CORNERSTONE EDUCATION KIT

(On 220 nm SOI and 300 nm SiN platforms)

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CORNERSTONE Education Kit - SOI & SiN

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"Making cutting-edge photonics more open, accessible, and ready to improve everyday life — from concept to chip, faster than ever."

1 Introduction

The Education Kit from CORNERSTONE Photonics Innovation Center (C-PIC) is specially designed for universities, research institutes, and beginners who are eager to explore the fundamentals of integrated photonics. The kit includes a variety of silicon photonics chips fabricated on SOI and SiN platforms, available in three versions to suit different learning and experimental requirements: bare dies, fiber-array packages and fully-integrated optoelectronic packages.

Accompanied by clear documentation and safety guidelines, this kit offers an accessible, application-oriented entry point into photonic integrated circuits for those new to the field.

2 Safety Guidelines

I. Laser Safety

- Laser Classification:
  The laser source used with this kit is typically a Class 1M laser according to IEC 60825-1. Under normal conditions, **Class 1M** laser are safe for the naked eye due to their low accessible emission, but they can still pose a hazard if the beam is viewed through optical instrument (e.g. microscopes, collimators, fiber connectors).
- Wavelength Range:
  The typical operating wavelengths for this kit are in the **near-infrared (NIR)** range - **c-band** (1530-1565 nm). **NIR** light is invisible to the human eye, so you cannot rely on visual cues to detect the beam.
- Safety Rules:
  1. **Never look directly** into a fiber connector, grating coupler, or free-space beam path.
  2. **Wear appropriate laser safety eyewear** if using a source above Class 1M or if alignment procedures require closer observation.
  3. **Keep beam paths horizontal** and at a stable height to avoid unintentional exposure.
  4. **Post laser warning signage** at lab entrances when the system is in use.
  5. **Turn off the laser** before making adjustments to the optical path or changing the chip.

II. Electrical Safety

Some experiments may require **electrical probes** for heaters or active modulators on the chip.

- Always switch off and discharge the electrical driver before connecting or disconnecting probes.
- Avoid touching exposed conductive parts.
- Use low-voltage, current-limited drivers for student experiments.
- Keep liquids away from all electronics.

III. Mechanical Safety & Chip Handing

- Silicon photonic chips are fragile; handle them only with clean tweezers for bare dies.
- Avoid scratching or touching the grating coupler region or heater areas.
- Store chips in their protective container when not in use.
- Handle fiber (arrays) with care to prevent bending beyond their minimum bend radius.

IV. Lab Conduct

- **No food or drinks** in the lab area.
- Keep the workspace tidy to avoid accidental damage to fibers or the chip.
- Ensure all cables and fibers are routed safely to avoid tripping hazards.
- Report any damaged equipment to the supervisor immediately.

3 Kit Contents

Table 1. **SOI220 Education Kit**

Component	Inspected specs or explored phenomena
Self-aligned grating couplers	Coupling efficiency of the grating coupler
Directional coupler	Coupling coefficient, thermal tunability of coupling
Ring resonator	FSR, group index, thermo-optic coefficient
Phase shifter	Thermo-optic coefficient
Spiral waveguide	Propagation loss

Table 2. **SiN300 Education Kit**

Component	Inspected specs or explored phenomena
Self-aligned grating couplers	Coupling efficiency of the grating coupler
2×2 MMI	Imbalance, insertion loss, back-reflection
1×2 MMI	Imbalance, insertion loss
Crossing	Insertion loss, crosstalk
Tunable MZI	FSR, modulation bandwidth, thermo-optic coefficient
Spiral waveguide	Propagation loss

4 Getting Started

I. Required Equipment

Before using the CORNERSTONE Education Kit, ensure that you have access to the following equipment:

- **Optical Source:** Tunable laser source (c-band, 1530-1650 nm) with fine wavelength tuning capability.
- **Optical Detection:** Optical powermeter or photodetector.
- **Fiber Alignment:** Manual or automated fiber alignment stage with micro resolution.
- **Polarization Controller:** Fiber polarization controller for optimizing coupling efficiency.
- **Electrical Source:** Low-voltage (15 V), current-limited source (10 mA) source meter or driver for active devices.
- **Microscope:** For visual alignment and inspection of chip/fiber interface.
- **Monitoring Tools (optional):** Digital oscilloscope (for modulation measurements), PC for data recording.

If the model has been packaged optically and/or electrically, the fiber alignment tool and the microscope can be ignored.

II. Setup Overview

A typical test setup includes a tunable laser connected to an optical fiber array (or fibers), which is aligned to the chip's grating coupler array. The output port is generally connected to a photodetector; an electrical signal will be outputted if the designs are fully-packaged with integrated photodetectors.

For active devices (phase shifters, ring resonator, tunable MZI), electrical probes are connected to the contact pads, and the electrical driver is controlled while monitoring the optical output. Ensure the laser power is sufficiently low during all alignment steps to avoid device degradation.

III. Comparison of SOI vs SiN designs

Some overlap exists between the design principles of the SOI220 and SiN300 components; relevant information on these components is only presented once in the following section. The majority of the test routines are the same; however, note the following differences between the SOI and SiN platforms:

- **Grating Couplers**: While the gratings in both platforms are compact (instead of linear), the SOI design is a fixed-pitch, 0.5 fill factor grating with a designed fibre angle of 10°; whereas the SiN gratings are designed for a 20° incidence, and are also apodised (adaptive pitch and fill factor) for optimised free-space coupling.
- **Fibre Height:** Due to differences in grating angles and stack thicknesses between SOI220 and SiN300 platforms, fibre z-axis will need to be adjusted between different plaftorms.
- **Thermo-optical coefficients:** The SiN platform exhibits a lower thermo-optic efficiency, making it difficult for the MZI to achieve a full π phase shift and necessitating higher electrical power for the heaters. Care must be taken to ensure applied electrical power remains within the safety limits.

