An Optical Sensor for DUMAND II - European Version

The DUMAND Collaboration [1]
presented by P.C.Bosetti
Vijlen Institute for Physics, Netherlands

ABSTRACT

We have developed and built an optical sensor for very faint light sources for the DUMAND II Experiment. The sensor is based on a new type of a large area photomultiplier (Philips XP2600). In conjunction with our specially developed read-out-electronics, the sensor provides excellent timing and energy resolution. The module is equipped with its own computer for monitoring and controlling its internal parameters. It is designed for long term operation in the deep ocean.

1. INTRODUCTION

The primary purpose of the DUMAND II experiment is the detection of high energy neutrinos from galactic and extragalactic point sources [2]. In DUMAND II, 216 optical modules (OM) will be deployed at 4760 m depth at about 25 km off the west coast of the Big Island of Hawaii. The modules are arranged in an octagon of eight strings and an additional string in the center. They detect the Čerenkov–light originating from charged secondary particles produced in neutrino interactions in the deep ocean. The OM's are widely spaced permitting detection within a volume of more than $2 \cdot 10^6 m^3$. The OM's have large area, highly sensitive cathode and good collection efficiency enabling them to detect low light from muons at distances up to tens of meters. Furthermore good timing characteristics are necessary for an accurate reconstruction of the origin of the incoming neutrino. An excellent energy resolution, i.e. the possibility to separate one, two, ...photoelectron signals, is desirable for the supression of backgrounds and for triggering purposes. For long term operation in the deep ocean, as planned for DUMAND II, all components of the OM's have to fulfill very high reliability standards. We have developed such an optical module for the DUMAND II detector, which is described in the following.

2. THE EUROPEAN OPTICAL MODULE FOR DUMAND II

2.1 The Photomultiplier Tube

The central element of the EOM is the large area (15") photomultiplier Philips XP2600 ("Smart PMT"), embedded in a standard pressure housing for deep ocean applications. This photomultiplier consists of the combination of an electro-optical preamplifier with a conventional small phototube. Photoelectrons are accelerated with a high voltage ($25kV$) to a scintillator placed in the center of the glass–bulb. This scintillator is read out by a small fast 11–stage phototube (XP2982).

The result of the high acceleration voltage is a high gain in the first stage and essentially 100% collection efficiency over whole cathode area. As a typical value, 30 photoelectrons (PE) are converted in the small phototube for each primary PE. Due to the good statistics in the first stage, the tube provides excellent timing and pulse height (energy herein) resolution at low photoelectron–levels [3].

The energy–resolution on the $1PE$–level is better than 50% FWHM, resulting in the possibility of clear separation between one, two and more PE. This is demon-

HE 7

EOM \2

strated in figure 1, which shows a typical distribution of integrated charge when the tube was illuminated with a blue LED of constant low intensity. A fit with linearly spaced, Poisson distributed Gaussians fits the observed distribution well. Amongst other benefits, this permits an accurate gain calibration of this photomultiplier to be done in situ any time using the dark-current signal originating from thermal emission of photoelectrons from the cathode (see figure 2).

The time–jitter for this tube is $\sim 5ns(FWHM)$ for $1PE$ and decreases as $1/\sqrt{n}$ with n, the number of PE, as can be seen from figure 4, where the measurement of point illumination with a fast green LED with an intrinsic time-jitter of $1.8ns$ is shown. The contribution of transit–time differences resulting from different origins of the photoelectron on the cathode are estimated to be $\sim 1.4ns$ [4].

2.2 The fast readout

The pulse-structure of this PMT can be seen from figure 3, where a typical pulse for a low PE–signal is shown as recorded with an 300MHz FADC. The signal is determined by the decay time of the scintillator, which we have measured to be $\sim 60ns$. This requires the readout-electronics to integrate the complete charge of the induced signal to obtain an optimized energy resolution. Due to the long decay–constant of the scintillator conventional charge to time converters require long conversion-times. Therefore we have designed the system to convert the charge parallel to its collection. As a result, the time of conversion of a pulse is proportional to the number of photoelectrons of the signal. This leads to a small deadtime ($\sim 180ns$) for $1PE$-signals as such as background light in the ocean (K^{40}–decays).

