Supplemental Document

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Optimization of optical waveguide antennas for directive emission of light: supplement

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S1. Parametric Study of the Optimized Si Rectangular-Shaped Antenna

To check the robustness of the optimized Si antenna, we investigate the degree of influence of the design parameters on its directive characteristics.

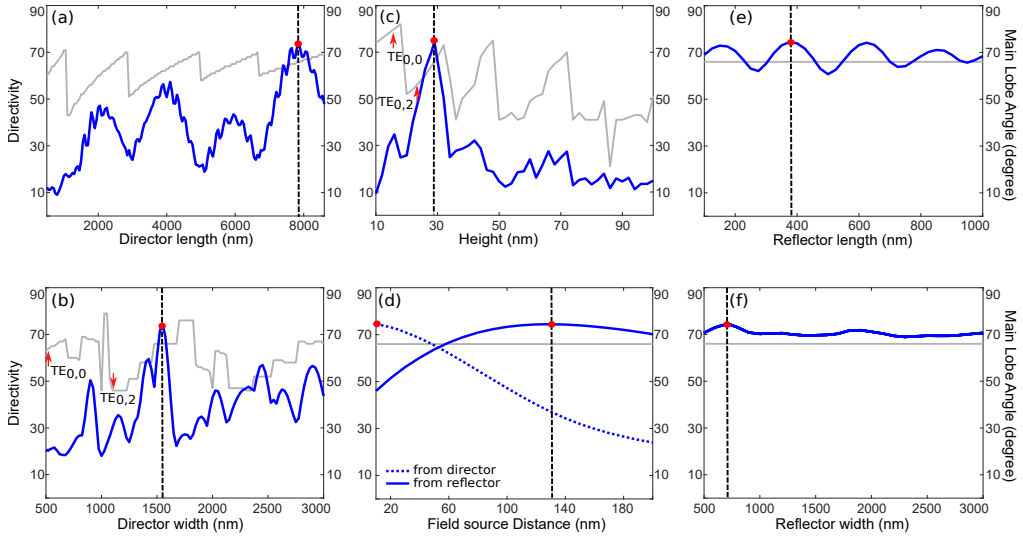

Fig. S1. Dependence of the directivity of the optimized Si antenna on its seven design parameters: (a) the director length, (b) director width, (c) antenna height, (d) distance of the field source from the director and the reflector, (e) reflector length, and (f) reflector width. The red point and dashed line on each plot represents the chosen optimal value of the corresponding parameter as shown in Fig. 3e, that results in the linear directivity of 74.8 (18.74 dB). The gray curve in each plot shows evolution of the main-lobe polar angle θ for the corresponding design parameter and the red arrows indicate the cut-off frequency of the relevant guided modes.

S2. Side-lobe Level Investigation

The horn-shaped antennas presented in this work have a higher side-lobe level in comparison to their rectangular counterparts. The study below shows how the side-lobe levels can be adjusted with respect to the geometrical parameters that define the horn-section of the director, i.e., the horn length and width.

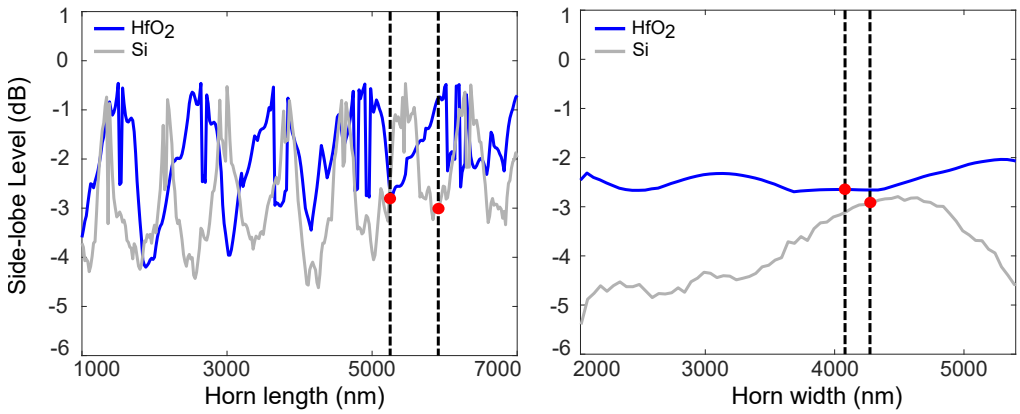

Fig. S2. Dependence of the side-lobe level of the optimized HfO_2 (blue curves) and Si (gray curves) horn-shaped antenna on its: (a) horn length and (b) horn width. The red point and dashed line on each plot represents the optimal value of the corresponding parameter as shown in Fig. 4b.

S3. Mode Analysis

To understand the resultant radiation patterns, we investigated which modes are excited by the dipole in the horn-shaped antennas.

