# Proposal of a new generation of Laser Beacon for Time Calibration in the KM3NeT Neutrino Telescope

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**VLVnT13 - Very Large Volume Neutrino Telescope Workshop 2013**

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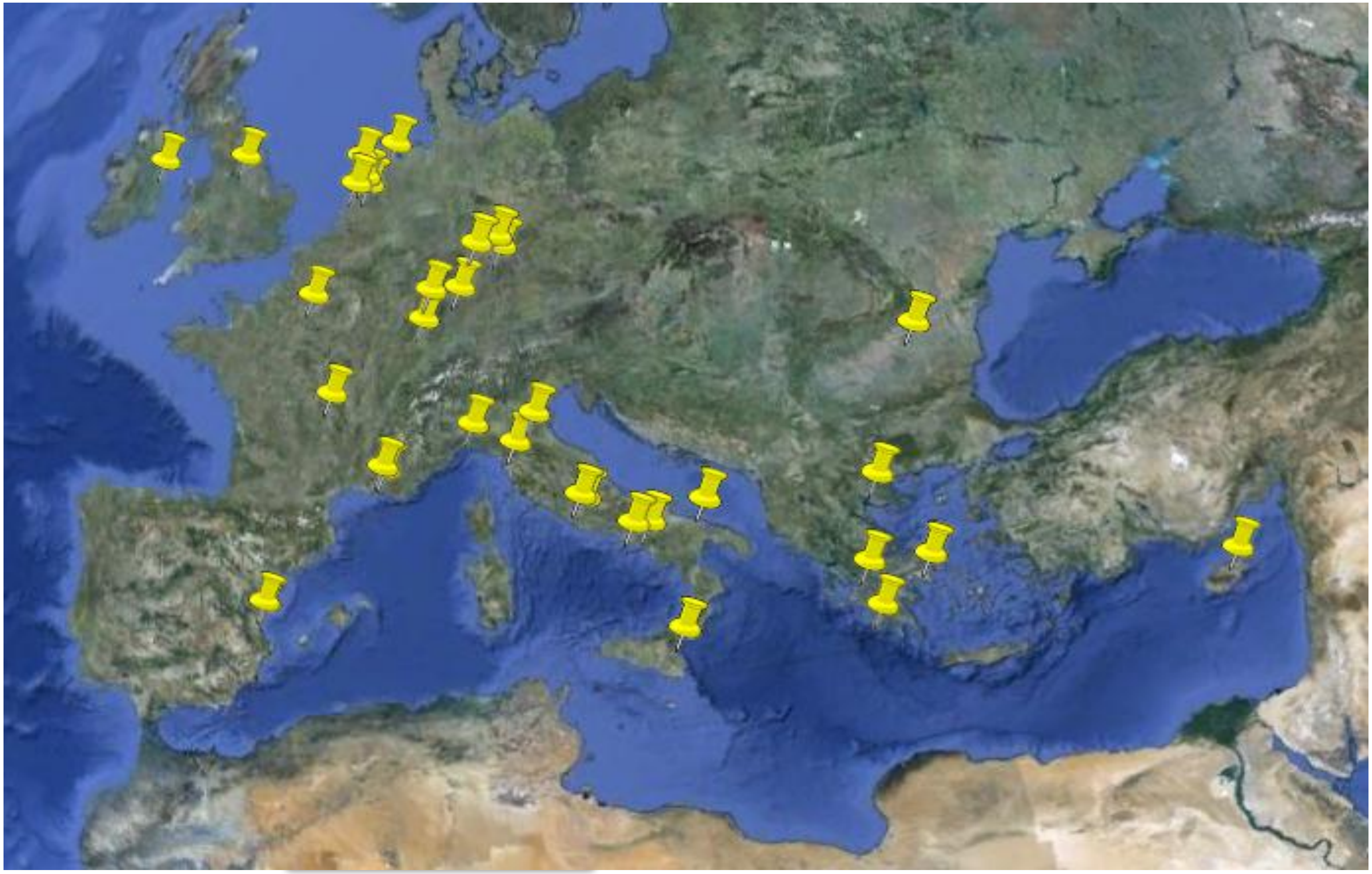
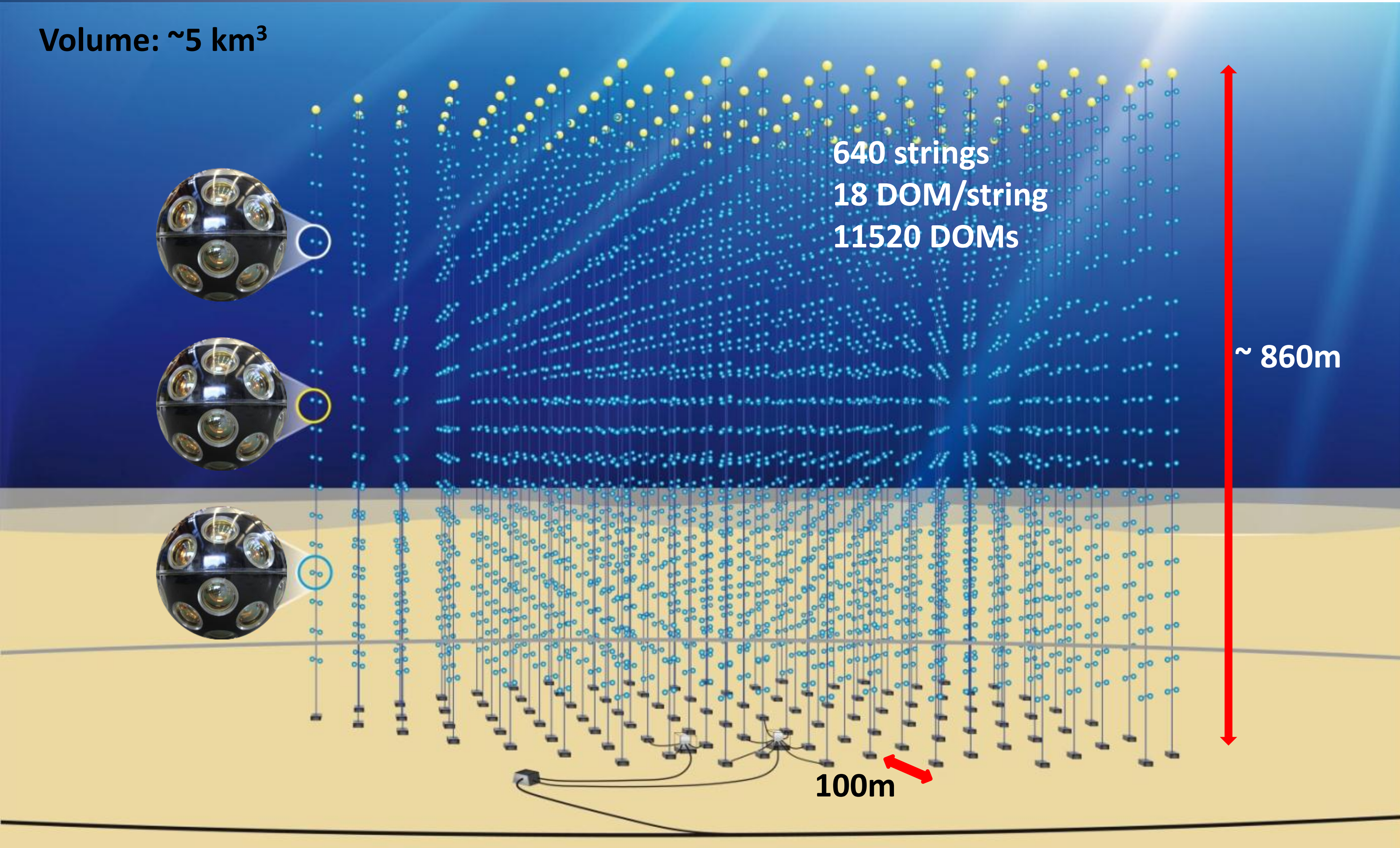
# KM3NeT Collaboration

