Multi-length Fiber Delay Line for the Wind Turbine Pitch Control with a Doppler Wind Lidar System

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In this paper we present our result of the developing a cost efficient coherent Doppler wind Lidar (CDL) system for the preview pitch control of wind turbines. Particularly, we focused on the design and evaluation of a fiber delayline concept for a short coherence length laser system.

1 Introduction

The State-of-the-Art wind Lidar systems which are normally used ultra-narrow linewidth fiber lasers are in a very high price regime. Those systems are very difficult to integrate into individual wind turbines due to the economic consideration. However, our concept of using a lower cost shorter coherent length laser along with a corresponding fiber-delay-line for a multiple range sensing can reduce the Lidar system cost into an acceptable range for wind turbine control applications. The main focus of this paper is to develop and evaluation of such a Lidar system with multi-length fiber delay line and shorter coherence laser.

2 Doppler wind Lidar system for wind energy

CDL systems work on the principle of measuring the Doppler shift in frequency due to the amount of atmospheric aerosols and molecules for obtaining the wind velocity. A laser beam is projected into the atmosphere where aerosols and molecules scatter the laser beam. The backscattered laser is Doppler shifted in frequency by an amount proportional to the line-of-sight (LOS) velocity of the atmospheric aerosols and molecules. By collecting the scattering light and analyzing the Doppler frequency, the LOS wind speed is estimated [1].

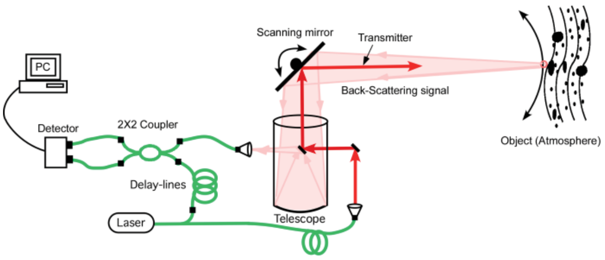

Fig. 1. Concept of a Doppler wind Lidar system

3 New concept

Reducing the price is current most important for the research and development of Lidar systems. Windar Photonics uses a unique SL-MOPA laser module to reduce the price of laser source [2]. In 2012, we presented an idea by using a broad spectrum laser with fiber delaylines to achieve a cost efficient system [3]. Comparing to state of the art systems in which fiber lasers with couple kilometers coherence length is used, broad spectrum laser has a relative shorter coherence length which is normally not used in a coherent Doppler Lidar system, due to the high phase noise. However, such kind of lasers cost less than 1/5 in compare with fiber lasers. Hereby, our approach is to introduce such lasers for Doppler wind Lidars.

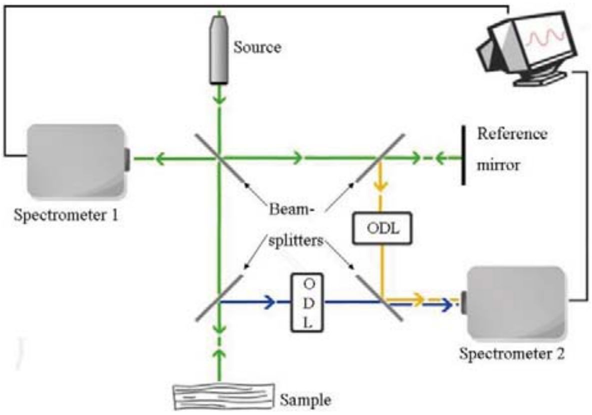

Fig. 2. OCT system for paper quality measurement [4]

This idea is coming from our earlier research of using a super continues laser on a frequency domain OCT system for paper production applications (Fig. 2). The laser sources with hundreds nanometers coherence length are used. By adjusting the reference mirror position, measurement can only be achieved when light path difference between sample and reference beam is within the coherence length. Therefore, the coherence length of laser sources defines the depth resolution.