We have implemented two different discriminator thresholds. The first (low threshold) determines the time of the signal, triggering on the leading edge of the PMT-pulse. The second (high threshold) requires the pulse-height to be above a preset level. The circuit measures the integrated charge of PMT-pulses with good linearity and time accuracy. The output signal is an ECL-pulse which can be easily handled in further data aquisition [5].

2.3 System Overview

Signals registered by the large PMT are converted in the readout into ECL-pulses giving both the time of arrival of the signal and the integrated charge. This information is fed into a fibre optic cable, connecting the Optical Module with the local string controller, using an LED.

The module is controlled by a 68301-CPU based computer with an OS/9 operating system. This enables not only downloading software via a 300 baud modem-signal superimposed on the 48V DC power supply line, but also allows for the regulation of relevant OM-parameters. These parameters include the monitoring and setting of the two internal readout–thresholds and the high voltage of the PMT. It also monitors the PMT count rates, the temperature within the module at three different locations, possible water leakage and the internal reference voltages and their currents. The implemented software also constantly checks on the performance of the module and is capable of reporting on alarm conditions [6].

HE 7

3. SUMMARY AND CONCLUSIONS

We have built an Optical Module for the detection of faint Čerenkov light with excellent timing- and energy-resolution characteristics. The module fulfills the requirements for a long term operation in the DUMAND II experiment, designed for the detection of astrophysical neutrino sources in a deep water environment.

It should be noted that such an optical module is also capable of simultaneously investigating and monitoring other light sources in water, offering applications in disciplines such as ocean-sciences, ocean-biology and environmental-studies.

ACKNOWLEDGEMENTS

We are indebted to F.Beißel and V.Commichau for taking major roles in the development of the readout electronics. Special thanks goes to C.Camps for many useful discussions and support in software as well to L.Thollander for improving the design of the electronics and producing the layout of the final circuitry. With the support of T.Boylen, E.Fahrun, U.Keussen and J.Rathlev the production of the optical modules became possible. Last but not least we thank S.O.Flyckt for many fruitful discussions and continuous support.

REFERENCES

[1] Update on the status of DUMAND II. Contribution to these proceedings.
[2] DUMAND Collaboration. DUMAND II — Proposal. Hawaii DUMAND Center, *HDC-2-88*, August 1988.
[3] G.van Aller, S.O.Flyckt, W.Kühl, P.Linders and P.C.Bosetti A "smart" 35cm Diameter Photomultiplier. *Helvetia Physica Acta*, 59, 1119 ff., 1986.
[4] C.H.Wiebusch. Zum Nachweis schwacher Lichtquellen im Ozean mit Hilfe eines neuartigen großflächigen Photomultipliers. *PITHA 91/20.* Diploma thesis, RWTH Aachen, October 1991.
[5] F.Beißel und V.Commichau. A fast charge to time converter V04. Internal report HD04. RWTH Aachen, February 1991.
[6] U.Berson. Entwicklung und Test eines Optischen Moduls zum Nachweis schwacher Lichtquellen in Wasser–Čerenkov–Detektoren. Diploma thesis, RWTH Aachen, February 1993.

FIGURE CAPTIONS

Fig.1 Distribution of integrated charge of PMT-pulses resulting from the illumination with an LED of constant low intensity. Together with the experimental data, a theoretical parametrisation for the contributions of the different PE-signals is shown.
Fig.2 Distribution of integrated charge of the dark current resulting from thermal emission. The fitted gaussian under to the distribution specifies the energy calibration of the PMT.
Fig.3 The pulse structure of a typical low-PE pulse.
Fig.4 Time jitter (FWHM) as a function of the number of photoelectrons. The dashed curve shows the indicated parametrisation.