Nonlinear Optics in High-Q Micro-Resonators

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Like a tuning fork for light, optical resonators have a characteristic set of frequencies at which it is possible to confine light waves. At these frequencies, optical energy can be efficiently stored for lengths of time characterized by the resonator Q factor [1]. In the last ten years there has been remarkable progress in boosting this storage time in micro and millimeter-scale optical resonators. Chip-based devices have attained Q factors of nearly 1 billion [2] and micro-machined crystalline devices have provided Qs exceeding 100 billion [3]. The resulting long, energy-storage times combined with small form factors have made it possible to access a wide range of nonlinear phenomena and to create laser devices that operate with remarkably low turn-on powers. Also, new science has resulted from radiation-pressure coupling of optical and mechanical degrees-of-freedom in the resonators themselves. I will review some of these results including parametric oscillators [4], optical frequency microcombs [5] and opto-mechanical cooling and amplification [6]. The adaptation of resonator fabrication methods to optical delay lines as long as 27 meters on a silicon wafer will also be discussed [7].

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