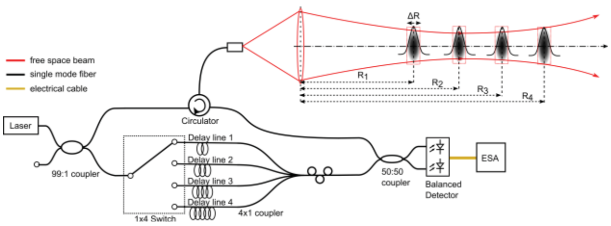

Fig. 3. Illustration of CW Lidar concept with range independent probe length

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Inspired by this work, in order to overcome the deficiency of CW Lidar system, losing the range resolution for long distance measurement, the broad spectrum lasers not only lower down the system price but also benefits for selecting stable probe lengths on a CW Lidar system. **Error! Reference source not found.** illustrates the work principle of such Lidar systems.

4 Experimental setup

On our earlier publication [5], different designs are present and evaluated. Here we use the monostatic un-confocal system for the testing and evaluations in this paper (Fig. 4). This setup uses an off-axis parabolic mirror with a center-hole for collecting the scattering light. A collimated sending beam passes through the center-hole and transmits to the target. The laser illuminates the target and is back-scattered with a Doppler shift frequency by the movement of the target. The back-scattering light is collected and mixed with the reference beam to achieve a coherent detection. The interference pattern via time is detected by the balanced detector to obtain the Doppler frequency.

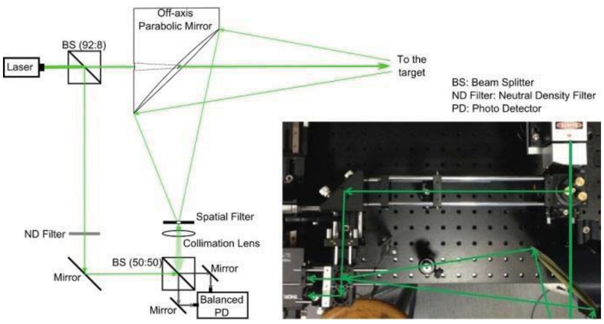

Fig. 4. A free space monostatic un-confocal Doppler wind Lidar system design for experimental testing

5 Experimental results

To evaluate the broad spectrum laser for a Doppler wind Lidar system, a laser diode (LD) “TO810-PLR170” from Ondax is used. This LD has maximum optical power of 170mW with a spectrum linewidth of 50MHz centered at 810nm which corresponds to a coherence length of ~2m.

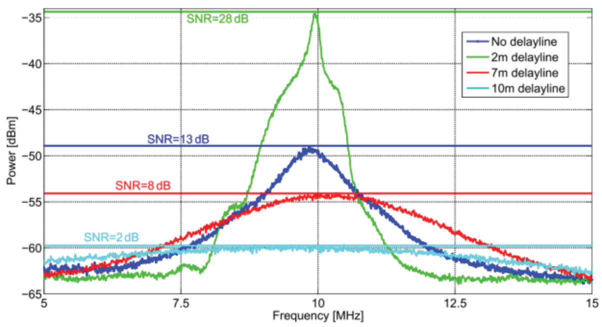

Fig. 5. Doppler spectrum with different delayline lengths for measuring at a target distance of 2m

Fig. 5 shows the Doppler spectrum measurement with different delaylines at a target distance of 2m which corresponds to a fiber delay length of 2.8m with the fiber core refractive index of 1.43. Therefore, the closed 2m delayline length shows the best SNR. Then, Fig. 6 shows the SNR measurement results for different target positions with a 7m fiber delayline length which corresponds to 5m measurement distance. The plots also show the best SNR position is about 5m.

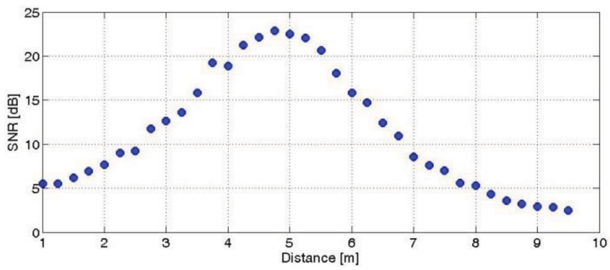

Fig. 6. Experiments result of the SNR for different target distance with a 7m fiber delayline

6 Conclusion

We present the concept and development of a cost efficient CDL system based on a short coherence laser for wind turbine control applications. In order to bring such broad spectrum laser into application, a fiber delayline is introduced to match with the initial phase for a long distance measurement. In this paper, the evaluation results of fiber delayline concept have been shown.

Acknowledgement

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