WIDE SPECTRAL RANGE IR FOURIER TRANSFORM SPECTROMETER FOR ATMOSPHERIC RESEARCH FROM SPACECRAFT

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Abstract

Fourier-spectrometer has been developed to study the surface and atmosphere of Mars from the orbit of the Mars satellite. Spectrometer comprises two Michelson interferometers, operating with the same electromechanical driver for simultaneous measurements in spectral regions 1.2 to 5 μm and 7 to 50 μm, two detectors on PbSe and LiTa, test channels of monochromatic (l = 0.6328 μm) and "white" lights, a servo alignment system,a thermostabilizing system and a heat-removing wire to cool (190°K) the PbSe detector. The spectral resolution on two-sided interferogram is 1 cm . The registration time for each interferogram is 4.3 seconds. Possibilities of using Fourier-spectrometer for the monitoring of the Earth atmosphere and other applications are considered.

1.Introduction

One of the main area in the investigation of near -earth space is infrared (IR) measurements. Lower atmosphere has got only two narrow transparency windows (3.4 - 4.2 mkm and 8 - 13 mkm), so IR radiation measurements from upper atmosphere in wide spectral range became possible only after launching instruments out of atmosphere. Of a great interest is the investigation the thermosphere where higher 90 km the temperature increases from 200K to 1000- 2000K. Processes in thermosphere results in irradiation in UV, visual and IR spectral range. The most bright illuminance is seen during northen lights (Aurora Borealis). These measurements are limited mainly by the lack of high sensitive instrumentation. It should be mentioned that concentration profiles for NO, CO, H2O, OH may be defined only on base of wide spectral range measurements.

To investigate processes in Mars and Earth atmosphere the wide spectral range Fourier spectrometer was designed in 1991. This Planetary Fourier Spectrometer (PFS) was prepared to be mounted onto spacecraft. Its main designers are State Optical Institute (St.Petersburg), Institute of space research (Moscow) and Technishe Hochschule Wismar (Germany).

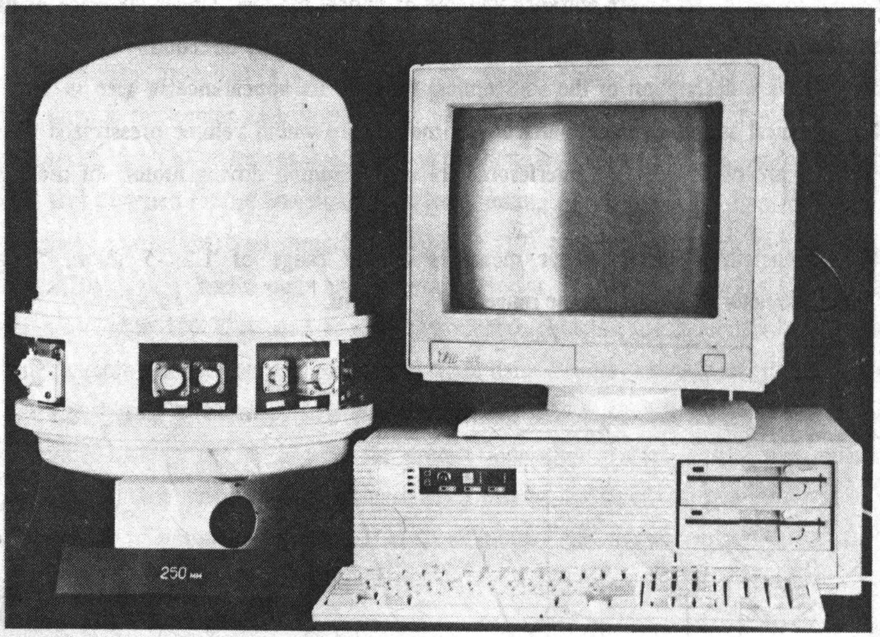

Fig.1.

2.Instrumentation system

Fourier spectrometer consists of :

- optical module (interferometer module),
- controller/processing module,
- pointing system = two mirror scanner + controller.

Scanner is installed just before entrance window of optical module. Under guidance of its controller the scanner is able to point field of view of the instrument at any direction.

Below there is a description of the PFS optical module. Its appearance is seen in Fig.1. Main optical, machanical and electronical parts of the module are within volume pressurized with nitrogen. In it there are two Michelson interferometers with common driving motor of moving mirrors.

"Short wavelength" interferometer measures in the range of 1.2 -5 mkm, "long wavelength" interferometer measures in the range of 7 - 50 mkm.

