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The new MTLRS#1 Receiving System

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Abstract.
In this report we are giving a detailed description of the new receiving system of the German Modular Transportable Laser Ranging System MTLRS#1 consisting of a spectral time and field of view filter and a Single Photon Avalanche Diode (SPAD) as single photon detector. The system gives full day and night ranging capability to all satellites with cm accuracy.

1. Introduction

In order to improve the ranging accuracy and the sensitivity of the German Modular Transportable Laser Ranging System MTLRS-1 a major system upgrade was scheduled and performed from Dec. 1990 to July 1991 (P. Sperber et.al.). Together with the exchange of the whole transmitting part (Laser and Start Diode) (P. Sperber et.al.) the installation of a new receiving system was the main point of the upgrade.

The receiving system has two parts, which will be shown in detail

- Filter (Frequency, Range, Field of View)
- Single Photon Detector.

2. Receiving System

To extract reflected photons from the satellite from noise photons which are entering the telescope mainly in daylight, a powerful filter equipment has to be installed in SLR systems.

This filtering in modern systems is realized in three steps

- Range (time interval) filter: A rotating shutter is commonly used to supress straylight during laser firing and to open the detector at the time, the echo from the satellite is expected.
- Field of View: A pinhole ensures, that only light coming from a small angle around the telescope axis can hit the detector.
- Spectral Filter: The most effective filtering process is the filtering in frequency which allows just light of the well defined laserwavelength to propagate.

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The new receiver package of MTLRS#1 is a very compact, field qualified realization of this three requests, deliverd by Technisch Physische Dienste (TPD), Delft, Netherlands.

The setup is shown in Fig. 1.

The light from the telescope is focussed to a field of view pinhole, which is remote adjustable with a motor driven micrometer from 0 to about 30 millidegrees. Connected to the field of view filter there is a rotating shutter, synchronized to the predicted range window, which opens the receiving system 10 times per second for about 3 ms and mainly protects the single photon detector from straylight during laser firing.

The spectral filtering is done by an echelle grating (efficiency: 55 %) used in 7 th order, which gives a bandwidth of 0.2 - 0.65 nm depending on the opening of the filed of view pinhole. The grating has a surface of almost 100 mm top-top in air, therefore the range difference of the beams over the grating surface is not neglegible. To compensate this range difference the grating is used a second time in opposite order. At the end of the receiving package a lens is generating a 8 mm diameter, parallel beam with excellent optical quality.

3. Single Photon Detector

To see the full advantage of the short laser pulses and of the errorfree receiving package a single photon detector with high accuracy is necessary. In the world of SLR two types of high accuracy receivers are used in the moment:

- Microchannel Plates
- Avalanche Diodes.

We decided to install a single photon avalanche diode (SPAD) (I. Prochazka et al.) developed by the Czech Technical University in our system. The reasons for this decision were:

- High ruggedness under field conditions
- High Quantum Efficiency (20 %)
- Low jitter (35 ps)
- Low operating voltage (25 V)
- High dynamic range and neglectable influence of signal strength to the range measurement
- No additional electronics (CFD) between detector and counter.

The housing for the diode has to meet some demands:

- Adjustable in three dimensions in the μm range.
- Possiblity to cool the diode below -10^o C.
- Protection against humidity (condensation).
- Flexible for usage of different types of diodes.

The cooling of the diode is necessary because of the high termal noise (some 100 kHz) at room temperature. The temperature of -30^oC, which is possible with this setup will decrease the noise far below 100 kHz (Fig. 2) and therefor make the search for satellites at night more easy.

To meet all this points, we designed a new housing (Fig. 3) with the following specifications:

- adjustement accuracy in each dimension: $5 - 10\mu m$

- input beam: 5-10 mm diameter, parallel
- optics: effective focal length: 11 mm
- field of view in our system (100 μm diode): 30 mrad
- coploing: to $-30°C$ with peltier cooler and water ($5°C$)
- good mechanical stability under field conditions (temperature change, humidity)

The housing is made from aluminium, the inner moving part which makes the termal isolation of the diode to the housing is DELRIN.

For the fixing of the diode a very special material with high mechanical stability, high thermal conductivity and good electrical isolation was necessary.

