Progress in Development of a Laser Radar with Long-Duration Frequency-Modulated Pulse for Measuring Wind

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A 1550-nm wind lidar with frequency modulation and long duration pulse was proposed. Although conventional wind lidars require shorter transmitting pulse length to improve range resolution, shortening the pulse width results in poor Doppler velocity resolution because of a very high frequency of 1550-nm laser. That is, it is necessary for peak power of pulse to be increased in order to improve SNR. Thus, range resolution and velocity resolution are in a trade-off relationship, and the design of lidar system is not as flexible as radar. The proposed wind lidar can designate range resolution and velocity resolution independently [1], and it accomplishes a high SNR by pulse compression technique [2]. However, the radar’s pulse compression technique does not work on lidars since a laser’s high frequency causes a large Doppler frequency shift. For example, a particle with a radial velocity of 1.0 m/sec gives a Doppler frequency shift of 1.3 MHz. When transmitting a signal with band width of 1.0 MHz (equivalent to 1 μsec pulse), its returned signal is no longer correlated with a reference signal that is usually a replica of the transmitting signal. The proposed wind lidar generates multiple reference signals with presupposed Doppler frequency shifts, and matched filter processing is performed with each of them. The result of each Matched filter processing corresponds to the distance profile at each of the presupposed Doppler velocities. That is, the multiple Matched filter processing derives a distance-velocity profile of the received signal. According to an analytical performance evaluation under ideal conditions, accuracies of wind ranging and velocimetry increase in proportion to the square root of pulse duration while maintaining the range resolution [1].

For demonstrating the proposed wind lidar, we have been developing a prototype of the wind lidar. The prototype is constituted as follows. As a laser source, a semiconductor laser is used, and a continuous laser light of 1550 nm wavelength is generated. The laser light is mixed with microwave pulses with frequency modulation by an acousto-optic modulator. Laser pulses with frequency modulation are amplified by erbium-doped fiber amplifier. Then, they are output from the fiber, collimated by a lens, and emitted to the free space by a telescope. A returned laser light is received by the same telescope and is input to a fiber. The transmitted laser light and the returned laser light are separated by a fiber optic circulator. The returned laser light is down-converted to microwave by a heterodyne detector, and the microwave signal is digitally sampled by an analog-to-digital converter.

In this research, we verified the accuracy of waveform shaping of the modulation signal by directly connecting the fiber outlet and inlet via an optical attenuator. As a result of analyzing the received signal obtained in the experiment, a peak appeared in the range-velocity-profile. The peak has a relative velocity of 0 m/sec, therefore, it is the direct return in the experiment system. In the experiment, a signal having a bandwidth of 15 MHz and a pulse width of 10 μsec were used, thus, the theoretical range resolution is 10 m and the velocity resolution is 0.077 m/s. With respect to the peaks of the received signal, it is measured that the range resolution is 14.7 m and the velocity resolution is 0.08 m/s, that are almost equivalent to the theoretical values. It has been confirmed that the signal modulation works in the experiment system as well as the theory.

In the near future, we will emit the modulated laser pulses to the free space, and will obtain signals returned from aerosols flowing with wind, whose results may be included in the presentation.

references
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