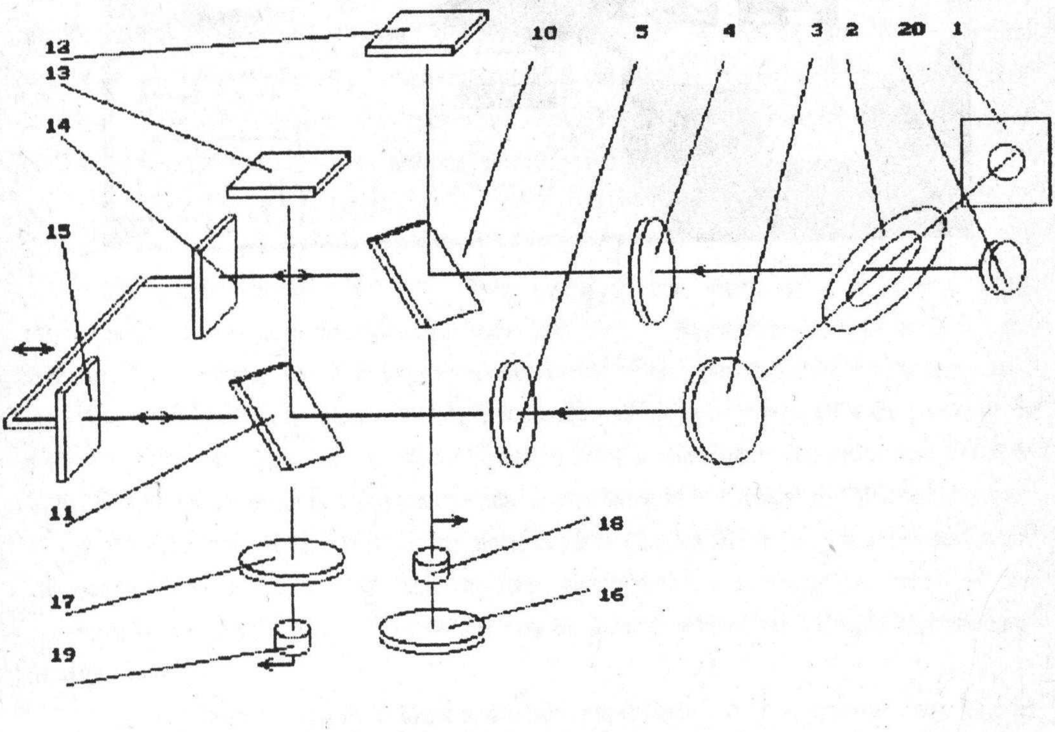

Fig.2. Diagram of the PFS optical module.

Optical scheme of the module is shown in Fig.2. The radiation to be analyzed enters the module through a window in the wall (1). One part of it is reflected from ring mirror (2) comes into the pressurized part of the module through the KRS-5 window onto long wavelength interferometer. This interferometer consists of fixed mirror (12), moving mirror (14) and beamsplitter of CsJ (11). Above orifice in the ring mirror there is a black body with precisely controlled temperature.

The radiation reflected from mirror (3) comes into the pressurized part of the module through silicon window (5) to the "short wavelength" interferometer. This interferometer consists of fixed (13), moving (15) mirrors and beamsplitter of CaF2.

Beamsplitters have got a combination of special coatings to cover the operational wavelength range in the center and visual range at the periphery. The problems of non-selective protective coating for CsJ were resolved. For the first time wide spectral range coating for beamsplitter was designed for the wavelengths up to 50 mkm.

Parabolic mirror (16) and three lens objective (17) of BaF2 concentrate radiation onto detectors (18,19). Long wavelength pyroelectric detector is made of LiTaO3 (18). PbSe photoresistor cooled to 190 K is used as short wavelength detector. Each interferometer has got sources and detectors for reference radiation and white light. Prisms serve to direct this radiation through periferical zone of beamsplitters. HeNe laser of 2 mW is used as reference source. The tungsten filament lamp of 0.5 W is used for precise indication of zero optical path difference. Moving mirrors are suspended on flat springs. They can be displaced at +- 3 mm from zero position by means of linear electromagnetic drive motor. Angular deviation of the mirriros does not exceed 1". Displacement linearity is produced with negative feedback signal from special coil.

Fixed mirror of each interferometer incorporate automatic adjusting device. Optimal adjusment criteria is maximal contrast in reference channel.

The module incorporate several electronic submodules: preamplyfiers of main measuring channels, reference and white light channels, controller of driving motor, laser power supply, lamp power supply, thermal control module and also blocking device.

Described instrument is able to work on board of spacecraft but also in the field and in laboratory. Main parameters of the optical module are given in the table.

3.Main parameters of optical module

PARAMETER	VALUE
SPECTRAL RANGE, cm-1	
short wavelength	2000 - 8000

long wavelength		250 - 1400
RESOLUTION		
without apodisation, cm-1		1.6
MIRROR MOTION, mm		+- 3
SPEED OF MOVING MIRROR, cm/sec		0.14
TIME OF MEASUREMENT, s		4.3
APERTURE, cm2		7
FIELD OF VIEW , rad		
short wavelength		0.03
long wavelength		0.06
WAVELENGTH OF REFERENCE		
SOURCE, mkm		0.6328
NESR, min	W/m2 sr cm-1	
short wavelength		4x10-8
long wavelength		6x10-4

Analysis of these characteristics shows that this instrument may be used for upper atmosphere investigation.

Provided the interchanges of the chosen detectors and the beamsplitters the other required ranges could be covered.

Recently the possibility of the use of multielements detectors in the main channel of Fourier spectrometer was received. This provides the unique feature of the device: simultaneous two-coordinate space resolution (accordingly to one element of the multielement detector matrix) and spectral resolution (by moving of the interferometer mirror).

Application of the described Fourier spectrometer or its modification to the investigation of the spectral features of atmosphere and, particulary the Aurora Borealis, results in the enriched data quantity.