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FOCAL POINT ON EMERGING PHOTONIC AND QUANTUM TECHNOLOGIES IN JAPAN

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JAPAN PREPARES FOR THE NEXT WAVE OF PHOTONICS

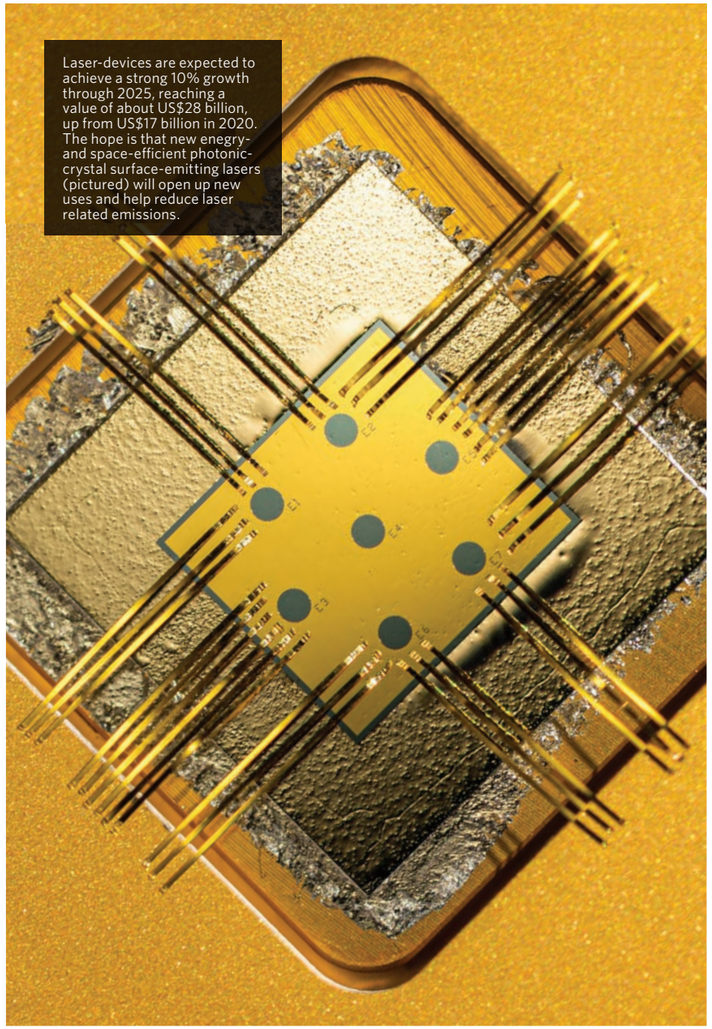
Japan is poised for a switch to technologies driven by QUANTUM-SCALE PACKAGES OF LIGHT, that manufacturers will embrace for their flexibility, security and energy efficient production.

For at least 10 years, Koji Yasui, senior chief technologist at Tokyo-based electronics manufacturer, Mitsubishi Electric, has suspected that energy-efficient photonic lasers are the inevitable next step for laser-based manufacturing. "The majority of my customers are outside Japan and so we are constantly talking, and my sense is that there will be a global move towards photonic lasers," he says.

Lasers use gases, solids or liquids as a source of optical amplification, creating coherent laser beams composed of photons — particles that represent the smallest discrete amount, or quantum, of electromagnetic radiation. Carbon dioxide (CO_2) lasers, for example, use gas for optical amplification, while photonic lasers, which are more energy efficient and compact, use semiconductor crystals to directly amplify beams.

Today, laser-based manufacturing is dominated largely by CO_2 lasers and fibre lasers — even for routine tasks such as making small holes in circuit boards for smart phones. Yasui believes that photonic lasers, which harness electricity directly, have the potential to bring manufacturing power costs right down. "I think halving the cost and emissions attached to laser cutting is possible. And because of their compact size, perhaps more," he says.

