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High-quality electro-optic beam steering

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Abstract: Optical beam steering is essential for free-space optical communication, light detection and ranging (LiDAR) and other fields. Thin-film lithium niobate (TFLN), as an efficient integrated photonics platform, offers strong electro-optic (EO) effect, low propagation loss, high-speed, and low-power modulation, making it highly attractive for optical phased array (OPA) based beam steering. However, despite these advantages, OPAs still face inherent trade-offs among field of view, sidelobe suppression, and scanning resolution. Recently, Prof. Huihui Lu's group presented a two-dimensional (2D) EO-steered OPA using a non-uniformly spaced X-cut TFLN superlattice-waveguide array and a trapezoidal grating emitter. The compact device achieves narrow main beam, wide steering range and high sidelobe suppression, demonstrating great potential for high-performance beam-steering applications.

Keywords: integrated optical phased array; thin-film lithium niobate; electro-optic beam steering; narrow main beam; side lobe suppression

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Optical beam modulation is fundamental to modern photonics, providing essential support for beam manipulation[1,2]. Optical beam steering is critical in free-space communication[3], light detection and ranging (LiDAR)[4], and advanced imaging[5]. Traditional mechanical scanners are bulky, slow in response, and limited in reliability, making optical phased array (OPA) a superior next-generation solution with compact size, high speed and precise manipulation. Integrated OPA platforms include silicon, thin-film lithium niobate (TFLN) and other material systems, where beam steering is achieved by independently tuning the phase of each sub-aperture to engineer the overall interference pattern for flexible and programmable beam manipulation. Nevertheless, conventional OPAs often face limitations such as high optical losses, limited steering range and poor sidelobe suppression. Silicon OPAs benefit from complementary metal oxide semiconductor (CMOS) compatibility but are limited by high power consumption and slow thermo-optic tuning, while electro-optic (EO) polymers enable high-speed operation but lack stability and have high loss. In addition, InP-based OPAs offer monolithic integration and efficient EO tuning, yet suffer from high loss, elevated cost and limited scalability, hindering large-scale applications.

In contrast, TFLN provides a superior platform due to its strong EO effect, low propagation loss, and high-speed, low-power modulation. Recent advances in TFLN fabrication have enabled high-performance integrated OPAs, including two-dimensional (2D) beam steering[6–9]. However, existing TFLN OPAs still face challenges in simultaneously achieving narrow beam width and effective sidelobe suppression, which are critical for high-quality beam steering. Overcoming this trade-off remains essential for advancing integrated photonic beam steering technologies.

In a recent article published in *Opto-Electronic Science*, Prof. Huihui Lu and Prof. Heyuan Guan demonstrate a non-uniform TFLN OPA to achieve high-performance EO beam steering with narrow main beam and suppressed sidelobes, which successfully tackles key challenges[10]. As illustrated in the top-right inset of Fig. 1, a central feature of this work is the superlattice ridge waveguide design, which significantly reduces inter-channel optical crosstalk and sidelobe level. By suppressing crosstalk, the authors ensure high-fidelity phase modulation across the array, thereby preserving beam quality. This highlights the importance of waveguide-level engineering in addition to system-level optimization. Another key contribution lies in the adoption of a non-uniform

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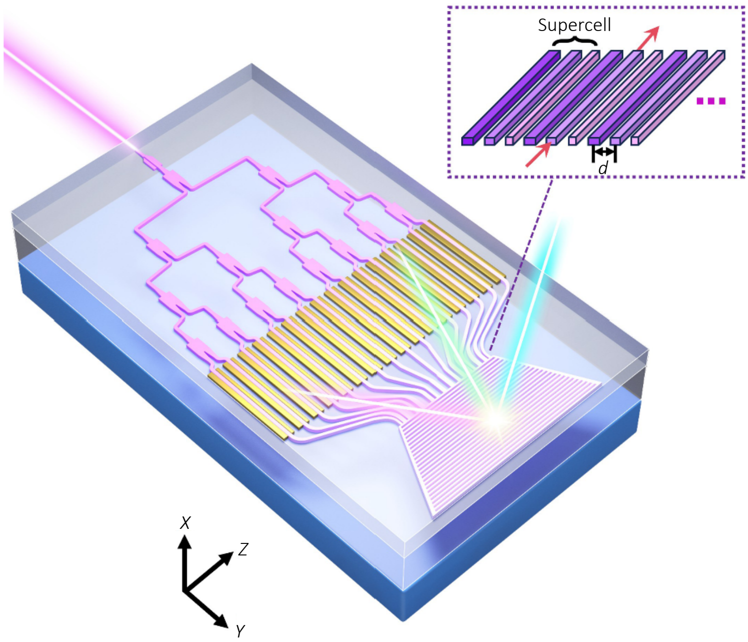

