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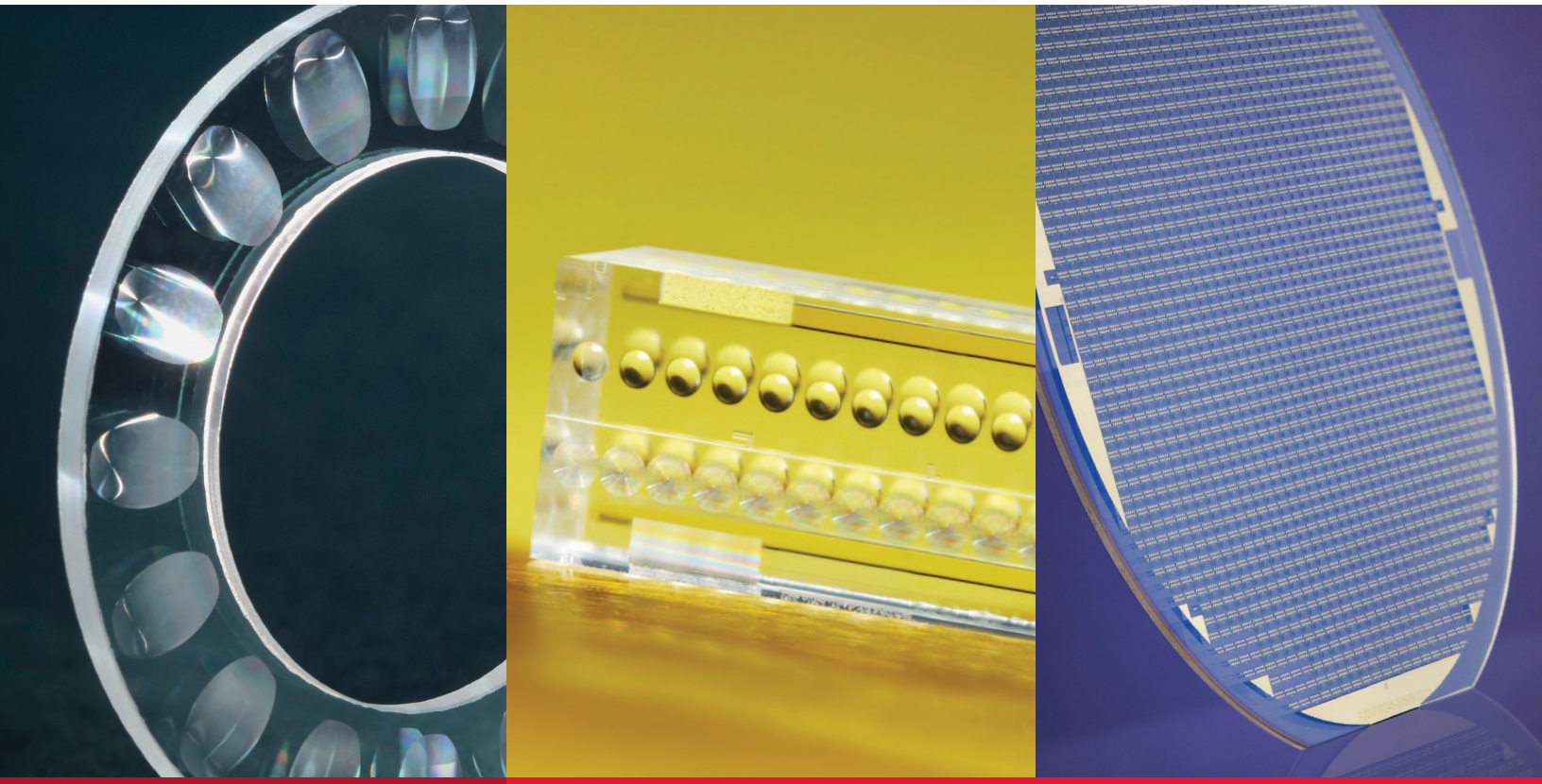
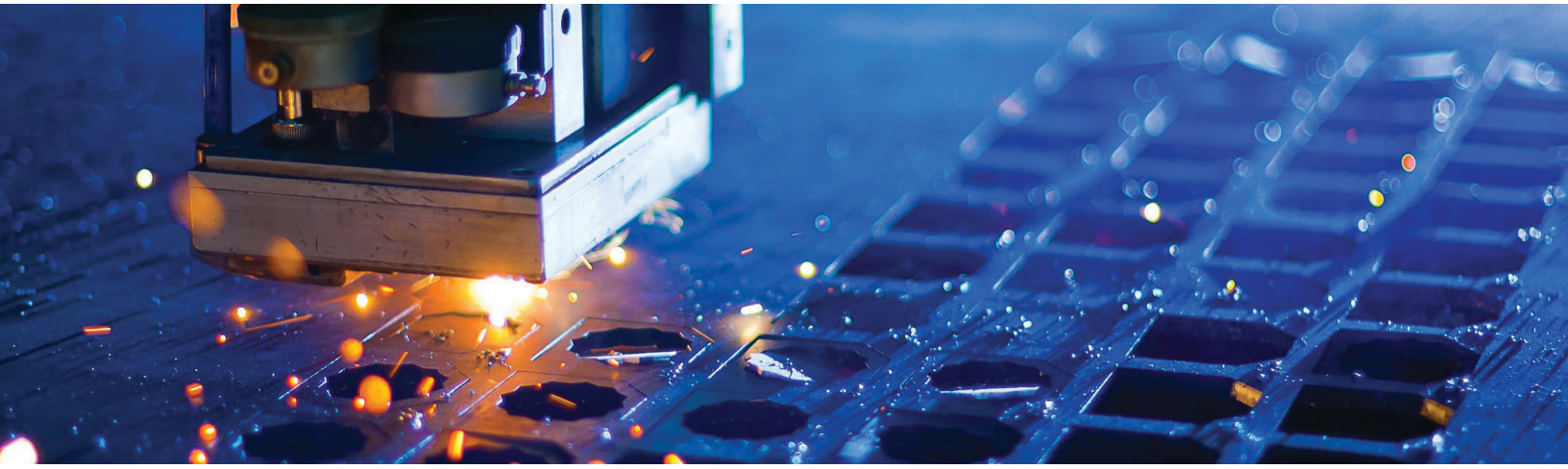


