Press release

Keio University

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Next Generation In-vehicle Optical Communication System Demonstrated in Proof-of-concept Experiment —High-Speed In-Vehicle Optical Communication System Supports Fully Automated Driving—

In a joint effort involving four institutions, a research team has tested their novel Silicon Photonics-based in-vehicle Optical Network (SiPhON) in a proof-of-concept experiment, demonstrating data transmission speeds of 50 Gb/s. Their highly reliable, low-latency, in-vehicle optical network was developed for central and zone architecture systems, which are essential for the development of advanced self-driving technologies. The team included Professors Hiroyuki Tsuda and Ryogo Kubo from the Department of Electronics and Electrical Engineering, Faculty of Science and Technology, at the Keio University, and researchers from the University of Tokyo, Osaka University, and Furukawa Electric Co., Ltd.

1. Main Points of Research

- The team proposed SiPhON, a highly reliable in-vehicle optical network with a transmission capacity of 100 Gb/s. The network utilizes silicon photonic devices,[1] which are vital technological infrastructure for fully automated driving.
- The team developed and successfully verified a proof-of-concept system that integrates a silicon photonics module, a harness combining optical fiber and power cables, multiple 4K cameras, a light detection and ranging (LiDAR) device, and a radar.

2. Background of Research

To achieve advanced autonomous driving, a high-capacity and low-latency in-vehicle network that can accommodate the increasing number of electronic devices equipped, such as cameras and sensors, is essential. In addition, this network must meet the stringent requirements specific to vehicles, such as environmental resistance, electromagnetic compatibility, and reliability. In this study, to ensure a highly reliable system, the team proposed SiPhON, a communication network wherein a semiconductor laser is placed only in the master device of the central electrical control unit (ECU), which handles the vehicle's core functions. Meanwhile, modulators/receivers based on silicon photonics integration technology are placed in the gateway devices of the zone ECUs that manage each sections of the vehicle. Communication between them is facilitated via silica single-mode optical fibers.

3. Research Design and Findings

SiPhON has a physical layer consisting of a data transmission network (D-plane) with more than 50 Gb/s capacity and a control signal transmission network (C-plane). It is designed to be manufactured at a low-cost and highly reliable through redundancy achieved by duplicating both transmission paths and light sources, using silicon photonics technology (Figure 1). Light transmitted from the master device passes through each gateway device, where it is transmitted, received, or modulated, before returning to and being received by the master device. The electrical circuit section implements control signals and protocols for error correction and link establishment, as well as interfaces with upper layers. The central and zone ECUs are equipped with ethernet-compatible interfaces, enabling flexible traffic control by adjusting the transmission capacity between ECUs. SiPhON's system-level reliability is high, with a mean time to failure (MTTF)[2] exceeding 50 years at a capacity of 100 Gb/s. By using a newly developed combined wiring system of optical fibers and power cables, researchers were able to simplify routing while simultaneously accommodating high-speed communication at over 50 Gb/s (which can be expanded to capacities beyond 100 Gb/s).

The researchers also constructed a high-capacity in-vehicle optical network proof-of-concept system that simulates in-vehicle networks (Figure 2). The team demonstrated low-latency, error-free transmission by simultaneously transmitting video signals from two 4K cameras (each at 10 Gb/s) and low-speed data from peripheral monitoring radars and LiDAR between the master device and four gateway devices. Information obtained from the 4K cameras is transmitted via SiPhON to the image processing unit, where objects and traffic signs are recognized in real time. The proof-of-concept system also incorporated the silicon photonics devices (Figure 3) and the combined optical fiber and power cable harness (Figure 4; FASPULS® - Flexible Automotive Signal and Power Unified Line System) developed in this research, successfully demonstrating its operation. (FASPULS is a registered trademark of Furukawa Electric Co., Ltd. in Japan.)

