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Radiationless anapole states in on-chip photonics

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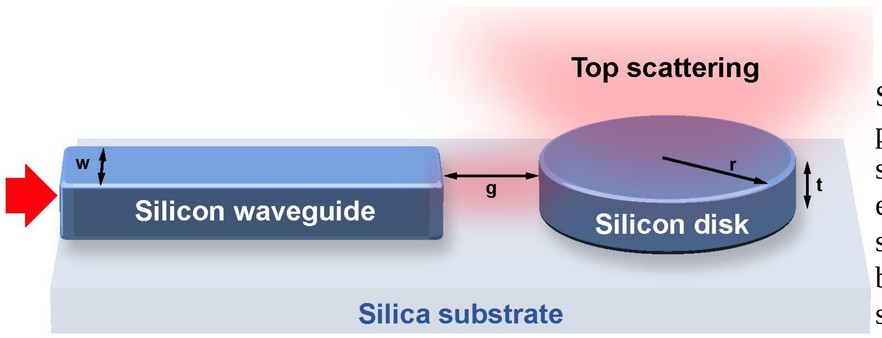
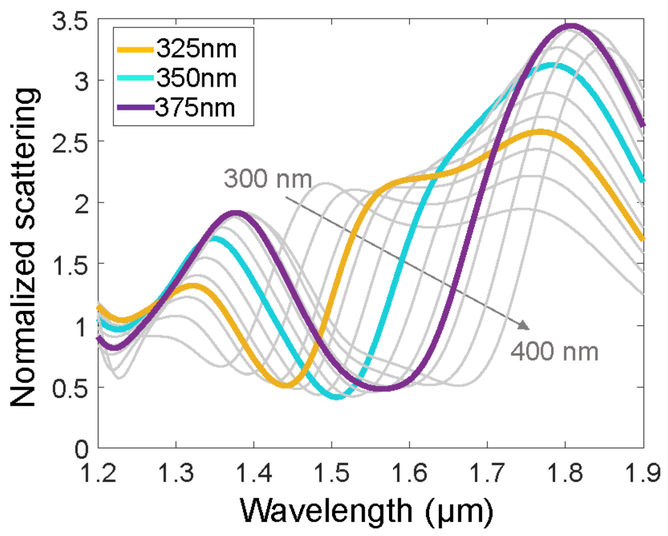
ABSTRACT

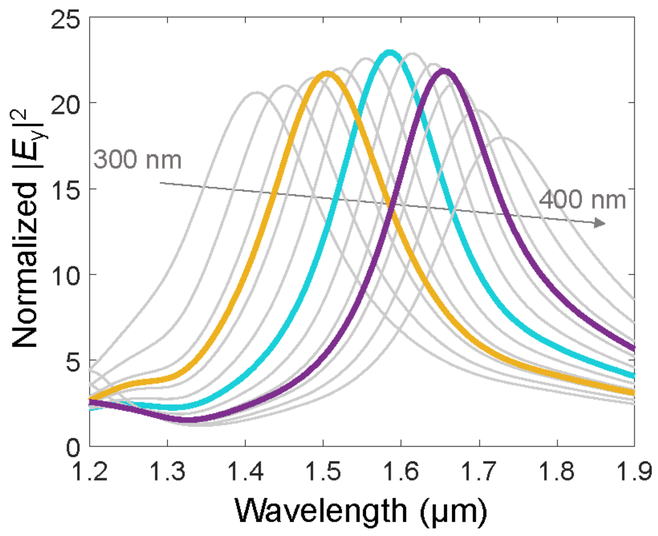
Interference between different radiative modes supported by high-index dielectric particles can eventually lead to scattering cancellation in the far-field, resulting in anapole resonances [1]. In this work, we report on the reduction of scattering produced by silicon nanodisks resulting from anapole resonances when excited on-chip using silicon waveguides at telecom wavelengths for use in photonic integrated circuits. We also show near-field measurements showing the typical dual vortex near-field pattern attributed to anapole states.

