The Essential Laser for Orthopedics

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The “futuristic” technology of lasers is not so far fetched anymore. In fact, most don’t give them a second thought. They are used in a variety of industries, including both the manufacture of medical devices and in the finished devices themselves. This article reviews the critical role of lasers in the development of orthopedic implants and the key role they serve.

Ask any orthopedic surgeon to show you the tools of the trade, and the evidence of laser processing is not difficult to spot. Most devices and tools–even single-use items–bear the telltale traces of marking lasers used to indicate depth, part number, and lot or serial number. The growth of laser usage is apparent wherever you look, driven by several trends, including: 1) the miniaturization of manufacturing technologies is bringing new possibilities to the development bench, 2) minimally-invasive therapies are shortening recovery times, 3) the field is on a quest for improved patient outcomes in the long term, and 4) laser-processed components can reduce device cost with rapid processing and by reducing part and process count.
This prominent use of laser-marking in orthopedics is flanked by numerous other laser applications that are less obvious to the user, but vital for the device engineer.

Laser-Welding

Laser-welding is a well-established technology in the fabrication of instruments for orthopedics. Although a designer will look for any opportunity to eliminate an operation, welding persists and spreads because, when performed correctly, it is reliable and enables elegant solutions in design that would otherwise be impossible or impractical. Compared with other techniques, laser-welding is a fast, non-contact process which produces a clean, filler-free weld. Moreover, skilled laser-welding can handle an impressive array of geometries.

Laser Surface Treatment

A particularly interesting application for orthopedics is laser surface treatment, or texturing. A laser beam can produce surface characteristics on an implant to improve the adhesion of live tissue to the device. Better resulting bone ingrowth spells a dramatic difference in the success of the implant.

Laser-Cutting

Laser-cutting brings substantial new possibilities to orthopedics. A wide variety of instruments and implants are benefiting from laser micromachining techniques pioneered in other fields, including vascular medicine. Laser-cut sheet and tube components produce uniquely useful shapes for intramedullary fixation, spinal fusion and stabilization, and minimally-invasive components, for example. Laser-cutting is extraordinarily advantageous in machining tubes, which opens quite an expansive design space.

Many Materials of Choice

Laser processing offers a profoundly flexible suite of tools in the engineer’s toolkit. Any variety of medical materials can be successfully and commercially processed including metals, ceramics, and polymers. The most difficult-to-machine metals and ceramics often yield to laser processing in a similar fashion to more process-friendly materials. The most common orthopedic materials–cobalt-chrome, stainless steel, titanium, zirconium–lend themselves to the laser processing toolkit.
After laser-processing, metals can be treated with special surface finishing including electropolishing, for example, to radius corners, smooth surfaces, improve biocompatibility, and increase resistance to fatigue, wear, and corrosion. Similar processes can be used to achieve a desired surface texture.

Nitinol–Laser-Processing a High-Performance Metal

One example of a difficult-to-machine metal with compelling orthopedic characteristics is nitinol–NiTi–known for its shape-memory and superelastic properties. Nitinol in tube, sheet, or rod form can be processed by laser and shapeset into impressive configurations by deformation and heat-treatment. Nitinol attracts research and commercial interest due to these properties, as well as for its use in fixation components that can lock into position, produce engineered compression or expansion forces, promote bone ingrowth, influence bone remodeling, or reduce stress-shielding of the adjacent bone.

PEEK–Laser-Processing a Promising Polymer

One interesting polymer for orthopedics applications is PEEK (polyetheretherketone). Processes to laser-cut PEEK open up a realm of component design beyond the reach of conventional machining or other processes.

Process Opportunities, Pitfalls, and Path to Success

So laser processing can sidestep some conventional hurdles. Yet, this happy situation belies deep waters in the material and process interactions. Laser processes are inherently engineerable, where differing parameter combinations can be used to achieve equivalent results. On the other hand, what appears to be equivalent can also be slightly, or even crucially, different.

To make matters even more interesting, there is an ever-increasing variety of available laser sources today. The traditional CO2 and Nd:YAG laser sources now contend with a variety of fiber, diode-pumped Nd:YAG, disk, UV, picosecond, femtosecond, and other lasers. Each laser system has its notable advantages, but laser manufacturers are working all around the edges of their performance envelopes, producing significant areas of overlap. These developments make laser processing a challenging area to keep up with. This spells opportunity–and any number of dilemmas–for the designer and the manufacturing engineer. One important principle is to remain flexible as to the method of production. Another is to remember that the success of a process is all about the process. Process engineering matters more than the name alone of the laser of the day.

A project equipped with the necessary experience in material selection, design, and process engineering can achieve noteworthy gains in economy, time-saving, and performance. The right laser processing know-how can give a currently laser-processed product new life, or score a successful “first,” bringing better-performing, more cost-effective tools to orthopedics.

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For Additional Information on the products and technologies discussed in this article, see Lumenous Device Technologies [2].