Brilliant Performance – Efficiency, Power, Brightness, Reliability – of nLIGHT Diode Laser Systems

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Current economic situation: (might skip as total debrief)

We are in the midst of one of the worst economic climates in decades. As a case in point, a measure of the relative health of the industrial production market is the bookings for industrial tooling. While the increase in bookings historically has been cyclical (see Fig. 1) up to 2008, we can see the deep economic recession. With the prospects for economic recovery on the horizon, product developers now have the opportunity to deliver innovative processes and products that enable new applications, helping to stimulate new growth and future prosperity. These new applications are driven by cost-effective solutions – solutions that are scalable to the requirements of the customer, low capital expenditures and low operating costs. nLIGHT Photonics is enabling development of such applications by providing customer-specific, state-of-the-art of laser diode systems that offer industry-leading brightness, efficiency, power, and reliability.

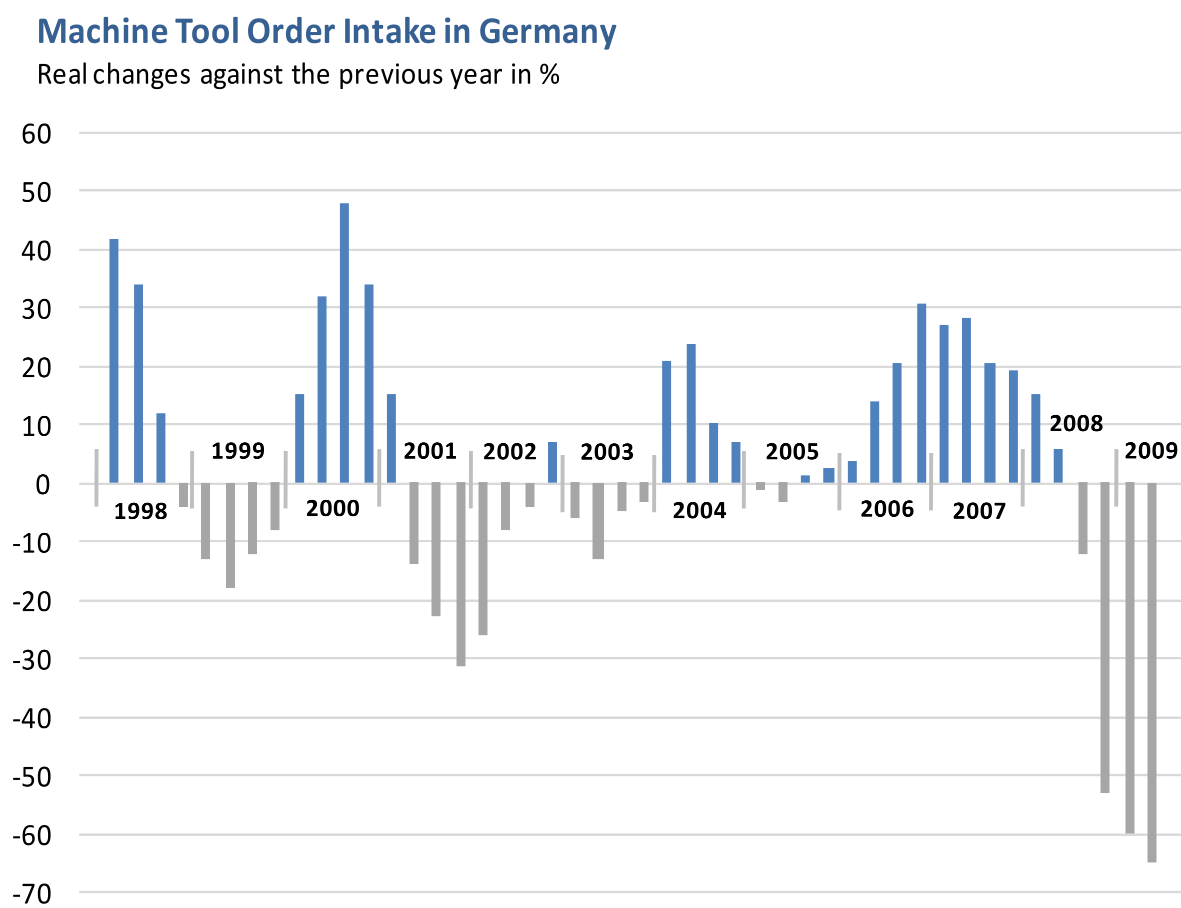

Figure 1: Yearly changes in machine tool booking orders in Germany.

