Polymer Micro-Optics for Today's Compact Photonic Devices

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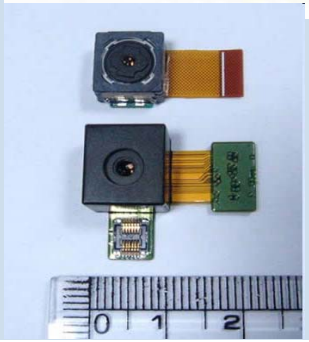
As the world markets push towards miniature, pocket-sized, compact devices requiring optical components, size matters.

Consumer Electronics

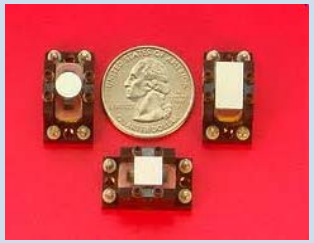
Optical Mice

Pico Projectors

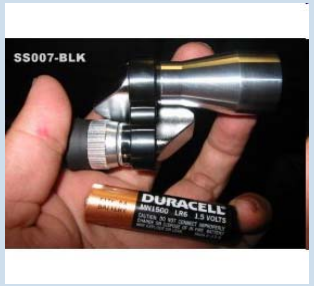
Cell Phone Camera Modules



Scanners



Surveillance & Security



Optical Encoders

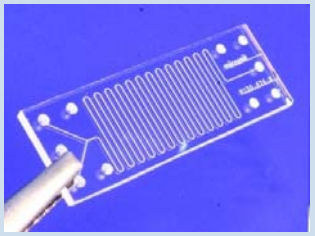
Size matters……

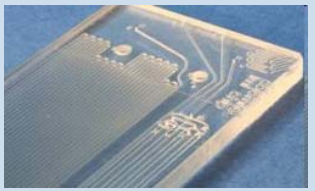
Health Care & Life Science

Endoscopes

Ophthalmology

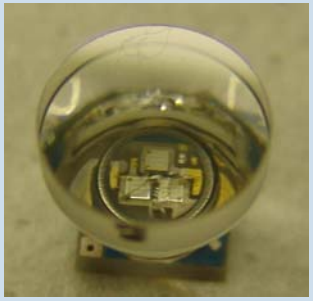
Micro-Fluidic

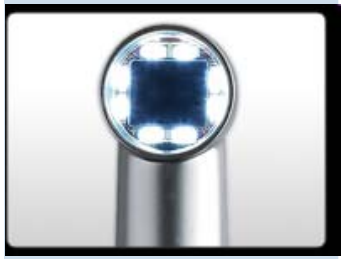




Bio-Sensors

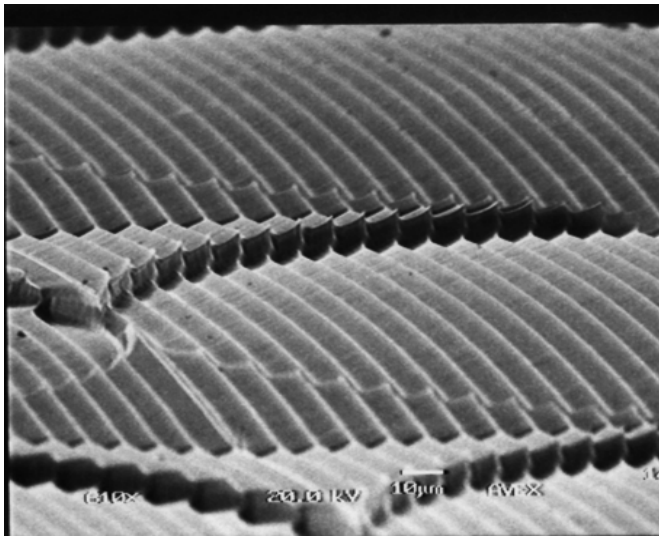
Dental Appliances





What is Micro-Optics?

Micro-optic is a term that can be used to describe optical components with small overall dimensions, or optical components that are physically large, but with small optical features.



JENOPTIK Opto-Electronic Systems

Specialize in the manufacture of polymer based micro-optics components and systems of both types.
Here I will highlight the unique challenges and technologies associated with the manufacture of these small components and assemblies.

