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Laser Drilling Tablets for Use in Osmotic and Other Novel Drug Delivery Systems

An overview of laser drilling, a technique used in medical device manufacturing, shows that it might offer benefits for use in combined drug-devices. It allows precise drilling of tiny holes into tablet surfaces at high throughput levels.

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Dec 21, 2006

The organic materials used in drug delivery systems nearly all display strong absorption in the infrared, so a carbon dioxide (CO_2) laser, with nominal output at a wavelength of 10.6 µm, is well matched for this task. In contrast, many organics are transparent at the near infrared output wavelength (1.06 µm) of industrial lasers based on Nd:YAG.

Most organics also are strongly absorptive in the deep ultraviolet, and therefore could be processed using excimer lasers. However, the material removal mechanism in the ultraviolet is substantially different than in the visible and infrared. Specifically, visible and infrared lasers remove material in a thermal process. In contrast, deep ultraviolet lasers directly break interatomic bonds, atomizing the material in a process called photoablation. Generally, heating removes material much faster than photoablation, making the former method better suited for high speed tablet drilling. Photoablation is more advantageous in high precision applications, in which either the amount of material to be removed is small or processing speed is a secondary concern.

There is a diverse range of commercially available CO_2 lasers, offering output powers from a few watts to multi-kilowatts. Furthermore, some CO_2 lasers operate in a continuous wave (CW) mode, while others are pulsed. A CW laser produces an uninterrupted beam of light, while a pulsed laser emits a stream of very short duration (<1 millisecond) bursts of light at high repetition rates (up to 100 kHz). Pulsed lasers exhibit very high peak power, which is the instantaneous power level at the most intense part of the output pulse, even if the total average power is relatively modest.

The high peak power of pulsed lasers enables processing of a wide range of materials, even including metals, with relatively low average power. This is advantageous because laser costs rise with increasing power. The short duration of a pulsed laser means that the material being processed is only heated for a very brief period. This allows for very precise process control and minimizes any heat induced effects, such as discoloration or debris formation. As a result, pulsed lasers are favored for processing applications where heat damage of surrounding or underlying material is a concern, or for structuring of high melting point materials. In contrast, CW lasers are typically used with materials, such as plastics or textiles, where bulk heating is not a concern, or for applications where it is actually desirable (e.g. heat treating and annealing).

On-the-Fly Drilling

In order for throughput rates in the 100,000 tablets-per-hour range, it is necessary to perform tablet drilling on the fly. This means there is no stopping or slowing the forward motion of the tablets on the conveyor. There are two different ways to support on the fly operation in terms of the laser drilling process. First, the tablet can be drilled with a single laser pulse when it reaches a predefined spot along the conveyor. This pulse must be of sufficient peak power to remove the entire outer layer of the tablet, and of short enough duration so that there is no significant tablet motion during the drilling process (otherwise it will yield a slot, rather than a hole).

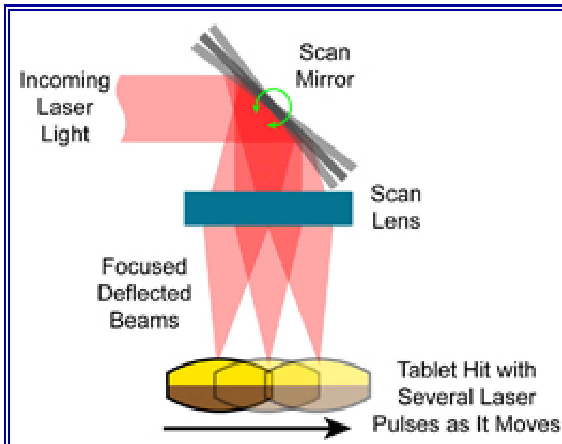

Figure 2. A galvanometer-mounted mirror and a scan lens optically track the motion of the tablet on the conveyor so each pulse hits the exact same spot on the tablet surface.

The second approach is to perform drilling using multiple pulses. In this case, it is necessary to optically track the motion of the tablet on the conveyor so that each pulse hits the exact same spot on the tablet surface. Typically, this is achieved with a galvanometer mounted mirror and a scan lens (see Figure 2, above right). The galvanometer scan mirror moves the beam in order to follow product motion. The scan lens is configured to maintain the proper beam focus even though the distance from the lens to the tablet changes slightly as product moves along the conveyor. The use of encoder feedback, together with a conveyor design that does not allow slippage of the tablet relative to belt, ensures that each pulse hits the tablet at precisely the same spot. This method also allows the process to produce multiple holes per tablet as well as other geometries, such as characters or graphics, although rates may be affected.