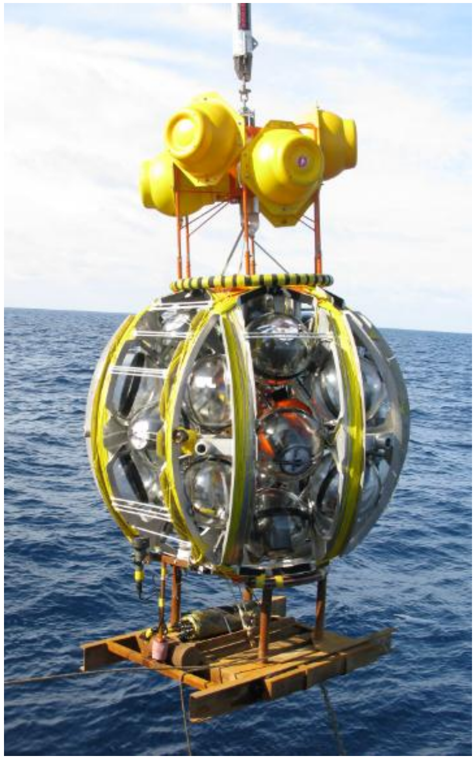


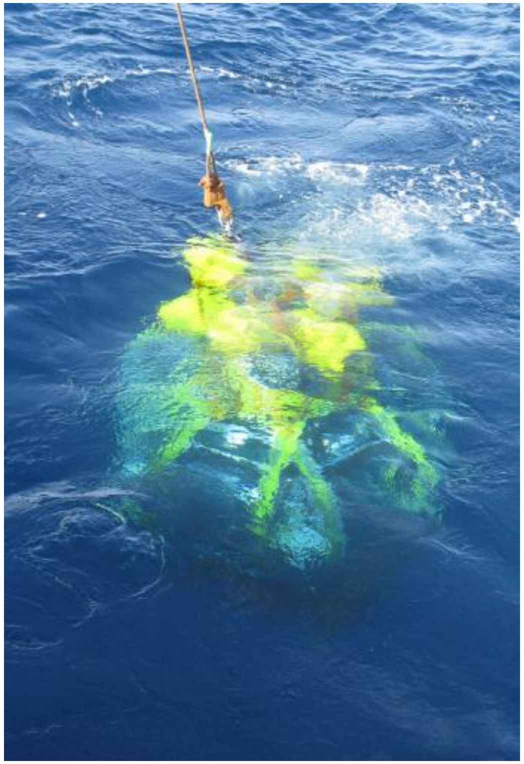
**40 Institutes**

# KM3NeT  Neutrino Telescope



# Deployment Of KM3NeT Detection Units



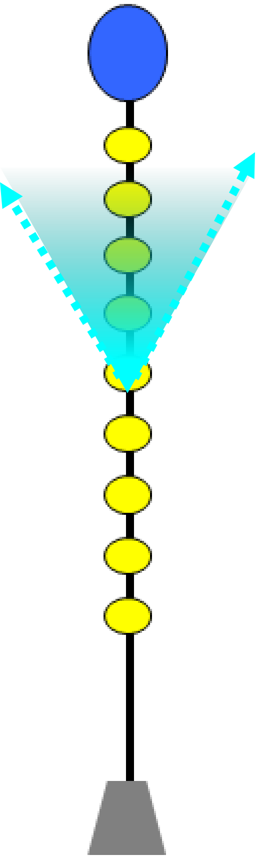


640 string with optical sensors
in the deep sea at 3-5 km depth

# KM3NeT Time Calibration System (I)

- The experience from the previous projects shows that a system of **external light sources** with a **known emission time** ensures the time calibration and provides measurements of the optical water properties.
- Decoupling the intra/inter detection unit (DU) calibration seems the best solution.
- The **calibration constants** are obtained putting all the information together.