NUMERICAL SIMULATIONS

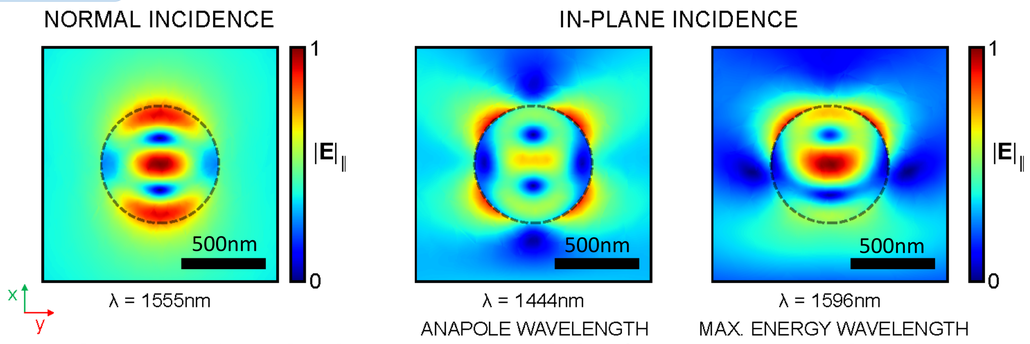


Structure considered to archieve in-plane excitation of the silicon disk: a silicon strip waveguide of width w ended abruptly by a flat termination and spaced by a gap g from the disk boundary, both situated on a silica substrate.

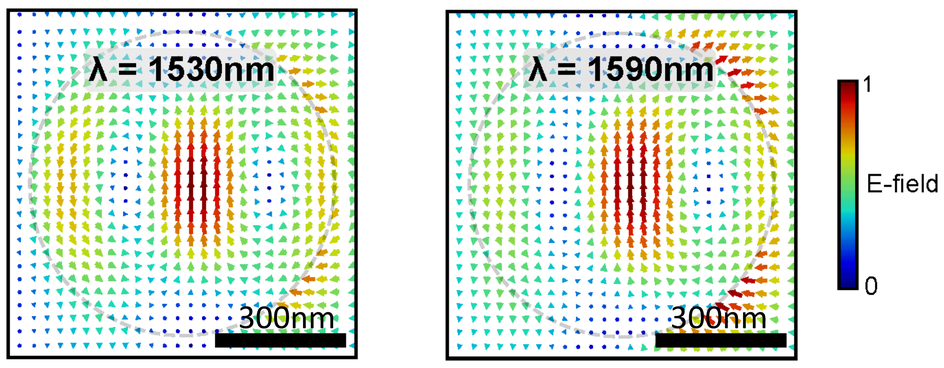




Normalized top scattering and the electric field intensity $|Ey|^2$ at the disk center for disk radius r varying between 300 and 400nm. Normalization is performed by comparing with the same case without the silicon disk.



