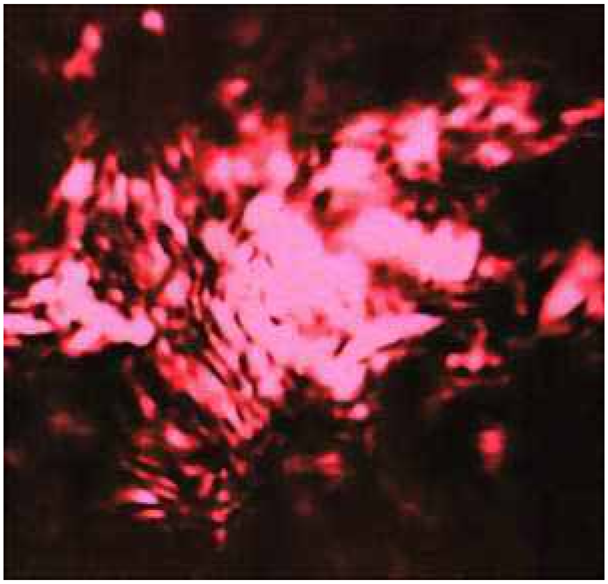
Application to Homeland Security: A Long-baseline Optical Anemometer (LOA) to Monitor the Drift of Chemical, Biological, and Radioactive Agents

(June 2003)

Ting-I Wang
Optical Scientific Inc.
Gaithersburg, Maryland 20877
(www.opticalscientific.com)

OSi Long-baseline Optical Anemometer (LOA) sensor uses optical scintillation as the detection method. Originally developed by NOAA, the technology has been proven, tested, and operating in the field for almost thirty years. Since 1995, the LOA has been successfully tested for runway crosswind and wake vortex measurements at JFK and DFW Airports. Many government labs and military proving grounds used the LOA for wind profile and turbulence measurements.



Optical scintillation is a general term that describes changes in the apparent position or brightness of an object when viewed through the atmosphere. Starlight twinkling is a common example of scintillation. Scintillation effects are caused by optical refraction occurring in small parcels of air whose temperature and density differ from their surroundings (atmospheric turbulence eddies). The attached photo shows when a light beam passes through several kilometers of atmosphere, the turbulence eddies refract the light beam to produce light intensity fluctuations at the receiving plane. If there is no turbulence, the received light pattern should be a uniform disc. The LOA transmitter emits a modulated beam of infrared light. The receiver detects this beam and converts it to an electronic signal. Variations measured between the transmitted and detected signals caused by the scintillating air parcels provide the basis of the turbulence measurement. The strength of the atmospheric turbulence is commonly represented as a refractive index structure constant (C_n^2). The amplitude of the scintillation is related to the turbulence intensity. The dual detector modules in the receiver furnish the capability of measuring crosswind by detecting the temporal correlation between the two detected signals as the air parcels move across the beam path. The movement of the scintillation from one receiver to the next is related to the wind speed.

