Commercial Development of Doppler Laser Radars

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1. INTRODUCTION

Infrared Doppler laser radar systems have been developed at Coherent Technologies, Inc. for the remote measurement of atmospheric wind velocity and turbulence. Significant advancements in technology now enable these systems to be compact, rugged, diode-pumped, all solid-state with user-friendly interfaces. Widespread use of graphite composites in the construction of the optical bench allow these systems to be operated over a wide temperature range and in severe vibration environments. Some of the applications of infrared Doppler radar include: remote atmospheric wind field measurement for meteorological uses; on-board commercial airline detection of wind shear and clear air turbulence for improving safety; aircraft wake vortex, wind shear, and gust front monitoring at airports; aerosol cloud and plume tracking; as well as improving the precision of dropping military air cargo.

Infrared Doppler radar provides a unique capability for measuring and monitoring 3-dimensional wind and aerosol fields. The atmospheric aerosol is utilized as the tracer for the atmospheric wind velocity measurement. The backscattered laser energy is Doppler shifted in frequency by an amount proportional to the radial line-of-sight velocity of the atmospheric aerosols. Coherent laser radars have been utilized for wind measurements since 1966.[1] Solid-state pulsed 2-micron coherent laser radar systems have been developed at Coherent Technologies, Inc. (CTI), for a variety of meteorological, environmental, and aviation related applications. These diode-pumped solid state laser radars are now capable of turn-key operation. The Tm:YAG laser transceivers operate at 2.02 microns with output energies of 1-10 mJ with PRFs of 1000 to 100 Hz. respectively. Wind measurement range resolutions of 30-75 m are typical. The principle of pulsed laser radar measurement of wind velocity is shown in Figure 1.

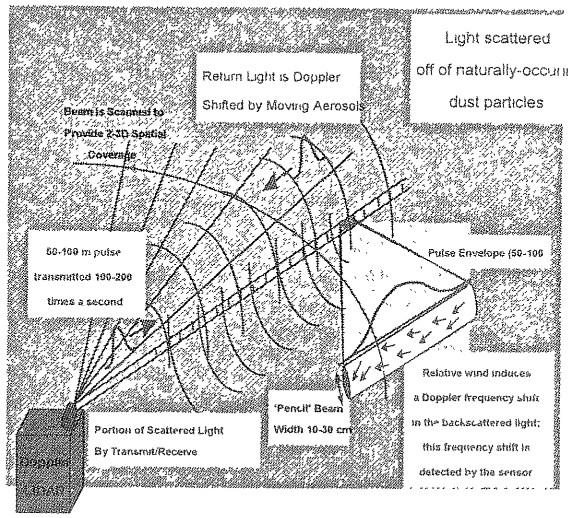


Figure 1. Principle of pulsed coherent laser radar measurement.

2. WIND TRACER PRODUCT

CLR Photonics, Inc. (CLR) is the commercial products division of CTI. CLR has been offering the WindTracer® as a turnkey wind sensing system to both domestic and international customers since the fall of 1996. The WindTracer® is a turnkey, eyesafe, pulsed coherent Doppler laser radar that provides direct range-resolved, spatially-distributed measurement of atmospheric wind and aerosols. Eyesafe coherent Doppler laser radar is the most accurate and direct method of remote wind field measurement. Coherent Doppler laser radar has proven itself to be the standard for remote wind sensing over the past ten plus years.[1]

Figure 2 is a block diagram showing the various subsystem modules. The major subsystems are the scanner, the transceiver, and the signal processor (or data system).

