Few-Mode Whispering-Gallery-Mode Resonators

Simple structures function similarly to single-mode optical fibers.

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Whispering-gallery-mode (WGM) optical resonators of a type now under development are designed to support few well-defined waveguide modes. In the simplest case, a resonator of this type would support one equatorial family of WGMs; in a more complex case, such a resonator would be made to support two, three, or some other specified finite number of modes. Such a resonator can be made of almost any transparent material commonly used in optics. The nature of the supported modes does not depend on which material is used, and the geometrical dispersion of this resonator is much smaller than that of a typical prior WGM resonator. Moreover, in principle, many such resonators could be fabricated as integral parts of a single chip.

Basically, a resonator of this type consists of a rod, made of a suitable transparent material, from which protrudes a thin circumferential belt of the same material. The belt is integral with the rest of the rod (see figure) and acts as a circumferential waveguide. If the depth ($d$) and width ($w$) of the belt are made appropriately small, then the belt acts as though it were the core of a single-mode optical fiber: the belt and its adjacent supporting rod material support a single, circumferentially propagating mode or family of modes.

It has been shown theoretically that the fiber-optic-like behavior of the belt-on-rod resonator structure can be summarized, in part, by the difference, $\Delta n$, between (1) an effective index of refraction of an imaginary fiber core and (2) the index of refraction ($n$) of the transparent rod/belt material. It has also been shown theoretically that for a given required value of $\Delta n$, the required depth of the belt can be estimated as $d = R\Delta n$, where $R$ is the radius of the rod. It must be emphasized that this estimated depth is independent of $n$ and, hence, is independent of the choice of rod material.

As in the cases of prior WGM resonators, input/output optical coupling involves utilization of evanescent fields. In the present case, there are two evanescent fields: one at the belt/air interface and one in the boundary region between the belt and the rest of the rod.

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