Ansys + Waseda University

"Using Ansys Lumerical FDTD, we were able to accurately simulate and optimize complex structures and thus reach our research goals. Lumerical's intuitive support for scripting is backed by a broad set of application gallery examples, making it easy to quickly develop complex workflows. With its simulation speed and accuracy, hundreds of development hours were saved, and the fabricated device was in close agreement with simulation results."

Professor Tomohiro Kita

Lead Investigator / Waseda University

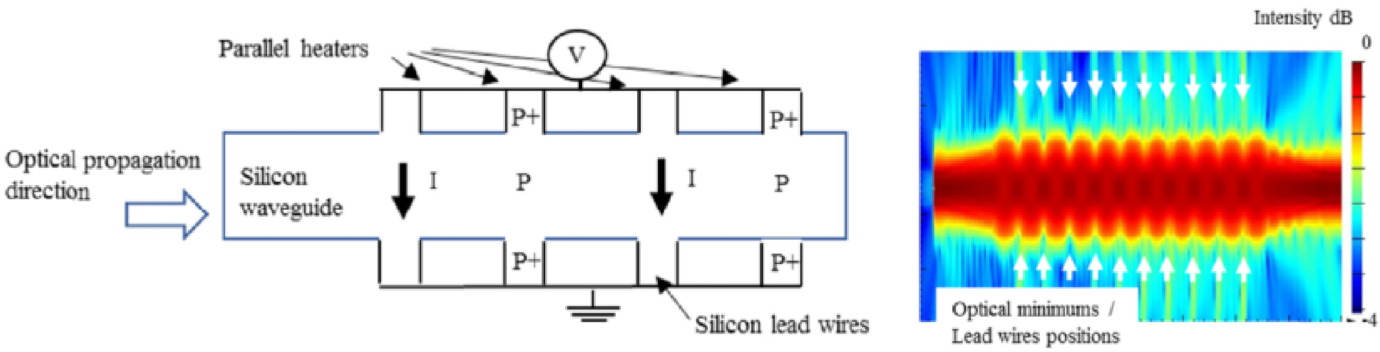

Figure 1. Waseda University's heating structure (left). Finite-difference time-domain (FDTD) simulation results (right) of the optimal mode profile at 1540 nm while taking into consideration the wavelength dispersion of silicon.

/ Research Summary

Professor Tomohiro Kita's research group in the Department of Applied Physics at Waseda University in Tokyo, Japan, set out to develop a direct carrier injection thermo-optic phase shifter that can be used for optical switching in a Mach-Zehnder interferometer (MZI) configuration. Their goal was to develop a device well suited for lidar systems in self-driving automotive systems. To meet this goal, the Waseda team focused on reducing the device footprint while maximizing switching speed. Further, the ohmic resistance value of the device had to be small enough for the device to be driven with a low-voltage source. Figure 1 (left) shows a schematic of the Waseda team's proposed phase shifter, based on a multimode straight waveguide.

A design based on multimode structures was chosen because the interference between different optical modes can be tailored to minimize optical losses by reducing the field intensity at the position of the contacts where the electrical current is injected. The drawback of this approach is that there are many design parameters that must be precisely tuned to achieve the desired performance. In addition, multimode structures are usually large, so it can take a long time to simulate them and evaluate the impact of each parameter. To tackle this problem, Professor Kita chose Ansys Lumerical FDTD due its superior simulation performance, accuracy, and ease of use. Figure 1 (right) shows the results of an FDTD simulation of the proposed device for the optimal mode profile at 1540 nm.

/ Results

Using the Lumerical FDTD software, the Waseda team was able to quickly develop and optimize a prototype to meet their requirements. FDTD's intuitive scripting interface broad set of application gallery examples helped them get started and achieve their research goals with minimum turnaround time.

In Figure 2 (right), the transmission spectrum calculated from simulation demonstrates that shorter periods of the silicon lead wires leading into the heating structure result in higher insertion loss but longer bandwidth. Using this kind of insight, the Waseda team picked a design with a pitch of 2.35 µm to be fabricated at a CMOS foundry.

