New Technology Simplifies 3D Free-form Laser Marking

Laser marking is a widely used tool in many industries because it offers several advantages over traditional methods. In fact, the flexibility and power of the technology have motivated many manufacturers to expand its use from simply labeling product information (e.g. part numbers and serial numbers) to more complex marks and sometimes producing purely decorative features. However, in the past, these marks have mostly been applied to flat surfaces, which limit the potential applications. This article reviews the basics of laser marking and explores new technology, developed by Coherent | Rofin, which simplifies marking of even highly complex, 3D shapes.

Laser Marking Basics

The exact requirements of a particular marking task vary tremendously by application, but in most cases, manufacturers want to produce a permanent mark, and often, one that is difficult to deliberately alter or counterfeit. Another common requirement is that the marking process not adversely affect surrounding (unmarked) material, and that minimal or no post processing (e.g. cleaning) be required.

Laser marking can satisfy all these requirements, typically much more readily than alternative marking methods, such as ink printing. Specifically, laser marking usually creates either a permanent color change at or near the surface of a material, or is used to remove material (engraving or complete ablation). Lasers can perform these tasks in a high speed, noncontact process which is also flexible, meaning that customized marks, such as sequential serial numbers or complex graphics, are easily produced. Furthermore, lasers enable marking over a very wide range of materials and scales, from minute marks on metal medical implants to large designs on plastic automotive parts. In fact, as the capabilities of laser marking improve, the use of the technology has expanded from producing merely utilitarian marks to decorative design or features that provide a significant added value to the product.

While there are a variety of different marking lasers having a wide range of output wavelengths (from the ultraviolet through the infrared), output powers and pulse durations, most are employed using the same basic optical configuration. The essential elements of this so-called "vector scan" setup include a beam expander to enlarge the raw output of the laser, a pair of computer controlled galvanometer mirrors to move the beam in two axes (perpendicular to the optical axis), and then a scan lens to focus the radiation on the work surface. This method enables the laser beam to rapidly traverse the work surface in order to mark or ablate patterns of nearly any complexity.

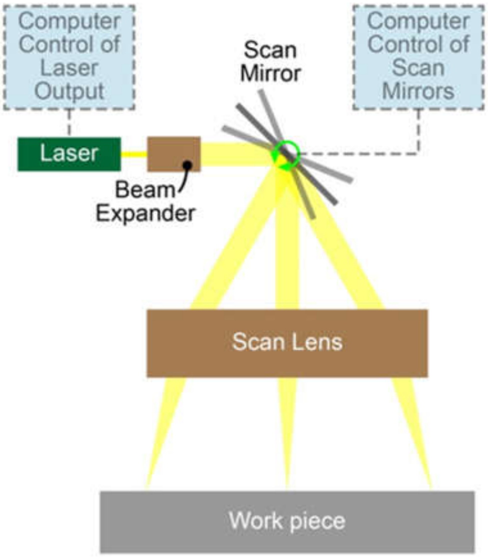

Figure 1. *Basic optical elements of a typical scanning system for laser marking or ablation. For simplicity, only one of the two scan mirrors is shown.*

From the standpoint of the optics, there is one major limitation to this approach. This is that most scan lenses are designed to cover a "flat field." That is, to achieve optimum focus (minimum spot size) at a fixed distance over their entire field of view. Therefore, if the work piece is not flat, then relative motion between the optics and work piece may have to be utilized to allow marking. For a work piece having a particularly complex three-dimensional shape, sophisticated robotics may be necessary to enable the optics to follow the part contour.

The Coherent | Rofin Solution

Coherent | Rofin has developed an alternative solution which delivers the flexibility and capabilities typical of a sophisticated robotic tool for marking and micromachining complex, free-form, three dimensional shapes. However, it is far simpler, faster and economical because it does not involve moving either the optical system or the part.

Functionally, there are two main elements to this system. The first is a fast focus module placed *within* the optics. This allows rapid focal length adjustment. Depending upon the particulars of the laser and scan system, a total range of up to ±130 mm from the nominal focal distance can be accommodated. The second element of the system is a sophisticated yet easy-to-use software package that imports a 3D CAD drawing of the workpiece and the desired mark, and then automatically determines the combination of focus module and galvanometer mirror movements required to produce the mark.

This system marks 3D surfaces without moving either the laser or the work piece. Since the laser beam emanates from a fixed point during the entire process, the scan system must therefore also correct for the geometrical distortions that would otherwise occur during the marking process. This type of distortion correction has been widely employed in the past when working with relatively simple shapes, such as angled flat surfaces and cylinders. But, it becomes substantially more difficult for arbitrary, free-form 3D shapes.

