KM3NeT INFRADEV – H2020 – 739560

Report on the Water Properties Measurement service

KM3NeT INFRADEV GA DELIVERABLE: D9.5

Document identifier:	**KM3NeT-INFRADEV-WP9-D9.5**
Date:	**25/01/2019**
Work package:	**WP9**
Lead partner:	**NCSR-D**
Document status:	**Final**
Dissemination level:	**Public**
Document link:	

Abstract

This document reports on the status and the activities connected to the establishment of a Water Properties Measurement service.

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I. DELIVERY SLIP

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Approved by	PMB		25/01/2019

II. DOCUMENT LOG

Issue	Date	Comment	Author/Partner
1	20/12/2018	1st version circulated to reviewer	E. Tzamariudaki NCSR-D
2	09/01/2019	2nd version including comments from PMB reviewer	E. Tzamariudaki NCSR-D
3	25/01/2019	2nd version including comments from IB reviewer	E. Tzamariudaki NCSR-D

III. APPLICATION AREA

This document is a formal deliverable for the GA of the project, applicable to all members of the KM3NeT INFRADEV project, beneficiaries and third parties, as well as its collaborating projects.

IV. TERMINOLOGY

A complete project glossary is provided:

ARCA: Astroparticle Research with Cosmics in the Abyss
ORCA: Oscillation Research with Cosmics in the Abyss
PMB: Project Management Board
LAMS: Long Arm Marine Spectrophotometer
PD: Photodiode

V. LIST OF FIGURES

VI. LIST OF TABLES

None

VII. PROJECT SUMMARY

KM3NeT is a large Research Infrastructure that will consist of a network of deep-sea neutrino telescopes in the Mediterranean Sea with user ports for Earth and Sea sciences. Following the appearance of KM3NeT 2.0 on the ESFRI roadmap 2016 and in line with the recommendations of the Assessment Expert Group in 2013, the KM3NeT-INFRADEV project addresses the Coordination and Support Actions (CSA) to prepare a legal entity and appropriate services for KM3NeT, thereby providing a sustainable solution for the operation of the research infrastructure during ten (or more) years. The KM3NeT-INFRADEV is funded by the European Commission's Horizon 2020 framework and its objectives comprise, amongst others, activities on technology transfer and innovation in the KM3NeT Collaboration (work package 9).

VIII. EXECUTIVE SUMMARY

The main goal of WP9 is to establish methodologies both for exposing to interested parties in the industrial sector technological choices and innovative solutions that have been developed or adapted by KM3NeT, and for following the technological advances in key areas of interest to KM3NeT. In addition, technology transfer in the form of services can be provided from KM3NeT to industry or to Institutions with potential interest. Such a service is being established based on past experience and will include a device to measure the optical properties of water accompanied with the corresponding methodology, to be used on demand.

Table of Contents

1. Introduction

KM3NeT is a large Research Infrastructure (RI) currently under construction. When completed, it will consist of a network of deep-sea detectors with user ports for Earth and Sea sciences, deployed at the Mediterranean sea. The main science objectives, a description of the technology and a summary of the costs are presented in the KM3NeT 2.0 Letter of Intent (Adrián-Martínez, 2016).

KM3NeT/ARCA (Astroparticle Research with Cosmics in the Abyss), aims at the discovery and subsequent observation of high-energy neutrino sources in the Universe and is currently under construction at a depth of 3500 m, ~ 80 km off-shore Portopalo di Capo Passero in Sicily. KM3NeT/ORCA (Oscillation Research with Cosmics in the Abyss) at a depth of 2450 m, ~ 40 km off-shore from Toulon, will use atmospheric neutrinos at low energies to measure neutrino oscillations and determine the neutrino mass ordering, which is a fundamental property in neutrino physics.

