26PA9 REVISED VERSION OF A RAMAN LIDAR FOR REMOTE MONITORING OF ATMOSPHERIC EMISSIONS FROM PLANT STACKS

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Urgent needs for better and more efficient control of the quality of the environment permanently imposes new and more strict requirements on the techniques and facilities for ecological monitoring. Worsening of the general ecological situation in big industrial centers in Russia and other states of the FSU obseved during recent time has stimulated an increased interest in the development and arranging of new systems for monitoring the air quality and the intensity of atmospheric emissions from organized emission sources. It is noteworthy that the interest in such systems is shown not only by municipal authorities but also by directorates of individual enterprises.

Most attractive, in this connection, are the means of remote monitoring of the emissions. From the standpoint of technological applications such means would allow the control of the emissions at the end of a technological process, that is after possible transformations of the exhaust gases inside a stack. It is important that a single Raman lidar, if properly located, can provide for surveillance of several emission sources in turn. Moreover, a single mobile station of ecological monitoring equipped with a Raman lidar can give the municipal authorities a possibility of keeping all the plants of an industrial zone in a constant tension relative to maintenance of the proper technology.

From this point of view it can be stated that in Russia we have a situation when public interest in the environmental protection stimulated, to a certain degree, the second birth of the Raman lidar as a mean for remote control of contaminating gases emission from plant stacks.

As known a Raman lidar is a device that enables one to perform Raman spectroscopy of a remote scattering volume when using pulsed monochromatic radiation for exciting the Raman scattering process. It is characteristic of the Raman scattering process that the spectrum of scattered radiation contains Raman bands of most of the contaminating gases present in the scattering volume simultaneously with the Raman bands of nitrogen and oxygen, the main atmospheric constituents. Quantitative information about the content of contaminating gases is normally obtained in the form of mixing ratios after normalizing the intensity of their Raman lines by the intensity of that from nitrogen, with the account for relative cross sections of corresponding gases.

However, Raman-lidar technique, being very simple in data interpretation, requires quite sophisticated instrumentation to be performed. An extreme weakness of the Raman scattering process is the main feature that imposes some specific and very tough requirements to the optical arrangement and components of a Raman lidar facility. Table 1 presents a summary of most important requirements and the ways to meet them.

Block-diagram of the Raman lidar is shown in Fig.1, and its main characteristics can be found in Table 2. As seen from the figure we were forced to use a nontraditional optical arrangement of the lidar. Thus, for transportation of sounding radiation from a copper-vapor laser to a lidar transmitter we use a monofiber waveguide of fused quartz, like in Ref.1. To make the construction of lidar receiver-transmiter more rigid and stable and, at the same time, not very heavy we have designed a matrix optical antenna composed of seven identical parabolic mirrors. Central mirror of the matrix makes up the transmitter with the output end of the monofiber from the laser put at its focus. Six other mirrors work as an optical receiver. Such an optical arrangement of the receiver allows the formation of the lidar spectrometer entrance slit to be performed of the output ends of the receiving monofibers from each mirror of the matrix that, in turn, provides more narrow instrumental contour of Raman lines isolated with the lidar spectrometer. As a result we managed to built a compact, light weight transmitter-receiver which, at the same time, is enough rigid. As a result of the measures undertaken we managed to efficiently suppress the cross-talk between Raman lines and the line of unshifted scattering and blocking filter fluorescence. Thus the measured value of contribution from the broadband fluorescence of a blocking filter did not exceed 10 of the intensity of elastic scattering line. Of course such a spectral purity of isolated Raman lines is insufficient for detecting air pollutions at the level of maximum permissible concentrations in the background atmosphere, but it is quite enough for detecting and measuring number densities of contaminating gases emitted into the atmosphere from stacks.

This version of the Raman lidar have been tested in field measurements to monitor the atmospheric emissions from stacks of electric power plants in Ulan-Ude city and at a steel production plant in Novokuznetsk city. At present an advanced version of this lidar is under construction and it will be used for ecological monitoring by the municipal authorities of Khabarovsk city.

