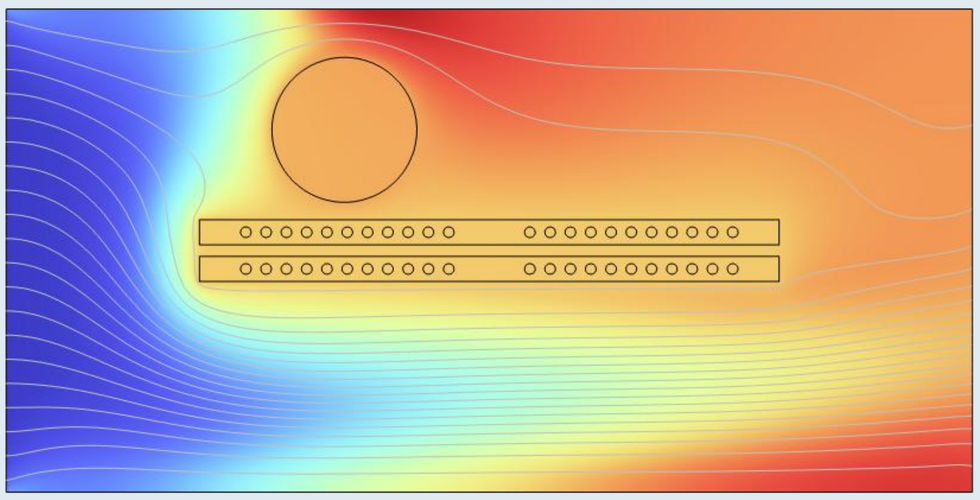


Simulation of Airflow-Induced Modulation of Thermo-Optic Characteristics in Coupled Silicon Photonic Crystal Cavities

Optical–Thermal–Fluid Multiphysics Coupling Analysis Based on COMSOL Multiphysics.

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Introduction & Goals

Silicon photonic crystal nanobeam cavities exhibit significant thermo-optic effects, where temperature variations shift cavity resonances through changes in the silicon refractive index. (ref. 1) Packaging airflow further affects local heat transfer. In this work, an optical–thermal–fluid model of coupled silicon photonic crystal nanobeam cavities is developed in COMSOL Multiphysics. By varying the inlet airflow velocity, local temperature, cavity-to-cavity temperature difference, and optical eigenmode responses are investigated to reveal airflow-induced thermo-optic modulation.

Methodology

The model consists of two silicon photonic crystal nanobeam cavities, an air domain, and a cylindrical obstacle. Electromagnetic Waves, Laminar Flow, and Heat Transfer are coupled following “cold-state eigenmode → steady flow/thermal field → hot-state eigenmode”. A temperature-dependent refractive index accounts for the thermo-optic effect, while inlet airflow velocity is varied to evaluate thermal and optical responses.

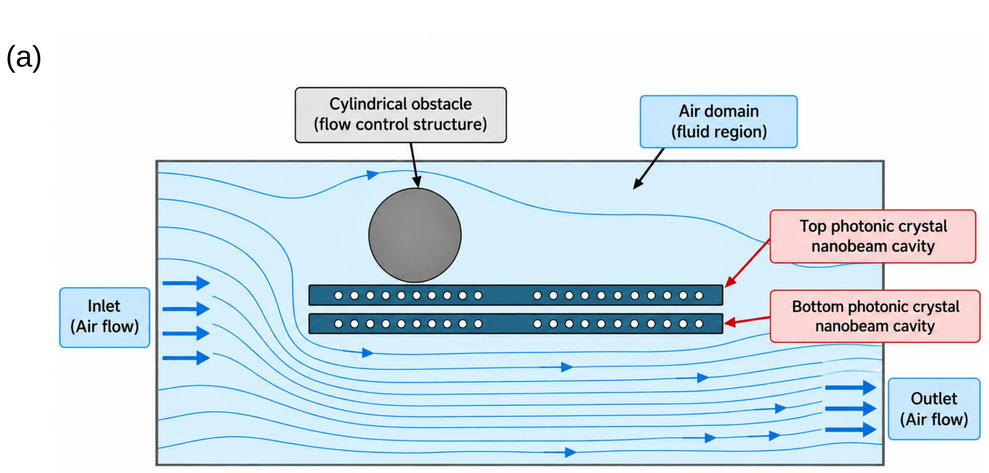


FIGURE 1. (a) Model geometry in COMSOL.

