Mobile coherent Doppler LIDAR system for wind sensing

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ABSTRACT

We have developed ultra compact all-fiber Coherent Doppler LIDAR (CDL) system for wind sensing, called Man-pack LIDAR. The dimension of the Man-pack LIDAR is 40x30x16.5 cm, its weight is reduced to 13.9 kg and its power consumption is only 46.7 W. Thanks to low power consumption optical transmitter/ receiver unit, this new CDL system can be operated by two Lithium polymer batteries, and it can continue to measure over two hours without exchanging batteries. This Man-pack LIDAR has also successfully marked the maximum range for wind velocities more than 1 km as long as our conventional all-fiber CDL product (LR-FC series).

INTRODUCTION

A Coherent Doppler LIDAR (CDL) is an attractive sensor for wind sensing because it offers a method of remote wind speed measurement in clear atmospheric condition. All-fiber CDL using the wavelength of 1.5 micron has such many advantages as its eye-safety, its reliability for various environmental conditions and its flexibility for deployments [1]. Mitsubishi Electric has been released commercial product of all-fiber CDL system (LR-05FC) since 2005 [2]. As to the CDL deployments at a steep mountain, small islands, or disaster areas, it required not only small enough to be transported by one person but also battery drivable. This paper introduced an ultra compact and battery drivable CDL prototype system.

SYSTEM CONFIGURATION

Figure 1 shows that block diagrams of the mobile CDL system. The main container includes a fiber-based optical transmitter/ receiver (Optical TRX), RF electronics and a power supply unit (PS-unit). In the optical TRX, the wavelength of 1.54 micron DFB laser diode as a master laser was split into a local and a seed signal to double pass AO pulse modulator. This seed pulses were amplified by a dual stage Erbium Doped Fiber Amplifier. The pulse repetition frequency was 16 kHz, the duration was selectable from 200, 500 and 1000 ns whose transmitting pulse energy of 1.8 - 4.6 uJ.

Optical pulse output is transferred through fiber circulator to an optical antenna via 3-meter fiber cable. The optical return signal was transferred to optical balanced receiver after photo mixing to local light. In the Rf electronics unit optical heterodyning signal were 8-bit digitized at sampling rate of 216 MS/s, then averaged Doppler spectra obtained by executing 256-points Fast Fourier Transform (FFT) for each range gate using a PC based signal processing unit with a Field Programmable Gate Array (FPGA) pre-processing board [3]. Note that the wind lidar signal processing is executed in a mobile personal computer connected with card-bus interface, making it easy to upgrade a PC as well as application software. The optical antenna was used fully compatible to our CDL product which included a fiber collimator with a mechanical wedge rotating scanner.

In the power supply unit, two Lithium polymer batteries (16 V, 60 Wh) were used, which the battery voltage was converted by DC-DC converters to applying its power for an optical TRX and an RF electronics, and an optical antenna. The designed power consumption was 50W.

Figure 2 shows the outer view of Man-pack LIDAR system. A mobile PC with a touch panel screen was built in the top of the CDL main container not only to control measuring condition but also to make a quick look of the measurements. The dimension is 40(W) x 16.5(H) x 30(D) cm, and its weight is 13.9 kg including a mobile PC. Thanks to small dimension this CDL can be put in an attaché case and carried by a man. The time for deployment is less than 5 minutes to open the cover, fix a tripod of optical antenna, and connect two cables between a main container and an optical antenna.

Figure 2(c) shows the snap shot for exchanging batteries from a main container of CDL. Note that it is also possible to exchange battery during wind measurement by exchanging it alternately.