Plastic optical components with small overall dimensions

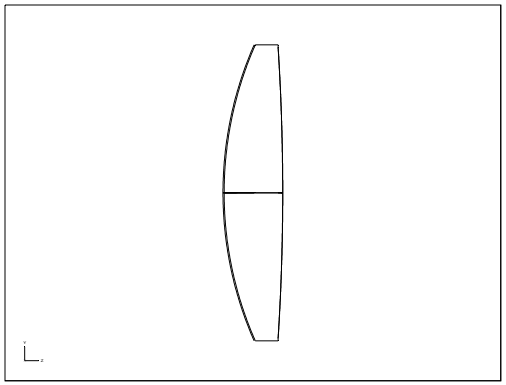
- Lenses
- Prisms
- Beam splitters
- Light Pipes

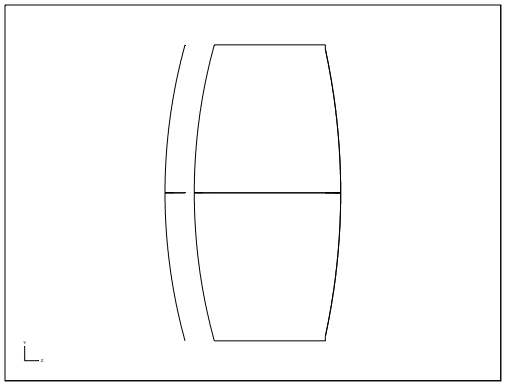
Although the optical surfaces of these components are small, it is the impact on mechanical tolerances of scaled down optical components that present unique challenges for manufacturing.

Absolute mechanical tolerances easily attained and suitable for larger optical components may be insufficient for their smaller counterparts.

Comparison of Mechanical Tolerances
Center Thickness (CT)

0.020 mm error is shown 10x for visualization





Lens is Magnified: 25x

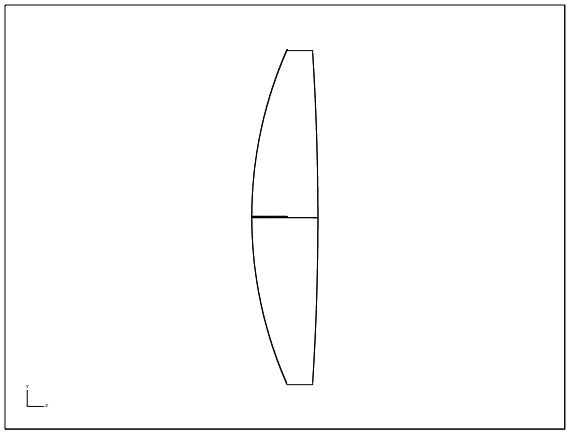
- Focal Length of 100 mm
- Diameter of 50 mm
- 10 mm center thickness

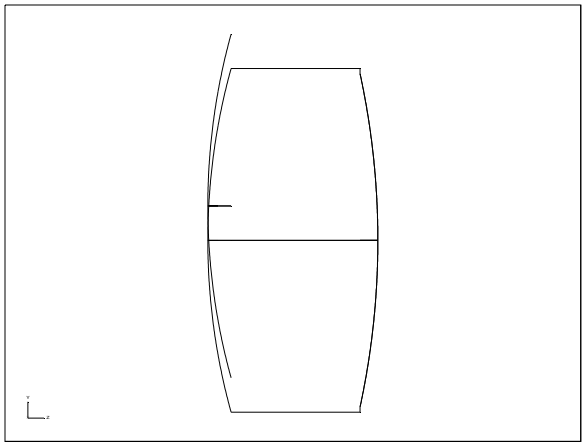
- Focal Length of 4 mm
- Diameter of 2 mm
- 1 mm center thickness

A typical center thickness tolerance of +/- 20 µm corresponds to a much greater percentage of error for the smaller, thinner lens when compared to that of its larger counterpart. This often translates to a more severe impact on lens performance, unacceptable for most applications.

Comparison of Mechanical Tolerances
Center-to-Center Displacement (CCD)

0.020 mm error is shown 10x for visualization





Lens is Magnified: 25x

The same is true for center-to-center displacement between the front and back optical surfaces of miniaturized lenses. Asymmetric errors such as this are often the most critical to control in a lens assembly. A typical tolerance of 25 – 30 microns can consume 10% of the semi-diameter of a micro-optical element, which is unacceptable for many applications on this scale.

