N94-15619

MARS LASER ALTIMETER BASED ON A SINGLE PHOTON RANGING TECHNIQUE

I.Prochazka, K.Hamal, B.Sopko
Faculty of Nuclear Science and Physical Engineering, Czech Technical University
Brehova 7, 115 19 Prague 1, Czechoslovakia
ph/fax +42 2 848840, tlx 121254 fjfi c, bitnet TJEAN@CSEARN.BITMET

S.Pershin
Space Research Institute,Moscow,Russia

GENERAL

The MARS 94/96 mission [1] will carry, among others, the balloon probe experiment. The balloon with the scientific cargo in the gondola underneath will drift in the Mars atmosphere, its altitude will range from zero, in the night time, up to 5 km at noon. The accurate gondola altitude will be determined by an altimeter. As the balloon gondola mass is strictly limited, the altimeter total mass and power consumption are critical, maximum allowed is a few hundreds grams and a few tens of mWatts of average power consumption, only. We did propose, design and construct the laser altimeter based on the single photon ranging technique.

PRINCIPLE OF OPERATION

The system operation is based on the single photon laser ranging technique : the short and low power laser pulse is transmitted in the nadir direction, the signal reflected from the planet surface is collected by the receiver lens and detected by the photon counting device. The light time of flight is measured. Completing the series of measurements, the altitude, the range to the surface, may be evaluated. The number of individual laser fires needed for one altitude determination is limited by the altitude itself, the background illumination intensity and hence the signal to noise ratio and the balloon gondola vertical velocity. Thanks to the relatively high repetition rate of the laser transmitter (currently 7 kHz, the 25 kHz version is expected to be available in the near future), one altitude measurement may be completed within fractions of a second.

The single photon ranging technique has several key advantages in this application :

* the low power, high repetition rate diode laser may be used as a transmitter,
* the wavelength of such a transmitter well coincides with the maximum sensitivity of the semiconductor photon counting detector,
* no analog signals are treated within the device, all the information is obtained from the statistical treatment of the set of range measurements. This fact is resulting in overall simplification of the device and its performance stability within a wide temperature range. All the electronics may be based on digital, low power CMOS circuits only, what is resulting in low mass and low power consumption,
* the laser ranging system may be used, for the atmospheric clouds, haze and aerosols monitoring, as well.

ALTIMETER CONSTRUCTION

As a transmitter, the integrated laser diode pulser LDI 91 is used. It delivers uniform, fast risetime pulses at 880 nanometers wavelength 100 nanoseconds long with the energy of 2 microJoules. The receiver consists of a Single Photon Avalanche Diode detector package [2], its operating voltage is controlled by a newly designed circuit in a wide temperature range -60 to +20 Centigrade. The diode's quantum efficiency reaches 20 % at this wavelength range. The transmitter and receiver share the same optics of 40mm aperture, the optical path is separated by a polariser. To keep the optics as simple as possible, the diode aperture and hence the receiver field of view is not perfectly matched to the laser transmitter one. By this compromise the optics mass and alignment precision requirements have been significantly reduced on the expense of the energy budget link. The bandpass filter 5 nanometers wide having the transparency of 60% is used to reduce the background illumination. The altimeter electronics consists of a flying time counter having 33 nanoseconds resolution, the programmable range gate generator, the control logic and interface to the board computer.

To facilitate the single photon ranging even under the Mars daylight conditions, the combination of the detector limited field of view, optical bandpass filtering, the adjustable range gate electronics and the data processing software have to be applied. One out of three main strategies may be selected for setting up the range gate :

1. 'Start from scratch' all the possible range gate settings are consequently applied, the echo signal is recognized. This is an emergency solution not requiring any a priori knowledge of the altitude to be measured.
2. ' Morning take off' starts from the range gate interval 0 - 150 meters. It is based on the presumption, that the gondola will take off after the sunrise.
3. ' Routine operation ' the range gate setting is predicted on the basis of the previously measured altitude and vertical velocity. The signal search in the +/- 1 range gate interval may be carried out, if necessary.

