

Technical Report

Subsurface precision machining of glass substrates by innovative lasers

Keming Du and Peng Shi

EdgeWave GmbH, Aachen (Germany)

At very high laser intensities, achieved with modern, diode-pumped solid-state lasers having high beam quality and high pulse power, even transparent materials such as glass can be easily machined with high efficiency and precision. Examples are given by the subsurface engraving, the cutting and the drilling of glass, where the physical effect of nonlinear absorption in transparent media is used. This enables machining processes and results which are not feasible with any other tool known before.

1. Introduction

In the past laser machining of glass was mostly limited to far-infrared or ultraviolet lasers [1 and 2]. This is due to the fact that glass absorbs laser radiation only in these wavelength regimes (figure 1). At other wavelengths glass is highly transparent and merely a small fraction of the laser power is transformed into thermal energy – not sufficient for materials processing.

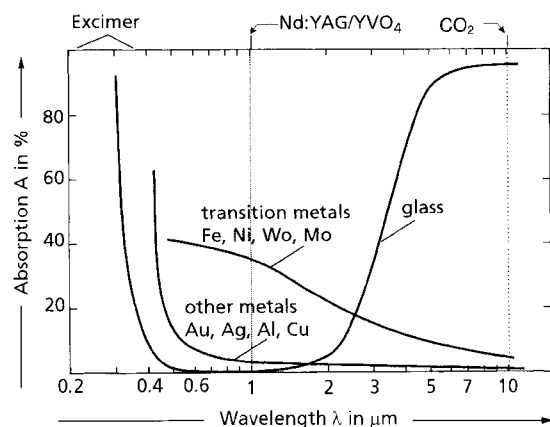


Figure 1. Absorption of different materials as a function of the wavelength.

Excimer lasers with wavelengths in the ultraviolet spectral range and CO₂ lasers with infrared radiation are absorbed in a thin sheet at the workpiece surface due to their high absorption coefficient and subsequently the glass is melted or evaporated, if high pulse energies are applied. Due

to their good absorption properties excimer or CO₂ lasers are common tools for cutting, welding or surface-structuring of glasses [2 and 3].

With solid-state lasers such as Nd:YAG or Nd:YVO₄, which are widely used in industrial applications due to their advantageous properties such as compactness and simple operation, glass machining was not possible as the radiation at 1.06 μm wavelength is hardly absorbed: the laser beam gets through the glass without being weakened significantly. By using the physical effect of the nonlinear absorption, however, in combination with the modern diode-pumped solid-state lasers it has become possible for some years to machine highly transparent materials such as glasses with processes enabling entirely new opportunities.

2. Principle of laser material interaction

The principle of the machining of transparent materials with solid-state laser radiation is illustrated in figure 2a: a laser beam is focussed into a transparent medium and initially gets through the material nearly unaffected, due to the negligible absorption. If the laser however is focussed to a very small spot and is emitting very short and intensive pulses, a very high intensity is achieved in the focal spot, exceeding the threshold intensity I_s as shown in figure 2b. Above this threshold intensity an electron avalanche is created, starting from a couple of free charge carriers, being always present. Due to the strongly increased charge carrier density the absorption coefficient for electromagnetic radiation abruptly increases to values of several 10% and the laser power, thus absorbed, leads to melting and evaporation of a small amount of material. It is specific for this process that the interaction between laser and material is localized to the focal point of the laser beam, the material below and above is not affected at all.

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