Industrial Laser Applications

Industrial applications have increased requirements for brilliant products. Laser brilliance is defined as the power radiated in a given beam parameter product (BPP). A higher brightness system corresponds to a small BPP; higher brightness systems allow the laser to be focused into a smaller spot with a longer working distance. The advent of high power laser systems made possible a broad variety of applications including marking, plastics welding, brazing, hardening, cladding, deep penetration welding, and sheet metal cutting. A pictorial representation of the brightness and power requirements for each of these applications is shown below in Fig. 2.

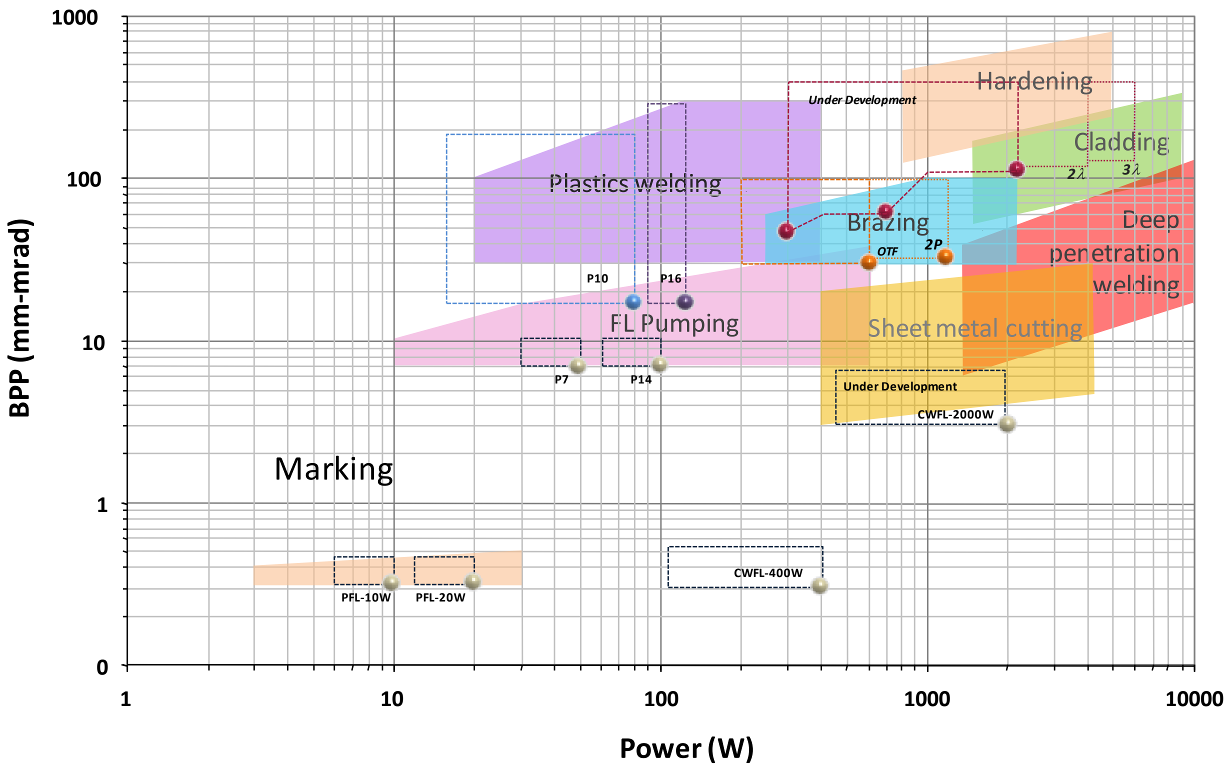

Figure 2: Power and brightness requirements for the industrial laser applications space. Fiber laser and direct diode laser products available from nLIGHT are also shown.

In addition to the industrial uses shown above, the broad spectral range of diodes lasers enable consumer, military, medical, fiber and disk laser pumping applications (see Fig. 3). The electrical-to-optical efficiency (useful light produced divided by the total power consumed by the system) for each of these wavelengths is also reflected in this figure. The electrical-to-optical efficiency ultimately drives the reliability, capital expenditure, and operating cost of the laser system. nLIGHT's ability to engineer flexible systems with single emitter laser diodes enables a portfolio of high power, high efficiency, and broad spectral range of laser diode systems. These developments, in turn, enable new markets and applications, even for the most demanding industrial requirements.

