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Final Report on the Water Properties Measurement service

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Abstract

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

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I. DELIVERY SLIP

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II. DOCUMENT LOG

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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

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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 includes a device to measure the optical properties of water accompanied with the corresponding methodology, to be used on demand. The original Long Arm Marine Spectrophotometer (LAMS) device was used to measure the transmission length in deep sea during past sea campaigns. Although the original LAMS was successful, in order to provide the water properties measurement as a service, a new version of the device was necessary to allow a simplified measurement process.

A description of the original device and of the modifications and improvements with respect to the original LAMS is reported in D9.5, which presents the status of the task activities in M24 (task started M13) and is also included here, with more detail, for completion. A description of components for the new system that had been ordered, received and tested before M24 is also included here for completion. In this report, the experimental methodology for the water properties measurement is outlined and information is given of the existing light source. Several tests have been performed to ensure satisfactory performance of the components used and of the integrated system. Finally, a description of the mechanical components and of the integrated system is also included in the report.

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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 [1].

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 of fundamental importance in neutrino physics.

During the technical design phase for the construction and deployment of the detector in waters of extreme transparency deep in the Mediterranean sea, the need emerged for a reliable measurement of the optical parameters of the deployment sites. The inherent optical properties (IOP) mainly used by the oceanographic community to describe the propagation of light in water are the absorption, scattering and attenuation coefficients. For the measurement of the IOPs, oceanographers use a well-collimated beam where rays scattered by more than a few mrads are lost, thus the attenuation measured is due to both absorption and scattering. However, this method is not optimal for the case of extremely clear water, as in this case the absorption represents the main light attenuation mechanism, since the scattering length is much longer than the absorption length [2]. Therefore, commercially available instruments are not well suited for measurements in very clear water. Moreover, such instruments require a complicated calibration process, which is difficult to be performed 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), has been constructed. The LAMS is an instrument that measures light intensities over a long and variable light path. 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 [3], [4].

Although the original LAMS device was successful, since the measurement procedure required several deployments indicating the importance of a simplified process. The D9.5 reports on the work carried out during the first half of the project and includes a short description of the existing system, the modifications and improvements that were deemed necessary in order to accomplish a simplification of the measurement process and a description of the photodiodes and other components for the new system that had been ordered, received and tested at the time of the document. The document also presented the status of the electronics boards and the preliminary designs of the steel casings, as well as a list of the steps needed for the successful completion of the task. Since D9.5, several tests have been performed leading to considerable improvements of the electronics boards. The linear response region of the receiver electronics board was measured, suitable power banks have been purchased, the design of the internal support structure was finalised, the deep sea casings for the PD boards were constructed and subjected to a pressure test. Several tests were performed after integration of the system. The current document is the final report on this project, hence it also incorporates the work reported in D9.5, as it includes a description of all work accomplished throughout the project.

2. Description of the original LAMS and experimental methodology

The original LAMS device was constructed for measuring the transmission length L_β ($\beta = 1/L_\beta$ is the $1/e$ transmission coefficient), a quantity well suited for the propagation of light in the sea water in an "open geometry" regime. As described in ref. [3], [4], when the scattering length is much longer than both the absorption length and the measurement distance R, the transmission coefficient β can be determined experimentally from a combined $1/R^2$ and the Beer-Lambert law [5] :

$$I(\lambda, R) = \frac{I_0(\lambda)}{4\,\pi\,R^2}\, e^{\frac{R}{L_\beta(\lambda)}}$$

where $I(\lambda, R)$ is the measured intensity of light of wavelength λ at a distance R from the isotropic light source, I_0 the intensity of the light source, $L_\beta = 1/\beta$ the transmission length, and β is the transmission coefficient. The relative error in the measurement of β is given by:

$$\frac{\Delta\beta}{\beta} = \frac{1}{\beta\,R}\,\frac{\Delta I}{I}$$

In clear waters the transmission coefficient has small values (since the transmission length L_β has large values), therefore an accurate measurement of β requires either an instrument able to measure the light intensity with extreme accuracy (so that $\Delta I/I$ can be very small) or an instrument with a long optical path (so that R is adequately large). Commercially available instruments have a small length optical base, so they are not well suited for measurements in very clear water as, for providing an accurate measurement of β, this constraint imposes the need of a very accurate measurement of the light intensity.

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 ranging from 375nm to 520nm) at a set of fixed length optical paths. By comparing the measurements one can eliminate the geometrical factor $1/R^2$ and thus determine the exponential transmission coefficient. The original LAMS, shown in Figure 1, was used to measure the transmission length in the deep sea during the sea campaigns of 2008 and 2009. The measurements were taken at various distances between source and detector distances, namely at 10m, 15m, 17m and 22m. The light emitter and the receiver were mounted 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 (shown in Figure 2) and the mechanical structure are described in detail in [3]. In order to achieve the optical paths of different length required 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. Since the time needed to deploy the instrument to the desired depth is approximately 2 hours and taking into account that another 2 hours are needed to retrieve it, in order to take one hour of useful measurements at the desired