While the multiple pulse method increases the complexity of the laser beam delivery system, it enables a given processing task to be performed using about three to four times less laser power than in the single pulse case. This allows the use of a lower power, and therefore less costly, laser. The maximum number of pulses that can be used to process a single tablet depends on conveyor speed, the field of view of the scan lens and laser repetition rate. A typical tablet drilling process utilizes around nine laser pulses in order to drill a single hole.

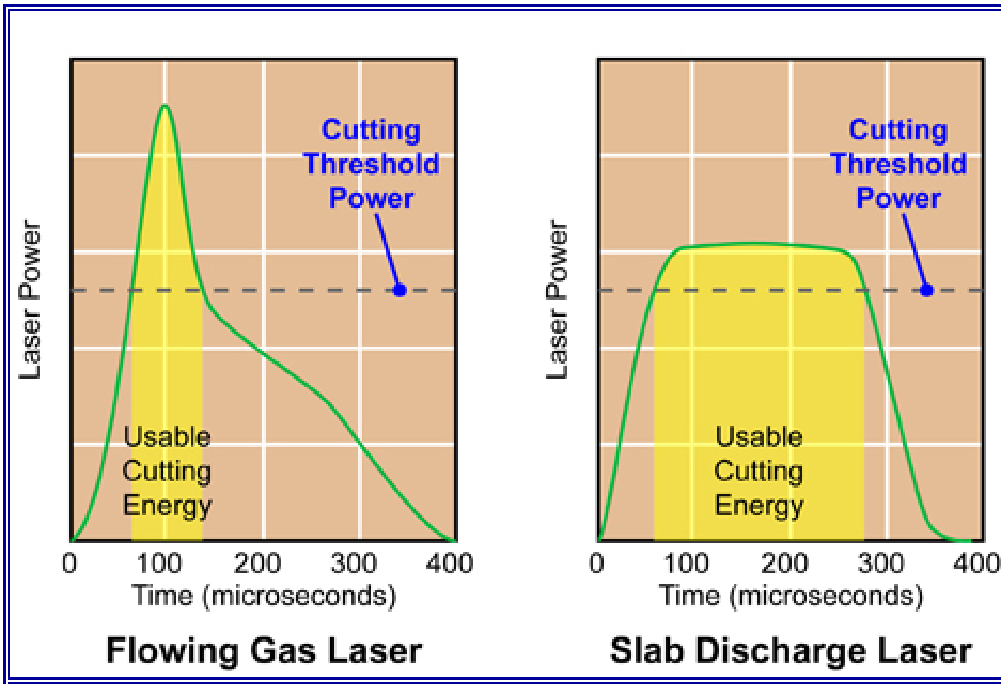

Figure 3. Output power as a function of time for a typical flowing gas CO_2 laser (left), compared with that of a slab discharge CO_2 laser (right).

The exact pulsing characteristics of the laser have a significant impact on the economics and efficiency of the drilling process. For example, the graph in Figure 3 (above) compares the output power as a function of time for a typical flowing gas CO_2 laser with that of a slab discharge CO_2 laser. The output pulse from the flowing gas laser is roughly triangular in shape. In contrast, the short rise and fall times of the slab discharge laser lead to an essentially square wave shaped pulse. While, in the case illustrated, the peak power of the flowing gas laser is higher than that of the slab discharge laser, much less of this power is actually usable for cutting (the specific cutting threshold power is highly dependent on the particular material being processed).

The fact that each square wave pulse delivers more useful cutting energy means that it takes fewer of these pulses to perform a given processing task. Because of the interrelationship between maximum possible pulse count and throughput speed in on-the-fly drilling, this translates into a wider process window and greater flexibility. In addition, the reduction of waste energy serves to further minimize any heat induced damage in the processed material.

Some of these slab discharge CO_2 lasers provide power on demand. This refers to the capacity to control the lasers pulsing characteristics, in real time, down to the single pulse level if necessary. In contrast, many industrial lasers operate with a fixed or narrowly variable pulse repetition rate. In many other laser types, individual pulses cannot be relied on to produce consistent results because the laser takes several pulses to reach its steady state performance level. However, the slab discharge design does not have this limitation and can be perfectly pulsed instantaneously. Therefore, power-on-demand allows the laser to be slaved to any arbitrary (and even variable) feed rate in a real production line. This is substantially simpler than attempting to adjust the mechanics of the conveyor system so that tablets are supplied at exactly the right time to synchronize with a fixed pulse-rate laser.

About the Authors

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