Performance Evaluation of a Mid-infrared Spectrometer for Remote Sensing Applications

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We report on the development of performance evaluation technologies for mid-infrared (mid-IR) spectrometers. The mid-IR continuous-wave (cw) optical parametric oscillators (OPOs) based on a fan-out grating Mgo:PPLN pumped at 1064 nm and laser diodes were used for wavelength-calibration of mid-IR spectrometer. We used these light sources to evaluate the wavelength resolution, accuracy and optical signal-to-noise ratio (OSNR) of the mid-IR spectrometer.

INTRODUCTION

In recent days, various remote sensing applications such as biomedical sensing, gas sensing, missile tracking, lunar exploration and earth observation have been actively investigated in the mid-IR region [1]. Therefore, it is increasingly important to have accurate mid-IR spectrometer to ensure the meaningful results of such applications.

In this paper, we present the development of performance evaluation technologies for mid-IR spectrometers using cw OPO and laser diodes. The cw OPO is based on the fan-out PPLN crystal pumped at 1064 nm. By changing the poling period of the crystal, we can achieve wavelength-tunable radiation from 2500 nm to 3600 nm. The three laser diodes used in our experiment have 2000 nm and 3800nm, 4000 nm, respectively. By using these wavelength-tunable light sources, we evaluated performance of mid-IR spectrometer from 2000 nm to 4000 nm.

EXPERIMENTAL SETUP

Figure 1 shows the example of the experimental setup for calibration of mid-IR spectrometer. The main light source for the spectrometer calibration were single cw OPO and three diode lasers. To obtain stable mid-IR OPO operating in a single mode, we used modified Pound-Drever-Hall technique [2]. The detailed interpretation of the cw OPO performance is introduced in Ref. [3] (not shown in this paper).

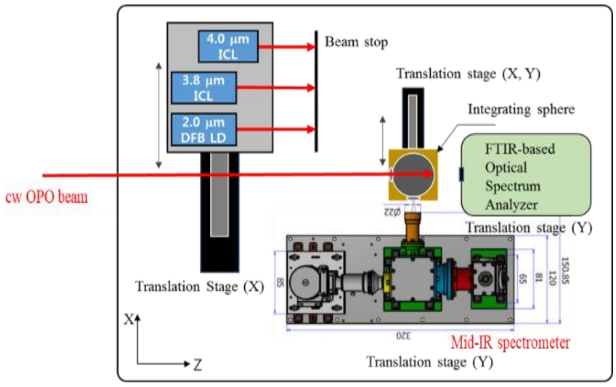

Figure 1. Example of experimental setup.

In general, a mid-IR spectrometer can capture surface images of objects, such as a camera with spectral functions. The experimental setup for calibration of mid-IR spectrometer is equipped with a gold-coated integrating sphere to implement the luminance measurement conditions. The mid-IR spectrometer can measure the lambertian light source from the output port of integrating sphere. Laser output from the cw OPO can be delivered in free-space, and the integrating sphere can be mounted on a two-axis automatic linear stage to align the output port of the integrating sphere to the mid-IR spectrometer. The used distributed feedback (DFB) laser diode (LD) and DFB interband cascade laser (ICL) have a center-wavelengths of 2 um and 3.8 um, 4.0 um, respectively. According to the types of the spectrometers, the light sources can be delivered with optical fibre or free-space.

EXPERIMENTAL RESULTS

Now, we present experimental results for the performance evaluation of the mid-IR spectrometer. In our experiment, we evaluated two kinds of spectrometers such as a Fourier transform infrared (FTIR)-based spectrometer (OSA205, THORLABS)

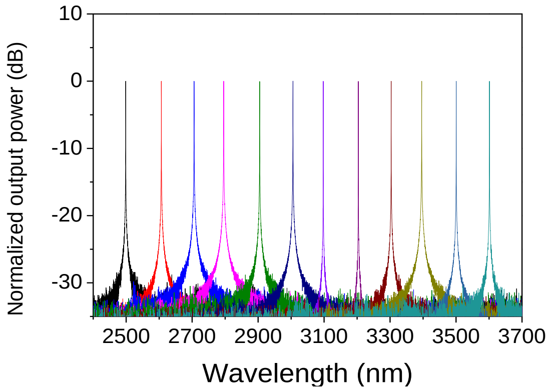

Figure 2. Wavelength spectra of cw OPO.

and a diffraction grating based spectrometer (AQ6376, YOKOGAWA). The combined wavelength spectra of cw OPO recorded by FTIR-based spectrometer is shown in Fig. 2. The poling period of the PPLN crystal moves between 28 um and 32 um, the wavelength of the cw OPO output can be tuned from 2500 nm to 3600 nm. Each OPO spectrum was measured in step of 100 nm. From the results, we can clearly confirmed the single mode operation of cw OPO in a wide wavelength tuning range wider than 1 μm. This ensures that the OPO was enough stable to evaluate performance of mid-IR spectrometer.

Fig. 3 shows the laser wavelength of signal and idler of the cw OPO measured using a diffraction grating based spectrometer and FTIR-based spectrometer, respectively. The wavelength of signal measured using the diffraction grating based spectrometer was 1647.7 nm, and the wavelength of idler measured using the FTIR-based spectrometer was 3004.1 nm.

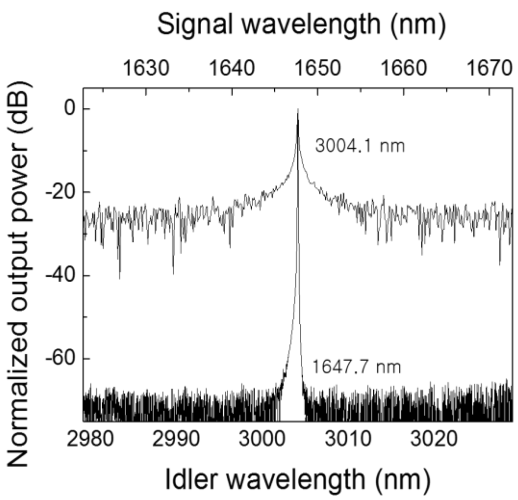

Figure 3. Laser wavelength of signal and idler

The optical signal-to-noise ratio (OSNR) of the FT based spectrometer is about 30 dB at 0.1 nm resolution, and the OSNR measured by the diffraction grating based spectrometer is about 75 dB. Since signal and idler are twin-photons generated from one pump photon and theoretically follow the same physical generating mechanism, we assumed that idler also has OSNR of at least 75 dB. Finally, we conclude that the FTIR-based spectrometer cannot measure the background noise of a signal with OSNR greater than 30 dB.

SUMMARY

Here, we reported on the experimental setup that can evaluate the characteristics of the mid-IR spectrometer. By using the mid-IR lasers, we evaluated OSNR, wavelength resolution and accuracy of the mid-IR spectrometers. We believe that these experimental results will be helpful to evaluate the performance of mid-IR spectrometer.

REFERENCES

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