During the technical design studies for the construction and deployment of a large neutrino telescope in waters of extreme transparency at the greatest depths of the Mediterranean sea, the need emerged for a reliable measurement of the optical parameters of the deployment sites. Commercially available instruments are not well suited for measurements in very clear water as the small length optical base of such instruments requires an increased accuracy of the light intensity measurement. Moreover, such instruments require a complicated calibration process, which is not easily available on board. In order to avoid these problems and to obtain a reliable measurement of the water transparency, an open geometry light measuring system, the Long Arm Marine Spectrophotometer (LAMS), was constructed. The LAMS is an instrument that measures the light transmission length in deep sea for eight different wavelengths from the near UV to green visible region, where the transmission length is maximum. The operation principle is based on measuring the light intensity from a point source (LED sources of different wavelengths) at a set of fixed lengths of optical paths. By comparing the measurements, one can eliminate the geometrical factor and thus determine the exponential transmission coefficient. LAMS was developed several years ago and has been used successfully to perform measurements during three sea campaigns in the deep Ionian sea, off-shore Portpalo di Capo Passero in Sicily and off-shore Pylos in Greece (2-3).

2. Description of the existing LAMS, modifications and improvements

The original LAMS device that was used to measure the transmission length in deep sea during the sea campaigns in 2008 and 2009 took measurements at distances of 10m, 15m (or 17m) and 22m. The light emitter and the receiver were mounted at fixed distances on a mechanical support frame consisting of four titanium girders, each 5m long, and a stainless steel, 2m long girder, attached to each other to form a long linear structure. The light source and the mechanical structure are described in detail in (2). In order to achieve optical paths of different length, needed for the different measurements, parts of the frame were added or removed appropriately on board before each deployment and measurement. Although this method proved to be successful, in order to perform measurements at all three different distances needed for an accurate determination of the transmission length, three consecutive deployments were necessary. This resulted in a great and unnecessary increase of the time required for the measurements. A typical set of complete measurements could last well over 18 hours. As a consequence, the complexity of the system was also increased, as more batteries were needed in order to make it possible to perform successive measurements at different sites (Opening the LAMS to replace the batteries is a process that is advisable to be done in a clean room and not on board). More important was the increase of the cost of the whole operation, as a long deployment requires the rental of an expensive ship for a longer time.

For the water properties measurement service, we plan to construct a new version of the LAMS device keeping the same idea of measuring the transmission length, but simplifying the process by performing in a single deployment, simultaneous measurements at all three different distances between emitter and receiver. In this way, the total measurement time could be reduced to just a few (~6) hours, the time being dominated by the time required to deploy and recover the system at the intended water depth. The light emitter and the support structure (without the 2m long steel arm) of the original LAMS device are utilised, while three autonomous receiver units are redesigned. Since the receivers need to be smaller in size compared to the original LAMS, they will be mounted inside the metal frame supporting the LAMS at distances of 10m, 14m (or 16m) and 20m. The new receivers will be housed in custom made cylindrical steel casings. Two of them will be placed diagonally inside the frame at 10m and 14m (or 16m) and the third one will be attached at the centre of the opposite end of the frame, all facing the light emitter (scheme in figure 1).

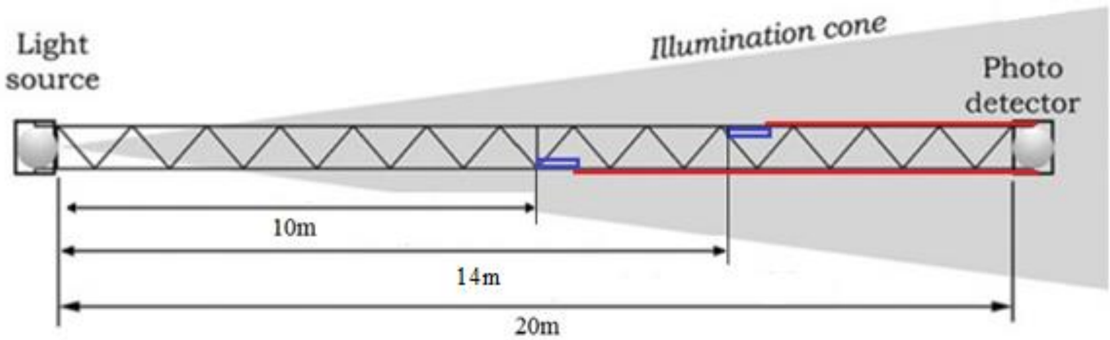

Figure 1: Rough schematic showing the placement of light receivers and light source