- **Device Function Overlap:** Some components (e.g., spiral delay lines) are similar between platforms - see the SOI section for detailed descriptions if not repeated in the SiN section.

5 Component Introduction: SOI220 Education Kit 2025

The SOI220 Education kit will be fabricated on the standard C-PIC Silicon-On-Insulator (SOI) platform with a 1 µm-thick top cladding and a 2 µm-thick buried oxide (BOX) layer. Metal heaters were integrated as thermo-optical phase shifters. All devices work at 1550 nm wavelength.

The layout of this demonstration cell is shown in Fig. 1.

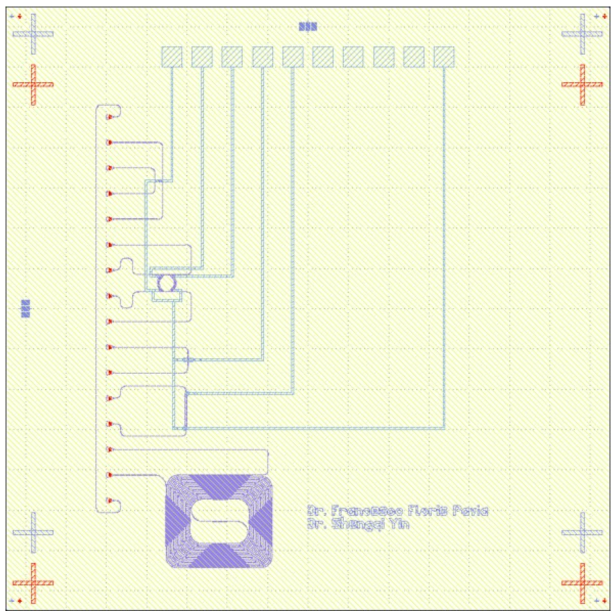

Figure 1. Layout overview

For high-level integration, a PIC chip can be optically and electrically packaged. This education kit offers an example of packing: optical fiber bonding and wire bonding, as shown in Fig. 2.

On the left side, there is one array, which has 16 gratings with a pitch of 127 µm. In this grating coupler array, the first and last gratings are connected directly using a so-called 'optical shunt' to align the fiber array to the grating array during the fiber attach process.

On the top side, there is an array of 12 pads for wire bonding with a pitch of 150 µm, where each pad has dimensions of 100×100 µm.

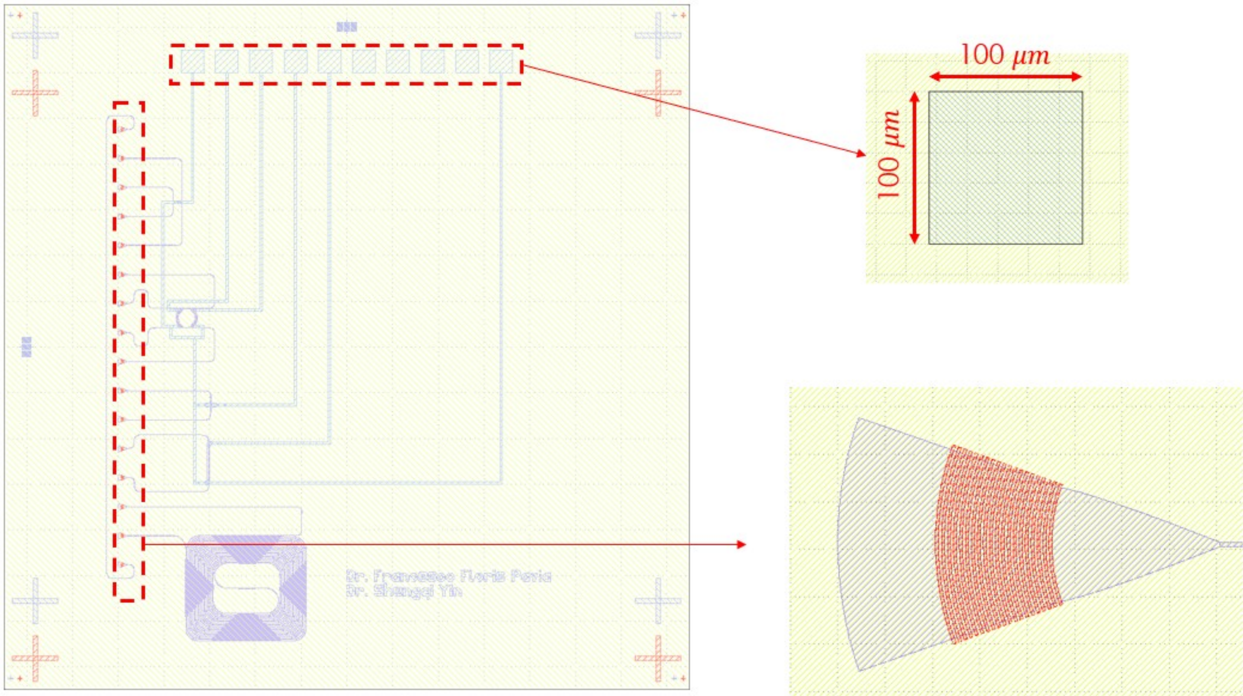

Figure 2. Optical and electrical port arrays

In order to make useful devices, the patterns for different lithography steps that belong to a single structure must be aligned to one another. Alignment marks are used for system calibration and for aligning patterns to previously fabricated layers, as shown in Fig. 3. Typically two alignment marks are used to align the mask and wafer, one alignment mark is sufficient to align the mask and wafer in x- and y-axes, but it requires two alignment marks, preferably spaced far apart, to correct for fine offset in rotation. Additionally, Vernier marks are used to measure offsets, allowing for more precise measurement of overlap bias.