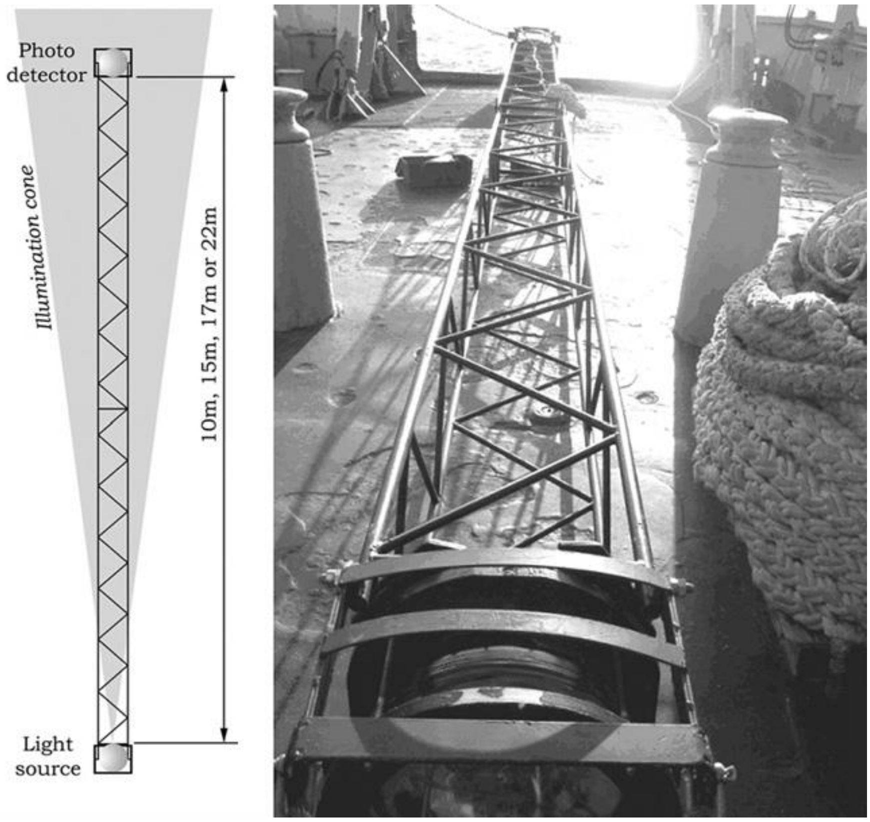

Figure 1: LAMS – The Long Arm Marine Spectrophotometer. *Left:* Schematic of the original apparatus. *Right:* The original LAMS before deployment on the deck of the R/V "Aegeo". Figure taken from [3].

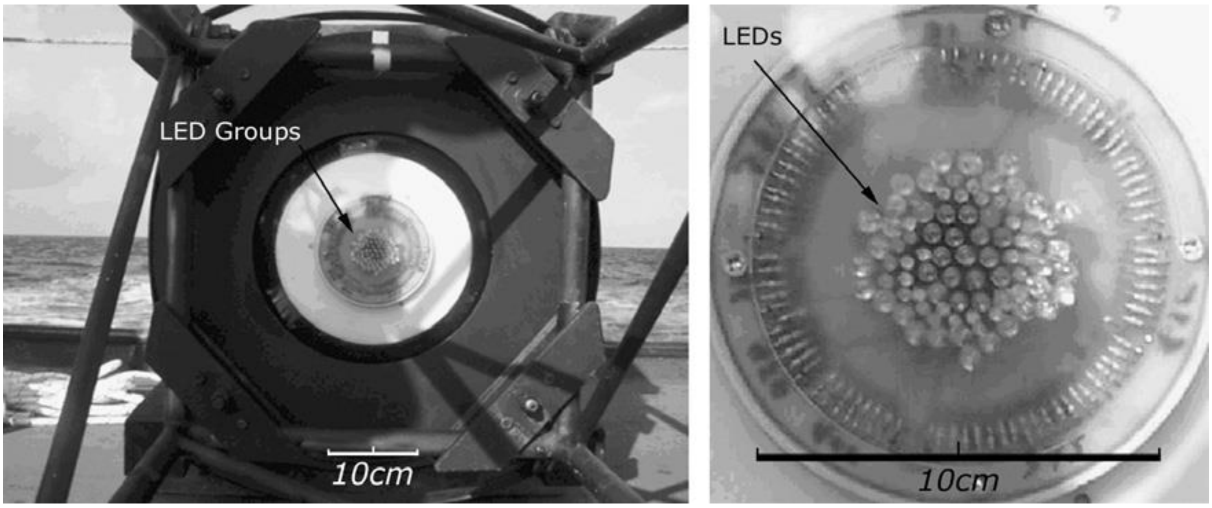

Figure 2: The light source of the LAMs: the cluster of LEDs inside the glass sphere and the mechanical support (*left*) and a close-up of the cluster of LEDs (*right*). Figure taken from [3].

depths, a total time of over 6 hours for each deployment was necessary; hence a typical set of complete measurements could last well over 18 hours. This resulted in a great and unnecessary increase of the time required for the measurements, which could however not be avoided with the original design. 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.