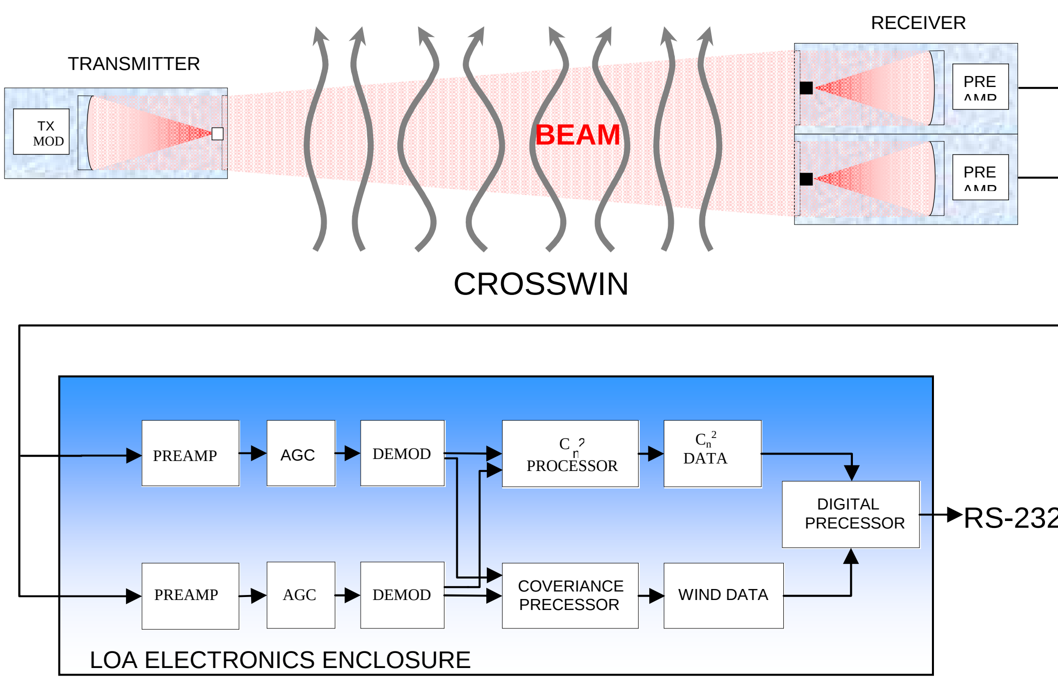
The attached photo shows the originally designed LOA by ETL/NOAA (courtesy ETL/NOAA). The LOA consists of:

1. A stand-alone transmitter head which contains an LED, a 150-mm optical collimating mirror, and transmitter electronics. The normal installation of the LOA transmitter requires the user to supply either 110/120 VAC or 12 VDC to the unit. The LOA transmitter is shown as the white round head in the attached photo.

2. A receiver head contains two 150-mm optical receivers mounted side-by-side on parallel axis. The black box in the attached photo is the LOA receiver.

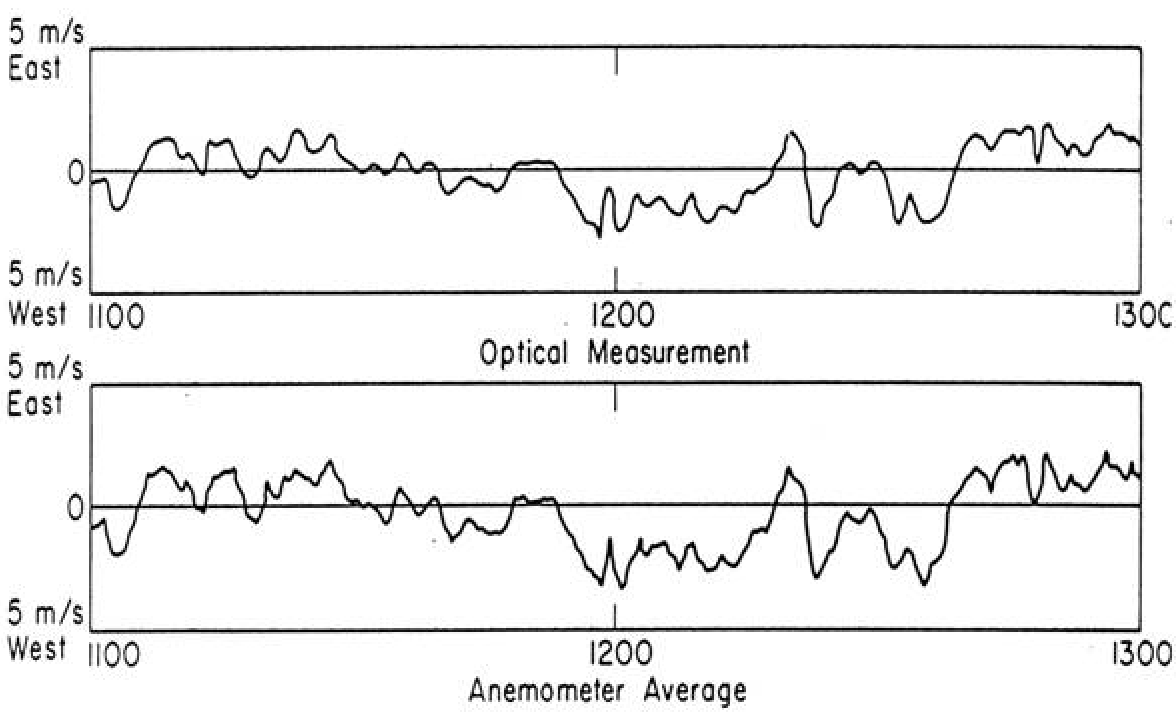
3. An interconnecting cable carries signals from the receiver head to the electronics enclosure. The connecting plugs are uniquely keyed to prevent wrong connections.

