SPACE-BORNE LIDAR "ALISSA" FOR ORBITAL "MIR" STATION

G.F.Tulinov[1], V.Melnikov[2], M.Gitkova[3]
M.L.Chanin[4], C.Malik[4], M.Desbois[5]

1-Institute of Applied Geophysics, 2 - RKK Energia, 3 - NPO Polus (Russia)
4 - Service Aeronomy, 5 - LMD - Ecole Polytechnique (France)

Introduction

In 1996 it is planned to launch "ALISSA" [1] lidar on the "PRIRODA" module to the space station "MIR". This project is being carried out within the framework of Russian-French cooperation program between the RSA (Russian Space Agency) and CNES. Together with usual observations the coordinated observations with other equipment of the "PRIRODA" module as well as observations from a network of ground-based stations are envisaged. While preparing the "ALISSA" mission more effective lasers were developed which in future may successfully be used for the lidar of an "ALISSA" type for space, aircraft and ground-based experiments.

Performances of "ALISSA".

The "ALISSA" project has been initiated in 1985 and was conceived as a simplified fixed and unique frequency lidar, using Mie scattering to detect clouds and aerosols, the primary objective being to study the impact of the altitude determination on the description of the cloud field provided by geostationary satellites. Operations have also been limited to night-time.

The main characteristics of "ALISSA" are as follows:

Emitter: Second harmonic of Nd-YAG lasers ($\lambda=532$nm).

Energy per pulse: ....40mJ.

Repetition rate: ....50Hz.

Natural divergence: ....10^{-3}rad.

Divergence after collimator: ....10^{-4}rad.

Receiver: Cassegrain telescope of area $A=0.12m^2$.

Field of view: ....10^{-3}rad.

Bandwidth of the filter: ....0.5nm.

The analysis of the signal is made by a pulse counting system with a gate of 1s which provides a height resolution $\Delta_z=150$m.

The integration of 6 consecutive pulses to increase the signal to noise ratio gives a horizontal resolution along the satellite track $\Delta_{x,y}$=1km.
The pulse counting system has 512 channels of 1s which can be adjusted at 2,4 and 8s. The emitter consists of 4 synchronously working lasers. The performed calculations show that the expected echoes from different types of scatters are as follows:
cumulus: ~ 300 photons.
cirrus: ~ 30 photons.
tropospheric aerosols: ~ 10 photons.
stratospheric aerosols: ~ 1 photon.
It is evident that an increase in accuracy of observations of cirrus and aerosols is reached due to degradation of spatial resolution of observations.

Peculiarities of the construction and operation of a space lidar.

The peculiarities of the lidar construction and operation are stipulated by the requirements to the space equipment on the "MIR" station as well as by the possibilities of this station to ensure the reliability of the experiment. The main peculiarity of the lidar is its block construction. The lidar consists of the following blocks: block of electronics ((BE)-made in France), optical block (OB) (French) completed with 4 lasers (made in Russia); 4 blocks of laser power supply (Russian) and the system of laser thermostabilization (Russian).

1. BE provides:
- electronic control of a lidar,
- registration and processing of the received signal;
- electric interface of the "ALISSA" lidar with the "MIR" station systems (the system of control of an on-board complex and a telemetry system).

1.1 Electronics control is realized by an operator from a control board on a front panel of the block of electronics. This block is responsible for the choice of modes and parameters of the lidar operation. The operation control is made using display, light and audio signals of emergency situations. The possibility of repair of the block is provided including the replacement of all electronic boards and photomultipliers (PM). There is a set of spare electronic boards and PM.
1.2 The registration of an optical signals made with PM located in the electronics block. An optical signal is fed to the PM through a quartz light guide, 10m in

length. A spare light guide is provided for. A reserve channel is envisaged: the results of measurements are registered simultaneously in the Random Access Memory (RAM) of the BE and in the tape recorder. Information from RAM may be transmitted many times to the telemetry system of the "MIR" station. The cassette with recording is used for receiving information with its subsequent transmission to the telemetric system of the "MIR" station or to the Earth and for its reproduction in laboratory conditions. The cassette may be used many times. There is a set of reserve cassettes on the "PRIRODA" module.

1.3 There are two kinds of interfaces of BE with a telemetry system of the "MIR" station:

- the first interface provides the transmission of digital information (measuring scientific information) from RAM of the BE during the contacts with the ground-based measuring points. Information transmission rate over the digital interface - 4.7 kilobauds, volume - up to 1.4 Mbd. The digital interface has a reserve channel both in the BE and in the telemetry system of the "MIR" station.
- the second interface - analog - is for registration of service parameters when the lidar is operating. This information is registered in the recording device of the "MIR" station telemetry system and then is transmitted to the Earth. The interface with the control system of the on-board complex (CSBC) of the "MIR" station provides reception and execution of CSBC commands as well as the transmission of commands to the CSBC from the lidar. It can be used both by the cosmonaut and automatically. To ensure safety commands are provided for switching off lasers and the whole lidar system from the power system of the "PRIRODA" module.