3. Modifications and improvements

The modifications of the original LAMS device are described in D9.5 and are also detailed here for completion. Keeping the same idea of measuring the transmission length, we have constructed a new version of the LAMS device, by simplifying the process so that in a single deployment, simultaneous measurements can be performed at all three different distances between emitter and receiver. In this way, the total measurement time can 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 have been redesigned. In order to perform the three light intensity measurements simultaneously, the light sensor modules need to be smaller in size compared to the original LAMS, and to be mounted on the inside of the metal support at distances of 10m, 16m and 20m away from the light source. Custom made cylindrical steel casings have been constructed to house the new receivers. The new pressure steel casings are placed diagonally inside the frame at 10m, 16m and 20m mounted securely at the corners of the square cross section titanium frame, all facing the light emitter (scheme in figure 3).

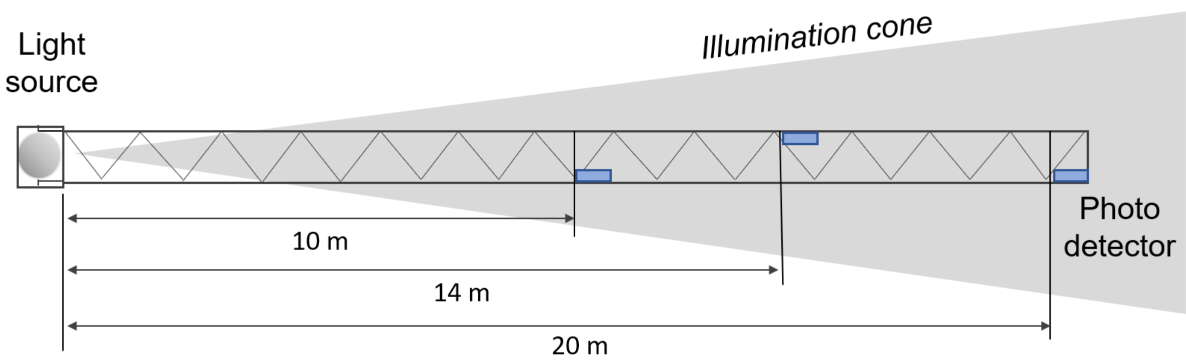

Figure 3: Rough schematic showing the placement of light receivers and light source.

The new receiver, like the old system, has two 18mm x 18mm photodiodes (PDs). The photodiodes (P/N: S3204-08) by Hamamatsu are new (shown in figure 4). The boards driving the PDs have a data taking rate of 100Hz and data are 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 thus allowing the recording of multiple measurements. The new system will also record data from an external pressure sensor rated for a maximum pressure of 600 bar by BD Sensors (P/N: DMK331) in order to register the depth of the system during deployment. Finally, for monitoring purposes there is also a thermometer on the data taking electronics, to ensure that the PD response is not affected by temperature.

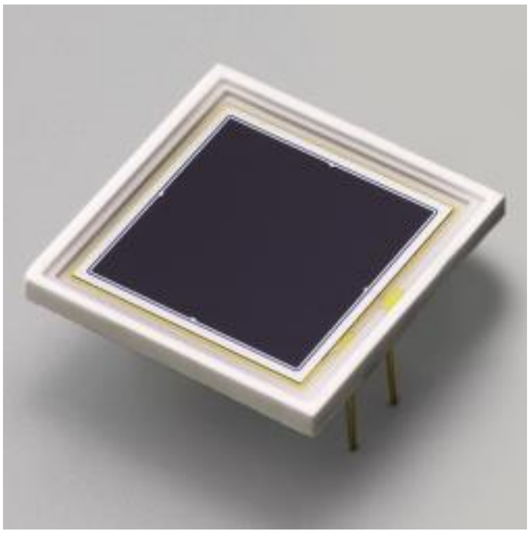

Figure 4: The Hamamatsu S3204-08 photodiode used for light intensity measurements. Each autonomous receiver unit is equipped with two photodiodes and is placed at a different distance from the light source.

4. New photodiode board

Since the design and operation of the old version of LAMS was successful, it was decided that the changes of the redesigned system are limited to those necessary, that is the replacement of obsolete components, 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. This choice was made in a very early stage, so the new photodiode is described in D9.5. A more detailed description is presented here including linearity tests as well as the PD board response stability and accuracy. The PD has the same photosensitive area as the one of the old system, 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 to ensure redundancy for the measurement. Seven photodiodes have been ordered and were received in mid-July 2018. They have been handed over to the electronics engineer developing the new photodiode boards. Two pressure sensors have also been ordered to be implemented in the system. The power conversion board (PCB) layout was finalized in August 2018 and the prototype board was ready late October 2018. The first two of the photodiodes were placed on a prototype board in October 2018 and extensive tests were performed. The first calibration measurements with the new prototype electronics board were performed in November 2018 and the gain of the board was fixed after a second calibration measurement in December taking into account the light intensity of the LAMS existing light source and the intended distance between source and light sensor. Due to the operation principle of the LAMS, the intensity of the light sensor to be placed at the closest distance of 10 m should be set at the high end of the linear response range of the PD module as the farthest PD module will "see" one quarter of that intensity due to the geometrical spread of the point like light source. In addition, one should take into account (since tests are performed in the air) that the intensity of the light source in water will increase due to the difference in refractive index. Additional tests on the new board included tests for the dark current noise, light measuring stability, random noise, linear response range (Figure 5), power consumption and data storing.

