Ministry of Science and Technology
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Novel silicon chip allowing terahertz waves to pass through barriers could enable future 6G networks

A new silicon chip that allows terahertz waves to pass through an engineered barrier with little loss, while carrying data at 100 Gbit/s, points to compact terahertz circuits for future 6G communication technologies.

Future sixth-generation (6G) wireless networks are expected to use terahertz frequencies, which lie between microwaves and infrared light and offer wide bandwidth. Guiding these waves through compact circuits is challenging, as bends, junctions and abrupt changes in a waveguide can scatter or reflect part of the signal, weakening it as it travels.

By arranging triangular holes in a carefully designed pattern in a silicon slab, researchers can create a photonic crystal that guides terahertz waves along the boundary between two regions. Such boundary channels resist certain kinds of backscattering, but a practical circuit must also tolerate deliberately introduced obstacles and changes in geometry.

Researchers at the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR), an autonomous institute of the Department of Science and Technology (DST), approached this challenge through topological photonics and demonstrated data transmission at up to 100 gigabits per second (Gbit/s) across an engineered barrier. A single barrier added only about 1–2% loss, and two barriers in sequence about 2–3%. In a conventional, non-topological waveguide, a comparable barrier markedly reduces transmission.

The team designed a silicon photonic crystal whose structure mimics the honeycomb lattice of graphene, and created a barrier by changing the sizes of the triangular holes over a short section of the waveguide.

Transmission remained close to its barrier-free level as long as the barrier strength stayed below a characteristic coupling strength of the crystal. Because the barrier is set by hole geometry, this offers a practical design rule for such devices.

The researchers tested the concept in three devices fabricated on high-resistivity silicon, a material compatible with established semiconductor manufacturing: one with two barriers in sequence, one with an omega-shaped route containing four sharp bends and a central barrier, and a power splitter with a barrier in one of its two branches.

Measurements across 310–360 GHz agreed closely with simulations. In the splitter, the two output signals were nearly identical, showing that the barrier had little effect on transmission.

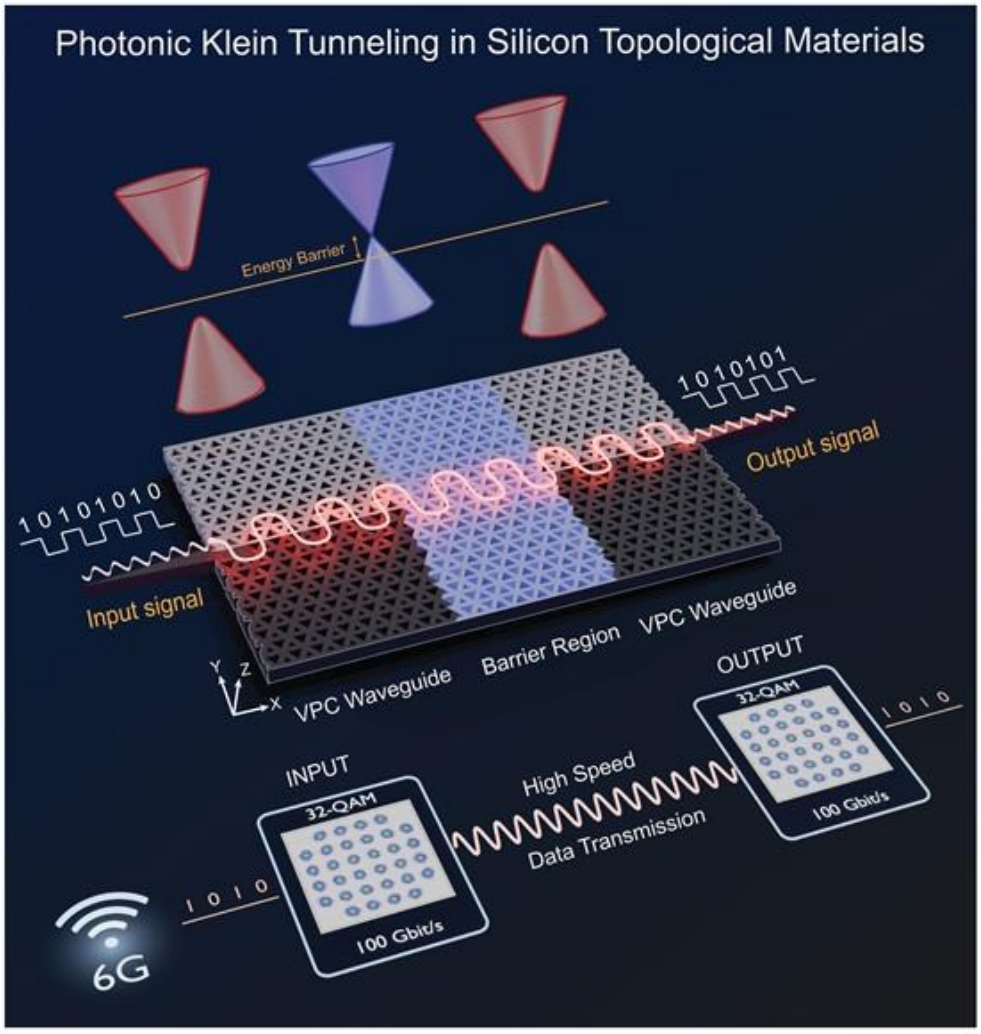


Figure 1. *Artistic illustration of photonic Klein tunnelling in a silicon valley photonic crystal chip. A terahertz signal carrying high-speed data crosses the engineered barrier (blue) without significant loss, supporting 100 Gbit/s data transmission for 6G communication.*

In high-speed data tests, the double-barrier and omega-shaped devices carried 48 and 60 Gbit/s, respectively. The splitter supported 100 Gbit/s using QAM-32 modulation, which encodes information in the signal's amplitude and phase. At this rate, a 5-gigabyte high-definition film could in principle be transferred in under half a second.



Figure 2. *The research team in the Meta Optics Laboratory (MetoLab), JNCASR, with the fabricated silicon chip used to demonstrate photonic Klein tunnelling.*

The study was led by Dr Abhishek Kumar, Assistant Professor at JNCASR, where he heads the Meta Optics Laboratory (MetoLab), with Samina Mulla and Sangram Kumar Sadhu of JNCASR as joint first authors. Collaborators included Asif Iqbal M and N. S. Vidhyadhiraja (JNCASR); Siddhartha Lal (IISER Kolkata); Anshuman Kumar (IIT Bombay); Zhonghua Gu and Prakash Pitchappa (Institute of Microelectronics, A*STAR, Singapore, and Pascal Szriftgiser and Guillaume Ducournau (University of Lille and CNRS, France).

“Showing that terahertz waves can cross a barrier created simply by changing the hole geometry, while carrying 100 gigabits per second, suggests that this effect can become a useful design tool for terahertz chips,” said Dr Abhishek Kumar.

The results could help researchers develop terahertz circuits that route and split signals on a single chip with low loss. The team next plans to tune the barriers electrically, thermally or mechanically, which could allow a device to redirect signals between paths on demand. The work has been published in the journal *Advanced Materials*.

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