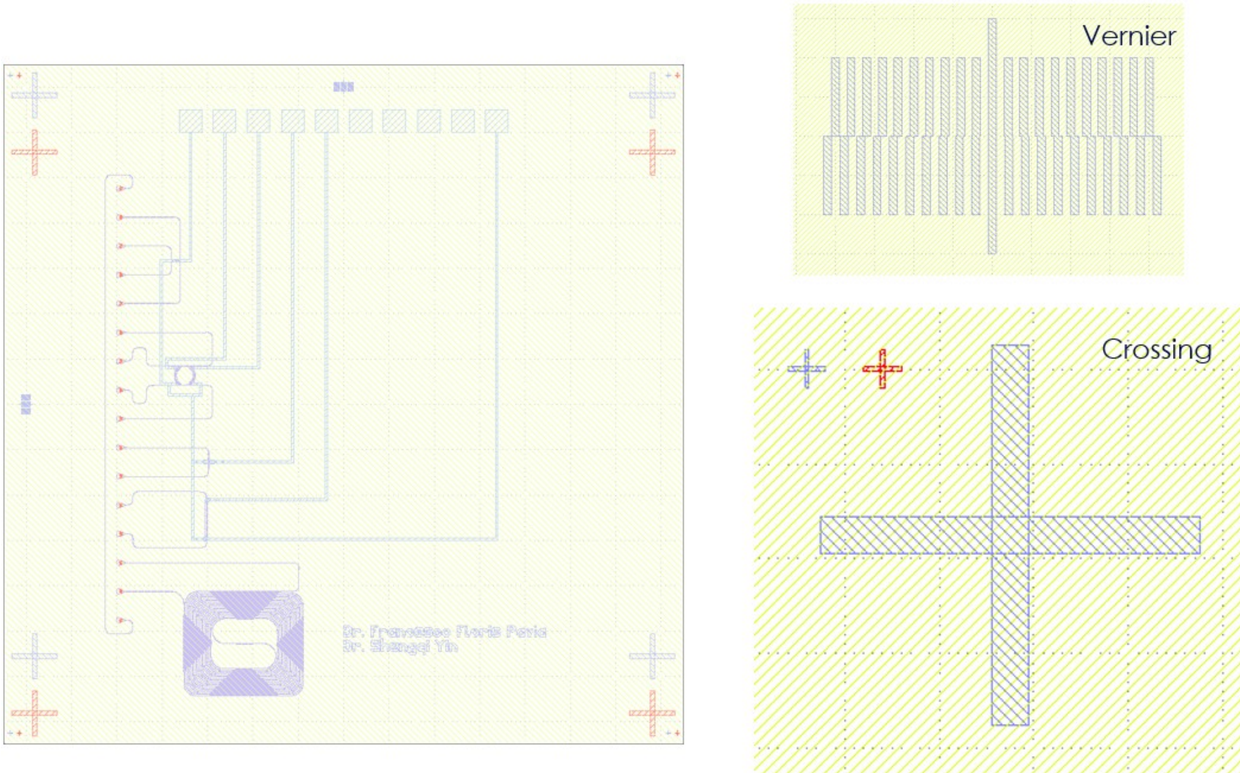

Figure 3. Alignment marks

I. Directional coupler

As shown in Fig. 4, there is a directional coupler with a heater. When two waveguides are placed close to each other in parallel, they are coupled evanescently and the optical power will exchanged between them. With a fixed coupling gap of 250 nm and coupling length of 200 µm, the power exchange rate (power per unit distance) is fixed. By varying applied voltages on the heater, different amounts of optical power will be transferred from one waveguide to the other, due to the variation of refractive index under heating. So if the light is launched in the device from one of the grating couplers, the transmission ratio at the grating couplers on the other side will be different with different add-on voltages.

The directional coupler is widely used in PICs. By modifying the coupling length, it can be employed to implement different optical functions, e.g. 50:50 for beam splitter/combiner, 1:99 for generating a local oscillation signal. Please note that the same directional coupler provides different coupling efficiencies for TE and TM modes.