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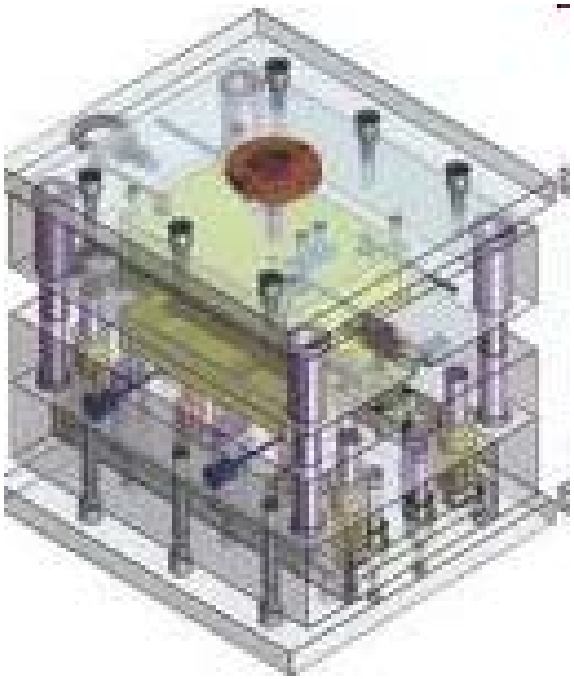
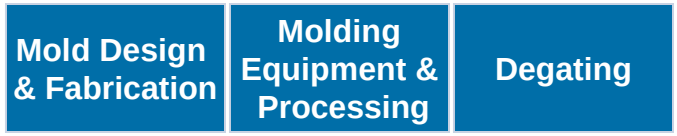
Proprietary Tooling Technologies

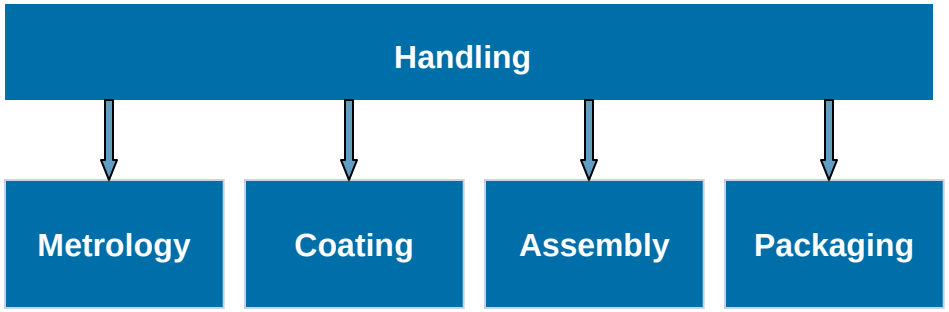
To address these challenges, Jenoptik has developed proprietary tooling technology designed and build within our injection molds that allow for independent cavity adjustment of the center thickness, and precise alignment of the optical surfaces of a lens to within 2-3 microns.

Although this tooling technology is significant for miniature lens manufacturing, it can be incorporated into molds for the manufacture of lenses of all sizes.



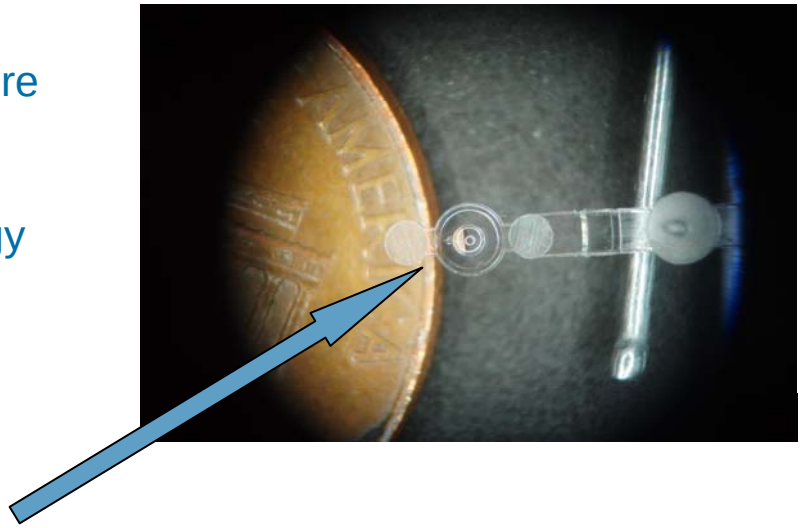
Addressing the full manufacturing process chain





Manufacturing challenges of micro-optics extend beyond the tight mechanical tolerances that require non-conventional tool construction.