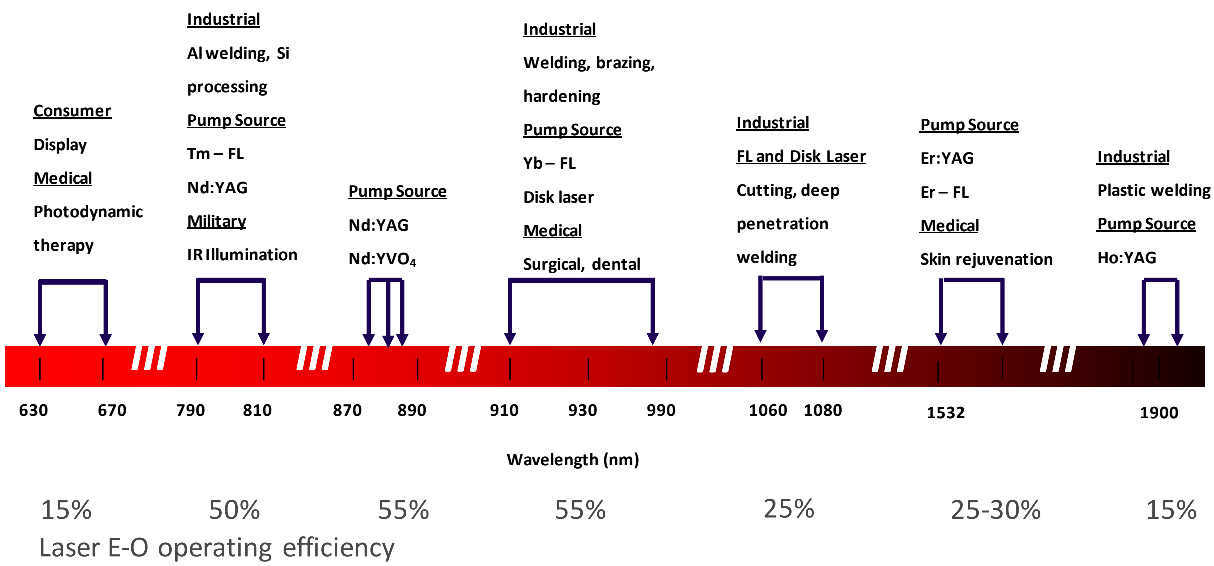

Figure 3: Wavelength requirements for industrial, pumping, medical, and consumer applications with laser electrical-to-optical efficiency.

Leapfrog in innovation – single emitter-based systems

Traditional fiber coupled diode lasers have been based on diode laser bars. In bar-based systems, the asymmetric beam quality in the fast and slow axis requires the use of expensive micro-optical beam shaping systems. These systems, which rotate the fast and slow axes of individual emitters in the laser bar, are typically implemented with the use of step mirror arrays or arrays of micro-optical cylinder lens telescopes rotated by 45°. While these systems are effective at rotating the optical axes, the optical to optical efficiency is diminished by multiple optical interfaces, imperfect beam rotation, and low fill factor after rotation. The brightness of bar-based systems is further limited due to emitter cross heating and bar “smile.” Cross heating increases the effective thermal resistance, forcing the individual emitters within the diode laser bar to run at lower power to maintain a reasonable junction temperature. Microchannel cooled laser diode bars allow for lower junction temperatures through direct cooling. Unfortunately these bars suffer from relatively poor reliability due to corrosion of the microchannel coolers. While high overall powers can be achieved, the linear power density of each emitter, and hence the brightness, is reduced. Bar smile introduces fast axis pointing error and optical defocusing, further diminishing optical to optical efficiency. In summary, microchannel cooled bars achieve high powers, but suffer from poor reliability. The lower operation powers of conductively cooled bars result in systems with reduced brightness.

nLIGHT has developed a novel approach to achieve extremely high brightness fiber coupled diode lasers. This approach is based on high power broad area single emitters, free space combined in an elegant and inexpensive manner. This approach provides the high power and high brightness operation of individual emitters, while achieving the high power levels of bar-based systems. Each device is bonded, tested, and screened, insuring excellent device performance with superb reliability. The single emitters are capable of being run at high linear power density, increasing the brightness of the diode laser system. Finally, the optics are designed to efficiently image the diode laser onto the fiber, maintaining the brightness and high system efficiency of the single emitter diode lasers. The result of nLIGHT’s single emitter-based architecture are modules that are unsurpassed in terms of electrical-to-optical efficiency and system brightness. A summary evolution of laser diode systems is shown below in Fig. 4.

