HCMT interaction of whispering gallery modes in circuits of integrated optical microring or -disk resonators

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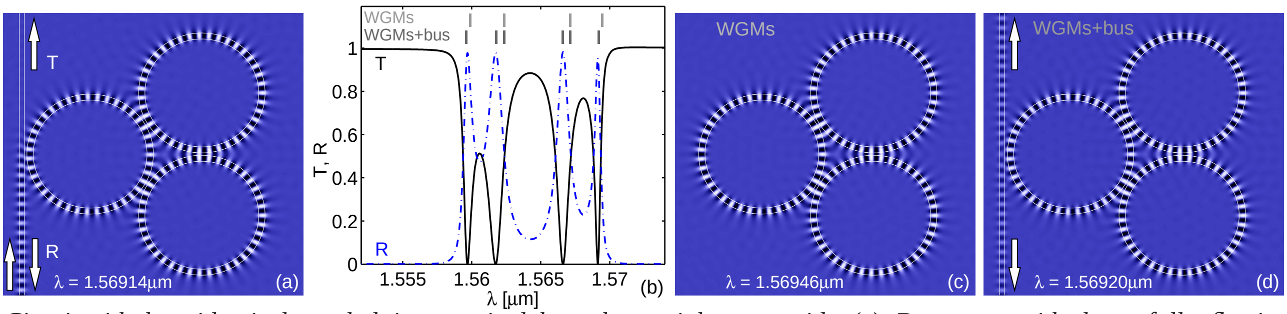
Whispering gallery modes (WGMs) supported by open circular dielectric cavities are embedded into a 2-D hybrid coupled mode theory (HCMT) framework. The model enables convenient studies of supermode formation in composite circuits (CROWS, photonic molecules), and of their excitation by straight access channels.

Summary

Whispering gallery modes (WGMs*) of dielectric disks or rings, prototypes for the eigenmodes of open optical cavities, are characterized by by their *complex* eigenfrequency, *integer* angular wavenumber, and, in 2-D, by a radial order. We introduce analytical WGMs into a framework of hybrid analytical / numerical coupled mode theory (HCMT, [1]). The model relies on a plausible "template" for the overall field. Known profiles, typically directional guided modes of optical channels, are superimposed with unknown influence functions. WGMs enter with single coefficients. Upon discretizing any unknown functions by 1-D finite elements, a Galerkin procedure, based on the first order Maxwell equations in the frequency domain, leads to a set of linear algebraic equations. For given input the response for the prescribed frequency is obtained. For a configuration without excitation, looking for nontrivial solutions establishes an eigenvalue problem for the "supermodes" (SMs) of the composite circuit. We benchmark this approach versus bend-mode (*real* frequency and *complex* angular wavenumber) HCMT [2], conventional CMT ([3], couplers only), and FDTD. The WGM-HCMT model permits easily interpretable studies of SM formation in quite arbitrary composite structures, of their perturbation, and of their excitation by straight access channels. Coupling induced shifts of resonance frequencies [4] or similar effects can be investigated conveniently and systematically.



Circuit with three identical coupled rings, excited through a straight waveguide. (a): Resonance with almost full reflection of the incoming wave. (b): Spectral transmission and reflection (WGM-HCMT model) around the WGM$_{(0,\pm 39)}$ *resonance at* $1.5637\ \mu$*m of a single ring (free spectral range* ≈ 35 *nm); vertical lines: SM resonance wavelengths, cavities only (top row), and cavities + bus. (c): "Fundamental" SM of the three-ring "molecule", HCMT model with 6 unknowns based on the directional WGMs of the individual rings. (d) Respective SM of the entire structure, here the HCMT template includes also the vertical modal outlets. 2D-TE simulations; time snapshots of the single electric field component; parameters: refractive indices* 1.5, 1.0*, ring radii* $7.5\ \mu$*m, core widths* $0.75\ \mu$*m (rings) and* $0.6\ \mu$*m (bus), gaps* $0.3\ \mu$*m.*

References

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* For lack of a better name, we apply the term WGM also to cavities with more than one circular interface.