# The future is **OPSL**

In the first of our new Technology Focus columns highlighting a new technology development in photonics, **Matthias Schulze**, director of marketing for Coherent, explains why his company believes in the future of optically-pumped semiconductor lasers

In the late 1990s, Coherent observed that there were a number of applications still utilising gas lasers that could benefit by moving to an all solid-state source. Solid-state technology promised benefits in terms of reduced package size, higher operating efficiency, greater reliability and lower costs compared to available gas lasers. We believed the development of next-generation, solid-state sources at legacy wavelengths would lead to a new era of laser-based systems and tools.

Our goals were to develop a CW source that offered at least the same performance as gas lasers, in terms of output power, beam quality and noise – while embodying a new paradigm for physical size, reliability and efficiency. We were also looking for a platform that would be scalable in terms of wavelength and power, to service the broadest possible range of applications.

While solid-state and semiconductor lasers had already been replacing gas lasers, it didn't seem to us that these technologies would deliver. Instead, we identified optically-pumped semiconductor laser (OPSL) technology as being promising. OPSLs had originally been investigated during the telecoms boom as a high-power source for pumping Er-doped amplifiers.

The design principle of an OPSL rests on a vertical cavity semiconductor laser (VCSEL). The semiconductor gain medium is optically pumped by one or more diode lasers. The output coupler is an external, dielectric mirror; this allows intracavity placement of various optics, such as a frequency doubling crystal to convert the near-IR fundamental to a visible wavelength.

OPSLs possessed several inherent advantages over other technologies. First, the technology is wavelength scalable; VCSEL quantum wells can be structured to produce output anywhere from 700nm to 1,200nm; harmonic frequency generation extends operation through most of the visible spectrum (350nm to 600nm).

Next, OPSL output power can be scaled up by increasing the number or power of the pump diodes. Also, OPSLs don't suffer from thermal lensing, a major limiting factor in scaling the output power of diode-pumped solid-state lasers. In addition, the OPSL gain medium absorbs pump light over a very broad range, meaning that pump diodes do not have to be wavelength selected, or even wavelength-stabilised, during operation. This reduces cost and complexity.

The OPSL gain medium also has a very short upper state lifetime, which delivers two important benefits. First, it reduces the fluctuations between various longitudinal modes leading to amplitude noise; this noise can make implementing harmonic generation very problematic in other laser types. Second, it allows the laser to be directly modulated at repetition rates up to 100kHz.

While OPSL technology held promise, there's a long way between theory and a commercial product. We overcame several technological hurdles in the process of transforming OPSLs into an industrial grade technology.

The first was that the OPSL gain medium behaves like a homogeneously broadened material. This means that the highest gain mode competes for all the energy, depressing other modes. So if a loss mechanism such as a non-linear crystal is introduced into the cavity, the laser wants to jump to another mode where the loss is absent. We eliminated this by use of an intracavity wavelength control element in the form of a birefringent filter (BRF). Both rigorous testing and theoretical calculations were required to optimally balance the trade-off between wavelength stabilisation and the frequency conversion processes in the cavity.

Our push towards higher output powers also made heat removal from the gain medium a significant issue. Normally, these thin (<10µm thick) VCSEL structures are grown on a substrate around 100 to 300µm thick, and whose low thermal conductivity represents a limiting factor in heat removal. We created a unique packaging design in which the VCSEL structure is grown upside down. It is then bonded to a diamond heat sink and then the entire structure is released from the original substrate so that the top now becomes the bottom. The result is a structure that can tolerate more than 50W of pump power.

Coherent debuted its first OPSLs in 2001, and these have enjoyed success in the cytometry market and in several other applications; in fact, there are now more than 20,000 OPSLs in the field. For cytometry system builders, higher available laser power has increased cell sorting speed and reduced system noise. Moreover, the introduction of OPSLs at wavelengths beyond the original 488nm of ion lasers has enabled instruments that can simultaneously count or sort on the basis of a larger number of parameters, which reduces overall measurement time and cost. New laser wavelengths also support the ever-expanding range of fluorescent proteins and dyes used in other life science applications, such as DNA sequencing, three-dimensional microscopy and drug discovery.

At the multi-watt power level, OPSLs have also been a big hit in laser light shows. Here, they offer the practical advantages of small size, low power consumption, high reliability and the ability to be directly modulated, while also providing a broader palette of colours to the show designer than ever available before. Other CW visible laser applications benefiting from OPSL technology include medical therapeutics, inspection and even Ti:Sapphire laser pumping.

Most CW laser technologies used commercially have offered output at just a few wavelengths, which have not always matched the needs of specific applications. Now, wavelength and power scalable OPSL technology overcomes these limitations, while also providing favourable practical and cost characteristics. As the market responds positively to OPSLs, expect to see many more products based on this technology. ●