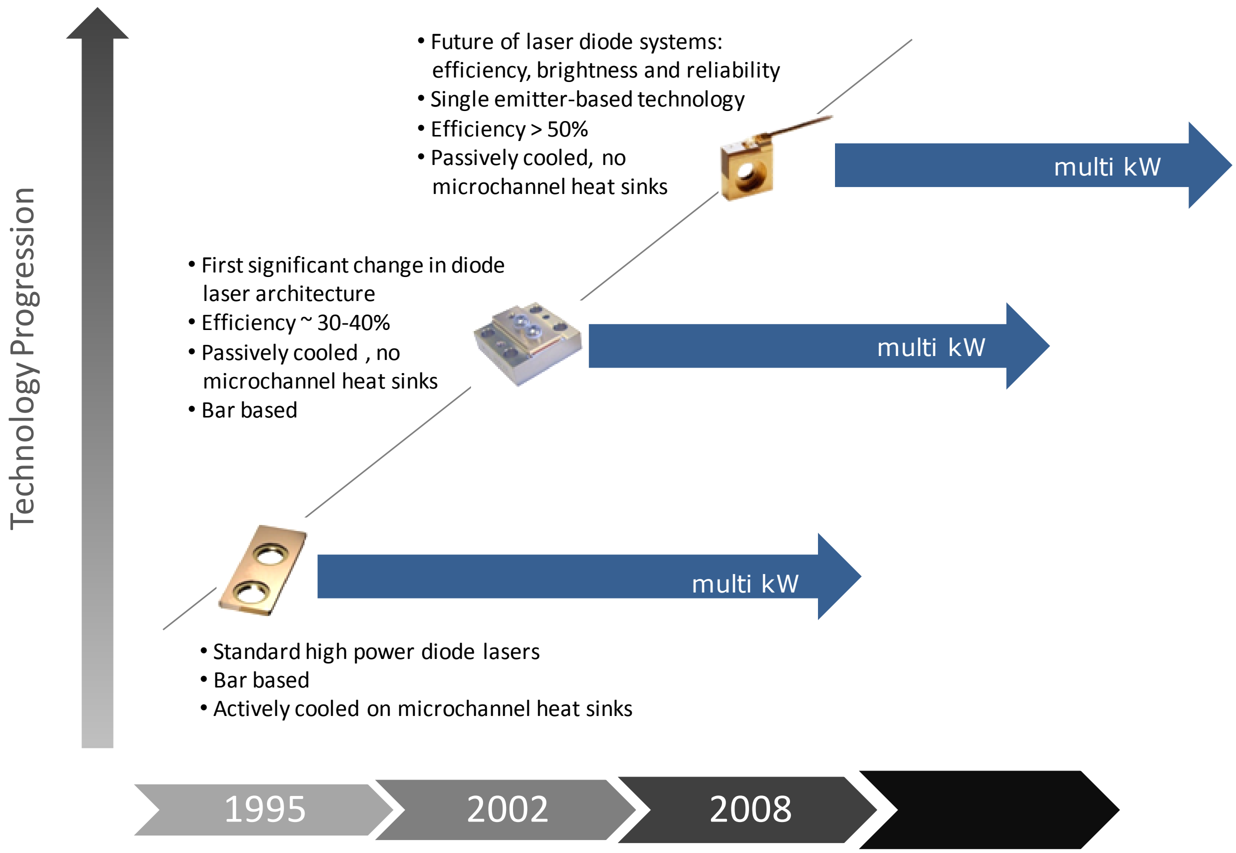

Figure 4: Technology progression of laser diode systems. The move to single emitter-based diode lasers simultaneously improves brightness and efficiency from the diode laser system.

Since the development of these free-space fiber-coupled systems in 2006, there has been an exponential increase in the laser diode brilliance (see Fig. 5). These modules can be used for solid-state, disk and fiber laser pumping as well as direct diode applications. A variety of wavelengths from 639 to 2100 nm are available, albeit with reduced performance due to lower power diode lasers at wavelengths other than 9xx nm. The electrical-to-optical efficiency for all of these modules is in the 50% range, showing some of the most efficient results in the industry. In terms of brightness, these development efforts have culminated with the development of a laser diode module capable of coupling 100W into a 105um, 0.15 NA fiber.

