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Dual-beam coaxial amplification system of stimulated Brillouin scattering based on polarization control technology

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ABSTRACT

In the field of Brillouin lidar, it has very important significance to find one method that can amplify the Brillouin scattering signal in real time. One new-type Brillouin lidar detection system based on Nd:YAG pulsed laser and polarization control device is designed in this paper. The key point of this detection system is to have two pulsed coherent lights with same frequency, same polarization and same initial phase, of which one beam is taken as the detection wave for generating stimulated Brillouin scattering signal and the other beam is taken as pumping wave for real time and effective amplification of stimulated Brillouin scattering signal. This detection system mainly includes two pulsed lasers and one electro-optical polarization controller. The laser is mainly used to obtain the pulsed lights with same frequency and same phase, and the polarization controller is mainly used to change the polarization state of two coaxial beams to make them change into same polarization state from orthogonal polarization state thus to enable the pumping wave to amplify the backward stimulated Brillouin scattering signal. It is shown from the experimental results that the adoption of this new system can realize the effect of pumping amplification and can increase the signal to noise ratio to a certain extent.

1. Introduction

Compared with spontaneous Brillouin scattering technology, the detection technology of stimulated Brillouin scattering has higher signal to noise ratio and detection accuracy, so wide attentions have been paid to the theory and experimental research related to it for many years [1–5]. Especially in the ocean exploration aspect [6–9], the phase-conjugation characteristics of stimulated Brillouin scattering appear to be more prominent. We know that the high-energy laser will generate various nonlinear scatterings during underwater transmission [10,11], at the same time, due to the attenuation effect of water, the SBS signal will be weakened to different extents and even will be fully overwhelmed in the noise. Even if there is weak signal returning to the receiving system, the detection effect will be reduced because the signal strength is lower than the sensitivity of receiving device. For this reason, the author of this paper has put forward a new-type dual-beam coaxial amplification system of stimulated Brillouin scattering, which can realize real time and effective amplification of weak stimulated Brillouin scattering signal. In the existing reports, the main method used for amplifying Brillouin signal is dual-cell amplification [12,13]. However, this dual-beam amplification method is infeasible in the actual ocean exploration because it is very impractical to separately build an amplifier for amplifying the SBS signal in ocean exploration. But for this dual-beam coaxial amplification system, the greatest advantage is to solve the inconvenience caused by dual-beam amplification. This amplification system carries out detection with dual beams, one beam is taken as the detection wave for stimulating SBS signal and the other beam is taken as pumping wave for real time amplification of SBS signal. The detection wave and the pumping wave are coaxial beams and the polarization states of the two are orthogonal. The traditional method for coupling of two beams into one beam is polarization coupling. We know that two orthogonal beams of polarization states are non-coherent and cannot be directly used to amplify the SBS signal. So, the key point of this amplification system is to change the polarization states of pumping wave and detection wave into the same polarization state from the orthogonal state.

2. Obtaining of coherent light

If the pumping wave is used to amplify the SBS signal, the detection wave and pumping wave must be coherent light with same frequency, same initial phase and same line width. One method is to divide one beam into two beams, this method is simple but will weaken the energy of two beams simultaneously. For this reason, we use two pulsed lasers to obtain two beams through the method of cascade connection. The first laser outputs 1064 nm fundamen-

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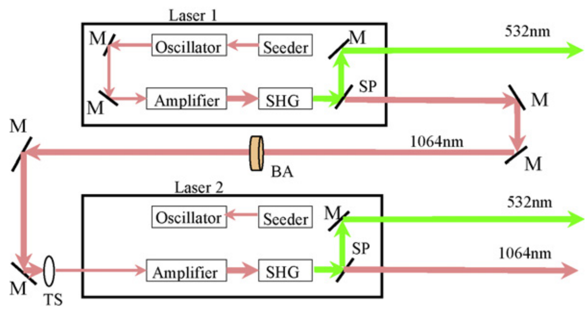

Fig. 1. Obtaining of coherent light (M represent the reflective mirrors, SP represent the spectroscopes, BA represents the beam attenuator, and TS represents the telescope system).

tal frequency source and two beams separately with wavelength of 1064 nm and 532 nm and with basically same energy are obtained after the second harmonic crystal and beam splitting prism, of which the 532 nm beam is taken as the detection wave for generating SBS signal. The 1064 nm beam is taken as the seed light and is injected into the amplifier stage of the second laser after the beam converting system, then another group of 1064 nm and 532 nm beams can be obtained. We take the second 532 nm beam as the pumping wave for amplifying the SBS signal. Since these two 532 nm beams are obtained from the amplification of same one seed light, they have good coherence. It needs to be explained here that though the light output from its oscillator stage is not used, the normal running of oscillator stage shall be guaranteed in order to ensure the operation stability of the second laser itself. The basic principle diagram is as shown in Fig. 1.

