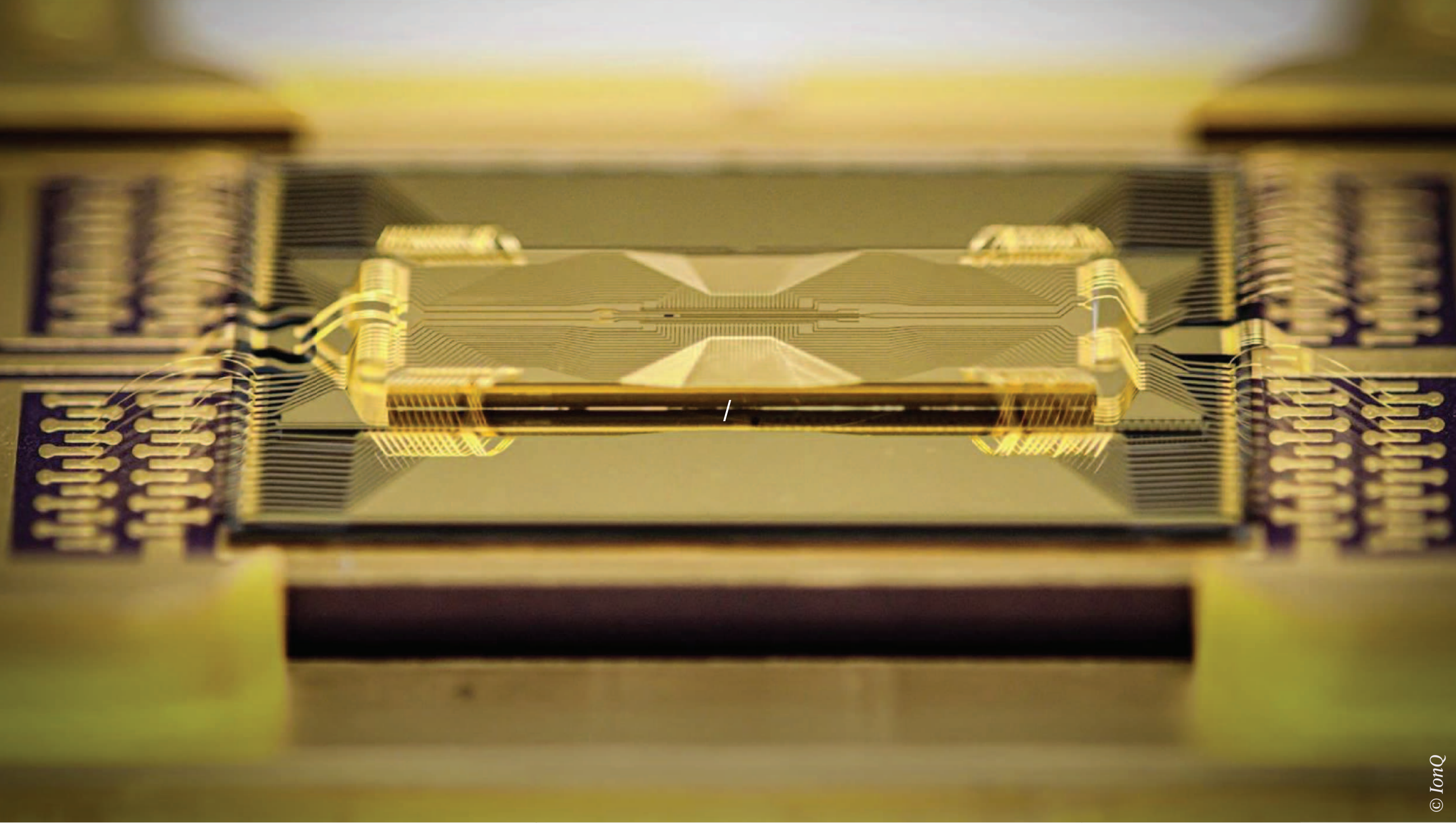
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Hyundai and IonQ use quantum computing to propel EVs and AVs

Quantum computing's near-infinite problem-solving capacity could propel automotive into the next stage of autonomy and electrification. By Elle Farrell-Kingsley

While the latest generation of connected cars have been upgrading their human-machine interface (HMI) systems to run via computers, supercomputers and gaming computers, the next development could very well be quantum computing. Quantum computing leverages quantum physics and engineering to perform advanced calculations and data simulations. According to market researcher Statista, the quantum computing market could reach US$93bn in the US alone by 2040. China, Japan and the EU are at the forefront of quantum patents, while China, the Netherlands and the UK are leading in quantum adoption.

