Computerized infrared fiber-optic system for gas analysis based on diode lasers.

A.I.Kuznetsov, A.I.Nadezdinsky, E.V.Stepanov.

The Institute of General Physics of the USSR Academy of Sciences, 117942 Moscow, Vavilova 38

ABSTRACT.

One of the modern achievements of fiber optic technology is the development of IR (2-20 mm) optical fibers. Several types of such fibers are available now in the General Physics Institute due to the works of groups, headed by V.G.Artjushenko and V.G.Plotnichenko . For IR fibers fabrication several materials such as chalcogenide and fluoride glasses, as well as thallium, silver and alkali-metal halide crystals are used. These are 0.3-1 mm diameter fibers with optical losses about 0.1-1 dB/m. Although this parameter is far from ideal it is possible now to use such fibers in diode laser spectroscopy having in mind the rapid technological progress.

The main reason for this work was to make the first, experimental iteration to IR diode laser fiber optic spectrometer, to receive concrete experience in manufacturing and exploitation of this device. The present paper is the first short report about this work. The development of this device was based on previous experiments on coupling IR diode lasers and fibers[1,2].

2.SYSTEM DESCRIBTION.

Figures 1,3,4 show the general structure of the system and its time diagrams. System consists of cryogenic module with fiber optical input and output, conventional optical path and electronic box connected to IBM computer.

Cryogenic module (USSR patent 14541977) can be submersed directly into a transport vessel with liquid coolant (nitrogen or helium). On the module cold conduit there are two thermocontrolled seats for laser and photo diode. On the opposite end - the box with preamplifier and electrical connectors. Two optical fibers in a specially protected cables pass directly to the cold conduit without any connectors. Three modifications of this module for different vessel types were manufactured : for big transport nitrogen vessel, for transport helium vessel and for little table-placed nitrogen vessel.

Optical path consists of fibers, gas cell and two lense.

Electronic box provides all the functions necessary for diode laser control and signal processing. It consists of number of modules joint by the eight bit data bus. These modules are:

- interface card that allows direct computer access to the box data bus, and the corresponding card for IBM computer;
- temperature controller, stabilizes diode laser temperature with the accuracy up to 0.003K under computer control;
- laser drive unit, provides the complete control of the laser current parameters shown on fig.2;
- programmable high bandwidth amplifier for analog prepossessing;

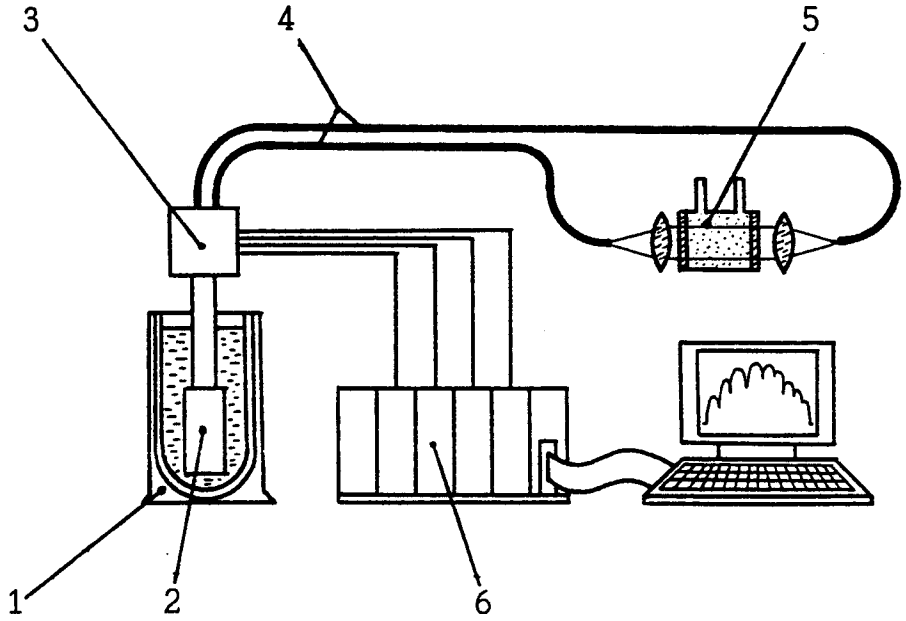

Figure.1. Diode laser based fiber optic IR spectrometer. 1 - nirogen vessel; 2 - diode laser and photo diode; 3 - preamplifire; 4 - optical fibers; 5 - gas cell; 6 - electronic box.