2. An optical block (OB) is carried to the "MIR" station in a special container by a cosmonaut and is mounted on N 2 window of the "PRIRODA" module. Window D420mm is of two quartz glasses of high transparency (over 90% for λ=532nm). A transmitting optical path has 4 channels for 4 lasers, which are very compact and provide 10 milliJoules/pulse (each). Their life time is about 25 hours or 4.5 millions pulses. The whole laser box is changed when the energy goes below 6 milliJoules. This change should be done without disturbing the alignment beyond limits which can be corrected by the cosmonaut.

Connection of lasers to the system of thermostabilization when they are being replaced is made with hydroconnectors.

3. Four power supplies for lasers are identical and do not require maintenance. The cosmonaut controls their operation visually (from the indication of 4 (on each block) lightdiodes). Every power supply block consumes up to 25A in the pulse mode. Air-cooling of power supply blocks is used. Power supply of every laser is regulated by a cosmonaut, that permits to change pumping energy from 4 to 6 J.

4. The system of thermostabilization is a heat exchanger between the hydrocircuit of the "ALISSA" lidar and the cooling system of the "PRIRODA" module. It operates automatically. The possibility of the change or of addition of cooling liquid is provided. This procedure is made by the cosmonaut.

Scientific and techological objectives of "ALISSA".

"ALISSA" scientific objectives are in first priority to improve the determination of clouds parameters versus the passive radiometric methods: mainly, the cloud height, structure and optical properties. The lidar provides a unique ability to sound several layers of clouds of thin optical thickness (sub-visible cirrus) and gives access to the detection of multilayered and discontinuous cloud structure. As second priority "ALISSA" will be able to detect aerosols at stratospheric height in periods of post volcanic activity, and more generally the tropospheric aerosols. To satisfy these objectives it was planned for "ALISSA" to operate on long sequences corresponding to the crossing of operational meteorological satellite image as METEOSAT in order to compare with IR imagery.

"ALISSA" can be operated also on small scales, mainly in correlation with radiometric measurements taken from the "MIR" platform. Such possibility is offered by the combination of "ALISSA" with other "PRIRODA" instruments.

The combination of "ALISSA" --"PRIRODA" will also participate in specific regional experiments with particular objectives.

For example:

- local experiments using ground lidars and airborne lidars, specifically designed for satellite measurements validation and scale integration problems.
- local experiments for stratospheric studies (aerosols, constituents, temperature).

Such lidar experiments are performed by SA in France and are being planned by the IAG in Russia in the Kislovodsk Observatory (Caucasian mountains). In particular, investigations of the impact of orographic effects on the dynamics and chemistry of the strato-mesosphere are being planned.

The technological objective of the "ALISSA" lidar is the evaluations of future space lidars. For example, on the basis of developments of lasers for the "ALISSA" experiment new, more perfect space lasers with the following parameters were created:

- closed-cycle cooling system with liquid to air heat exchanger,
- possibility of replacement of laser pump lamp without laser realignment,
- external lock input,
- can operate in any premises with usual electric network.

Specifications:

wavelength 532nm

pulse energy 30mJ

repetition rate .... up to 30Hz

laser pump lamp life .... 10000000 pulses

weight (total) 12kg

laser transmitter 1.9kg

dimensions .... 275x380x100 mm

laser transmitter ....50x300x50 mm

power consumption 250W

electric source 198-212V,50Hz,100-120V,60Hz

These lasers can successfully be used when creating space, aircraft and ground-based lidars.

References:

