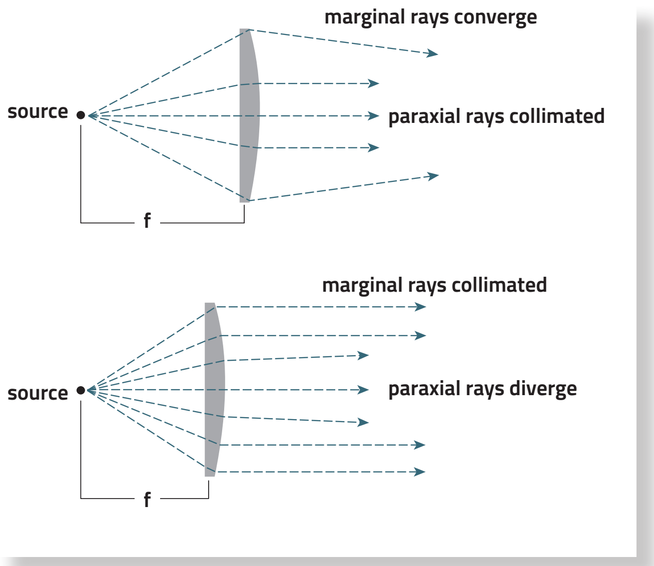



Geometry of collecting and imaging a real source

The "collimated" beam is divergent. The arc and filament sizes given in the specifications and the focal length of the optics are a good guideline for the divergence. Our 400 W halogen lamp for example has a 10 mm long cylindric filament with 5 mm diameter. With the filament in the focus of an ideal 50 mm focal length condenser, the collimated beam shows a divergence of 0 to ±5° to the optical axis in the worst case.

## Spherical aberration

Due to manufacturing most lenses have spherical surfaces. A spherical surface is not an ideal lens. The focal length of a spherical lens is shorter for marginal rays than for paraxial rays. The marginal rays of a single element condenser diverge, whereas only the paraxial rays are collimated (see figure). This effect is called spherical aberration.




Spherical aberration

The aberration of a condenser increases with widening collimation angle. This means the wider the collimation angle, the more difficult a good quality image can be achieved.

Especially when a second lens should be used for imaging, (e.g. a monochromator slit or fiber optic), even little spherical aberration can lead to great losses in performance. Focusing collimated light through an optic with spherical aberration always leads to a magnified, diffuse image of the source. Better results can be reached by placing the lens closer to the lamp.

The best position depends on the lens, source size and your application. Our condensers have focus adjust (independent from lamp adjustment), which allows you to find the best position by trial and error.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