LABORATORI NAZIONALI DI FRASCATI
SIS – Pubblicazioni

LNF-01/029 (NT)
30 Novembre 2001

NERONE: FIRST TESTS IN SEA WATER

Marco Cordelli[1], Roberto Habel[2], Agnese Martini[1], Luciano Trasatti[1]

[1)] INFN-Laboratori Nazionali di Frascati Via E. Fermi 40, I-00044 Frascati, Italy
[2)] INFN–Sezione di Cagliari, Dipartimento Scienze Fisiche
Università di Cagliari, Cittadella Universitaria
Strada prov. Monserrato09042 – Sestu Km 0,700, 09042 – Monserrato(CA), Italy

Abstract

We have built a prototype of a new instrument designed to measure with high accuracy and without any bias the attenuation length of light in clean water (NERONE). The instrument has been tested for the first time at low depth in the sea during a cruise on the CNR oceanographic ship THETIS on November 6, 2001, and its performance was satisfactory.

PACS.: 06.70.Dn

1 INTRODUCTION

We are working on the measurement of the attenuation length of light in the green - blue range of frequencies in water. This is one of the most important numbers to be measured to design a large area deep sea Cerenkov detector for neutrinos. We know that it lies somewhere around 50 m, but a small difference implies a third power influence on the number of optical modules needed to fill a given amount of water. Somebody said that this number should not be measured in meters, but in million dollars (or EUROs).

Quite a few measurements exist of λ, but more are necessary. For example, talking to oceanographers it appears that nobody can guess at the stability of λ over periods of months and years.

Deep seawater is quite close to theoretical "clean water" in attenuation length, thus making the measurement very difficult.

Many instruments are commercially available for the measurement of λ. However, they are usually designed to handle rather dirty water, to deduce information on environmental variables at different wavelengths. This is the case for the AC-9 that was used by our group to compare different sites[1]. Although extremely accurate, and therefore perfectly adequate for the purpose of comparing different situations, the AC-9 needs, to produce an absolute number, the knowledge of the parameters of "clean water", that must be derived from the literature. This implies an error that is difficult to estimate.

It is possible to design an instrument to measure the attenuation length without depending on the characteristics of clean water. Such an instrument must be capable of measuring the attenuation at different distances in water, thus allowing to derive the attenuation parameters directly.

2 NERO: a laboratory prototype

To prove the feasibility of the idea, a laboratory prototype was built and tested in different types of water. The reflector movement was manual and the data acquisition was performed using a Powerbook G3 equipped with a National Instruments DAQ-card 1200.

The schematic design of NERO is shown in Fig. 1.The results[2] are shown in Fig. 2. The test proved the feasibility of the measurement and, although the water used was not sufficiently characterized, it should be noticed that the data for deionized water and red light are in very good agreement with the literature.

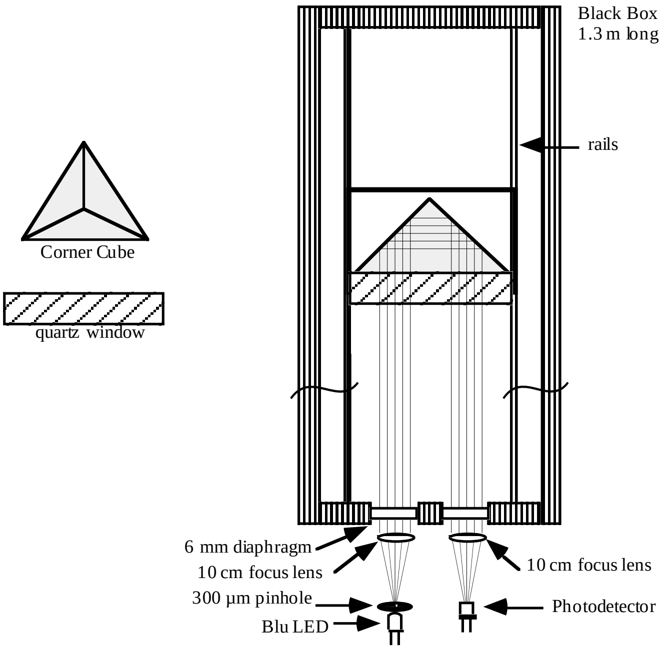

FIG. 1: NERO, the demonstrator for the instrument.