1. M.L.Chanin, M.Desbois, A.Hauchecorne, B.Mege, G.F.Tulinov,V.Melnikov, M.Ivanov.

ALISSA. A French - Russian cooperation in the PRIRODA mission.
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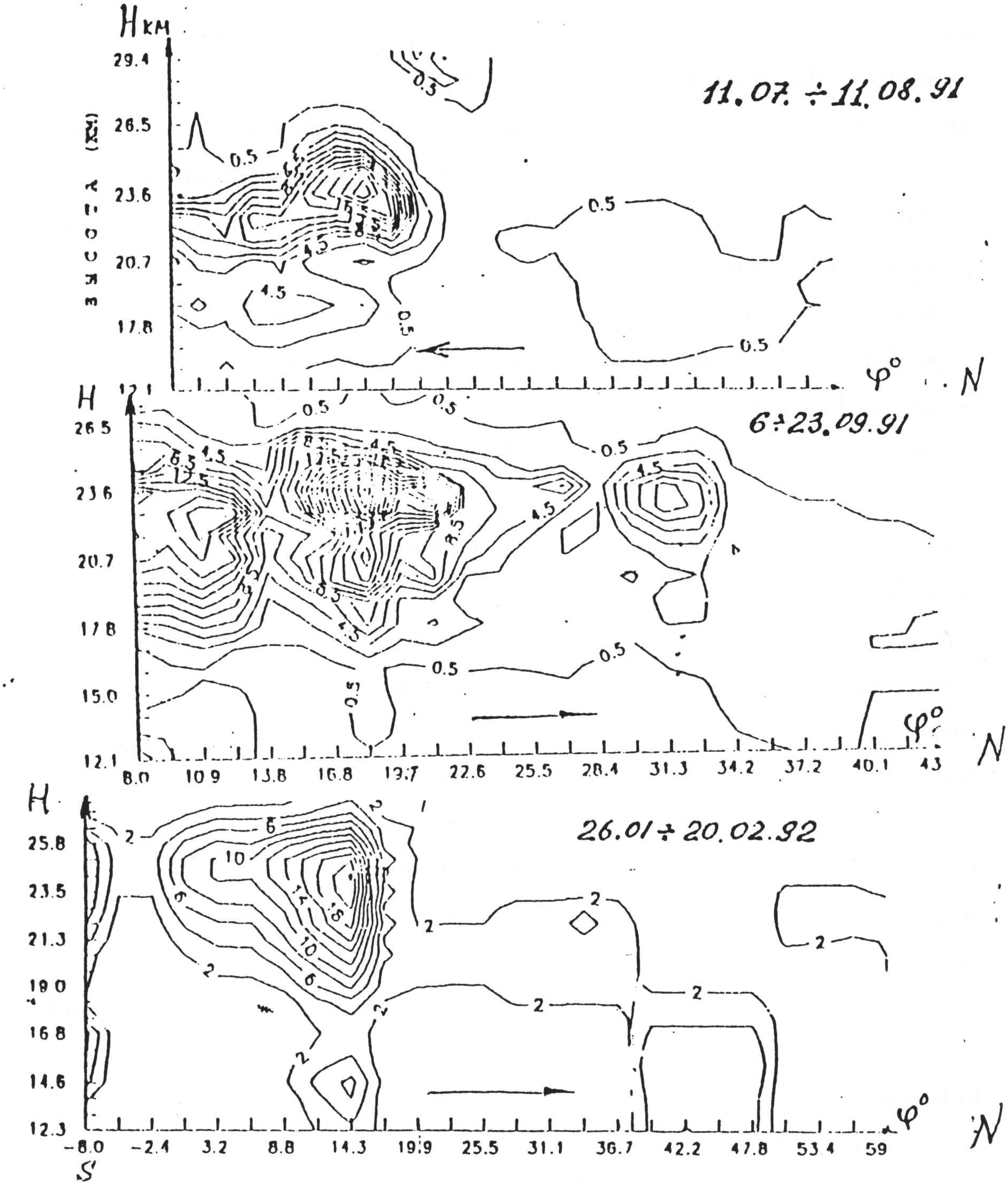

LIDAR OBSERVATIONS OF LATITUDINAL DISTRIBUTION OF PINATUBO ERUPTION PRODUCTS REGISTERED IN DIFFERENT PERIODS DURING THE 51st AND 52nd VOYAGES OF THE RESEARCH SHIP "PROF. ZUBOV" AND RESEARCH SHIP "PROF. VIZE". THE ARROW SHOWS THE SHIP'S DIRECTION.

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G. Tulinov, V. Melnikov, M. Gitkova
(Russia)
M:L. Chanin, C. Malik, M. Desbois
(France)