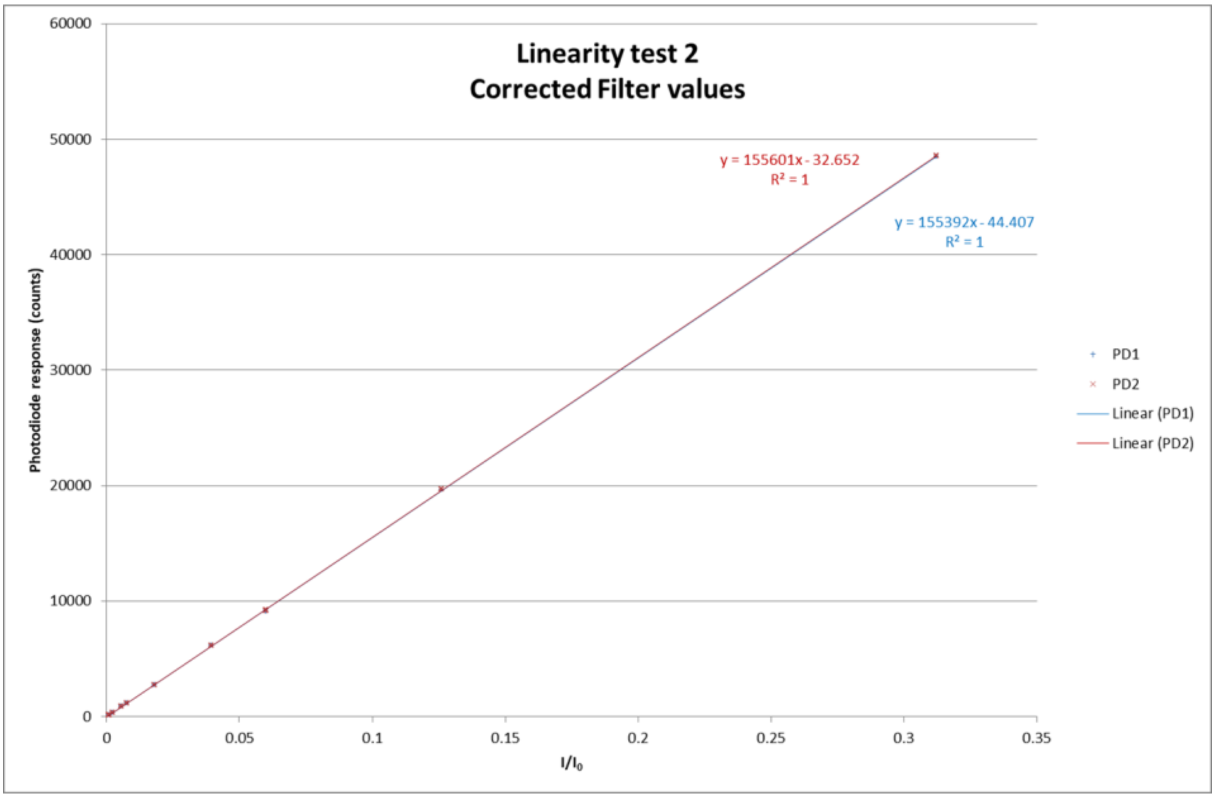

Figure 5: Response linearity test for one sensor board using light filters and a steady light source.

Once the tests were deemed satisfactory, the photodiodes were soldered onto the board (picture of the board shown in figure 6). Two more identical boards were produced which underwent through the same extensive testing procedure as standalone units in order to confirm their functionality. These tests have shown that all three boards have a comparatively very low dark current level (in the order of 10 - 20 counts with a dynamic range of 65535 counts). Under constant illumination, the registered light intensity from the photodiode boards has a FWHM which is less than 0.3% of the mean value (shown in Figure 7), thus resulting in a measurement with good accuracy.

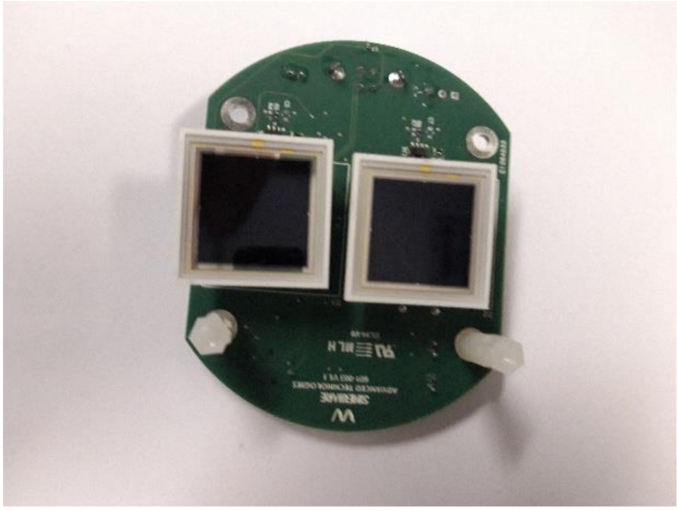

Figure 6: The electronics of the receiver board of LAMS with the two photodiodes - here attached on the prototype board.

