What will India's new National Quantum Mission achieve?

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Updated – April 29, 2023 11:42 am IST

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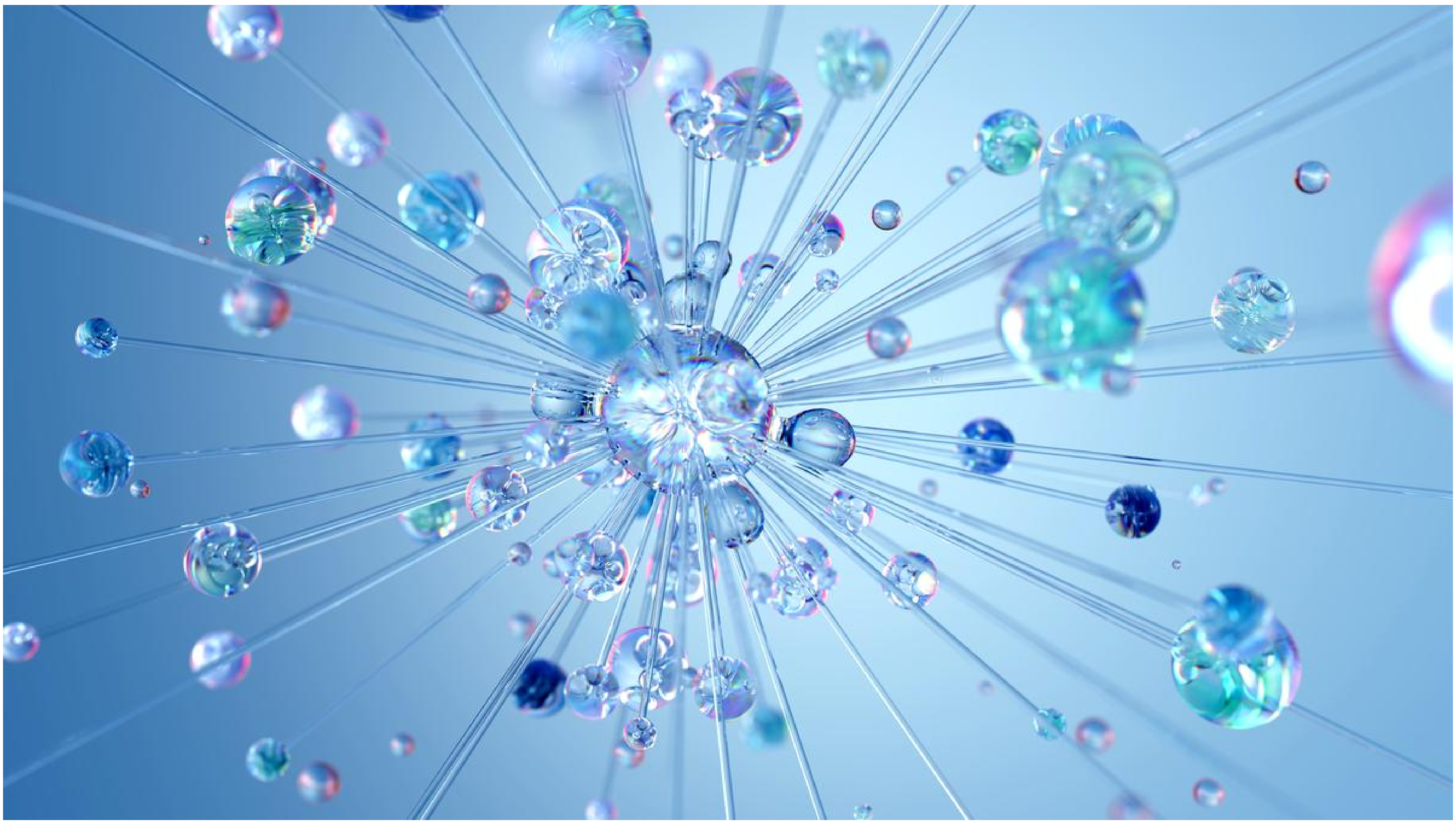

Representative illustration. | Photo Credit: DeepMind

Sensors – systems that help detect electric and magnetic fields, rotation and acceleration, measure time, and image biological systems with increasing accuracy – are an inalienable part of essential enterprises like healthcare, security, and environmental monitoring today and practically indispensable for day-to-day life.

