Resonantly Enhanced Interaction of Light and Microwaves via Whispering Gallery Modes

A. B. Matsko, V. S. Ilchenko, A. A. Savchenkov, and L. Maleki

Jet Propulsion Laboratory, California Institute of Technology,

4800 Oak Grove Drive, Pasadena, California 91109-8099

Abstract

We propose a scheme of a resonant cw microwave-optical parametric oscillator based on high-Q whispering gallery modes excited in a nonlinear dielectric cavity. Such an oscillator has an extremely low threshold and stable operation, and may be used in spectroscopy and metrology.

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We report experimental observation of efficient all-resonant three-wave mixing using high-Q whispering gallery modes excited in a millimeter size spheroid cavity fabricated from $LiNbO_3$. We implement low noise resonant electro-optic modulator in the mm-wave frequency range based on this wave interaction. We observe modulation of light in broad power range for coherent microwave pumping within 50 mW power range. Used as a receiver the modulator allows us to detect nW microwave radiation.

Using results of our experiments we propose a new configuration of a solid state monolithic optical parametric oscillator (OPO) which converts light into light and microwaves. To achieve low threshold and high performance of the nonlinear interaction we consider all-resonant system.

We show that the threshold of oscillations is as low as μW of light pump power for realistic parameters. The stability of the signal is better that of the pump due to high quality factor of the whispering gallery modes. Therefore, this OPO configuration not only gives a promise for use as a new configuration of optical microwave modulator, but also for use as a light source for optical frequency measurement and high precision spectroscopy.

We assume that pump laser radiation is sent into z-cut $LiNbO_3$ spheroid optical cavity via coupling diamond prism. Oblate spheroid cavity shape is essential to obtain a large free spectral range [1]. The optical cavity is placed between two plates of microwave resonator. The resonant frequency of the microwave field can be adjusted to fit the frequency difference between optical modes by change of the resonator shape.

Due to $\chi^{(2)}$ nonlinearity of $LiNbO_3$ the modes of the microwave resonator and optical cavity are effectively coupled. This coupling increase significantly for resonant tuning of the fields due to high quality factors of the modes of optical cavity and microwave resonator, and small mode volumes [3].

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