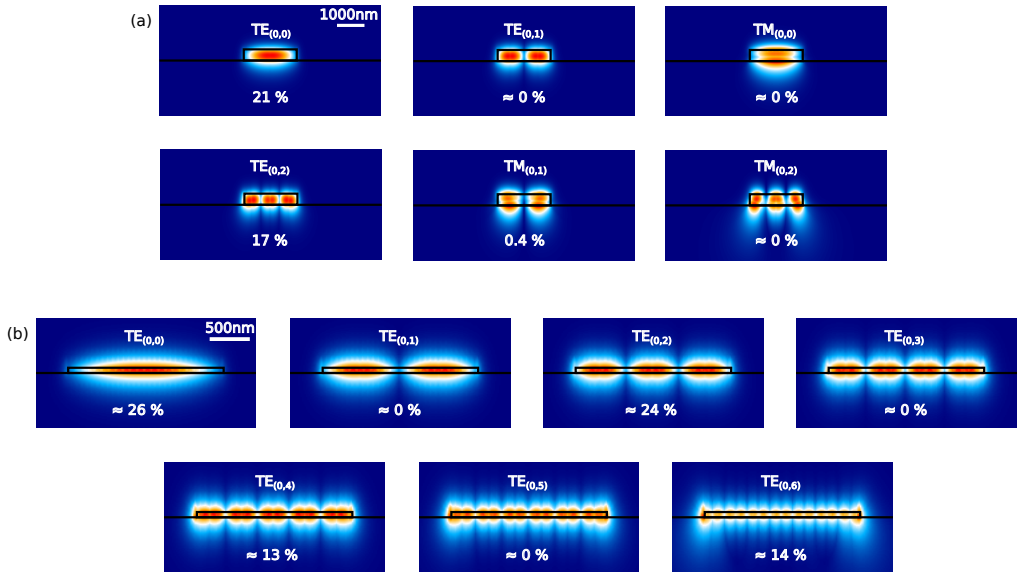

Fig. S3. The absolute electric field intensity distribution of the guided modes excited by dipole emitter in the rectangular section of the optimized (a) HfO_2 and (b) Si director of the horn-shaped antenna, together with the amount of power coupled to them.

S4. Parametric Study of the Optimized HfO_2 Horn-Shaped Antenna

Fig. S4 shows the degree of influence of the design parameters of the HfO_2 horn-shaped antenna on its directive characteristics.

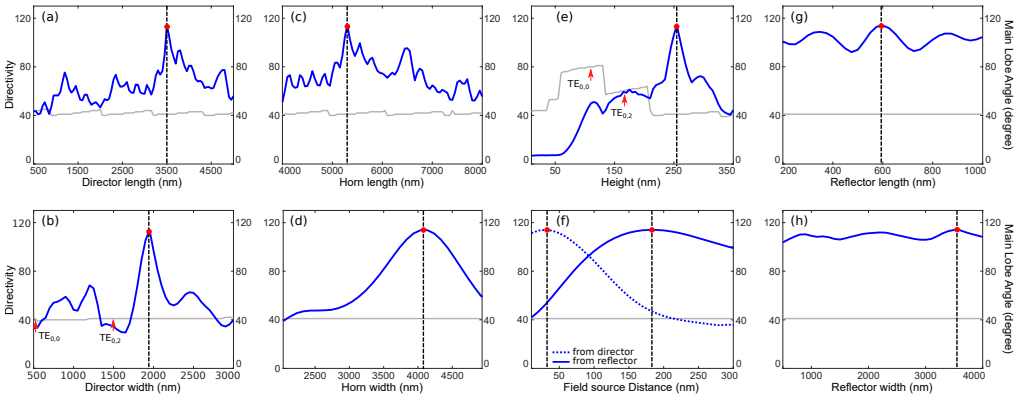

Fig. S4. Dependence of the directivity of the optimized HfO_2 horn-shaped antenna shown in Fig. 4a on its nine design parameters: (a) the director length, (b) director width, (c) horn length, (d) horn width, (e) antenna height, (f) distance of the field source from the director and the reflector, (g) reflector length, and (h) reflector width. The red point and dashed line on each plot represents the chosen optimal value of the corresponding parameter as shown in Fig. 4b, that results in the linear directivity of 114 (20.56 dB). The gray curve in each plot shows evolution of the main-lobe polar angle θ for the corresponding design parameter and the red arrows indicate the cut-off frequency of the relevant guided modes.

S5. Parametric Study of the Optimized Si Horn-Shaped Antenna

Fig. S5 shows the degree of influence of the design parameters of the Si horn-shaped antenna on its directive characteristics.

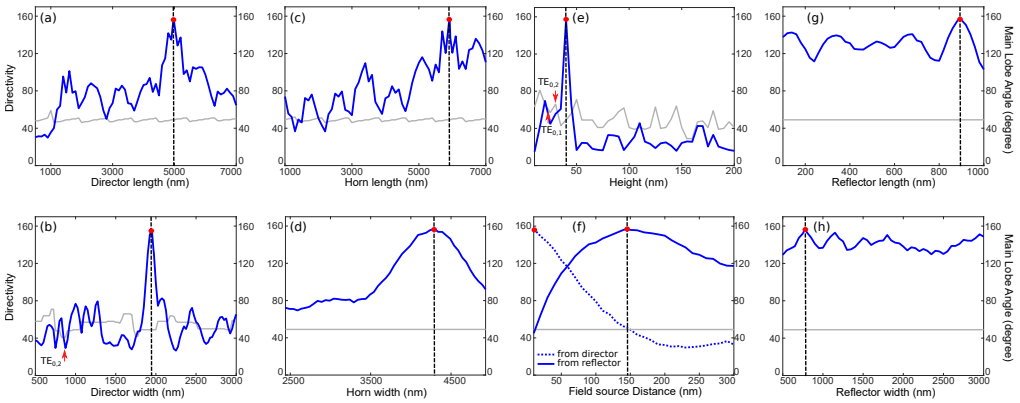

Fig. S5. Dependence of the directivity of the optimized Si horn-shaped antenna shown in Fig. 4a on its nine design parameters: (a) the director length, (b) director width, (c) horn length, (d) horn width, (e) antenna height, (f) distance of the field source from the director and the reflector, (g) reflector length, and (h) reflector width. The red point and dashed line on each plot represents the chosen optimal value of the corresponding parameter as shown in Fig. 4b, that results in the linear directivity of 157 (21.95 dB). The gray curve in each plot shows evolution of the main-lobe polar angle θ for the corresponding design parameter and the red arrows indicate the cut-off frequency of the relevant guided modes.