SOLUTION GUIDE

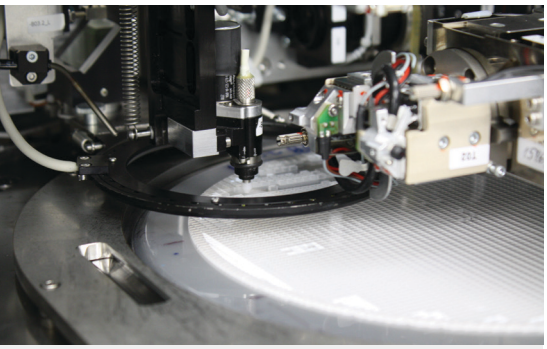
Greater Efficiency, Performance, and Cost Savings with Customized Micro Optics

Broadcom Digital Optics Solutions

broadcom.com



As optical technology continues to drive innovation, the demand for custom refractive and diffractive optical elements that meet specific performance, cost and volume requirements is growing faster than ever. To stay ahead of industry demands, Broadcom Micro Optics offers customized wafer-based passive optic solutions for next-generation communications, semiconductor, industrial, defense and medical applications. From design and optimization through high-volume manufacturing, Broadcom Micro Optics offers its customers outstanding performance, superior quality, and significant cost savings over more conventional technologies.



Broadcom Micro Optical Components Feature:

- Single-side and double-side wafer processing
- Diffractive and refractive optical elements (DOEs & ROEs) on the same die
- Patterned metalization for reflection, aperturing, marking, and attachment
- Dielectric AR and functional coatings
- A wide variety of materials, including specialty glasses, UV quality fused silica, silicon, and crystalline materials