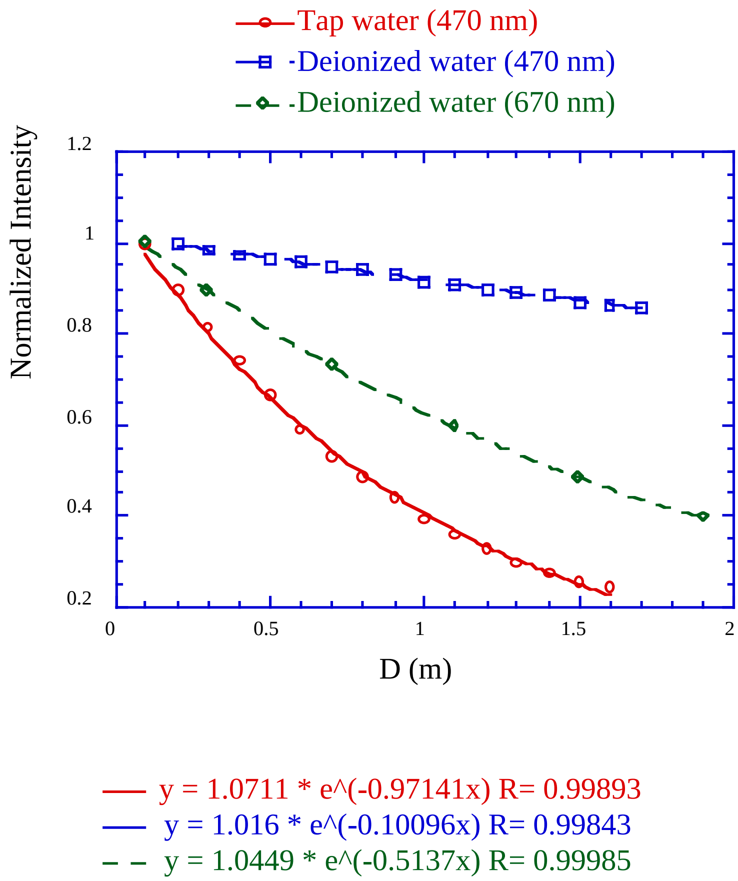

FIG. 2: Results from NERO.

3 NERONE: a seagoing prototype

After these results we built an instrument with optics, reflector movement and data acquisition capable to operate in the sea, although not at the maximum depth. Fig.3 shows the basic principle of the instrument.

