Development of a laser transmitter for a 1.6-μm CO_2 DIAL

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Abstract

A 1.6-μm CO_2 DIAL has been developed. A high power laser oscillator with single mode oscillation and high spectral purity, has been instrumental in high precision measurement of less than 1 %. Since high-energy laser sources with wavelengths of around 1.572 μm have not been reported, commercial avalanche photo diodes used for photon counting can be employed. We consider few laser systems, namely, the high power laser, which can oscillate at around 1.572 μm. We report the fundamental characteristic of optical parametric oscillators and stimulated Raman scattering systems to determine a transmitter for the CO_2 DIAL.

1. Introduction

Carbon dioxide is an important trace constituent of the Earth's atmosphere and is considered to be a potent greenhouse gas. The vertical distribution of carbon dioxide from the ground to an altitude of 10 km is necessary in atmospheric dynamics in order to accurately predict the global carbon cycle in the future. The precision of carbon dioxide content in the atmospheric layer is required to be less than 1%. An overview by Nagai et al. that includes system design with regard to a 1.572-μm CO_2 DIAL is described in reference [5].

In order to precisely measure CO_2 using the DIAL operated at 1.57 μm, the development of a high power laser oscillator for this system is the primary objective. An optical parametric oscillator (OPO) as well as stimulated Raman scattering systems are considered as transmitters for the DIAL system. Each laser system can be oscillated in a single mode oscillation. However, certain issues such as long term stability and higher power operations have yet to be addressed. To determine which of the two laser systems considered for the transmitters for the 1.6-μm CO_2 DIAL is better, we investigate their fundamental characteristics.

2. Optical Parametric Oscillator

The OPO is a well-known laser system that is capable of broad wavelength tuning. We have carried out a fundamental injection seeding experiment. Figure 1 shows the OPO architecture. The generation of a 1.572 μm wavelength depends on the single pass configuration of two nonlinear KTP crystals that are pumped using a flashlamp pumped Q-switched Nd:YAG laser.

This process satisfies the nonlinear phase matching condition—$k_p = k_s + k_i$, where k_p is the pumping component, k_s is the signal component, and k_i is the idler

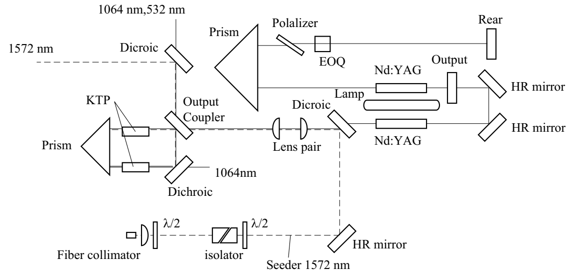

Fig.1 Schematic diagram of the injection seeding experiment is carried out in a 1572-nm OPO architecture.

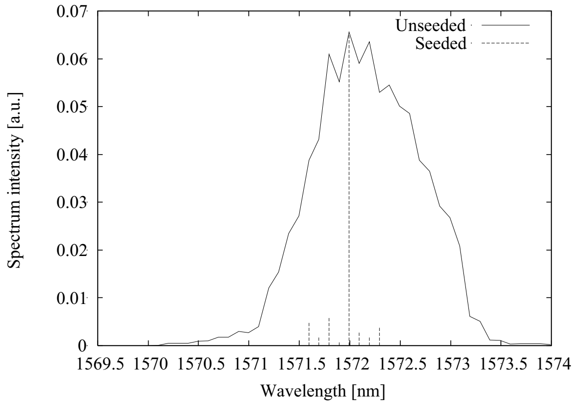

Fig. 2. Monochromator output for the unseeded and seeded OPO around 1572 nm. Both the outputs obtained under same conditions—energy, 16 mJ and repetition rate, 30 Hz.

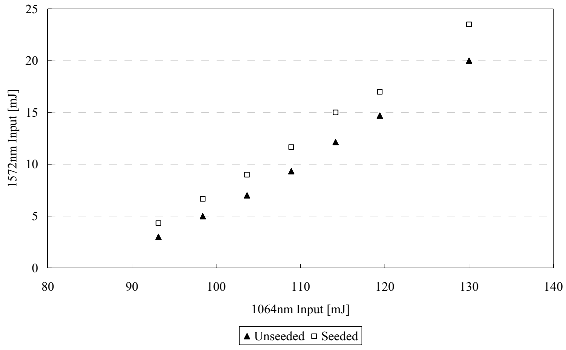

Fig. 3. Seeded and unseeded energies of the OPO at 1572 nm versus those at 1064 nm. The pumping energy. The blank square denotes the seeded output. Maximum pulse energy: 23.1 mJ.

component. The KTP crystals with dimensions 6 × 6 × 20 mm were cut for type 2 noncritical phase matching in the XY plane. (Θ = 90°, Φ = 0°). The beam moves along the X axis of the crystal. The pump beam and signal wave are polarized along the Y axis, and the idler wave is polarized along the Z axis of the crystals. Varying the phase matching angle slightly enables continuous tuning. In a single pass OPO, the incident angle of the pump beam to the nonlinear crystal has is small. The maximum output of this OPO is limited by the damage threshold of the KTP coating. Figure 2 shows the typical spectrum of the OPO. The single mode oscillation and the long-term stability experiment are tested.

3. Stimulated Raman Scattering

Stimulated Raman scattering (SRS) can be employed for the conversion of laser frequencies at Q-switched operation regimes. The nonlinear crystal and molecule using the SRS produce a fixed frequency shift due to the vibration of the molecules and photons. In reference [1], the frequency control of the SRS laser using an external cavity configuration with flashlamp pumped Nd:YAG with barium nitrate is shown.

In order to make the SRS operation more effective, we consider the intra-cavity SRS using the barium-nitrate-pumped 1.35-μm LD-pumped Q-switch laser. The gain of the nitrate moiety vibrational mode at 1047 cm^{-1} dominates those of all other modes. The vibrational dephasing time for the 1047 cm^{-1} mode is about 25 ps. The internal SRS generation, the single mode oscillation, and long-term stability experiment will be conducted in the future.

4. Conclusion

We have developed a high power laser transmitter for the 1.6-μm CO_2 DIAL in order to achieve a precise measurement of CO_2 of less than 1%. The optical parametric oscillator and the Raman shifter for the stimulated Raman scattering as well as other options are considered for use as transmitters. Among these systems, the one suitable for use as a transmitter with the CO_2 DIAL will be determined by investigating their characteristics.

References

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