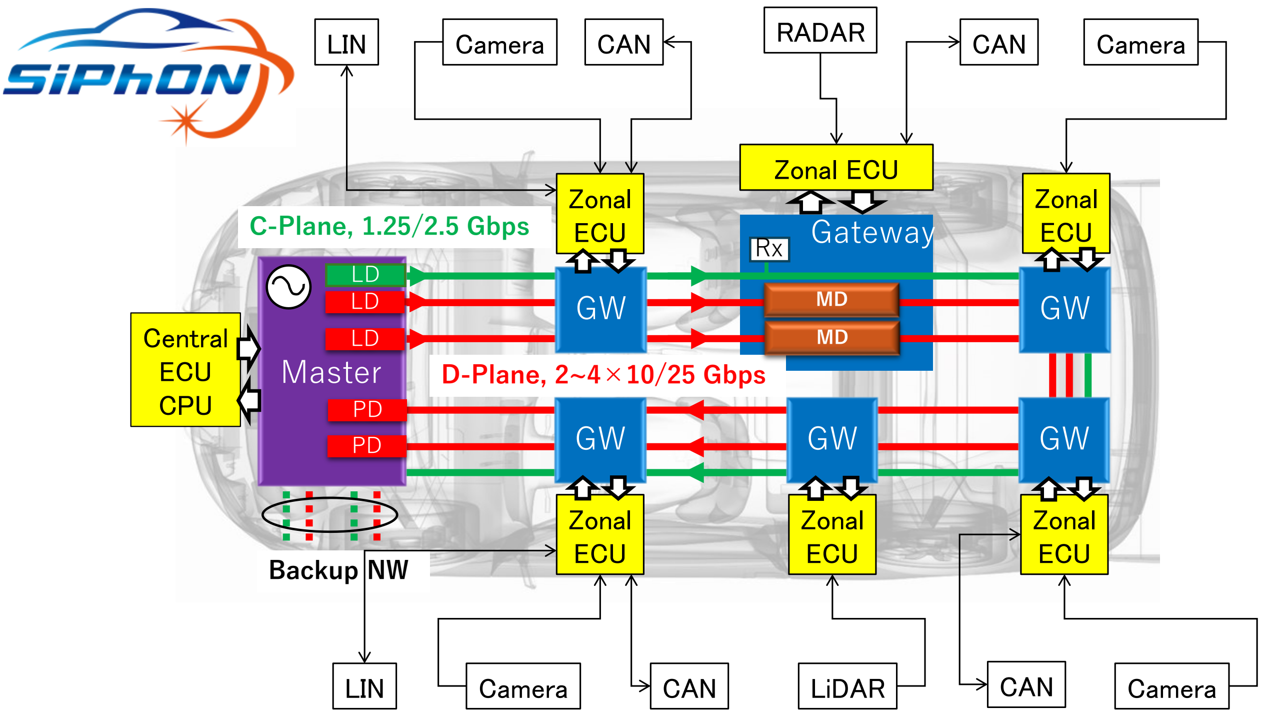

Figure 1: Configuration of SiPhON (Silicon Photonics-based In-vehicle Optical Network).