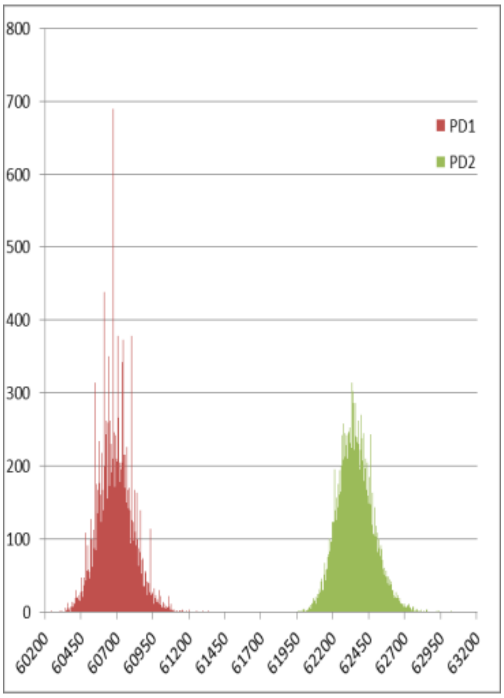

Figure 7: Example intensity histogram plots (number of counts versus intensity values), showing the response stability and accuracy (with a FWHM ~ 200 counts) at ~ 60000 measurements.

The three photodiode boards were then installed into the pressure casings and powered by the battery power banks in order to make a cross-calibration of the boards, since each photodiode has a slightly different response value, which has to be taken into account in order to make a direct comparison of the incident light on each sensor module. The sensor modules were mounted on the titanium frame in their respective positions in order to check and quantify shadowing effects from the modules closer to the source.

All three boards have the capability of powering and reading data from the pressure sensors that were chosen for the LAMS. Although only one is needed to measure the depth, it was considered wise to equip the LAMS with two pressure sensors for redundancy. Therefore, two out of the three sensor modules are equipped with a pressure sensor. The pressure sensor has its own, separate power supply (comprised two 9V type 6LR61 batteries), with a common ground with the battery pack that powers the photodiode board. The board communicates with a PC via USB connection and custom-made software stores the recorded data in a text file. The data output file includes the response of the photodiodes, the temperature from the on-board thermometer and the reading from the pressure sensor (if no sensor is available, the pressure sensor column will record 0000) arranged in a four-column text file. All data is in hexadecimal form, the PD columns giving the light intensity in ADC counts (0 - 65535), the temperature sensor in degrees and the pressure sensor in mA. The data analysis software developed for the original LAMS has been recovered. Although new analysis software has been developed to cope with the new data format and has been used for all functionality tests, comparisons with the older analysis have been carried out in order to improve and optimize the performance.

Since the LAMS is an autonomous system, special care had to be taken to minimize the power consumption in order to reduce the capacity of the battery pack needed to run the system. After several tests, it was decided to use Kingston micro SDHC memory cards since these resulted in significantly lower power consumption. The tests showed that the power needed for the PD board when using cards of other brands, can be as much as double compared to the storage card chosen. It was decided that the data be written in the card in raw mode and not using a file system, as it was realized during the tests that the latter affects the timing of the data taking, resulting in slower performance. Even though the value stated by the card manufacturer is 16GB, the capacity of the card is reduced to less than 4GB, due to the way the data is written in the card. This however is not a problem as the size of the data output file after a 7 hours deployment is expected to be in the order of 100MB. However, any SD or SDHC card could be used for the system.

According to specifications, the system will be able to run for at least 100 hours of continuous 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 D-Cell Alkaline batteries as they are readily available in the market. A system loaded with alkaline batteries can be stored for longer periods without a significant drop in battery capacity and therefore output voltage.

5. Light source

We are using the light source of the original LAMS which is described in detail in ref. [3]. It was constructed using eight groups of LEDs, which emit over a significant spectral region and are mounted on a circuit board and arranged in an almost circular pattern as shown in Figure 2. The LEDs are driven from a regulated 5 V source. A different number of LEDs was used for each wavelength in order to provide the light intensity needed. The wavelength for the peak of the light intensity distribution, the full width at half maximum (FWHM) of the spectrum and the number of LEDs used for each one of the eight wavelength groups, are found in Table 1. Each LED group is activated sequentially and is controlled by a microcontroller with a crystal oscillator clock to count time. During a measurement cycle the LEDs of a particular wavelength are turned on for 10 s, are then switched off and after 2 s the LEDs of the next wavelength are turned on. The overall measurement cycle has a period of 110 s including a 14 s no-light gap which is inserted between the light cycles.

Peak intensity wavelength λ_m (nm)	375.7	385.7	400.3	425.0	445.4	462.6	501.6	519.5
FWHM (nm)	12.9	13.7	13.8	16.6	18.2	26.8	30.7	31.8
Number of LEDs	15	15	7	4	4	7	8	15

Table 1: Light source LED parameters. Table taken from [3].

