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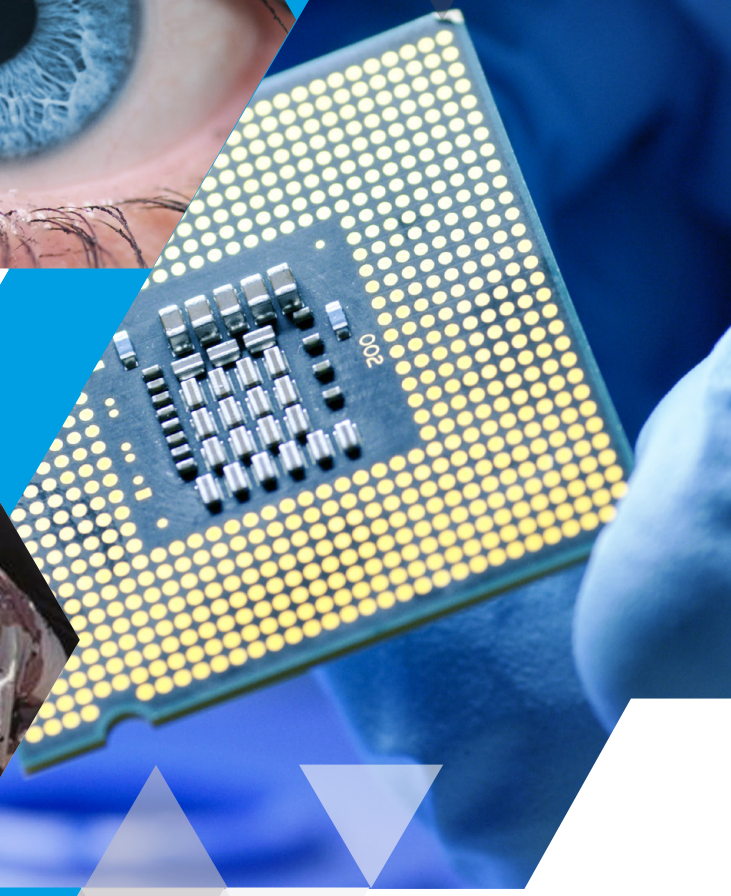
INSIGHT



The Growth of Laser

JUNE 2021

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As we start exiting the tunnel, is this light or the train coming right at us?

Photonics Emerges Stronger from the Pandemic, Proving its Robustness and Resilience Against Market Disruptions

AS WE START EXITING THE TUNNEL, IS THIS LIGHT OR THE TRAIN COMING RIGHT AT US?[1]

The year 2021 has forced enterprises and indeed entire economies to completely re-baseline their expectations of how sectors and markets will perform. Unfortunately, there have been several casualties along the way, especially for those businesses with narrowly targeted offerings in applications affected by the pandemic.

Photonics being a truly cross-cutting, enabling technology is stubbornly bucking this trend and shows strong growth across many different market sectors.

From micro-machining and materials processing for semiconductors, to applications including industrial and telecom, aerospace and defense, and life sciences, a recent study[2] predicts that by the end of the year we will witness:

- Growth of over 28.5% in some categories of industrial laser use
- Overall industrial laser market increase of 10.4%
- A global industrial laser market worth $18.2 billion (£13.2 billion)

These are positive signs that create optimism and hope for businesses across the complete value chain – from component manufacturers and value-add OEM vendors, to Tier-1s relying on photonics to manufacture the end-products their customers buy – from smartphones to wind turbines.

With strong growth in high-volume industrial lasers, increased ubiquity is expected to lead to more demanding expectations of cost versus performance in industrial laser systems for commoditized products in this specific market sub-sector. On the other hand, innovative photonic products are expected to continue to dominate in the semiconductor processing market, as well as in life sciences and aerospace and defense, driven by high-performance, field reliability, qualification standards and product differentiation.

In short, to be at the vanguard of industrial laser use, laser component manufacturers need to be at the forefront of industrial laser design. Anything else is going to put them – and, ultimately, the businesses they serve – behind the curve.

28.5%
Growth in some categories of industrial laser use

10.4%
Overall increase in industrial laser market

$18.2 billion
Value of global industrial laser market

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In this article we explore the demand for photonics-based solutions across sectors, applications and pain-points, and set out industry needs for photonic components to address the challenges customers face today.