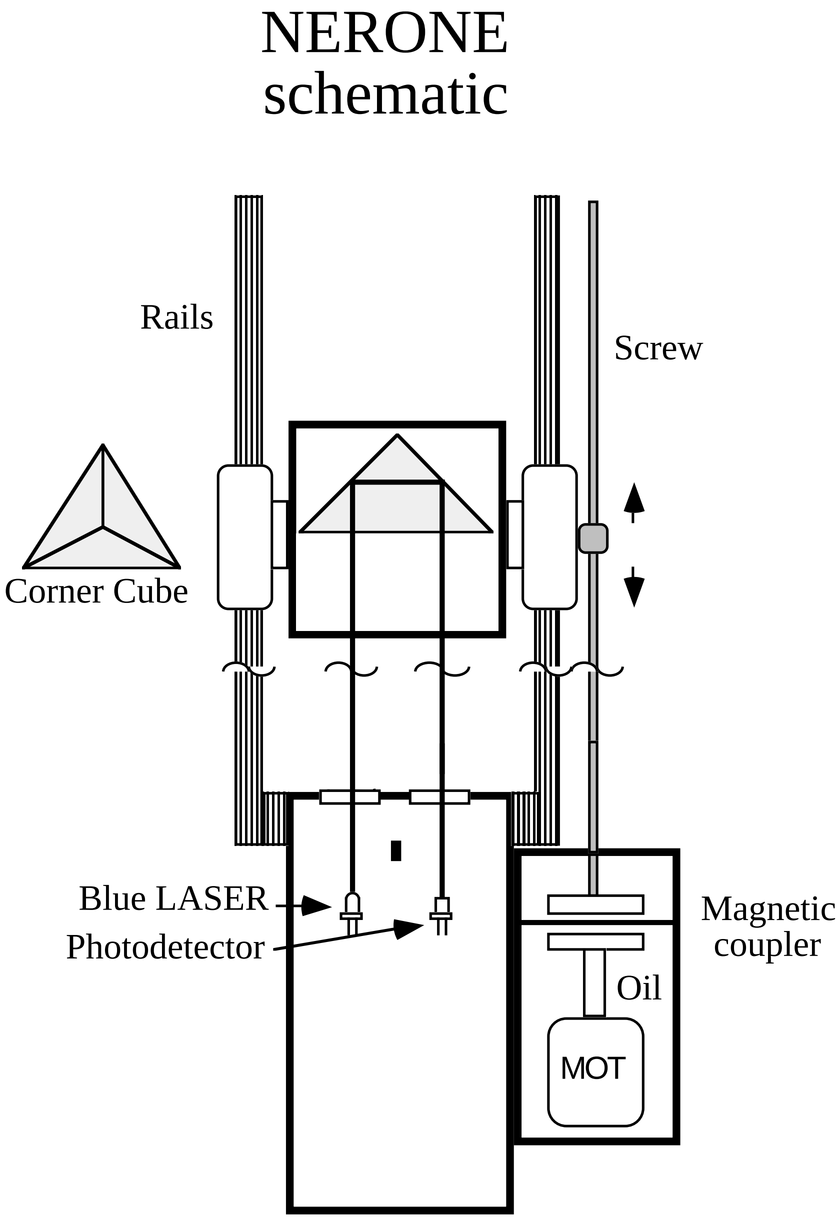

Fig. 3: Schematic diagram of NERONE

One of the hardest problems to be solved for an automated version was the movement of the corner cube, to provide a variable length optical cell. Since it is very difficult to keep high pressure on one side of a rotating shaft, we decided to use a magnetic coupling to eliminate the problem. Fig 4 shows a schematic diagram of the motor assembly. Since the distance between the two magnetic discs must be kept to a minimum to avoid slipping, the separation diaphragm was very thin, and could not accept the pressure difference. Therefore we put oil around and inside the motor, to counteract the external pressure.