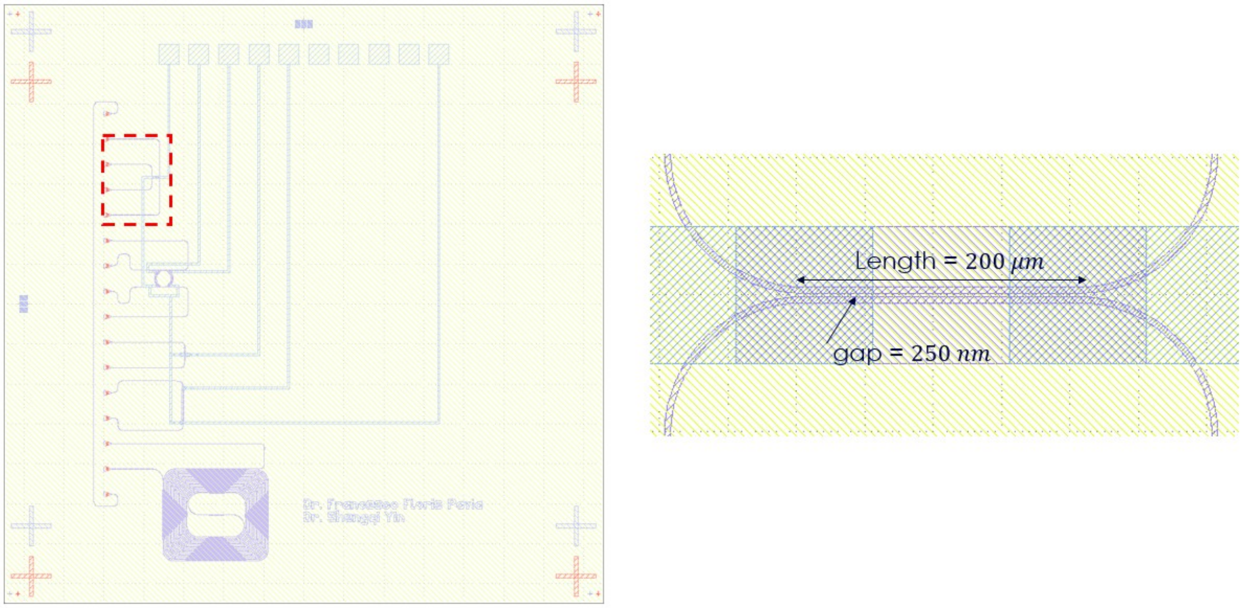

Figure 4. Directional coupler

II. Ring resonator

Ring resonator is one of the most common resonant components used in PICs. An example of ring resonator is shown in Fig. 5. The user should expect dips in the transmission spectrum, which are caused by the constructive interference within the ring resonator. The period of the spectral patterns, known as free spectral range (FSR), is mainly determined by the circumference of the ring. The heater filament over the ring can tune the effective circumference when potential difference is applied across its terminals. On the other hand, the coupling gap is a key factory in the design and control the Q factor and the coupling depth (extinction ratio) of the resonances.

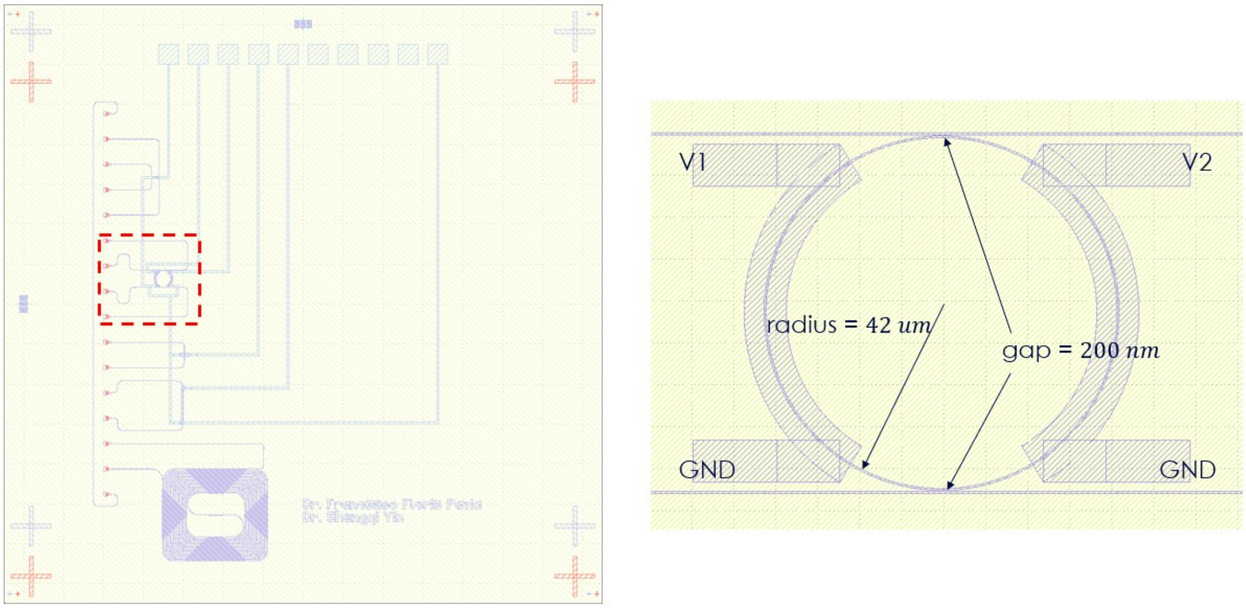

Figure 5. Ring resonator

III. Phase shifter

As mentioned above, a heater filament placed above the waveguide can alter the optical performance, shown in Fig. 6. When a voltage is applied to the heater, it generates heat that increases the temperature of the waveguide beneath. This temperature rise leads to an increase in the effective refractive index of the waveguide material, which in turn reduces the propagation speed of the optical signal. As a result, the light acquires more phase; its phase is "shifted". A phase shifter therefore introduces a controlled time delay to a portion of the input signal by adjusting its optical path length through thermal tuning. Two sets of phase shifters with different heater lengths (10 µm and 175 µm) can reflect power efficiently.

