Zero Width Glass Cutting with CO_2 Laser

Mohammed Naeem
GSI Group, Laser Division
Cosford Lane, Swift Valley
Rugby

mnaeem@gsig.com

Introduction

Laser cutting of glass in not a novel technique, excellent results have already been achieved by various research institutes. There are several patents concerned with controlled cutting of glass with zero width and other brittle materials in a straight line using CO_2 laser beam. Laser beam glass cutting produces a high quality cut edge with minimal microcracking. This is achieved using a controlled cleaving of glass through a combination of heating and cooling. Laser separation of glass with zero width can be summarised by the following steps:

- The glass surface is heated by laser beam
- Compressive stress builds up in surface layers, but there no surface damage
- When a coolant is applied, this cools surface on cutting line
- Steep temperature gradient generates high tensile stress on the glass surface.
- This causes propagation of incipient crack in the glass sheet

Today various types of glass varieties are in use in a range of applications **[1]**. This can be anything from small optical filters in micrometer to 19 inches glass substrates for flat panels e.g. for notebook, also even to bigger size glass for automotive or architectural industry in a mass productions. The glass industry can be categorised into five groupings ***(Table 1)***.

The most common type of glass is soda- lime glass, also known as alkali- glass, which is used for automotive and architectural/ home appliances. The common glass thickness ranges from 1.6mm to 10mm. Glass plates that are 1 mm thick or less are referred to borosilicate glass and are mainly used for flat panel displays (FPDs) and electronics products.

Table 1: Various types of glass

Industry Type	**Thickness (mm)**	**Glass type**
Architectural	4 -10	Soda - lime
Automotive	1.6 - 4	Soda - lime
Medical	1	Soda – lime, Borosilicate
Flat panel displays	0.3 – 1.1	Borosilicate
Electronics	0.05 – 0.5	Borosilicate

Soda- lime glass also known, as alkali- glass in the range of 1.6mm to 10mm thick is the most common type of glass that, is used in a number of industries including automotive, architectural and home appliances. Borosilicate glass also referred to as non- alkali- glass is mainly used for flat displays (FPDs) and electronics products. Typical glass thickness for these applications ranges from 0.7mm to 1mm.

What ever the application, the current trend are that the devices are getting smaller and demand of laser cutting of glass is increasing because the conventional procedures are inadequate because of micro cracking and edge quality. The development of flat screen televisions, notebook computers and portable phones has increased rapidly, so that demands for LCDs and PDPs used in these products have also increased rapidly. Traditionally cut edges require considerable grinding and polishing processes to remove the edge defects. Laser cutting of glass produces a high quality cut edge with minimal microcracking. This is achieved using a controlled cleaving of glass through a combination of heating and cooling. Since use of a laser avoids the need for additional edge finishing to remove micro- cracks this technology promises considerable economic advantages in terms of higher productivity rates and improved edge- finish quality. Removal of grinding and polishing should reduce manufacturing costs by about 75%.

Background

Historically, laser processing of glass has been very difficult due to its inherent physical properties, so there are several challenges that have to be addressed when using lasers for glass processing. The first is choice of laser wavelength. Most glasses transmit in the visible portion of the spectrum, and many transmit over very wide portions of the spectrum outside of the visible. This is usually a disadvantage as it limits the choice of available laser wavelengths for processing, but actually in some applications the transmissive properties can be used to advantage, such as in 'backside processing' where the beam goes through bulk substrate and is used to machine material on the far side. In most cases, the choice of laser wavelength is limited to the infrared (IR) and/or Ultraviolet (UV). All the cutting work to date been performed with CO_2 laser, because of its high absorption characteristics. Full absorption on various borosilicate glass types starts from 5000nm (5µm).

The CO_2 laser cutting involves propagation of a shallow micro crack on the glass surface (approximately 1/6th of the thickness of the sheet) driven by controlled heating and cooling of the glass from a CO_2 laser and water spray respectively **[2]**. The presence of the heating and cooling sources induces a stress field that weakens the glass immediately ahead of the crack and a clean break occurs in a straight line ***(Figure1)***. By carefully controlling the temperature profile of the glass, this process can be used to create a clean fracture along any straight dimension of the glass. The advantage is there is no material loss or a particle generated during the process and the quality of the cut is excellent ***(Figure 2)***. The laser cut system is optimised to produce a stable straight line cut consists of 100W line or elliptical laser heating source (around 2x20mm in size) with the major axis along the cut direction and fine water mist separated by centre-to-centre distance of around 18mm. This leads to surface heating of 80°C enabling a stable straight line cut in 2mm glass at rates of about 0.5m/sec. The scanning of laser beam in order to alter the perceived laser beam mode has been investigated by Schott Glas **[3]**.

The elimination of lateral cracks in the laser cut edge results in a part with greatly improved ability to withstand handling damage since, not only is the impact strength of the edge increased, the overall component strength is increased typically by up to 80%. This higher material strength reduces production damage losses as well as premature failure in the field because of this latent product defect. This is a major advantage for product design allowing the use of thinner, lighter materials with the same or longer life expectancy.