To get a thermal equilibrium even at high outside temperatures we decided not only to cool the diode, but the whole fixing plate with powerful peltiers (the hot side of the peltier is water cooled). As some diodes (mainly the diode we use) needs an electrical isolator around it, a material with the mentioned specifications was necessary.

In cooperation with the Material Research Departement of Hoechst AG, a new ceramic material - Aluminium Nitride- was selected. The important properties of this are its high thermal conductivity of 170 W/mk (comparable to pure Aluminium) and its dielectric constant of about 8.5 (good insulator). The powder, together with a sintering aid, are prepared for pressing. The cold isostatic pressed parts, in the form of rough discs, are then turned to improve their finish and a hole is bored in the centre. The binder is then burned out. The samples are sintered at $1840°C$ for 3 h under a nitrogen atmosphere in a special graphite crucible. After the heat treatment the ceramic parts were finished. They were grond with diamond wheels in all directions to get the high dimensional accuracy and surface smoothness for installation of the measuring diode and for the mounting of the peltier elements. The specifications of the material are given in table 1.

Due to the flexibility and the good experience with this housing in the last field campaign it is now also used at the new Wettzell Laser Ranging System (WLRS) for the tests of different diodes.

3. Summary

The new receiving system of MTLRS#1, consisting of a filter package for field of view, time and spectral filtering and a single photon avalanche diode as detector gives the possibility of SLR with cm accuracy during night and day. The whole system is build very modular and flexible, so easy exchange or usage in other SLR systems is possible.

All parts are designed and manufactured in a way, that even under extreme environmental changes in field an adjustement is not necessary.

In the last field campaign the new receiver proved to work very reliable and satisfactory.

References

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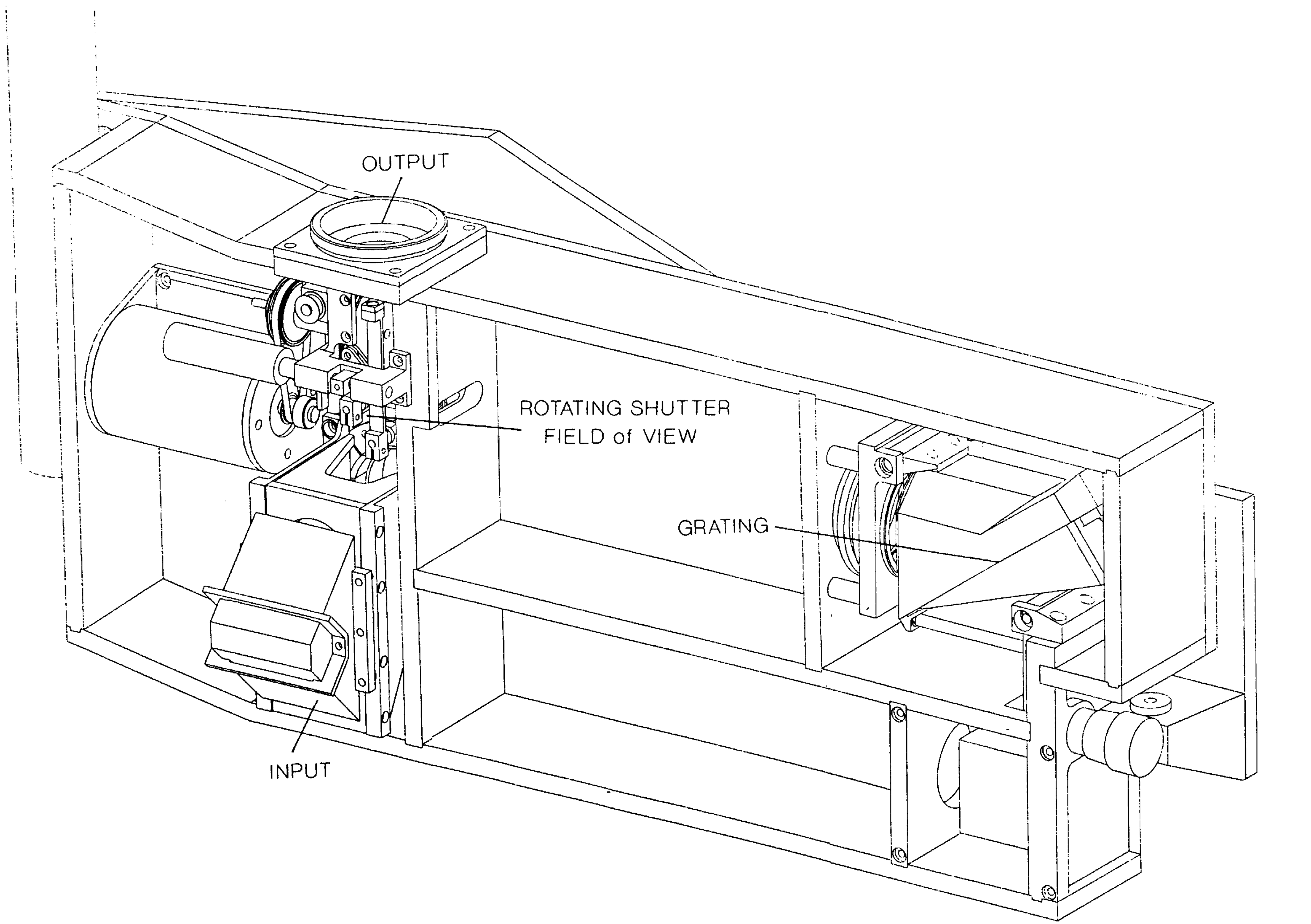