To ensure that we could rely on using the existing light source, the light source has been taken out of storage and has been tested at an early stage of the project. As already reported in D9.5, the visual inspection showed 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's functionality has not been affected. The glass sphere has been replaced with a new one. The sphere was filled with nitrogen to ensure that there is no humidity inside the sphere which could cause corrosion of the electronics as well as condensing on the inside of the glass sphere during the deployment which could affect its transparency during the measurements. The layout and schematic of the light source boards have also been recovered, allowing for a new source to be produced and equipped if that is deemed necessary in the future. Since D9.5, the existing light source has been extensively tested both powered by a stable power supply as well as autonomously powered by its own bank. As mentioned before, the gain of the new photodiode boards has been adjusted in such a way so that in the closest distance of 10m the sensor is at approximately 80% of the dynamic range.

However, the new photodiode has a slightly different response curve and as a result the two LED groups with the lower wavelength give a slightly lower intensity reading. The effect is enhanced when the photodiode boards are installed in the pressure casings as the plexiglass window of the casings (discussed later) has a low transmissivity at that wavelength region. This becomes evident in Figure 8 in which a snapshot of typical cycles of LAMS data (obtained in the LAMS assembly area) from a configuration with optical path of 10m is shown. The photodiode response is given in ADC counts. This region of wavelengths is a region where, according to bibliography and to our previous measurements carried out with the original LAMS system, the transmission length is half, or less, compared to the maximum transmission length which is located around 450 – 470 nm (blue).

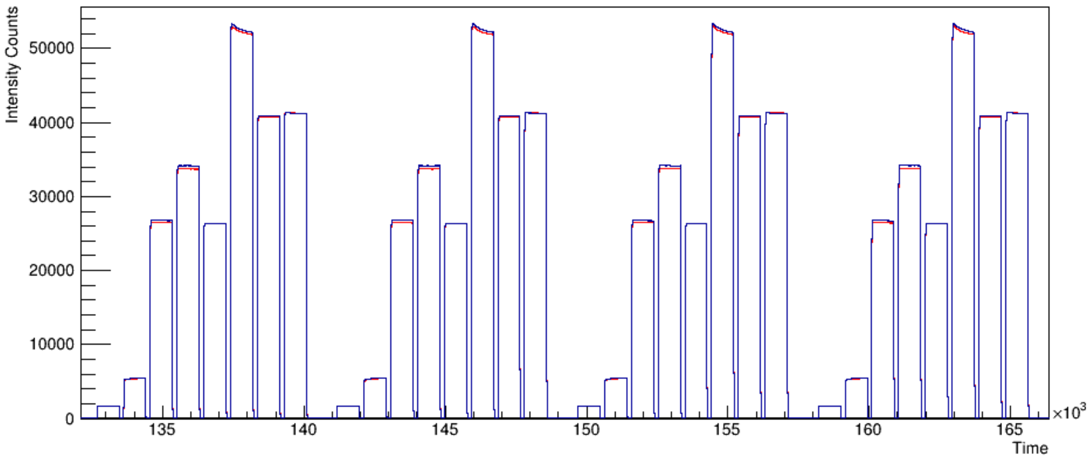

Figure 8: A snapshot of typical cycles of LAMS data (obtained in the LAMS assembly area) from a configuration with optical path of 10m.

6. Mechanical components

A mechanical design of the complete structure and casings has been carried out. The titanium support frame is of square cross-sectional area with a side of 40cm internally. The new pressure casings for the sensor modules are therefore limited as to their size in order to be able to place the three different casings at varying distances inside the frame without having shading effects between them. The pressure casings shown in Figure 9 comprise a stainless steel tube with outer diameter 105mm and 12mm thick walls thick in order to withstand the pressure, an end cap 25mm thick which is attached with M5 through bolts and a 70mm thick clear acrylic window that is attached to the tube with a thread in the internal diameter of the tube. A single Viton O-ring is used on either end to ensure water tightness. On the steel end cap, holes have been drilled to accommodate one GISMA Series 35 7-pin electrical connector, a vacuum port and in two of the endcaps an extra port to accept the pressure sensor. Four casings have been constructed in total, two of which are equipped with a pressure sensor.

Figure 9: Design of the pressure casing that houses the sensor modules.

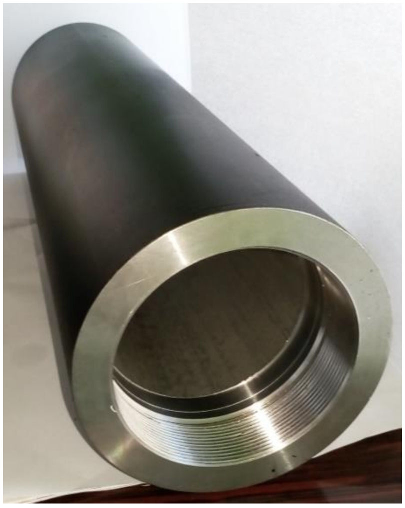

Figure 10: Main body of the pressure casings of the PD boards. The internal thread which is visible in the picture is used to attach the PD window.

Figure 11: Acrylic window for the photodiodes with O-ring seal in place.

All complete casings have been pressure tested successfully. The casings and the titanium frame have been painted with matte black paint to reduce light reflections that could affect the measurements.