Fig. 1 | Schematic illustration of the thin-film lithium niobate (TFLN) optical waveguide phased array with high-performance beam steering. Figure reproduced from ref.[10], under a CreativeCommons Attribution 4.0 License.

waveguide array. In contrast to periodic arrays, which inherently suffer from pronounced grating lobes when the element spacing exceeds half a wavelength, non-uniform arrangements provide an additional degree of freedom to tailor the far-field radiation pattern. Here, the array geometry is optimized using a particle swarm optimization (PSO) algorithm, enabling effective redistribution of the spacing between waveguide elements to suppress sidelobes while maintaining a narrow main beam. This approach reflects a broader trend toward aperiodic and sparse array engineering for performance enhancement in OPA. Furthermore, the incorporation of a trapezoidal end-fire radiator with etched gratings improves radiation efficiency and beam shaping, contributing to the overall beam quality.

Accordingly, the authors present the theoretical design of the proposed 16-channel OPA in Fig. 1. To evaluate the optical performance of the fabricated OPA chip, they characterize the chip using a home-built experimental system. Experimental results exhibit a main beam width of 0.99° × 0.63° from an optical aperture of only 140 μm × 250 μm, along with a sidelobe suppression ratio of 20 dB. Such performance is particularly notable given the compact footprint of the device. The TFLN OPA also demonstrates 2D beam steering over 47° × 9.36° by phase EO modulation and wavelength tuning, indicating its capability for wide-angle scanning.

For LiDAR systems used in autonomous driving and robotics, narrow beam enables long-range high-resolution detection, while low sidelobes avoid false alarms from off-target reflections. Benefiting from the mature TFLN platform, this OPA scheme facilitates fully integrated chip-scale beam steering for sensing and communication. Its non-mechanical EO beam steering reduces cost and enhances reliability, unlocking new applications in augmented reality and free-space optical interconnects. Notably, analogous requirements for fast, reconfigurable, and energy-efficient optical routing are emerging in optical circuit switching (OCS) for AI clusters and high-performance computing systems, suggesting that OPA-based beam steering may play a broader role in scalable photonic interconnect architectures.

In conclusion, this work demonstrates a high-performance TFLN-based OPA that successfully reconciles key trade-offs between beam steering resolution, sidelobe suppression, and device footprint. This achievement not only advances the state of the art in integrated beam steering, but also underscores the potential of combining non-uniform array design with low-loss EO platform. As research in TFLN photonics continues to evolve, such approaches represent an important step toward chip-scale, high-efficiency, and low-sidelobe solid-state beam steering. It enables next-generation LiDAR, free-space optical links and reconfigurable photonics, offering different pathways for compact, high-speed EO beam-steering modules.

References

1. Ji J, Ye ZL, Wang ZZ et al. Dynamic holographic display with addressable on-chip metasurface network based on lithium niobate photonics. *Light Sci Appl* **14**, 332 (2025).
2. Zhong HZ, Zheng Y, Sun JC et al. Gigahertz-rate-switchable wave-

front shaping through integration of metasurfaces with photonic integrated circuit. *Adv Photonics* **6**, 016005 (2024).
3. Ma XY, Yuan MR, Li JC et al. Multi-target and ultra-high-speed optical wireless communication using a thin-film lithium niobate optical phased array. *Nat Commun* **17**, 969 (2026).
4. Li BZ, Lin QX, Li M. Frequency-angular resolving LiDAR using chip-scale acousto-optic beam steering. *Nature* **620**, 316–322 (2023).
5. Chen RX, Wu YC, Zhang K et al. Integrated bionic LiDAR for adaptive 4D machine vision. *Nat Commun* **17**, 24 (2026).
6. Tan S, Liu J, Liu Y et al. Two-dimensional beam steering based on LNOI optical phased array. *In 2020 Conference on Lasers and Electro-Optics* 1–2 (IEEE, 2020).
7. Yue GC, Li Y. Integrated lithium niobate optical phased array for two-dimensional beam steering. *Opt Lett* **48**, 3633–3636 (2023).
8. Wang ZZ, Li XY, Ji JT et al. Fast-speed and low-power-consumption optical phased array based on lithium niobate waveguides. *Nanophotonics* **13**, 2429–2436 (2024).
9. Ye YQ, Lian DX, Chen ZS et al. Visible-light optical phased array on a thin-film lithium niobate platform for high-speed beam steering. *Opt Lett* **50**, 3090–3093 (2025).
10. Li Y, Deng SY, Ma X et al. Narrow beam and low-sidelobe electro-optic beam steering on thin-film lithium niobate optical phased array. *Opto-Electron Sci* **5**, 260002 (2026).

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