P2-19 Twin Photon Beams from a Free-Running cw Semimonolithic Optical Parametric Oscillator

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1. Introduction

Optical parametric oscillators (OPO's) are undoubtedly useful devices which produce coherent tunable radiation, and numerous experiments have been conducted by many workers since 1960's. Besides this coherent tunable characteristics, OPO's have been become interesting devices in quantum optics since 1980's. The parametric interaction in OPO's creates a strong quantum correlation between the signal and idler photons, and this results in producing different nonclassical states of light [1], such as squeezed light and twin photon beams. Such nonclassical states of light have potential to overcome the standard quantum limit (SQL) in the field of optical communications and precise optical measurements. Generation of nonclassical light from OPO's has been demonstrated in cw region by several groups [2][3][4][5], with skillful feedback servo control schemes to stabilize the OPO's.

In the case of twin photon beams, one observes the intensity difference between the signal and idler photon beams. Noise on the intensity difference is reduced with respect to the SQL, since the intensity fluctuations between the twin photon beams are highly correlated. Phase between the twin photon beams is irrelevant to the observation of this intensity difference squeezing, or rather phase-free. This suggests that even a free-running OPO's, the cavity length of which is not feedback controlled, can produce twin photon beams. Here we preliminarily demonstrate generation of the twin photon beams by using a semimonolithic KTP OPO, in the free-running condition.

2. Experimental Setup

The experimental setup is displayed in Fig. 1.

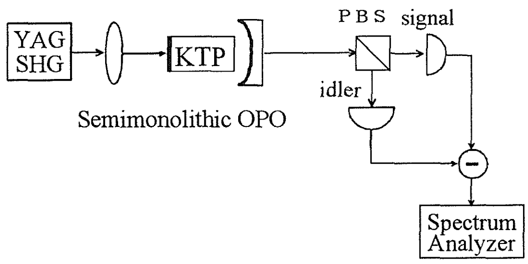

Fig. 1 Experimental setup

We have developed a semimonolithic optical parametric oscillator consisting of a KTP (TYPE II) crystal with a reflecting coating on one side and an antireflection coating on the other. The reflecting coating mirror and a spherical output mirror constitute the optical cavity of about 2-cm length, which is mounted inside a rigid stable mount. This optical cavity is resonant at both wavelengths of 0.532 μm and 1.064 μm. It is pumped at a wavelength of 0.532 μm by a diode-pumped monolithic, cw, frequency-doubled, YAG laser and generates the signal and idler beams at the wavelength close to 1.064 μm, which can be adjusted by temperature tuning. The optical cavity resonates with the pump, the signal, and the idler simultaneously, what is called a triply resonant OPO.

The signal and idler beams, which have orthogonal polarizations, are separated by a polarizing beam splitter, and directed onto InGaAs photodiodes. The photocurrents are amplified by carefully balanced, low-noise amplifiers. Noise power spectrum of the subtracted photocurrent is monitored by a spectrum analyzer. The shot-noise level is confirmed by injecting a laser beam at the wavelength of 1.064 μm onto another port of the polarizing beam splitter.

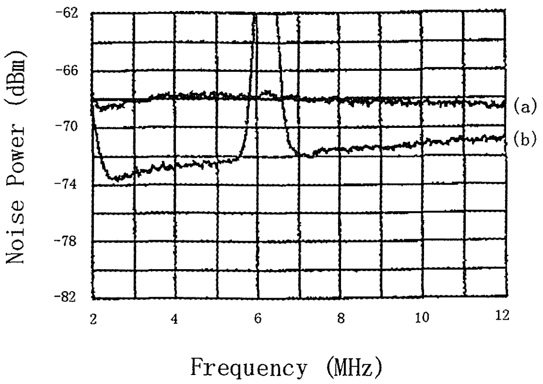

Fig. 2 Noise power spectrum of (a) the shot-noise level and (b) the intensity difference between twin photon beams.

3. Experimental Results

The oscillation threshold of this OPO is about 6 mW at exact triple resonance. This low value is obtained by the high efficiency of triply resonant parametric coupling. Total output power is 30 mW when the pump power is 160 mW, that is, the conversion efficiency is 19 %. Optical bistability is observed in this OPO [6], and stable cw output is obtained even in the free-running condition. The oscillation continued over 40 minutes, and the output power gradually decreased with frequency drift of the pump laser.

The temperature of the KTP crystal is tuned to obtain degenerate condition, since the intensities of signal and idler beams are different in nondegenerate condition, due to the difference of crystal losses between the signal and the idler wavelengths. The imbalance of their intensities degrades squeezing of the intensity difference.

Figure 2 shows noise power spectrum observed on the spectrum analyzer. Curve (a) shows the shot-noise level of total intensity of the twin photon beams, and curve (b) shows noise power spectrum of the intensity difference of the twin photon beams. Significant squeezing is observed in spite of the free-running condition. The maximum noise reduction is 5.4 dB (71 %) below the shot-noise level, at a noise frequency of 2.8 MHz. We observed noise reduction below the shot-noise level upto about 50 MHz. Peaking around 6.2 MHz is unexpected modulation originated in the pump laser.

4. Summary

We have generated highly quantum-correlated twin photon beams by using a cw semimonolithic KTP OPO in the free-running condition. The maximum noise reduction observed in this experiment is ~71 % below the shot-noise level. Considering the total detection efficiency, the inferred squeezing between the twin photon beams is 90 %. According to the theoretical calculation in conditions close to the experimental situation, squeezing of 90 % is expected. This calculation is in agreement with the experimental result. An improved experiment is now in progress, and the quantum-correlated twin photon beams will be useful for sub-shot-noise optical measurements and sub-shot-noise optical telecommunications.

Acknowledgments

The author wishes to thank C. Fabre, T. Coudreau and J. Gao for helpful discussions.

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