The molding process parameter control, metrology equipment capabilities, and the handling after molding must always be considered.



Equipment & Processing

Precise control of the shot size, or volume of resin injected into the mold at each cycle is essential to maintaining the accuracy and repeatability of the component manufacturing shot-to-shot, run-to-run.

Micro-molding machines are specifically built with injection units designed for shot control when molding lenses weighing < 1 g. Shown here, the Desma press is designed specifically for shot sizes of 10 - 20 mg.

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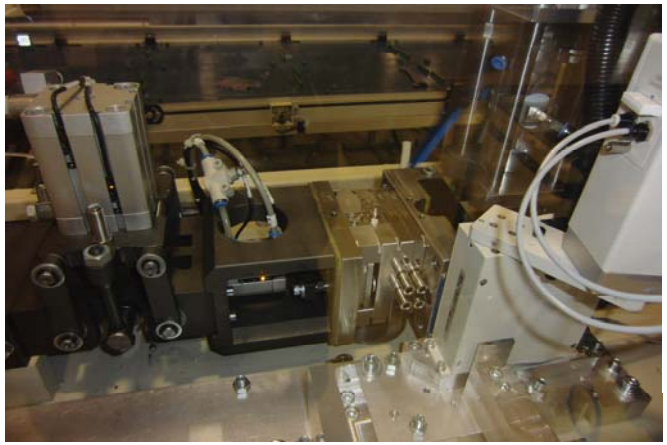

Handling

Imagine manually removing of a <1 mm lens from a runner, maintaining orientation and placing that lens into a barrel all without touching the optical surfaces or introducing environmental contamination to the element.

Jenoptik applies a hands-off approach to the manufacturing of molded micro lenses.

