White light measures atmospheric molecules

Researchers dream of placing a white light at an arbitrary point in the sky instead of having to rely on the Sun or Moon as a light source for spectroscopic measurements.

German scientists have combined a terawatt power lidar method with differential optical absorption spectroscopy to measure the amounts of atmospheric compounds in the atmosphere, including pollutants.

A detailed understanding of the chemical and physical processes in the atmosphere requires a knowledge of the vertical distribution of the compounds and the temperature profile.

Scientists employ two techniques at the moment: lidar, with nanosecond monochromatic pulses; and differential optical absorption spectroscopy (DOAS), with continuous-wave white light. However, these methods have disadvantages: both rely on a white-light source in the sky.

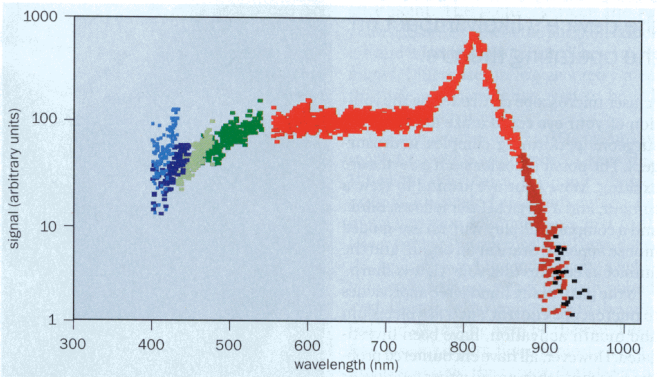
Roland Sauerbrey and colleagues at the Institut für Optik und Quantenelektronik in Jena, Germany, in collaboration with the Free University, Berlin, have demonstrated a new technique with intense near-infrared femtosecond pulses operating at a peak of 800 nm in the terawatt range. The pulses ionize the air and produce a white-light continuum. Employing DOAS, recording the backscattered white light spectrally determines the partial pressure of gases as a function of height. The molecules absorb the backscattering, thereby identifying them and giving their concentration.

White-light continuum

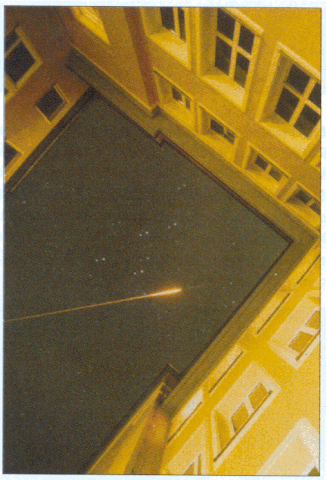
When the terawatt beam passes through the atmosphere, a range of nonlinear effects occur: self-focusing, self-phase modulation, Raman scattering and four-photon mixing. The white-light continuum created extends from 350 to 900 nm (figure 1).

In the confines of a laboratory, the laser beam is deep red in colour and almost invisible to the eye. However, after a distance of about 30 m, a white shining "channel" forms with enough power to reach altitudes of more than 10 km (figure 2).

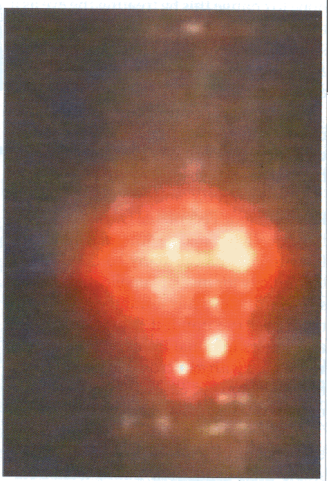
"The main advantage of this method," said the institute's Stefan Niedermeier, "is that it can cover a range of compounds, because white light is used, and not a single laser line, as in conventional lidar methods. Also, height resolution is achieved because a pulsed laser source is used."



1. White glow: spectrum of ionized atmosphere generated by a terawatt pulse.



2. A white-light channel forms about 30 m high.



3. The channels form in the heart of the laser beam.

The team is now looking for the lowest measurable concentration of trace gases.

"To date we have measured the concentrations of major air compounds. With an increasing spectral detection range in the infrared and higher sensitivity, it should be possible to start on trace gases with lower concentrations," said Niedermeier.

He also thinks that the channels could prevent lightning. Physicists are working on triggering and guiding the lightning to a place where it can cause no harm. Niedermeyer has measured the conductivity in the channels and found it high enough to guide lightning, but triggering may require another kind of high-power laser. □