GROUND TESTS

To proof the feasibility of the device, the experimental system has been constructed at the Space Research Institute, Moscow and tested in a series of ground test at the Czech Technical University. The ultimate single shot range resolution and the measured range dependence on the echo signal strength (the range bias) have been measured. The LDI91 laser diode pulser, the single photon detection package and a high resolution time interval unit has been used. The results are plotted on Figure 1 together with the return rate. From the single shot range resolution of 4-5 meters one can conclude, that the ranging precision of one meter may be obtained averaging more than 25 returns. The ground target ranging within the ranges 0-3.5 km has been obtained using the optics aperture of 17 mm only. The example of the ranging result is on Figure 2,

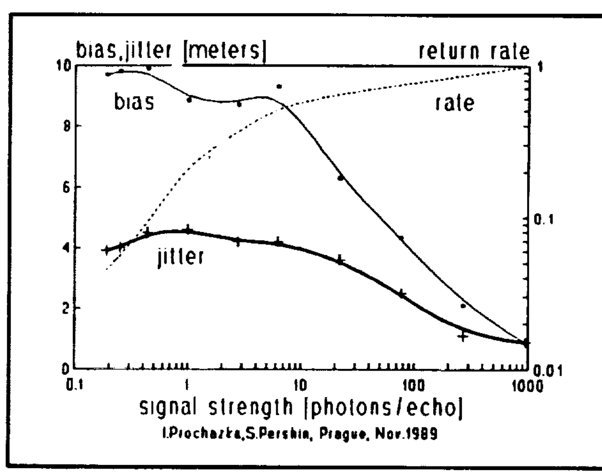
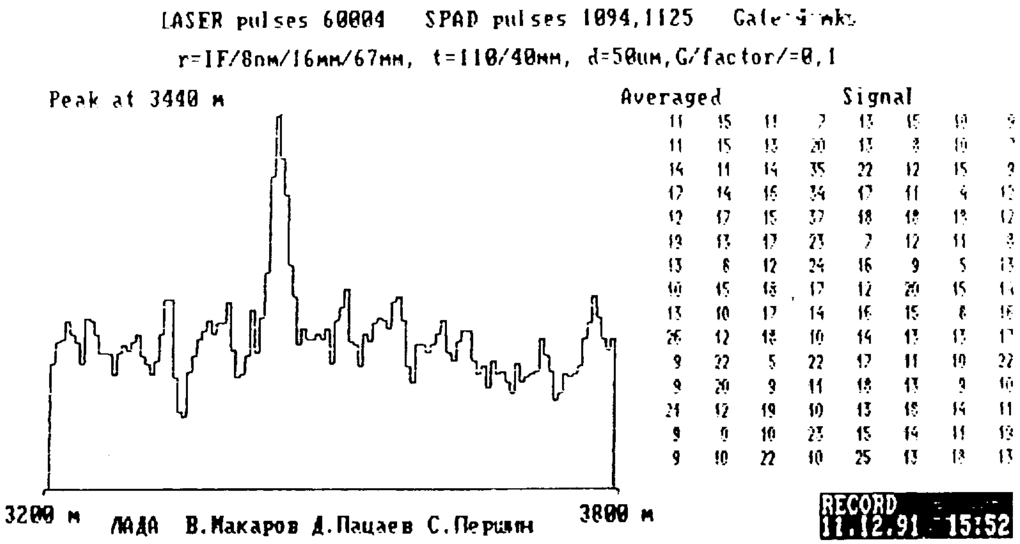
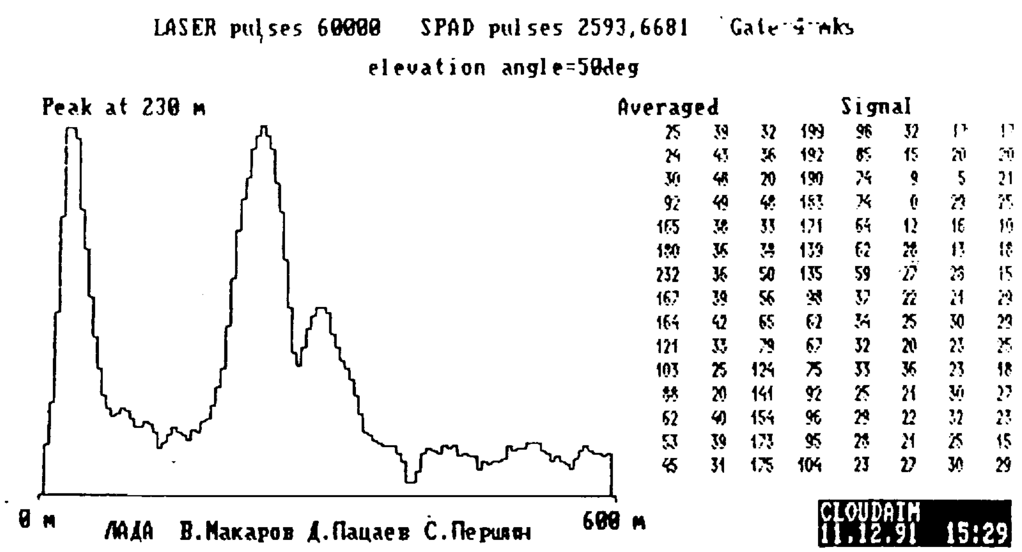


