



# Custom Optical Homogenizers Competitive with Stock Components? Not a Light-Pipe Dream

A whitepaper from:



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## Executive Summary

Custom, high-performance homogenizers fill a need for dimensions and quality specifications not available from stock components.

IRD Glass (IRD) has been manufacturing custom homogenizers for well over a decade. They have produced high-end homogenizers in a wide range of shapes, sizes, and volumes for the most demanding applications across various industries.

Through these applications, IRD has demonstrated that custom homogenizers can be price competitive compared to stock items, especially as volumes increase.

This white paper illustrates IRD's capability to produce the highest performance rod-style homogenizers for a range of applications. Through their continuous improvement efforts, you can expect their capability as a homogenizer manufacturer to grow with customer needs and developments in the market.

## Introducing the Optical Homogenizer

Homogenizers are optical waveguides designed to combine and integrate one or more sources of light, including lasers. They accomplish this using total internal reflection to transform a non-uniform source or multiple sources into one with uniform output throughout its cross section.

These flexible optical design elements are used in many industries. Since they can combine sources of the same or different wavelengths or power levels, homogenizers are found in applications as diverse as automotive display panel backlighting,

entertainment, [medical device imaging](#), UV lithography for semiconductor fabrication, wafer inspection, and high-power lasers for materials processing.

## Many Design Tradeoffs

When designing a homogenizer, the optical engineer has several parameters to specify, all the while considering cost, quality, and size. While stock products are available on the market, these rarely offer the highest efficiency or optimum size.

Homogenizers are capable of transmitting and mixing wavelengths in the UV, visible, and infrared spectrum through the designer's choice of material, including the more common options of fused silica, n-BK7, and [sapphire](#).

Optical engineers design homogenizers with various shapes - round, square, hexagonal, and octagonal being among the most common - to achieve the desired efficiency. For example, a homogenizer with a hexagonal cross section provides 35% greater transmission than the equivalent size rectangular rod.

The end faces of homogenizers are another critical aspect to the capability of the homogenizer. Often designers will make the input face of the rod perpendicular to the side faces, in order to make it easier to couple the input to the homogenizer. Likewise, some homogenizers also use a perpendicular output face, while many others tilt the facet at Brewster's angle to help minimize losses due to reflection at that surface.

Depending on the application, many homogenizers also utilize a custom optical coating on the end faces to further minimize cost and reduce optical noise in their system.

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## Surface and Edge Quality Are Critical

This higher efficiency comes at a cost. More facets mean more handling and more surfaces to inspect. And, with twice the number of surfaces and edges, the octagonal homogenizer pictured in Figure 2 is substantially more complex to produce than a rectangular one. Nevertheless, they are reliably produced in volume at IRD – see the case study below.

Since rod-style homogenizers make use of total internal reflection, defects in the reflective surfaces, whether scratches or pits on planar surfaces or chips along edges or even variations in surface dimensions can cause light to leak from the component. All of these reduce the efficiency of a homogenizer. More handling also increases the opportunity to damage the part by creating loss-inducing edge chips and surface defects.

Some designers choose a tapered design in order to reduce the divergence (numerical aperture) of the light from the homogenizer. However, since the efficiency of tapered rods is influenced by dimensional precision, this higher quality output also comes at a cost.

## From Design to Manufacturing

Customers continue to push the precision optics manufacturing envelope, demanding higher and higher performance. The power available from industrial lasers is increasing, instrumentation is becoming more compact, medical devices are shrinking to become less invasive, and electronics are becoming ever smaller.



*Figure 1: IRD has produced thousands of straight and tapered homogenizers of various shapes and sizes.*

## Becoming Part of the New Product Development Team

Having a knowledgeable optics manufacturing partner with whom you can bounce off design ideas is key to beating your competition in the market while also optimizing cost and performance and to eventually securing a supplier partner to give you problem-free deliveries.

IRD's goal is to become a manufacturing partner in the truest sense, bringing their extensive knowledge of optics testing and manufacturing to improve your product development process. For companies integrating a new homogenizing component into their product, IRD involvement ideally begins as early as possible in the design phase.

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During an IRD design for manufacturability review, optical engineers and designers sit down with IRD manufacturing engineers and technicians. IRD's approach is to provide unlimited access to their technical people, "engineer to engineer", to produce a design that not only meets performance requirements but does so at the lowest overall cost and most consistent quality.

## Commitment to Quality and Delivery

Once the requirements have been agreed upon and the customer freezes the design, IRD does whatever necessary to meet quality requirements and delivery commitments. While this may involve investments in process equipment or process capability, the goal is always to build quality into each operation. The IRD philosophy, a key to quality and reliable delivery, is "to control quality rather than inspect it".