3. Dual-beam coaxial amplification system

The experimental system is shown in Fig. 2. Two lasers are seed-injection Nd:YAG pulsed laser with line width of 90 MHz, pulse width of 8 ns and repetition frequency of 10 Hz. Of which, the single pulse energy of 532 nm beam output from Laser 1 is about 1.5 J and the single pulse energy of 532 nm beam output from Laser 2 is 650 mJ. We use 1.5 J 532 nm beam as the detection wave for generating SBS signal and 650 mJ 532 nm beam as the pumping wave for amplifying the SBS signal. Two beams have good coherence and meet the requirements of the system for coherent light. In this system, M1–M6 represent the reflective mirrors, P1 and P2 represent the polarizers, λ/2 represents the half-wave plate, λ/4 represents the quarter-wave plate. The solid thick lines represent the connections of light, dashed lines represent electronic connections.

The pulsed laser output from Laser 1 is vertical polarized, the first 532 nm beam is converted into horizontal polarized beam after half-wave plate and passes through the polarized coupling mirror P1 with low energy consumption (the penetrating rate is about 90% for horizontal polarized light). The other 532 nm beam is coupled with the first beam into one beam after optical pathway delay and enters the electro-optical crystal of polarization controller. Since there is time delay between two beams, we can change the polarization state of two beams through adjusting the high voltage signal of the polarization controller. Its basic principle is described as follows.

The principle diagram of polarization controller is as shown in Fig. 3. The KD*P crystal is specially processed. When the high voltage signal is not applied to the polarization controller, the optical axis of the crystal is vertical. However, after the 7000 V half-wave voltage is applied to the polarization controller (the voltage is voltage-increasing mode and the width of increasing is about 27 ns), the optical axis of crystal is changed to 45° incline from vertical, its function is equivalent to a half-wave plate. This also means the birefringence effects of the crystal are changed by the applied high voltage signal.

Fig. 4 shows the whole working process of polarization controller. Before beam 1 and beam 2 enter the polarization controller, the electro-optical crystal of polarization controller does not work. At that time, beam 1 will enter the electro-optical crystal and will completely pass through the crystal after 8 ns (the laser pulse width is 8 ns). We can make beam 2 lag 27 ns relative to beam 1 through adjusting reflector M1–M3 so that we can ensure that the high voltage signal will not have influence on beam 1 after beam 2 arrives in electro-optical crystal. When beam 2 arrives in the electro-optical crystal, the power driver starts working and outputs high voltage signal to the polarization controller. At that time, the crystal is equivalent to a half-wave plate and the polarization state of beam 2 is changed into horizontal polarization from vertical polarization. After another 8 ns, beam 2 completely passes through the crystal. At that time, the whole polarization control process is completed to wait for the arrival of next group of pulses and repeat the above process.

When beam 1 and beam 2 pass through λ/4 wave plate, their polarization states are changed into circular polarization from horizontal polarization. We know that when the high-energy pulsed

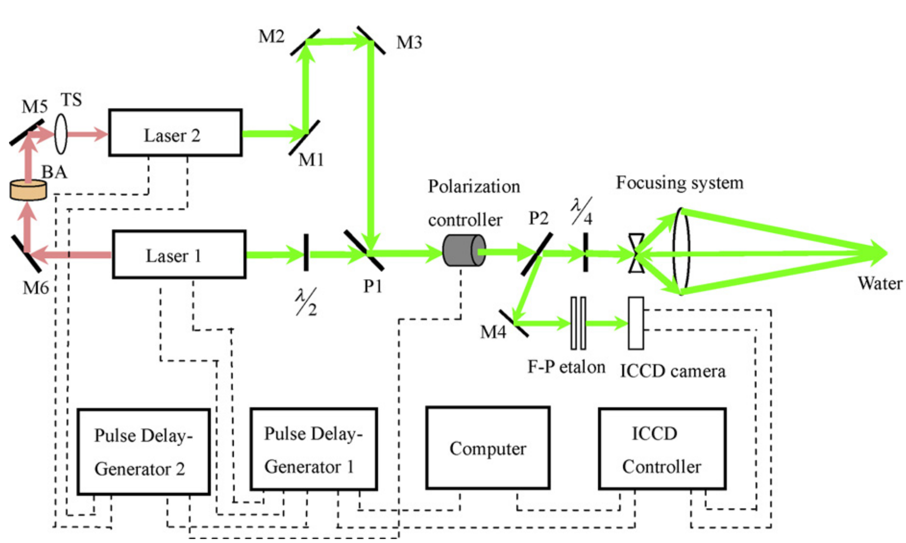

Fig. 2. Configuration of the coaxial amplification system.