Learn how to reduce lead time and expense by transforming standard optics into custom designs

Transforming standard optics into custom designs

SAVE TIME AND MONEY BY USING OFF THE SHELF, STANDARD OPTICS TO QUICKLY CREATE CUSTOM OPTICAL COMPONENTS FABRICATED TO YOUR SPECIFICATIONS

Even off the shelf optical components require an investment of time and money, and custom optics represent an even more significant investment, on both counts. Traditional custom optical fabrication starts every component from scratch, but you can save both time and money by leveraging the investment already made to produce off the shelf components. Start your custom design from a stock component and lead time can dramatically drop.

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As optics continue to play an increasing role in the world of science and technology, the demand for custom optics will continue to grow as well. In any industry, producing custom components often increases lead time – sometimes so much that the delay becomes untenable to the customer. When completing a prototype build or developing a small lot of unique systems, customers need their parts quickly. To meet those customer needs, fabricators must rapidly turn around custom requests. There are several ways fabricators can quickly modify off the shelf optics to fulfill performance and schedule requirements.

Traditional Fabrication

Long lead times are not a matter of choice for optical fabricators – simply put, producing high-quality optical components takes time. Fabricating an optical element from start to finish is no small task, whether it be at the simpler end of the spectrum (a window, perhaps) or as complex as a two-sided asphere. The general process more or less involves three basic steps: grinding, polishing, and centering, but the techniques used to execute them can vary.

Raw glass material often begins in the form of a blank (a cylinder that is either pressed into shape or cut from a longer rod) roughly the diameter and thickness of the optic to be fabricated. The first step is to roughly shape the surface by grinding away material until the surface nears the desired profile. The blank is ground one side at a time utilizing diamond impregnated grinding tools which are gradually stepped down in coarseness. A coarser grit (or diamond size) allows for more removal, but results in a rougher surface. One begins with the coarsest grind tool to remove material quickly and produce the rough shape of the surface. Finer and finer grit tools are then successively used to bring the surface closer to the design shape while also removing enough material to eliminate subsurface damage from the previous step. Most optics will go through two to four separate grind steps to create the desired surface shape and roughness.

Next, the surfaces are polished to achieve a smooth, accurate finish. Polishing will commonly use a loose abrasive in

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suspension (vs. a bound abrasive in grinding) that flows between the polishing tool and workpiece in the form of a slurry. Similar to grinding, polishing is a mechanical removal of the glass, but there is a breakdown of the surface on a chemical level as well. Polishing times vary based on the particle size of the abrasive along with the desired surface irregularity and roughness. A smaller particle size removes material more slowly, but provides a smoother surface. Depending on the application, the large majority of optics will only undergo a single polishing process, however if extremely accurate or smooth surfaces are required a two-step process similar to grinding will be used.

Once the surfaces are complete, the final step in the fabrication process is centering or edging the optic. This process brings the element in to its designed outer diameter and, if the surfaces are curved, also aligns the optical axes of each surface to the mechanical axis. The centering step requires that the optic be either clamped on the top and bottom surfaces or mounted to a stem and held in place using a temporary adhesive. A grinding wheel is then brought in from one side to cut down the outer diameter of the part. It is during this stage that bevels, chamfers, or sag flats can also be applied.

All those steps are required whether the part has a production run of 1000 or of 10, but when your custom optic can be produced by modifying an off the shelf part many of those steps are already done. Of course, a custom optic – by definition – requires some special fabrication, but using a stock part as a starting point leverages the time already invested in production. Your modification might be as simple as reducing the diameter of an existing filter or lens, or improving the surface accuracy beyond the λ/4 of an off the shelf part. You can even save time and money with custom aspheric lens fabrication by starting from a lens with a similar spherical surface. To leverage from stock parts you need access to a large catalog of existing optical components and the experience to make the appropriate modifications.

