Precision freeform surface manufacturing and surface structering using plasma jets

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Abstract

Precision optics with freeform and structured surfaces are used in a broad application spectrum from refractive beam shaping elements for laser intensity homogenizing (needed e.g. for improved material treatment) to wavefront error correction in imaging systems. Besides the challenge of measurement new approaches for manufacturing of freeform surfaces are needed. The presented techniques based on atmospheric pressure plasma jets have the potential to overcome limitations of the classical process chain using abrasive techniques. On one hand they can contribute to freeform generation by local chemical etching with high material removal rates (MRR) as well as to the final surface error correction realized by small plasma jet etching with sub-mm lateral resolution. On the other hand plasma jet based surface smoothing in combination with mechanical grinding or ultra-short puls laser machining is promising for a really new and efficient way to make freeform and structured surfaces with nearly arbitrary design. The etching processes mainly foot on a flourine chemistry and do not induce any sub-surface damage. Hence, they are predestined to make precision optics from silicon based materials like fused silica, silicon, or silicon carbide with high laser damage thresholds (LDT). But also other materials like crystalline quartz or materials with a sufficient high portion of SiO_2 like the low thermal expansion materials (LTEM's) ULE®, and Zerodur®, or optical glasses like N-BK7® can be machined to some extend. The smoothing process is thermally driven and can be applied currently only to fused silica and ULE®. Starting from mechanically ground or laser machined surfaces with a micro-roughness of a few 100nm rms the surface can be "polished" to less than 1nm rms in one step without changing the overall shape. The cutoff-length is in the range of 100µm, i.e. structures with a spatial wavelength less than 100µm are smoothed out, whereas longer ranged structures more or less remain.

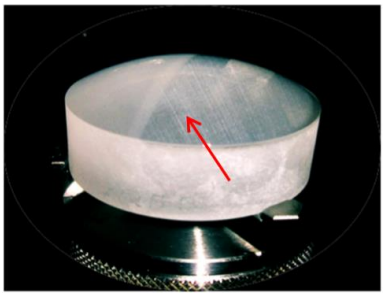

Figure 1: Half side plasma-polished aspheric lens.