# KM3NeT Time Calibration System (II)



**Decoupling within the same Detection Unit (intra- D.U.) and between D.U. (inter-D.U.) calibration systems**

## INTRA D.U. Calibration (See David's talk):

**One Nanobeacon per Digital Optical Module. Looking upwards**

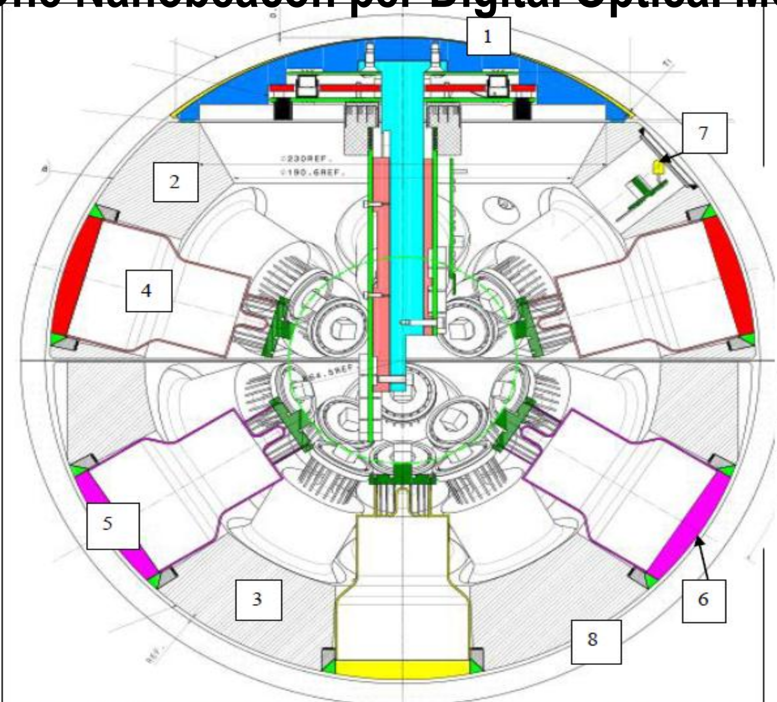
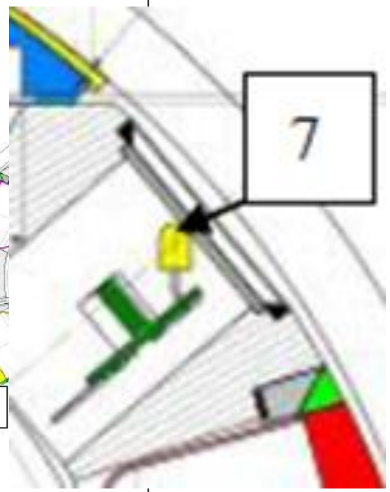



Figure 7 DOM-PPM, Cross section A-A. Numbers refer to: 1-Heat conductor, 2,3- Foam cores, 4-PMT with PMT base, 5-Expansion cone, 6-Optical coupler, 7-Nanobeacon, 8-Glass sphere, 9-Piezo element.



# KM3NeT Time Calibration System (III)

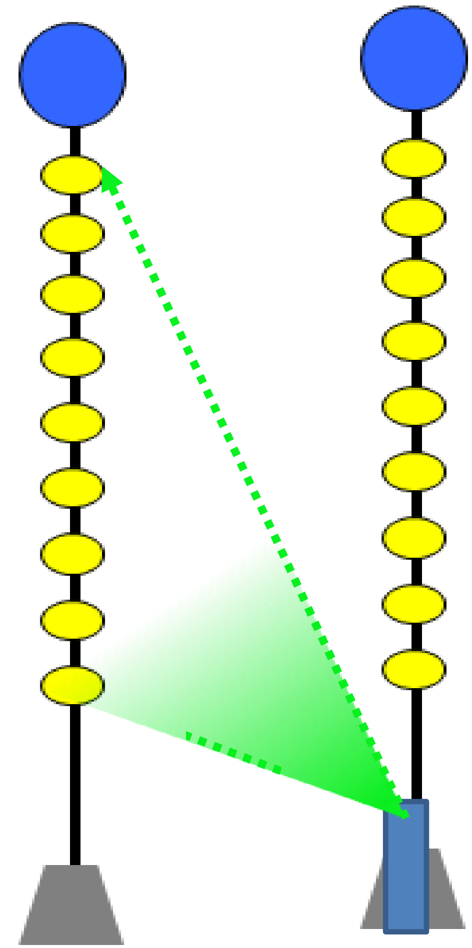
**Decoupling within the same D.U. (intra- D.U.) and between D.U. (inter-D.U.) calibration systems**

