Guest Editorial

The instrumentation of environmental optics: remote studies of the atmosphere

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From the viewpoint of the optical and instrumentation engineer, the instrumentation of environmental optics has two outstanding features: it challenges the instrumentation state of the art, and if successful it is exceedingly useful.

To define the field, we excluded the trivial case of near-classical laboratory optical instrumentation being used for local measurements. Given the history and membership of SPIE, we can further leave out from the discussion the thousand and one photographic, photogrammetric, and TV imaging techniques used to measure ground and marine environmental phenomena.

Instead, we concentrated on remote measurements of our atmosphere, and of man-made additions thereto. It is here that environmental research shows some of its most serious gaps, and it is here that even the most sophisticated existing instrumentation is barely adequate. Such instrumentation is nearly all optical, defining a new field of work in optical engineering, which requires just about everything that existing optical technology can offer.

Given the undeniable technical difficulties of the task, why do we want to resort to remote methods of measurement in studying our atmospheric environment? A number of reasons come readily to mind:

1) *Dangerously aggressive samples.* One of the initial driving forces behind remote environmental instrument development was the chemical warfare detection problem, where local sensors could only inform the operator that he was dead. Remote sensing at any price was clearly justified here, and much of our current technology stems from this effort. Geysers, volcanoes, hurricanes, large rocket or jet engines, are other examples of phenomena best studied from a distance.

2) *Unaccessible observation areas.* The upper atmosphere is a costly place from which to bring back samples, and from the stratosphere on upwards the problem is bad enough to make administrators cry. Sending just a light beam out to the sample, or merely observing it from afar, is often far more cost effective.

3) *Faithful sampling problems.* Reactive or trace samples in the atmosphere will usually not survive unaltered if they must be collected in a container and returned to the laboratory. Remote *in situ* sampling in real time neatly disposes of this problem.

4) *Mapping sample concentrations.* To understand atmospheric phenomena, meteorological interactions, and the behavior of pollutants, we require three-dimensional (and possibly four-dimensional) chemical maps of the atmosphere. Here freely pointing, and if possible range resolving, remote measurements are essential.

5) *Multipoint monitoring.* Air pollution control ultimately demands continuous monitoring of effluents at a large number of points throughout an area. An uneconomically large number of local sensors can be advantageously replaced by a single, pointable, remote sensing device.

The number of variables that can so be measured is rather large. Chemical composition of the atmosphere, starting with water vapor and CO_2, continuing with industrial or military pollutants, and extending to important trace constituents such as hydroxyl and the alkali atoms, can all be determined remotely. So can natural or artificially produced ozone, aerosols, air mass tracer compounds, wind velocities, turbulence, temperature, pressure, and precipitation. And all of this will eventually be available in glorious 3-D, and time resolved, yet . . .

An embarrassment of riches might eventually occur if this became a routine operation. In the meantime, however, existing instruments are marginally sensitive at marginally slow measurement rates, creating a need for extensive technological advances.

This special issue of *Optical Engineering* describes seven different approaches to remote studies of the atmosphere using optical instrumentation.

Several of these are based on the LIDAR (Light Detection and Ranging) principle, an optical analogue of radar in which echoes from a transmitted laser pulse are used for long-distance measurement.

Different optical effects can be used to produce these echoes, affecting both the instrument design and their measurement capabilities. We can thus observe scattering (Abreu, "Lidar from Orbit"), fluorescence (McIlrath, "Fluorescence Lidar") or absorption (Stewart and Bufton, "Development of a Pulsed 9.5 μm Lidar for Regional Scale O_3 Measurement"). A paper on Raman emission (Leonard, "Remote Raman Environmental Studies") will appear in the January/February 1981 *Optical Engineering.*

A different family of instruments uses long-range atmospheric transmission measurements based on interferometric spectroscopy (Herget and Brasher, "Remote FT-IR Pollution Studies," and Baker, "Large Field-of-View Interferometers for Environmental Sensing"). The latter instruments are also suitable for remote thermal emission spectroscopy of the atmosphere and pollution sources.

A last group of papers deals with remote measurement of atmospheric dynamics using high resolution spectroscopy (Hernandez, "Measurement of Thermospheric Temperatures and Winds by Remote Fabry Perot Spectrometry"), or laser Doppler velocimetry (Bilbro, "Atmospheric Laser Doppler Velocimetry: an Overview").

Remote measurements of our environment are essential to a better understanding of this important field of research, and optical technology is a key part of the instrumentation required. Further advances will require extensive efforts by optical engineers, whose interest this special issue is meant to attract.