WHAT'S DRIVING LASER MARKETS? UNRAVELLING THE UPLIFT

Rather ironically, the pandemic itself has been responsible for a significant uptick in certain areas of the laser component market, both in 2020 and 2021.

Arguably, this is unsurprising in the communications sector, given the exponential increase in the use of online conferencing tools and the electronic devices that facilitate them.

It is equally unsurprising that China leads the world in this respect, via the famed '3C' triumvirate ('computer, communication, consumer electronics'), particularly when one considers that the country's ultrafast laser market alone grew at a CAGR of 70.5% from 2015-2019, compared to a global CAGR of 11% over the same period[3].

And the stability of several other sectors is in itself, revealing. Demand in these sectors has increased or remained roughly the same against the backdrop of an extreme economic downturn – indicating that the market for industrial laser components in these applications is, by its very nature, highly resilient.

Growth in the telecom sector for photonics is driven from 'both sides'; on the one hand, core and subsea networks are racing for more capacity, and on the other hand, the increased bandwidth at the network edge is pushing adoption of photonics further out, including interconnection of the mast to the base of 5G antennas and within massive data centers.

Global internet traffic continues to increase, driven also by remote working and the impact of Covid-19. Globally, the total number of Internet users is projected to grow from 3.9 billion in 2018 to 5.3 billion by 2023 at a CAGR of 6%, and as of January 2021 stood at 4.66 billion[4].

To intercept this global traffic increase, all the 'background' enabling technologies need to step-up and deliver. Amongst others, these include a new generation of faster microchips, higher-speed printed circuit boards, new compound semiconductors and more advanced and high-throughput manufacturing techniques. Innovations in photonics technology have been the primary enabler in all these advancements in the microelectronics industry; from lasers used in wafer fabrication and inspection, to laser-based manufacturing equipment.

The continuous advancement of equipment and more precise and high-throughput lasers can only be maintained if the components used to build these systems continue to meet the specific and rapidly evolving needs of those applications; and because photonics has the potential to deliver quicker, cheaper, and 'better than' alternatives, all eyes are on it – so the competition to meet those needs skyrockets.

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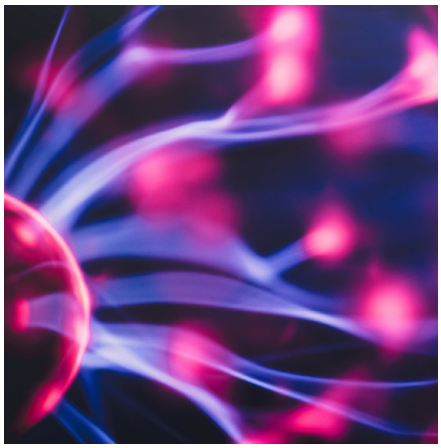


Beyond the industrial market, photonics is currently also underpinning the aerospace and defense sector, outperforming the sector average. The technology's potential for faster, miniaturized, power-efficient and EMI-free systems is attracting significant attention for generating photonics-enabled mission-critical functionality. From advanced multi-band imaging systems in aerospace platforms, to ground-based sighting systems using augmented reality (AR) is going to be a game-changer in the defense sector.

From advanced multi-band imaging systems in aerospace platforms, to sighting systems on the ground, using augmented reality AR is going to be a game-changer in the defense sector.

Although certain biophotonic sub-markets have suffered through the pandemic, the sector was resilient and most importantly, the outlook for photonics-enabled life sciences is 'brighter' than ever. Our ageing population, the ever-increasing shift of healthcare funding from therapy to early diagnosis, coupled with the advancements of high-resolution and multi-modal imaging systems will continue to challenge and push for new biophotonic components and systems.

What, then, are these applications, what are their needs, and what does it take for one component to underpin a laser that outperforms another?

TARGETING THE APPLICATION PAIN-POINTS – WITH LASER PRECISION

Over the 70 years we have been active in optics and photonics, we have seen markets rise and fall and application requirements and customer pain-points evolve rapidly. In the section below, we describe the applications, current challenges and try to define the required technology advances to support the industries under consideration.

