Photonic Computing Highlighting Ultimate Nature of Light

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Research Area Information	Number of Research Area : 22A401　　Project Period (FY) : 2022-2026 Keywords : Photonic computing, Optical information processing, Optical devices, System architecture

Purpose and Background of the Research

●Research Outline

Optics and photonics play critical roles in modern society, ranging from communication to sensing. Furthermore, optics and photonics are expected to be utilized in computing to accommodate the increasing data-processing demands in an ever-growing information society. Novel physics-based computing has been investigated extensively to overcome the limitations of conventional computing principles, and photons are among the most important fundamentals. Optical sciences and photonic technologies have evolved significantly over the last few decades, and information science and technology have experienced a dramatic revolution and evolution. The combination of photonics and computing is one of the most exciting research frontiers (Fig. 1).

This research initiative explores photonic computing from the viewpoint of highlighting the ultimate nature of light. The frontier of photonic computing is advancing rapidly worldwide. Especially, optical hardware accelerators are intensively studied with solid connections to artificial intelligence (AI) and beyond 5G communication applications. On the other hand, novel fundamental research and innovative ideas that combine various physical properties of light and computing are emerging. This Research Area attempts to develop versatile, cutting-edge research perspectives. Simultaneously, this initiative pursues the unity of research to establish the Research Area of photonic computing.

●Principal Concept of The Project: *Highlighting Ultimate Nature of Light*

The principal concept of this Research Area is the *ultimate nature of light*. This concept has three characteristic perspectives.

- **Perspective 1:** Overcoming **architectural limits** that prevent the successful utilization of photons for computing.
- **Perspective 2:** Utilizing the **physical limit** of light for computing.
- **Perspective 3:** Cultivating the **potential capability** of photons for computing.

We propose a way for transformative research on photonic computing by intertwining these viewpoints. Such a formation reflects the importance of multidisciplinary approaches, including information and communication science, optics, physics, materials, and devices science, among others.
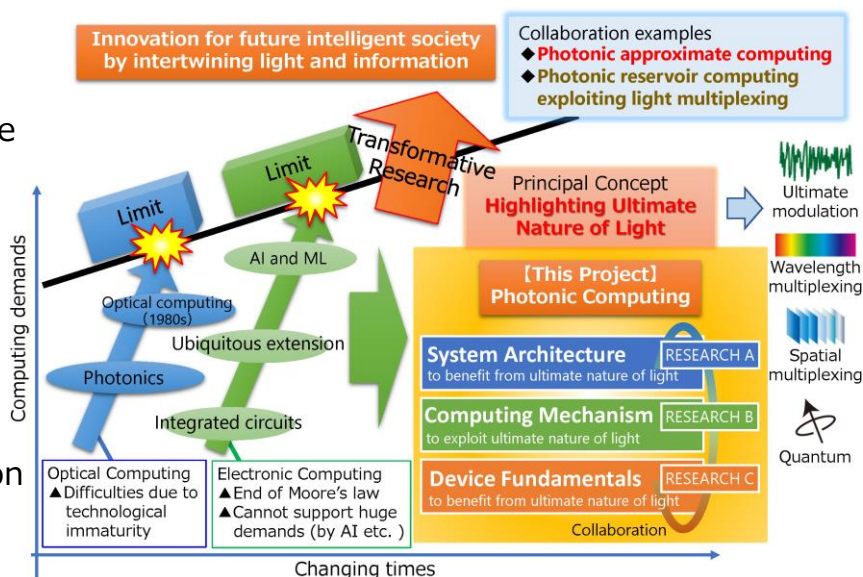

Figure 1. Background of the Research Area

Expected Research Achievements

● Three principal approaches

This Research Area highlights the ultimate physical nature of light and photonic technologies–notably their high bandwidth, energy efficiency, multiplexing attributes, and interfacing ability to real-world environments–for computing and intelligent functionalities. There are three principal approaches to this Research Area (Fig. 2).

■ Research A: System architecture to benefit from ultimate nature of light

Resolve architectural limits that prevent the successful utilization of light in computing. The topic includes **(A01)** Photonic approximate computing and **(A02)** Optimal system design wherein optimal task decompositions are realized based on the characteristics of light- and electron-based computing platforms.