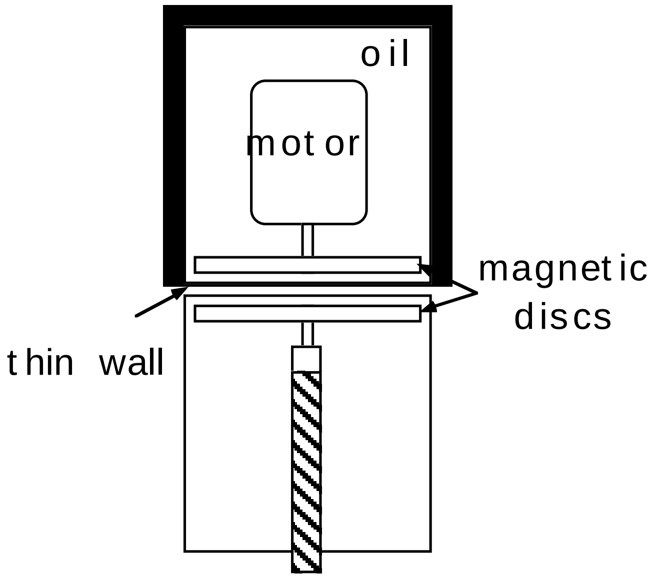

Fig. 4: Underwater motor system

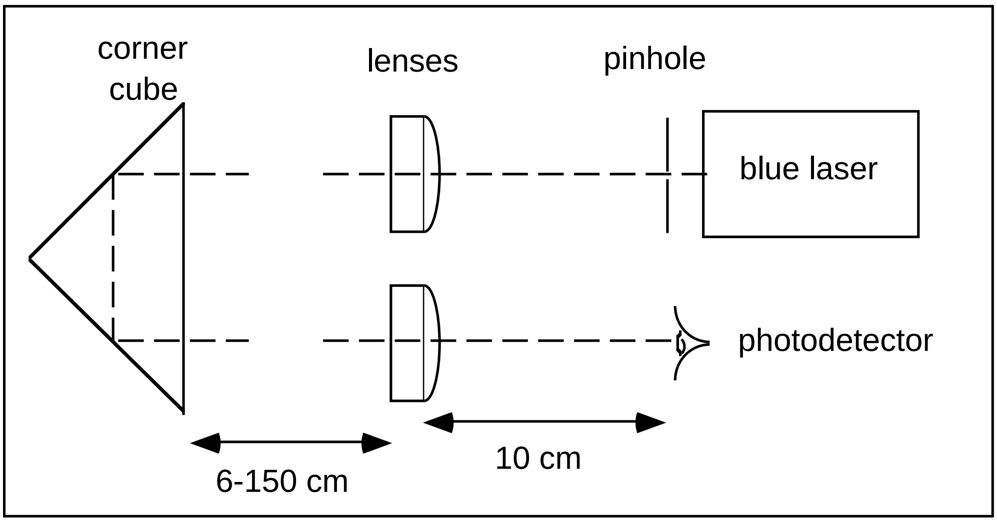

Fig. 5: Optical system.

3.1 NERONE: optical system

The reflector is a corner cube, 10 cm diameter, housed in an aluminum box with quartz windows.

In the first experiment we used a blue laser light source, 5 mW power and 405 nm wavelength. The laser light was focused to infinity, a pinhole with .1 mm diameter was inserted in the beam, that was then focused by a lens with 10 cm focal length. An identical lens was used to concentrate the light on the photodetector. Fig. 5 shows the layout of the optical system.

3.2 NERONE: data acquisition system

We built the data acquisition and motor control at LNF. The board was based on a PIC 16F873 microcontroller, that read the photodetector through an embedded 10 bit ADC, sent out the averaged data on the RS/232 link to the ship, and received commands to move the motor.
Fig. 6 shows the electronics diagram.

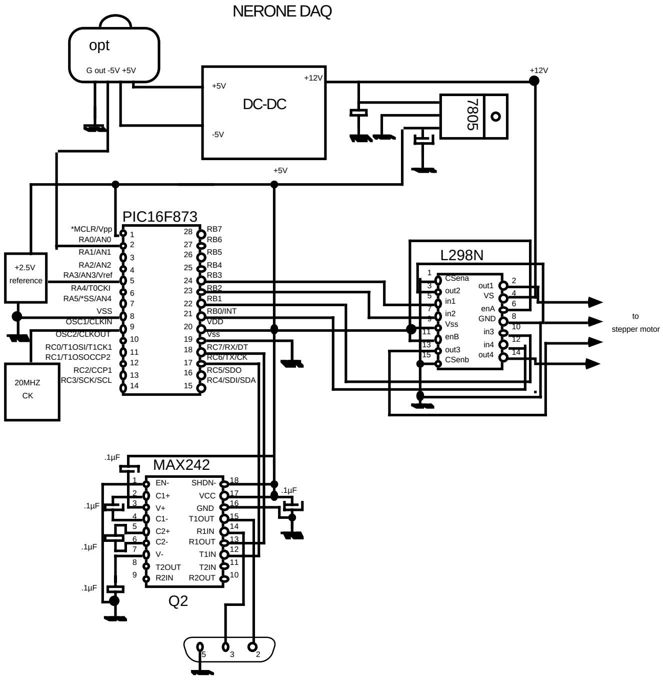

Fig. 6 : NERONE DAQ schematic.

Fig. 7: NERONE DAQ BOARD and blu laser.

Fig. 7 shows the internal attangement of the NERONE DAQ and optic system.

A LabVIEW interface was designed to drive the whole system from the ship.

