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Pioneering 3D photonic integrated circuits

HIGH PRECISION, COMPLEX GEOMETRY, M x N FIBER ARRAYS

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Just as the semiconductor industry is struggling with demands to pack transistors on chips at densities previously thought to be impossible, the fiber optics industry is grappling with the need for ever higher capacity data transmission. A key difficulty in this task is accurately connecting large numbers of often densely packed fibers to the next link in the chain. 2D hole arrays manufactured using laser-induced selective etching offers the ideal solution.

2D hole arrays – into which the end faces of multiple optical fibers are inserted for high-precision fiber alignment – are a key low-loss coupling technology enabling numerous applications. These applications include coupling to optical switching hardware, free-space optical systems, photonic integrated circuits, and datacenter interconnects, such as reconfigurable optical add drop multiplexers (ROADMs). At present, 2D hole arrays can be fabricated using various methods and materials. For example, a range of lithographic techniques can be used to manufacture precision hole arrays with high levels of positional accuracy. However, it can be difficult to control absolute hole diameters, sidewall angles and geometric profile throughout the depth of the material. Meanwhile, laser-induced selective etching is a novel two-stage microstructuring process in glass that uses a focussed ultrashort pulsed laser to induce subsurface material patterning, localised to the focus of the laser beam. CNC milling is another option, however this technique suffers from tolerancing and tooling limitations, especially in achieving the desired aspect ratios for smaller holes, and it is relatively slow in brittle materials such as glass.

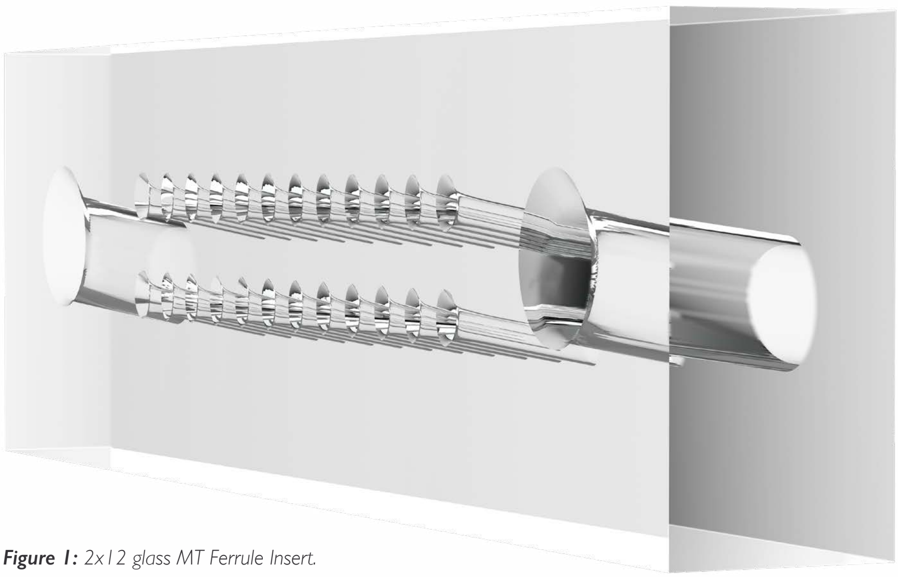

Figure 1: *2x12 glass MT Ferrule Insert.*

Flexible frontrunner

Where silicon patterning and laser-induced selective etching primarily differ is in their adaptability – a crucial factor in a rapidly advancing industry. For example, because silicon patterning relies on existing MEMS technology and fabrication facilities, the tools used to manufacture 2D arrays can only produce standard silicon wafer thicknesses, typically 650 microns thick. Given 2D arrays require thicknesses in the 2 mm range, three silicon-patterned 2D arrays are often stacked and bonded together to produce the required thickness and provide the mechanical rigidity and integrity to hold the optical fibers in place. This not only creates an additional unnecessary processing step and cost, but also introduces a potential new stackup misalignment error.

