Novel link between optical fibers, nanometer-scale silicon structures could aid development of integrated optical circui

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Silicon is a unique material that has revolutionized electronics; it enables engineers to put millions of electrical devices onto a single chip.

Replacing the electrical currents in this technology with beams of light could enable even faster information processing. Qian Wang at the A*STAR Data Storage Institute and co-workers1 have now designed a crucial component for such optical chips — a connector that links the silicon chip to an optical fiber. Such a device should enable efficient light input and output.

Silicon is a promising platform for dense photonic integration because sub-micrometer-sized silicon wires, known as waveguides, are capable of tightly confining and guiding light. As the technology required for processing silicon in this way already exists, silicon nanowires are attracting attention from the electronics industry. The challenge, however, is to be able to insert and extract a beam of light efficiently into and out of such tiny structures.

Wang and his team have now designed an ultra-compact lens that can be directly integrated into the silicon chip at the end of the waveguide. Their proposed lens is based on an idea known as a graded refractive index (GRIN) lens. The common GRIN lens usually distorts a light beam as it is collimated or focused, resulting in a so-called aberration. “We now propose a computational algorithm that can generate a novel graded refractive index profile for the GRIN lens and thus achieve aberration-free sub-wavelength focusing and highly efficient coupling,” says Wang.

The team of researchers’ graded index structure consists of a stack of alternating layers of two materials — for example, using silicon, which has a high refractive index, and silicon dioxide, which has a low refractive index. The layers of silicon are thicker than those of silicon dioxide at the optical axis, but this gradually reverses higher up in the stack.

Simulations showed how this structure could expand out light travelling along a 300 nanometer-thick silicon waveguide so that it couples to a fiber with a diameter of 10.4 micrometers. With appropriate anti-reflection coating, the coupling efficiency was calculated to be as high as 90%. The team of researchers also assessed the sensitivity of the optical coupling to any movement of the fiber, indicating that the new approach would provide a compact, efficient and robust way of achieving fiber-to-nanophotonic chip coupling. The next step will be to demonstrate this concept experimentally. “We plan to incorporate the idea into an electronic–photonic integration platform,” says Wang.

More information: Read more in IEEE Journal of Selected Topics in Quantum Electronics.

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