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CO_2 LIDAR SYSTEM FOR ATMOSPHERIC STUDIES

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ABSTRACT

A Lidar facility using a TEA CO_2 laser source is being developed at the ENEA Laboratories for atmospheric studies. The different subsystems and the proposed experimental activities are described.

INTRODUCTION

The Lidar technique has been well recognized as a potential tool for atmospheric studies /1/. Among the various types of Lidar measurements, the DIAL technique is particularly suited for pollution monitoring and measurement of trace constituents because of its high sensitivity and long ranges /2/. The 9-12 μm IR spectral region is rich with specific absorption signatures of many atmospheric pollutants, it is relatively eye safe and the atmospheric trasmittance is high in this region. Coherent (Doppler) CO_2 Lidars also find unique application for precise wind measurements both from ground based and airborne platforms /3/.

LIDAR FACILITY

a) Lidar Transmitter

The Lidar system (Fig. 1) /4/ uses a tunable pulsed TEA CO_2 laser source in the 9-12 μm region as its transmitter. The transmitted beam should have low divergence to minimize the illuminated area. The beam should also have narrow pulse length to improve the range resolution. A laser source with these characteristics has been achieved using the Self Filtering Unstable Resonator (SFUR)/5/ concept. In this configuration (Fig. 2) ,a

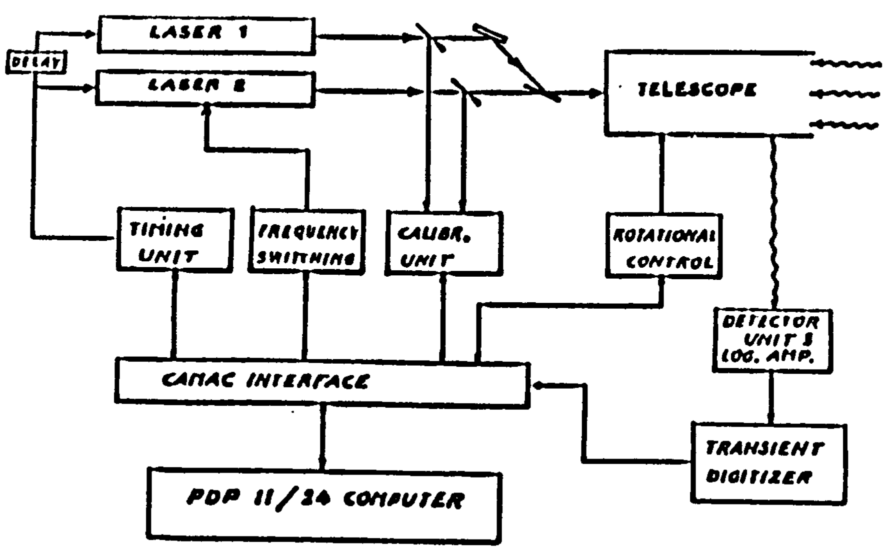

Fig. 1 - Layout of the LIDAR/DIAL facility.

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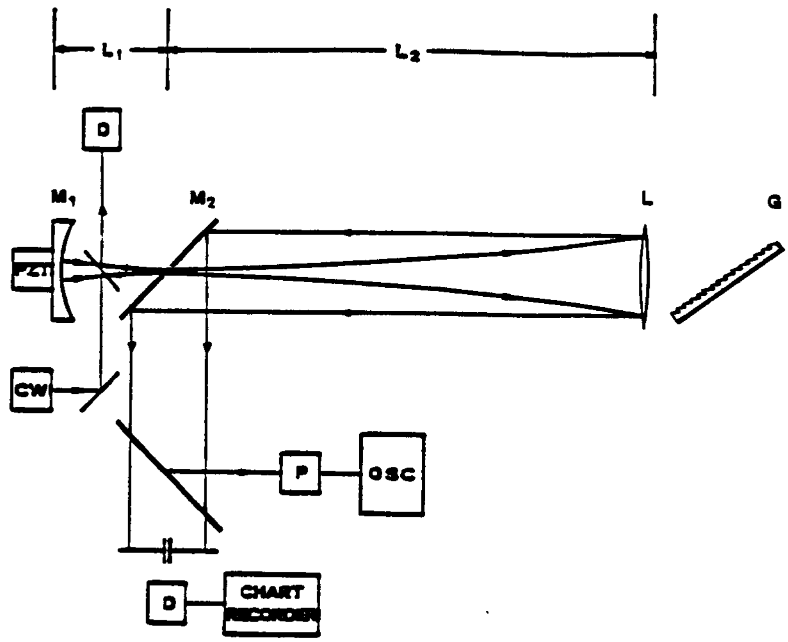

Fig. 2 - The CO_2 SFUR resonator: M_1, M_2 are mirrors; D = pyroelectric detector; P = photon drag detector; C.W. = CO_2 injection laser; PZT = = piezo transducer; L = lens; G = grating.

plane mirror with a suitably chosen hole, placed at the confocal point of a negative branch unstable resonator, limits the output beam to single transverse mode with small divergence. Diffraction at the hole effectively counteracts the focusing action of the negative branch cavity thereby avoiding the hot spot and associated gas breakdown or damage to the optical components. The line tunability of the cavity can be achieved using a plane grating with a lens in front of it (Fig. 2) which replaces one of the cavity mirrors. Alternatively a concave grating can also serve the same function. However, a major problem in this case is the appearance of astigmatism in the output beam: work is under way to correct this aberration. Single longitudinal mode locking has been achieved by injection of an external CW CO_2 laser. Insertion of an intra-cavity low pressure section is under way. The measured parameters of the laser source along with other Lidar system parameters are listed in Table I /6/.

b) The Receiving System

The signal backscattered by the naturally occurring aerosols in the atmosphere (for range resolved measurements) or returned by a calibrated or topographic target (in path averaged measurement) is collected by a telescope (Fig. 3) and focused on the HgCdTe (SBRC) detector cooled to lN_2 temperature. The detected signal is amplified and fed to the data processing system.

c) Data Processing System

The analog signal from range resolved measurement is digitized by an 8 bit transient digitizer (Transiac) at a sampling rate of 100 MHz and stored in the computer (PDP 11/24) via CAMAC data acquisition system.