Several types of modifications can be made to transform a stock component into a custom optical design. Changing the diameter of an optic, known as ›edge down‹, is one straightforward modification, and other common options improve surface quality or modify surface figure. But the possibilities don't stop there. Additional final touches like cementing, edge blackening, or coating open up almost limitless possibilities for customization with very rapid delivery. This makes it possible for customers to produce prototypes quickly and inexpensively, and make any necessary system design iterations in record time.

Edge Down

One of the most basic modifications that can be applied to any optic is an edge down, or a reduction of its outer diameter. Such an alteration requires that nothing be done to the optical surfaces and can therefore be completed with minimal processing. For plano-plano optics, that is, optics with no curved surfaces, an edge down may be more difficult and time consuming if the surfaces are coated. There's also a chance the layers may peel where they have been cut. The optic must be held properly so as not to damage the coated surface. A temporary protective layer may sometimes be applied to preserve very fragile coatings.

For any optic with a curved surface, be it on one side or both, a characteristic known as beam deviation (**Figure 1**) must also be taken into account. Beam deviation is the angular mismatch between the optical axis and the mechanical axis of an optic. When a curved optic is edged down these axes are aligned as best as possible before the cut is made. After the cut, the final beam deviation can then be measured.

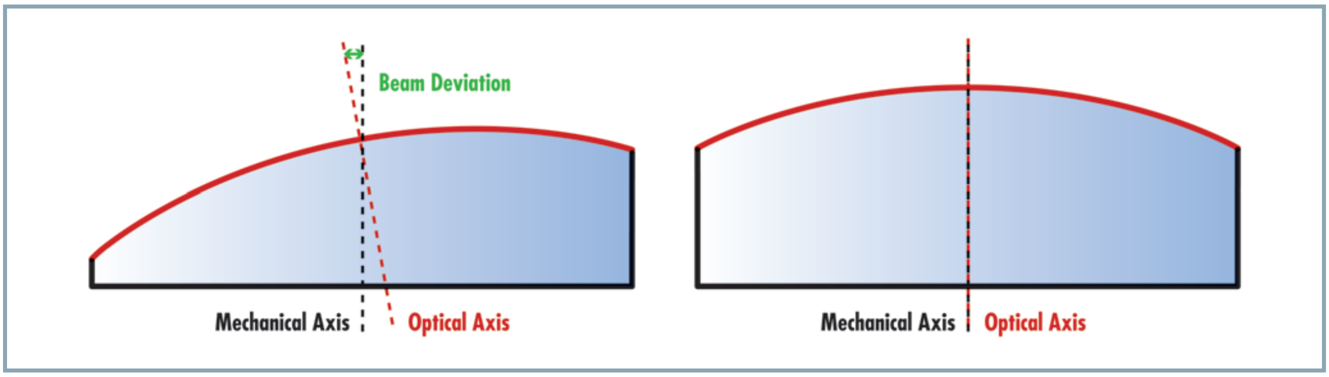
Since the surfaces aren't touched, an edge down requires very little setup time and this approach becomes a rapid form of optical prototyping.

Surface Improvement

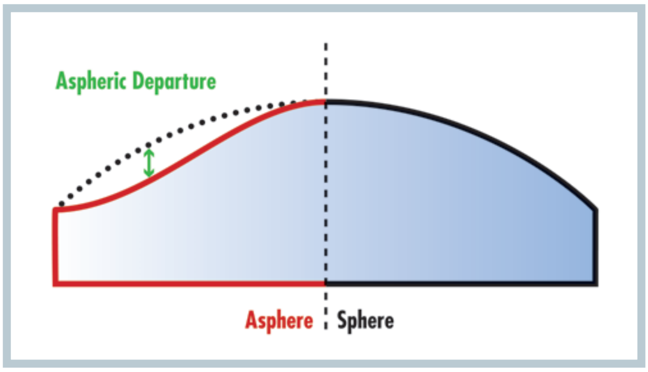
The next level of complexity in a stock optic modification would be improving an already polished surface using advanced technology such as magnetorheological finishing, or MRF.