An example steel tube is shown in Figure 10. On one end of the tube 6 holes were drilled to accept the M5 bolts that hold the steel endcap in place and on the other end an internal thread (as shown in the picture) for attaching the glass window. The window for the photodiodes shown in Figure 11 was manufactured from a clear acrylic plastic which was cut to size and polished. The diameter of the cylindrical window is 100mm and it is 70mm thick. A thread was made to attach the steel tube as well as the groove where the O-ring seal is placed. Since this is a component that is more delicate compared to the rest of the casing (even few surface scratches on the surface could affect its transparency and interfere with the measurements), 6 such acrylic windows have been constructed so that at least one spare window will be on board during the deployment operations to be replaced if it is deemed necessary. More raw material is in storage and more windows can be produced if needed.

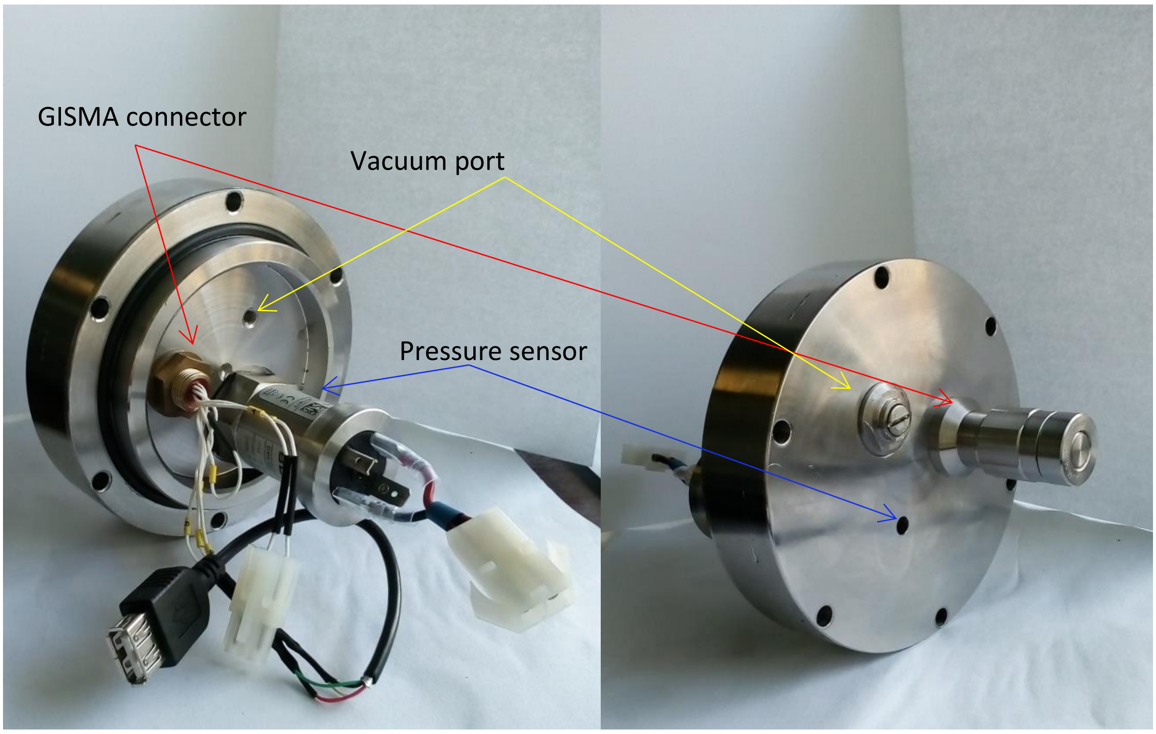

Figure 12: Stainless steel endcap equipped with pressure sensor. The cabling that connects with the PD board is also visible.

The stainless steel endcap, shown in Figures 12 and 13, has an outer diameter of 105mm, the same as the casing tube and a thickness of 25mm. There is a wall that fits on the inner diameter of the tube and acts as a guide to center the cap to the tube and 6 holes for the M5 bolts to securely fix it onto the casing body. A groove for the O-ring seal has been carved that sits on the casing leaving the bolts on the outer diameter, making the inside of the casing water tight. Holes have been drilled on the face of the endcap to accept the GISMA connector that is used to start and stop the system and to extract the data, a vacuum port and, in two out of the four casings, a socket for the pressure sensor.

Figure 13: Stainless steel cap without pressure sensor.

Figure 14: Battery pack for the sensor module, holding 8 D-cell and two 9V batteries.

The sensor modules are powered by two banks of four D-cell alkaline batteries each connected in parallel. Additionally, for the casings that also house a pressure sensor two additional 6LR61 9V alkaline batteries are required. These are held by the battery packs shown in Figure 14 and are connected to the PD board via a 4-pin connector and to the GISMA connector of the casing via a 2-pin connector to be able to start the system once the casing is closed. The battery packs have two long PVC tubes which hold four D-Cell batteries in series for a voltage output of 6V. One end is closed by a sheet of copper, providing the positive pole of the banks and on the other end a cap is screwed and the negative pole is provided by a spring holding the batteries in place. The 9V batteries are glued on to the side of the main body with silicone and connected in parallel. Both the 6V and the 9V battery packs share a common ground.

