4.11 NEW LASER CEILOMETER USING ENHANCED SINGLE LENS OPTICS

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1. INTRODUCTION

The single lens, or coaxial, optics has established its position as the leading technology applied in laser ceilometers. As compared to the traditional two lens, or biaxial, design the main advantage of the single lens optics is the strong and stable signal starting virtually at zero altitude. This means reliable detection of also the lowest clouds and ground based obscurations, the phenomena being most critical from the aviation safety point of view.

The new Vaisala ceilometer is based on enhanced single lens optics. The new technology practically removes the internal optical cross-talk between the laser transmitter and the receiver, a feature that requires separate compensation techniques in current single lens ceilometers. The enhanced optical design also provides improved robustness against contamination of the window by dirt or precipitation. This paper will provide an overview on instrument design and performance.

2. INSTRUMENT DESIGN

2.1 Enhanced single lens optics

The main advantage of the single lens ceilometers is the good overlap of the emitted laser beam and the receiver field of view even at the lowest altitudes. This leads to strong and well defined backscatter signal and reduces the effect of multiple scattering, resulting the signal to be less dependent on the weather conditions.

The backbone of the new Vaisala Ceilometer is the second generation single lens optics. The main innovation is the way the common lens is used for transmitting and receiving light. In the new design the center of the lens is used for collimating the outgoing laser beam, whereas the outer part of the lens is used for focusing the backscattered light onto the receiver. This division between transmitting and receiving areas is provided by an inclined mirror with a hole in the center. The principle of the optical solution is shown in Figure 2.

This arrangement reduces significantly the optical cross-talk between transmitter and receiver leading to lower requirements for the receiver dynamical range as compared to the case in which the whole lens area is used for both transmitting and receiving. Due to the lower level of optical cross-talk, the need for separate compensation mechanisms is avoided leading to a more simple and more reliable instrument design.

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Fig. 1. New Vaisala Ceilometer

A practical benefit of the new design is that the receiving area of the window is not illuminated by the outgoing laser beam and the ceilometer therefore becomes more resistant to contamination of the window by dirt or precipitation.

Despite the division of the lens into transmitting and receiving areas the key benefit of the single lens optics, i.e. strong signal also from the lowest altitudes, is preserved as the laser beam area is encircled by the receiver field of view. Being separated on the lens surface these two areas start quickly overlapping each other due to divergence and because of the coaxiality the overlap develops all around the laser beam. The inverse square relationship between signal strength and distance assures a strong signal even from the area of partial overlap.

The new single lens design is also robust against changes in the mechanical alignment of the optical parts. Due to the nature of the coaxial optics any change in the relative position of the laser beam and the receiver field of view compensates for itself.

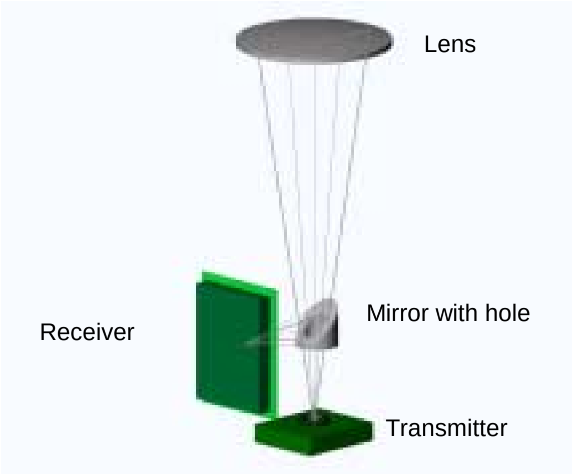

Fig.2. Division of the lens into transmitting and receiving areas.

2.2 System design

The new Vaisala ceilometer has a modular structure for easy handling by one person: it consists of a shield and a measurement unit. The single lens design allows compact size and light weight for the measurement unit which is also suited for mobile use.

The measurement unit can be mounted on the pedestal either in the vertical or in a tilted position. Tilting the ceilometer provides better protection of the window during precipitation leading to a more reliable cloud detection. Tilting is beneficial also in areas where specular reflection from ice crystals may cause erroneous cloud detections with a vertically installed ceilometer. In the new Vaisala ceilometer a tilt angle sensor automatically detects the tilt position and corrects the measured distance to a vertical cloud height.

The electronics of the new Vaisala Ceilometer is based on DSP (Digital Signal Processor) technology. Instead of a separate gating logics and a microprocessor a powerful DSP is used. The new technology provides much more processing power than the traditional designs, enabling for example a measurement cycle of 2 s as opposed to the 12-30 s of the current ceilometers.

The new Vaisala Ceilometer has comprehensive self monitoring features. These include monitoring of laser power, receiver sensitivity, internal voltages, various temperatures, and window contamination. In addition to the monitoring functions it also has an intelligent user interface giving troubleshooting guidance for the user in case of an instrument failure. The receiver, transmitter, and the electronics boards can be easily replaced on site without need for recalibration. The modular structure, self monitoring with a help feature together with easy service access through a door assure high data availability and low down times.

3. TESTING RESULTS

The performance testing and verification of the new instrument have been carried out under different weather conditions. Outdoor test period started in late 2002 at Vaisala test field, Helsinki, Finland. In these comparison tests the references have been the CT12K, the ceilometer currently used in the ASOS systems, and the CT25K, the FAA approved ceilometer capable of detecting clouds up to 25,000 ft. Figure 3 shows the new ceilometer together with a CT12K.

