

I CIFICITION OF CONTRACT OF CONTRACT.

Wafer scale direct-write fabrication of precision micro-optics >>

sales@powerphotonic.com www.powerphotonic.com



- Short Manufacturing Process \rightarrow Rapid Prototyping
- Wafer Scale Production \rightarrow High Volume Low Cost
- Freeform Micro-Optics \rightarrow No Symmetry Restrictions
- Fused Silica Material \rightarrow High Power Handling

Contents

A World Leader in Laser Micro-Optics
Our Team and Technology4
Our Products5
Slow Axis Collimators (SAC) including Smile Correction5
Smile Correctors5
Beam Correctors for High-Power Diode Lasers5
VBG Lock Optimizers6
Fast Axis Collimators Arrays (FACA)6
Lens Arrays6
Freeform Optics
LightForge™ Rapid Fabrication Service8
Markets and Applications9
Industrial Laser Materials Processing9
Defense9
Optical Communications9
Medical and Scientific9
Customer Support
Reliable Supply
Quality and Test
About PowerPhotonic - "Enhancing Beam Performance"13
Contact Details

A World Leader in Laser Micro-Optics

PowerPhotonic is a pioneer in the use of laser micro-machining for the manufacturing of precision micro-optics products for laser and optical applications.

PowerPhotonic Ltd. was formed in 2004 to commercialize the technology from fundamental research undertaken at the world renowned Institute of Photonics and Quantum Sciences at Heriot-Watt University in Edinburgh. With operations in the United Kingdom and North America, we are well positioned to support companies across the globe.

Suppliers have traditionally used lithography, micro-grinding and micro-molding to manufacture a wide range of laser micro-optics products. However, there are intrinsic limitations with these techniques. Time to first prototypes is lengthy; new designs are expensive to set up; and there are limitations in the range of surface forms and levels of surface roughness that can be achieved.

The PowerPhotonic laser micro-machining technology overcomes these issues. And these advantages apply not only to our standard products. These benefits are leveraged in our custom design and manufacturing service and the LightForge[™] rapid fabrication service.

The PowerPhotonic manufacturing process is based on a laser system that shapes and then smooths the refractive surface of fused silica glass. This gives us unprecedented flexibility to create a complete range of standard products including slow and fast axis collimators, lens arrays, beam shapers, transformers and correctors, as well as offering a cost effective custom micro-optics fabrication service called LightForge[™].

The new LightForge[™] rapid fabrication service is revolutionizing the purchase of custom microoptics. Up until now, the specification, ordering and supply of new micro-optic components has been an expensive and time-consuming process, involving design and drawing review, long fabrication lead-times and substantial NRE. By standardizing component specification, shortening lead time for custom parts and removing the need for NRE, LightForge[™] has created a new paradigm in micro-optics manufacturing. Customers are able to create innovative new freeform surfaces, test new ideas and verify designs for production without incurring expensive upfront engineering charges and lengthy prototyping lead times.

PowerPhotonic's business is underpinned by two decades of fundamental research and development and a growing portfolio of patents. Combined with a team skilled in the art of designing, manufacturing and testing high performance **laser optics**, we believe that **PowerPhotonic is your ideal solutions partner**.





PowerPhotonic Inc. Headquarters, North America



Our Team and Technology



Laser micro-optics are manufactured using a range of conventional techniques such as micro milling, greyscale lithography and molding, each of which has its own inherent limitations. Lead times for first prototypes, oneoff charges for new designs and process restrictions all impact on how readily new micro-optic designs can be evaluated and implemented in laser systems.

PowerPhotonic's products are manufactured using a unique and patent pending technique based on laser micro-machining. A high-precision laser milling process first generates the required net-shape in a fused silica substrate, and then a second laser process generates an ultra-smooth, low-scatter, refractive surface.

There are many advantages intrinsic to this direct-write

freeform fabrication process. It can be used to generate single lenses, lens arrays, aspheres and acylinders, beam shapers or any other refractive optical surface. Multiple functions can be integrated into a single optic, for example a diode laser slow-axis collimator array can also incorporate smile correction. This reduces component count, assembly and test time. Multiple parallel components can be integrated onto a single substrate, for example in our fast-axis collimator arrays, bringing further benefits in manufacturing cost and reliability.

New designs can be realized quickly, without incurring NRE charges for mask sets or hard tooling, and multiple design variants can be fabricated in parallel, shrinking the design cycle time. The wafer-scale process enables successful designs to be taken directly from prototype, through rampup, to volume production without the need for design or process change. Our optics are fabricated in fused silica, ideally-suited to demanding applications, particularly those involving high power CW beams and high fluence pulsed beams.