The National Quantum Mission, launched by the Department of Science and Technology of the Government of India, aims to catapult efforts across the nation to engineer and utilise the delicate quantum features of photons and subatomic particles to build advanced sensors that boost the value added by these enterprises and to support sustainable development.

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How can quantum physics help?

Classical sensors are based on familiar principles and as such their mechanisms are intuitive to us. In medical diagnostics, these sensors play a central role in sensing the very feeble signals emitted by atomic nuclei in tissues and detecting diseases. They sense the weak magnetic fields generated by neurons and map the brain's activity, helping experts detect neurological illnesses at an early stage.

They are also used in the Global Positioning System (GPS) to measure small deviations in space and time, allowing us to build sophisticated transportation and logistics systems on the ground.

When we push the limits of these classical sensors by taking advantage of processes happening on the subatomic scale, our devices access a level of sensitivity that lets us develop game-changing applications.

Consider the ‘squeezed states’ of light. They overcome a detection limit that comes up when we use light to detect physical phenomena. This is because of Heisenberg’s uncertainty principle: we can’t measure the intensity and the phase of photons (the basic particles of light) with the same accuracy at the same time. That is, there is a natural limit on how accurately we can measure the intensity of light when it is reflected from or absorbed by objects or when the phase of light changes.

Quantum mechanics can help us overcome this barrier by allowing us to measure only the parameters of interest with higher accuracy (‘squeezed states’), at the expense of parameters that are not of interest.

How can technologies take advantage?

It is worth noting that quantum mechanics works counterintuitively to our experiences in the macroscopic world. This is because systems operating at atomic and subatomic scales are governed by phenomena like quantum superposition (like two circular waves adding up in the water when two pebbles are thrown), quantum entanglement (a characteristic that leads to knowing the properties of two distant particles instantaneously), wave-particle duality (particles behaving as waves and vice versa), and quantum tunnelling (particles sometimes finding their way through a barrier).

When these possibilities – which don’t exist in the macroscopic world – are used in technologies, the technologies seem capable of doing wondrous things.

For example, an electron microscope takes advantage of wave-particle duality. An optical microscope uses visible light as the medium of imaging. An electron microscope uses electrons instead of visible light. The wavelength of electrons (considered as waves) can be reduced to a limit where an electron microscope can image nanometre-sized objects – a task impossible with visible light.

The results of quantum mechanics are not limited to sensors. The successive application of the principles of quantum mechanics has led scientists to discover semiconducting devices like transistors and superconductors and to understand the forces between atoms in molecules. It gave rise to the boom in semiconductor technology, clean energy, and the development of novel drugs.

In the 21st century, scientists worldwide have been able to control and harness quantum mechanical features to build devices that are coming to define new paradigms in several sectors, leading to the second quantum revolution, or Quantum 2.0. This is expected to address humankind’s need for faster transportation, faster and more secure communication, short lead-times in designing drugs, securing national borders, and exploring deep space.

How will Quantum 2.0 help India?

On the Quantum 2.0 front, India has thus far had small-scale and isolated efforts led by various scientists in academia, government laboratories, and some other facilities. These scattered efforts have led to restricted capacity in the field and with a limited translatability into useful products.

The National Quantum Mission is designed to boost these efforts through coordinated efforts to consolidate existing knowhow and create a nationwide knowledge generation, translation, and indigenisation endeavour.

As far as quantum-sensing is concerned, the Mission will focus on research and technology development to build a plethora of devices and systems, including:

> Magnetic sensors that can sense magnetic fields that are a million-times weaker than the earth’s magnetic field, using virtual atoms trapped in diamonds, atoms cooled and trapped at near absolute-zero temperature, collections of atoms at room temperature, etc.
>
> Precise clocks that will lose less than one second in more than 300 billion years, allowing us to develop navigation devices that are more than 1,000-times precise to help study the origin of the universe – an open question in astrophysics

Navigation devices that can operate autonomously, without the need for GPS signals – an important part of autonomous driving systems and deep space navigation

Affordable sensors that can detect anatomical changes within human bodies with minimal intervention

The Mission will also help attain these at a cost that is affordable and scalable for a wide range of applications.

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Published – April 28, 2023 02:30 pm IST