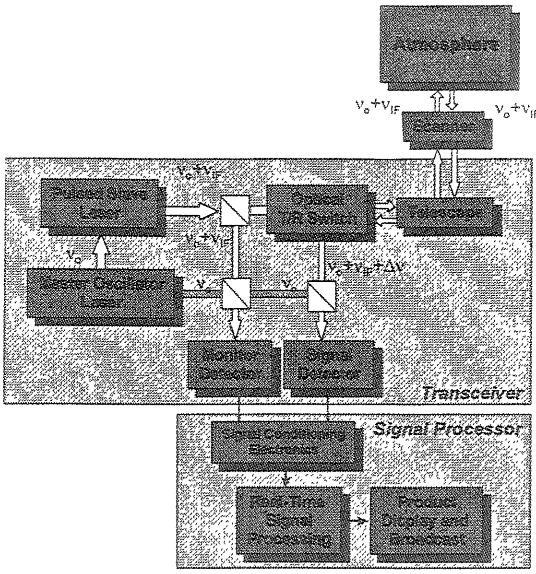


Figure 2. WindTracer® Block Diagram

The WindTracer® shelter (8 ft. high by 8 ft. long by 7 ft. wide) is fully insulated with an extremely durable fiberglass exterior and will withstand years of deployment with exposures to salt, rain, sand, snow, high winds, etc. This shelter has allowed the WindTracer® system to be successfully deployed in a variety of harsh operational environments, including: aboard a Hovercraft in an ocean environment, in the Arizona desert, and in the wintertime in Alaska. For more information on range performance, please check the Website.

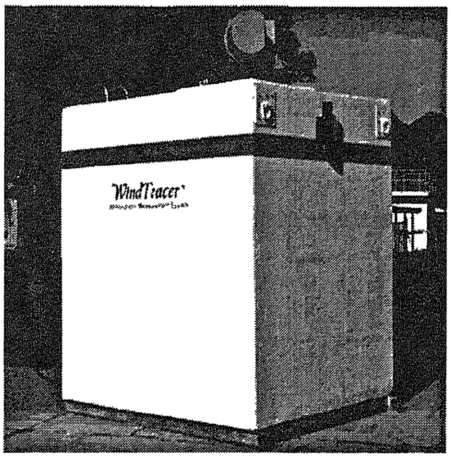


Figure 3. Exterior of WindTracer® with Equipment

3. AIRPORT SURVEILLANCE OF WIND SHEAR AND AIRCRAFT WAKE

An example of microburst wind shear detection is shown in Figure 4. This data was collected at Stapleton Airport in Denver, Colorado. The upper panel shows the radial velocity for a 2 degree elevation angle sector scan toward the north. The lower panel shows the resultant wind shear index, which is a measure of wind hazard to aircraft. Large positive values for the index indicate a performance loss condition, typically associated with a microburst, and large negative values indicate a sudden airspeed typically associated with a gust front.

Azimuth Scan Towards Isolated Convective

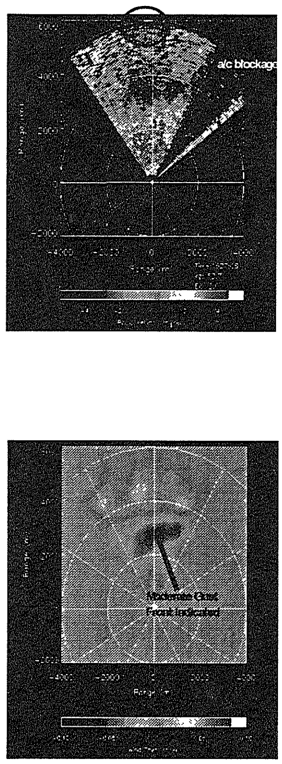
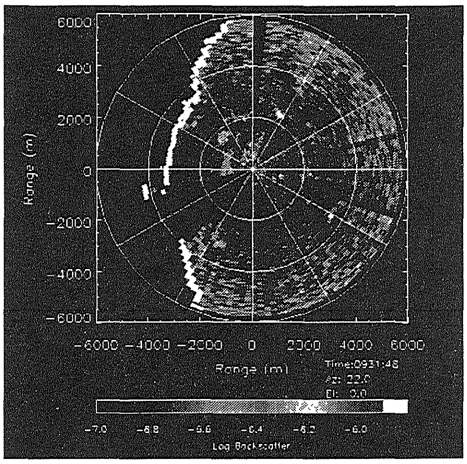