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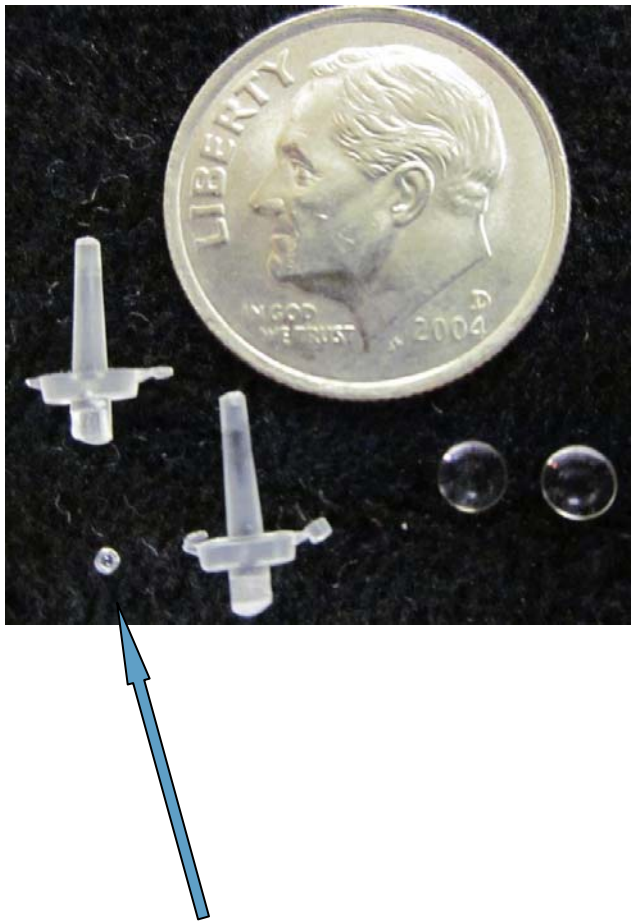
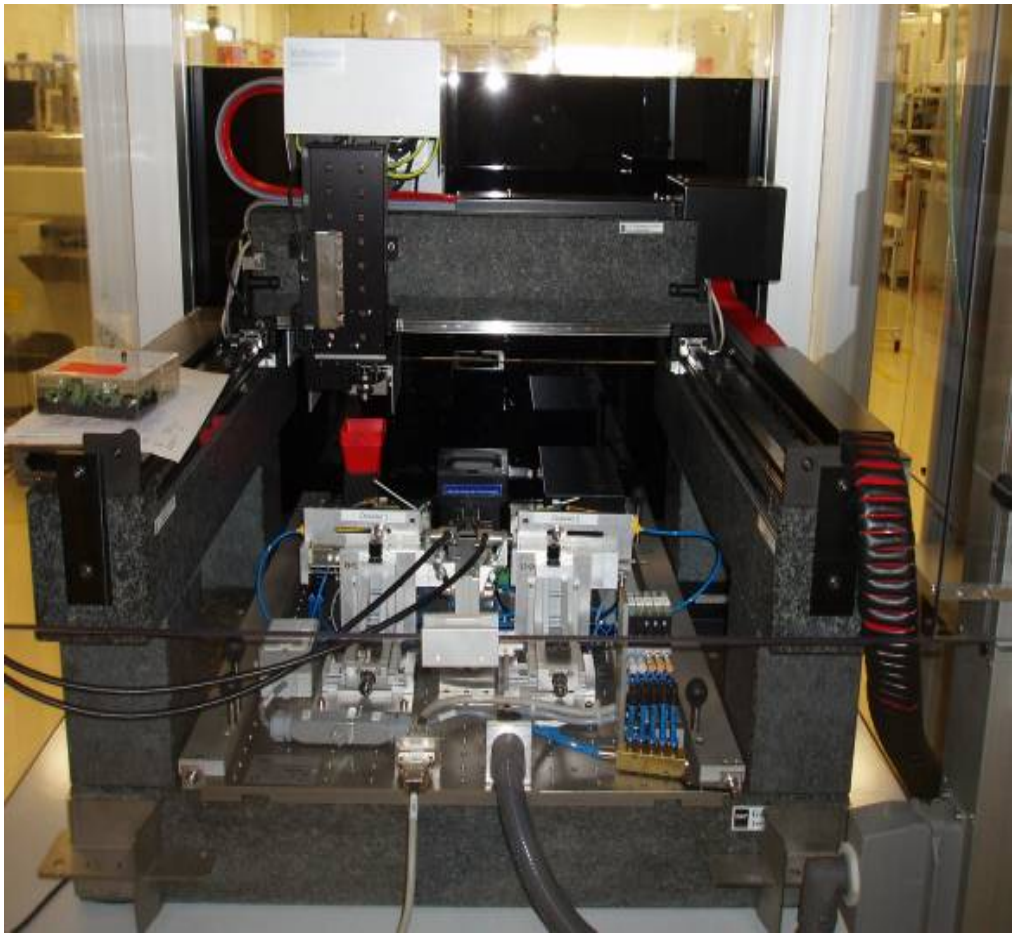


Hands-Off Assembly

Shown here is our fully automated ‘modular’ assembly cells that allow for quick interchangeable platforms to accommodate many different assembly configurations from a single machine.