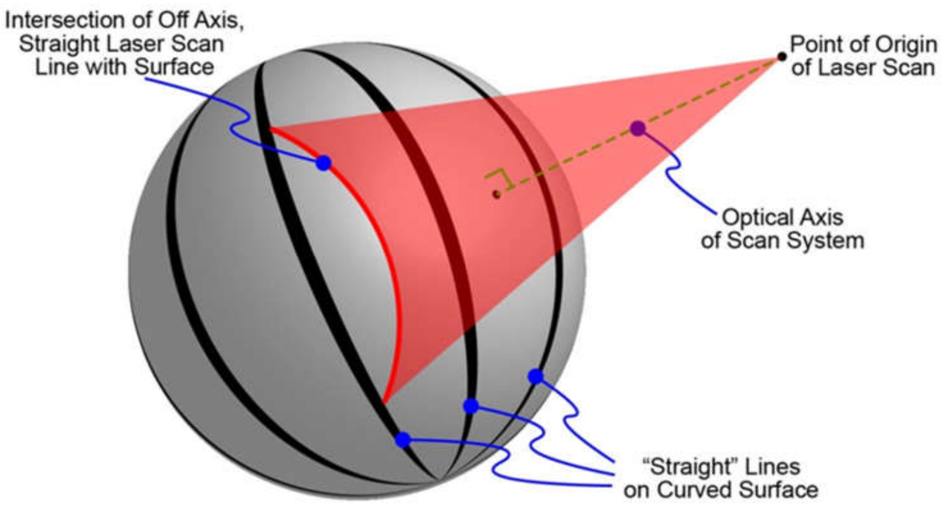

Figure 2. *Distortion occurs when marking a "straight" line at non-normal incidence on to a curved surface.*

Despite the underlying computational complexity of this process, the Coherent | Rofin system is user transparent. The operator sees a software preview of the work piece overlaid with the intended mark, and then adjusts it to their satisfaction in the software before proceeding. Internally, the software "unwraps" the 3D shape to a flat surface, determines the focus depth and the angle of incidence for the laser beam at all points, and applies the necessary correction in order to produce an undistorted mark for the desired viewpoint. This progression is illustrated in figure 3, which shows a CAD model of a part (in this case, a series of keyboard keys) that has been imported into the software, the intended marks positioned on the parts in software, and then the actual marked parts. Note that, in this case, the parts were specifically positioned at the edge of the scan optics' field, and the surface of the key was turned away from the scan optics, in order to make the process more difficult. However, the Coherent | Rofin system had no difficulty in compensating for all these conditions. For the key closest to the edge, distortion correction was purposefully not utilized to show that the mark would not be rendered correctly without it.

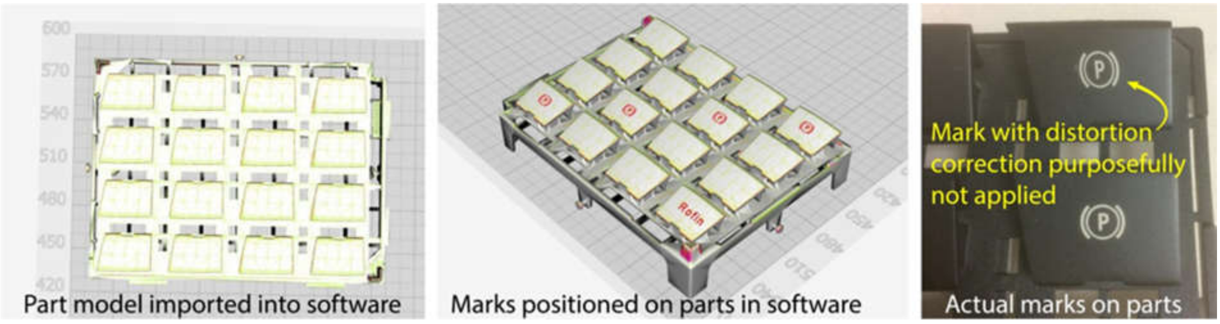

Figure 3. To utilize the Coherent | Rofin 3D marking system, a CAD model of the part is imported into the software, and the user positions the desired marks on the piece(s). The final results show that distortion correction is necessary to achieve the correct mark geometry on the work piece.

Coherent | Rofin produces custom 3D marking and ablation systems incorporating this technology for a wide range of applications. These systems are offered with a wide choice of laser types: diode-pumped solid-state lasers, fiber lasers or solid-state ultra-short pulse (USP) lasers. This range of technologies enables marking and ablation of everything from micro-scale marks to large designs on numerous different materials.

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