Leveraging Precision Fabrication Technology

Broadcom combines the use of high-resolution lithography with precision glass etching to create customized, extremely robust, and high quality optical elements at wafer scale. Wafer-based manufacturing offers four distinct advantages over conventional manufacturing methods: Miniaturization, high precision, unsurpassed functional density, and reduced cost. By applying state-of-the-art semiconductor manufacturing methods to a variety of glass and crystalline materials, Broadcom is able to satisfy the requirements of even the most demanding optical applications. This unique tool set allows Broadcom to create precisely controlled features with sub-micron resolution. As a result, Broadcom's diffractive optical products are able to offer an exceptionally wide field of view with high optical efficiency and uniformity for applications like AR/VR, 3D mapping, and Lidar. As an ISO-certified manufacturer, consistent quality is assured. And our highly integrated manufacturing facility takes advantage of automated test and inspection systems to provide the maximum value at the lowest cost.

Superior Design Leads to Superior Results

As Broadcom Micro Optics manufacturing has led the steady advance in precision fabrication over the past two decades, Broadcom's optical design team has developed a suite of proprietary tools for quickly optimizing designs for both high performance and robust manufacturability. By integrating proprietary and industry standard design tools, Broadcom's designers are able to thoroughly explore the design space to find creative solutions to today's demanding optical applications. Combined with its state-of-the-art manufacturing facilities, Broadcom is able to deliver high-volume, cost-effective products with the unparalleled precision demanded by a variety of markets, including optical communications, semiconductor equipment, VR/AR, 3D mapping, high-power materials processing, industrial/machine vision, metrology, and medical.

High-Quality, High-Performance Diffractive Optics

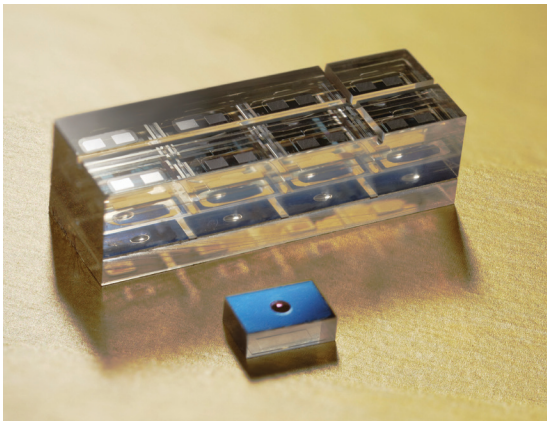
Broadcom Micro Optics Diffractive Optical Elements (DOEs) provide precise light control for a broad array of applications, including semiconductor lithography, optical targeting/positioning, 3D mapping, beam shaping, pattern generation, and source homogenization. Though traditionally designed for narrow band optical systems, Broadcom DOEs can also be customized to simultaneously cover multiple operating wavelengths such as in display and diffuser screen applications.

Defense and Security

Broadcom Digital Optics diffractive solutions address some of the most challenging applications in the defense and security sector, including heads-up display, night vision, LIDAR, and laser targeting. Commercial and defense aircraft rely on Broadcom products to allow pilots to visualize critical information in real time without the need to shift their field of view. The use of robust materials such as fused silica along with the monolithic structure created in Broadcom's manufacturing process provides for the highest reliability in these demanding environments.

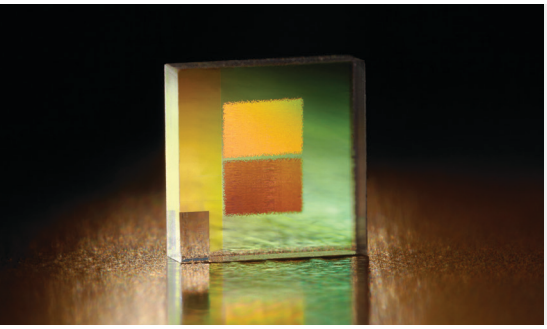
Illumination Systems

Customized diffuser elements are critical in optimizing illumination systems in high-performance lithography and manufacturing inspection tools. These solutions use controlled angle diffusers to enable optimum illumination of masks — minimizing feature size and maximizing the operating process window for the tool. For more than twenty years, and across multiple generation of semiconductor manufacturing nodes, Broadcom's custom diffusers have provided the precision illumination performance to support the steady advance of Moore's Law. Through continual innovation and a close partnership with the acknowledged leaders in the lithographic equipment industry, Broadcom's customized diffusers have continued to push the state of the art toward higher spatial resolution, more precise intensity control, and reduction of stray light. Broadcom low-stray-light DOEs suppress the diffractive scatter within the dark regions of the pupil providing higher contrast, reduced optical flare, and a dramatic improvement in the overall signal to noise ratio. One key to implementing these improvements has been the use of Broadcom's advanced DUV lithography, which has been demonstrated to reduce stray light by up to 60%.