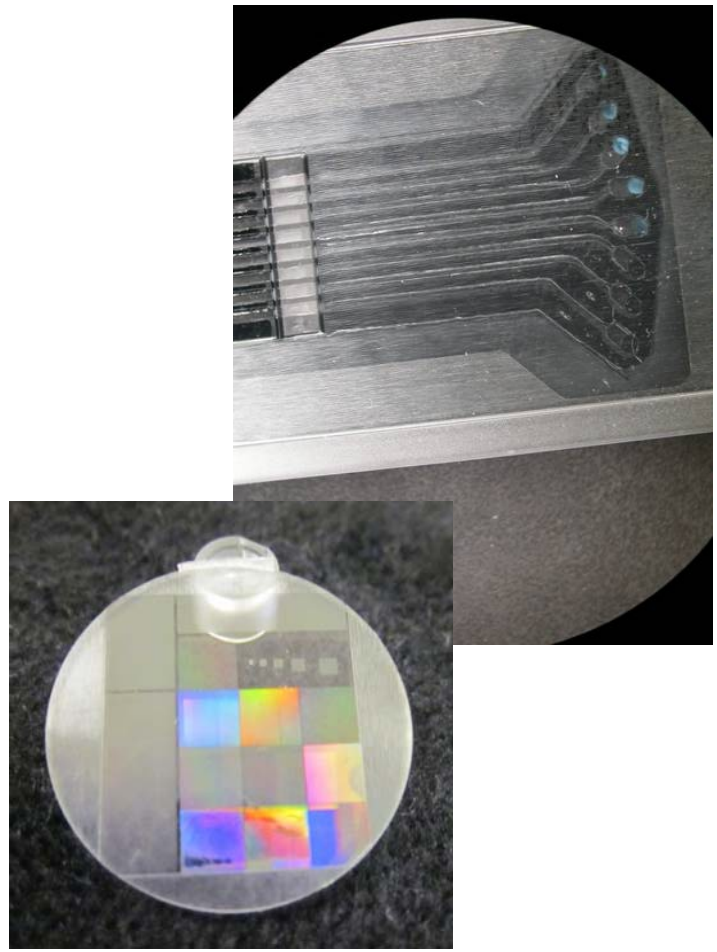


Micro-size features on plastic optics

The second ‘type’ of micro-optics are lenses with small optical features.

These type can be;
- refractive elements with individual apertures on the order of tens of microns up to 1 mm,
- diffractive micro optics have patterns on the micron scale

Here the accuracy of the optical surfaces are the most critical detail, and the fabrication process for the optical mold inserts presents the largest challenge.



Ultra Precision Manufacturing Technology

The features are machined directly onto the base curve of the tool insert with our ultra precision manufacturing technology allowing for the manufacturing of complex high precision free-form and non-rotationally symmetric structured optical surfaces.

The diffractive (or similar) pattern can be spherical, aspherical, cylindrical, torical or free form.

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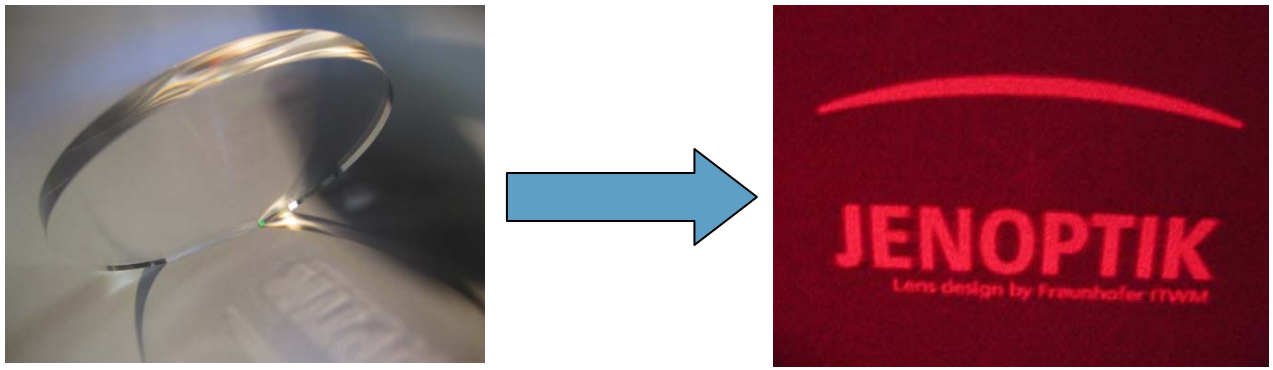
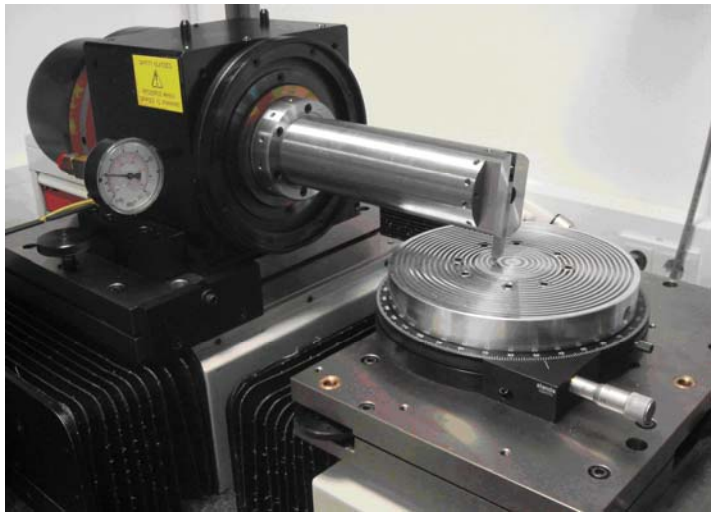
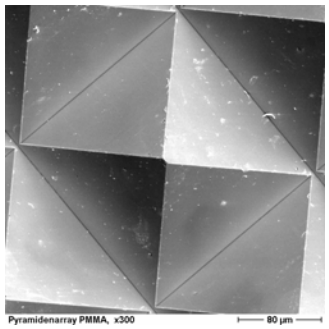