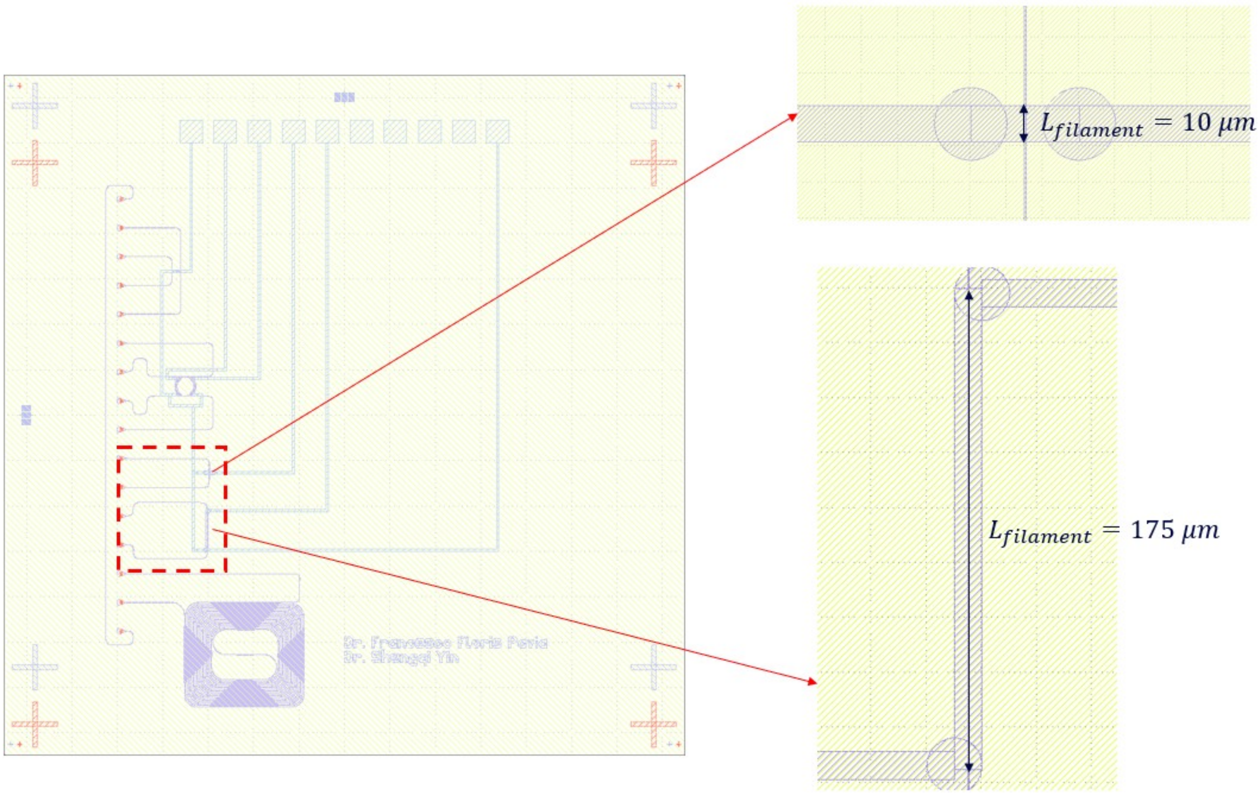

Figure 6. Phase shifter

IV. Spiral waveguides

As shown in Fig. 7, the straight part of the waveguides are multi-mode (MM) waveguides, with a width of 2.5 µm, whilst the waveguide bend has to be single-mode (SM) to avoid mode crosstalk in the bend. They are connected using a waveguide tapers. From one grating coupler to the other, the delay line has a total waveguide length of 3 cm and can be used for measuring the propagation loss using the cutback method.

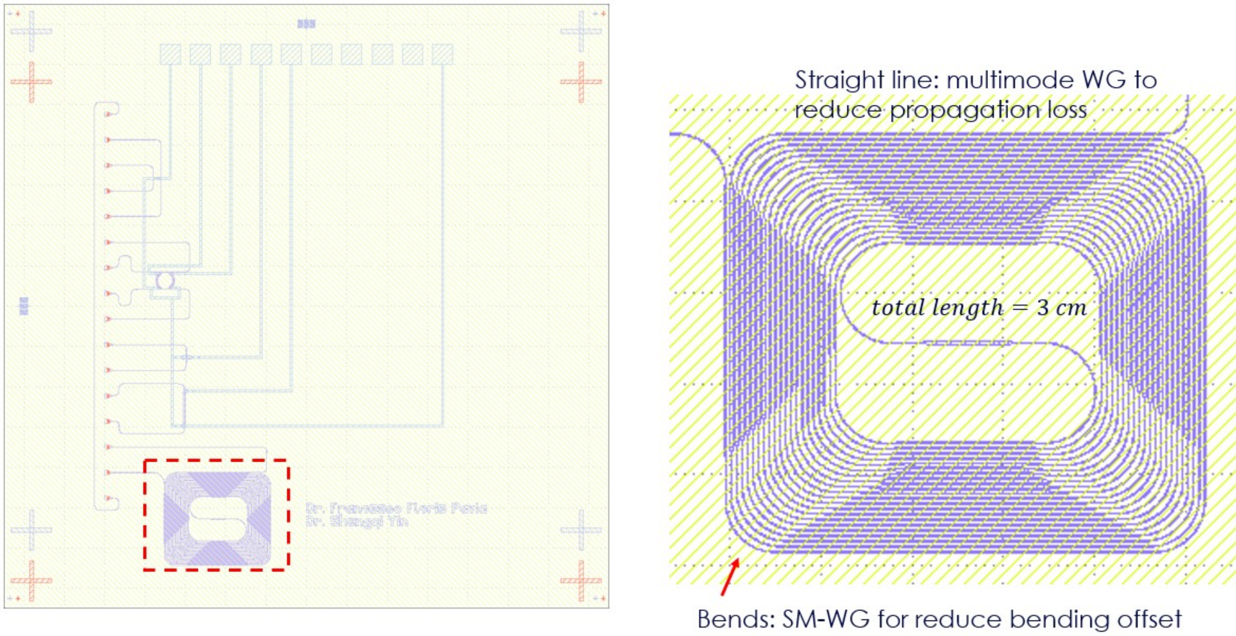

Figure 7. Spiral waveguides

6 Component Introduction: SiN300 Education Kit 2025

The SiN300 Education kit will fabricate on the standard C-PIC SiN platform with a 2 µm-thick top cladding and a 3 µm-thick BOX layer. The overview layout is shown in Fig. 8. All components integrated on this chip work at 1550 nm wavelength. The working principles of the grating couplers, phase shifters and delay lines were explained in Section 5, and will not be replicated here.