l'ATMOSPHERE PAR LIDAR
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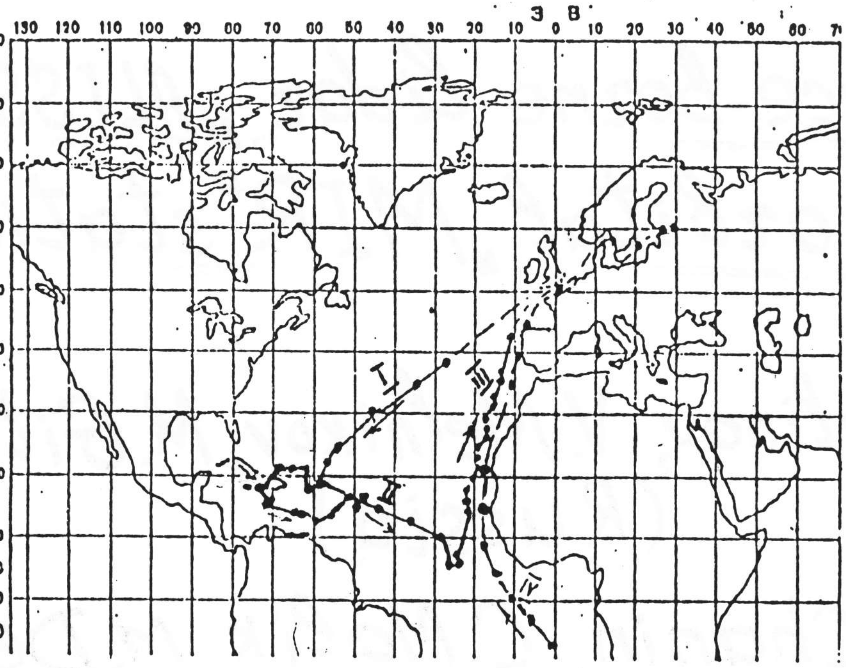
ALISSA



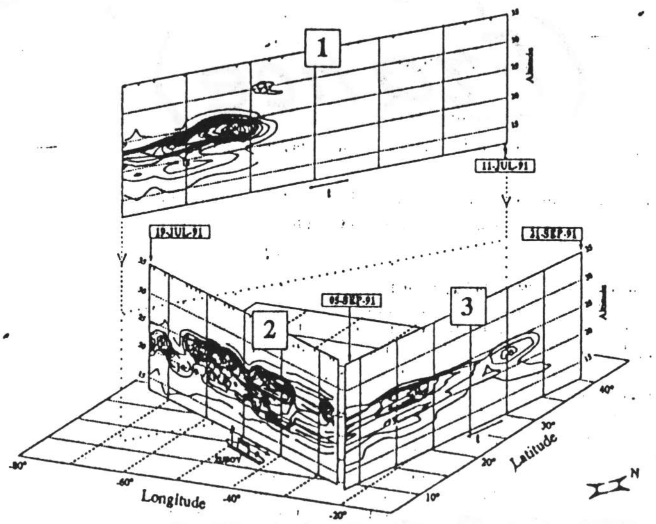


Fig. 1. The extinction corrected scattering ratio measurements from the ZUBOV-51 mission are shown in a 3-panel representation which roughly describes the path of the ship during acquisition of the data. Peak scattering ratios of 50 were observed at 24 km near 20°N latitude.

