TECHSPEC® FOCUS NEWSLETTER

INTEGRATING STOCK OPTICS

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by Katie Schwertz

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5 CONSIDERATIONS FOR THE MECHANICAL DESIGN, ASSEMBLY, AND ALIGNMENT OF OPTICAL SYSTEMS

Planning ahead can save design time and reduce overall cost – not to mention eliminate unnecessary frustration.

by Katie Schwertz

In Issue 3, Volume 1 of the TECHSPEC® Focus, Jeremy Govier wrote an article that provided tips for designing with off-the-shelf optics. I'd like to expand on those tips and discuss some important assembly items to consider when working on an optical design. Typically, optical designers use ray tracing software to construct an optical design, however, the software presents a system that is, essentially, floating in air. When you ultimately purchase and/or manufacture the optical components, you'll need a way to mount, assemble, and possibly align that system. By including considerations for mechanical design, assembly, and alignment in the optical design stages, you can save significant time and reduce the need for costly changes and component redesign later.

1. CONSIDER PACKAGE SIZE AND WEIGHT. One of the first things you should consider when planning how to mount optical components is potential size or weight limitations; this can drive your overall approach to the mechanical mounting design for the optics. Are you setting up prototype components on a breadboard with an entire tabletop available? Is there a limited amount of space? Is this being carried by a person? These types of considerations may limit the number of possible mounting and/or alignment options. You should also consider where the object, image, and stop of your system will be located, and if you need to be able to access them after the final assembly. The stop, a fixed-size or adjustable physical aperture that limits the bundle of light that can pass through a system, can be located somewhere within the optical design, or at either end. It is important to ensure that there is enough space where the location of the stop is in your optical design so it can be physically achieved in the mechanical design. As shown in *Figure 1*, the left optical design example is a feasible design, whereas it is unlikely an adjustable iris could be fit between the doublets in the right example. The potential space restriction is an easy fix in the optical design stage, but difficult to fix later on.

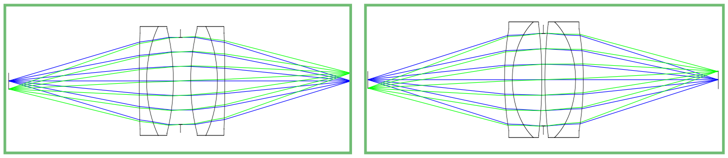


Figure 1: Optical design examples of a 1:1 image relay system requiring an adjustable iris.

2. IS IT DESIGNED TO BE REASSEMBLED? When you are planning the assembly process for your optical design, one detail that can drive design decisions is whether or not the assembly is one-time only or if it will be disassembled and reassembled. If there is no need for disassembly, then using adhesives or other permanent/semi-permanent mounting methods may not be a problem. However, if you need to disassemble or modify the system, consider in advance how this will be done. If you are swapping out parts, such as rotating different coated mirrors in and out of the same setup, determine if you will be able to access those components easily and if you need to maintain the alignment of the component. This is where kinematic mounting options or the TECHSPEC® Optical Cage System, such as those shown in *Figure 2*, can save you a lot of time and frustration.

Figure 2: Kinematic mounting options or the TECHSPEC® Optical Cage System can simplify system adjustments.

3. UNDERSTAND MOTION AND ALIGNMENT REQUIREMENTS. For some simple systems, optical components can simply be placed in their holders or a barrel and the assembly and alignment is complete without need for adjustments. However, in many cases, optical components must be aligned properly and possibly adjusted during use to maintain the required design performance. When creating an optical design, consider if you will need adjustments for decenter (translation in X and Y), axial motion (translation in Z), angular motion (tip/tilt), and, in the case of components such as polarizers, waveplates, or diffraction gratings, orientation. Such adjustments may be required for individual components, the light source, the camera/image plane, or the entire system. Not only is it important to know what adjustments are required, but also how precise those adjustments need to be made. Typically, the finer the resolution required by an adjustment, the more expensive the mechanics will be and more skill will be required from the assembler. Understanding the motion requirements can save time and money.

Figure 3: Stray light analysis can help avoid image contrast problems in the final design.

4. AVOID STRAY LIGHT. Stray light is a general term that applies to any unwanted light in an optical system. Light traveling where it was not intended in the optical design can cause a variety of issues including ghost (multiple) images, reduced image contrast, or even glass failures in the case of high power laser applications. Standard ray tracing software packages typically have some level of first order stray light analysis that can be used to evaluate if this is a potential concern for your optical system. More thorough investigations can also be completed using a non-sequential ray trace analysis. *Figure 3* shows a stray light analysis completed in FRED (optical design software) to investigate the effects of light reflecting off a particular metal surface.