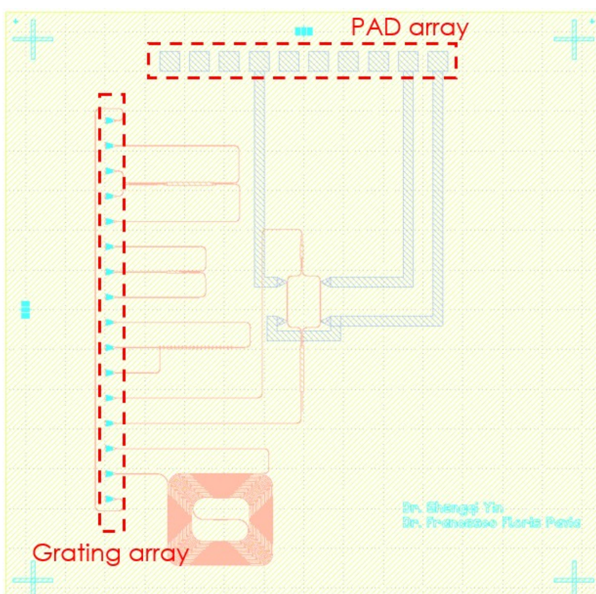

Figure 8. Overview of SiN300 layout

I. 2×2 MMI

A multi-mode interferometer (MMI) is a structure that can split or combine optical power in a predictable manner. As shown in Fig. 9, this 2×2 MMI is designed to split and mix the power from the left input paths in a 50:50 ratio.

The demonstration on the right panel of Fig. 9 illustrates another application of a 2×2 MMI, in which the routing is designed to detect back-reflections from grating couplers. When optical power is injected from one of the left-side input paths, the 2×2 MMI splits the power equally (50:50) and directs it toward the connected grating couplers. Any reflected light returning from the grating couplers is recombined by the same MMI and propagates toward both the input and output grating couplers (highlighted in the figure). By monitoring the signal from the output grating coupler, the portion of back-reflected power can be observed on the screen. This is enabled by a designed path-length difference of 10 μm between the upper and lower arms.

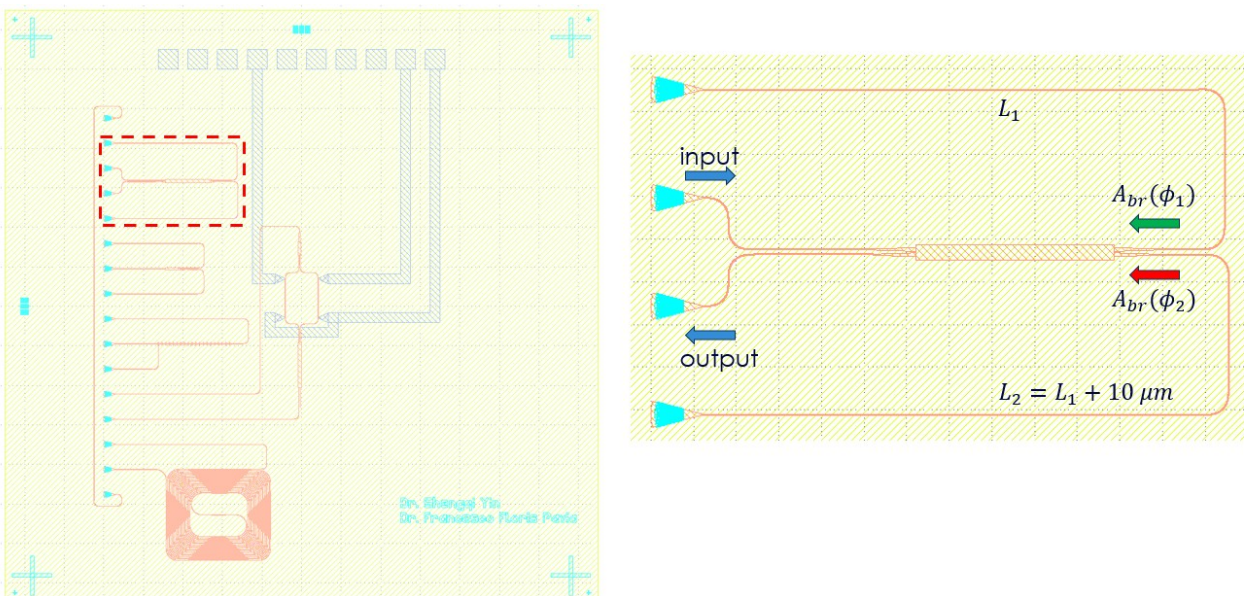

Figure 9. 2×2 MMI

II. 1×2 MMI

In Fig. 10, a 1×2 MMI functions as a beam splitter, equally distributing the optical power between the two output ports on the right. Please note that this 1×2 MMI coupler cannot be directly used as a 1×2 combiner. It may suffer from unexpected interference between the two terminals on the right-hand paths if it is used as a combiner.