4. An electronics enclosure houses the signal processing circuitry. The normal installation of the LOA Enclosure requires the user to supply either 110/120 VAC or 12 VDC to the unit.



The LOA is a microprocessor based instrument that measures turbulence and crosswind over a long path length (up to several kilometers). The LOA Serial Input/Output (SIO) signal interface consists of a 3-wire RS-232-C connection. Data transfer across the LOA/computer interface is implemented via a serial, ASCII encoded, full duplex, asynchronous transfer link. Data transfer in the computer-to-LOA direction is configured as a simple, single character poll. Data can be collected using the OSi QwikCollect QCS-004 software. QwikCollect runs under Windows and allows a personal computer to collect, display, and archive data from the LOA. The graphics screen displays the data in large font characters for ease of viewing and as real-time graphs. The time series have auto-scaling vertical axes and display the data for the past 60 minutes.

The results of a field test are shown in the following figure (courtesy ETL/NOAA). The LOA transmitter and receiver were separated along a 500-meter path, ten propeller-type anemometers were installed along the optical path equally spaced from the transmitter to the receiver. The LOA measured path-averaged crosswind over the 500-meter path shown as the upper trace in the following figure(courtesy ETL/NOAA). The averaged crosswind of the ten propeller-type anemometers is shown as the lower trace. It is clear that the agreement between the two measurements is excellent with a correlation coefficient of 99%. **A major advantage of the LOA is that it provides an averaged crosswind along the whole optical path whereas the traditional anemometers can only provide a point measurement.** Field test results also indicated that the correlation coefficient between the LOA and the averaged anemometer measurements is usually higher than the correlation coefficient among the two adjacent anemometer's measurements because the crosswind varies substantially along the path.



In addition to measuring these parameters, the LOA also monitors key operating parameters of the sensor to verify performance. The LOA provides a sophisticated automatic gain circuit (AGC) that automatically corrects for signal loss. If the received infrared light level decreases below a certain threshold, excessive noise may be generated that will make signal detection unreliable. Low signal strength may be caused by a number of factors including low transmit power from optical misalignment, LED aging, decreased receiver sensitivity, dust build-up on the optics, and/or excessively heavy fog/smoke/dust in the optical path between the transmitter and receiver units. The LOA employs built-in test features that automatically detect and flag low light levels as a warning in the output data string before the sensor performance is degraded. The LOA sensor has been tested in environmental chambers over the range of -40 to +60 C. No degradation in performance was noted over this range. The LOA sensor is packaged in a weatherproof enclosure (NEMA-4X type) with plate glass windows.