References

1. Yu.F.Arshinov, S.M. Bobrovnikov, et al., Remote Determination of the Composition, Temperature, and Velocity of Outflow of the Atmospheric Emission from Plant Stacks Using a Raman Lidar, Atmosphere and Ocean Optics, 1992, v 5, No 5, pp. 323-328.

Table 1. Specific features of a Raman lidar

Specific features of using Raman effect	Ways of overcoming the difficulty	How it is done in the lidar described
1. Small value of Raman cross section; low intensity of the Raman-lidar returns.	Increase of receiving aperture area; increase of mean power of a laser.	Use of a matrix of receiving mirrors; use of a Cu-vapor laser
2. Narrow spectral intervals to be isolated; $\Delta\nu \approx \Delta\nu$ of a Q-branch.	Narrow field of view of an optical antenna and use of a polychromator; more rigid mechanic construction and fine alignment of a lidar.	Unstable resonator of a Cu-vapor laser; diffraction grating poly chromator; use of monofiber optical waveguides
3. High level of spectral rejection to supress the on-line light scattering; suppression of the off-band spectral noise induced in the optical components of a lidar.	Use of a combination of a bandpass absorption filter and a monochromator.	Bandpass absorption filter, type OS-11, and a single grating monochromator; use of spectral and angular discrimination of the Raman bands against the fluorscence spectrum of a bandpass absorption filter; removal of the SRS noise, induced in a monofiber by a laser pulse, from the sounding beam.
4. High spatial resolution necessary for proper spatial isolation of return signals from the emission jet at a stack mouth.	Photon counting technique; high count rate of a photon counter.	IBM PC-compatible photon counter with the maximum count rate of 100 MHz; spatial resolution ≈1.5 m; eight independent spectral channels.

Table 2. Specifications of the Raman lidar

TRANSMITTER-RECEIVER:	
Efficient diameter of receiving area (six mirrors of 0.16 m diameter each)	0.39 m
Diameter of transmitting aperture	0.16 m
Focal length of a mirror	0.4 m
Field of view	0.5 mrad
LASER:	
Wavelength of sounding radiation	510.6 nm
Divergence of sounding beam	0.3 mrad
Mean power of sounding radiation	10 W
Pulse duration	10 ns
Pulse repetition frequency	8 kHz
Lifetime of the active element of Cu-vapor laser (gas-discharge tube)	1000 hours
SPECTROMETER:	
Diffraction grating monochromator Width of the instrumental contour	0.4 nm
Size of the diffraction grating	140×150 mm
Transmission	0.6
Number of spectral intervals isolated simultaneously	8
RECORDING SYSTEM:	
Multichannel photon counter with eight channels aqcuired in parallel Number of time gates in each channel	256
Duration of a time gate	10 ns
Maximum count rate	100 MHz

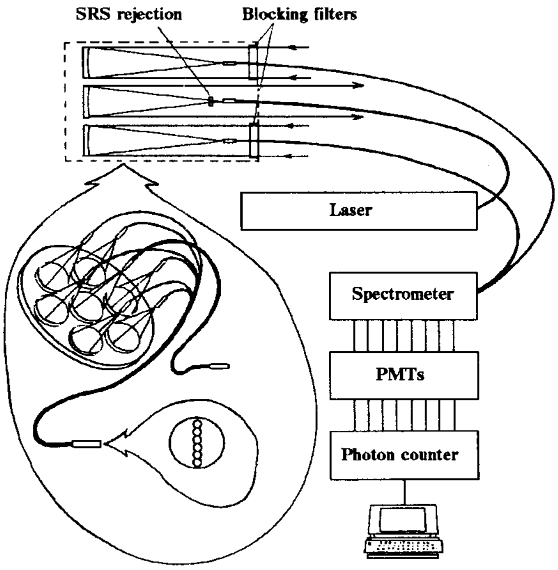

Fig. 1.