Side-lobe Level Reduction in Two-dimensional Optical Phased Array Antennas

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Abstract: We experimentally demonstrate that by arranging the array elements according to Fermat's spiral, the side lobe level of an 8-element SOI-array is reduced by 0.9 dB. Additional experiments show a 6.9 dB reduction for 64-elements.

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All-dielectric antennas are becoming an essential part in applications ranging from optical communications to sensors [1, 2]. As in the case of RF antennas, phased array antennas have been proposed to enhance the radiation properties of photonic antennas. The fabrication constrains, however, limit the minimum separation among elements, giving rise to undesired side-lobes when the elements are periodically arranged [3]. In this work we experimentally show that if array elements are positioned following Fermat's spiral, as suggested in [4], the side lobe level (SLL) can be significantly reduced. In particular, experimental results reveal a SLL reduction of 0.9 dB in an 8-element array fabricated on a CMOS-compatible SOI platform. Furthermore, in order to verify that the SLL reduction is more notorious as the number of antenna elements grows, we use spatial light modulator (SLM)-based emulation to achieve a drop of 6.9 dB for a 64-element array.

Two SOI-based phased array antennas designed to operate at 1550 nm were fabricated at an external foundry (imec/Europractice): a 2×4 uniformly distributed phased array with an inter-element separation of 9 µm (5.8λ); and an 8-element array arranged according to the Fermat's spiral having a minimum separation of 9 µm. In both cases, the antenna presented in [5] was used as radiation element because its broadside radiation pattern allows a clearer observation of the SLL. Scanning electron microscope (SEM) images of the fabricated uniform and Fermat arrays are shown in Fig. 1a.i and ii, respectively, whereas the inset in Fig. 1a.ii shows a detailed view of an antenna element. Light was coupled into the chip using a lensed fiber and an inverted taper, after which three 1×2 splitting stages were used to equally distribute power to the 8 elements. Special care was taken to ensure that the optical path lengths to all antenna elements were the same. Figures 1b.i and ii show the near-field images measured using a 4f-system of the uniform and Fermat arrays, respectively, showing that indeed the elements are evenly fed in the two cases. The simulated far-field obtained employing 3d-FDTD are represented in Fig. 1c.i and ii, whereas the experimental radiation

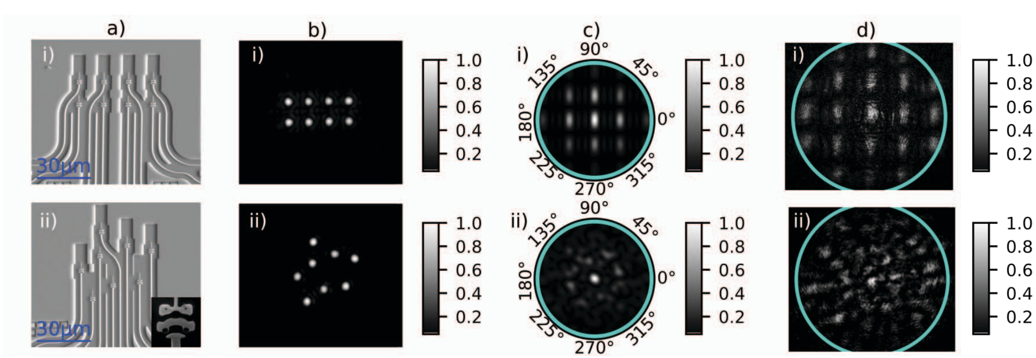

Fig. 1. (a) SEM images of the fabricated uniformly and non-uniformly distributed array antennas; and the corresponding (b) near field measurements; (c) simulated far-fields; and (d) measured far-field intensities.

patterns captured using a 2f-lens system are presented in Fig. 1d.i and ii. As can be appreciated, both simulation and experimental results show that the uniform array presents significant SLL, while in the Fermat array, the SLL is lower, as theoretically predicted. We measured an SLL reduction of 0.9 dB of the Fermat spiral with respect to the uniform array.

In order to measure the SLL reduction of larger arrays, we employ SLM-based emulation, which allows us to write an arbitrary phase mask representing the desired array. Figure 2a.i and ii show examples of uniform and Fermat phase masks with 64-elements, respectively. These phase masks are built by pixel-by-pixel multiplication of a mask of square antenna elements (square apertures) and a blazed grating optimized to maximize the power in its first diffraction order, since employing the zero-th diffraction order leads to far field radiation pattern with a poor signal-to-noise ratio. The SLM is illuminated by a beam generated using a continuous wave laser operating at 633 nm and whose output is expanded to have a beam diameter of 3.5 mm. The far-field pattern of the phased array written on the SLM is then collected using a 2f-system, after which the pattern is captured in a CCD camera. The captured far-fields of the the two example 64-element phased arrays are shown in Fig. 2b, demonstrating that indeed arranging the elements according to Fermat's spiral leads to a reduction of the SLL: 6.9 dB for this configuration. In order to quantify the SLL reduction in terms of the number of elements, we defined arrays with element numbers ranging from 4 to 64 on the SLM. The measured SLL are shown in Fig. 2c, together with the SLL of the fabricated SOI-based antenna. As can be seen, experimental results are in good agreement with numerical calculations.

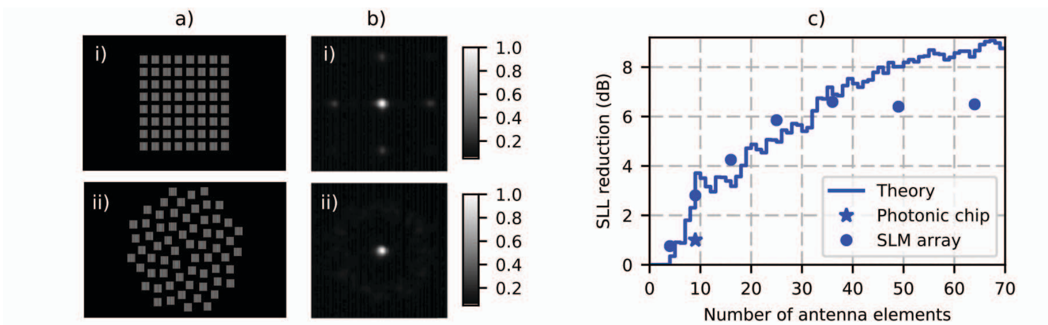

Fig. 2. (a) Phase masks for uniformly and non-uniformly distributed arrays; (b) captured far field measurements; and (c) SLL reduction in terms of the number of elements.

In summary, we have experimentally demonstrated that arranging the antenna elements according to Fermat's spiral, the SLL can be significantly reduced with respect to periodic arrays, revealing the proposed aperiodic configuration as a high-potential candidate for applications demanding power efficiency and security.

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