## INTER D.U. Calibration:

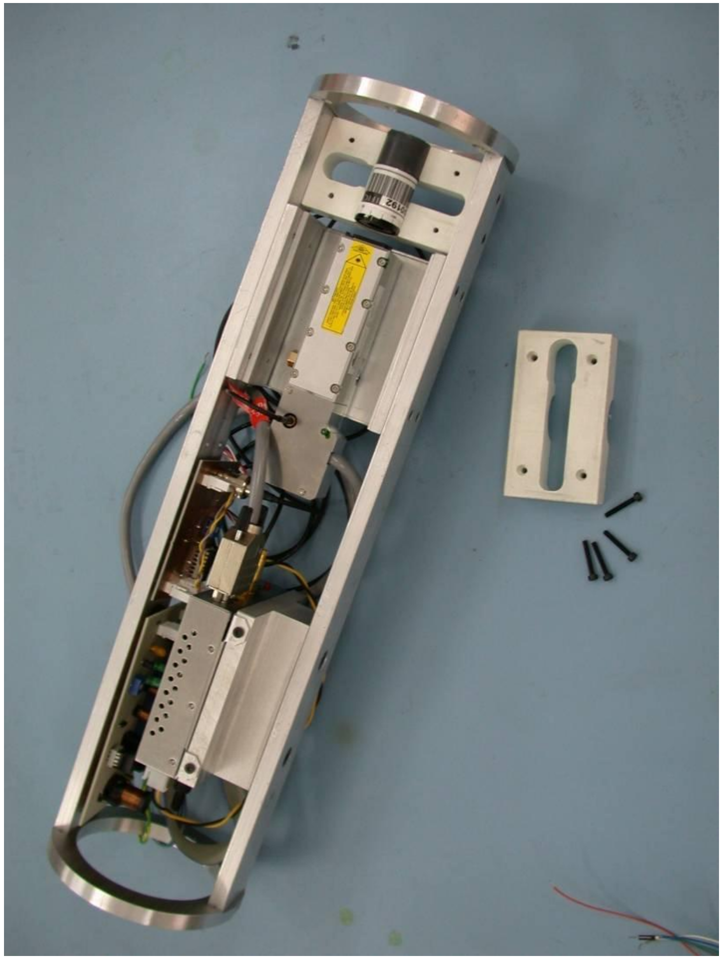
- **One Laser Beacon every 8 D.U**

**Laser Beacons @ 532 nm**

- ✓ Higher in intensity and shorter pulses < 1 ns
- ✓ More expensive but less redundancy required
- ✓ Tunable by Liquid Crystal Optical attenuator
- ✓ Collimated beam -> Diffusion device needed

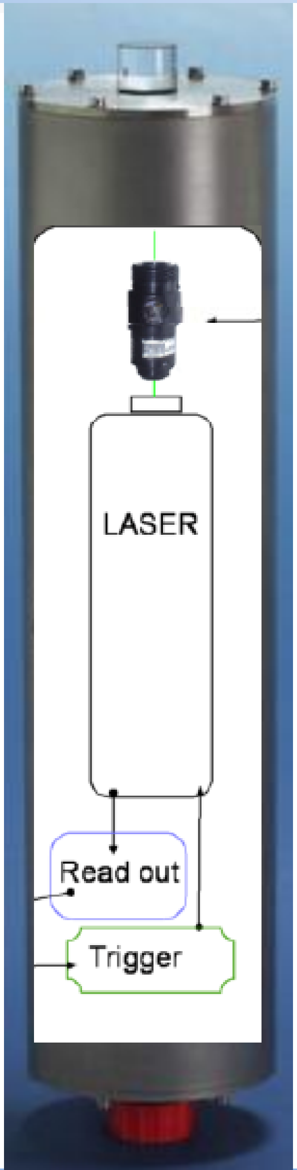


# Laser Beacon Description



## LASER BEACON:

- ✓ Titanium Container
- ✓ Internal Mechanics
- ✓ Connector
- ✓ Laser Head
- ✓ Built-in Photodiode
- ✓ Antibiofouling system
- ✓ The Voltage Controller Optical Attenuator