In the US, IonQ is leading the revolution—opening the first quantum computing manufacturing facility in Washington. Subsequently, IonQ Co-founder and Chief Technology Officer Jungsang Kim states that his focus has been building on innovations in quantum mechanics and transforming them into a more practical technology. "We're at a very exciting place of looking at the technology's industry applications, starting companies, and pushing commercialisation," he says. Automotive presents one such promising application: quantum hardware's extensive problem-solving capacity makes it well suited for addressing prevailing issues in electric and autonomous mobility.

Quantum vs classical

The advantages of quantum systems over classical computers involve superposition and entanglement. For superposition, classical computers process and store units of data (bits) in a binary system of zeroes and ones. Comparatively, quantum computing contains quantum bits (qubits) that can represent a zero and one simultaneously. "If there's one bit, it doesn't make too much difference. But for sums with ten bits, two sets (the zeroes and ones) of ten bits means there are ten sets of 24 possibilities," notes Kim. For classical computers to consider all these possibilities, they would need to process this a thousand times.

> "AVs are still in their infancy, yet the quantum-derived algorithms we're testing today have the potential to shape the commerciality, efficiency and safety of such systems

"By the time it reaches 300 bits—which is still not very much, as a typical smartphone has hundreds of gigabytes of memory—the number of possibilities that this can represent is larger than the number of atoms in the universe," he says. To put this power into perspective, in 2019, Google's quantum computer, Sycamore, calculated in four minutes what would have ordinarily taken over 10,000 years for the world's most powerful computer at that time, IBM's Summit.

Meanwhile, the second feature—entanglement—was the topic of the Nobel Prize in Physics in 2022. When two particles, such as a pair of photons or electrons, become entangled, they remain connected even when separated by vast distances. Entangled quantum states have the potential for new ways of storing, transferring and processing information, according to Prize winners Alain Aspect, John Clauser and Anton Zeilinger. "Using superposition and entanglement together, we can solve problems in automotive that would have taken classical computers ages to solve," says Kim.

The development of AVs

Superposition and entanglement are key in taking quantum systems to the next level. "If you utilise them carefully, you can achieve highly functional computational powers that are otherwise unavailable," says Kim.

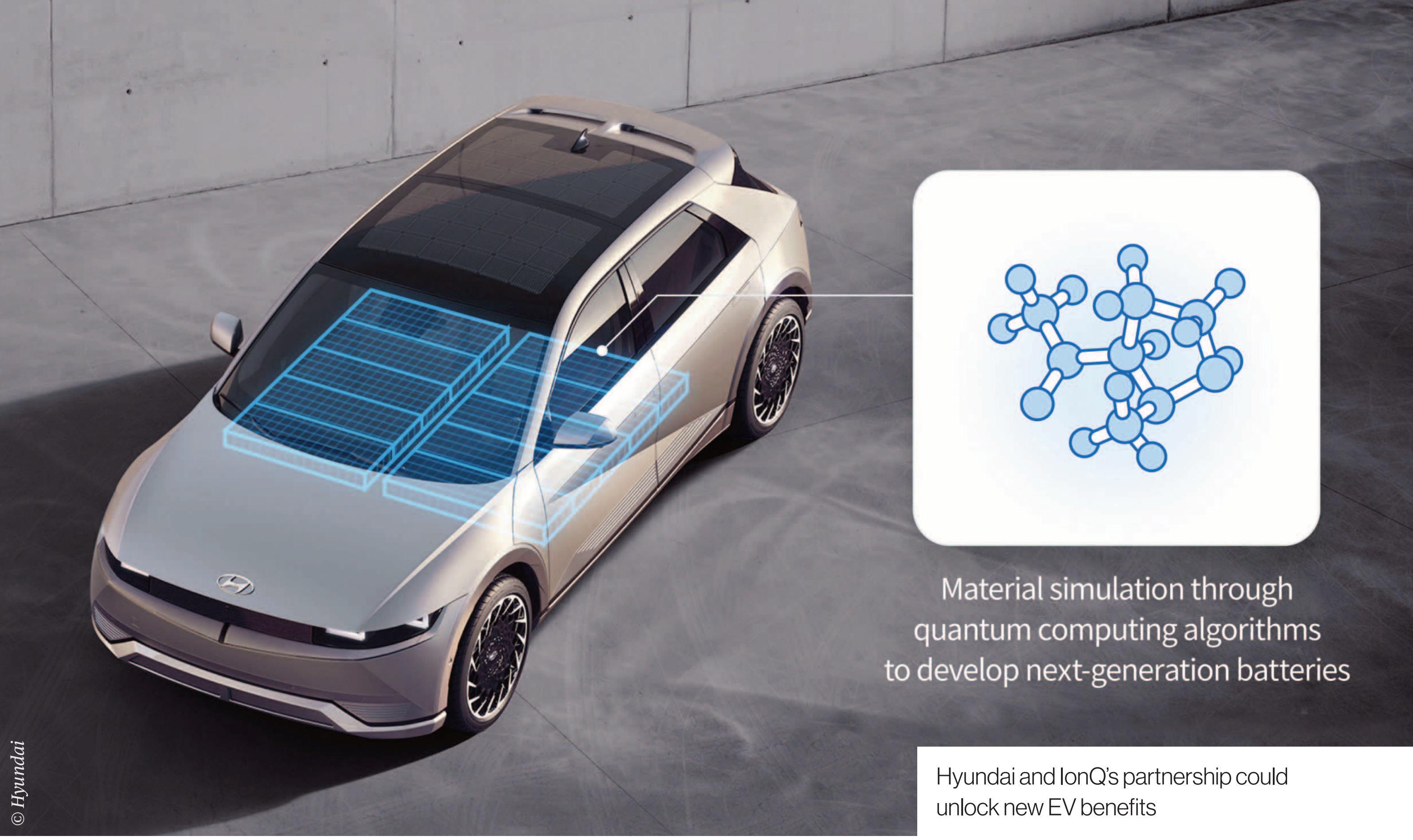
Subsequently, Hyundai and IonQ are working together to make the latter's quantum computer machine vision algorithms capable of conducting object detection on three-dimensional data captured by autonomous vehicles' (AV) sensors. "AVs are still in their infancy, yet the quantum-derived algorithms we're testing today have the potential to shape the commerciality, efficiency and safety of such systems," says Kim.

