Demonstration of High Precision Silicon Photonics Wafer Measurements Using a PLC-Probe and Its Applicability to Multi Channel Inspection

Shinji Mino, Masaki Ueno, Akihito Doi, Kenya Suzuki, and Yoshinori Hibino
NTT Innovative Devices Corporation

➢ Introduction

- A PLC (planar lightwave circuit) probe is made of silica glass, the same material as optical fibers, and is fabricated using a photolithography process.
- In this work, edge-coupling using the PLC-probe enables high-precision wafer measurements equivalent to fiber-based diced chip testing.
- Compared with conventional lens-based edge-coupling approaches, which can be less suitable for scalable multi-channel integration, particularly in dense configurations, the PLC platform offers better scalability.
- We confirmed that the PLC-probe's beam and coupling characteristics to Si photonics (SiP) dies are comparable to those of optical fibers, with no wavelength dependence, unlike grating couplers.

➢ Structure and Characteristics of the PLC-probe

- An example of the basic structure of the PLC-probe is shown in Fig. 1. Key features are as follows:
  - An optical integrated circuit made of silica glass, the same material as optical fibers, resulting in low optical loss.
  - Fabricated by photolithography, enabling multi-channel (up to 100 ch) (*), narrow pitch (~15 μm), and compatibility with various SiP devices.
  - No wavelength dependence, supporting multiplexing such as wavelength division multiplexing (WDM); polarization is maintained and can be controlled.

(*) A 96-channel PLC device for WDM applications has already been commercialized.

