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CERTIFICATE OF ATTENDANCE

To Whom It May Concern

This is to certify that **Andri Abdurrochman** from Univ. de Strasbourg attended the SPIE Photonics Europe Symposium, 14-17 April 2014 in Brussels, Belgium and presented paper number 9135-76

"Photonic jet to improve the lateral resolution of laser etching"

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Laser Sources and Applications

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Photonic jet to improve the lateral resolution of laser etching

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ABSTRACT

The techniques applying laser beams or optical systems are limited by the diffraction limit of the optical heads used. We demonstrate theoretically and experimentally that the use of the photonic jet allows an improvement in the optical resolution to achieve smaller etching without reducing the wavelength of the source. The potential of the photonic jet using a nanosecond pulsed near-infrared laser for micro-fabrication is also demonstrated. These lasers are the most common type of laser used in industrial processes because of their price and the fact that well-packaged sources are available. Their typical spatial resolution in laser etching is limited by the spot size of their focus point at around 25-70 μm. This is the reason why a photonic jet, a high spatial concentration onto a half-wavelength spot of a beam that emerges in the vicinity of a dielectric microsphere, is of great interest. In our experiments, micro-scale glass ($n_s = 1.5$) and $BaTiO_3$ spheres ($n_s = 1.9$) have been used to achieve photonic jets. The etching process has been tested on two substrates: silicon wafers, which have a significant absorption at 1064 nm, and glass plates, which have a lower absorption at this wavelength. The smallest marking achieved on silicon has an average diameter of 1.3 μm and despite the low absorption, micrometric etchings have also been achieved on glass using larger microspheres.

Keywords: photonic jet, nanosecond laser, near-infra red laser, laser etching, glass micro-sphere, silicon wafer, spatial resolution, microstructure.

1. INTRODUCTION

The phenomenon of the localized sub-wavelength beam generated at the shadow-side surfaces of micro-scale dielectric cylinders[1] or spheres[2], when they are illuminated by an electromagnetic wave, is known as the photonic nanojet or the photonic jet. The photonic jet does not necessarily have a cylindrical symmetry because of the polarization of the incident wave[2]. Some applications of the photonic jet have already been proposed, such as in scanning near-field optical microscopy[3, 4], microscopy using near-field probes[5] and immersion lens microscopy[6, 7]. This paper presents our experimental attempt to improve the lateral resolution of 1064 nm direct laser etching applying the photonic jet for material etching or surface processing.

In materials processing, it is necessary to engineer laser beam features in order to obtain accurate results, i.e. a small beam spot size, low heating effects in the material and the taking into account of the beam absorption by the material[8]. In general, lenses are used within the diffraction limit[9] to adjust the beam size. Then ultrafast (femto-seconds and pico-seconds) lasers are applied to minimize the heat affected zone (HAZ) as well as to reduce feature sizes, achieve greater lateral resolution and better aspect ratios[10]. Despite these advantages, femto-second and pico-second lasers are not cost-effective for present industrial processes. On the other hand, because the energy of short wavelength beams can be absorbed by many materials, ultraviolet (UV) lasers are used in many applications. But most of these lasers are excimer lasers which require expensive gases. Also,

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