AVs rely on AI to power cameras, sensors, and advanced drive assistance systems. Similarly, self-driving cars must react to dangerous scenarios, such as a person running out in front of the car and potentially causing a collision. "All of this is achieved by computing and algorithms today, and, as the complex situations come about, this is where a lot of computational power is being used," he says.

Kim states that using quantum computing could fine-tune complex AI decisions and improve overall predictive capabilities: "We are shifting the paradigm by which we're tackling this problem. As the technology evolves, we can do computations billions of times faster." This will allow AVs to be deployed faster as the technology and its current problems are solved quicker. Kim notes that using quantum computers can also secure future commercial advantages, such as reduced costs and quicker processing times when developing AV software.

Increasing battery range

IonQ and Hyundai will also utilise IonQ's industry-leading quantum computers to simulate electrochemical reactions of various metal catalysts. The new projects build upon previous work conducted between the two companies and further the role quantum computers have in developing the smart, environmentally friendly vehicles of the future. A positive outcome of this partnership, notes Kim, is that Hyundai has highlighted problems that quantum engineers had not previously considered: "It's kind of where two imperfect parts meet: people who know the problem but don't know any more advanced algorithms, and vice versa."



Hyundai and IonQ's partnership could unlock new EV benefits

Some of the problems experienced by automotive companies, he notes, are relatively easy to solve. For example, connecting iPhones to the screen on the car is a problem for which automakers already have the technology and solution. However, more complex issues, such as how automakers can triple or quadruple the range of a battery in an electric vehicle (EV), require a more complex approach.

In terms of extending battery range and fast charging, Kim explains that these are rooted in the underlying principles of battery chemistry and catalytic reactions, which must be understood to be resolved. However, he warns that "fundamentally, these chemical reactions are quantum mechanical, and therefore the complexity of these computations is exponentially more difficult." The aim of IonQ's research paper, titled *Orbital-optimised pair-correlated electron simulations on a trapped-ion quantum computer*, is to help automotive engineers better understand the electronic configuration of molecules–lithium in this case–and chemical reactions in batteries.

In December 2022, IonQ developed a new quantum algorithm to help make EV batteries cheaper and extend their charge. The algorithm can simulate the molecules involved in the lithium-air reactions that occur within lithium-ion batteries. It can then yield accurate predictions that help battery engineers understand the configuration of molecules, their energy profile and how they react. "If we can understand these battery chemistries and learn how to improve either the charging characteristics or the storage capacity, we can improve the efficiency of current technology and develop the next generation of batteries," concludes Kim.