If stray light is a potential problem for your optical system, there are a few approaches to mitigate the effects. For example, threading the inner diameters of barrels or placing additional apertures to block stray light from exiting the system can be used to block unwanted light rays. Additionally, mounting components can be blackened (i.e black anodized for aluminum or black oxide for steels) or covered with material. The edges of lenses can also be blackened with paint or ink, as shown in *Figure 4*. Ideally, any stray light problems should be recognized during the design phase and the elements or image plane can be moved or modified to resolve the issue.

Figure 4: Edge Blackened Lens (left) compared to Standard Lens (right) reduces stray light and increases signal to noise ratio in optical systems.

5. WATCH OUT FOR ENVIRONMENTAL EFFECTS. As mentioned earlier, when designing an optical system using modeling software, it is typically floating in air with no environmental effects acting upon it. In reality, however, the optical system may see many adverse environmental conditions including stress, acceleration/shock (if it is dropped), vibration (during shipment or operation), temperature fluctuations, or it may need to operate underwater or in another substance. If you anticipate your optical system will not be operating in air under controlled conditions, further analysis should be completed to either minimize the environmental effects through the design (passive solution) or having an active feedback loop to maintain the performance of the system. Most optical design programs can simulate some of these aspects, such as temperature and pressure, but additional programs might be required for a complete environmental analysis.

USING C-MOUNT FOCUS TUNABLE LENSES

Electrically focus-tunable lenses, now offered in a C-mount configuration, can be used with standard imaging lenses to create an electrically focused imaging system.

by Dr. Selina Casutt, Optotune

Optotune Electrically Focus-Tunable Lenses provide flexible, fast-focusing solutions for a wide variety of machine vision applications, including quality control, sorting, or bar code reading. Unlike traditional optical setups, in which mechanical adjustments must be made for objects at different working distances, Optotune's Electrically Focus-Tunable Lenses take only milliseconds to refocus and are free of mechanical translation. In addition to focusing applications, these lenses can reduce the number of light sources and the overall power consumption of adaptive illumination applications by providing highly flexible lighting parameters.

The C-mount version of the standard electrically focus-tunable lens EL-10-30*, the Optotune C-Mount Focus-Tunable Lens EL-10-30-C*, is compatible with standard industrial cameras. To allow for additional adjustments to the focal range, an offset lens can be integrated into the C-mount focus-tunable lens. When combined with a positive power offset lens, the tunable lens can achieve short focal lengths and be used directly with standard industrial cameras. With a negative power offset lens, the lens combination can be focused at infinity, allowing the EL-10-30-C to be placed in front of existing optical components as a close-up lens for fixed focal length lenses.

CLOSE-UP CONFIGURATION: EL-10-30-C IN COMBINATION WITH FIXED FOCAL LENGTH LENS. With an integrated plano-concave offset lens, the EL-10-30-C can also be used as a close-up lens for fixed focal length lenses. This combination creates a high optical quality, electronically controllable focusing unit. The fixed focal length lens alone would need to be refocused to accommodate different working distances. In the combined setup, all of the elements stay at a fixed position; only the curvature of the tunable lens is varied to achieve focusing for different working distances.

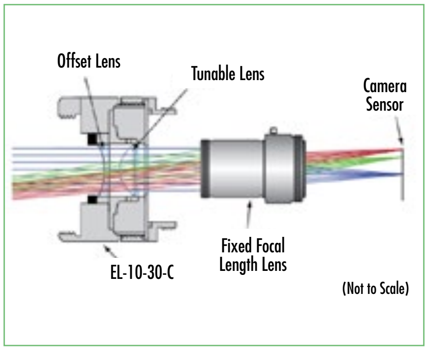


Figure 1: *Diagram of combined setup.*

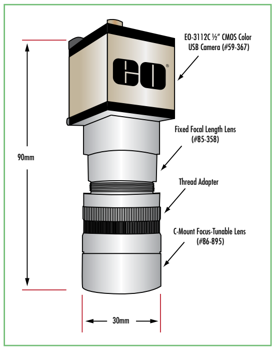


Figure 2: *Combined setup with stock numbers.*

An example of a combined setup can be seen in *Figures 1* and *2*. A -150mm focal length plano-concave offset lens (#86-905) is used with the plano side facing the tunable lens.

