Laser Smoothing of Silica

Figure 1 : Laser micro-machining set-up.

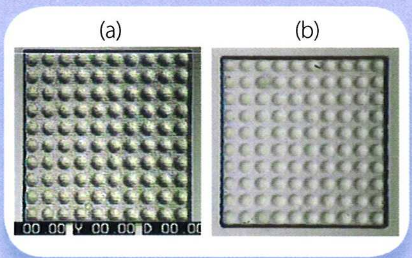

Figure 2 : Micro-optical element (a) before and (b) after laser polishing.

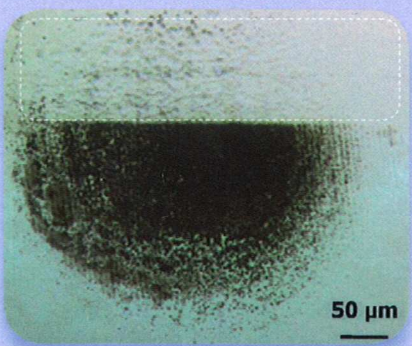

Figure 3 : Repair of laser damage (area inside white dashed square).

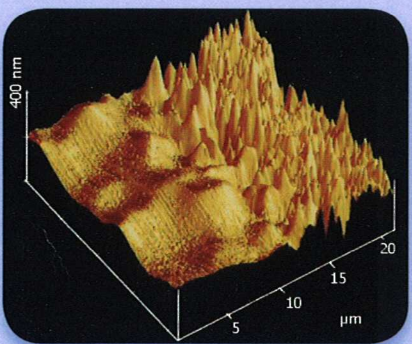

Figure 4 : AFM scan of laser smoothed and non-smoothed damage region.

Rationale

Silica (silicon dioxide) is a high purity synthetic amorphous material that combines very low thermal expansion with excellent optical qualities over a wide spectral range, making it an ideal optical material for many applications.

Silica micro-optical structures produced by laser machining have been shown to provide excellent correction of beam imperfections in High Power Diode Lasers. To provide low loss components, the fabricated micro-lens requires polishing to reduce the surface roughness without significant change to the initial (laser-machined) surface profile. Laser polishing can achieve this.

Laser polishing of silica is also useful for repairing damage in highly specified and expensive laser optics. Optical damage limits the lifetime of optics used in some applications, such as high energy laser systems, due to increased absorption at damage sites. This damage can be repaired by laser surface heating, which can melt a thin layer that will flow under surface tension effects, so 'healing' the damage and mitigating its further growth.

Research Aims

The main purpose of the project is to understand in detail the laser smoothing process and its limitations as a function of laser parameters and material properties.

The research focuses on two main areas:

(i) Development of laser polishing as a manufacturing process for micro-optics.

(ii) Localised repair and mitigation of laser-induced damage sites in silica optics.

Research Objectives

- Configure a CO_2 laser system for precise control of power, pulse duration and spot-size on target.
- Determine the ideal laser conditions for surface smoothing, e.g. dependence of melt depth on laser irradiance, pulse length, laser spot size, etc.
- Develop a theoretical model for laser smoothing in fused silica and validate it.
- Determine optimum conditions for polishing custom micro-optics.
- Develop an effective procedure for repairing surface damage in high-cost optics.

Research Outcomes

- The ablation threshold irradiances were determined for a wide range of laser pulse lengths and spot diameters, and shown to agree with the results of modelling.
- Shown that the smoothing process acts as a low-pass filter with a spatial frequency cut-off controlled by melt depth and process surface temperature.
- Developed a technique for polishing micro-lenses with rms roughness down to <1nm and a cut off frequency of 20-50 cycles/mm.
- Developed a technique for damage repair, without modifying the adjacent surface, that removed cracks to 0.5µm depth without significant mass loss, whilst localising the treated region to <5µm lateral size (200 cycles/mm).

Collaborators

PowerPhotonic

SELEX

BAE SYSTEMS

AWE