INDUSTRIAL AND TELECOM

Application description:
Photonic applications in the industrial sector are primarily focusing on laser-based microelectronic manufacturing and semiconductor fabrication and metrology. Typical applications include photolithography, metrology, laser-based equipment for flexible and high-density interconnects (HDIs), printed circuit boards (PCBs), via drilling, integrated circuit (IC) packaging applications and display manufacturing and processing.

In the telecom sector, fiber-optic passive and active components are used to generate, modulate, amplify and guide light in fiber-optic links for diverse applications. These links can be a few meters long (e.g. interconnecting 5G antennas or data centers) to a few thousand kilometers long (e.g. subsea network bridging two continents).

Current and future challenges

In industrial applications, higher power lasers need high-quality and low-loss components, whereas higher throughput and more precise lasers require faster and more efficient photonic modules.

In telecom, higher speeds, power efficiency and capacity scaling are going to drive next-generation system architectures, supporting convergence from wireless and space-based networks.

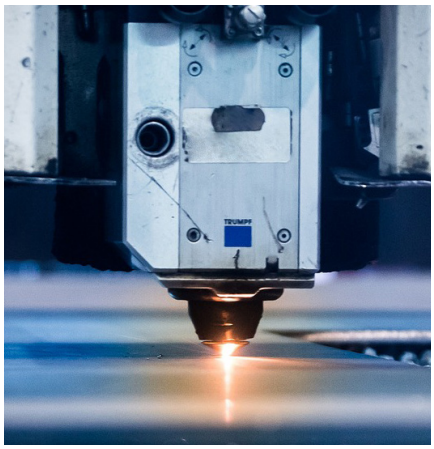
Outperform indicators

Industrial

- Ultrafast (femto- and pico-second capability)
- High-throughput equipment
- Higher precision and repeatability

Telecom

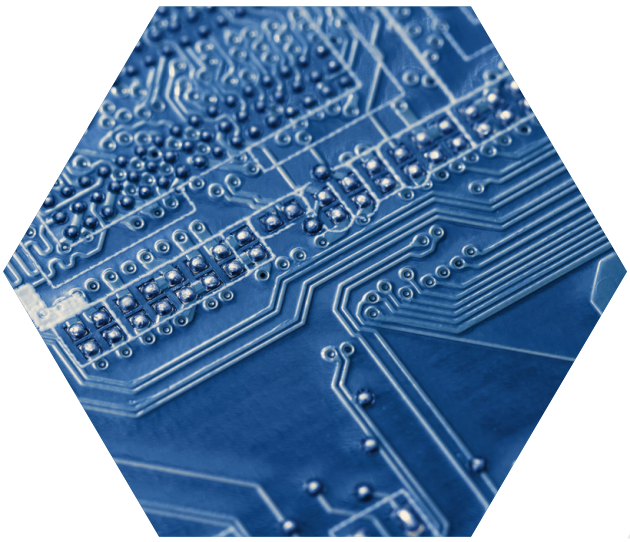
- Power efficient systems to enable higher capacity
- Higher speed networks
- Converged networks merging wireless and wired communication infrastructure

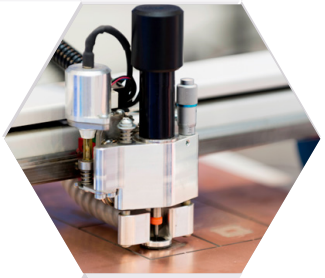


Token critical technologies

- Low-loss and high-damage threshold optical components
- Miniaturized photonic components
- Power-efficient and high-speed lasers and modules
- Faster optical switches and deflectors

Associated keywords: Precision optics (PO); fiber optics (FO); acousto-optics (AO); microelectronics, semiconductor wafer fabrication and processing, industrial lasers, UV lasers, PCB via drilling, smartphone display processing





AEROSPACE AND DEFENSE

Application description:
Aerospace and defense sectors rely on lasers for mission-critical, inertial navigation systems, including ring laser gyroscopes for airborne and maritime navigation, and guidance systems for missile and UAV (drone) guidance.

Photonics is also key for sensing and imaging in harsh environments as part of airborne, spaceborne or ground military assets.

