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THz topological Waveguides in 600 GHz frequency Region

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Abstract— We experimentally demonstrate a silicon-based valley photonic crystal (VPC) waveguide for the 590-620 GHz frequency region. We specifically conduct measurements on the transmission and group delay for normal silicon waveguides and Valley photonic crystal waveguides and state that topological valley kink states are promising for THz communication applications enabling high-speed 6G data transfer systems.

I. INTRODUCTION

Terahertz (THz) technology is becoming attractive for future technology due to its unbeatable range of applications in sensing, safety imaging, and data communications. The majority of the current THz systems have not much enjoyed the silicon-based chip-scale integrated technology but rely on voluminous and bulky systems. Recently, silicon-based THz photonics has become a mature technology in offering a range of passive functions enabling cost and power-efficient data-communication applications. Conventional THz photonic circuits used are suffering from back scatterings, sensitivity defects, and structural perturbations, which will be more prominent upon the further miniaturization of devices going towards the THz range. Hence, the recent progress in Valley Photonic Crystal (VPCs), which is known for its topological protection, holds much promises for high-performance photonic circuits, densely integrating various optical components. Extremely low loss and low dispersion topological THz VPC has already been designed and demonstrated in the 300 Gigahertz (GHz) frequency region and its high performance in data communication applications [1-3]. Driven by the high demand for higher data rates for data-hungry applications like augmented and virtual reality, there is a need to experiment on higher frequencies rather than the 300 GHz band. Higher frequency bands will pave the way toward Tbit/s systems and enable high-speed data communication systems.

II. VPC DESIGN

In this work, building on the topological phase of light, we design, fabricate, and experimentally demonstrate a low-loss, low-cost, silicon-based VPC waveguide for the 590-620 GHz frequency region. We use Silicon on Insulator (SOI) wafers with 90 μm -thick high-resistivity silicon (HR-Si) with resistivity $> 10 \text{ k}\Omega\cdot\text{cm}$ and 11.7 relative permittivity. HR-Si offers CMOS compatible Platform with low absorption loss and a non-dispersive refractive index (~ 3.42). Here, the VPC device layer is asymmetrically placed between the SiO_2 substrate and the top air region along the z-axis. Figure 1 shows the schematics of Si-VPC designs, composed of a well-known graphene-like honeycomb lattice with equilateral triangular air holes with lattice constant $a=136.8 \mu\text{m}$.

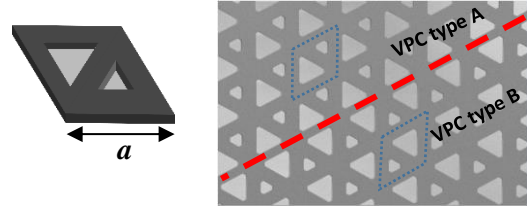


Fig. 1 (a). Schematic of the unit cell of the fabricated sample (b) SEM image for the fabricated sample. The blue dashed lines show Wigner-Seitz and unit cells and the red one shows the interface where edge modes propagate.

III. RESULTS

The experimental measurements were performed for the silicon VPCs and normal silicon chips without topological protection for the frequency range 500-750 GHz using VNA based measurement system as in figure 2 (a). After calibrating the system using a waveguide-based TRM (Thru, Reflect, Match) procedure to compensate for VNA systematic errors, we measured the transmission and group delay for the straight and 2-bends topological waveguides fabricated with well-known graphene-like lattices containing equilateral triangle holes.

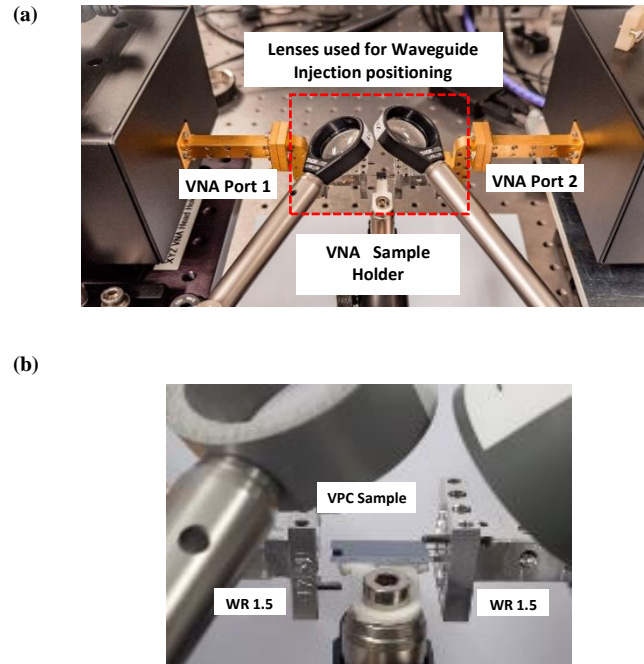


Fig. 2(a) Setup representation: Silicon VPCs coupled to the VNA measurement system (b) Zoom on the injection from hollow-core metallic waveguide (WR1.5) to VPC sample.

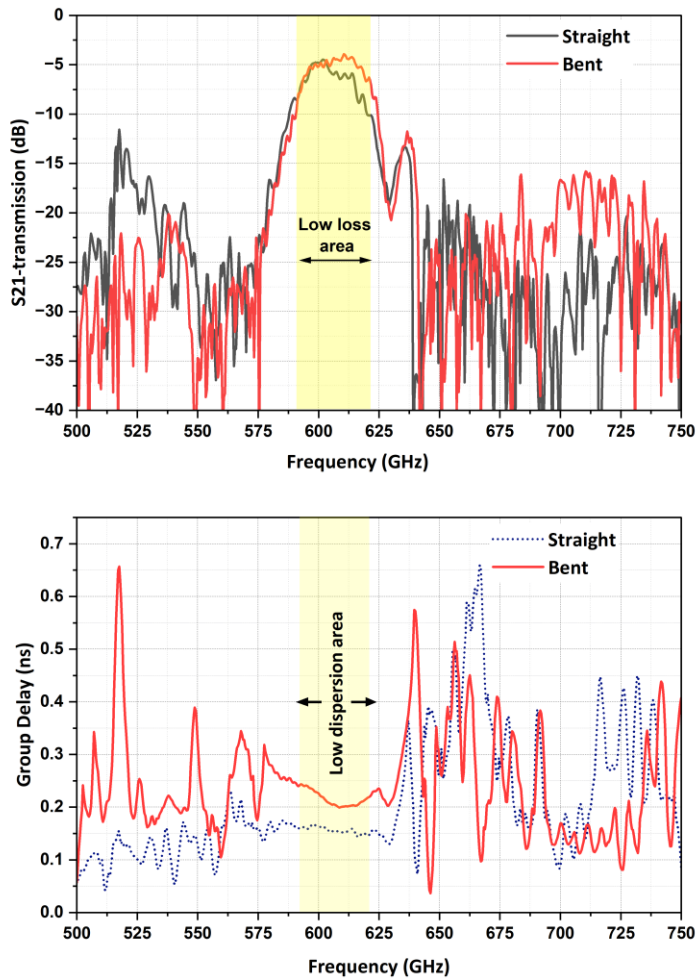


Fig. 3 Transmission and Group Delay from VNA measurement for 2 bends and straight topological waveguides.

IV. SUMMARY

Silicon-based valley Photonic crystals have been experimentally demonstrated. Low loss and low dispersion areas were spotted in 590-620 GHz. The results prove that topological valley kink states are promising for THz communication applications enabling high-speed 6G data transfer systems.

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