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Application Note

Femtosecond Laser Irradiation and Chemical Etching (FLICE); waveguide writing

Microfabrication technologies have miniaturised many fields, from microelectronics to photonics, paving the way for a wide range of new applications. In particular, the capability of realising microfluidic channels has revolutionised the field of optofluidics.
Microfluidic channels and patterns are typically fabricated by lithographic and chemical-etching techniques, but these approaches are primarily limited to the fabrication of two-dimensional patterns on the surface. Indeed, in order to create a true 3-D structure several layers of glass substrates need to be patterned, etched and fused together.

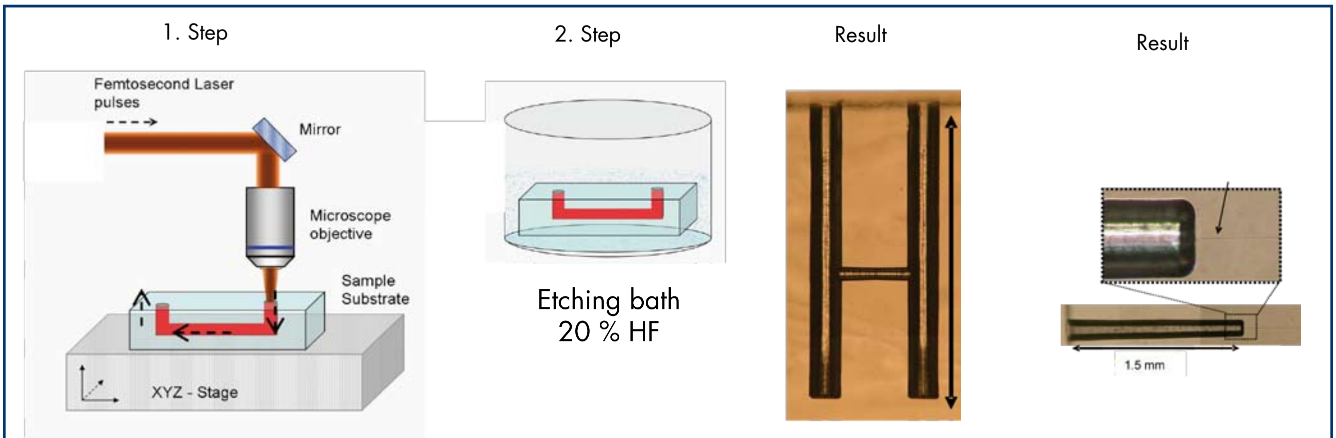
Femtosecond Laser Irradiation and Chemical Etching (FLICE) allows 3-D micromachining, thus permitting the direct fabrication of buried microchannels with various aspect ratios and patterns.

Being a maskless technology, it enables rapid low-cost prototyping of new devices. Moreover, since the same femtosecond laser can be used to produce low loss optical waveguides in a 3-D geometry , these femtosecond laser based technologies could become one-stop solution for fabrication of microfluidic channels and their integration with optical circuits.

The FLICE fabrication procedure

1. Step: Femtosecond laser irradiation with intensities below the laser ablation threshold
   –> Design of microchannels is imprinted into the substrate volume (typ. fused silica)

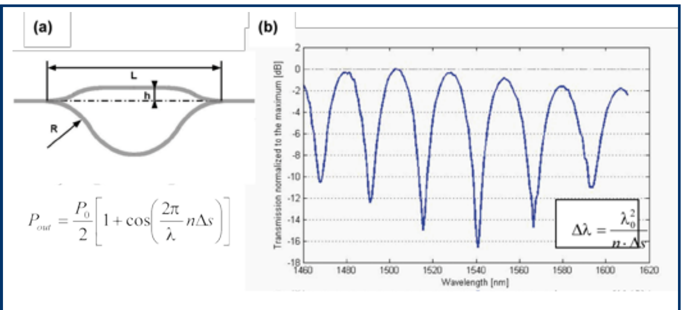
2. Step: Etching of the femtosecond laser modified region using HF acid (highly selective)



Application Example: Mach-Zehnder Interferometer

Femtosecond laser writing technique allows to fabricate unbalanced Mach-Zehnder interferometers in fused silica substrate. It has been used SHG (at 515 nm) of 350fs laser pulses at 1MHz repetition rate, focused with a 50x 0.6NA objective.. Devices were written 200µm below sample surface, with a translation speed of 100 µm/s and pulse energy (at 515nm) of 90nJ.