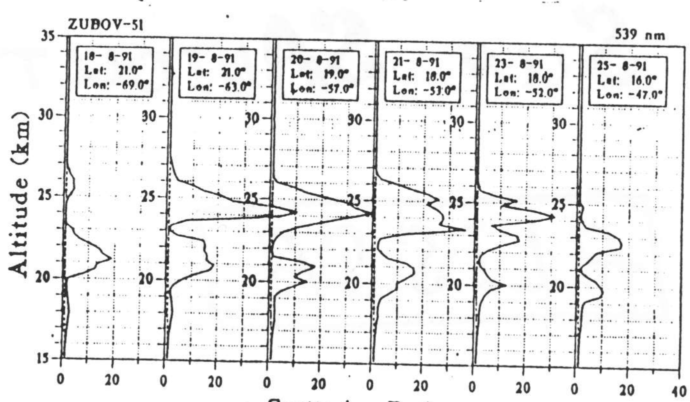
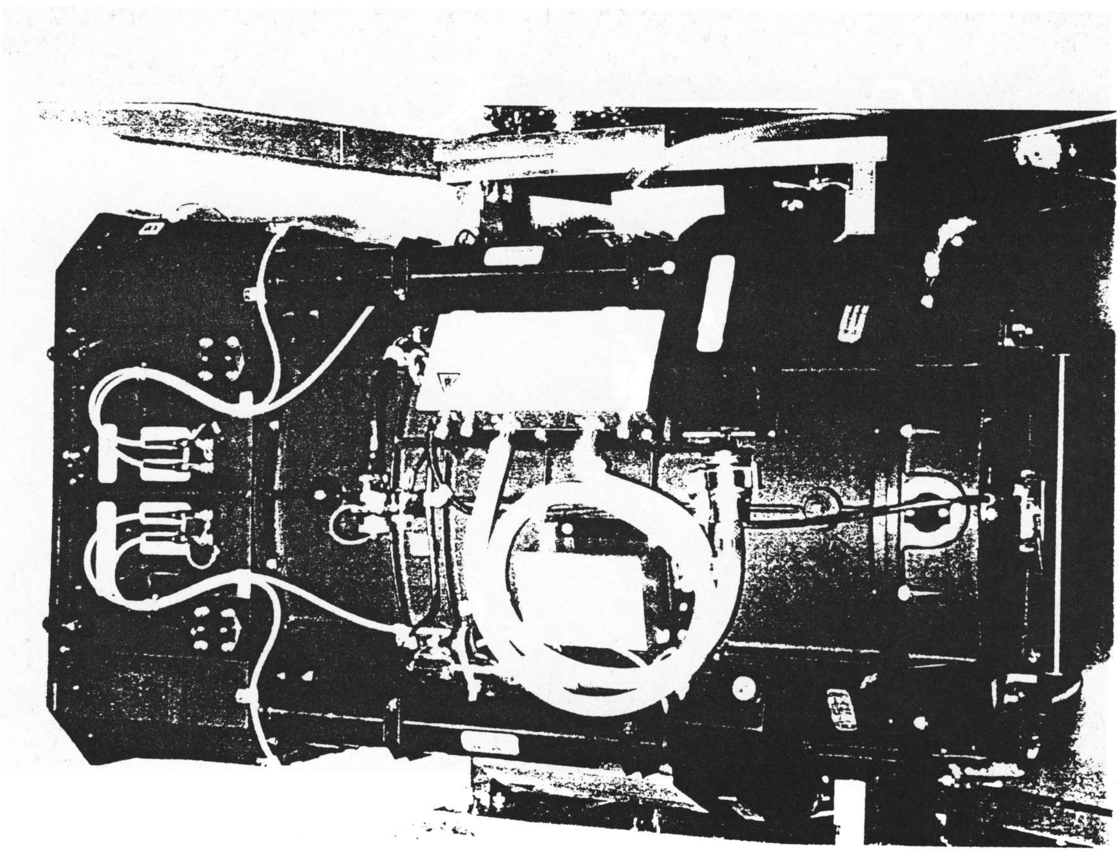
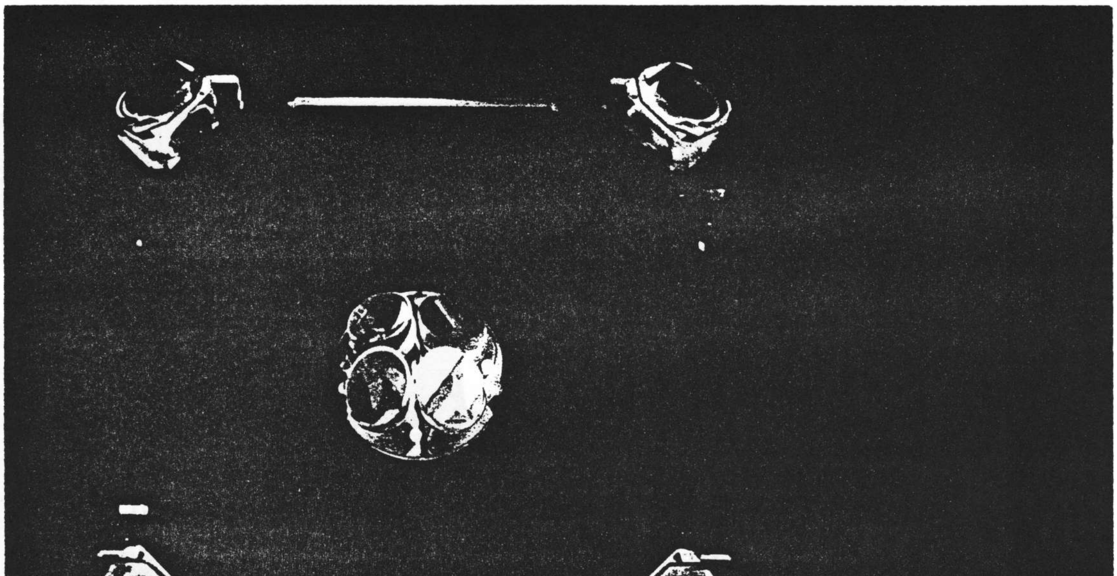