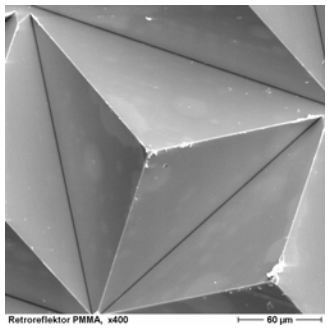
This lens is designed to bundle and form parallel light for projection of, for example, a logo on the image plane.

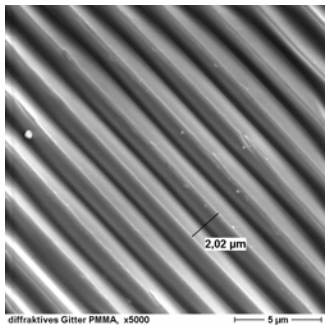
Ultra Precision Fly Cutting Technology

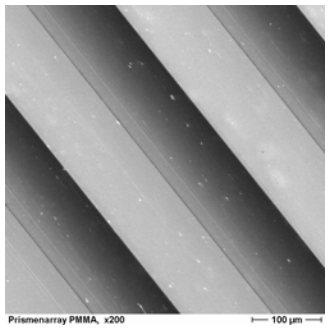
- Diffractive Gratings
- Cylindrical array
- Prism Array
- Pyramid Array
- Retro-reflector Array

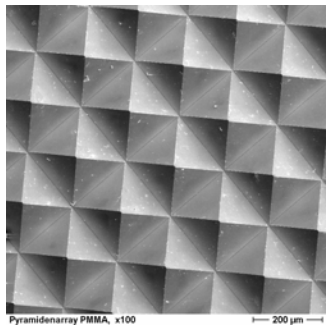












Gray Scale Photolithography Manufacturing Technology

When the feature size or aspect ratios of the features do not our permit ultra precision machining, grayscale photolithography technology can often be used for the mold insert.

This technology enables the fabrication of precise and arbitrarily shaped 3D microstructures including curves, ramps and torroids.

Here the diffractive or refractive features are generated in photo-resist, followed by an etching process that then transfers the pattern into a substrate used to produce the tool master for the injection mold.

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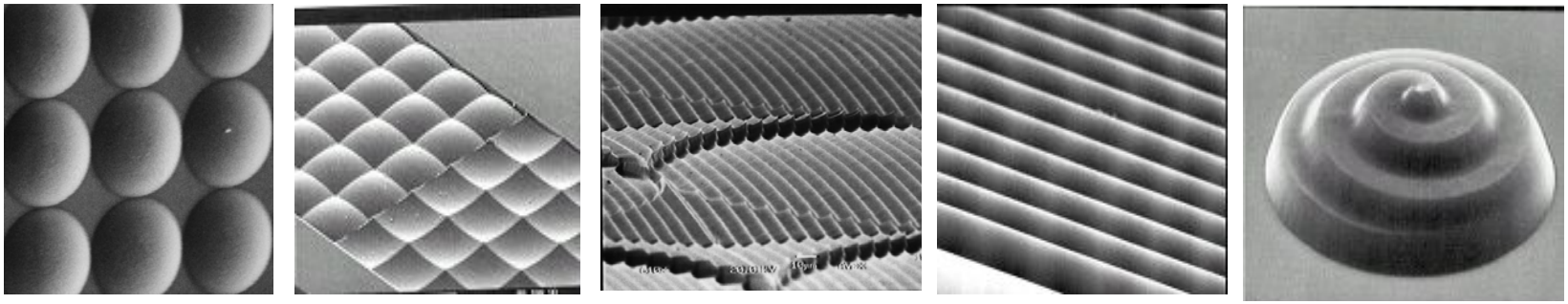


SEM pictures of shapes created with our gray scale technology that can replicated in plastic optical components with our injection molding process.