TABLE I - CO_2 LIDAR/DIAL SYSTEM

Laser source:	TEA CO_2 grating tuned	$\lambda = 9 \div 11\ \mu m$
	Pulse energy	$E = 2.7$ J TEM_{oo}
	Pulse width	$\tau = 80$ ns
	Pulse repetition rate	$f = 1 \div 5$ Hz
	Beam divergence (half angle)	$\theta = 0.65$ mrad
Receiver:	Telescope	
	Newtonian	d = 33 cm
		f # = 3
	FOV (adjustable)	≈ 1 mrad
	Detector: HgCdTe	@ 77 °K
	Area	1x1 mm^2
	NEP (band integrated)	$10^{-8} \div 10^{-12}$ W

Data Aquisition System

Transient digitizer	a)	Tektronix mod. 7912 Sampling rate 1 GHz
	b)	Transiac Sampling rate 100 MHz Resolution 8 bit CAMAC interface with PDP 11/24 computer.

In the case of path averaged measurements using targets the return signal is digitized by Tektronix 7912 transient digitizer having a sampling rate of up to 1 GHz. The CAMAC system also controls the measurement cycle, telescope movements and other instrument settings.

d) Calibration

Since the Lidar system employs the backscattering from the aerosols to provide the return signal, precise knowledge of the aerosol backscattering coefficient β is necessary at the different CO_2 wavelengths. In order to obtain

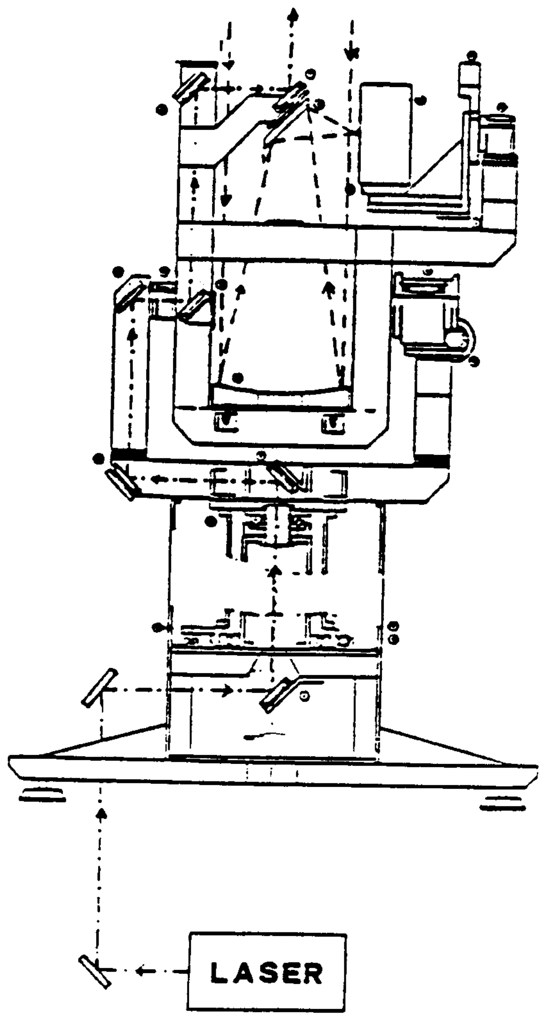

Fig. 3 - Telescope

this, the Lidar system has to be calibrated with targets of known reflectivity. We are planning to make measurements of the reflectivity ρ* and its spectral and angular dependence with various targets, such as flame sprayed Aluminium, flowers of sulfur, Silicon Carbide sand paper which are expected to be Lambertian surfaces,in the 9-12 μm region.
The Lidar beam will be directed horizontally through the atmosphere to obtain backscatter coefficients of aerosols well below the boundary layer. Such measurements will also be used to study the amplitude and phase perturbations to the propagating beam introduced possibly by atmospheric turbulence using optical image processing techniques.

e) Absorption Measurements
For the Differential Absorption Lidar (DIAL) it is necessary to know the different absorption cross sections which depend on the laser line shape, pressure broadening effect and interference. An experiment to introduce a cell containing the desired gas at controlled pressure into the laser beam path and to measure the absorption coefficient at different CO_2 laser wavelengths is being set up. Preliminary measurements for ozone will be reported.

f) Wind Measurements
It is planned to incorporate heterodyne detection in the future whereby the Lidar can measure wind velocity to a precision of the order of a m/s. Coherent detection also improves the sensitivity of pollution measurements and increases the range.

REFERENCES

1) - D.K. Killinger and A. Mooradian: in "Optical and laser remote sensing" eds. Springer-Verlag (1983)

2) - R. Baumgartner and R.L. Byer: Opt.Lett. 2, 163 (1978)

3) - J. Bilbro et al.: Bull.of the American Meteorogical Soc. 65, 4, April 1984

4) - R. Barbini et al.: paper presented at X Int.Conference on Infrared and Millimeter Waves, Lake Buena Vista (USA), December 1985, Conference Digest p. 71.

5) - P.G. Gobbi and G.C. Reali: Opt.Comm. 52, 195 (1984)

6) - R. Barbini et al.: paper presented at Lasers'85 Conference, Las Vegas (USA), December 1985