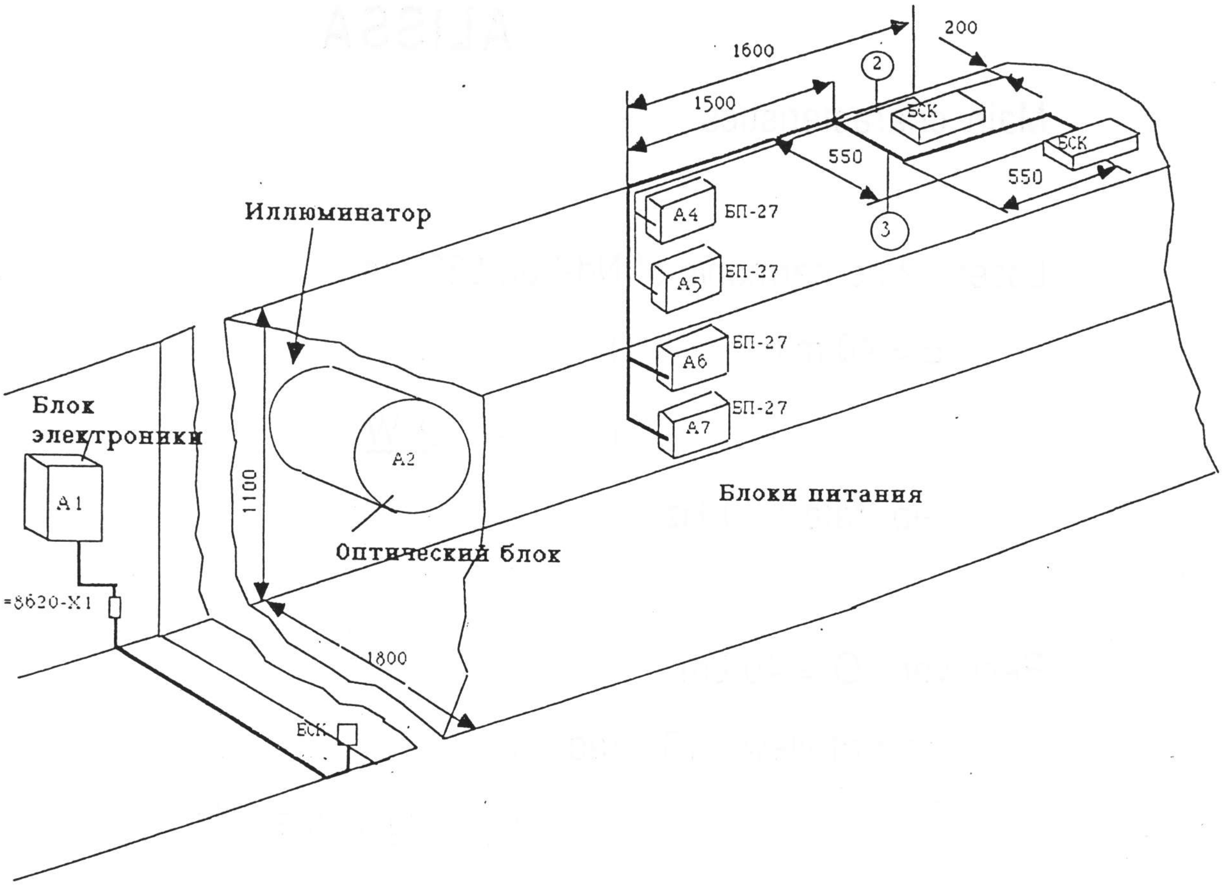
Fig. 2. Several nearly-consecutive nightly mean scattering ratio profiles show a predominant double layer structure as well as a very high degree of variability in the observed magnitudes.

Lidars of Inst. of Appl. Geophisics

Lidar locaton	Heyss Island (80 37`N;58 E)		Kapustin Yar (48 N;49 E)	Ship "Prof. Zubov"	Ship "Prof. Vise"
Measurement technique	Resonance	Rayleigh ahd Mie scattering			Resonance
Constituents measurements	Na 80-100km	ρ; T K (30-80km); aerosols up to 30km			Na 80-100km
Vertical resolution	1200m	300-1200m	300-1200m	600-1200m	600-1200m
Laser wavelength	589nm	539nm	539nm	532nm	589nm
Pulse repetition	0.5 Hz	1 2-30Hz	12-30Hz	12-30Hz	1-5Hz
Laser energy/pulse	0.8 j	350mj	400mj	120mj	1.2 j
Receiver size	0.4 m	1.10m	1.10m	1.10m	1.10m
Field of view	5.10 rad	5.10 rad	5.10 rad	5.10 rad	5.10 rad
Receiver bandwidth	0.5nm	1nm	1nm	1nm	0.5nm
Detector used	PM	PM	PM	PM	PM
Signal processing	-- Pulse counting --				







Расположение блоков лидара "АЛИСА" в модуле "ПРИРОДА"

ALISSA

Main characteristics

Laser : 2 nd harmonic of Nd-Yag 532 nm

E = 40 mJ)

(→ <u>2 W</u>

rep. rate : 50 Hz)

Receiver : Ø = 40 cm

field of view : 10^{-3} rad)

(night time only

band pass : $\Delta\lambda = 0.5$ nm)

Spatial resolutions

$\Delta_z = 150$ m (1 µs)

$\Delta_{z,y} = 1$ km (6 pulses)

Expected echos from different types of scatterers :

cumulus :	>	100 photons
sub visible clouds :	~	10 photons
tropospheric aerosols :	~	10 photons
stratospheric aerosols :	~	1 photon

Necessity for cirrus and aerosols of degrading the resolution.

