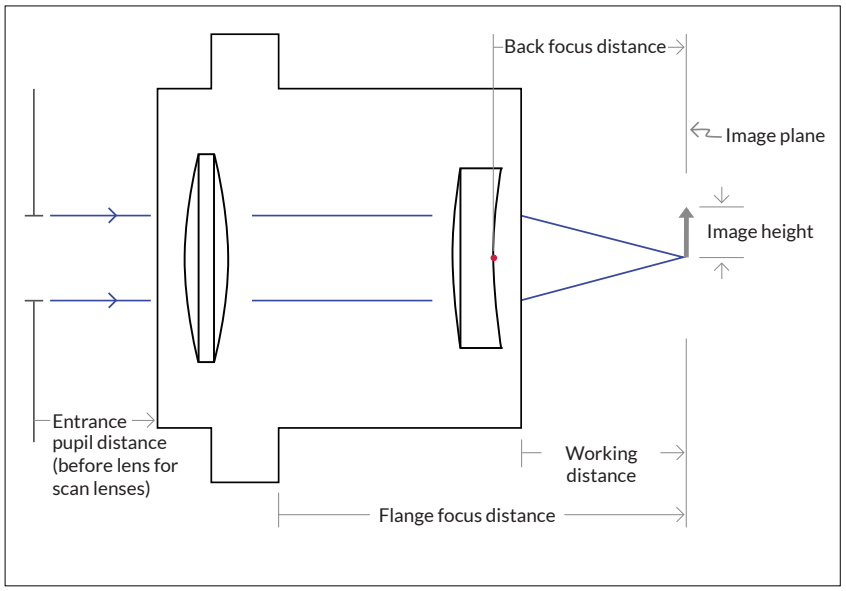
General Guide for Specifying Lenses



We commonly design lenses to a customer's given specifications. In many cases, development of those specifications can be a critical first step in finding a lens design solution. In this paper, we outline many of the commonly required specifications, along with an explanation of their importance.

Back focus distance – The distance from the rear vertex of the last element to the image plane.

Entrance pupil location – For scan lenses where the scanning mechanism is in front of the lens (pre-objective scan), the scanning mechanism is located at the entrance pupil. The entrance pupil needs to be sufficiently in front of the lens to allow clearance.

Field of view – Generally defined as the angular extent of the scene (for imaging lenses) or the angular input (for scan lenses). For an imaging lens, the field of view would be in degrees. For a scan lens, the term scan angle may be used instead of field of view. If the lens is imaging an object at a finite distance, the field of view may be expressed as a linear distance.

Flange focus distance – The distance from a mounting flange, which serves as a mechanical datum, to the image plane. This is not an intrinsic optical property but used to locate the assembly properly in the system.

F-number (f/#) – The ratio of the focal length to the entrance pupil diameter. Lower values for f/# will, in general, form brighter images. If the lens is well-corrected, lower values for the f/# will form smaller spots.

Focal length (often called effective focal length, or EFL) – A measure of how the optical power of a lens, or how strongly the lens focuses. EFL is important since the field of view of a lens, for a given sensor size at the image plane, scales inversely with the focal length.

Image height – This is the size of the semi-aperture that encompasses the image. In systems using image sensors, the x and y sizes of the image may be different, and then the distance from the axis to the corner of the sensor is commonly referred to as the image height. The image height should never be specified as zero, even if the lens is only used on axis. A non-zero image height is necessary in a design to accommodate reasonable manufacturing errors.

Performance – Methods of specifying performance vary with the application. Here are commonly used methods:

Blur spot size – May be used for lenses that are not diffraction limited.

Distortion – Distortion relates to a mapping error between the object and image planes of a lens. The term can loosely be used to describe either the mapping or the deviation from the expected mapping. For example, laser scan lenses often are specified to have f-θ distortion, where the input angle is given by θ, and the output image height is given by $h=f\theta$.

Field curvature – Commonly required on scan lenses, where the focused spot must stay within a given depth of focus with respect to the image plane over the given scan range.

MTF (modulation transfer function) – often used for lenses used with image sensors. MTF is frequently specified as a given contrast level at one or two spatial frequencies.

rms wavefront error – used for diffraction limited or near-diffraction limited lenses

Wavelength range and weighting – The system wavelengths are typically specified in nm. The wavelength weights are critical for optimizing the performance of the application and are relative weights to each other.

Weight (mass) – This is critical for applications where the lens is moved, as in an autofocus system.

Working distance – The distance from the last physical surface of the assembly to the image plane. Increasing working distance often makes it easier to fit the lens in place, but a larger working distance also means larger elements and higher cost.