The new receiver, like the old system, will have two 18mm x 18mm photodiodes (PDs). The photodiodes (P/N: S3204-08) by Hamamatsu are new (shown in figure 2), since production of the photodiode type used in the original LAMS has stopped. The boards driving the PDs have a data taking rate of 100Hz and data will be stored in an SDHC card up to 16GB. This data storage is more than sufficient as the file output from a single deployment is expected to be in the order of 50-100MB, but the choice of using a high-capacity SD card was made due to the fact that “low capacity” SD cards are nearly obsolete and therefore difficult to find in the market. The new system will also record data from an external pressure sensor in order to register the depth of the system during deployment. Finally, for monitoring purposes there will also be a thermometer on the data taking electronics, to ensure that the PD response is not affected by temperature.

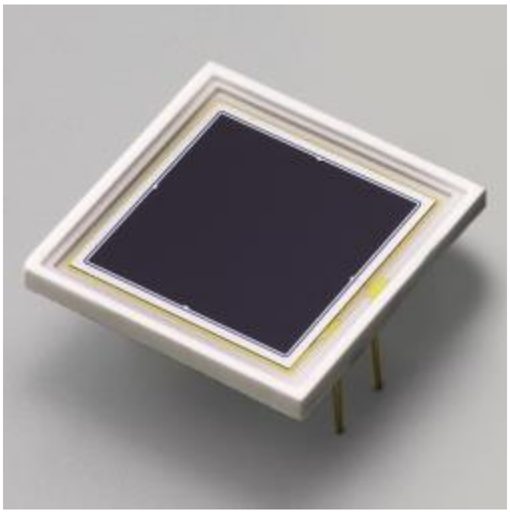

Figure 2: The Hamamatsu S3204-08 photodiodes used for light intensity measurements. Each autonomous receiver unit will be equiped with two photodiodes and will be placed at different distances from the light source.

3. Status

The light source of the original LAMS has been taken out of storage and has been tested. The visual inspection has shown that although the oceanographic glass sphere has suffered from a recent transportation of equipment (from Pylos to Kalamata) due to a relocation of offices, the light source seems to function satisfactorily. The layout and schematic of the light source boards have also been recovered, allowing for a new source to be printed and equipped if the extensive tests which are planned reveal faults with the existing source. The glass sphere will also be replaced with a new one after the tests with the new receivers have been completed to avoid accidents that could damage the new sphere.

Since the design and operation of the old version of LAMS was successful, it was decided that the changes of the redesigned system be limited to those necessary and cannot be avoided (due to the lack of components which are no longer in production for example), or to small changes that would greatly improve the efficiency of the measurement. One of those necessary changes was the choice of a new photodiode to replace the one in the old system which is now out of production. We have chosen to use a photodiode which is very similar to the old one. The new photodiode has the same photosensitive area, is also sensitive in the wavelength region of interest and has a smaller capacitance which is an advantage for designing the electronics. For a complete system six photodiodes are needed, two in each receiver board. The photodiodes have been ordered and were received in July. They have been handed over to the electronics engineer developing the new photodiode boards. Two pressure sensors have also been ordered and are currently being implemented in the system. The PCB board layout was finalized in August and the prototype board was ready late October (picture of the board shown in figure 3). The first calibration measurements with the new electronics were performed in November and the gain of the board was fixed after a second calibration measurement in December.

