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Sum Frequency and Second Harmonic Generations in Lithium Niobate Microdisk Resonators on a Chip

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Abstract: We report both sum frequency and second harmonic generations in on-chip lithium niobate microdisk resonators under the pump of two individual lasers. The conversion efficiency of sum frequency generation was measured to be 8.3×10^{-9} mW^{-1}, which are on the same order of the accompanied second harmonics. The dependence of upconversion signals on the wavelength of one pump laser was investigated.

1. Introduction
Lithium niobate whispering gallery mode (WGM) microresonators are a good platform for nonlinear frequency conversion due to outstanding nonlinear optical properties of lithium niobate crystal and the enhanced light-material interactions in the microresonators. Various nonlinear optical effects were observed in millimeter sized lithium niobate WGM resonators with quality factors of the order of 10^7. Recently, on-chip lithium niobate microdisk resonators with quality factors higher than one million was fabricated from lithium niobate on insulator film [1]. Second harmonic generation (SHG) [2-4] was reported in such on-chip microdisk by several groups. Here we report the first observation of sum frequency generation (SFG) accompanied by SHGs in lithium niobate microdisk resonators on a chip.

2. Experimental setup for nonlinear optical effects investigation
Light from two individual lasers in 1550 nm band functioning as pumps were launched into a lithium niobate disk with quality factor of the order of 10^5 by using a tapered fiber. The tapered fiber was also used to collect SFG and SHG signals. These signals were then analyzed utilizing a spectrometer. The wavelength and output power of each pump laser can be tuned separately. Therefore, the dependence of the nonlinear signals on experimental parameters was studied systematically.

3. SFG and SHG in lithium niobate microdisks
We first sent two pump lasers into the lithium niobate microdisk simultaneously. By adjusting the wavelength of the two pumps, we observed sum frequency generation signal from the grating spectrometer. We also observed second harmonic generation signals of two two pumps when both of the input wavelengths and the signal wavelengths matched the resonances of the cavity. Sum frequency generation together with the second harmonic generation signals are shown in different colors in Fig.1. The conversion efficiency of the SFG signal was measured to be 8.3×10^{-9} mW^{-1}.

We also investigated the variation of the intensities of the SFG and SHG signals with respect to the frequency detuning of one pump laser about the resonance of the lithium niobate microdisk. The wavelength of the other laser was fixed during the measurement. The measured results are shown in Figs. 1(b-d). It is seen from those figures that the SFG and SHG of the laser whose wavelength was tuned reach their maximums twice when the pump wavelength passed through two nearby resonances of the lithium niobate resonator. On the contrast, the SHG of the laser with fixed wavelength obtained minimum signal intensities due to energy consumption of the SFG process.

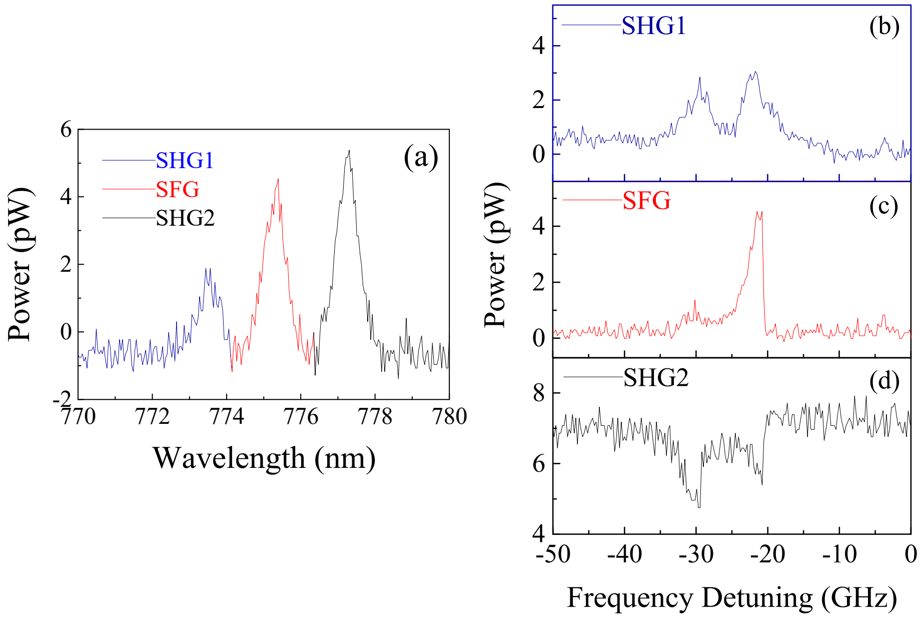

Fig. 1. (a) Spectra of nonlinear optical signals. SFG (red line) and SHG (blue and black lines) signals obtained when the wavelengths of the two pump laser were set to be 1546.9 nm and 1554.6 nm, respectively. (b-d) Dependences of nonlinear optical signal intensities on the wavelength of one pump laser measured when the wavelength of the other laser was fixed.

4. Conclusions

In conclusion, SFG signal together with SHGs were observed and studied systematically in lithium niobate microdisk resonators on a chip. The SFG process in on-chip lithium niobate WGM resonators may be used in applications ranging from infrared single photon detection to sum-frequency vibrational spectroscopy.

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