We provide our customers with the easiest possible path from design to fabrication, manufacturing optics directly from surface profile data in industry-standard formats, providing tools to generate this from CAD packages such as Zemax. This ensures complex optical designs are faithfully realized, and minimizes the need for design and drawing reviews.

PowerPhotonic's revolutionary technology builds on two decades of research and development, giving us market-leading insight into both laser-based fabrication of micro-optics and micro-optics design, allowing us to offer a complete range of services from build-to-print through to designing and realizing parts to our customers' functional specifications.



Our Products

PowerPhotonic manufactures a range of standard products suitable for use right across the microoptics community; for the materials processing, medical systems, and optical communications industries; for big science and the industrial R&D sector; and for defense applications. Our product development is aimed at ensuring we stay ahead of the competition and remain as the industry's foremost leader in delivering innovation, functionality and performance.

Slow Axis Collimators (SAC) including Smile Correction



Our slow-axis-collimator optics minimize the slow axis divergence of diode laser bars and stacks. They consist of a monolithic array of lenses and are available in a range of standard sizes. Our unique laser micromachining process means that additional functionality can easily be included at minimal cost to further shape and manipulate the beam in both fast and slow axes. Our SACs can also be specified with built-in smile correction or wavefront correction.

Smile Correctors

The brightness achieved by fast-axis collimation of diode laser bars is typically limited by micronscale deviations from flatness of the mounted diode bar, known as "smile". Our smile correction products compensate the systematic effects of smile by effectively applying a separate fast-axis deflection correction to the collimated beam of each individual emitter in the bar. When smile is consistent from bar to bar, a single design of smile compensator can be used for all bars. Where bar-to-bar variation in smile is larger, select-on-test smile compensators can be used to effectively eliminate smile. Smile correction reduces the fast-axis divergence of the collimated bar, maximizing power coupled into optical fiber and optimizing the sharpness of a line focus. Smile correction also dramatically improves the locking efficiency and locking range of VBG-locked diode lasers.

Beam Correctors for High-Power Diode Lasers

In contrast to our smile correctors, which tackle systematic smile effects, our beam correctors for High Power Diode Lasers null the laser beam wavefront error restoring the intrinsic ex-facet brightness of the laser beam. Our products provide near-diffraction limited performance in fastaxis collimated beams by decreasing beam divergence, improving beam homogeneity and coupling power, improving laser beam brightness by between 2 and 10 times. Our direct-write fabrication process allows us to economically fabricate a custom correction optic for each bar or stack, based on wavefront scan or beam profile measurement data provided by the customer.



VBG Lock Optimizers

When volume and surface gratings are used to lock the wavelength of diode laser bars, locking efficiency and locking range are critically-dependent on emitter-FAC alignment. Micron-scale misalignment due to bar smile dramatically reduces the feedback from the grating to the emitter, reducing the locking efficiency and locking range, and greatly slowing the grating alignment process.

PowerPhotonic's VBG lock optimizers are beam correction phaseplates that are specifically designed for the task of optimizing performance in wavelength-locked applications, implementing the wavefront corrections that have the greatest impact on wavelength-locked performance and which offer the most straightforward system alignment.

Fast Axis Collimators Arrays (FACA)

High power laser diode laser stacks are typically collimated by individually aligning a discrete fastaxis collimator lens to a specific bar, applying and curing adhesive, and repeating this cycle for each bar in turn, resulting in a lengthy overall lens attach process. For tight-pitch stacks, with bar pitches of 500µm or less, independently aligning and mounting several lenses is also a significant challenge in precision engineering high density packages.



PowerPhotonic's fast-axis collimator arrays solve both these problems by collimating the entire diode stack with a single monolithic element, reducing the lensing process to the alignment and attach of a single optic. This extremely robust and compact lens array offers a scalable route to high-volume assembly of collimated stacks, and provides a practical lensing solution for bar pitches as low as 350µm. Our FACAs are typically used in SSL pumping and illumination applications requiring output divergences in the range 3-10°.

Lens Arrays

PowerPhotonic offers a wide range of standard and custom lens arrays, with high uniformity of RoC, conic constant and pitch. All lens parameters can be customer-specified: spherical, aspherical, astigmatic or acylindrical lenses can be arranged on a linear, square, hexagonal or arbitrary grid. Both single-surface and dual-surface lens arrays are available, enabling free choice of PCX/PCV/BCX/BCV and meniscus configurations. Typical applications include diffusers, homogenizers and fiber-array collimators.



Freeform Optics



Obtaining a freeform optic from PowerPhotonic is more than just working with a trusted partner to manufacture a special product. It starts with our desire to really understand our customer's requirement and creating a solution that maximizes the optical performance and costeffectiveness of the complete system. We offer a portfolio of services ranging from build-to-print fabrication through to complete optic design, realization and verification, all based on our world-

class skills in micro optic design, fabrication and test.

