

Fabrication of Highly Transparent Anti-Fogging Glass Surfaces

Fogging of glasses is a widespread and well-known problem still searching for a solution. It occurs on the surfaces of objects that are colder than their humid environment. For example, this is the situation for eyeglasses if the wearer walks from the cold outdoors into a warm room. Further examples for glass surfaces affected by fogging are helmet visors, diving goggles, car mirrors, or windows in general. Fogging results from water that condenses in form of small droplets on the surface. These droplets scatter the transmitted light, and thus cause blurred vision through the glass (see Figure 1 A and B). Anti-fogging surfaces avoid the formation of scattering droplets on a surface. This is achieved by improving the wettability of the surface such that the droplets are spread completely across the surface (Figure 1 C). The challenge is to find the optimal surface morphology of glass to achieve high wettability and minimal scattering at the same time.

Recently, a femtosecond laser based process ClearSurface™ for fabrication of functional surfaces has been developed at the research center for micro-technology at the Applied University in Dornbirn, Austria in collaboration with Spectra-Physics. The ClearSurface process using an industrial femtosecond laser, Spirit® One™ (Figure 2), allows the fast and flexible fabrication of superhydrophilic and/or superhydrophobic surfaces (with water droplet contact angles between 5° and 160°) on a variety of substrates. The resulting contact angle and surface roughness can be precisely controlled by adjusting the laser parameters.

In order to investigate the influence of the laser-structured surface on optical transmission in the wetted state, a glass wafer was fabricated which was half laser structured and half pristine. Subsequently the glass was exposed to deionized water vapor and photographed in front of a test structure. Figure 3 shows that the word “transparency” appears blurry through wetted pristine glass (Figure 3 A), but clear through the wetted structured glass (Figure 3 B). The results showed that highly transparent anti-fogging surfaces can be fabricated by generating patterns on the glass surface using the Spirit One femtosecond laser. Both wettability and transmission were controlled by means of pattern geometry and period; however, a trade-off between superhydrophilic wetting behavior and visual perception must be optimized for the intended use case.

Spirit One is a compact, industrial femtosecond laser that delivers game-changing cost-performance with average powers up to >8 W. The laser delivers ultrashort <400 fs pulse width, high pulse energy and average power output, and repetition rate up to 1 MHz. The laser is an *It's in the Box™* design that combines power supply and laser head in a single rugged, compact and lightweight package for ease of integration. Spirit One provides additional flexibility with an adjustable pulse duration option, allowing the user to freely choose pulse durations between <400 fs and 4 ps by software in less than 3 seconds.

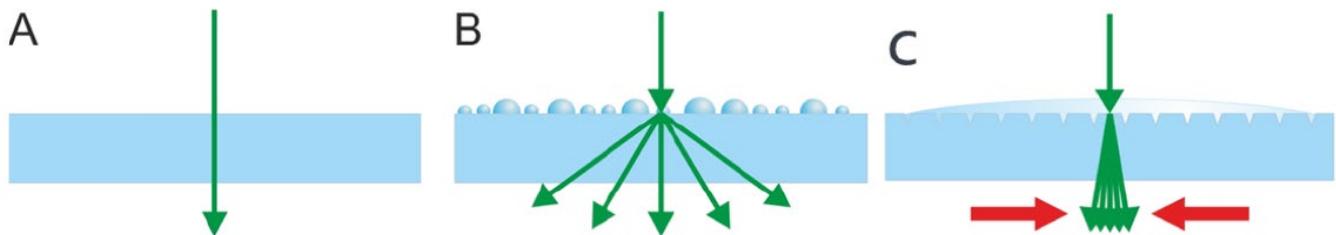


Figure 1. Light scattering on dry (A) and fogged (B) glass surfaces. Anti-fogging surfaces have super-hydrophilic property to provoke spreading of the fog droplets on the surface (C). As a consequence, light scattering reduces in the wetted state (indicated by the red arrows).

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Figure 2. Spectra-Physics Spirit® One™ high performance industrial femtosecond laser.

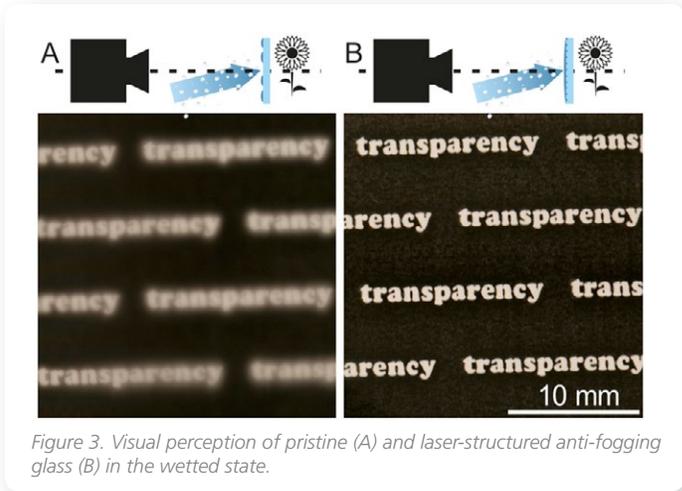


Figure 3. Visual perception of pristine (A) and laser-structured anti-fogging glass (B) in the wetted state.

PRODUCTS: **SPIRIT ONE**

Spirit® One™ is a compact, industrial femtosecond laser that delivers game-changing cost-performance with averages powers up to >8 W. With ultrashort <400 fs pulse width, high pulse energy and average power output, and repetition rate up to 1 MHz, the laser is an *It's in the Box™* laser that combines power supply and laser head in a single rugged, compact and lightweight package for ease of integration. Spirit One enables advancements in high precision applications including microsurgery, femtosecond micromachining, medical device manufacturing, optogenetics, and multiphoton microscopy.

With up to >8 W average power and >40 µJ pulse energy at 1040 nm wavelength, Spirit One provides additional flexibility with a new adjustable pulse duration option, allowing the user to freely choose pulse durations between 400 fs and 4 ps by software in less than 3 seconds. The amplifier is optimized for one factory calibrated repetition rate at either 200 kHz (40 µJ) or 1 MHz (8 µJ) that can be chosen by the customer. Additional or different pre-set repetition rates are

optional and can be configured in the factory during assembly on request. The laser includes an integrated pulse picker for fast pulse selection and power control by an analog input signal or via software commands for high process throughput.

The optional, high efficiency Second Harmonic Generation (SHG) module enables the fabrication of smaller and more accurate structures. The fundamental and SHG output beams are collinear at the laser exit for easy integration and beam delivery. The end user can easily switch between the 1040 nm and 520 nm outputs by software.

Spirit One is based on the proven and widely deployed Spirit industrial femtosecond laser platform and has passed extensive environmental qualification testing to ensure high reliability. Fully automated and computer controlled, Spirit One has exceptional power and beam pointing stability during 24/7 operation, resulting in high precision and reproducibility for demanding applications.

	Spirit One 1040-8	Spirit One 1040-8-SHG
Wavelength	1040 ±5 nm	
Output Power	>8 W	
Pulse Energy	>40 µJ at 200 kHz	
Wavelength (SHG)	NA	520 ± 3 nm
Output Power (SHG) ¹	NA	>4 W at 200 kHz
Pulse Energy (SHG) ¹	NA	>20 µJ at 200 kHz

1. Maximum conversion efficiency of 50% for SHG at 200 kHz; lower efficiency at 1 MHz.



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