Fig.3. Outdoor test setup with a CT12K and the new ceilometer in December 2002.

Figure 4 shows an example of a low cloud base. The CT12K was measuring with 12s interval and the new ceilometer at 2 s interval. It can be seen that in general the agreement is very good. However, with the lowest clouds around 9:00 the CT12K reports lower cloud bases with a greater variance in the reported altitude. The difference is an indication of the tendency of CT12K to report slightly too low heights for the lowest clouds (Giles,2001). The larger variance is caused by the poor or non-existing overlap caused by the CT12K biaxial optics.

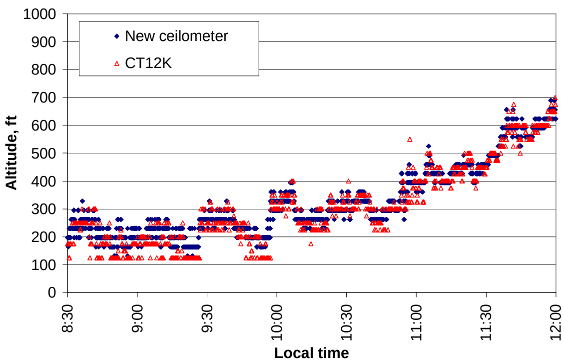

Fig. 4. Comparison result sample on September 29, 2003.

Figure 5 shows another example of comparison data. During the data period there was a cloud base with some precipitation moving from 4000 ft to about 2000 ft. At the same time a lower cloud base at about 1000 ft was developing from small cloud patches. It can be seen that the new ceilometer detects the lower clouds much earlier than the CT12K.

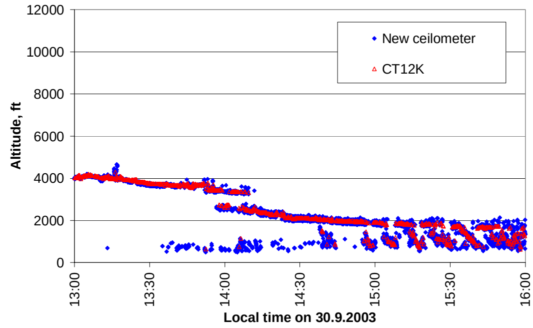

Fig. 5. Comparison result sample on September 30, 2003.

The main reason for the difference is the shorter integration time of the new ceilometer. It was measuring with 2 s integration time whereas the CT12K uses 12 seconds. The fast measurement enables the detection of the small cloud patches which with a longer integration period get smoothed out by the layer above. For the thin pathces, also the better signal to noise ratio improves detection capability.

Fig. 6 shows color coded profile data from the new ceilometer for the same period as Fig. 5. The development of the small cloud patches can be seen as well as precipitation especially at the beginning and the end of the period.

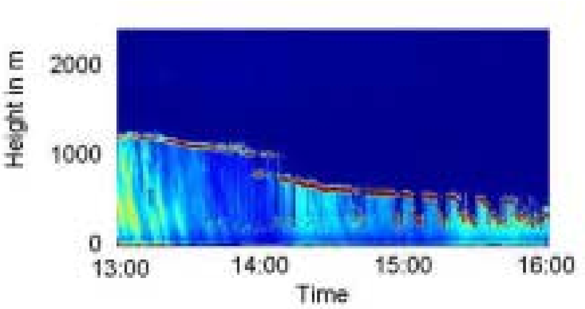

Fig. 6. Color coded profile data from the new ceilometer on September 30, 2003.

Figure 7 shows a comparison between the new ceilometer and the Vaisala CT25K for a high cloud. CT25K was reporting at 15 s intervals and the new ceilometer at 2 s intervals. It can be seen that both of the ceilometers detect the high cloud quite consistently, although some differencies can be seen. The CT25K reports somewhat higher cloud base with an average altitude of 22400 ft while the average altitude for the new ceilometer is 22100 ft. The difference is based on small revisions made in the cloud detection algorithm for the new ceilometer. There are also some occasional hits missed by either of the ceilometers, the largest number hits missing being in CT25K data after 21:10. However, as the ceilometers were not pointing at exactly same direction some difference can be expected.

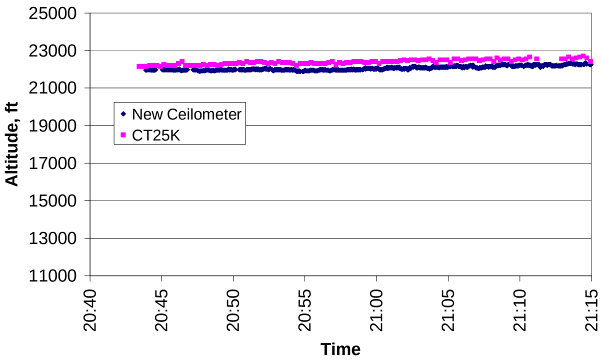

Fig. 7. An example of comparison data for a high cloud on October 3, 2003.

4. CONCLUSIONS

The technological advances in optics, electronics and data processing algorithms ensure high performance for the new Vaisala Ceilometer. Together with the state of the art technology professional mechanical design provides reliable operation and high data availability also during harsh weather conditions.

5. REFERENCES

Giles, D. M. "Tilting Ceilometers To Improve Cloud Base Height Detection in Precipitation", 11th Symposium on Meteorological Observations and Instrumentation, American Meteorological Society, Albuquerque, NM, 2001.