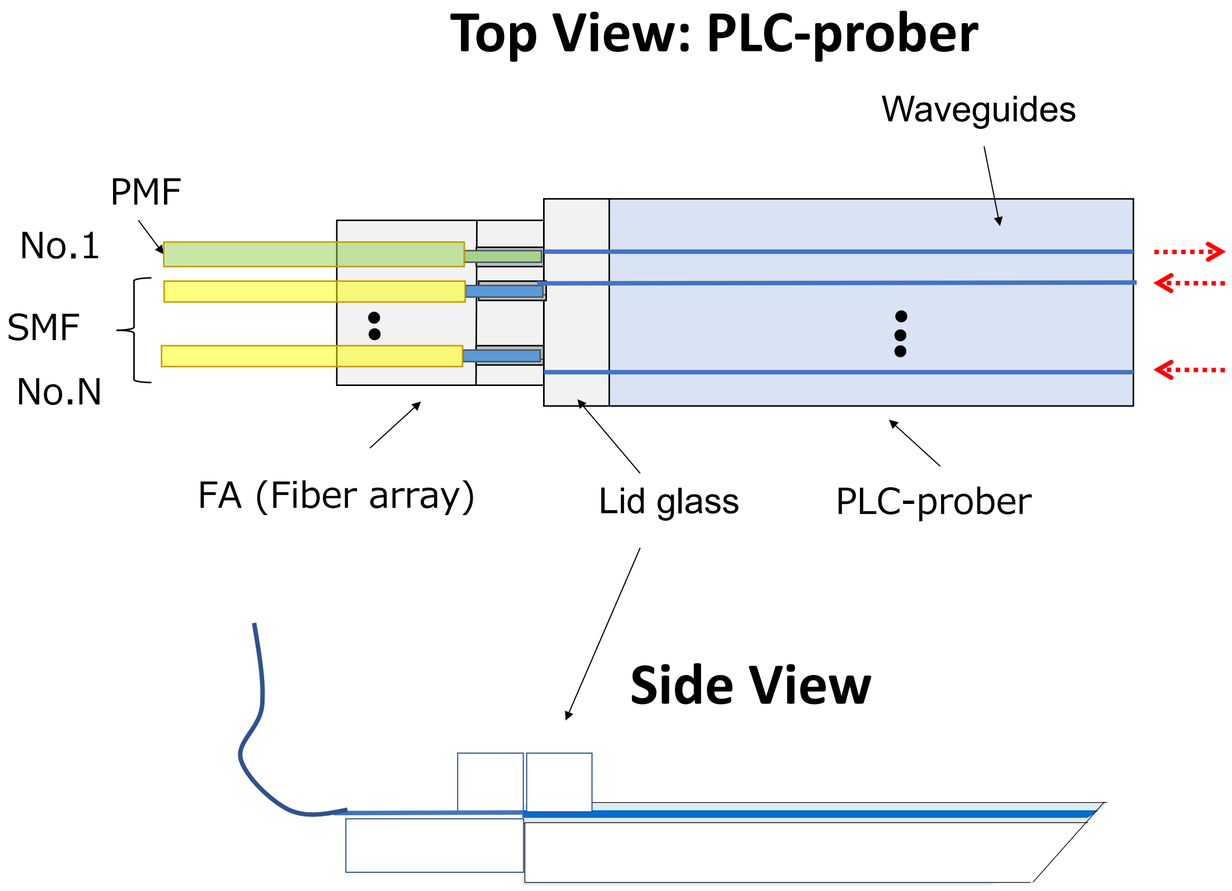
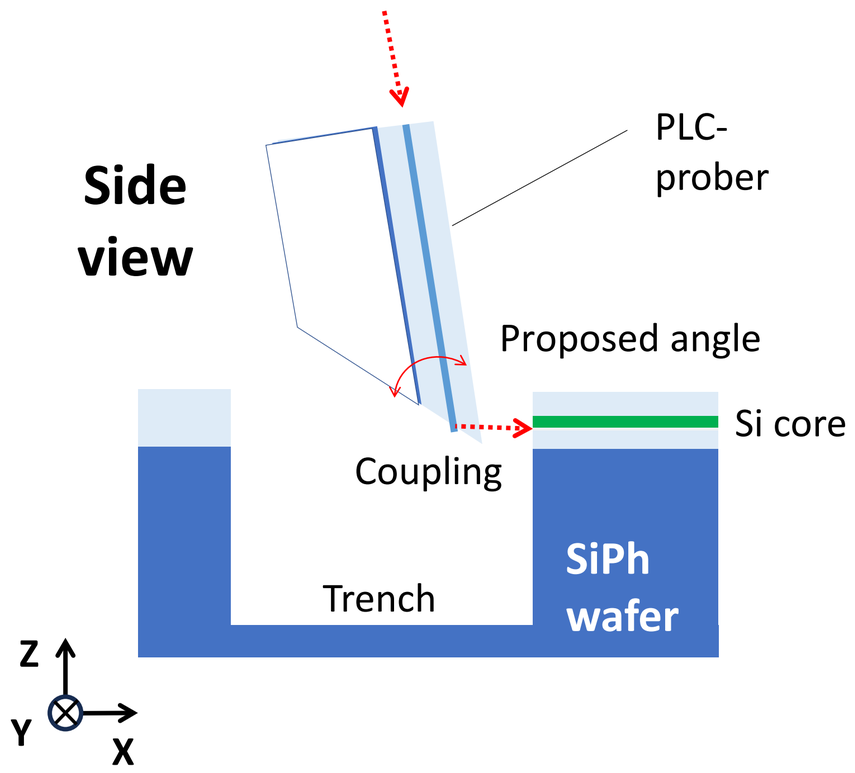


Fig. 1. (a) Basic configuration of the PLC-probe



(b) Application to edge coupling for Si photonics wafer

➢ Optical Characteristics of the PLC-probe

- **The far-field pattern (FFP) of the PLC-probe is shown in Fig. 2, together with that of a conventional optical fiber. As shown, the PLC-probe exhibits a beam profile essentially identical to that of an optical fiber.**
- **The positional misalignment tolerance curves between the PLC-probe and a silicon photonics (SiP) die are shown in Figs. 3(a) and 3(b). The tolerance curve of the PLC-probe agrees well with that of an optical fiber block.**
- **Fig. 4 shows the measured wavelength dependence as part of the optical performance evaluation of the PLC-probe. In this measurement, the output light from the PLC-probe was received by a single-mode fiber (SMF). It exhibits no inherent wavelength dependence, similar to an optical fiber.**
- **These results demonstrate that the optical characteristics of the PLC-probe are equivalent to those of conventional optical fibers. Therefore, die-level evaluation on Si photonics wafers using the PLC-probe enables measurements equivalent to conventional post-dicing inspections performed with optical fibers.**

