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Hamlet's Optical Parable - Old Lenses

To Refurbish or not to Refurbish old lenses? Cost is the question

Introduction

Reworking existing lenses is often seen as an attractive alternative to the manufacture of a brand new lens. At Computer Optics Inc. (COI), we are often asked if an existing lens can be refurbished, rebuilt or modified to either restore it to its original operating performance, or change it to operate for a different function altogether.At COI we have developed a set of informal guidelines that can help one to make this decision. The rebuild/refurbish/modify decision is based on feasibility, complexity, tooling, available machinery, spectral performance, uniqueness and cost. However, in the final analysis this reduces to two basic issues: first, is the proposed work cost effective, and second will the repair save significant time.

Feasibility

The first order of determining if an optic can be refurbished is to determine what the customer wants the lens or optical system to do. While it may seem elemental, too often the customer wants the performance of the lens restored to that which it never achieved in the first place. Optics seems to be treated as a form of generic scientific inheritance. The lens is in the lab and the new user is told; hey, we got this neat lens in the stock room, all you need to do is fix it up and use it for your hot project, after all a lens is a lens, right? By the way in this article, I use the words repair and refurbishment interchangeably as well as lens and optic.

Since an inordinate amount of engineering can be spent on an optical design review, the first order approach should be a limited evaluation. What does the customer want? If the lens simply has a scratched front or rear element, then one needs to know if the lens can be disassembled without damage to the barrel or the element. Next the elements themselves have to be evaluated for surface and/or coating defects.

As part of this individual element evaluation, at the same time data is collected on the radii and diameters to determine if there is existing tooling, test gauges etc, to remove the coating and resurface the elements. The spectral band for the coating must be determined. The remaining cost elements are the coatings themselves, reassembly, alignment and testing labor.

If the performance of the lens is an unknown then a preliminary design evaluation is required. This preliminary work is accomplished with computer based modeling of the lens. We use a variety of programs including our own COI's COPTOX OPA (Optical Performance Analysis) program, but there are a number of commercial computer programs that are available such as Zeemax, ACOS, Oslo, Code V etc., that one can use. The key is having access to the individual element and spacing data. This design analysis also allows one to both determine if restoring the lens to its original operating condition will achieve the performance required, or if it can be modified to meet the performance.

When the refurbishment is to change the operating wavelength, the issue is one of design change plus material plus coatings. Most good wide band optical designs are achromatized for their spectral operating region. When the spectral band is to be changed, then the materials from which the elements have been made need to be evaluated to see if they transmit in the new desired spectral band. The same problem exists for the coatings.

Optical coatings have defined and usually limited bandpass. To change the spectral band almost always requires a new set of coatings.

The refurbishment is more complicated when the optical design has to be modified to meet new performance criteria. If the design evaluation indicates that a limited number of elements will have to be changed and these changes involve reworking the surfaces to new radii, then it may be feasible to modify the lens. The more elements to be changed, the less the feasibility. For some changes, it has been found that a cost effective solution was to remove an element and replace it with a new doublet. In another case the solution was to replace part of the viewing system with a new beamsplitter and focussing elements. In both cases these existing optical systems were fairly expensive so that the cost of this complexity was less than designing and manufacturing a new system.

Aspherization is the new buzz word for refurbishment work. Aspherized elements can be a great improvement for certain systems. This is particularly the case for both the Mid and Far Infra Red where many of the materials can be diamond turned to complex aspheric curves. Understand that the replacement of spherical element with an aspheric element will always require optical redesign.

One feature of aspherization is that with clever optical redesign, often it will be possible to both improve the performance and reduce the number of optical elements in the system since the correction of secondary spectrum and higher order Seidel factors can be achieved without the requirement of additional surfaces.

In the visible, while some machinery is now available for aspheric polishing, most aspherics are still made in the conventional method and are labor intensive. Therefore the same cost philosophy applies, and aspherizing an existing system is more feasible for expensive systems or those with confined access for which conventional optics will not fit.

Complexity

This divides into two basic areas, one optical the other mechanical. First, is the repair/refurbishment simple, and second how easily can the lens be taken apart? We have already discussed the simple repair of a front or rear element. The complete disassembly of a lens is not a trivial exercise. In fact the method of the original assembly is one determinant in the refurbishment decision. If the lens was originally assembled such that a small amount of explosive will not dent the barrel then forget it. In this case at best the barrel and the internal spacers will have to be replaced and at worst the elements will be damaged beyond use. For the less destructive case, if the lens barrel is swaged together or the elements are installed in a plastic barrel that has been staked or glued together, then the barrel will probably be destroyed or at best be deformed, and will have to be replaced. Here we enter into a gray area where the cost of manufacturing a one off lens barrel and/or internal spacers combined with the mechanical design labor will determine if the lens can be refurbished.