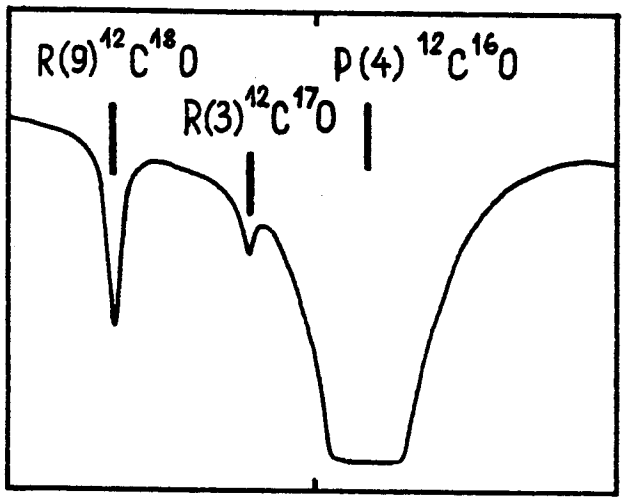

Figure.2. An example of CO natural isotope mixture adsorbtion spectra in the 4.7 μm wavelength, at 27 torr in 85 sm cell.

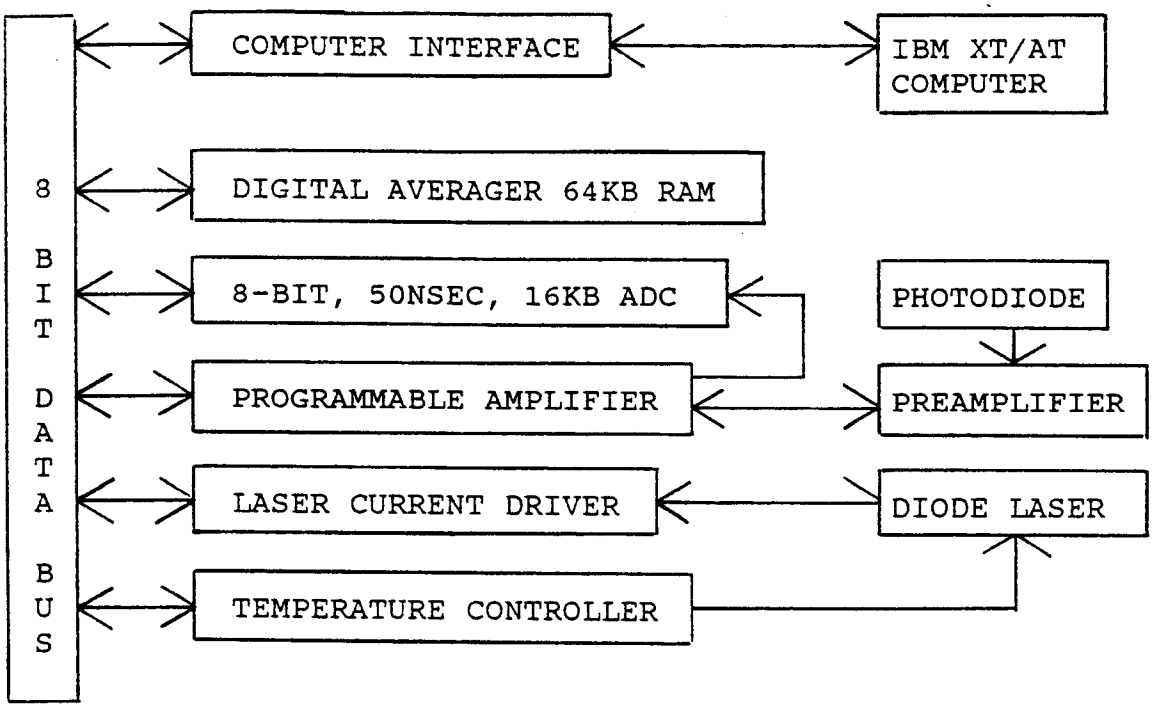

Figure.3.Laser controll and data registration system.

