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1.1 Optical Microresonators

Optical microresonators have demonstrated great promise as fundamental building blocks for a variety of applications in photonics. They can be implemented for such diverse applications such as lasers, amplifiers, sensors, optical channel dropping filters (OCDs), optical add/drop (de)multiplexers (OADMs), switches, routers, logic gates, and artificial media. For brevity and in keeping with their current usage in the literature of this field, we specialize the term "microresonators" and generalize the term "microring resonators." We use these terms interchangeably in this book to refer to any of a number of compact geometries that support cyclically propagating modes that close on themselves in a ring-like geometry.

One particular embodiment of a microring resonator consists of an ordinary waveguide that channels light in a closed loop. But in general, the loop can take the form of other closed shapes, such as a disk, racetrack, or ellipse. In the case of a ring, the microresonator is simply a curved waveguide closed onto itself forming a resonant cavity that supports both transverse and longitudinal (here azimuthal) modes. The confinement and channeling of light in this closed geometry, however, does not require an inner dielectric boundary. This is evidenced by the existence of optical "whispering gallery" modes in a microdisk or microsphere resonator. Placement of a microresonator near one or two waveguides (Fig. 1.1) enables access to modes of the resonant cavity. In this particular arrangement, the resonant modes are accessed through evanescent coupling — a phenomena analogous to tunneling in solid-state physics. Component wavelengths of an optical signal channeled in a waveguide are resonant with the cavity if its (effective) circumference supports an integer number of wavelengths. For these spectral components of the signal, an increased circulation of intensity can build up in the resonator. The presence of a second waveguide coupled to the ring enables extraction of the resonant, circulating signal. Component wavelengths that do not resonate with the ring bypass it altogether. Thus, at their most fundamental level, microring resonators act as a spectral filter and a temporary compressor of energy density. These properties are not unique to microring resonators.