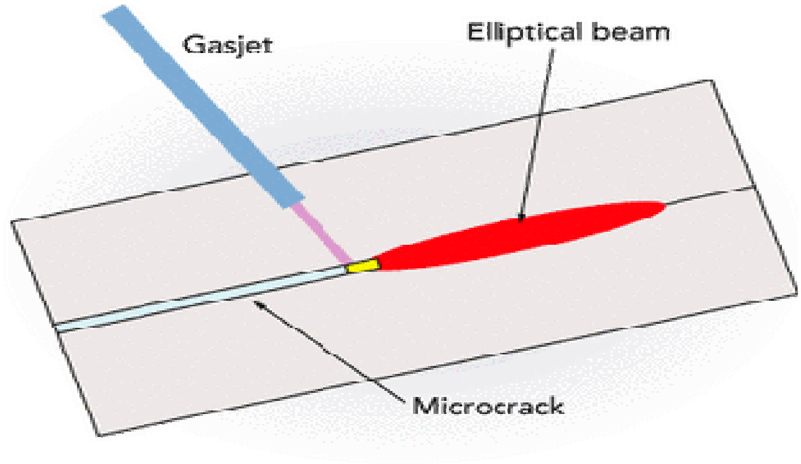

Figure 1: Illustration of assisted CO_2 glass cutting

Laser Mechanical

Figure 2: Edge cut quality **[4]**

Laser

As mentioned previously, CO_2 lasers average powers between 100-500W (depending on the thickness of the glass) are best suited for zero width cutting applications. The SLC150SD laser has been introduced to the GSI DC CO_2 product range specifically aimed at the glass laser separation application area. The key features are the production of a near 'top-hat' output mode profile with good stability. It is a laser based on the existing proven SLC200S laser, but uniquely combines the output from tubes with different modes to produce the required processing beam profile.

One laser tube has the 'donut' mode; the other produces a lower power Gaussian mode. The two tube have orthogonal polarisations and when combined generate a stable, controllable beam with effectively random polarisation and a quasi-'top-hat' mode profile ***(Figure 3)***.

The laser can produce typically 180W in this mode, with an end of life specification of 150W. The high efficiency of these CO2 lasers give low operating costs, whilst the sealed off nature of the technology means minimal maintenance. The special high voltage, low current supply needed for this type of laser is usually obtained from the laser tube manufacturer.

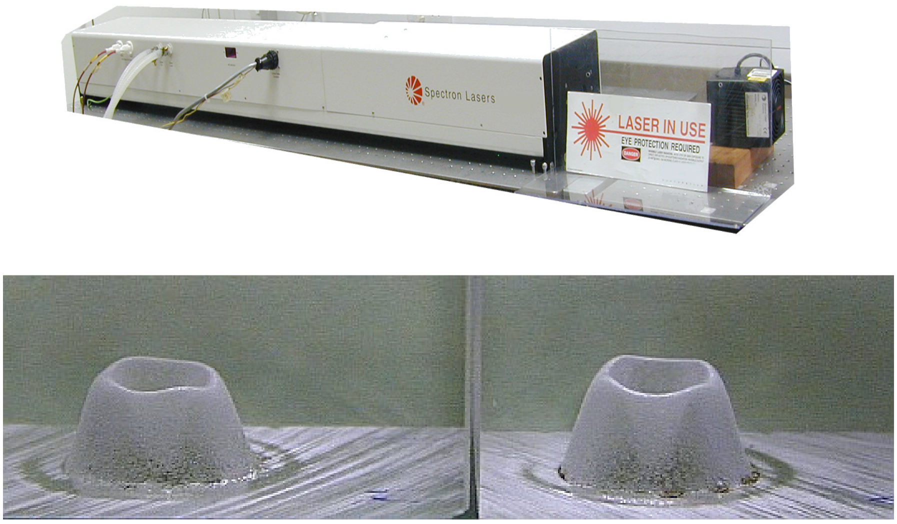

Figure 3: Glass Cutting Laser (SLC150SD) and typical beam profile

Summary

Laser zero width cutting methods surpass the traditional glass cutting/separating methods. With the right combination of heat and cold the laser beam precisely heats a specific line on the glass followed by a cold jet of air or an air/liquid mixture. These thermally induced tensions cause a precise fissuring of the glass. The result is a cut edge of the highest quality. The main advantages of this process are:

- High precision
- No micro-cracks, fragmentation or chipping
- Glass edges have a high resistance to breakage
- Glass edges virtually achieve optical quality
- Cost-effective production by reducing the need for washing, grinding, polishing and breaking machines
- Can be integrated in clean-rooms
- No loss of material

References

[1] Hermanns, C., Laser separation of flat glass, Proceeding of the Third International WLT-Conference on Lasers in Manufacturing 2005, Munich, June 2205, pp 805- 807

[2] KONDRATENKO, V.S., 1977, Method of splitting non-metallic materials, in U S Patent 5,609,284, Fornon Technology Ltd.

[3] OSTENDARP, H., et al., 1999, Method and apparatus for cutting through a flat workpiece made of brittle material, especially glass, in U S patent 5,984,159, Schott Glas

[4] PTG Europe (Fonon Group), PTG Europe GmbH P/O Box 25A-1184 Vienna, Austria