Applications of High-Q Optical Micro-resonators: Photonic Clocks, Cavity-QED and New Laser Sources on Silicon

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Abstract: *After a brief discussion of nonlinear optical sources (Raman and Parametric) based on microtoroid resonators, recent results which use radiation pressure in these devices either to: (1) create micro-wave-rate mechanical oscillations or (2) cool the mechanical degree of freedom to cryogenic temperatures are overviewed. The implication of these results for new science is discussed. Also, the recent application of toroids for cavity QED on-a-chip experiments is briefly described.*

Micro-toroid optical resonators on silicon [1] are finding a range of applications in basic science. Besides providing optical modes having Q factors as high as 500 million, these devices also exhibit high-Q mechanical modes. This added feature has provided access to a range of new opto-mechanical phenomena which are driven by radiation pressure. After describing the processing and passive optical properties of these devices, the consequences of resonant energy buildup in a microscale, ultra-high-Q system will be described. Beyond laser sources based on Raman and parametric oscillation [2], radiation pressure created by the high circulating power within the resonator couples the optical and mechanical degrees of freedom. Under appropriate conditions, this coupling leads to regenerative, mechanical-oscillation, up to microwave rates, which is driven solely by radiation pressure from a continuous-wave optical pump [3,4,5]. This phenomenon is a manifestation of a more general physical principle of dynamic back action [6], and has a counterpart in which cooling of the mechanical mode is possible [4,6]. Along with recent demonstrations in cantilevers [7,8], demonstration of radiation pressure cooling of a mechanical mode from room temperature to 11°K using a microtoroid resonator will be discussed [9]. Finally, the use of fiber-based couplers in these toroidal devices enables high coupling efficiencies [10]. This feature as well their high Q, low mode volume and wafer-based design make them interesting cavities for study of strong-coupling physics. We will describe the recent observation of strong coupling in collaboration with the Kimble group at Caltech [11].

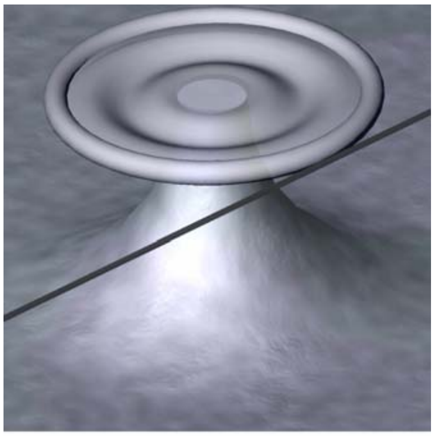

Figure: Rendering of a toroidal optical resonator exhibiting mechanical oscillation driven by radiation pressure. Black line is fiber taper waveguide used to couple the CW pump wave.

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