However, before these cost savings can be realized, significant technical hurdles must be overcome. The invention of photonic-crystal surface-emitting lasers (PCSELs) at Kyoto University in 1999 improved photonic beam quality in the lab. However, in order for them to be effectively harnessed by manufacturing, a trade-off between power output and beam quality needs to be resolved.



Laser-devices are expected to achieve a strong 10% growth through 2025, reaching a value of about US$28 billion, up from US$17 billion in 2020. The hope is that new enegry- and space-efficient photonic-crystal surface-emitting lasers (pictured) will open up new uses and help reduce laser related emissions.

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Maintenance of **CO_2 LASERS** outweighs their cost advantages in materials processing, while fibre lasers contain hundreds of laser diodes, which result in high energy consumption.

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Demand from the automotive industry for photonic laser sensors is expected to grow 21% per year through 2025, due to growth in assisted driving and **AUTONOMOUS VEHICLES**.

Overcoming this is a major goal of the 'Photonics and Quantum Technology for Society 5.0' programme. This is a five-year, Japanese government-funded, academia-industry partnership on the industrial application of light technologies, of which Yasui is a sub-programme director.

While the photonic lasers being produced by programme participants from Kyoto University still haven't quite solved the problems linked to manufacturing, in 2021 the group used mirrors and reshaped a PCSEL microstructure to reduce light loss. With this set-up, they performed the first successful processing of a metal surface using a single-chip PCSEL.

The next step is to enlarge the lasers, and develop packaging and cooling systems, says Yasui. Meanwhile, the programme has produced a number of technologies that are in use or on the cusp of it. PSCEL sensors will start cropping up in commercial devices as soon as next year, notes Yasui.

LIGHT WAVES

US patent numbers suggest there is room for a new laser technology. Laser patents have typically doubled each decade since the 1970s, but in the decade leading up to 2020, applications fell by about 17%.

"These things come in waves," Yasui explains. Many laser manufacturing technologies, which are the biggest segment of the laser market, entered the commercial market 20—30 years ago, he explains. "Once installed, people tend to stick to what works, so demand for new systems tends to drop off." But a few decades on and with new emissions goals at play, there's probably room for new investment.

Japan is well positioned to ride this wave, notes Šarūnas Vaškelis, CEO at Direct Machining Control, a Lithuanian laser software developer, based in Vilnius. While Japan has fallen behind competitors in the United States and Germany in terms of laser-processing technology production since its heyday in the 1990s, it remains a major force in the related optics and photonics industries, he explains.

For example, it is a global leader in photonics, which broadly encompasses technologies such as laser diodes and LEDs — pioneered by Japanese researchers — fibre optics, optical sensors, displays, and solar cells. "When looking by the country of manufacturer headquarters, Japan was leading with roughly 30% of the global market in 2015," notes Vaškelis, who authored a report on the co-operation potential in photonics between Japan and the European Union in 2018.

Recent world events are also accelerating demand for new technologies for efficient, secure and flexible smart factories, Yasui points out. For instance, the war in Ukraine — a major global source of oil and gas — has highlighted the potential for energy supply disruptions, "while the COVID-19 pandemic has reinforced a desire to move towards remotely operated facilities", he says.

Many technologies developed by Japan's five-year programme could bring benefits here. Uniquely small, efficient PCSELs for Light Detection and Ranging (LiDAR) provide new options for remotely guided factory robotics and electric vehicles. Materials processing AI and photonic communications systems are also reaching real-world use test cases, and could provide more flexible systems and unprecedented data security for a highly digitized production paradigm.

A sustainability tipping point will also impact uptake, points out John Lincoln, chief executive of photonics industry body, the UK Photonics Leadership Group. "There is a global push and pull between long-term government environmental plans and a much shorter-term company cost. I anticipate a rather sudden change in the need to try and align those two."

All these factors should create strong market movement, once the technology reaches maturity, speculates Yasui. "Between industry R&D and academia, I think Japan has all the talent and resources to make it happen." ■

KOJI YASUI
is a sub-programme director of the Photonics and Quantum Technology for Society 5.0 project.

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