The electrical and optical characteristics of the measured device confirmed the expected high performance. For example, the DC characteristics of the MZI presented in Figure 3 (below) show that an extinction ratio of approximately 18 dB is achievable with a relatively low driving voltage of 2.8 V. Furthermore, the dynamic response of the device shown in Figure 3 (right) indicates a high switching speed of 2.16 µs.

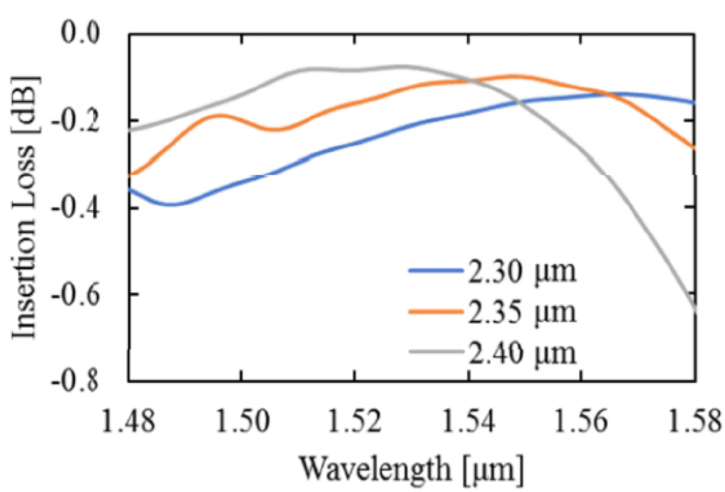

Figure 2. Simulated transmission spectrum of the device for various lead wire periods. Shorter periods have a higher insertion loss but a longer bandwidth. The bandwidth is estimated at 60 nm, enough to cover the C-band for most applications.

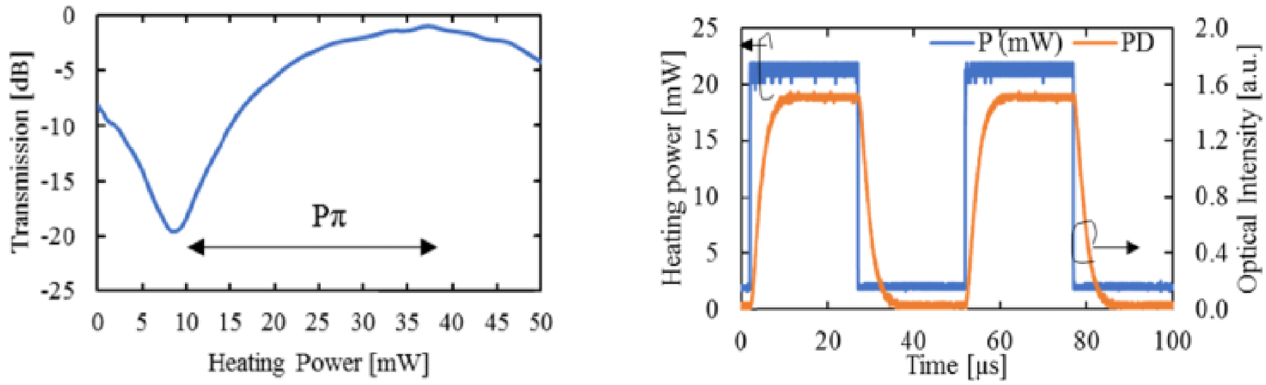

Figure 3. Experimental results showing the DC characteristics of the MZI when applying a bias voltage to one arm (left) and the dynamic characteristics of the device in response to an applied square wave of 50 kHz (right).

With the speed, accuracy, and ease of use of Lumerical FDTD, the Waseda team was able to develop a thermo-optic switch device that maintains a low optical insertion loss, compact footprint, and fast switching speed. Furthermore, the ohmic resistance value is small enough to enable the device to be driven with low voltage sources. The performance of the device is well suited for automotive applications, in which small size is important and only low-voltage sources are available.

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