Let us assume that the lens was assembled with threaded retaining rings and can be taken apart with limited damage to the elements. The next issue is how the individual elements were mounted. For production lenses the elements are mounted into metal or plastic cells (rings) which have a step and a thin lip around on one edge. The element is centered into the cell, and the thin edge peened over the circumference of the element to securely hold it in place. If the element needs to be refurbished then it will almost always have to be removed from its cell. While it is not difficult to cut the lip and free the optic, care has to be taken not to chip the optic.

Some lenses are designed to be refurbished. For example, the Angenieux brand of zoom lenses have threaded retaining rings, replaceable cams, galleys and pinions in the zoom mechanics and a repairable iris assembly, including individual iris blades.

By contrast, our experience with many of the Asian zoom lenses finds they are riveted and peened together. This means that to disassemble, the rivets must be drilled out which distorts the rivet hole making direct reassembly not feasible.

Tooling and Machinery

The physical procedure of manufacturing, coating and testing optics requires a range of tooling to hold and work the elements, and machines of the proper size to regenerate and polish their surfaces. While measurements of the curves can be accomplished interferometrically, in a working optical shop, a test gauge or test plate is used for the optician to measure the figure while the lens is on the lap. Having the right set of test plates as well as grinders and polishers is a requirement for efficient production. This tooling is expensive. For example at COI we have a test plate library of over 1000 gauges and it seems that we always have to make more.

Spectral Performance

If the transmission or reflection band is to be changed, then it is almost always the case that the optical coatings will also have to be changed. Most older lenses were coated with a single layer of magnesium fluoride and reflective optics with simple metallics. With multi layer optical coating machines, coatings can be significantly improved and higher transmissions or reflectivities achieved at reasonable cost.

Cost and Delivery

For the vast majority of customers, the cost element is paramount and delivery second. The one exception to this rule, is for optics which are unique. These are lenses or optical systems installed in restricted space and for which there are no other solutions, or the optic itself is unique. When one has an original third order Fresnel Lighthouse lens made by Le Master himself to refurbish, cost is a secondary issue to craftsmanship.

As indicated above, the production schedule is a function of a number of factors. These include some or all of the following: Redesign, disassembly, modification or replacement of optical elements, modification and/or replacement of mechanical components, reassembly, alignment and test. The delivery time can be shortest for the rework of complex multi-element optical systems if the basic mechanical assemblies can be preserved or reworked, and the changes to the optical components are nominal. Obviously substantial time can be saved in the production schedule if the changes are limited. What is not so apparent is that ancillary operations are also reduced. These include painting or anodizing, engraving, and ordering time for components such as new O rings.

Conclusions

The concept of modification of an existing lens or optical system in order to use it for a new project is appealing. The process is highly individualized with a variable cost envelope and must be evaluated on a case-by-case basis. A driving feature of rework is that one can reuse elements which can be expensive to replace, have overall unique properties, and save a significant amount of time in the process.

The rework procedure must be approach with attention to detail due to the wide variety of redesign, refurbishment/rework and other modifications that may be necessary in order be sure that the refurbished lens will perform as redesigned.

The key is the initial evaluation of both the lens and its new performance. We have seen that it first pays to perform an initial evaluation to get a rough idea as to what is required. This should allow for a rough order of magnitude of both cost and delivery. Once the rework budget limits are established, the decision can be made as to what modifications are feasible, including aspherization of selected elements, modification of spherical curves or insertion of additional elements. In addition, significant effort has to be allocated to the mechanics which include changes to the housings, spacers, apertures, irises and mounts.

From this in depth analysis, a performance specification can be established and the cost and delivery are determined.

While the variety of refurbishment requests vary in general we have found at COI that a lens costing under $500 is not economical to repair. From $500 to $5000 the refurbishment decision will be determined by the amount of disassembly and the number of elements to be repaired or replaced. Assuming a non-unique optic, the system has to be over $5000 in order for a redesign to be cost effective.

Thus in conclusion, there is a place for refurbishment of older existing optics, but each case is unique and has to be evaluated on cost and complexity to make a repair or new optic decision.

About the author:

Gordon Kane has been President and Chief Engineer of Computer Optics Inc. since 1985, an opto-mechanical company specializing in optical design, manufacture and rework of lenses and optics for the machine vision industry, defence and industrial processing. Previously he was program manager at Lockheed Sanders and EG&G for optical and electronic countermeasures and nuclear weapons instrumentation.

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