Current and future challenges

In these applications, many of the challenges seen in industrial and telecom also apply, but with the added critical dimension that defense applications operate in typically harsh environments that can drastically impact component reliability.

Modern warfare is increasingly reliant on deep-tech in order to provide the reconnaissance edge and operational superiority when active engagement is required on the battlefield.

Robust sensors and imaging systems, combined with communication in RF-denied and navigation in GPS-denied environments, are going to be key challenges where photonics can offer unique solutions.

Although lasers are progressively becoming the solution of choice for navigation, rangefinding, and target designation, we see photonics continuing to penetrate the market, enabling new applications, such as directed energy weapons (DEW). Pivoting on the advancements in high-power laser technology within the industrial sector, high-energy lasers are gaining traction, primarily due to the high efficiency, monolithic nature and power scalability of photonics and fiber optics.

We expect to see directed energy weapons fully operational in combat systems and vehicles globally in the next five years.

We also expect these systems to start penetrating into adjacent established markets like security and counter-terrorism to more futuristic developing markets such as planetary mining.

Quick to deploy and munitionless, they fire a noiseless, invisible, variable-intensity beam almost perfectly flat over long distances. The technology is currently in the demonstration phase and current challenges including operational stability in diverse and harsh environments as well as size, weight, power and cost (SWAP) are being engineered by several development teams around the world.

Outperform indicators

- Low-size, low-weight, low-power laser solutions
- Ruggedized designs to withstand high shock and high vibration
- Stability throughout wide temperature ranges
- Multi-band sensing and communication systems
- Military grade qualification levels
- Highly sensitive sensors

Token critical technologies

- New power-efficient laser diode modules
- Functional hermetic modules merging electronics and photonics
- Lightweight multi-band systems for reconnaissance and remote sensing
- Advanced sighting systems for increasing situational awareness in the battlefield

Associated keywords: diode lasers, fiber optic gyroscopes, lidar, hyperspectral imaging, sighting systems, radiation-hard precision optics, atomic clocks, laser cooling, gravimeters, high-energy lasers (HEL), solid state lasers (SSL), fiber lasers, optimal beam point, missile defense, drone defense

> **Robust sensors and imaging systems, combined with communication in RF-denied and navigation in GPS-denied environments, are going to be key challenges where photonics can offer unique solutions.**

LIFE SCIENCES AND MEDICAL

Application description:
Biophotonics, as the name suggests, is the cross-section between life science and photonics, fusing the Greek words Bio (meaning life) and phos (meaning light).

Biophotonics is essentially split into two main categories; medical diagnostics and medical therapeutics and both revolve around the traditional pillars of medicine (predict, monitor, diagnose and treat).

Current and future challenges

The advances in biophotonics continue to optimize, streamline, and automate treatment devices, making them more accessible, efficient, and as non-invasive as possible. These advances can be seen in laser surgery, fluorescence microscopy which has revolutionized our understanding of kidney physiology for example, and medical imaging generally. The global medical imaging market size was $33.69 billion in 2019 and is projected to reach $43.33 billion by 2027, exhibiting a CAGR of 5.1% during the forecast period [5].

In many senses, the burgeoning opportunities for laser technology in this sector are also its greatest challenges.

Driven not only by demographics (an increasingly ageing population) and changes in funding emphasis (from treatment to early detection), laser technology in this sector is also coming under pressure from the demand and expectation that real-time, lab-quality diagnostics and detection should now be achievable within minutes rather than hours – the so-called 'point of care' or 'with-patient' orthodoxy.

Arguably, this requirement has also been fueled by the recent Covid pandemic, and the accompanying realization that rapid diagnostics can be vital for the effective and immediate containment of virulent infections, and not just for the early detection and treatment of underlying health issues.

