The Sensitive Infrared Signal Detection by Sum Frequency Generation

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Abstract

An up-conversion device that converts 2.05-μm light to 700 nm signal by sum frequency generation using a periodically poled lithium niobate crystal is demonstrated. The achieved 92% up-conversion efficiency paves the path to detect extremely weak 2.05-μm signal with well established silicon avalanche photodiode detector for sensitive lidar applications.

Introduction

The near-infrared and mid-infrared wavelengths offer intrinsic advantages in remote sensing and lidar operations. The overtone and fundamental rovibrational spectrum of gas molecules are in this region, offering the opportunity to optically measure the concentration of these trace gases. Unfortunately, sensitive infrared photodetectors in this region are limited. Currently, the detector for the 2.05-μm signal is InGaAs PIN detector with extended wavelength capability that has no signal gain and limited NEP. In contrast, silicon avalanche photodiode detectors and single photon counting modules can operate at room temperature with much better detection efficiency and lower dark current in the visible region [1]. Our approach is to use high efficient frequency up-conversion device to convert the infrared light at 2.05-μm to visible/near-infrared signal at 700nm, and then to detect the 700nm signal by Si APDs. Thus, the weak 2.05-μm signal can be detected by well established high performance Si APD detectors.

Experiment

The schematic of the experimental setup for intra-cavity up-conversion is shown in Figure 1. One periodically poled 5 mol% MgO-doped congruent lithium niobate (PPLN) with 16.14 μm grating space was used in this study. The 50 mm long PPLN crystal is located inside a Teflon oven, which is mounted on top of a multi-axis stage. A CW 808 nm diode laser is used to pump a Nd:YAG rod inside the cavity to generate the 1064 nm beam. The leakage of 1064 nm light through M2 was used to monitor the circulating intra-cavity pump power. The 150 mm radius-of curvature mirrors M3 and M4 serve as the input (output) for the probe (signal) laser. A two-micron DFB laser was also aligned through the PPLN and the power was measured at the back of the M4 mirror. A CaF_2 dispersion prism and a laser line filter were used to separate the 700 nm and block the other wavelengths for accurate measurement.

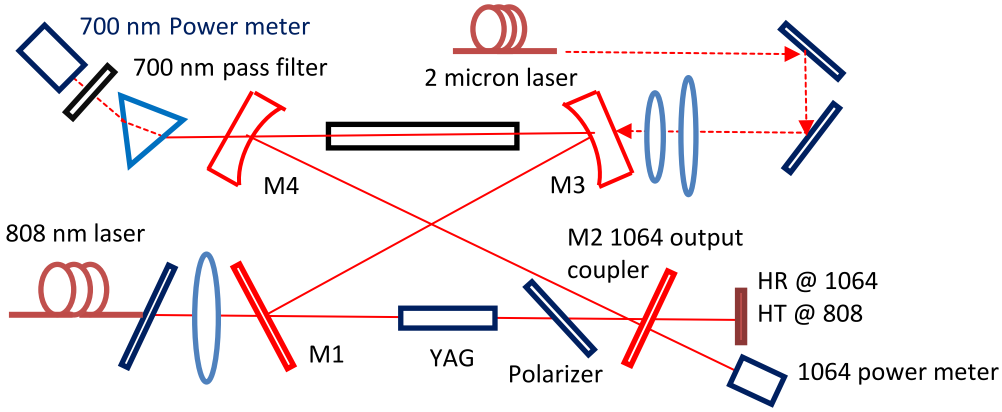

Figure 1. Schematic of up-conversion experimental setup

Result and conclusion

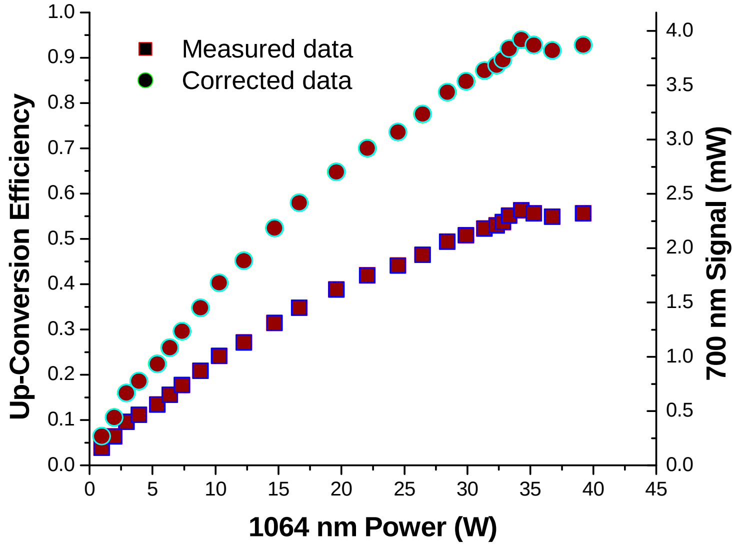

Figure 2. Pump laser power dependence and up-conversion efficiency

The temperature dependence and laser power dependence were carried out in this study. Figure 2 shows the results of pump power dependance and the up-conversion efficiency for 2-micron signal. The solid squares on the graph are the overall system detection efficiency, and solid circles are the data after correcting the system transmittance at 700nm. The corrected up-conversion efficiency reached 92% when the pump laser power is over 34 W.

In conclusion, we have demonstrated up-conversion detection of a 2-µm signal by sum frequency generation to generate 700 nm light using a periodically poled lithium niobate crystal. It is the first time such a technology has been developed for sensitive detection of 2-µm wavelength signal using Si-APD detectors in our knowledge. High conversion efficiency η = 92% was achieved and might still be limited by propagation losses of the optics and non-precise temperature controlling of the PPLN. Up-conversion detection is a promising technique to extend the use of well-developed silicon detectors for infrared signal remote sensing applications [2]. The linear dependence of probe power ensures the capability of single 2-micron photon detection.

References

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