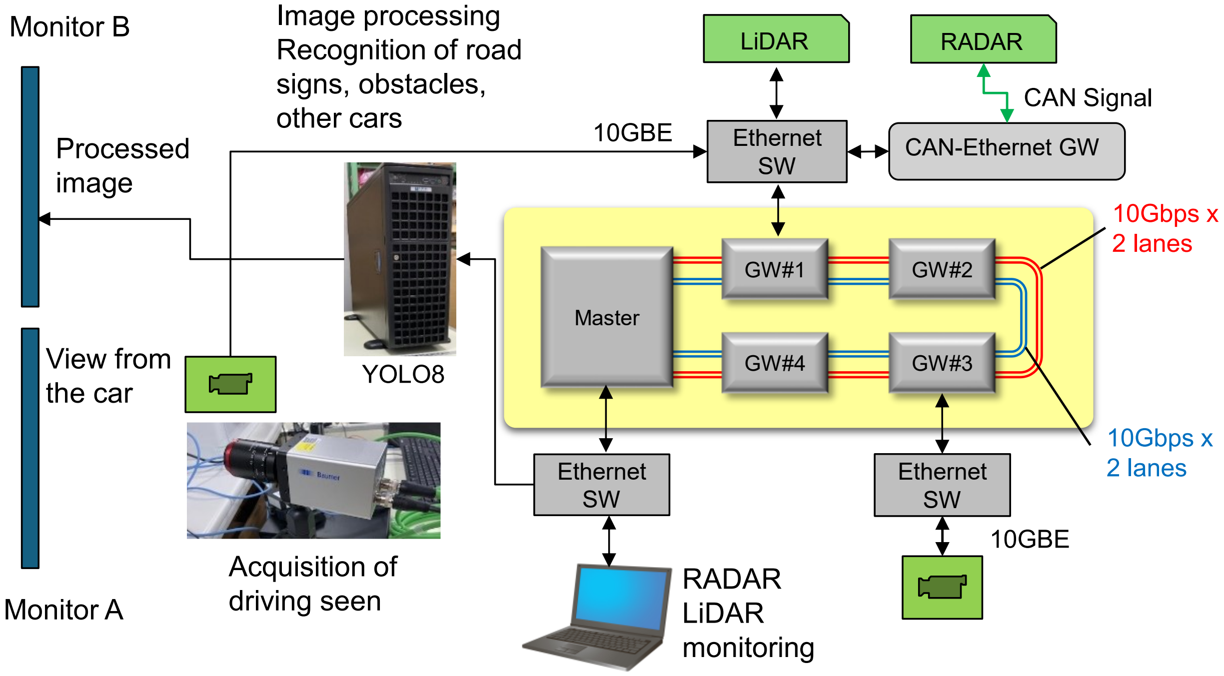

Figure 2: High-capacity in-vehicle optical network proof-of-concept system.