PowerPhotonic's direct write fabrication process can be used to manufacture optics with no symmetry restrictions, giving the designer complete freedom to create new types of refractive optic. Unlike alternative approaches that use complicated and costly manufacturing processes, our patent-pending laser micromachining process is capable of delivering results quickly and cost effectively, allowing custom optics to be used in a much wider variety of scenarios than has hitherto been the case.

We can create complex optics integrating arrays of multiple aspheres and prisms or generate any arbitrary surface profile. Complete monolithic arrays of optics can be created to reduce assembly cost and complexity with little extra effort.



There are several different ways to engage with PowerPhotonic's custom design service. We can fabricate an optic to a customer drawing or, leveraging our expertise in laser systems, we can design an optic to meet specific system performance targets. Alternatively, we can help target a customer-designed optic onto our laser micro-machining manufacturing process. Whichever path is chosen, PowerPhotonic's team of engineers will be there every step of that way, with in-depth consultations and design reviews to ensure that you get the best performance possible.



LightForge[™] Rapid Fabrication Service

For many years, optic designers requiring new lens arrays or freeform optics have faced the challenges of high NRE, long lead times and detailed technical communication with vendors, so that designs which would benefit from application-specific optics are often tackled with standard catalog products. This leads to laser optics systems that have multiple performance compromises, including brightness and power efficiency degradations. With LightForge™, designers can simply upload their design to the PowerPhotonic web portal using data output from a number of industry wide optic CAD packages such as Zemax. After upload, the optic design is compared with the LightForge™ design guidelines to ensure compliance, and a physical layout generated for verification by the designer.



This process is completely automatic. Once the designer is happy with their design, there is a simple sign-off and ordering procedure before the part goes into manufacturing

Using LightForge[™], optic designers have the ability to create innovative new freeform surfaces, test new ideas and verify designs for production without incurring expensive upfront engineering charges and lengthy prototyping lead times.

The new LightForge[™] offering from PowerPhotonic can be used to create a very

wide range of refractive optical elements, from generic functions such as beam transformers and microlens arrays, to unique components such as diode laser smile correctors, wavefront



compensator phaseplates and completely custom surface shapes. The scope of what can be done is limited only by the designer's imagination. The LightForge™ product comes with a variety of options including a broadband anti-reflection coating and a mounting option that enables quick and easy deployment using industry-standard 2-inch diameter lens mounts.



Markets and Applications

Industrial Laser Materials Processing

PowerPhotonic offer a wide range of optics for collimation and beam shaping in high power lasers for material processing. Our slow-axis collimators and smile correctors are used to increase brightness in HPDL-based systems, and our HPDL beam correctors offer the highest achievable brightness for the most demanding applications. We also provide systems for HPDL beam symmetrization, to maximize fiber-coupled efficiency. Our homogenizers and diffusers combine high beam uniformity with high efficiency. For high-brightness SSL and fiber-laser systems, our beam shapers can produce application-specific intensity profiles without loss of power, maximizing overall process efficiency.

Defense

The defense industry faces a constant challenge to deliver higher brightness and higher power in a smaller and more efficient package. Critical to this demand is the ability to improve the brightness of the laser without additional power or cooling. Our products have a particular advantage as each laser optic can be individually tailored to correct for specific pointing, defocusing or aberration problems. Our beam corrector products maximize the brightness achievable from diode laser stacks, and can incorporate additional functions, such as slow-axis collimation and correction for optical system aberrations, in order to realize the brightest, most compact stack solution. Our fast-axis collimator arrays, in contrast, are catalog products that provide an extremely robust and compact collimation optic for space-critical applications.

Optical Communications

Multi-channel optical communication systems require lens arrays for coupling between laser sources, fiber and waveguide arrays, optical multiplexing and optical switching. Our lens arrays are the ideal lens solution, providing a precise and monolithic component for array collimation and coupling. Made from synthetic fused silica, these lenses entirely avoid the need for polymer or epoxy in the optical path, offering a high-reliability solution for demanding optical communications applications.

Medical and Scientific

New applications for lasers in medical devices and scientific research require beams with wide range of properties. A single optic from PowerPhotonic can often replace a cascade of off-the-shelf lenses, beam shapers and correction optics, or provide functionality that is simply not achievable via any combination of off-the-shelf optics. Also, with our unique wavefront measurement process, our beam correctors can provide HPDL collimation performance close to theoretical limits, for the most exacting high-power applications. Our freeform optics offer unlimited scope for beam shaping and transformation. And our LightForge[™] rapid fabrication service allows new designs to be implanted and evaluated in short timescales, on tight budgets.



Customer Support

PowerPhotonic is more than just the products we manufacture and sell. In additional to our world-class range of standard products, the company prides itself on the depth and breadth of its engineering expertise that is accessible to our customers.