Outperform indicators

- Higher-accuracy, higher-resolution diagnostics
- Combination of imaging and therapeutics in surgery
- Functional imaging combining different technologies
- Minimally-invasive or non-invasive in-vivo diagnostics
- Cohesion of supply – one source for all necessary optics, modules and subassemblies

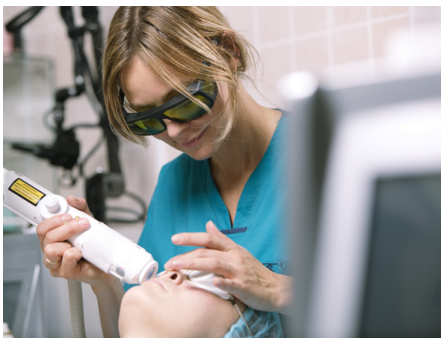
Token critical technologies

- Ultra-wide bandwidth components
- Biocompatible micro- and nano-photonic integrated components
- Laser active and passive components in new wavelengths
- Precision optical components for AR/VR in medical diagnostics and surgery

In the short term, we expect biophotonics and specifically aesthetic laser components and systems to outperform the sector average, propelled by a post-pandemic surge in cosmetic and minimally invasive surgeries worldwide.

Longer-term, we expect a 'collision' of photonics with other disciplines (robotics, artificial intelligence, augmented reality), driven by ever more accurate, reliable, stable, and integrated laser components and systems.

Associated keywords: Pockels cells, super-resolution microscopy, functional imaging, fluorescence microscopy, optogenetics, medical quantum sensing, fiber-optics



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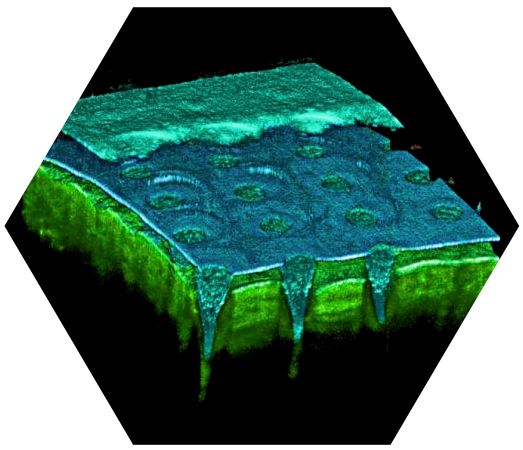

SPACE COMMUNICATIONS AND REMOTE SENSING

Application description:
High-speed connectivity between satellites and from satellites to ground using lasers has been identified as a promising technology solution for creating high-speed, low-latency and future-proof networks in the sky.

Moreover, relaying data from low-earth orbit (LEO) to geostationary satellites using high-speed laser communications can offer high-capacity and near real-time downloading of data from remote sensing satellites.

Current and future challenges

New communication architectures using space photonic components and modules must deliver the required performance and reliability in the required operational scenario and corresponding environment.

The Earth's orbit is an inhospitable environment for electronics and photonics. Satellites orbiting our planet usually do so within or close to the inner and outer Van Allen belt that traps transit galactic and solar cosmic radiation. Moreover, these systems must be able to meet the stringent cost targets in order to allow for mass manufacturing of space hardware using realistic funding levels.

Transitioning from traditional high-cost bespoke systems to higher volume, high-reliability systems in a cost-effective way is by far the biggest challenge faced.

Associated keywords: Space photonics, satellite communication, navigation, lidar, quantum-based sensors, atomic clocks

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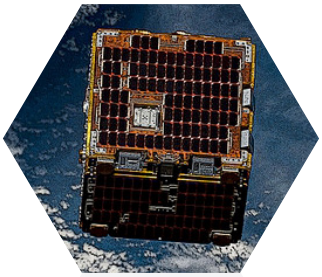
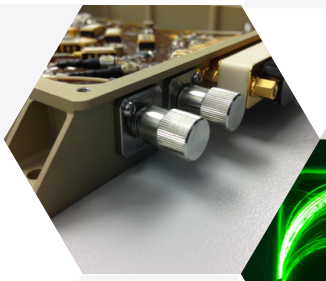
Outperform indicators