The images in *Figure 3* demonstrate that a combined setup can achieve the same level of quality as using only a fixed focal length lens. This configuration has a field of view of 14.5° (for 1/2" sensor sizes) and operates at f/4.

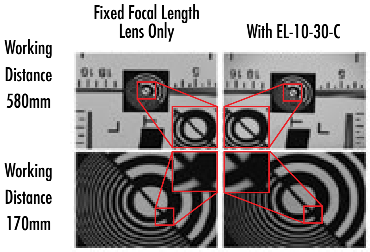


Figure 3: *Optical quality comparison of traditional and combined setups.*

In *Table 1*, recommended fixed focal length lenses with different field of views ranging from 6° up to 15° are listed, which are well suited to be combined with the EL-10-30-C lens.

Field of View**	Stock No.	Focal Length	Working Distance	Aperture (f/#)	Max. Sensor Size
14.5°	#85-357	25mm	20mm - ∞	2.8	2/3"
	#85-358			4	
	#85-359			5.6	
	#85-360			8	
14.5°	#59-871	25mm	20mm - ∞	2.8 - 17	2/3"
13.3°	#58-207	25mm	60mm - ∞	2.5	1/2"
	#69-266			4.0	
	#83-955			8.0	
10.4°	#85-365	35mm	50mm - ∞	4	2/3"
	#85-366			5.6	
	#85-367			8	
10.4°	#59-872	35mm	50mm - ∞	4 - 22	2/3"
8.2°	#54-689	35mm	90mm - ∞	4 - closed	1/2"
6.2°	#59-873	50mm	100mm - ∞	5 - 22	2/3"

**Horizontal FOV on ½" sensor format

Table 1: *Fixed focal length lenses with different field of views, focal lengths and f-numbers.*

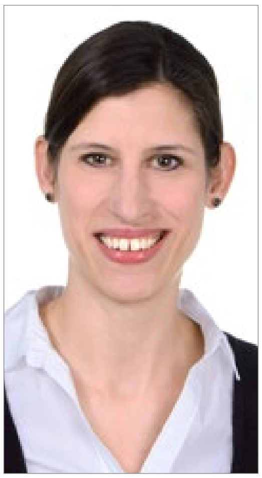
CONTROLLING ELECTRICALLY FOCUS-TUNABLE LENSES. The EL-10-30-C's focal length is controlled by changing the input current (0 – 300mA). For simple focusing applications, a calibration using a look-up table is sufficient to achieve good repeatability. If the heating of the lens is significant, then sensing the temperature is recommended to calculate more precise look-up values. Each lens has a temperature sensor and 256 bytes of memory built in.

**EO offers focus-tunable lenses with multiple coating options and configurations.*
Visitt ***www.edmundoptics.com/EL-10-30*** *for product details.*

MEET OUR AUTHORS

Katie Schwertz

Katie Schwertz is a Design Engineer in Edmund Optics' Tucson, Arizona, USA office. She is responsible for designing and drafting various optics and opto-mechanical systems for both stock and custom applications. Katie received her MS in Optical Sciences from University of Arizona, College of Optical Sciences located in Tucson, Arizona and a BS in Optics from University of Rochester, Institute of Optics located in Rochester, New York.
Direct correspondence to:
KSchwertz@edmundoptics.com



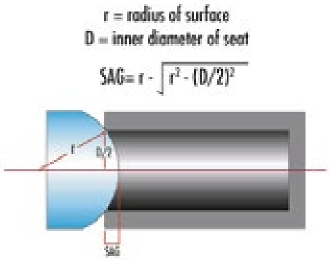
Dr. Selina Casutt

Dr. Selina Casutt is an application engineer at Optotune. Optotune develops focus tunable lenses enabling new technologies in wide areas such as lighting, machine vision or projection. Selina has a background in physics and holds a PhD in ultrafast laser physics from ETH Zurich. At Optotune, she is responsible for the implementation of novel products in diverse markets. Selina supports customers developing innovative solutions with Optotune's focus tunable lenses and laser speckle reducers.
Direct correspondence to:
sales@optotune.com

EO'S TECH TIP

Understanding Surface Sag

When mounting and aligning optics, understanding the exact location of each lens surface is important – particularly in tight spaces such as multi-element lens assemblies. One critical parameter when determining surface location is sag. Sag is the distance between the edge of a mount and the vertex of a surface (see illustration below).



Want a quick and easy way to calculate sag? Use our online sag calculator. Simply type in the radius of curvature of the optic and diameter, we do the rest!
www.edmundoptics.com/SAG

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www.edmundoptics.com/tradeshow

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