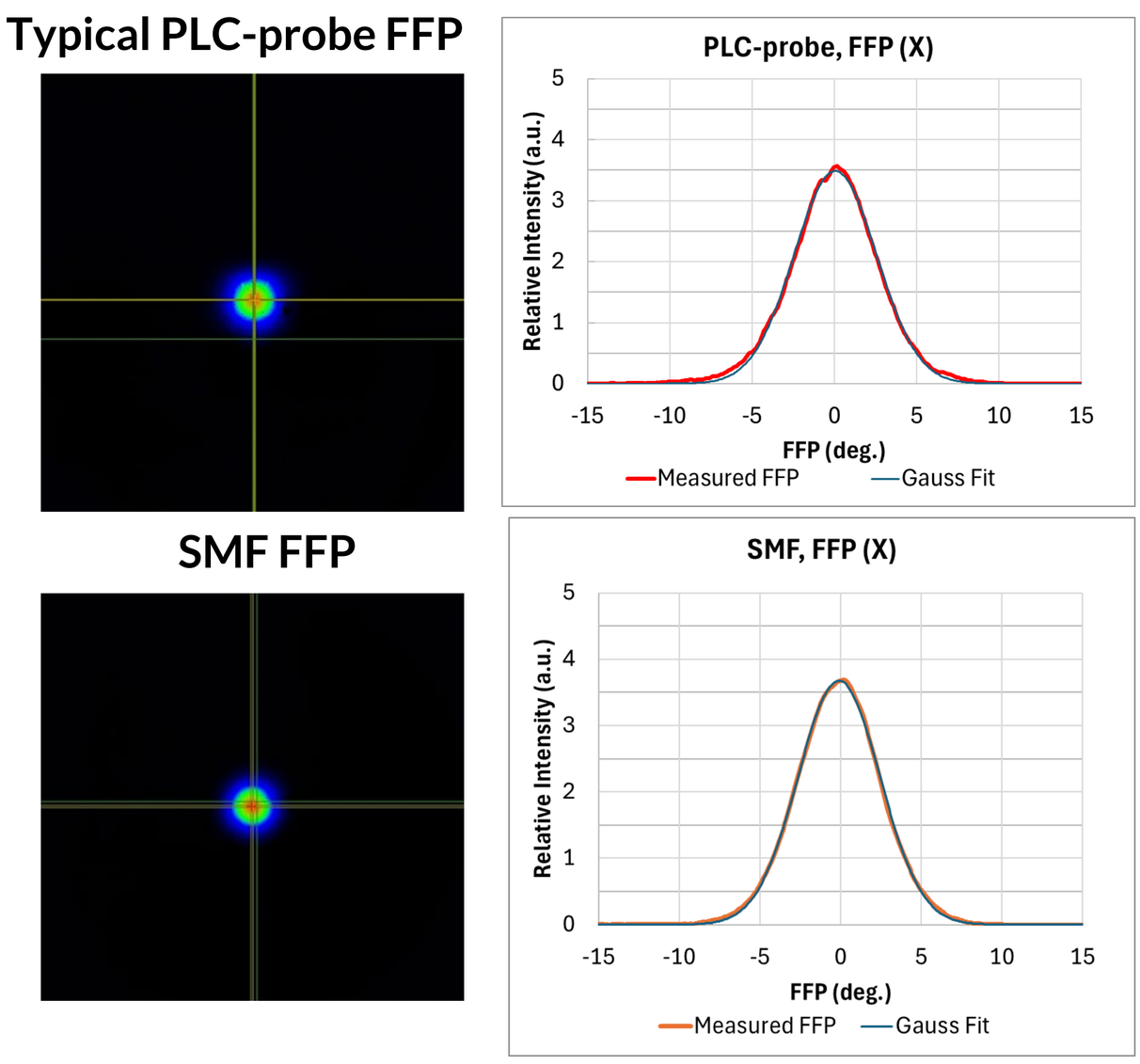


Fig. 2 Typical far-field patterns (FFPs) of the PLC-probe and a single-mode fiber.