Fig. 8 shows a diagram of the sea connections of NERONE. The CTD was an IDRONAUT Ocean Seven-MK317.

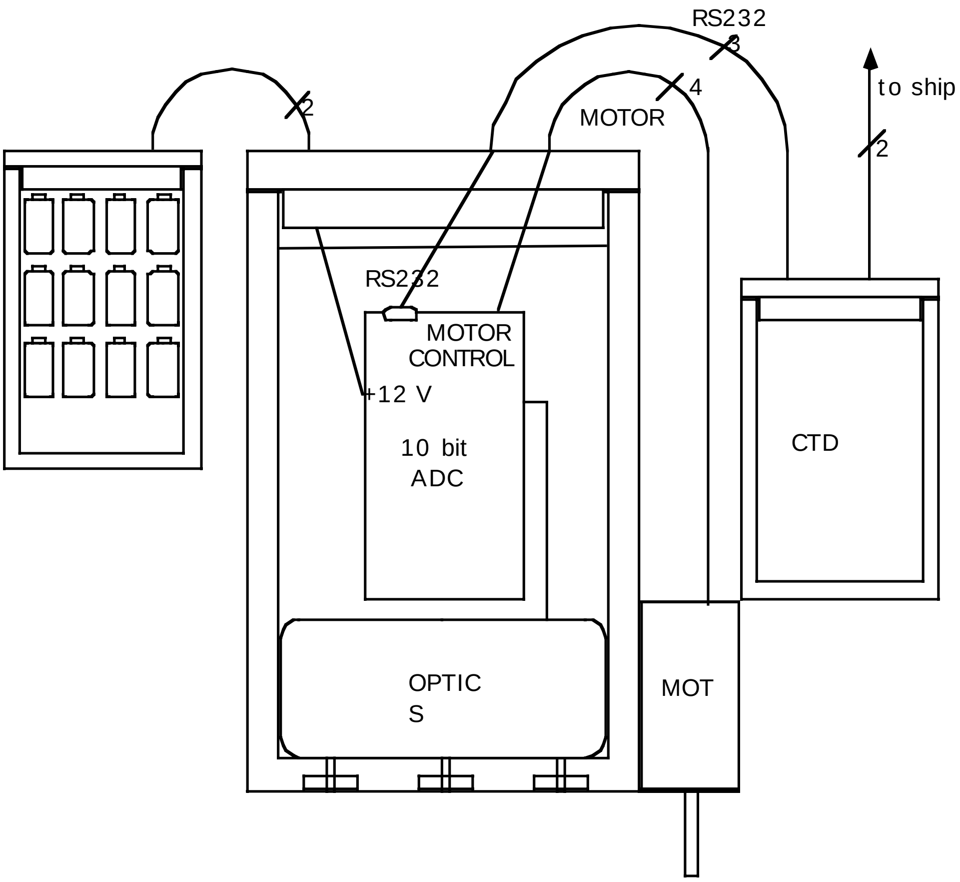

Fig. 8: Schematic diagram of the NERONE connections

4 Data analysis

Data were collected in air on the ship, with the apparatus hanging from the winch cable, to simulate all of the forces that were at play in the seawater, two times: before the immersion and after retrieval.

Both the measurements showed the same light quantity of light collected all over the race of the motor. The difference between the closest position and the farthest position was less then .5%. The absolute value differed from one measurement to the other by about 10%, which was probably due to cleanliness of the windows and ambient light conditions. This last number however, does not influence the precision of our measurement, because we do not use the absolute value, but only the differences between positions, at short time intervals.

The apparatus was deployed to 10 m depth and the motor was run for the full travel permissible. Then the system was lifted until it was visible from the ship, to control that the motor movement was satisfactory, and then again submerged for two measurements at 30 and 53 m depth. The results are shown in fig. 9. The data are in good agreement with the data collected later on by the AC-9, considering the ship drift and the time of day.