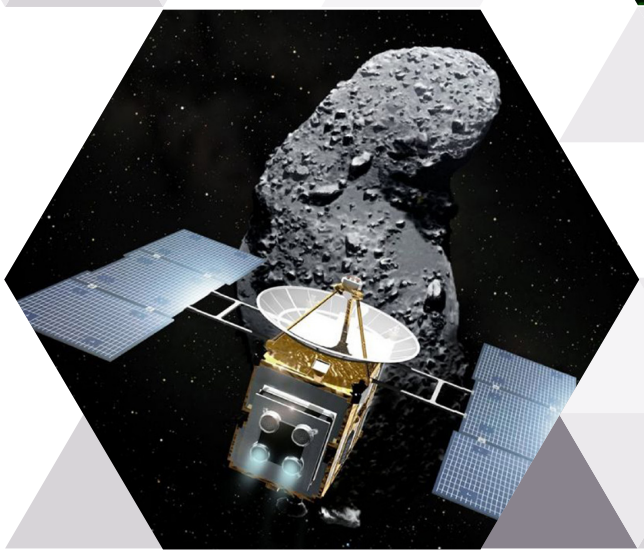
- Optimum SWaP-C (size, weight, power and cost)
- Ruggedized designs to withstand high levels of shock and vibration due to launch
- Survival and operation throughout wide temperature ranges
- Performance under radiation throughout its operational lifetime
- Cost-effective bootstrapping best practice from adjacent markets

Some critical technologies

- High-performance lasers coupled with photodetectors and passive fiber optics
- Laser electronics and digital control systems including u-ICs and FPGAs
- Optical pre-amplifiers; booster and high-power amplifiers
- Rad-hard space transceivers
- Highly stable laser sources and atomic clocks for navigation





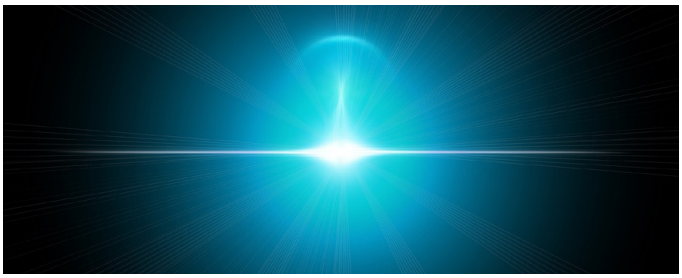


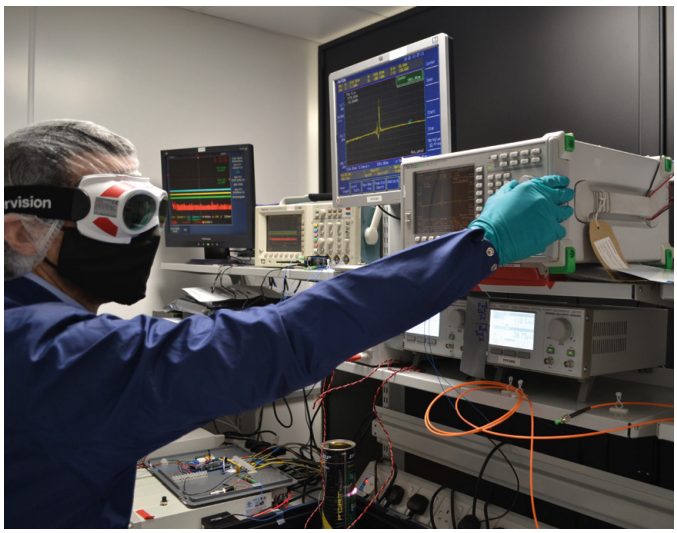
CONCLUSIONS

The pandemic has tested the agility and robustness of the photonics industry. The technology's fragmented nature that is usually seen as a disadvantage, this time has worked in its favor and enabled even deeper penetration into a plethora of emerging growth areas.

The laser market in 2021 is performing strongly with the electronics industry expected to drive the market's growth over the short term.

It would seem, therefore, that 2021 is indeed destined, in many sectors and across many applications, to see photonics and laser push the boundaries and demonstrate their resilience in what has undeniably been an unprecedented climate.





2021 is destined, in many sectors and across many applications, to see photonics and laser push the boundaries and demonstrate their resilience.

... But as the market grows, the competition inevitably increases; and in that crowded environment, the product differentiators and business capability to constantly innovate become more important than ever.

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G&H Insight looks at what's happening, why and how it affects your business in the world of photonics.

Written by specialists at G&H, it aims to share information learned from 70 years' listening to our customers, involving them in our product development, and sharing our insight-led approach.

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