In contrast, laser-induced selective etching can be performed on substantially thicker glass substrates, such as 2 mm. Another important feature highlighting the adaptability of laser-induced selective etching is the technique's freeform control of hole shape throughout the volume of the substrate. A crucial advantage this brings, and a capability silicon patterning does not provide, is the ability to form holes at arbitrary angles to the surface of the glass – providing the opportunity to minimise back-reflections, for example. Freeform 3D control also means that the hole entrance can be modified to any desired shape. Though silicon patterning can produce a flared hole to allow simple fiber insertion, the flare must be a standard-sized cone shape. Laser-induced selective etching can yield curved or conical flares of various lengths depending on requirements. Finally, laser-induced selective etching can produce fiducials anywhere on the glass and in any shape desired. Alignment fiducials etched on the glass can enable automated vision-based alignment, thereby eliminating the need for slow and costly active alignment.

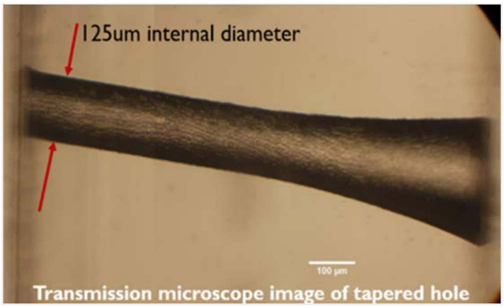

Figure 2: *Hole with 8-degree tapered entrance for smooth fiber insertion.*

Tight positional accuracies can be achieved with this manufacturing process, providing <0.5 μm tolerances across large arrays and throughout the volume of the hole. Figure 3 below summarises achievable tolerances using laser-induced selective etching:

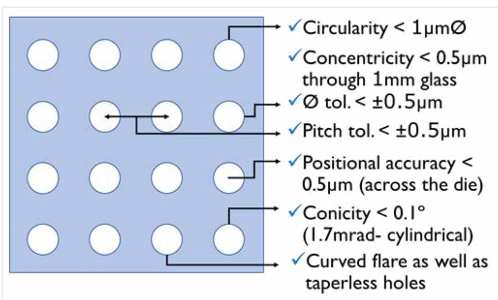

Figure 3: *Schematic of achievable tolerances.*

This tight control over positional accuracy as well as hole diameter, allows for a well-controlled alignment ferrule that can reduce fiber insertion loss and increase overall systems efficiency.

The speed of ultrafast direct laser writing allows for a production capacity of well over 50 million precision fiber alignment holes per year per laser machine. The wet etch process used is a standard semiconductor style process and so is inherently scalable.

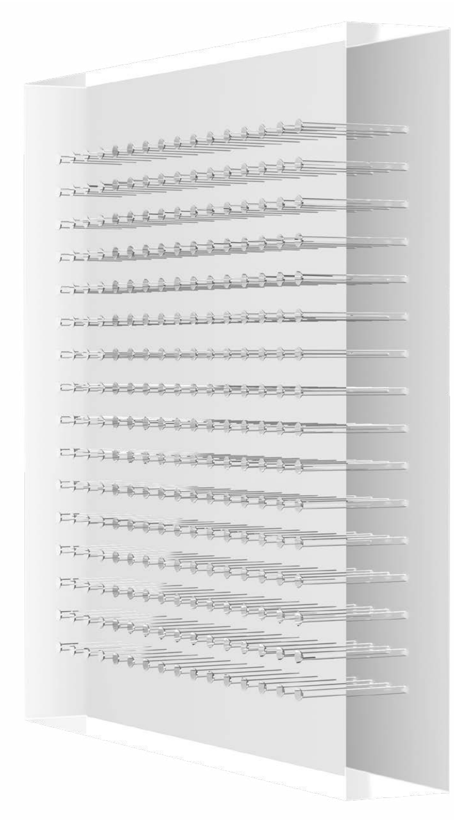

Figure 4: *Cubic structure array of >200 holes.*

About Optoscribe Ltd

Optoscribe uses its innovative laser direct write technology to manufacture glass-based photonic components primarily for the telecommunications and data communications markets. Optoscribe's technology allows for 3D waveguide formation and 3D laser induced selective etching with unprecedented design freedom.

Optoscribe's Precision Fiber Alignment Structures (OptoArray™) and SiPh Advanced Coupling Solutions (OptoCplr™) can solve many of the challenges associated with the drive for high density optical connections. The company is located in Livingston, UK, where it has a state-of-the-art manufacturing facility.

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