This approach has proven effective. The evidence comes from IRD remaining a sole-source supplier in countless cases because of its cost and quality commitments being met year-in, year-out.

## Case Study: Homogenizer for Multi-kilowatt Laser in Materials Processing

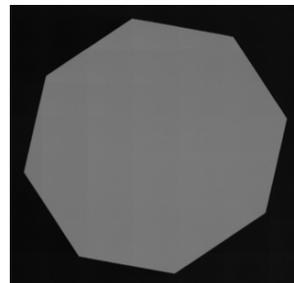
A major European laser manufacturer was struggling to secure reliable delivery of an octagonal homogenizer. Since the application required handling laser beams of several kilowatts, the design required stringent surface and edge quality specifications. Another complication was the material, a very pure and

low loss, but very brittle type of fused silica.

With success in producing a different high-quality component for another business unit of the manufacturer, IRD was asked to review the new application for this custom designed, high-performance homogenizer.

IRD took on the challenge, investing in a dedicated production cell with custom fixturing, new processes, and training in both manufacturing and inspection. For precision optics, the ability to inspect and verify the quality is critical. With the particularly tight tolerances associated with high power laser systems and manufacturing of precision, high power laser optics take specific equipment and months of training.

IRD has demonstrated impressive results and thoroughly satisfied this demanding, quality-conscious customer. Out of a sample of 25 rods, the customer found only one chip on the flat and angled edges larger than 30 microns. And, that was after the component had been shipped to and manually inspected at the customer's European facility.



*Figure 2: Representative image of the end face of an octagonal homogenizing rod showing the absence of edge defects. Image was produced using bright field illumination and 100x magnification.*

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## A Reliable, Cost-Competitive Second Source

You may have a homogenizer design already in production. The design may be frozen and not be a candidate for IRD's design for manufacturability review. Nevertheless, you can still enjoy the benefits of IRD's ongoing investments in new process and inspection equipment, including those recently targeted at:

- reducing manufacturing costs through custom automation,
- increasing yields through more effective polishing processes, and
- providing higher precision inspection.

"The IRD philosophy is to control quality rather than inspect it."

There are plenty of examples of IRD's continuous improvement investments having paid off for its customers. For an automotive customer, IRD applied its latest process know-how with custom automated optical inspection equipment to become a sole source for multi-million parts per year volumes.

For another customer, volumes were not as high but quality requirements were even stricter. IRD created a dedicated production cell that leveraged fixturing and state of the art polishing processes to deliver consistent quality.

Customers benefit from IRD's teams and specialists focused on particular types of components such as high-performance homogenizers. Their teams bear responsibility for all aspects of production,

from ordering the raw material to shipping and everything in between, including coating.

IRD has proven that for high volumes, they can be price competitive even against stock solutions. IRD's reliable delivery – better than 98%– and flexible delivery scheduling, including KanBan deliveries, JIT, or VMI mean lower costs associated with inventory.

## Proven Reliability in Optical Component Manufacturing

IRD Glass has maintained a 'Zero Parts Per Million' (PPM) defect rate over the last several years and a 98%+ on-time delivery rate. Reports from customers in industries as diverse as aerospace, medical devices, telecommunications, and semiconductor equipment testify to IRD's position as a leader in precision custom optics manufacturing.

Contact IRD whether you are designing a homogenizer for a new application or have an existing design for which you are looking to develop a second source.

For your new homogenizer design, IRD will provide a no-cost Design for Manufacturability review and, if you wish, a cost estimate for prototype and production volumes. For designs that are currently in production, IRD engineers will show you the benefits of their consistent, industry-leading quality and on-time delivery for your components.

"Your biggest challenges are our biggest successes!"

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## About IRD

Minnesota-based IRD has been manufacturing precision glass and ceramic components since 1982. The company has two sites:

- IRD Glass in Litchfield, Minnesota - 20,000 square feet (2,000 square meters) with a 10,000 square feet (1,000 square meters) addition currently underway (2019).
- IRD Ceramics in Alexandria, Minnesota - 10,000 square feet (1,000 square meters).

The company's 75 employees proudly serve some of the most demanding global customers including Honeywell, TDK, Rockwell Collins, 3M, CyberOptics, Trumpf, Alcon, L3, and Agilent. Steady growth of 10% year-over-year for the last 5 years has come from long-term partnerships and strategic manufacturing agreements in which IRD has manufactured custom designs of optical components.

While the company does not design optical components, it works closely with its customers' designers and engineers to create designs that most cost-effectively and reliably provide the required performance.

Recently, IRD has expanded its manufacturing capabilities, including investments for sapphire windows, precision components and laser reflector cavities.

IRD is veteran-owned, ITAR registered and holds several certifications, including ISO 9001:2015, AS9100, and NIST 800-171.