■ Research B: Computing mechanism to exploit ultimate nature of light

Create novel computing mechanisms that utilize the ultimate physical limit of light. The topic includes **(B01)** Photonic reservoir computing, **(B02)** Computing based on light modulation, and **(B03)** Design of higher-order functionalities such as photonic decision making.

■ Research C: Device fundamentals to benefit from ultimate nature of light

Novel substrates and devices to uncover the potential capability of light for computing. The topic includes **(C01)** Integrated photonic computing devices utilizing light multiplexing and **(C02)** Fusion of lightwave and ultrafast silicon electronics.

● Promotion of research

This Research Area seeks to intertwine various scientific disciplines, including optics, photonics, physics, informatics, and computer science, to establish an exciting emerging field of research represented by the title: *Photonic computing highlighting ultimate nature of light*.
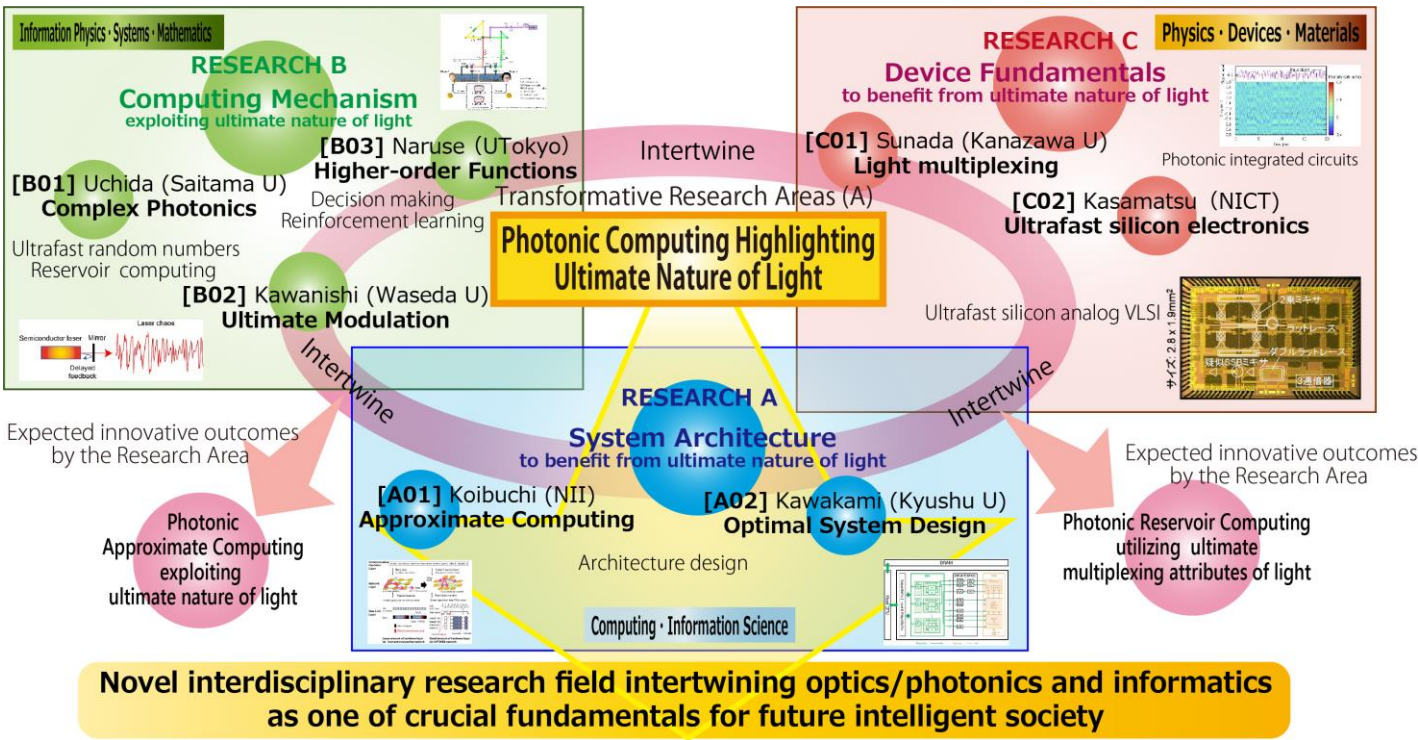

Figure 2. Overview of the Research Area