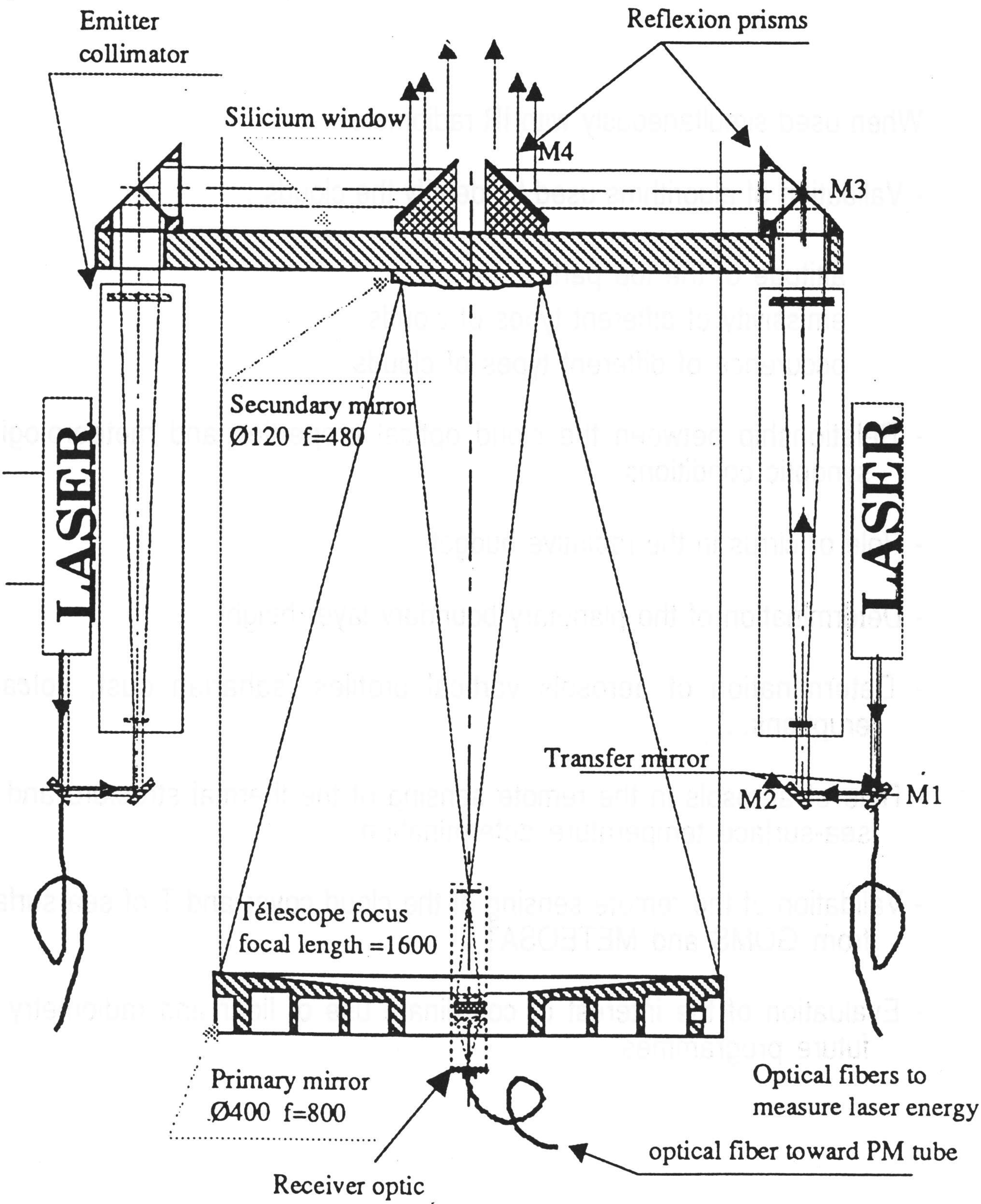


Figure 1: SCHEME OF THE OPTICAL DESIGN

SCIENTIFIC OBJECTIVES OF "ALISSA"

When used simultaneously with IR radiomet⌐

- Validation of algorithms used to identify the clouds :

  altitude of the top part
  emissivity of different types of clouds
  occurence of different types of clouds

- Relationship between the cloud optical properties and meteorological synoptic conditions

- Role of cirrus in the radiative budget

- Determination of the planetary boundary layer height

- Determination of aerosols vertical profiles (saharian dust, volcanic eruptions...)