Schematic of the unbalanced Mach-Zehnder interferometers fabricated. The formula of the transmitted power as a function of the input wavelength λ in the ideal case is reported below (n is the refractive index and Δs is the unbalance in the length of the two arms) (b) measured spectral response of an interferometer with h=50µm, R=30mm and L=18mm. A fringe visibility of more than 8dB is observed. The measured fringe periodicity of 25.8nm is in good accordance with the result of the formula in the inset (24.6nm), which gives the approximate periodicity of the wavelength fringes in a region around λ_0 (here assumed to be 1550nm).



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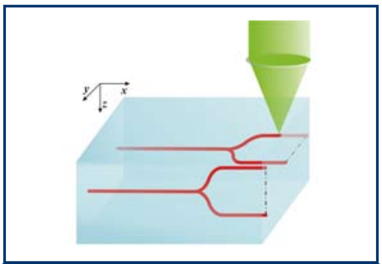
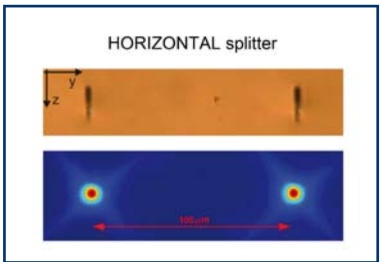
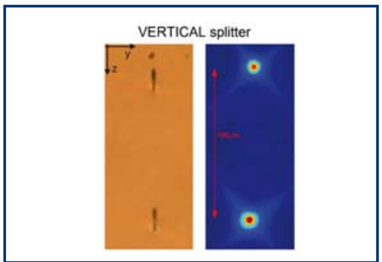
Application Example: 1x2 vertical and horizontal power splitters

In order to realize complex 3-D photonic devices, it is necessary first to fabricate the basic 3-D optical elements with good guiding properties. A core element is represented by a 1x2 power splitter with certain characteristics: directly buried in the substrate, different possible orientations in the volume, small size.



Scheme of the 1x2 power splitters with two different orientations



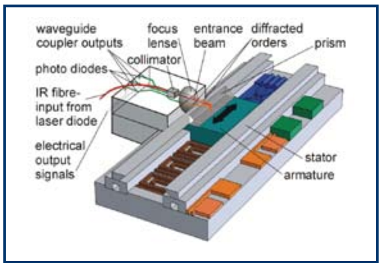


Intensity mode profiles at 1550nm of the horizontal and vertical splitters
Distance between the two waveguides: 100μm
splitter size: <2.5mm
total insertion losses lower than 5dB @ 1550nm.

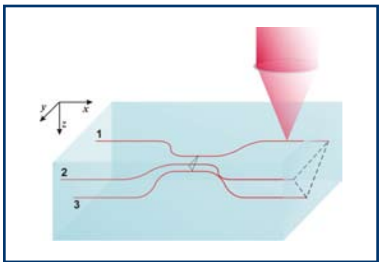
Material	Laser parameters	
fused silica	wavelength: 515 nm pulse length 350fs repetition rate 1MHz	pulse energy 90nJ scan speed 10μm/s 50x focusing objective with 0.6NA.

Application Example: 3-D directional coupler for a micromotor speed sensor

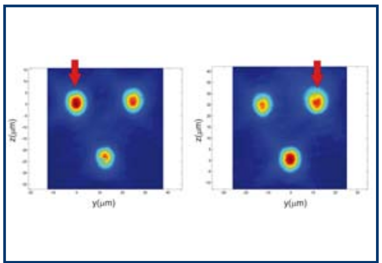
An important issue in the application of micrometric motors is the capability to fabricate integrated position sensors of high precision (< 100nm) and small size (< 10mm). The project of such a micromotor has been developed by the Laser Zentrum in Hannover; the core device of the speed sensor is represented by a 3-D directional coupler fabricated at Politecnico di Milano. This speed sensor is based on interferometric effects and it needs three coupled waveguides to detect both module and direction of the motor speed.



Scheme of the micromotor with the integrated interferometric speed sensor



Scheme of the 3-D direction coupler composed of three femtosecond laser written waveguides.



Result: Intensity mode profiles at the waveguide outputs of the 3-D directional coupler.

Material	Laser parameters	
borosilicate glass	wavelength: 1030 nm pulse length 350fs repetition rate 1MHz	pulse energy 300nJ scan speed 10mm/s 20x focusing objective with 0.4NA.

Acknowledgments

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This work was supported by the European Commission (STREP EU: FP6 IST-2005-034562, "HIBISCUS")