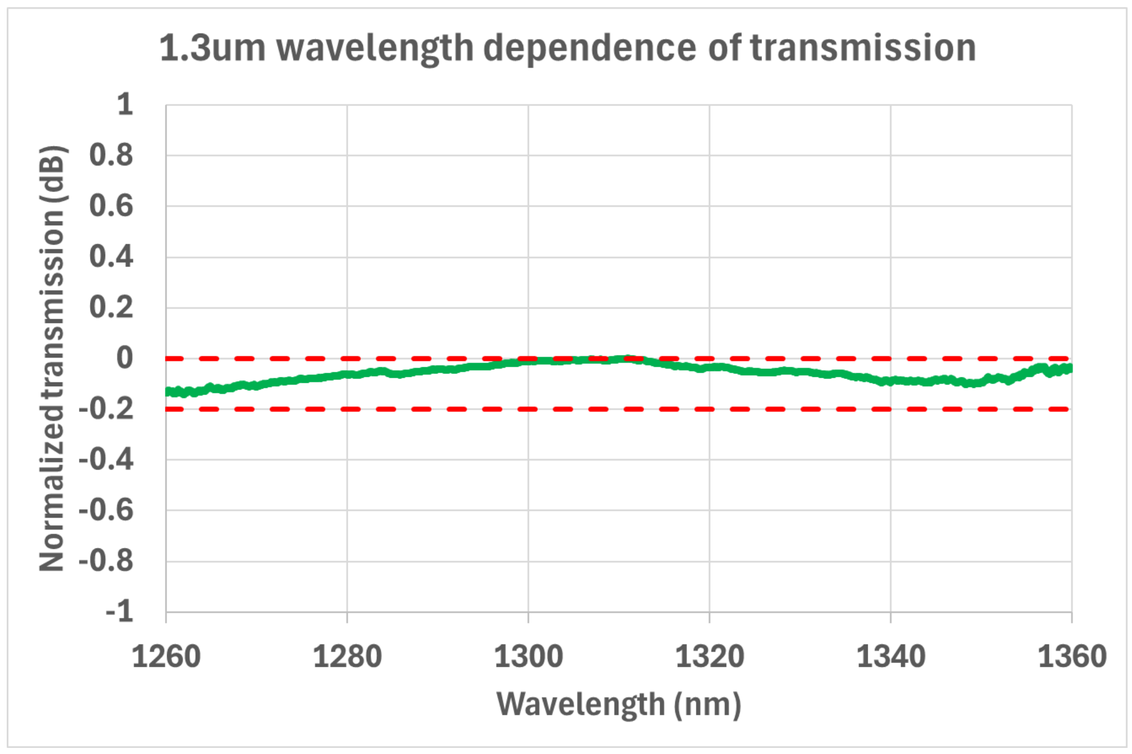


Fig. 4 Measured wavelength dependence of the PLC-prober around 1300nm. (< 0.2 dB over 100 nm)