- Role of aerosols in the remote sensing of the thermal structure and on sea-surface temperature determination

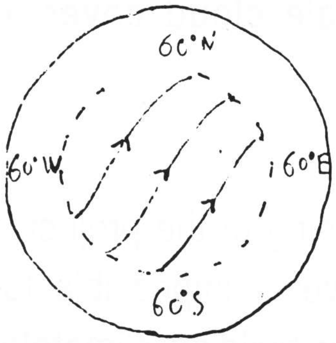
- Validation of the remote sensing of the cloud cover and T of sea surface from GOMS and METEOSAT

- Evaluation of the interest of coordinate use of lidar and radiometry for future programmes

ALISSA 1

Proposed scenario

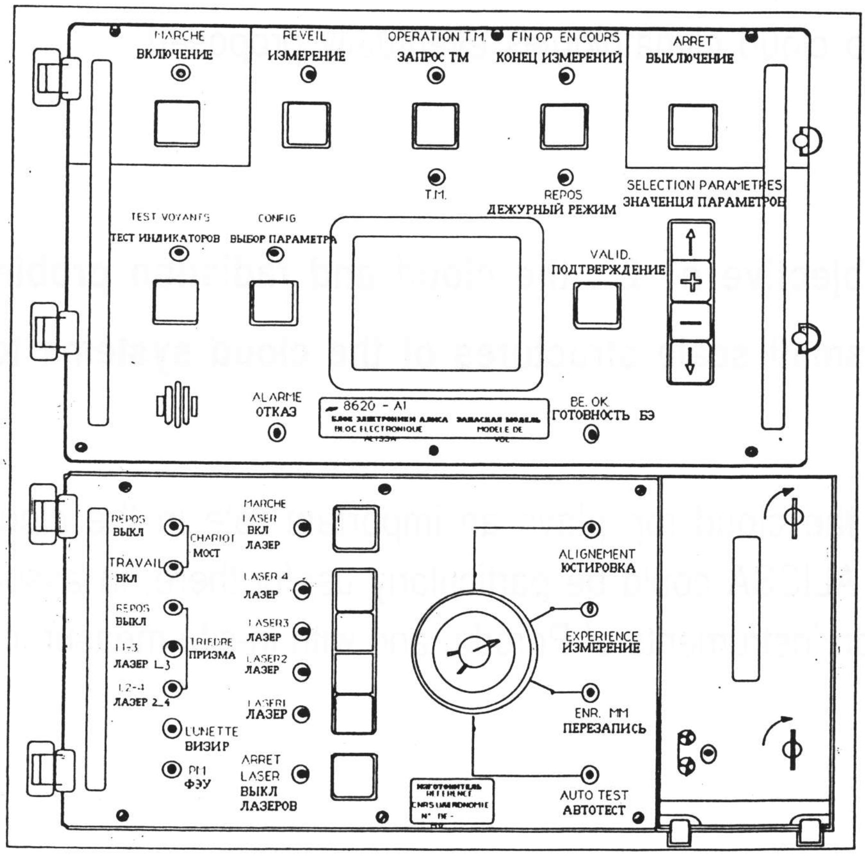
- Describe the cloud situation on 1 or several geographical sites for 4 periods (2 solstices and 2 equinoxes)



- Compare with satellite images obtained with a geostationary satellite

  One image corresponds to 3 or 4 parts or orbit

The expected lifetime of the laser flashes allows the study of ~ 30 such images.



Передняя панель блока электроники лидара "Алиса"

SCIENTIFIC OBJECTIVES

Scientific objective n° 1 : the cloud and radiation problem - improvement of large scale cloud cover and cloud properties restitution

This objective has been, from the beginning of the project, the main focus of the ALISSA instrument. As it is however impossible to use the time-restricted measurements of the lidar for building climatologies, the main aim is here to compare the height restitutions of ALISSA across different cloud systems to what would be produced by "conventional satellites" radiometric cloud properties extraction, as those used in the ISCCP. Errors of the conventional cloud restitutions will be evaluated and corrections to cloud climatologies eventually proposed.

Scientific objective n° 2 : the cloud and radiation problem - small scale structures of the cloud systems tops

Structure of the cloud top plays an important role in the cloud radiation interactions. ALISSA could be particularly useful there, in association with high resolution instruments of Priroda, and with in-situ measurements.

SCIENTIFIC OBJECTIVES (suite)

Scientific objective n° 3 : tropospheric aerosols -boundary layer

ALISSA will be able to detect in certain circumstances tropospheric aerosols (high density desertic aerosols, boundary layer aerosols - by integration over sufficient time -). Comparisons with the passive optical detection will be possible.

Scientific objective n° 4 : stratospheric studies -

Although not really adaptated to stratospheric measurements, the combination of different instruments of PRIRODA in conjonction with stratospheric ground lidar measurements could be profitable for such parameters as aerosols, temperature, ozone...