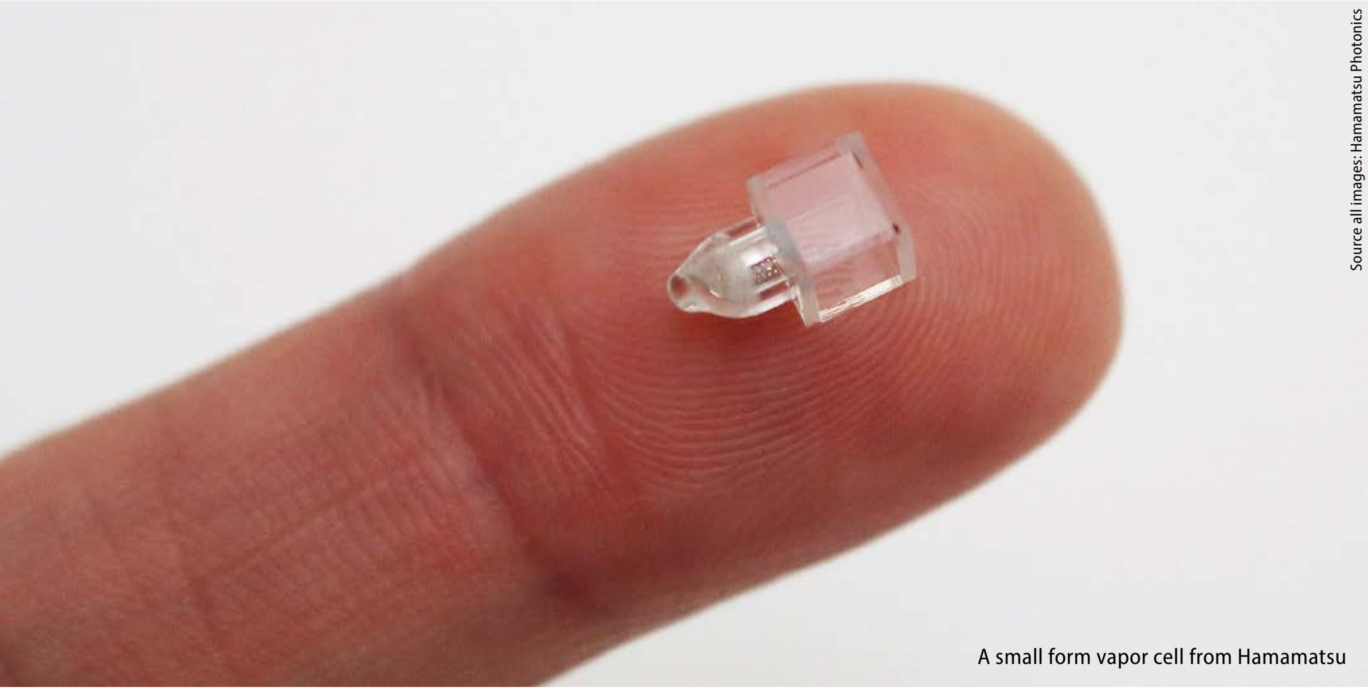
An expanding portfolio to support the development of quantum technologies

Hamamatsu Photonics provides photonics for the quantum world.

Naveen Balla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A small form vapor cell from Hamamatsu

Photonics plays a vital role in enabling quantum technologies across computing, sensing, and secure communication. This article explores Hamamatsu Photonics' expanding portfolio, from vapor cell-based sensors to advanced lasers and imaging systems. It highlights how the company's innovations are helping to bridge the gap between research and real-world quantum applications.

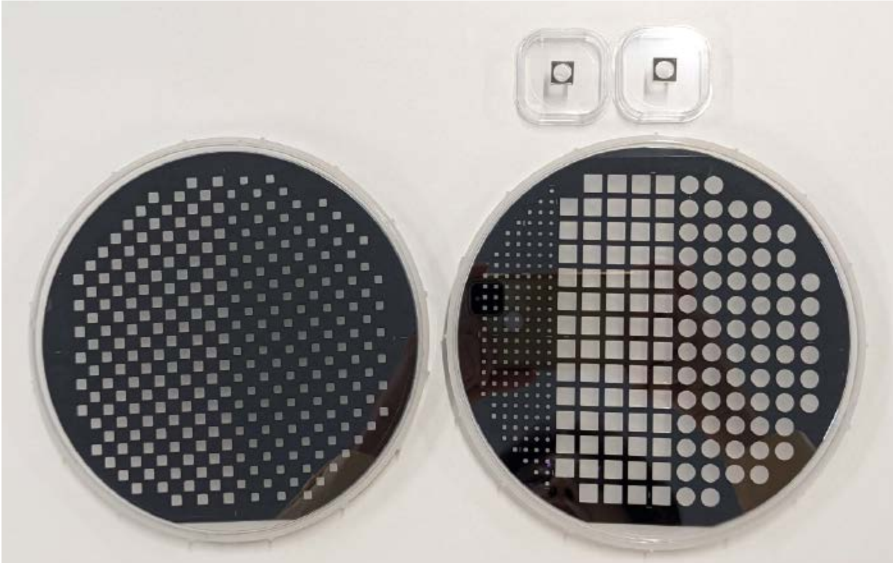
The transition of quantum technologies from research labs to industrial applications has been phenomenal in recent years. This trend is clearly reflected in public funding, venture capital investments, and patent applications for quantum applications [1]. Broadly, quantum technology refers to a collection of innovations that exploit quantum phenomena like entanglement, tunneling, and superposition to achieve tangible outcomes beyond limits set by classical systems. A few relatable examples include

- quantum computers which can solve complex problems faster than present-day supercomputers,
- high-precision time measurement for the synchronization of communications,
- measurement of minute magnetic fields using sensors that fit in the palm of your hand rather than occupying an entire room, and
- secure communications that are practically immune to interception.