Applications:

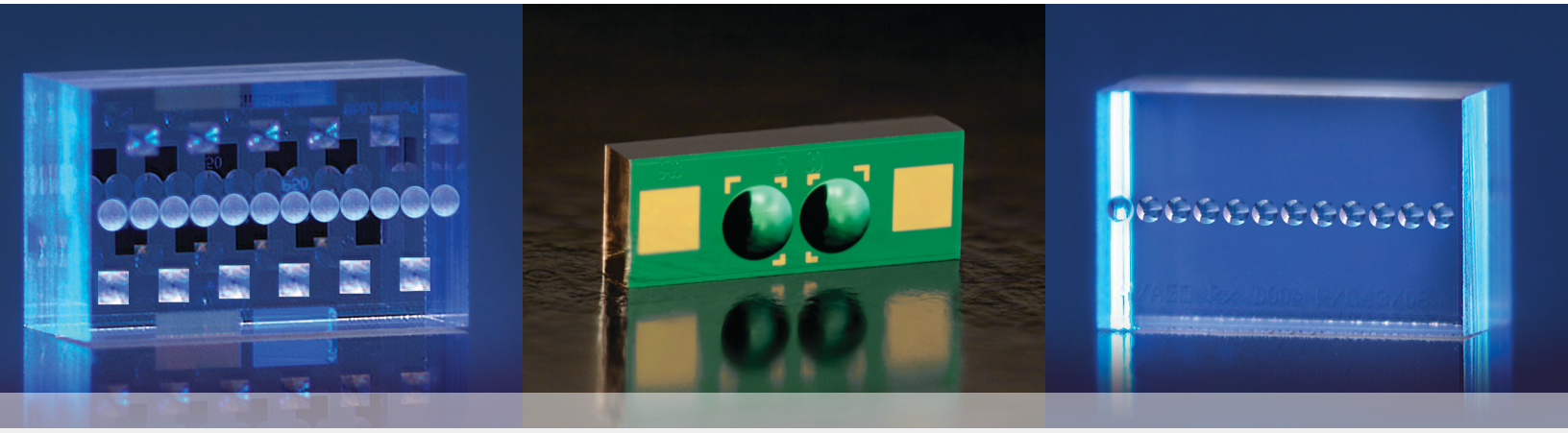
- Free-form designs for Source Mask Optimization (SMO)
- Off-axis illumination for optical/DUV scanners
- Custom illumination for reticle and wafer inspection equipment
- High-power beam conditioning for laser materials processing and surgical equipment
- 3D mapping/machine vision
- Head-mounted displays
- Ultra-compact imaging systems
- Optical sensors/metrology
- Missile guidance systems
- Near-field wavefront correction and beam shaping
- Advanced microscopy



Diffractive Optical Elements

- Diffusers
- Beam shapers
- Parallel optics
- Pattern generators
- Gratings
- Homogenizers
- Beam splitters
- Lenses (Fresnel and Vortex)
- Spot array generators
- Chromatic correctors

Achieve Superior Performance with Micro Refractive Optics



Refractive Optical Elements

- Spherical and aspherical lenses (Fused silica and Silicon)
- 1D and 2D micro lens arrays
- Single-sided and double-sided lenses
- Full fill factor lens array (Fly's Eyes)

Applications

- Datacom
- Telecom
- Medical
- Industrial and beam shaping

Through its pioneering use of wafer-level fabrication techniques, Broadcom Micro Optics has revolutionized the manufacturing of refractive optical elements, delivering significantly higher manufacturing efficiencies than traditional, grinding, molding, and polishing. Based on high-resolution lithography, this process simultaneously forms up to several thousands of lenses with submicron precision, guaranteeing an outstanding level of performance and thermal stability without the need for alignment of individual components. Direct etching into fused silica or silicon creates a structure of exceptional environmental performance with unmatched thermal, mechanical, and chemical stability. This ultra-precise process enables designers to create arrays of components on a single chip, adding mirrors, functional coatings, micro-labels, and registration features to the components. With a single-sided feature positioning accuracy of 0.1 microns and a back-to-front alignment accuracy of 5 microns, Broadcom's refractive elements provide unmatched unit-to-unit repeatability, functional density, and performance.