MRF is a CNC-based, subaperture polisher that uses unique magnetic polishing fluid to remove very small volumes of material. Coupled with a metrology-based feedback loop which adapts the polishing tool path to target areas requiring either more or less removal, MRF provides us with a powerful tool. A subaperture polisher allows a fabricator to improve the surface of a sphere, asphere, or even parts which are rotationally asymmetric.

Again, the original optic is already a finished part. Many commercial grade optics, however, are not polished to the tightest of surface tolerances (on the order of λ/2). For many laser-based applications (especially those that are high power) the surface accuracy and roughness can determine the success of a system. A larger surface roughness value can lead to scatter and loss of light or even damage to the optic. A touch up to the surface of ▶



1 Explanation of aspheric departure: The graph represents how aspheric departure is commonly defined. Note that the sphere (in black) represents the best fit sphere (BFS) as it intersects the asphere (in red) at the center and edge of the part.



2 Explanation of Beam Deviation: This graph demonstrates how an edge down can be used to correct beam deviation in a curved surface. At left, the optical and mechanical axes are not aligned. By edging the optic down, these axes can be realigned

a preexisting part utilizing MRF technology can improve both surface irregularity and roughness in a short amount of time. Surface irregularities of λ/10 or λ/20 and surface roughness of less than 10 angstroms are not uncommon.

Using a stock optic in this scenario means there's no need for grinding – a big help in reducing lead times.

Surface Conversion

Finally, perhaps the most unique way to take advantage of a stock optic is to modify its surface curvature. One such example would be converting spherical surfaces into aspheric surfaces. This can be complex, as it is not cost effective to simply turn any spherical surface into an asphere, but a preexisting sphere provides a convenient starting point.

For this modification to be worthwhile you need to select a spherical optic that matches (or is fairly close to) the best fit sphere (BFS) of your custom asphere. The BFS is the radius of curvature that crosses both the center and edge of the aspheric surface. Aspheric departure is defined as the separation between the aspheric surface and the BFS (Figure 2). The greater the departure, the more material needs to be removed, and the longer it takes to manufacture the optic. Starting sphere fabrication from a blank requires large amounts of removal. Manufacturing an asphere from an already polished optic however affords us the opportunity to bypass up to 75% of the standard manufacturing process, depending upon the aspheric departure. An asphere with larger departure, say, 0.1 mm, will take longer to manufacture than an asphere that has a slight departure, say, 0.01 mm.

This type of modification is not exclusive to aspheres. A spherical surface can also be transformed to a spherical surface of a different radius. Just as with aspheres the departure (or SAG) will impact processing time. The amount of deviation from the stock optic's SAG to the new design's SAG determines the required time to convert the off the shelf spherical optic to a custom spherical optic.

Summary

Innovators often require custom optics, but can't afford excessive lead times. Offering the option of modifying off the shelf optics allows for rapid processing, equating to reduced lead times (Table A). The larger the variety of off the shelf offerings, the more likely it is that a stock part can be modified to suit a customer's specific needs. In addition to edging, polishing, and subaperture surface figuring, options for specialized coatings and cemented lens combinations provide an almost limitless range of available custom components with accelerated delivery.

AUTOR

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■ **www.laser-photonik.de/LP110251**

	Source Material (4-6 weeks***)	Grind (1-2 weeks***)	Polish (1-2 weeks***)	Edge (< 1 week)	Coat (1-2 weeks***)	Estimated Cost** Traditional Fabrication
Traditional Fabrication	X	X	X	X	X*	€€€€€
Surface Conversion		X	X	X	X*	€€€€
Surface Improvement			X	X	X*	€€€
Dimension Modification				X	X*	€€
Coating Application					X*	€

*Optional process based on application requirements.
** Based on 1 to 25 pieces, number of €-signs symbolize involved cost
***These times are estimated based on a 25-piece lot size assuming a normal capacity load

A Optical Fabrication Process: traditional fabrication versus modification of standard optics