# Photonics at APL: Guest Editor's Introduction

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*The photon is a fundamental entity of light having both wave and particle properties. Photonics is the field of study associated with the science and engineering of controlling the generation, manipulation, and detection of such photons in an orderly fashion. Through this control, novel devices and systems can be developed to harness the unique properties of light for applications such as optical communications, optical processing, radar systems, and laser remote-sensing systems. This issue of the* Johns Hopkins APL Technical Digest *features articles related to applications of photonics for these important areas of interest to APL.*

What is photonics? Photonics is a science that is concerned with the generation, control, and detection of light. Technological advances that have occurred in the fiber-optic communication industry since the invention of the semiconductor laser in the 1960s and the invention of low-loss optical fiber in the 1970s have accelerated the advancement of photonics such that the 21st century is considered the age of photonics just as the 20th century was the age of electronics.

Photonics will play an increasingly important role at APL as demands continue to increase for high-speed and high-throughput processing, communications, and sensing. This issue of the *Johns Hopkins APL Technical Digest* highlights some of the application areas in RF photonics, optical communications, laser remote sensing, and quantum optics.

In the article by Callahan et al., the ability to digitize high-bandwidth, high-fidelity RF and microwave signals that cover many frequency bands is enabled through novel photonic analog-to-digital converter architectures being developed at APL. These architectures rely on highly stable mode-locked lasers and nonuniform sampling techniques to exploit the well-known advantages of photonic analog-to-digital converters, including bandwidth, timing precision, and timing stability.

In the next article, by Gross et al., a photonically enabled tunable precision frequency synthesizer that can operate in the RF, microwave, and millimeter-wave regimes is described. This low-phase-noise tunable microwave oscillator is based on a unique fiber laser architecture that relies on a common nonlinear fiber effect, stimulated Brillouin scattering. The beauty of this scheme is the ease with which one can tune the oscillator from the megahertz to the tetrahertz regime while maintaining the same low-phase-noise properties. This is extremely difficult to achieve using electronic synthesizer techniques.

In describing an application of the photonic frequency synthesizer, the article by Nanzer et al. demonstrates a millimeter-wave free-space communication system using the synthesizer as a millimeter-wave source. This article describes how a high-speed digital modulation signal can easily be encoded onto a millimeter-wave carrier using photonic techniques. In this article, baseband binary-phase-shift keying data with data rates up to 3 Gb/s are encoded onto a 60-GHz carrier frequency and transmitted over free space. The combination of a low-phase-noise photonic frequency synthesizer and photonic-based encoding schemes provides a flexible architecture that can be used to develop a millimeter-wave communications system capable of data rates near 100 Gb/s over distances of nearly 50 km.

Another article related to RF-photonic technologies describes a custom RF fiber-optic transport link that is part of a submarine-based buoyant cable antenna system used to receive Global Positioning System (GPS) signals. In the article by Karim et al., a prototype buoyant cable antenna system using compact photonic devices installed in sea-worthy deployable cable harnesses provides a capability to transport RF signals over significant cable distances by taking advantage of extremely low-loss optical fibers. This technology enables undersea systems to have easy access to broadband RF signals through fiber-optic antenna remoting.

The next article is related to optical communications. In the article by Hahn et al., new conformal free-space optical communications terminal designs are developed at APL for use on highly confined vehicles such as unmanned aerial vehicles where size, weight, and power are at a premium. Current high-performance free-space optical communications systems require bulky gimbals that are mounted in pods and protrude from the body of the aircraft. In these new designs, fiber bundles are used to allow conformal placement of the transmitter and receiver optics on the surface of the vehicle and provide wide solid-angle coverage without the need for bulky pointing systems based on gimbals.

The article by Bruzzi et al. describes a laser altimeter for spacecraft landing applications. The laser altimeter is designed to operate over a range from 1 to 2 km with a resolution of 3 cm. The major constraints for a spacecraft-based device are similar to those for Hahn et al.'s application: size, weight, and power. The APL design consists of a compact *Q*-switched solid-state laser and highly sensitive avalanche photodiode detector module interfaced to an APL-developed lower-power and -mass application-specific integrated circuit used for event processing. The resulting prototype unit represented a significant step toward a sensor with a small footprint that requires minimal spacecraft resources.

The final article, by Jacobs et al., describes current research in developing all-optical switching and logic elements needed for next-generation, all-optical computing systems. Their method for developing an ultra-low-loss switch is based on nonlinear two-photon absorption and the Zeno effect. Elements of a prototype switching device based on a high-*Q* optical resonator surrounded by an atomic vapor have been demonstrated in the laboratory. The goal is to develop a switch concept that is highly integrated and can be mass produced. This novel approach can be used for photonic quantum and conventional optical computing.

In summary, the articles in this issue provide a sampling of the research and development activities in photonics at APL. The need for photonics-based systems will continue to grow as demands for the unique properties of photonic systems, such as high bandwidth and broadband operation, grow. A common theme in most of these articles is the need for miniaturization to satisfy size, weight, and power constraints. Most of the prototype systems being developed are based on discrete photonic and fiber-optic components. The current trend in commercial fiber-optic communications systems is the development of *integrated photonic* subsystems. In the near future, integrated photonics will provide an ideal solution to satisfy ubiquitous size, weight, and power constraints.

# The Author

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