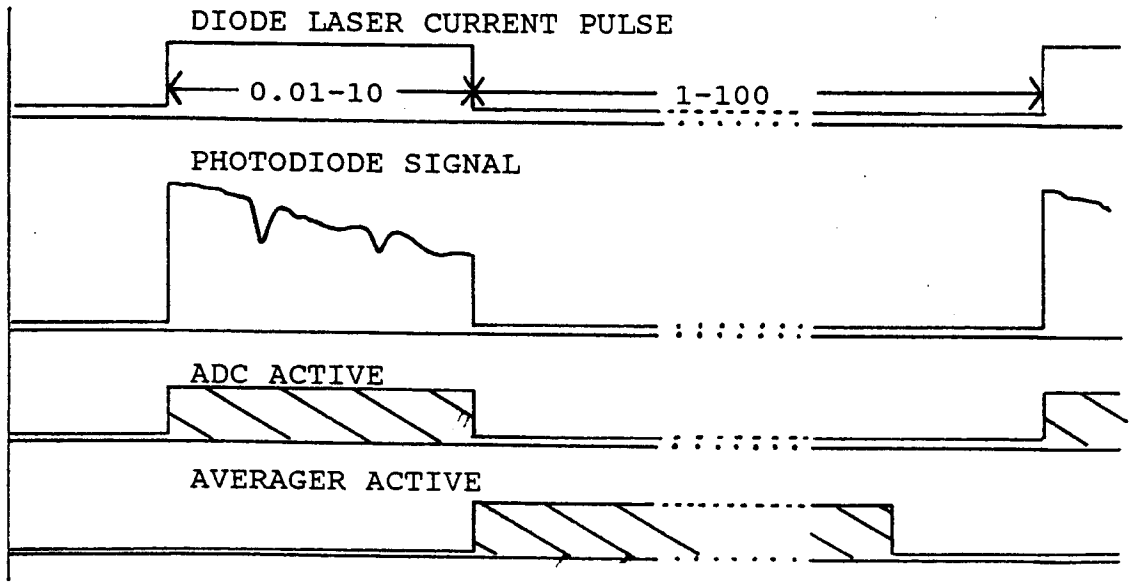

Figure.4.System timing.

- 8-bit 50nsec ADC with 16KB memory;
- high speed digital signal averager with 32bit word length and 16K word memory.

The wavelength range of the system depends on the spectral properties of fiber, laser and photo detector used. The system under consideration included 4.7 microns diode lasers manufactured in The Lebedev Physical Institute of the USSR Academy of Science and InSb photo diodes. Also we have used several modifications of chalcogenide glass fibers transparent in this spectral region.

3.EXPERIMENTAL RESULTS.

Fiber optic systems are much more convenient than conventional optic path systems in laboratory use, and have wide perspectives in application. But there are two maine problems: the optical signal looses and possible interference and feedback effects in fibers. Nevertheless no pronounced features due to these effects have been observed in our experiment. Achieved signal/noise ratio of the order of $5*10^2$ is some were smaller that in traditional diode laser spectrometers but is sufficient for most diode laser applications.

Fig.2 displays an example of molecule spectra registration. In this case 85 cm sample gas cell have been filled with 24 Torr of CO natural isotope mixture. Strong line belongs to CO molecule with main carbon and oxygen isotopes. One can see also two additional spectral lines of CO molecule isotope modification with rare 17 and 18 oxygen isotopes.

Presented system may be used as a multipurpose system for measuring concentration of any component in a complex gas mixtures (for example: CO_2, NO, NO_2, SO_2, NH_3, and H_2S in the atmosphere).

Following possible applications can be considered.

ENVIRONMENTAL PROTECTION. Atmospheric pollution control on the background level. Ecological monitoring of air in cities, countryside and protected woodlands, near big plants and traffic highways.

BIOMEDICINE. Analysis of human breath and disease diagnostic on this base. Sport medicine.

ADVANCED TECHNOLOGY CONTROL. Improving and control of micro electronic and fiber-optic high purity technologies.

NONSTATIONARY PROCESSES INVESTIGATION. Research of exited laser media, plasma-chemical reactions and combustion processes.

4.AKNOWLEDGEMENTS.

This paper presents a complete opto-electronic device, so a number of persons were engaged in this work. It is not possible to mention everybody, but only collectives. Laboratory of Diode Laser Spectroscopy, two fiber manufacturing groups, Design Burro of Institute.

5.REFERENCES

1.V.G.Artjushenko et al.,"Remote Diode Laser Spectroscopy Using IR Fibers", *Proc SPIE "New Materials for Optical Wave guides"*, Vol.799, pp.90-92, 1987.

2.Yu.V.Kosichkin, N.V.Lemekhov, A.I.Nadezhdinskii, S.Penchev, E.V.Stepanov, and A.R.Radionov, "A Diode Laser High Resolution Fiber optical Infrared Spectrometer", *Soviet Physical-Lebedev Institute Reports*, No.12, pp. 36-38, Dec.1986.