On-chip generation of Bessel-Gaussian beam for long-range sensing

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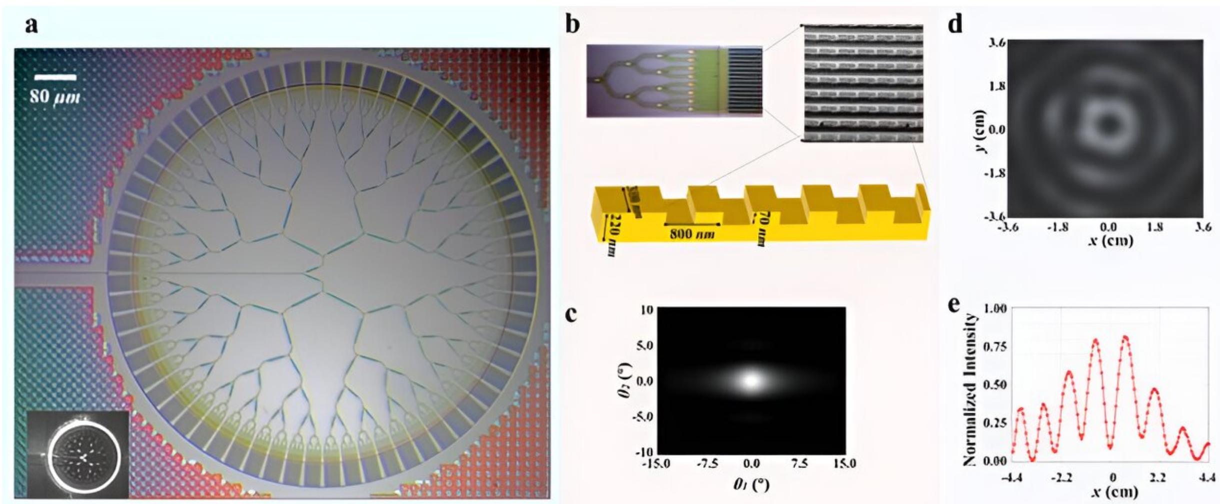

a Optical microscope image for an integrated photonic chip used as a Bessel Gaussian beam generator. The inset is a surface image captured when the laser light is emitted from the chip. b Enlarged view of local grating arrays in the photonic chip and Scanning electron microscope (SEM) image of the grating arrays. c Simulated intensity distribution of far-field from the grating emitters. d Experimentally measured BGb profile at 5.91 m. e One-dimensional intensity distribution of light field at 5.91 m. Credit: *Light: Science & Applications* (2023). DOI: 10.1038/s41377-023-01133-2

The Bessel beam, with a significant depth of field and self-healing characteristics, has been applied in widespread applications, including quantum entanglement, underwater 3D imaging, optical micro-manipulation, microscope, and so on. However, these methods, such as circular slit and lens, axicon, spatial light modulator (SLM), are complicated due to the usage of bulky optical elements and hinder the Bessel beam generation system from being applied in practical applications.

Recently, several compact systems have been proposed to generate Bessel beams by using photonic integrated circuits (PICs), meta-surfaces, integrated waveguide, and 3D-printed fiber. But the propagation distance of Bessel beams generated by the above technologies is short , which significantly restricts the applications of the Bessel beam in scenarios requiring long propagation distances.

In a new work published in *Light: Science & Applications*, a team of scientists, led by Professor Junfeng Song from State Key Laboratory on Integrated Optoelectronics, College of Electronic Science and Engineering, Jilin University, Changchun, China, Peng Cheng Laboratory, Shenzhen, China and co-workers have proposed an unprecedented structure based on silicon photonic grating arrays to generate the Bessel Gaussian beam (BGb) with a long propagation distance (measured 10.24 m).

The grating arrays are concentrically distributed on the chip. Moreover, the BGb profiles operated at wavelength range from 1500 nm to 1630 nm are obtained. The spatial distribution of the light intensity follows the first kind of Bessel function. Last but not the least, the researchers also applied the azimuthally polarized BGb to measure rotation speed and distance of a target simultaneously.

By the compact size, low cost, and mass production potential of the integrated process, The reported method and technique is promising to readily enable the Bessel-Gaussian beam in widespread optical communication and micro-manipulation applications.

The group summarized the principle of their integrated silicon photonic chip to produce long-distance Bessel-Gaussian beams:

"The BGb can be obtained by the superposition of a series of Gaussian beams. The process is not only related to the emission angle, but also to the divergence half-angle of Gaussian beams. Due to the coherence between the Gaussian beams and the symmetry of the circular distribution, Bessel-Gaussian beams are formed in the overlapping area. The emission angle and divergence angle of the Gaussian beam determine the spatial position of the overlapping area. In theory, the overlapping area can reach infinity."

"Next, In order to produce long distance BGb, the waveguide structure is carefully designed, especially grating arrays width and grating period. We have done lots of simulation, and finally determined their size. The whole ring structure has a diameter of 870 µm, and 64-channel grating emitters arranged circularly. The photonic chip is fabricated on a silicon-on-insulator (SOI) substrate by the Singapore Advanced Micro Foundry (AMF) standard 130 nm 8-inch CMOS process."

"Rotation is a fundamental phenomenon in nature and an effective approach to measure rotation speed is essential to reveal physics characteristics, manage precise machinery and analyze the composition of celestial bodies. To demonstrate the functionality of the generated BGb, we also experimentally measure the rotation speeds of a spinning object via the rotational Doppler Effect and the distance through the phase laser ranging principle. The on-chip BGb can provide an integrated solution for effective rotation measurement."

"Since the area of this device is less than 1 square millimeter, and the cost of a single device will be reduced to less than 50 cents in mass production. This low-cost, high-quality and long-distance BGb generator on-chip is the key to the future Bessel beam in large-scale, miniaturized and highly stable application scenarios," they added.

More information: Zihao Zhi et al, On-chip generation of Bessel–Gaussian beam via concentrically distributed grating arrays for long-range sensing, *Light: Science & Applications* (2023). DOI: 10.1038/s41377-023-01133-2

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