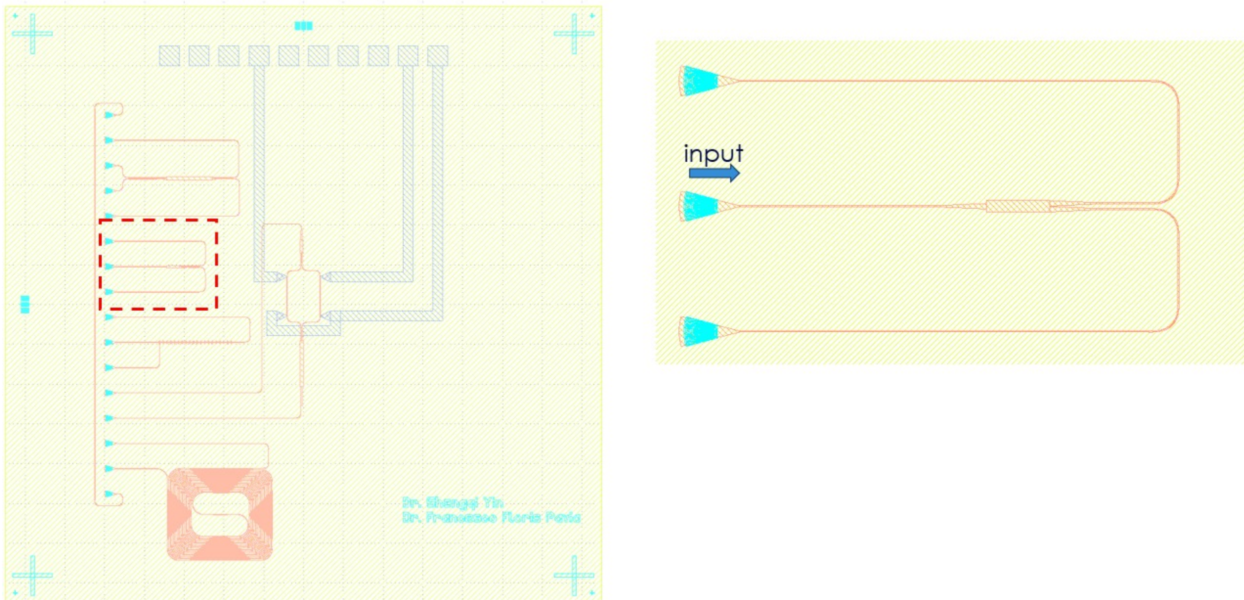

Figure 10. 1×2 MMI

III. Crossing

As demonstrated in Fig. 11, a cascaded array of 20 crossing units is integrated to evaluate the propagation loss and the crosstalk. The crossing is one of the most common passive devices used in PICs. In complex system designs, it is almost impossible to avoid waveguides crossing over each other. This component enables the distinction between crosstalk in the horizontal and vertical waveguides. Additional tapers are added on those floating ports to reduce the back-reflection happened on the truncated facet.

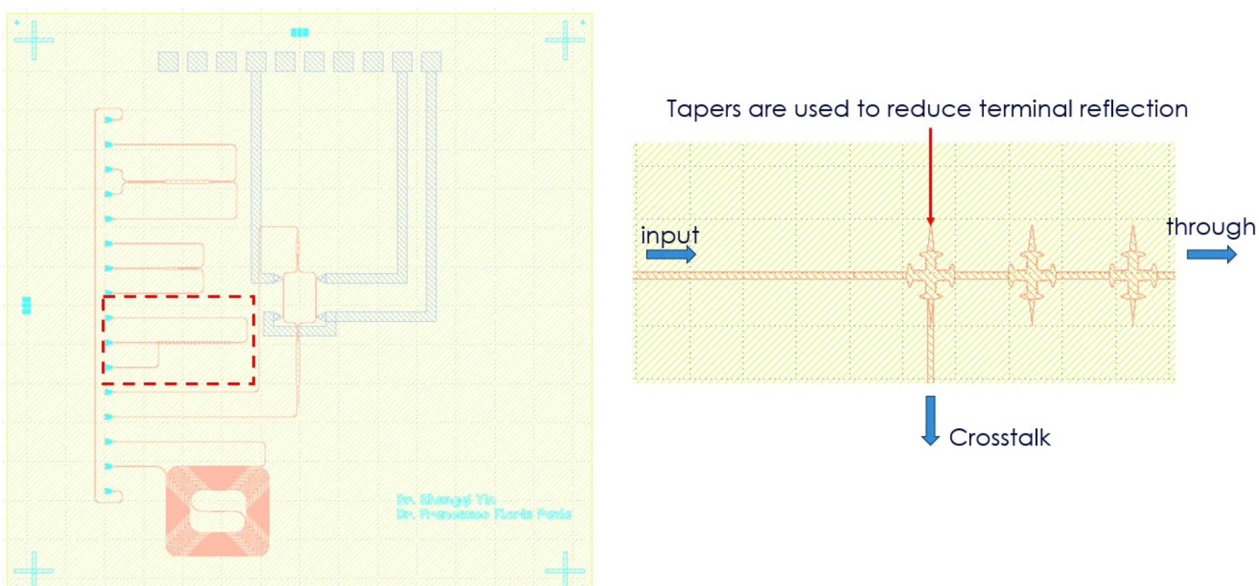

Figure 11. Cascaded crossings

IV. Tunable MZI

Using two MMIs, one can easily build a Mach-Zehnder interferometer (MZI). An exemplary dual-arms controlled MZI is displayed in Fig. 12. The device is formed by a 1×2 MMI, 2×2 MMI, straight waveguides, waveguide bends and grating couplers. On the transmission spectrum, one should observe periodic constructive and destructive interference. The period is the so-called FSR, which is correlated with the optical path difference of the two MZI arms between the 1×2 MMI and 2×2 MMI.

Please note that thermo-optic phase shifters are integrated on the MZI arms. When a voltage difference is applied to the two contact pads allocated upon one arm, there will be a current flow through the filament to heat the MZI arm up, eventually resulting in a change in the effective optical path. Thus when different voltages are applied, the constructive/destructive wavelength and the FSR can be tuned. Or, if the input wavelength is fixed and the output optical power is monitored, when the heating power is linearly increased, the monitored power should vary as a sinusoidal curve.