Fig. 1 Mechanical Layout of the MTLRS#1 Receiver Package

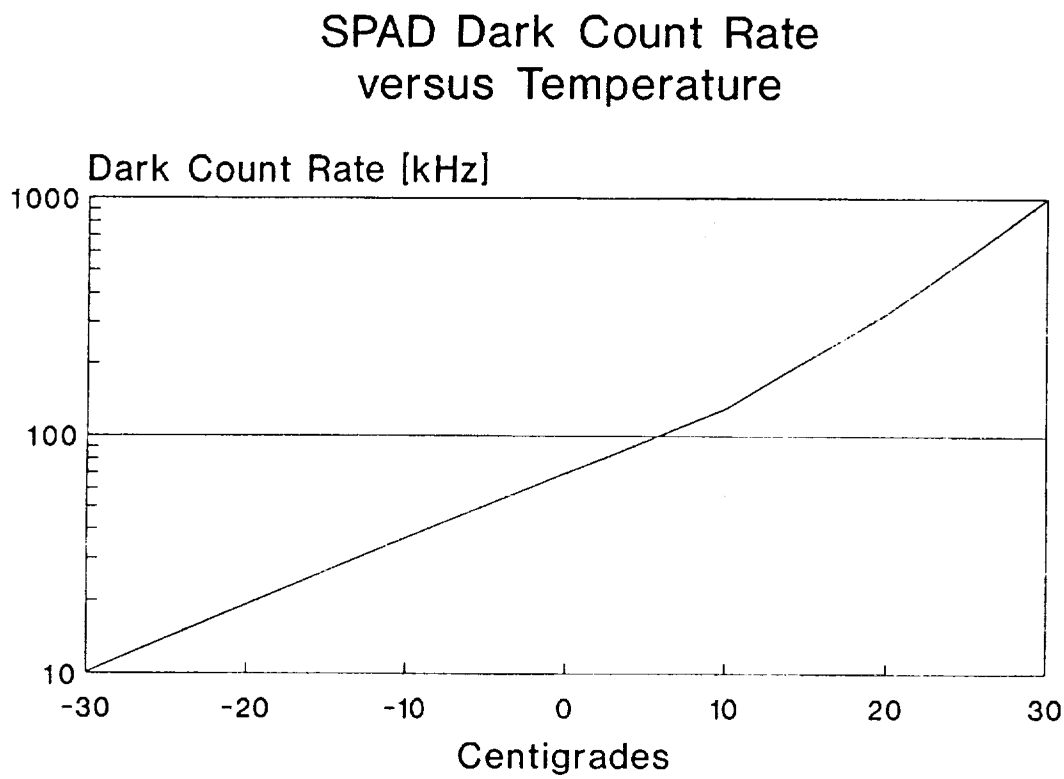

Fig. 2 SPAD Dark Count Rate versus Temperature (2.5 V above Break)