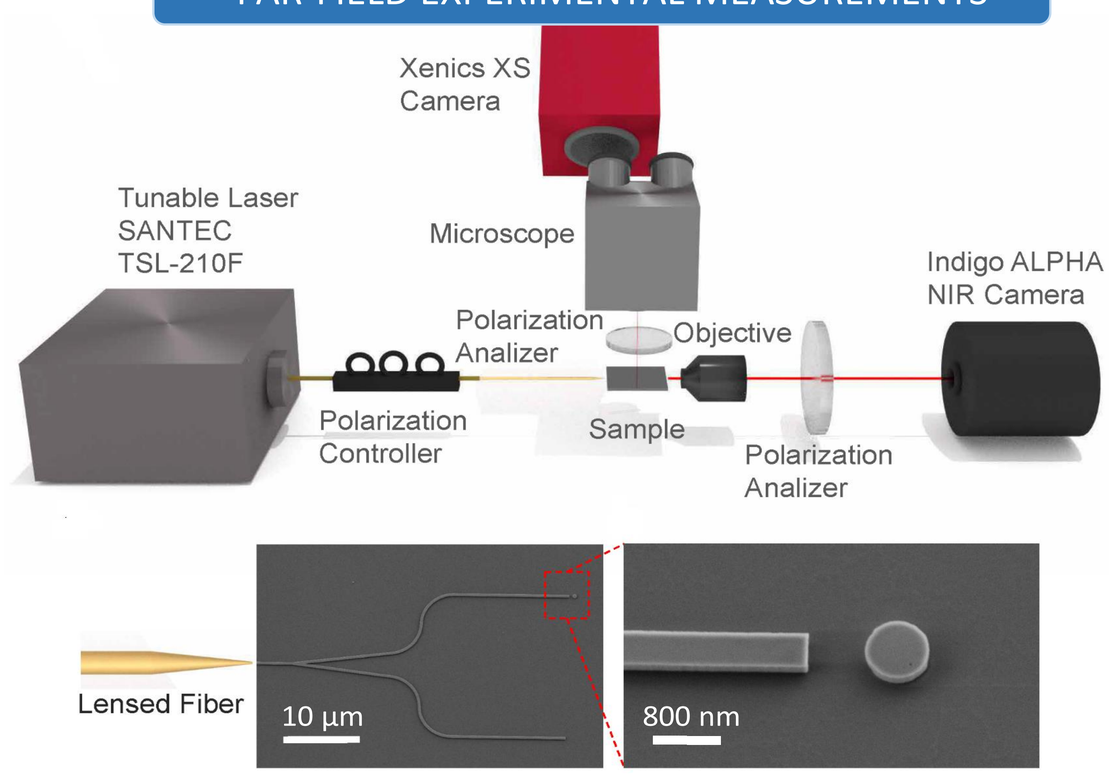
Electric field amplitude patterns in a disk of r = 350 nm at the relevant wavelengths for both normal and in-plane incidence. Disk surrounded by air



Electric field lines at the anapole and c maximum energy wavelengths under waveguide illumination for a r = 350 nm disk. Structure with substrate.

The similarity of the near field patterns with respect to the formation of three main lobes of the electric field confirms the ability of our approach to excite the anapole state.

FAR-FIELD EXPERIMENTAL MEASUREMENTS



Sketch of the experimental set-up and SEM picture of one of the fabricated circuits (nominal disk radius r = 350nm).