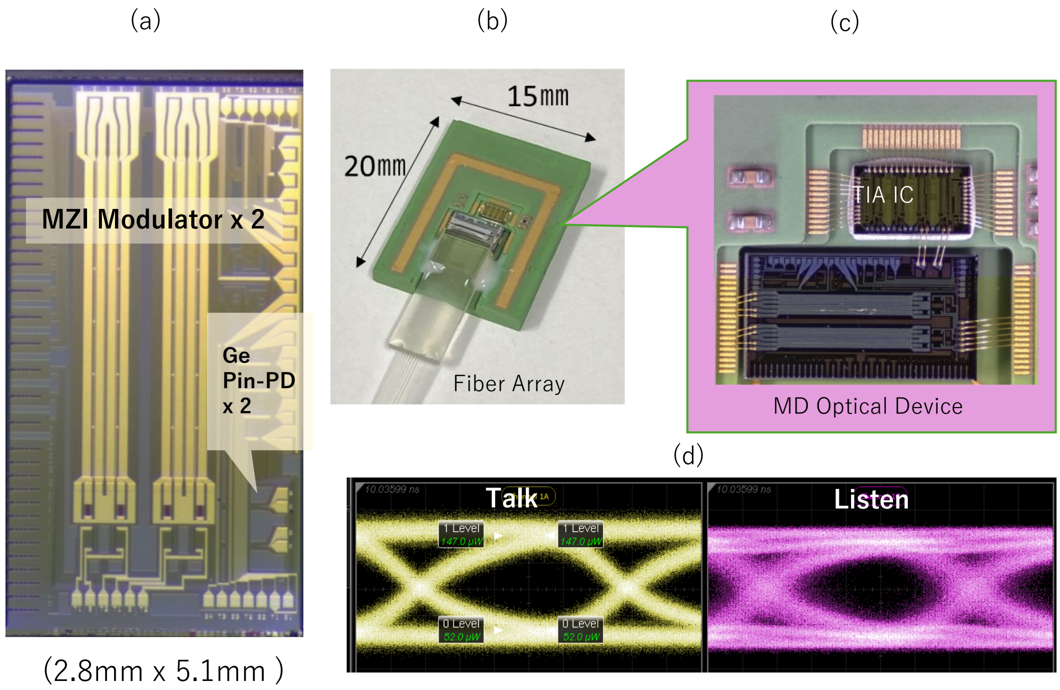

Figure 3: (a) Silicon photonics MD optical circuit, (b) Optical module, (c) Enlarged view of the optical module, (d) 10 Gb/s modulated (Talk) and received (Listen) optical waveforms.

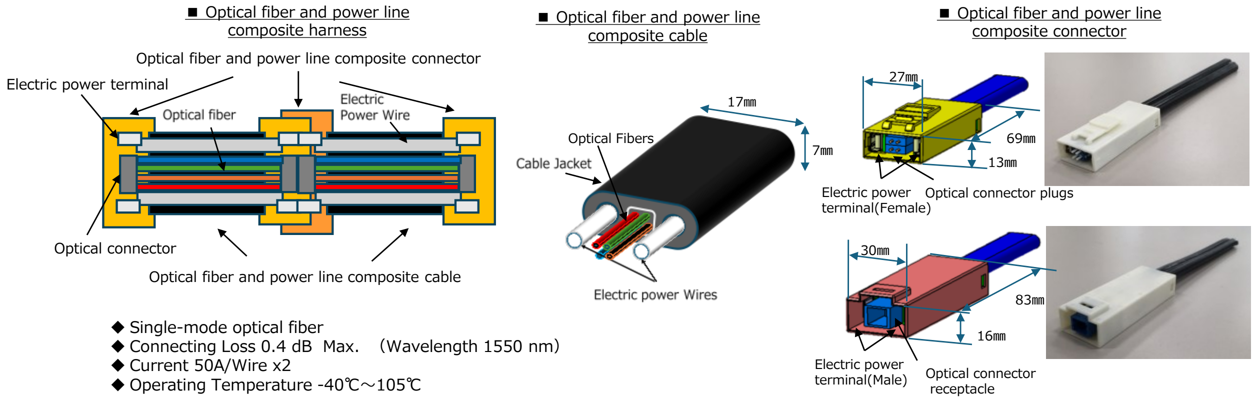

Figure 4: Optical fiber and power line composite harness (FASPULS®).

4. Future Developments

Looking ahead, researchers plan on continuing to research and develop faster, more reliable, and highly scalable systems for use in fully autonomous vehicles, with the hope that this will evolve autonomous driving systems and connected services. Research outcomes will be presented at ECOC2024, which is set to be held in Frankfurt from September 22 to 26, 2024.

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References

Hiroyuki Tsuda, et al., "Proposal for a Highly Reliable In-Vehicle Optical Network: SiPhON (Si-Photonics-Based In-Vehicle Optical Network)," International Conference on Photonics in Switching and Computing 2022, TuP-F-2, Toyama, July 3-6, Japan (2022).

Details of Journal Article

Hiroyuki Tsuda, et al., "Demonstration of a Highly Reliable Si-Photonics-Based In-Vehicle Optical Network (SiPhON) for Autonomous Driving," 50th European Conference on Optical Communications (ECOC2024), W2A.117, Frankfurt, Sept. 22-26, Germany (2024).

Glossary and References

[1] Optical circuits based on optical waveguides consisting of a silicon core and SiO_2 cladding. There is a plethora of research and development of optoelectronic fusion circuits in which lasers and electronic circuits are integrated.

[2] Average time from beginning of equipment operation until its failure.

*Please direct any requests or inquiries to the contacts listed below in advance of any press coverage.

*We have sent this news release to the MEXT Press Club, Science Press Club, and the science departments of other media outlets.

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