Figure 4. Wind Shear/Gust Detection

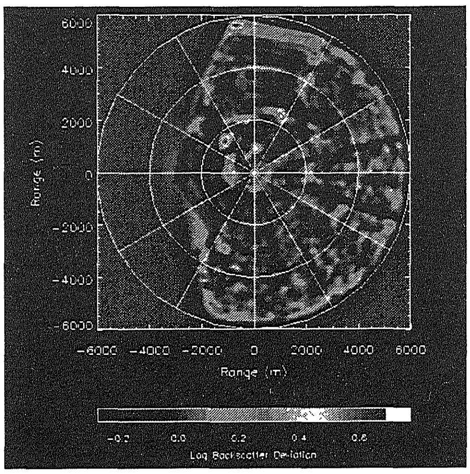
4. AEROSOL CLOUDS AND PLUMES TRACKING

The Aerosol Software Module provides an aerosol detection and tracking mode for locating and observing aerosol inhomogenities. The base aerosol data scan is processed to remove ground and large cloud returns. The aerosol information is then processed to yield a backscatter deviation map that is used by the detection and tracking logic. In Figure 5, the left panel shows the raw aerosol scan data. The middle panel shows the scan after removal of the ground and ambient backscatter levels. The right panel shows the aerosol map after threshold detection. In this example, the two largest above-threshold peaks are identified with circles and their respective aerosol deviation levels, in dB.

Aerosol Backscatter Surveillance



Ground and Ambient Backscatter Removal



Threshold Detect and Iconify

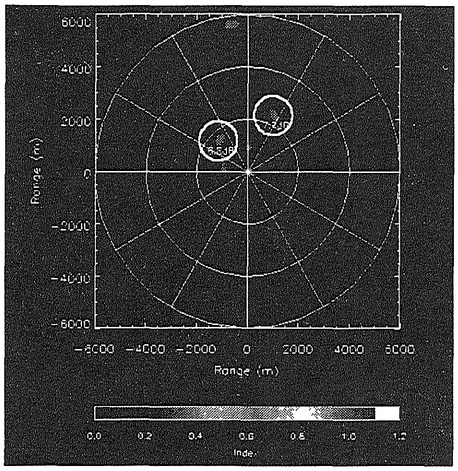


Figure 5. Examples of aerosol clouds and plumes tracking.

5. ON-BOARD COMMERCIAL AIRLINE DETECTION OF WIND SHEAR AND CLEAR AIR TURBULENCE

The Federal Aviation Administration states that: **"turbulence is the leading cause of inflight injury in commercial air travel today."** United Airlines reports 2 flight attendant injuries every 3 days from turbulence encounters. Clearly, a product is needed that will sense turbulence events ahead of the aircraft, measure its strength and provide enough warning time to allow the pilot and crew to take action to prevent potential injuries to passengers and flight attendants.

Figure 6. The National Science Foundation ELECTRA Aircraft used for flight test of the prototype turbulence sensor.

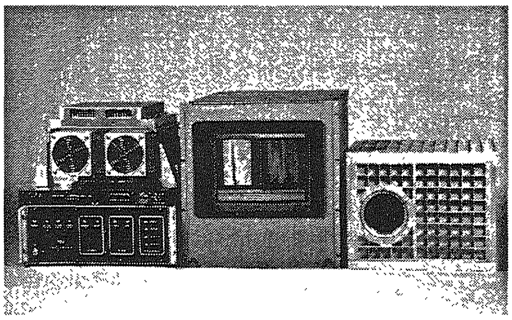


Figure 7. Prototype turbulence sensor (as flown) consisted of (R to L) signal processor, control electronics, CRT, and transceiver. Scanner and Chiller are not shown.

In March of 1998, CTI (under contract to NASA) successfully demonstrated the ability of an airborne coherent Doppler Infrared Radar to detect clear air turbulence, measure its strength and provide a time-to-impact warning to the cockpit. The system, shown at right above produced 12mJ of pulse energy at 100Hz PRF and was flown on an National Science Foundation Electra aircraft, shown in the picture on the left. Since those demonstrations CTI has signed an agreement with United Airlines (the largest commercial airline in the world) to work cooperatively to define a CAT product that would meet the needs of the airlines. Also, CTI has executed a separate agreement with AlliedSignal to work towards developing a collaborative product development and manufacturing arrangement for a CAT product. Product development is expected to take 30 to 36 months with the resulting product available for retrofit to existing airliners around the world as well as insertion to new aircraft in development by commercial airframers.

6. CONCLUSIONS

Coherent laser radar systems are now capable of commercial operational applications. Laser radar systems have demonstrated measurement capability in rugged environments including; hovercraft, airports, C-130 and C-141 cargo aircraft, C-130 Gunships, and civilian aircraft. A variety of commercial applications are anticipated.

7. REFERENCES

[1]R.M. Huffaker and R.M. Hardesty, "Remote Sensing of Atmospheric Wind Velocities Using Solid-State and CO_2 Coherent Laser Systems," *Proc. IEEE 84, 181 (1996).*