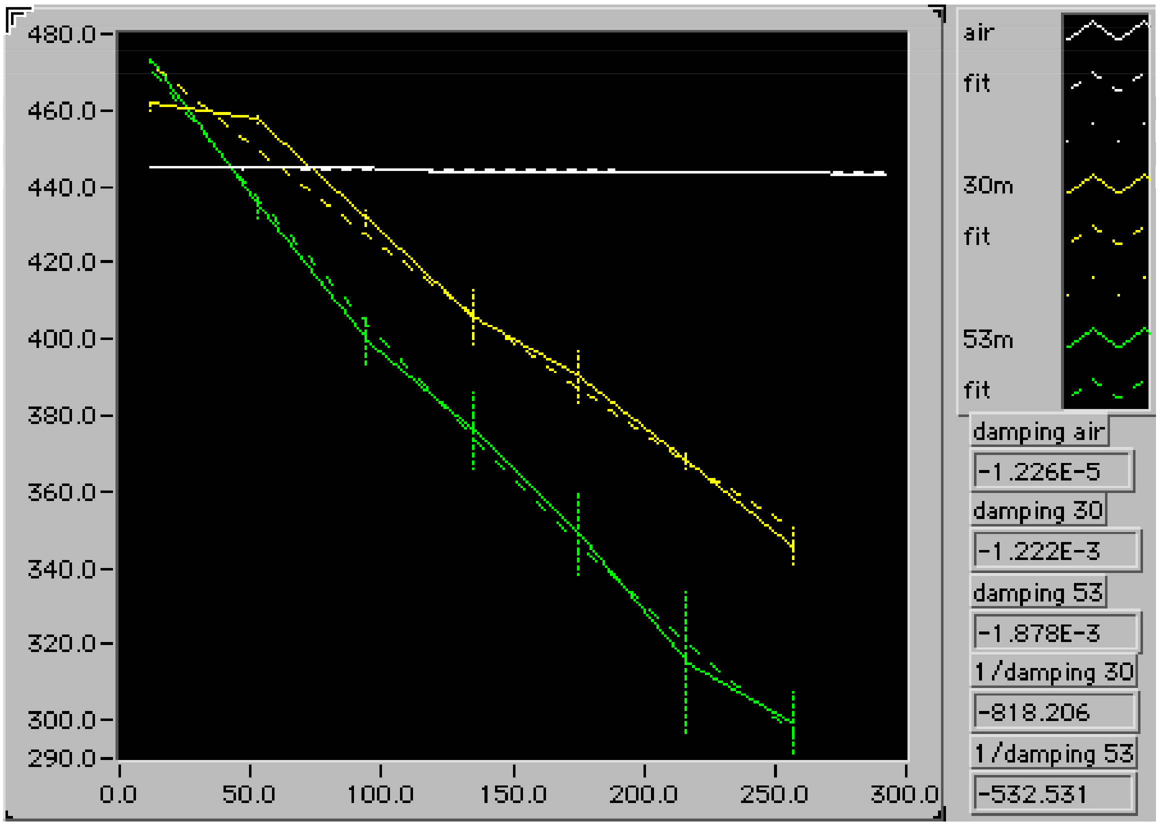

Fig. 9: First deployment data

5 THE FUTURE

Obviously many more tests are necessary before we are satisfied with the instrument.

Unfortunately it will not be possible to organize further deployments until February 2002. In the meantime we plan to extend the purpose of our data acquisition system, adding pressure and temperature sensors and making it independent of the CTD. We will also improve the mechanics to reach higher depths and try to achieve a better collimation of the laser beam.

6 ACKNOWLEDGEMENTS

NERONE was built at the INFN SSCR and, in part, at the machine shop of Sezione INFN di Cagliari . We want to thank everybody for their clever work.

We would like to thank Dr. Flavio Graziottin of Idronaut Srl[3] for the loan of the data acquisition system and stimulating discussion.

We are grateful to the Catania and Roma components of the NEMO group who lent us some necessary underwater cables and a lot of essential support.

We would finally like to thank the whole crew of the THETIS ship, that helped us in all possible ways.

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(3) Idronaut Srl, Via Monte Amiata, 10 1-20047 Brugherio (MI) ITALY
email: idronaut@askesis.it