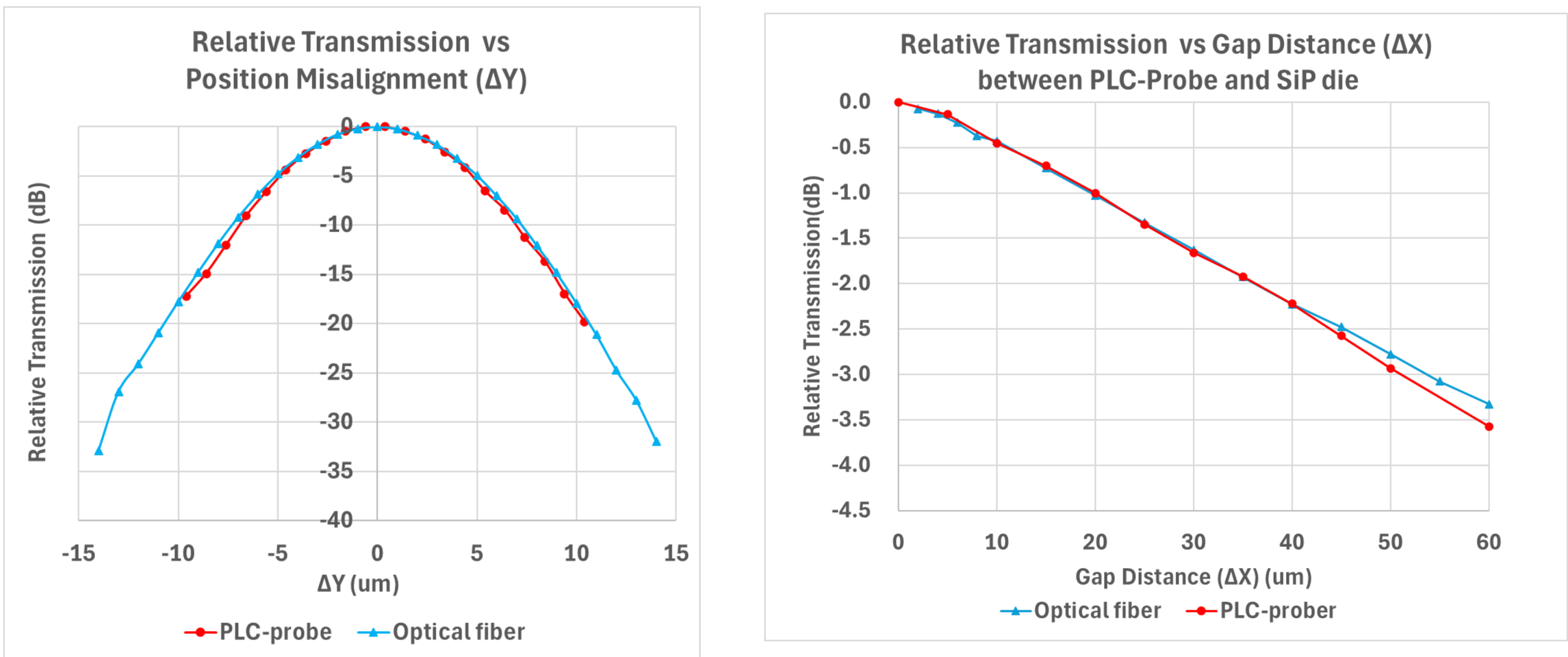


Fig. 3 Tolerance curve of PLC-prober and optical fiber (a) perpendicular to the optical axis (ΔY) and (b) along the optical axis (ΔX).

➢ Silicon Wafer Measurement Results

- Full-wafer insertion loss measurements were performed on an 8-inch SiP wafer using U-turn TEG waveguides (N=32 dies x 6 measurements) as shown in Fig. 5.
- For the full-wafer measurements, the gap between the PLC-probe facet and the silicon photonics die facet was set to 13 μm at the center die. After this initial alignment, the wafer was loaded from the cassette, measured across the entire wafer, and returned to the cassette without any further adjustment.
- The measurement was repeated six times, and the deviation from the average value of each die is presented in Figs. 6(a) and 6(b). In all cases, the deviation was within ±0.2 dB, demonstrating high measurement repeatability.

➢ Conclusion

- This study demonstrates that the PLC-probe enables wafer-level measurements equivalent to optical fiber-based SiP chip inspection.
- Using fully automated cassette-to-cassette measurements performed six times, we confirmed a small measurement variation of less than ±0.2 dB.
- Since PLC-probes can be fabricated by mask and photolithography, they are suitable for multi-channel (up to 100 channels), narrow-pitch measurements of various Si photonics dies, enabling simultaneous high-speed and high-throughput measurements.