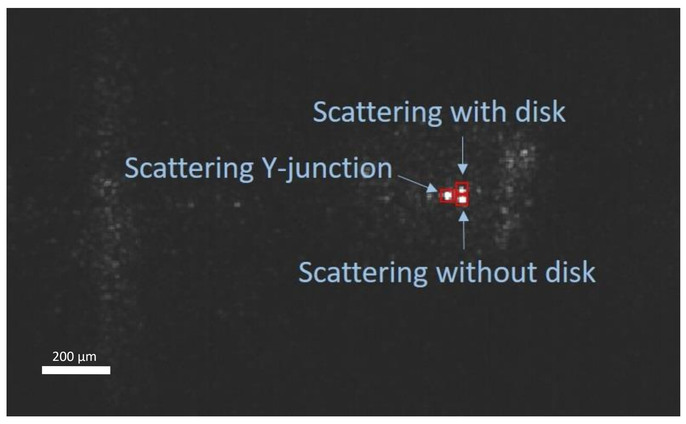
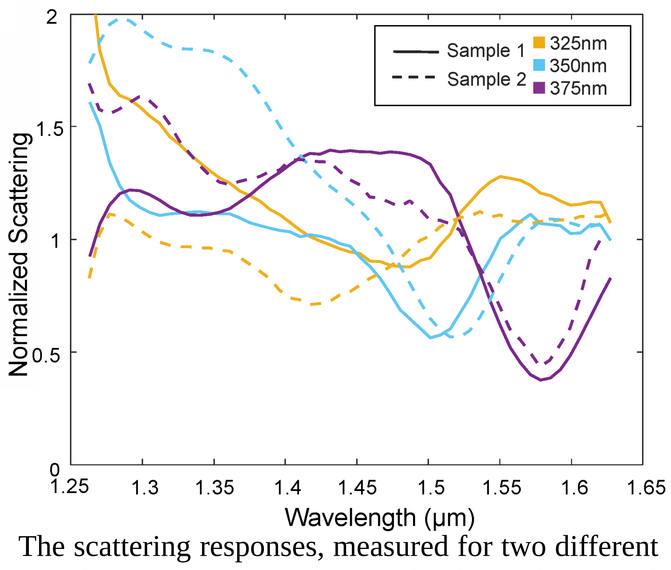
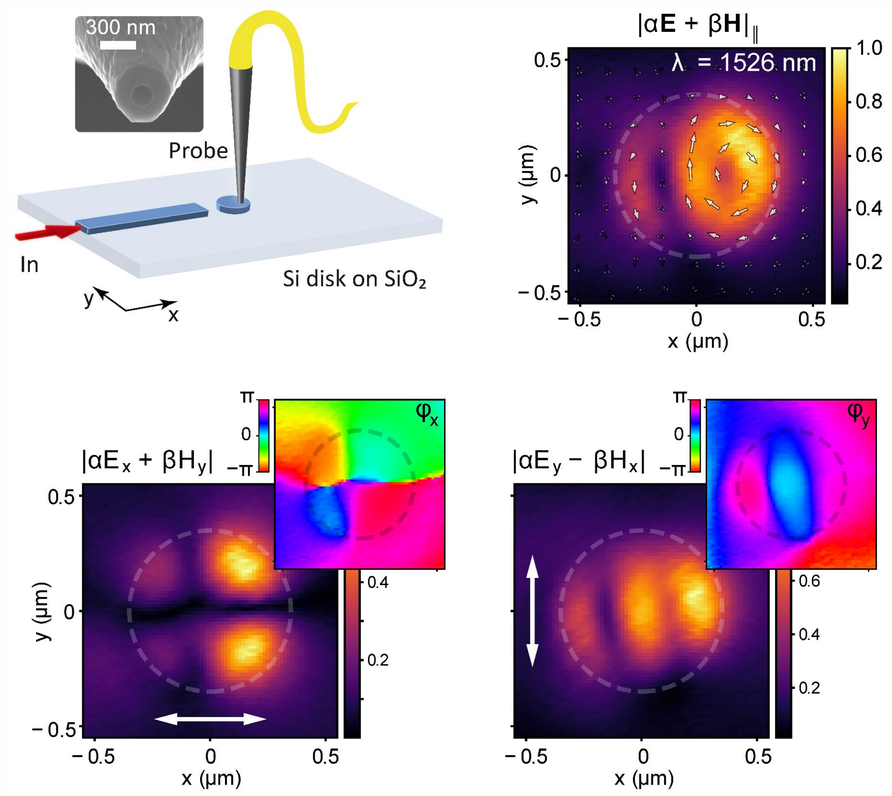


Image recorded with the infrared camera in the far-field measurements showing the spot corresponding to the Y-splitter, the waveguide termination with disk and the waveguide termination without disk.



The scattering responses, measured for two different samples containing circuits with identical nominal radii of the disks, are qualitatively similar to those obtained in the simulation. In particular, there is a region with reduced scattering that coincident with the predicted anapole condition.

NEAR-FIELD EXPERIMENTAL MEASUREMENTS



Phase- and polarization-resolved SNOM measurements. At wavelength around the expected anapole resonance, we observed the formation of three lobes in the transversal electric field component, a feature not observed at larger wavelengths, and a clear fingerprint of the anapole condition.

CONCLUSIONS

We have demonstrated that the anapole resonance of an isolated silicon disk can be efficiently excited using an in-plane silicon waveguide as illumination source. We observe a strong reduction of the top out-of-chip scattering from the silicon disks when the conditions for appearance of the anapole resonance are met. We confirmed the presence of an anapole mode by its near-field fingerprint of three lobes in the transversal electric field component. Our work can pave the way towards integration of silicon disks in complex photonic integrated circuitry for applications such as sensing or nonlinear photonics [2].

REFERENCES

[1] A. E. Miroshnichenko *et al.*, Nat. Commun. 6, 8069 (2015).

[2] E. Díaz-Escobar *et al.*, "Radiationless anapole states in on-chip photonics", submitted.

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