Plenary Talk
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NIST on a Chip: Revolutionizing Metrology through Deployable, Quantum-Based Sensors

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Summary:
This talk provides an overview of the NIST on a Chip program, which is transforming how precision measurements are delivered through a suite of fit-for-purpose, quantum-based, traceable sensors. A brief history of the program will be provided, and examples from the program will be used to highlight how the redefinition of the SI, nanofabrication and integrated photonics, and the quantum revolutions have enabled this completely new approach to metrology, which in turn is enabling the fourth industrial revolution. The talk will include a discussion of sensors versus standards, and the importance of public-private partnerships.

Keywords: Quantum Revolution, Metrology, Redefinition of the SI, Industry 4.0, Technology Readiness

NIST on a Chip Vision

NIST has embarked on a sweeping program called “NIST on a Chip” (NOAC) that will revolutionize measurement services and metrology by bringing them out of the lab and directly to the user. To that end, NIST is developing a suite of intrinsically accurate, quantum-based measurement technologies intended to be deployed nearly anywhere and anytime, performing uninterrupted without the need for NIST’s traditional measurement services.

These quantum-based measurement technologies will enable users to make precision measurements referenced to the International System of Units (SI) on factory floors, in hospital diagnostic centers, in commercial and military aircraft, in research labs, and ultimately in homes, automobiles, personal electronic devices, and more. NOAC thus provides an opportunity for the “democratization” of measurement technology, where affordable devices drastically reduce the cost and increase the availability of precise measurements that could previously only be delivered at the world’s best metrology institutes.

NOAC will meet those goals by creating prototypes for a new generation of ultra-compact, inexpensive, low-power measurement tools for quantities including time and frequency, distance, mass and force, temperature and pressure, electrical and magnetic fields, current and voltage, and fluid volume and flow. The program envisions eventually combining multiple measurement capabilities onto an integrated platform to enable, for example, a single, embeddable chip that senses absolute temperature, pressure, and humidity to immediately detect any excursions in safe storage conditions of sensitive goods, such as vaccines or food. Other applications will leverage inexpensive mass fabrication, leading to applications such as a chip-scale radiation monitor that could be embedded in every driver’s license or other ID card to serve as a ubiquitous monitor or early-warning system for radiation exposure.

These NIST-pioneered technologies will be manufactured and distributed by the private sector, opening new technology transfer and lab-to-market opportunities in accordance with NIST’s goal of strengthening U.S. economic competitiveness by supporting advanced manufacturing.

Defining Criteria for NOAC Devices

The integrated NOAC program will develop and deploy practical quantum-based standards and sensors, traceable to the new international system of units (SI), that are:

Deployable to where customers need them, such as on the factory floor, embedded into products, in a laboratory environment, in space or at home.

Flexible, providing a broad range of “zero chain” SI-traceable measurements and standards that are configurable into a single small-form package and adaptable to customers’ requirements.

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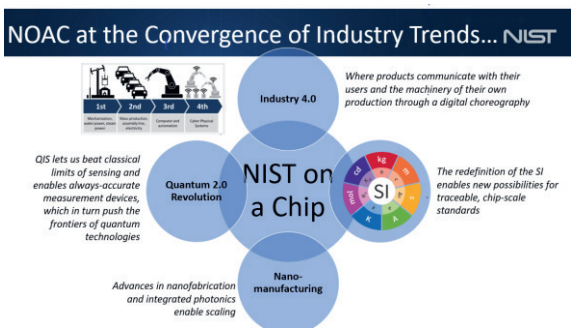
Manufacturable, with production costs that scale appropriately for applications, such as low-cost/high-volume for broad deployment.

Reliable, providing either the right value of a measurement or no value at all.

Fit-to-Function, tending towards small size, low power consumption, rugged, easily integrated and operated, with an operating range and uncertainty required by the application.

Propitious Timing



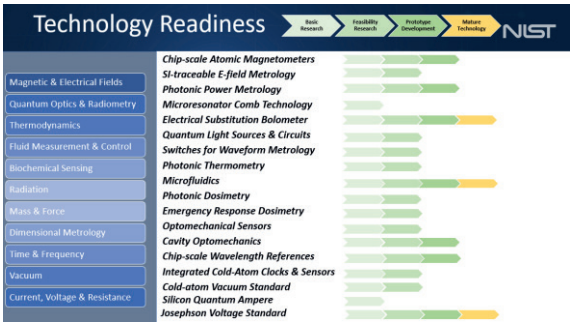
NOAC innovations will be increasingly valuable to industry, medicine, defense, and science because of the current convergence of major trends in technology advancement. For example, Industry 4.0 is an optimization strategy in which the machinery of industrial production no longer simply "processes" the product, but the product communicates with that machinery in a digital choreography of production.

This approach will come to redefine the consumer-manufacturer relationship, as products in the field (i.e., in the Internet of Things) communicate back to the manufacturing ecosystem that produced them (the Industrial Internet of Things) to influence everything from next-generation product design, supply chain management, peer-to-peer consumer networking, product maintenance and end-of-life. This new paradigm won't be possible without accurate sensors both in the field and in the plant to provide reliable information to drive automated, machine-to-machine communication and decision making.

At the same time, the emergence of the second quantum revolution – which depends on the control and manipulation of matter at the most fundamental levels – will spur a new generation of technologies based on phenomena such as entanglement and superposition. The preservation and manipulation of these very fragile quantum states will require reliable, in-situ sensors and measurements, a NOAC goal. In addition, advances in quantum information science will enable unprecedented advances in measurement precision and thus fuel a new generation of quantum-accurate standards and measurements.

Finally, the explosive demand for high-speed transfer of ever-larger volumes of data will benefit directly from NOAC's pioneering work in miniaturized photonic channels, novel signal transduction schemes, and accurate calibration standards for devices that must operate at unprecedented frequencies.

Portfolio at a Glance



NOAC technologies are at varying stages of technology readiness. NIST is actively building partnerships with industry, both domestically and globally, to bring these innovations from lab to market.