Figure 1 Indoor calibration test



Ground target ranging, 3.5 km distance

Fig. 2



Vertical humidity haze monitoring, daylight multiple haze layer may be seen

Fig. 3

this is a horizontal ranging to the 3.5 km distant target in a light haze visibility conditions. Employing the full 40 mm aperture optics of the final version, the full range will be guaranteed.

The single photon ranging system may be used for the atmospheric transparency/backscatter monitoring [3]. Currently, the proposal, that such a system may be used for the Mars atmosphere monitoring, is under investigations. Either using the independent unit installed in the 'Small Mars Station' [4] or directly from the balloon gondole in the night time, when is it located on the surface and it is not used for altimetry. In another words, the system may be used for the clouds distance and density profile monitoring, as well. On Figure 3 there is an example of the results of the clouds monitoring. The laser rangefinder was pointed to the zenith, the lower cloud boundary and its density profile may be recognized. The clounds may be monitored day and night up to the height of 1 km.

CONCLUSION

The altimeter based on the single photon ranging technique outranged the microwave and Nd YAG laser systems by low weight, low power consumption and the compact design. The mass, dimensions and price of such a system make it attractive not only for Mars mission, but also for mobile, air and space born remote sensing applications. The excellent stability of both the laser transmitter and the single photon detector permits to calibrate the receiver sensitivity to high accuracy and thus to use the system as a precise visibility and surface reflectivity sensor. The applications of a visibility sensor in automated meteo stations, traffic safety, air and ship safety systems seem to be quite promising. In all these applications, the eye safety of the laser transmitter is a significant advantage of the device decsign. The air and space born remote sensing application in agriculture, geology, large area forest monitoring, soil humidity and radioactive Cesium dust monitoring is under consideration.

References

[1] R. Sagdeev, Physics Today, **5**, 30 (1988)

[2] I. Prochazka, K.Hamal, B.Sopko, G.Kirchner, Technical Digest of the Conference on Lasers and Electro Optics, CLEO 91, Baltimore, May 1990

[3] I.Prochazka, K.Hamal, S.Pershin, Capabilities of Single Photon Detection in LIDAR for Atmospheric Studies, International Symposium on Radars and Lidars in Planetology, Cannes, France, Sept. 1991

[4] I.Prochazka, K.Hamal, et al, MARS 94 Mission Backscatter LIDAR for Small Mars Stations, Gound Tests Results, European Geophysical Society XVII General Assembly, Edinburg, April 1992