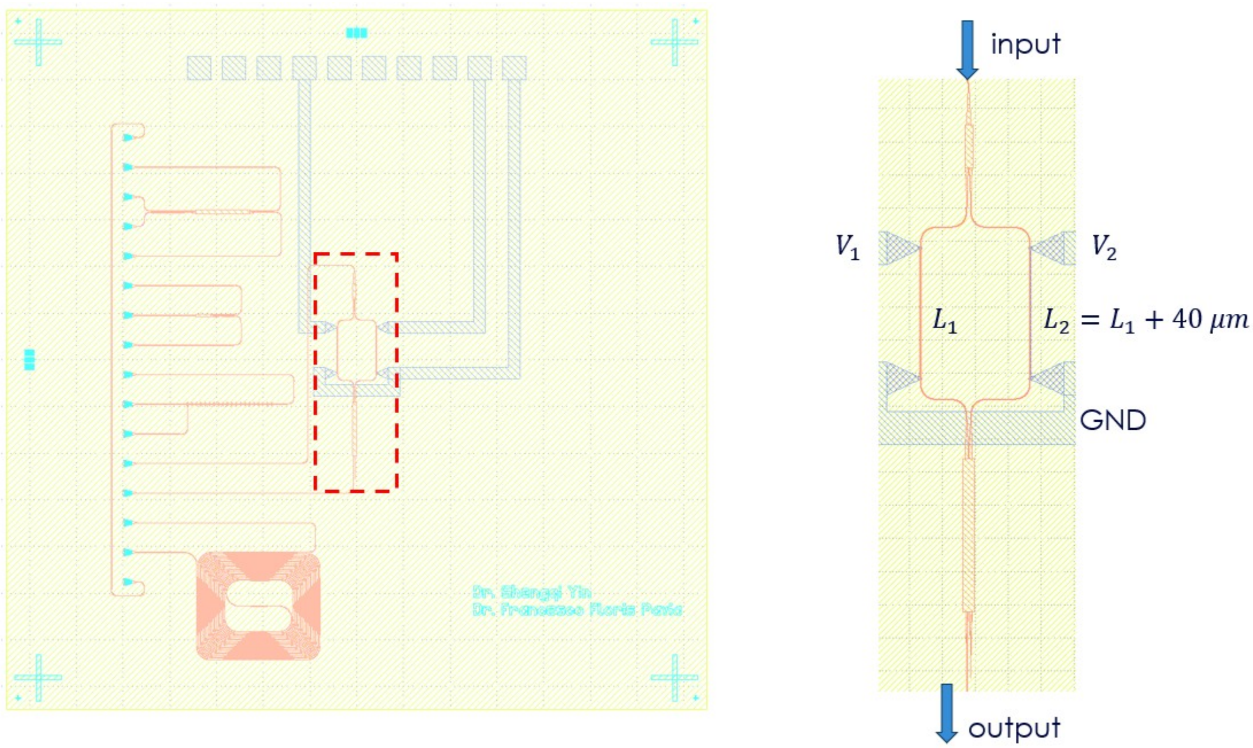

Figure 12. Mach-Zehnder Interferometer

7 Testing Guidelines

The suggestions in this section mainly focus on bare-die devices. Optically and fully packaged chips tend to offer greater stability and are easier to handle.

I. Pre-Test Checks

1. **Verify Equipment:** Ensure the laser wavelength range covers the device design wavelength (1550 nm)

2. **Inspect Fibers and Connector:** Clean all optical connectors and fiber facets with approved cleaning tools
3. **Set Laser Power:** Begin with low optical power ($< 10\,\mathrm{mW}$) to protect devices and detectors.
4. **Confirm Safety:** Wear laser safety glasses if operating above Class 1 conditions; ensure warning signs are in place

II. Optical Alignment Procedure

1. **Positioning:** Place the chip on the alignment stage and secure it by turning the sample holder vacuum on.
2. **Fiber Alignment:** Set the fibre holder tilt to match the angle of the grating couplers ($10°/20°$) and fix the tilt stage. Starting from a large Z distance, gradually reduce the distance between the fibre holder and the sample surface. Switch to fine tuning when the fibre tip appears to touch its reflection from the sample. Make a gentle touchdown of the fibre tip, then increase the gap to a safe distance ($\approx 10\,\mu\mathrm{m}$). Approach the grating using first coarse, then fine X&Y stages. Repeat the same steps for the other fibre stage.
3. **Optimization:** Maximise the detected output signal power by iteratively optimising the X&Y stages of the fibre stage. Repeat the steps for the other fibre arm at least once. If the initial detected power is low, you might benefit from multiple optimisation iterations.
4. **Reference Marking:** Once per alignment, take note of the stage coordinates to speed up switching between advices on the same chip (if stages is per-aligned in horizontal).

III. Measurement Guidelines by Device Type

- **Grating Couplers:** Sweep the laser wavelength and record the transmission spectrum; identify peak coupling wavelength and loss.
- **MMIs:** Measure output powers from all ports; calculate insertion loss and imbalance
- **Ring Resonator:** Record transmission spectrum; extract FSR and Q-factor; apply electrical power to the heater and tune the optical path difference between the arms to observe the spectral signature shift.
- **Tunable MZI:** Measure FSR and extinction ratio; apply power to the heater to demonstrate phase tuning
- **Spiral Waveguide:** Measure propagation loss; calculate loss vs. propagation length
- **Crossings:** Inject light into the designated port; measure crosstalk and loss across the cascade.

IV. Data Recording and Analysis

- Use a spreadsheet or data acquisition software to log wavelength, power, and applied voltage.
- Save spectrum for post-analysis.
- (Optional) Repeat testing to obtain a statistical distribution of performances.

V. Shutdown Procedures

- Turn off the laser and electrical drivers.
- Carefully remove fibers and probes to avoid chipping or scratching the device.
- Store the chip in its protective case.