VORPAL Finds Unexpected High-Q Photonic Structures

Problem Description

In cavities used to accelerate charged particle beams, the interaction between the beam and one mode - the accelerating mode - is desirable, while interaction with higher order modes (HOMs) generally degrades the beam quality. Photonic crystal (PhC) cavities can confine modes that have frequencies within the band gap of the PhC without trapping waves at frequencies outside the band gap; consequently, a PhC cavity can be designed to have only a single mode, without any HOMs [1]. However, to confine a mode effectively, traditionally a PhC cavity must be surrounded by several lattice constants of the crystal structure. In order to reduce the amount of material used, the cost, and the device size, a more efficient photonic structure is required to trap the mode.

Solution

Researchers at the University of Colorado have used VORPAL to find new optimal irregular structures for PhC cavities leading to greatly reduced material requirements and device size. They used VORPAL to do an optimization study on the structure of a two-dimensional truncated PhC cavity with optimal *Q*-factor. By gradually moving the rods from the lattice positions they found one can increase the *Q*-factor by orders of magnitude, e.g., from 130 to 11 000 for a cavity constructed from 18 rods. Achieving the same *Q*-factor with a regular lattice requires 60 rods [2].

Why VORPAL?

VORPAL was chosen to model the PhC cavities due to its ability to simulate the full Maxwell equations with dielectrics and absorbing boundary conditions. VORPAL's Python integration facilitates parametric scans of complex geometries. The distributed parallel computing capabilities of VORPAL were also vital to complete the thousands of simulations necessary in order to fully optimize the dielectric rod positions.

“In addition to providing a fast and accurate electromagnetic solver for our underlying computations, VORPAL also interfaced well with Python, which was used to encapsulate the optimization process and define complex geometries,” says Carl Bauer of the University of Colorado. “VORPAL's extensibility also allowed us to test custom dielectric boundary algorithms without too much hassle.”

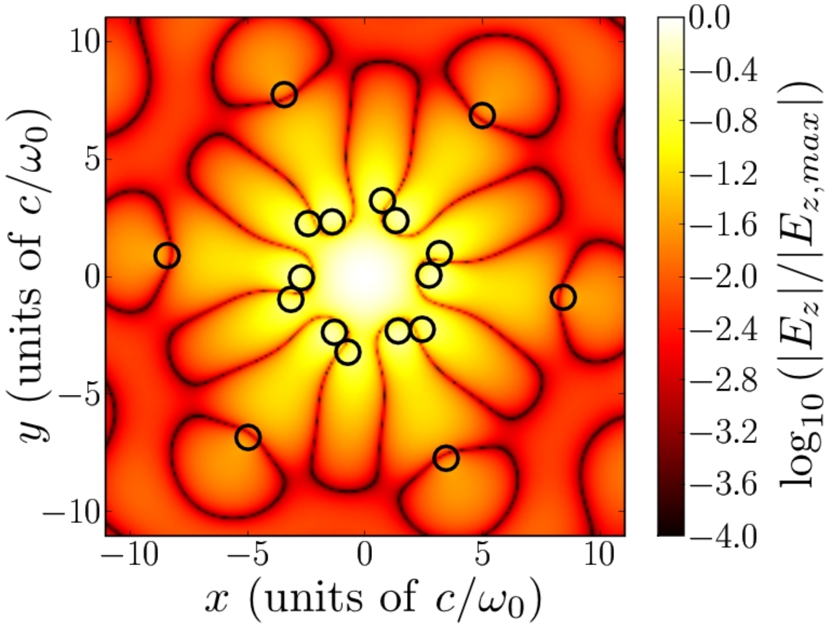

Figure 1: VORPAL results showing the normalized electric field of the confined mode in the optimized accelerating cavity. A similar VORPAL visualization is showcased by PRST-AB Kaleidoscope Images and the month of May for the 2010 APS calendar.

References

[1] Gregory R. Werner, Carl A. Bauer, John R. Cary, Wakefields in photonic crystal cavities, *Physical Review Special Topics – Accelerators and Beams, 12,* 071301 (2009) "Copyright (2009) by the American Physical Society."

[2] Carl A. Bauer, Gregory R. Werner, John R. Cary, Truncated photonic crystal cavities with optimized mode confinement, *Journal of Applied Physics, 104,* 053107 (2008)