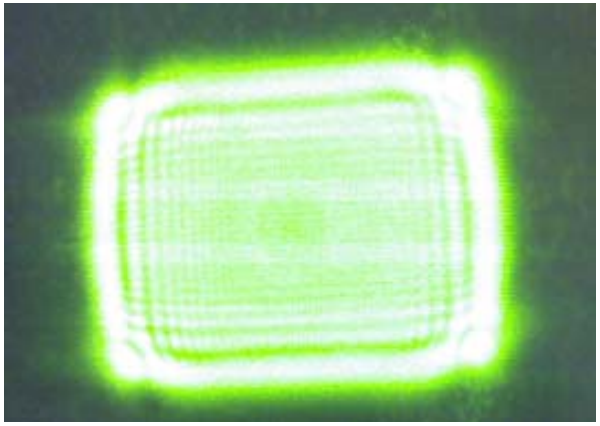
MLA Manufacturing

In response to the increasing interest in micro and pico projectors JENOPTIK introduced the development of injection molded double sided micro lens arrays (MLA).

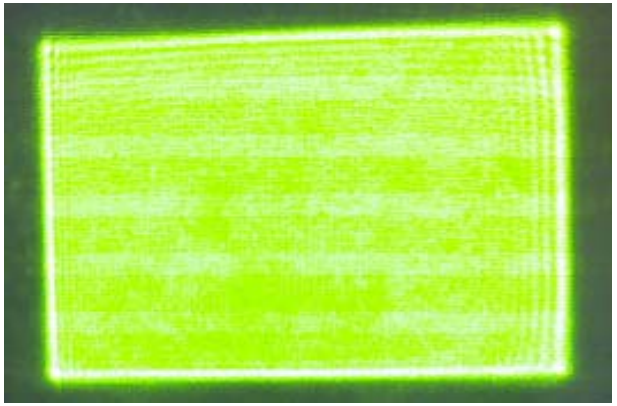
Here again our proprietary tooling technology allows us to align each lenslet in the array, to within 2-3 microns.

MLAs enable homogenization of laser sources and beam guidance in projection systems in a single component.

- significantly sharper imaging configuration
- excellent uniformity
- high efficiency
- less diffractive effects compared to a single sided approach as shown in the pictures below.



Far field pattern from a single-sided MLA



Far field pattern from a double sided MLA

Plastic Versus Glass – The Ongoing Consideration

As the market expands and the demand of modern optical applications increase, the perception of utilizing injection molded plastic optics is changing. Polymer based optics are now found in a broad range of products and the push towards green energy is also driving the need for plastic optics, whether for solar concentrator or solid-state lighting components.

Another advantage to note are the design freedoms that are easily achieved in injection molding over conventional glass optics manufacturing techniques.

Mounting and alignment features can be integrated into the optical components eliminating the need for additional components and assembly steps.

Unique cosmetic, functional filter, and other properties can be added or enhanced to improve the properties of the raw molding resin.

Polymer Optics Limitations

Plastic optics are certainly not without their limitations.

- Cannot be efficiently cleaned nor economically feasible
- Compromised by exposure to extreme environmental conditions such as elevated temperature, UV, humidity, and some chemicals, specifically acids.
- Refractive index is limited <1.7 of today's commercially available molding resins is also a consideration.

There will always be applications for which glass optics are the appropriate choice, but the need for low cost, light weight, and ease of scalability alternatives with plastic optics manufacturing technologies cannot be ignored.

In applications where injection molded lenses offer the best solution, JENOPTIK offers the market unique, non-conventional polymer based micro optical component manufacturing solutions for high volume, low cost applications.

Thank you for your attention!