We don't compete with our customers and as a consequence, we are valued by our customers to provide impartial technical advice on how to optimize the complete optics solution, not just our part of it. And that is what sets us apart from the competition.



We offer customers a complete optics design service that begins when we first engage on a new project and finishes when the product has been successfully introduced to production. Our sales and technical support teams are staffed by knowledgeable optics engineers who can help customers evaluate, test and qualify new designs at all stages of the development process.

PowerPhotonic's unique freeform optics products leverage several key technologies and expertizes within the company. For example, our wavefront mapping and beam profile analysis technologies allows us to design and fabricate beam correction phaseplates that perfectly match a customer's stack, without the stack leaving the customer's production line.

And because we have a prototype turnaround time of as little as two weeks, we

can often provide solutions to address optical performance issues that would otherwise only manifest themselves very late on in the development process.

Due to the unique nature of our manufacturing technology, PowerPhotonic is well positioned to support our customer's supply needs from small prototype runs through to mass production. We don't have a long supply chain and this gives us the ability to respond rapidly to changing requirements.



Reliable Supply

PowerPhotonic is committed to supporting the delivery needs of our customers for both one-off bespoke solutions and high volume production programs. This commitment is a core principle of the company, one that is at the center of everything we do.



Our unique manufacturing process, which is common to all of our products, allows us the flexibility to respond rapidly to changing manufacturing demands, with a high degree of scalability. It also allows us to offer pre-coat lead times of less than two weeks for many of our products, even if they are out of stock.

Our wafer scale production facility is fully automated and is capable of running 24/7 to support customer volume requirements. With no hard tooling to wear out, our optics are highly repeatable, delivering excellent performances on a consistent basis from batch to batch.



Quality and Test

The objective of the PowerPhotonic quality management program is to ensure that all aspects of our business surpass the requirements of our customers, from the intrinsic quality of the product to all aspects of customer support. Our quality system is centered on proven industry standards, consistent with the international standard "ISO 9001:2000 Quality Management Systems Requirements". This system is central to how we manage our business, from product inception through to product delivery and support. It also extends to all our suppliers, who are an integral part of our business. Our sub-contractors are ISO 9001:2008 and ISO 14001 certified. Our aim is to ensure that we are trusted by our customers to provide high levels of quality and reliability for our products.

Particularly for our custom design and fabrication services, we work very closely with the customer to ensure maximum clarity when it comes to understanding the correlation between the simulation on the optic CAD package and real life performance. We want our customers to clearly understand the benefits of using our products before they get them. This is our commitment; to not only the quality of the product but also the quality of the relationship between ourselves and the customer.

PowerPhotonic's products are manufactured in a class 1000 cleanroom facility and 100% tested to ensure that the delivered product conforms to our specification or to a customer supplied drawing. Knowing that each optic is 100% tested puts our customers' minds at rest when it comes to the determining the quality of the product. For extra security, every product can be supplied with a certificate of conformance, confirming the individual performance parametrics of the PowerPhotonic optic.



About PowerPhotonic - "Enhancing Beam Performance"

PowerPhotonic is a global leader in the design and manufacture of precision micro-optics. Our business was founded with the objective of providing unsurpassed excellence in all aspects of micro-optics product realization for laser applications. Our world-class design skills are supported by an innovative and flexible manufacturing process that allows the company to design both a broad range of state-of-the art industry standard laser micro-optics products and, uniquely, to offer a low cost rapid fabrication service for creating completely freeform optical surfaces.

Founded in 2004 and headquartered in the United Kingdom, the PowerPhotonic engineering team has developed many unique technologies that allow the company to produce a wide range of precision micro-optics that cannot be economically produced by using traditional glass molding or machining techniques, with higher efficiency, superior performance and increased functional integration.

Our focus today is on providing solutions for diode laser and high power laser applications, principally for the materials processing, medical systems, optical communications and defense industries. In addition, as experts in micro-optic technology and supported by our unique fabrication process, we are well-positioned to create products that solve many of our customer's real world problems, problems that cannot easily be addressed using traditional manufacturing techniques. This means that PowerPhotonic is uniquely positioned to meet the challenge of delivering world-class solutions for ever higher brightness, more power-efficient and more compact laser applications.



Contact Details

United Kingdom Headquarters

PowerPhotonic Ltd. 1 St. David's Drive Dalgety Bay Fife KY11 9PF United Kingdom

Tel: +44 1383 825 910 Fax: +44 1383 825 739 sales@powerphotonic.com

North America

PowerPhotonic, Inc. 4900 Hopyard Road, Suite 100 Pleasanton, California 94588 USA

Tel: +1 925 463 4876 Fax: +1 925 475 7422 sales@powerphotonic.com





SNRIGH

2288

sales@powerphotonic.com www.powerphotonic.com