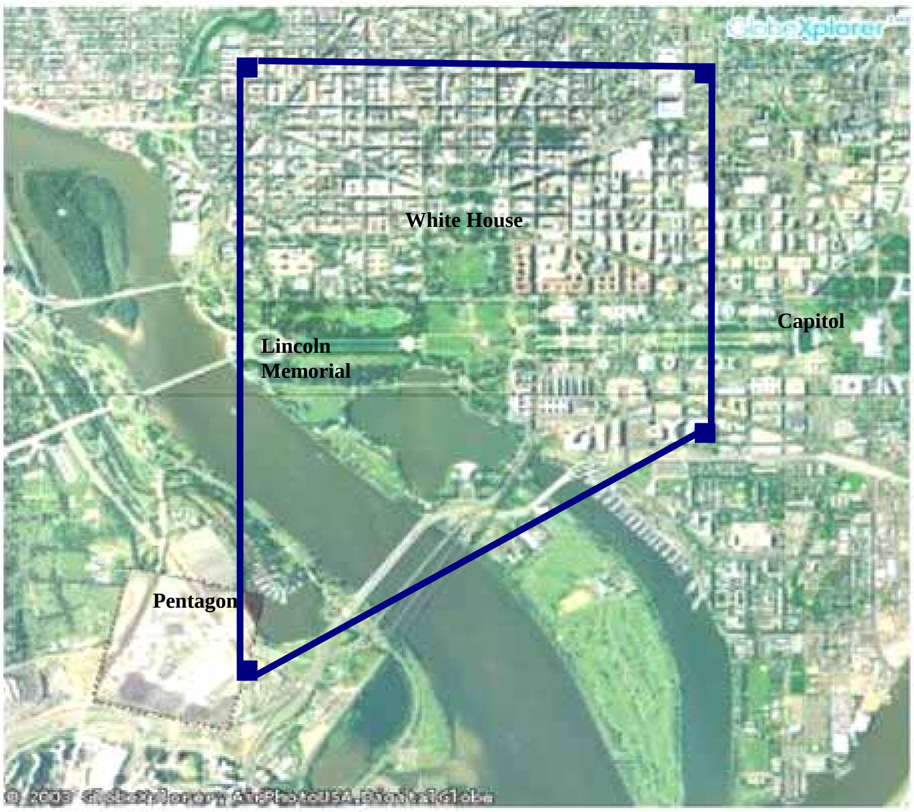
The terrorist attack (September 11, 2001) of the World Trade Center in New York City and the Pentagon in Washington D. C. has firmly highlighted the urgent need for a reliable, uninterruptible, atmospheric wind and turbulence monitoring network to help predict the source location and the airborne path of a chemical, biological or radioactive release. On June 2, 2003, Spencer S. Hsu of the Washington Post reported that:

> *In preparation for a terrorist attack, federal scientists have installed sensors to map wind currents in downtown Washington, Arlington and Silver Spring, the first deployment of a high-tech network to help predict the airborne path of a chemical, biological or radioactive release.*
>
> *A half-dozen aluminum weather towers, each 30 feet tall, have been installed atop government buildings in what officials describe as the most comprehensive wind analysis attempted in any U.S. city. With more towers planned, the sensors are being positioned near sensitive sites – including Capital Hill, the White House, the Pentagon, the Mall, the National Zoo and the National Arboretum – and on cellular relay towers within the Capital Beltway.*

For a large area with irregular terrain, point in-situ wind measurements usually vary greatly and can not be representative for a large area wind field. This is the major reason that the above proposed network needed so many wind towers. **Because of its path-averaged measurements, LOA can provide much more representative wind field for a large area than any combination of the point in-situ measurements provided by traditional anemometers.**

In addition to the measurement of crosswind, the LOA can simultaneously measure path-averaged turbulence refractive index structure constant (C_n^2) between the transmitter and receiver. A reliable measurement of C_n^2 is critical for the modeling of the atmosphere to predict the source location and the airborne path of a chemical, biological or radioactive release. **Because of its remote sensing capability, the LOA can measure wind and atmospheric turbulence where conventional sensors can not reach.**

Using several LOAs to enclose a large area will provide the whole area wind and turbulence field. As an example, using just four LOAs, a wind and turbulence network can be set up as shown in the Washington D.C. area (see photo). **The LOA does not need to be mounted on tall towers, they can be mounted on top of any building or even behind an office window as long as there are visually clear line-of-sight paths. The LOA will measure the crosswind and turbulence between the high buildings where no other sensors can reach.** The LOA wind network could also replace tens of point anemometers. This substantially simplifies the network and communications issues, as now only four sensors need to be connected to the host system, as opposed to dozens. **LOA will provide both crosswind and turbulence measurements that are critical for a high-tech network to help predict the source location and the airborne path of a chemical, biological or radioactive release.**



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