Numerical Design and Optimization Strategies for Annular Silica Microcavities

Denis Gagnon, Guillaume Painchaud-April, Julien Poirier, and Louis J. Dubé
Francis Vanier*, Ahmad Hayat* and Yves-Alain Peter*

Département de physique, de génie physique et d'optique, Université Laval, Québec, G1V 0A6, Canada
**Département de génie physique, École Polytechnique de Montréal, Montréal, H3C 3A7, Canada*
Tel: +1 418 656 2658, Fax: +1 418 656 2040, e-mail: ljd@phy.ulaval.ca

High *Q*-factor erbium-doped silica WGM microcavites are ideal candidates for integrated directional lasers. However, WGMs typically display an isotropic directional emission profile and modifying this far-field profile without significantly spoiling the associated high *Q*-factor remains a challenge. To achieve this goal, we study silica annular microdisk cavities fabricated with conventional photolitographic methods followed by wet etching of silica and dry underetching of the silicon base. The inclusions are produced with Focused Ion Beam techniques. To acquire design rules and to harness the far-field characteristics of these integrated optics devices beforehand, we make use of two complementary numerical approaches. First, a generalization of the Boundary Element Method (BEM) to annular cavities (in general, holey cavities) allows for the solution of the 2D Helmholtz equation, obtaining the resonant modes, their far-field distribution and their *Q*-factor. Second, ray-escape simulations, especially for long-lived resonances, offer the classical counterpart to the BEM results. These simulations provide universal far-field intensity profiles and help identify the leading mechanisms of dynamical escape. The well separated regions (regular and chaotic) of mixed phase-space of the annular cavities are noteworthy in this respect. We will show a series of comparisons to demonstrate how the wave and classical approaches enrich and complete each other and, in doing so, we will extract useful design strategies for emission robustness and directionality.

Keywords: Microfabrication, annular cavities, directional emission, boundary element method, semi-classical methods, phase space