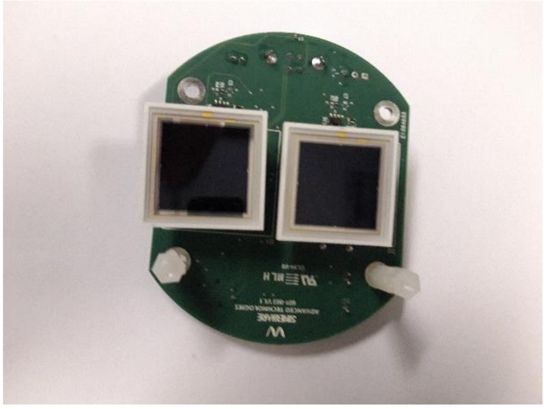

Figure 3**:** The electronics of the receiver board of LAMS with the two photodiodes **-** here attached on the prototype board for testing purposes. In the final board the photodiodes will be soldered properly.

Since the LAMS is an autonomous system, special care had to be taken to minimise the power consumption in order to reduce the capacity of the battery pack needed to run the system. According to specifications, the system will be able to run for at least 100 hours of data taking. Each deployment is expected to last 6 - 7 hours; this run time will allow the system to perform consecutive measurements without the need to replace or recharge the batteries between deployments. Regarding the battery packs it was decided to use commercial "power banks" including Li-ion battery packs will be used as the duration of the deployments is relatively short. Alkaline batteries would be preferred for a long term deployment, but rechargeable power banks not only reduce the cost of running the system but also include the circuit that regulates the output voltage and the charging circuit of the battery pack. Additionally, power banks are ready off-the-shelf components that are readily available in the market and easy to replace in the future. The board itself, and the casings can accept an Alkaline battery pack in the future if this is deemed necessary by a simple change in the internal support structure of the casing.

The board will communicate with a PC via USB connection and custom-made software and will write the measurement data in a text file. The file data output will include the response of the photodiodes, the temperature from the on-board thermometer and the reading from the pressure sensor. The software developed for the original LAMS system has been recovered and is currently being modified accordingly to cope with the changes in the data format.

A preliminary mechanical design of the complete structure and casings has been carried out. The support frame is of square cross-sectional area. Two different designs of the steel casings have been prepared (shown in figures 4 and 5). Depending on the alloy to be used for the construction of the casing, the outer minimum diameter needs to account for the fact that thicker walls will be needed for different alloys in order to withstand the pressure at depths up to (or slightly beyond) 4000m. We are currently in the process of collecting offers from potential suppliers for manufacturing the casings. The final choice will be made depending on the size and cost of each casing. The design of the internal support structure of the casings that will hold the PD boards and the battery packs is ongoing.

Figure 4: Option 1 for the deep sea casings for the PD boards

Figure 5: Option 2 for the deep sea casings for the PD boards. This design is preffered for harder stainless steel alloys such as alloy 17-4 and results in a smaller outer diameter.

4. Next steps

- The immediate next step is the delivery of the final electronics (expected in January).
- Once the electronics is delivered, the linear response region of the receiver electronics board will be measured to ensure that the photodiodes at all three distances get enough light intensity for an accurate measurement and at the same time not too much light that would saturate the measurement.
- The selection and order of suitable power banks will also be done once the electronics boards are delivered. When the power banks are received, the design of the internal support structure will be finalised and the construction will be done.
- The system will be calibrated measuring the electronic offset and the random noise.
- A power consumption and battery autonomy test will be included in the pre-deployment tests, confirming that the battery pack will provide sufficient running time for consecutive measurements.
- Once the deep sea casings for the PD boards are delivered, they will be subjected to a pressure test in the high-pressure chamber situated in the INPP in Demokritos.
- A pre-deployment testing will be carried out; first standalone and then for the complete system.

This task is progressing as planned and no significant problems are expected.

5. References

1. *Letter of Intent for KM3NeT 2.0.* **Adrián-Martínez, S., et al.** 2016, Journal of Physics G: Nuclear and Particle Physics, Vol. 43 (8), p. 084001. arXiv:1601.07459 [astro-ph.IM]. DOI: 10.1088/0954-3899/43/8/084001.

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