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Photonic Jet Etching: Justifying the Shape of Optical Fiber Tip

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Abstract. Photonic jet (PJ) is a low diverging and highly concentrated beam in the shadow side of dielectric particle (cylinder or sphere). The concentration can be more than 200 times higher than the incidence wave. It is a non-resonance phenomenon in the near-field can propagate in a few wavelengths. Many potential applications have been proposed, including PJ etching. Hence, a guided-beam is considered increasing the PJ mobility control. While the others used a combination of classical optical fibers and spheres, we are concerned on a classical optical fiber with spherical tip to generate the PJ. This PJ driven waveguide has been realized using Gaussian mode beam inside the core. It has different variable parameters compared to classical PJ, which will be discussed in correlation with the etching demonstrations. The parameters dependency between the tip and PJ properties are complex; and theoretical aspect of this interaction will be exposed to justify the shape of our tip and optical fiber used in our demonstrations. Methods to achieve such a needed optical fiber tip will also be described. Finally the ability to generate PJ out of the shaped optical fiber will be experimentally demonstrated and the potential applications for material processing will be exposed.

INTRODUCTION: PHOTONIC JET ETCHING USING MICROSPHERES

Before it was coined as the photonic jet (PJ) in 2004, phenomenon in the near-field of spherical dielectric particle has already observed and proposed for surface processing using microspheres [1-6] for laser direct-etching. It has been demonstrated that microspheres on sample material can decrease the laser direct-etching, especially if the ultrafast (pico- or femto-seconds) lasers or shorter wavelength (ultra-violet range) lasers [7-13]. This decreasing size potency also has been demonstrated for nanosecond pulsed near-infrared lasers [14,15] that considered as more economical option than ultrafast pulsed ultra-violet lasers – not to mention its availability in well-packaged source. Using glass microspheres, this laser (28 ns of 1064 nm laser) which will not absorb much by a transparent glass is capable to etch glass slide. And on silicon wafer, this laser can decrease the LDE etching about 40 times smaller than LDE etching without glass microsphere; the smallest average diameter was around 1.3 μm using 4 μm glass microspheres with the laser fluence of 0.75 J/cm² and the PJ fluence of 43 J/cm².

The capability of PJ to obtain smaller LDE etching is understandable since PJ can focus (f_c) the beams into a very small beam size (Γ_{FWHM}) so it has folded intensities (I_{max}) propagate at a certain length (l_{FWHM}). These parameters are shown in Fig. 1.

Even though microspheres can be used for PJ etching, there are some drawbacks we must consider, e.g. microspheres are disposable; they can be used only once. And, there is no space or distance between microsphere and etched material, so material debris from the first ablation will contaminate the microsphere and avoids the following laser pulses to etch the material sequentially. Our observations revealed that two pulses is the least

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