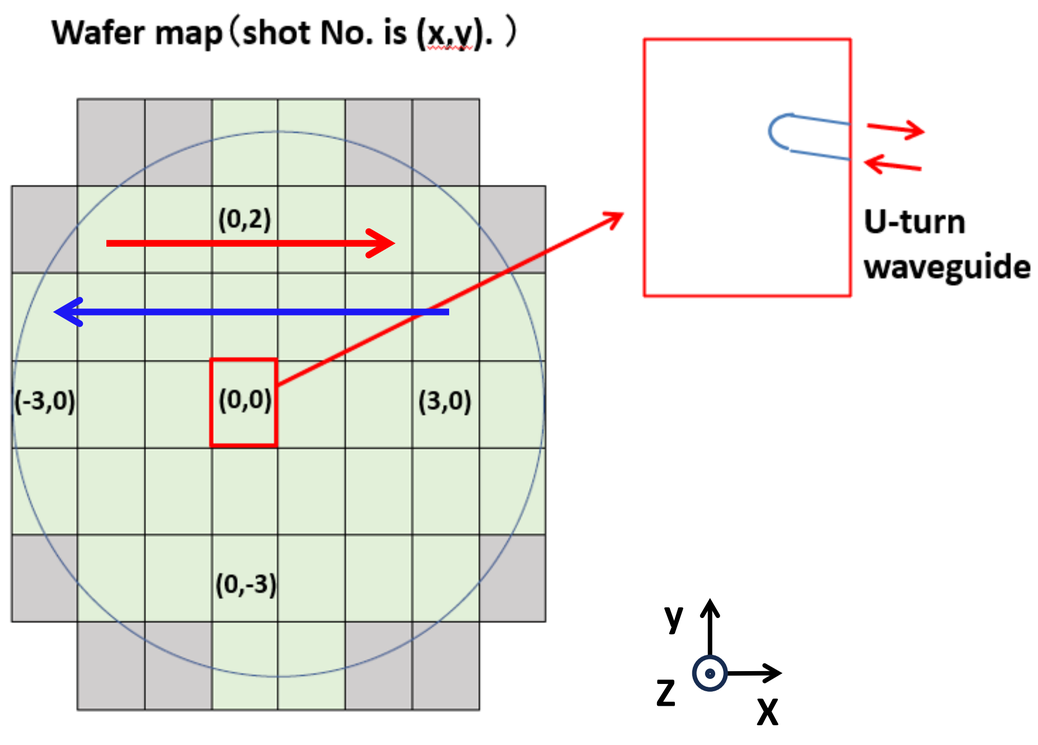


Fig. 5 Measured Si photonics wafer. U-turn waveguides in all TEG dies on a wafer were measured using PLC-probe.