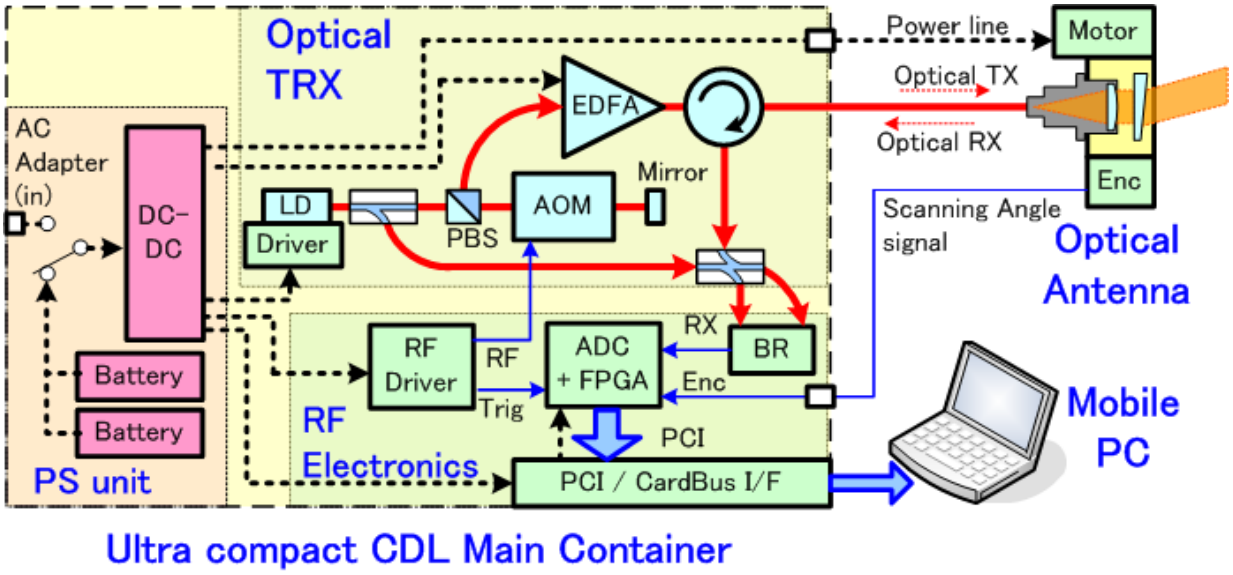

Fig. 1 The Block diagram of Man-pack LIADR system.

Bold red lines indicate polarization maintaining fibers, thin blue lines mean RF cables and dashed black lines mean power lines