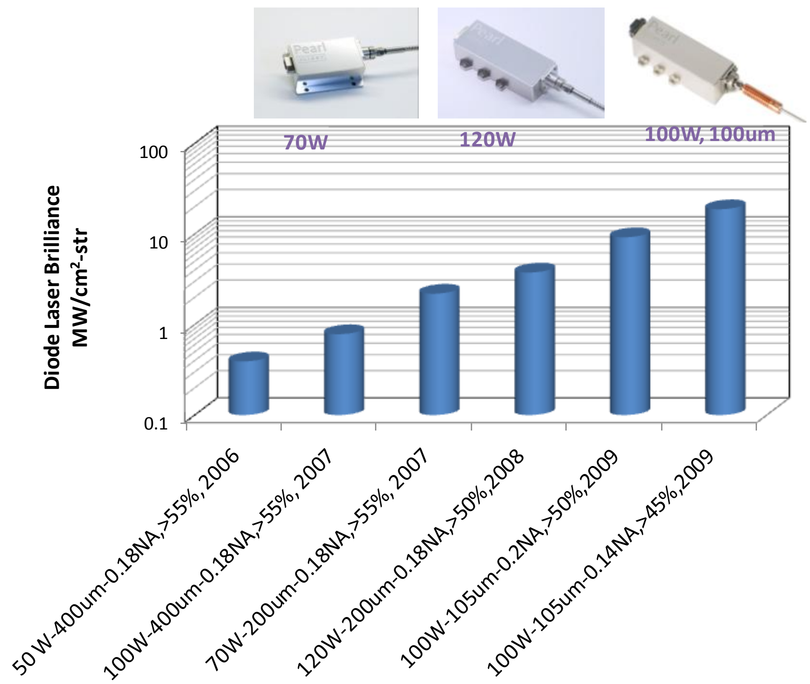

Figure 5: Brilliance scaling over time of single-emitter direct diode laser modules developed by nLIGHT Photonics.

Future outlook: high power single emitter-based systems

Until now nLIGHT has developed laser devices with record efficiency up to 100W. However industrial demand requires the reliability and efficiency of single emitter-based systems, but in power levels from 500W. nLIGHT is answering these needs with the development of a large format single emitter-based system that is capable of delivering up to 500W of optical power. This module is based on the proven performance of the free-space coupled Pearl architecture, resulting in a system with unsurpassed efficiency, reliability, and maintenance-free operation. This product, specifically designed for plastic and thin metal welding, also achieves the benchmark of ~ 50% electrical to optical efficiency. With a field-replaceable Trumph or Rofin compatible fiber, these devices are easy to integrate into the system of choice.

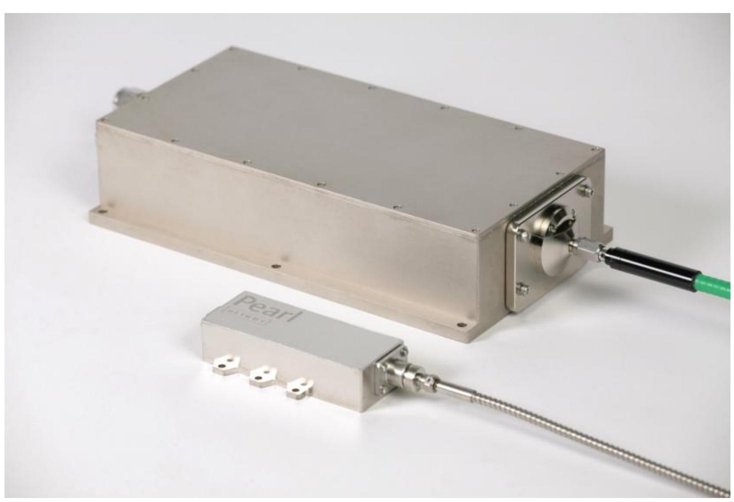

Figure 6: A prototype version of the high power single emitter-based diode laser module. A 120W Pearl module is shown in comparison.

Summary

Diode laser systems used in industrial products have undergone over 15 years of product maturity. Initial industrial diode laser systems based on microchannel cooled bars have been replaced by CS-based devices. This evolution has continued, leading to single emitter-based industrial systems. This continued evolution has been driven by increasing requirements on diode efficiency, brightness and reliability. nLIGHT's single emitter-based portfolio represent the pinnacle of laser diode development, meeting customer needs of high efficiency, power, and brightness laser systems. This high power, high efficiency, flexible laser platform will drive new markets and applications, driving future economic growth.