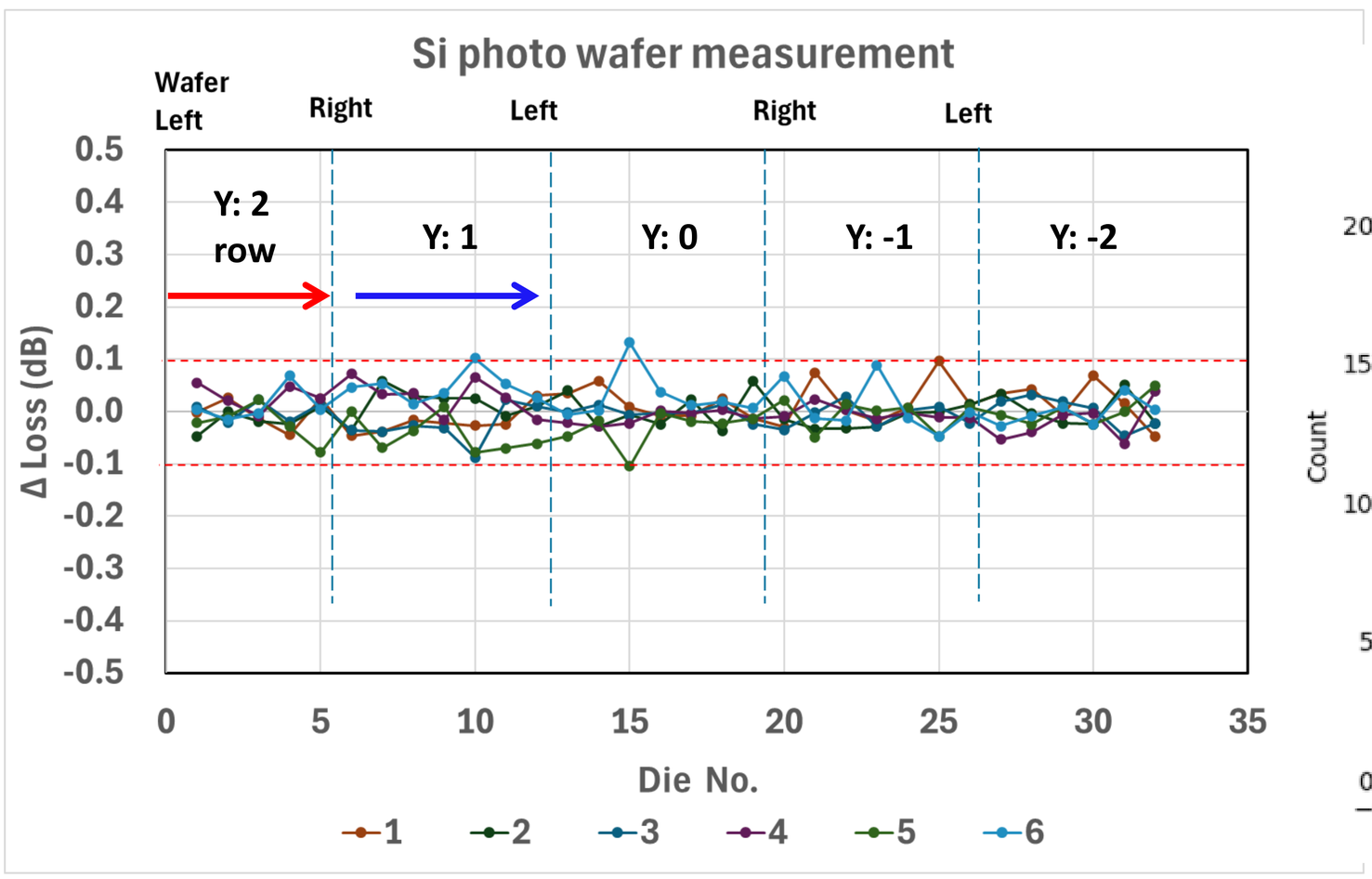


Fig. 6 (a) Measured results of repeatability of the loss deviation on all U-turn waveguides.

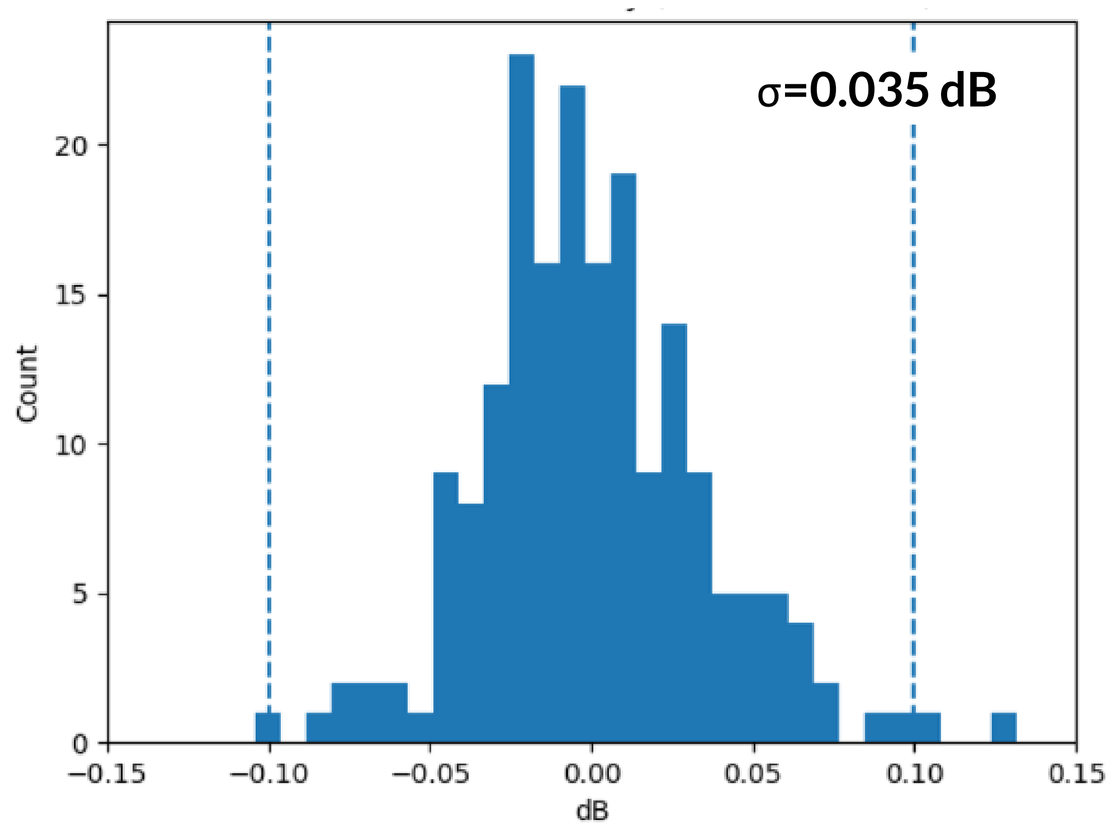


Fig. 6 (b) Histogram of the measured results of the loss deviation in Fig.6 (a).

➢ Contact Information

Shinji Mino, NTT Innovative Devices, Email: mino-shinji@ntt-devices.com

➢ Acknowledgments

This paper is partly based on results obtained from the project, “Research and Development Project of the Enhanced Infrastructures for Post-5G Information and Communication Systems” (JPNP20017), commissioned by the New Energy and Industrial Technology Development Organization (NEDO).