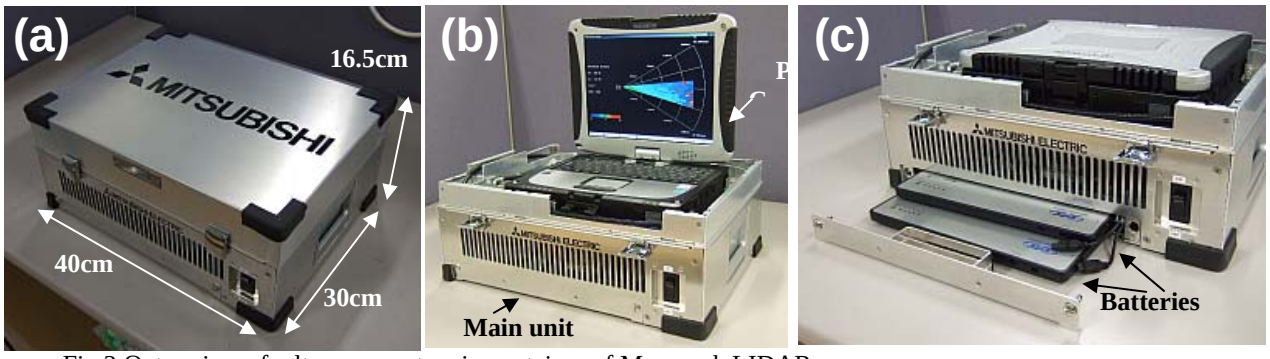

Fig.2 Outer view of ultra compact main container of Man-pack LIDAR

(a) For carrying, (b)in operation, (c) exchanging batteries

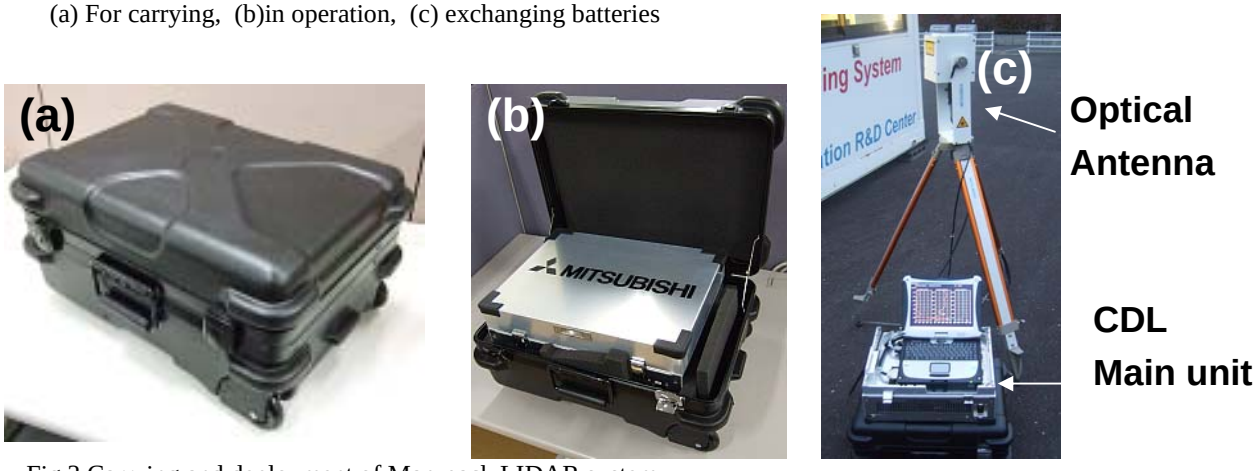

Fig.3 Carrying and deployment of Man-pack LIDAR system

(a) Outer view of attaché case for carrying. (b) Inner view of attaché case, (c) snap shot in wind measurement

EXPERIMENTAL RESULTS

In order to evaluate the system performance of the Man-pack CDL, wind velocities and directions are measured as shown in Fig.3(c). The measuring conditions were as follows: Elevation angle of 90deg, the number of incoherent integrating number of 16000, Azimuth scanning speed of 20deg/sec. The aerosol conditions were measured ~6000 counts per 0.047 L.

Figure 4 shows that the examples of measured data. In this example the height distribution of horizontal wind speed, wind direction and vertical wind speed are obtained at vertical resolution of 75m with the height more than 1300 m. This example showed this Man-pack CDL has the same measuring performance as our conventional CDL product.

Figure 5 shows the power consumption of Man-pack lidar in operation. Although the power consumption changed corresponding to the operating condition, (a) turn on the scanner, (b) turn on the main unit, (c) start the wind measurement, (d) halt the measurement, and (e) turn off the main unit, the maximum power consumption was less than 48W.

Figure 6 shows that the temporal variation of supplying power from fully charged batteries for continuously wind sensing under the same measurement condition as in fig. 4. In this figure the Man-pack CDL ran the wind measurement over 2 hour 9 minutes by using two batteries without exchanging batteries. The average supplying power was 46.8W. Note that it is possible to exchange each battery during wind measurement by exchanging it alternately, leading to continuous wind measurement more long term.

SUMMARY

We have developed ultra compact Coherent CDL prototype system for wind sensing, called Man-pack LIDAR. The dimension of the Man-pack LIDAR is 40x30x16.5 cm, its weight is reduced to 13.9 kg and its power consumption is only 50W. This new LIDAR can be operated by two Lithium polymer batteries, and continue to measure over two hours without exchanging batteries. The Man-pack LIDAR has also successfully marked the maximum range for wind velocities up to 1.5 km as long as our conventional all-fiber CDL product.

REFERENCES

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2. T. Ando et al., Proc. 13th Coherent Laser Radar Conference, Kamakura, 170 (2005).