Integrated Micro Optical Elements Save Time and Lower Costs

By combining elements on both sides of a wafer, very high functional densities and complex optical paths can be created. Further integration of passive optical elements (mirrors, filters, gratings) at the wafer or die level enables significant package size reduction, cost savings and improved signal integrity. When further paired with Broadcom's active components (VCSELs, lasers, detectors, sensors), these integrated subassemblies offer low-cost solutions with optimized performance and outstanding part-to-part consistency. Broadcom integrated micro optics provide high-performance solutions in a wide range of applications, including optical communications and 3D mapping.

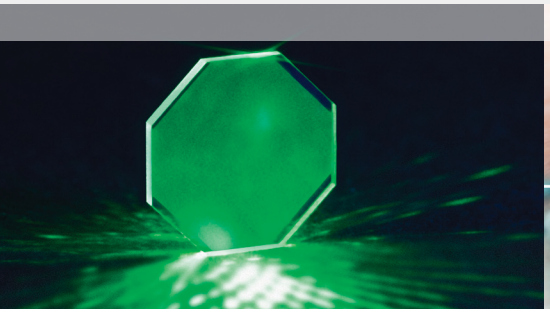
Parallel Optics

Broadcom parallel optics solutions enable optical interconnect designers to address the continuous market demand for higher-density, higher-data rate networking solutions. Broadcom patented lens technology provides increased bandwidth, reduces modal noise due to back reflection into the laser and attenuates the power of the launch, which is important for eye safety and signal regulation. Broadcom in-line source monitoring technology features real-time monitoring and adjustment of laser power for maximum efficiency. The monitoring technology is an integrated part of the lens element ensuring consistent performance and long term reliability.

Lens solutions for parallel optics include 1x12 Transmit, 1x12 Receiver, 4+4 Transceiver (for QSFP+ and QSFP28 applications), and 12+12 Transceiver (for CXP applications). All the transmit products can be outfitted with the Broadcom patented monitoring lens technology.

Advantages

- Lithographic precision alignment
- Volume scalability
- Small form factors
- High functional density
- State-of-the-art optical test and metrology
- Optical design expertise
- Robust monolithic parts



Specifications

Diffractive Optics	Key Performance Characteristics
Wavelength	193 nm to 14 µm
Materials	Crystal quartz, fused-silica, silicon, borosilicate glasses, germanium; other materials upon request
Pattern	Sub-micron patterning & alignment capabilities, single and double-sided
Die dimensions	0.5 mm to 125.0 mm
Projection Angles	Wide: up to 120° (full angle)
Coatings	Anti-reflective coating and metalization capabilities
Zero Order	Typically < 1.5%
Efficiencies	Up to 95%

Refractive Optics	Key Performance Characteristics
Wavelength	Materials and applications from 193 nm to 14 µm
Lens Materials	Fused-silica, silicon, IR materials
Lens Diameters	0.01 mm up to 10 mm
Lens Sags	<10 µm up to 100 µm
Wafer Sizes	150 mm and 200 mm

Broadcom Inc. is a global infrastructure technology leader built on 50 years of innovation, collaboration and engineering excellence.

With roots based in the rich technical heritage of AT&T/Bell Labs, Lucent and Hewlett-Packard/Agilent, Broadcom focuses on technologies that connect our world. Through the combination of industry leaders Avago Technologies, LSI, Broadcom Corporation, Brocade and CA Technologies, the company has the size, scope and engineering talent to lead the industry into the future.

Broadcom is focused on technology leadership and category-leading semiconductor and infrastructure software solutions. The company is a global leader in numerous product segments serving the world's most successful companies.

BROADCOM®
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AV-0303EN January 29, 2019