Results

FIGURE 2 shows the cold-state optical field, airflow velocity, and temperature distributions of the coupled photonic crystal cavities. The optical field is mainly localized around the two nanobeam cavities. With packaging airflow, the cylindrical obstacle redirects the streamlines and produces a high-velocity region below the cavities. The resulting convective heat transfer modifies the local temperature distribution and creates an asymmetric thermal gradient around the coupled cavities. These results demonstrate that packaging airflow can regulate the local thermal environment by modifying flow and heat transfer, providing the basis for further thermo-optic eigenmode analysis.

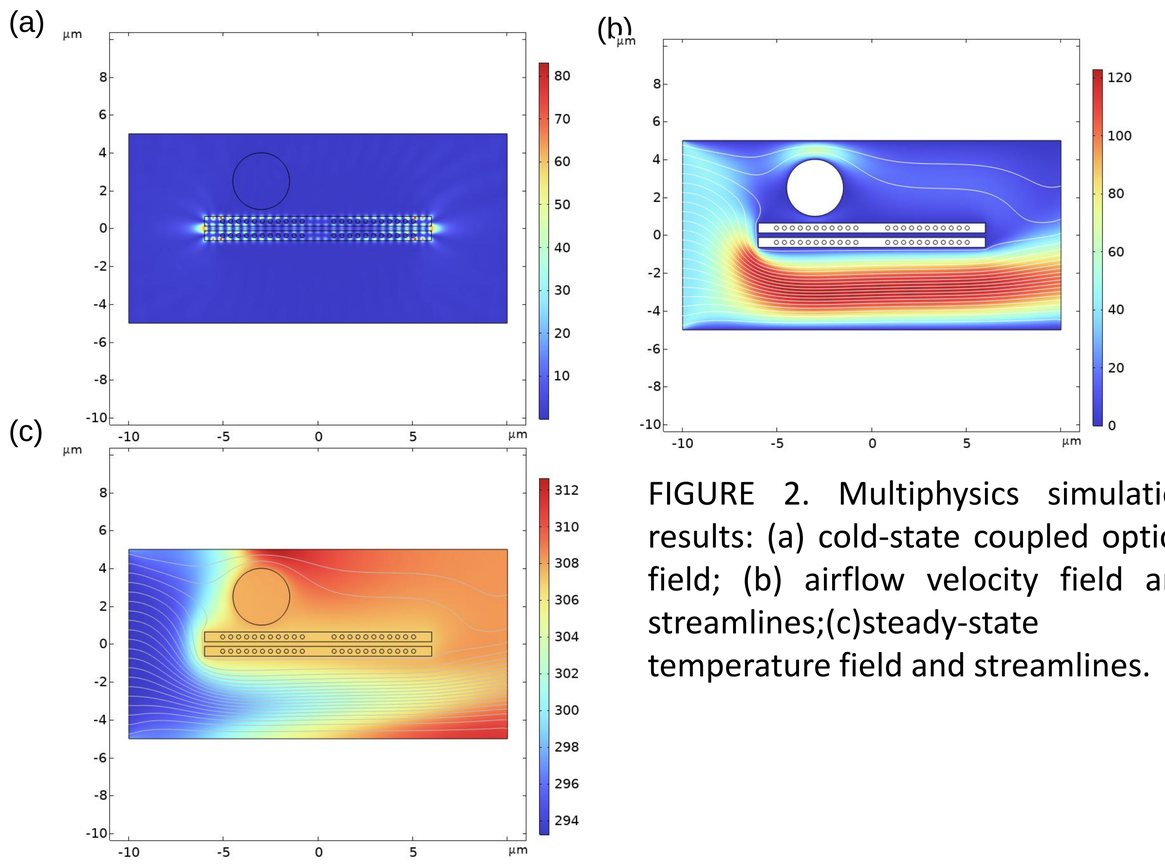


FIGURE 2. Multiphysics simulation results: (a) cold-state coupled optical field; (b) airflow velocity field and streamlines;(c)steady-state temperature field and streamlines.

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