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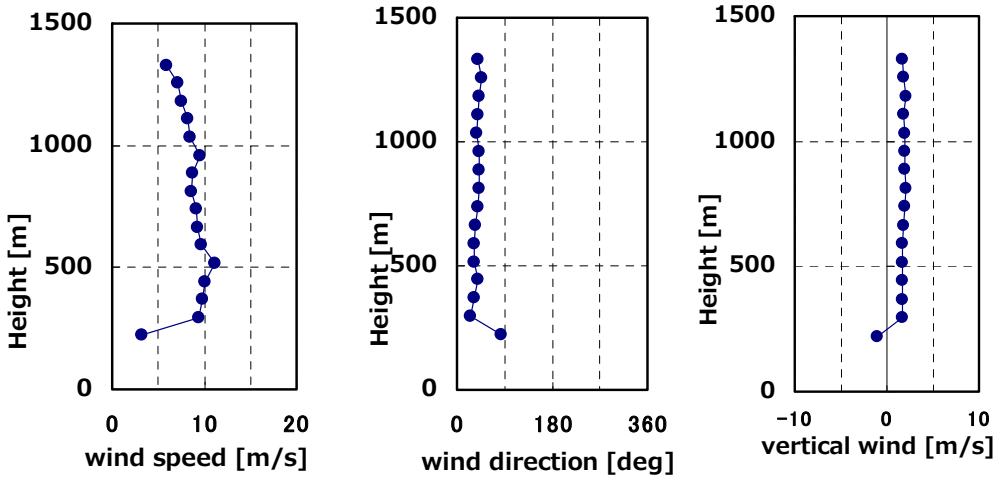

Fig. 4 Examples of measured wind speed / direction by Man-pack LIDAR

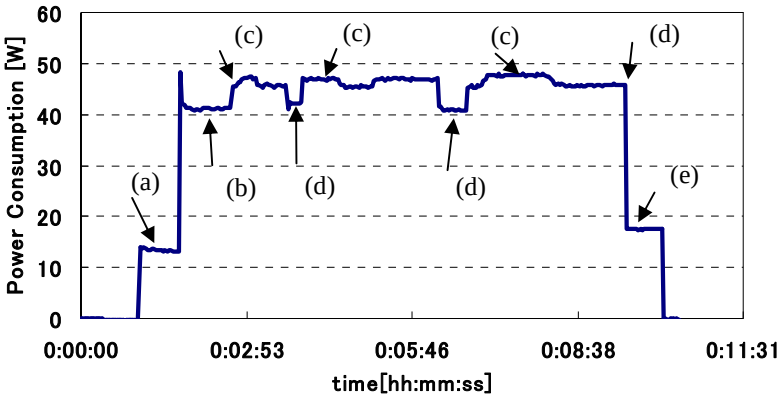

Fig. 5 Power consumption of Man-pack LIDAR in operation

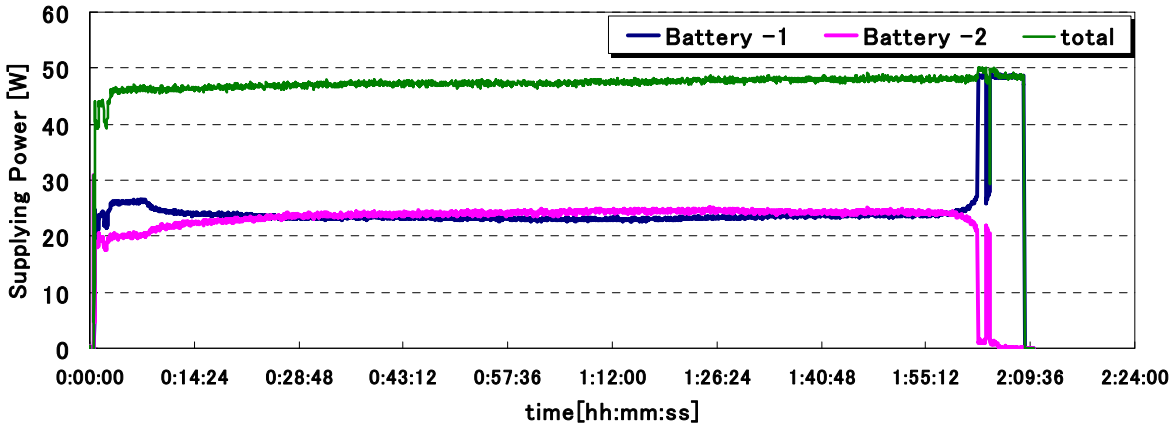

Fig.6 Battery supplying power under continuously wind sensing