- Density	3,3 g/cm^3
- Termal Conductivity	170 W/m K
- Specific Heat	738 J/kg K
- Flexural Strength	300 - 400 MPa
- Electrical Resistivity	> 10^{14} Ohm cm
- Dielectric Constant	8,5 - 9

Table 1 Specification of Aluminium Nitride

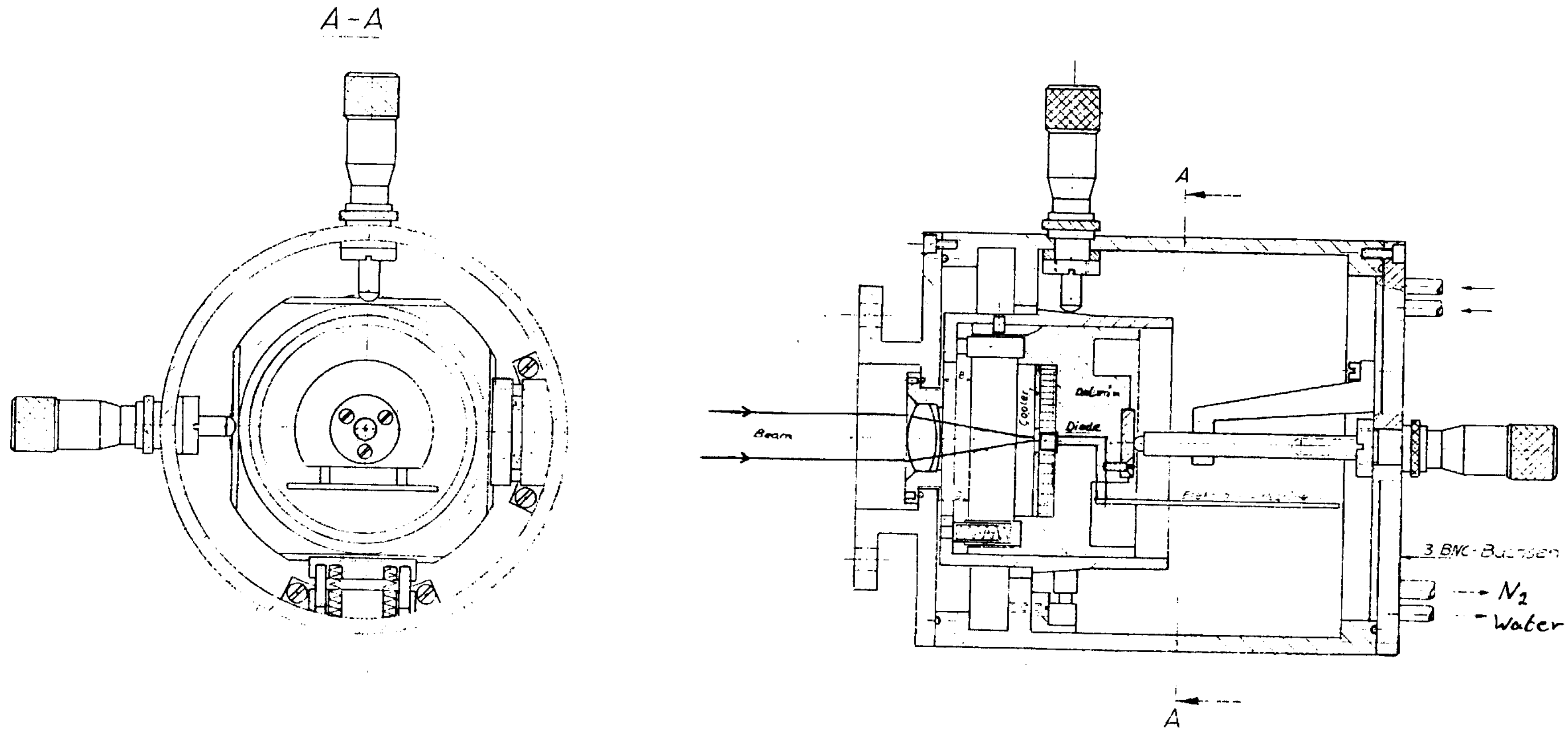

Fig. 3 Housing of the Single Photon Avalanche Diode