Central to all these quantum technologies is a medium which exhibits quantized behavior. In neutral atom computing, this medium consists of a collection of trapped atoms; in ion computing, it comprises trapped ions; in certain types of atomic clocks, it is a collection of alkali atoms in vapor phase. Photonics technology plays a crucial role in interacting with and manipulating these delicate quantum media while also exhibiting quantized behavior and acting as a reliable carrier of information for networks of quantum devices. In other instances, such as in photonic quantum computing or quantum communications, individual photons themselves act as the quantized medium. In addition, photons can transfer information over long distances with minimal losses compared to electrons, and they are unaffected by electromagnetic fields. In essence, photonics is integral to the advancement of several quantum technologies.

A trusted partner

Hamamatsu Photonics has been a trusted partner of the scientific research community since its inception. As a result, the company has developed some of the best photonic technologies available today, and continues to lead on this path. At the same time, Hamamatsu is no stranger to the requirements of industrial, medical, and semiconductor applications, which are also key markets for the company. High-volume production and quality control of robust optoelectronic products and systems are an integral part of Hamamatsu's business. With its legacy, expertise, and capabilities, Hamamatsu Photonics is well-positioned to be a photonics partner in the development of quantum technologies.



Hamamatsu's wafer-based vapor cells

Vapor cell technology

Shining examples of Hamamatsu's contribution to quantum technology are vapor-cell products. In the photonics world, Hamamatsu Photonics is synonymous with photomultiplier tubes (PMTs) which are based on vacuum tube technology. Building on this legacy, the company has established deep expertise in manufacturing vapor cells of different shapes and sizes, with different coatings, and containing diverse trapped alkali vapors and buffer gases.

When combined with light sources, detectors, optical elements, and electronics, these vapor cells can be molded into quantum sensors for specific applications. Hamamatsu recently presented its optically pumped magnetometer (OPM) based on this vapor cell technology. This OPM, packed into a compact volume of less than 8.5 cm^3, boasts a magnetic field sensitivity of 20 fT/$\sqrt{\mathrm{Hz}}$, making it suitable for biomedical functional imaging [2].

Hamamatsu is working with Cerca Magnetics, a startup from the University of Nottingham, to commercialize OPM for magnetoencephalography (MEG), which non-invasively maps neuronal activity of the brain. The compact size of OPMs allows them to be assembled onto a 3D-printed headset, making MEG measurements more lightweight, portable, and comfortable for patients. OPM revolutionizes MEG measurements when one compares it to the existing MEG machinery that relies on a large, liquid helium-based magnetic sensor. Hamamatsu is also in the process of


OPM detection heads for MEG application

developing other types of quantum sensors based on the core vapor cell technology and is open to industrial collaborations.

Beyond vapor cells

Hamamatsu's contributions to quantum technology extend beyond vapor cell technology. While not all of these can be listed here, a few notable innovations can be highlighted.

Liquid crystal on silicon spatial light modulators

These modulators are used to trap large numbers of atoms for neutral atom computing applications. Hamamatsu's liquid crystal on silicon spatial light modulators are known for their low phase jitter ensuring stable traps and their high laser power handling capability aiding in scaling up the power of quantum computers.

High-speed, low-noise cameras for qubit readout

Neutral atom computers require constant monitoring of trap stability and qubit states during operation, both of which are accomplished using high-speed low-noise cameras from Hamamatsu. The latest innovation, qCMOS technology, has been particularly disruptive in providing a unique combination of precision, speed, and resolution. Whether diagnosing and reading out ion or neutral atom traps or determining the precise number of photons absorbed in a given pixel for a quantum imaging setup, the ORCA camera series offers the right solution. Hamamatsu recently partnered with Quantum Machines to integrate ORCA cameras into their quantum computing hardware.

Single-frequency lasers for quantum state manipulation

Single-frequency lasers are used to manipulate quantum states in neutral atom computers, ion computers, atomic clocks, and other quantum systems. With the acquisition of NKT Photonics, Hamamatsu now offers a range of single-frequency, mode-hop-free, and ultrastable fiber lasers. The Koheras HARMONIK HP series provides high-power ultraviolet and visible-light fiber lasers, known for their narrow linewidth light and industrial reliability. They also have a robust design, low noise, and high OSNR, and are ideal for quantum computing, sensing, metrology, and communications.

Commitment to innovation

Hamamatsu's commitment to advancing quantum technology is evident through these innovations and partnerships. Beyond these examples, the company continues to develop cutting-edge photonic solutions tailored for quantum applications.

Our engineers are always keen to discuss these technologies as well as custom solutions through one-to-one interactions. If you would like to explore collaboration opportunities or learn more about our offerings, please reach out to us at *info@hamamatsu.eu*.

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Naveen Balla would like to humbly acknowledge the input of his Hamamatsu colleagues in the preparation of this article.

[1] McKinsey & Company, The Quantum Technology Monitor 2024; PDF available from *https://tinyurl.com/yc48zcwz*
[2] *Siming Zuo* et al., IEEE Transactions on Biomedical Circuits and Systems **14**(5), 971 (2020), DOI: 10.1109/tbcas.2020.2998290

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