7. System integration

The PD boards are attached to small plastic adapters (Figure 15) that fit on the inside of the main body of the pressure casing. The plastic adapters are fixed using (a small amount of) silicone to ensure that the PD boards will not move inside their casings during deployment. The acrylic window is then mounted securely as shown in Figure 16. The battery pack is inserted from the open end of the pressure casing, with the cabling running along the side of the main body of the battery pack and passing through the specially designed groove. The 4-pin connector coming from the PD board is connected to the 4-pin on the battery pack, the USB and 2-pin connector connects to the GISMA connector on the endcap and, if available, the second 2-pin connector which is marked with a blue label is connected to the pressure sensor. Finally, the endcap is installed and bolted in place to seal the casing.

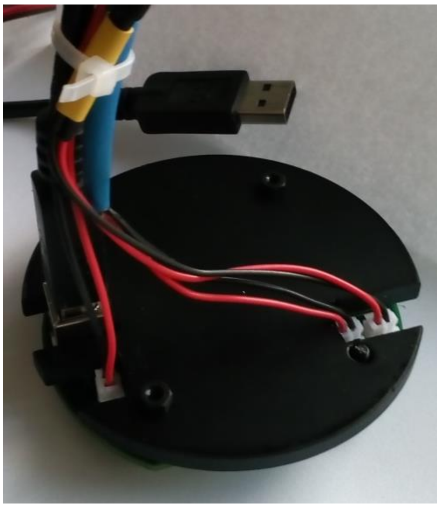

Figure 15: PD board fixed on the plastic adapter with the wiring connected just before getting installed in the pressure casing.

Figure 16: PD board installed in the pressure casing before and after installing the acrylic window.

The same titanium girder support structure that was used in the original LAMS is used for its updated version. In the new version the 2m long stainless steel section is not used so the new instrument has a total length of approximately 20 meters divided into four 5m long sections. On one end of the "Long Arm" the oceanographic sphere containing the light source is mounted on a frame which connects to the end of the titanium frame with 4 bolts. Once it is turned on, it is shining light inside the square cross-section frame. Inside the frame and at the corners of the square the three sensor modules are mounted at different distances from the light source (approx. 10m, 16m and 20m). A plastic base is permanently mounted on the frame, also acting as a guide as to the exact position of each module. The module sits on its base with the stainless steel endcap in contact with the end of the base and the window end facing the light source. The casings are mounted using stainless steel collars to hold them onto the frame (Figure 17). A strip of rubber is used between the collar and the casing/titanium frame to ensure a more secure fix that will not allow the casing to rotate within the collar and also prevents the stainless steel and titanium to come into contact to avoid corrosion due to electrolysis. Extensive tests have been carried out during the system integration to check the functionality and stability of the system.

Both the light source and all three sensor modules are autonomous, so the operation starts on board prior to deployment by attaching the provided dummy "start/stop" connector on each module. At the end of the deployment, the "start/stop" connector will be detached and the connector with a USB cable (readout connector) will be used so that the data can be read from each of the sensor modules independently via USB connection to a PC. Once the data has been read, they will be processed by the analysis software to calculate the light transmission length for each of the eight LED group wavelengths.

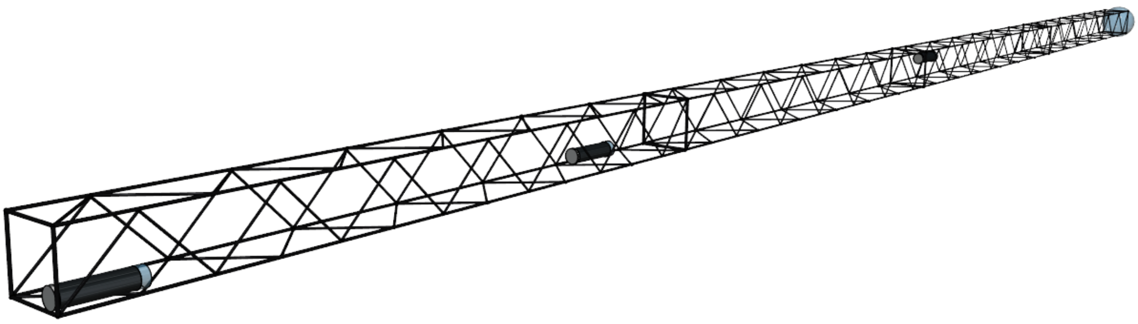

Figure 17: Schematic of the LAMS showing the placement of the light source and the light sensor modules.

8. Conclusions

A service for the measurement of the optical properties of water has been developed based on past experience with the Long Arm Marine Spectrophotometer (LAMS). The LAMS is an instrument that was developed several years ago and has been used successfully to perform measurements in the past. Several modifications to the original device have been made, which were deemed necessary in order to optimize and to a certain extent automate the procedure. This is important as it makes the LAMS device easier to handle and therefore more user friendly. With the new LAMS device, only a single deployment is needed to perform a measurement of the optical properties of water. Since the last measurements with the original LAMS at the KM3NeT deployment sites have been performed more than 10 years ago, interest has already been expressed to update them. We plan to take advantage of the upcoming sea operations for the deployment of KM3NeT detection units, in order to use the new LAMS device for measurements at both KM3NeT installation sites.

9. References

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