# Laser Beacon Mechanics

Cylinder of 650 mm high and 142 mm of diameter

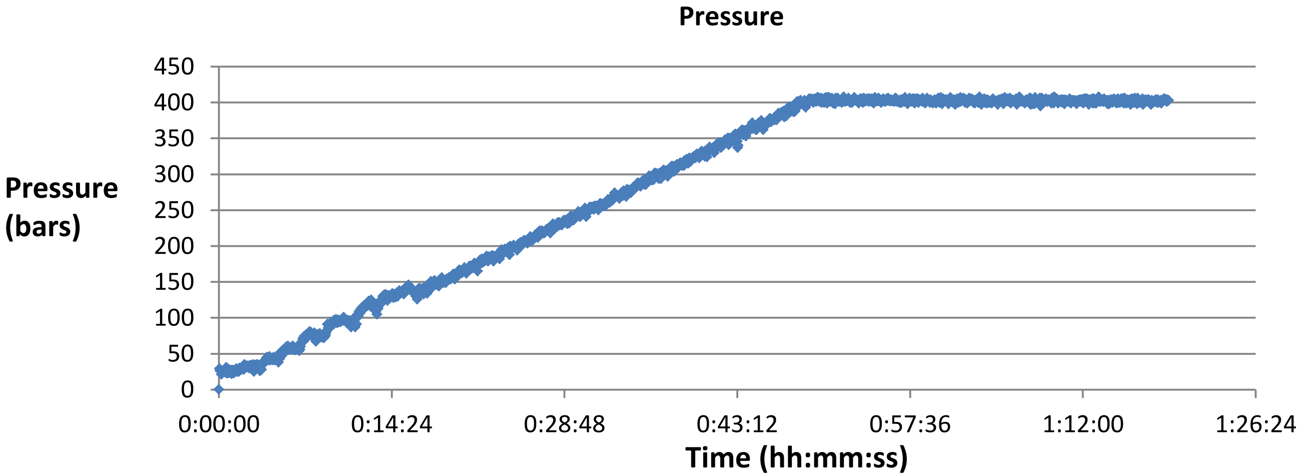
Made in Titanium grade 5 (Ti6Al4V) to avoid marine corrosion

Composed of three different pieces:

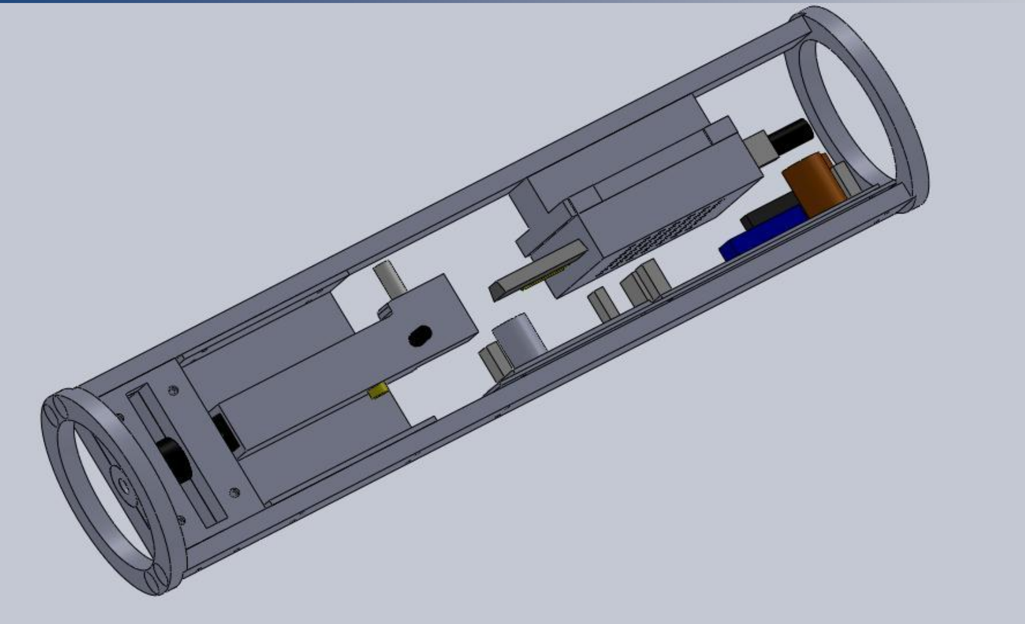
- ✓ The cylindrical tube
- ✓ The lower cap (connector cap)
- ✓ The upper cap with the anti-biofouling system

Designed to resist up to 5000 meters deep

Pressure test at 400 bars

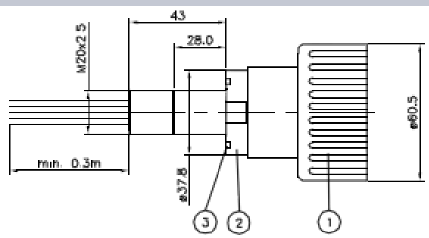


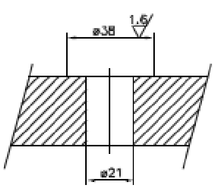
# Internal Mechanics And Connector

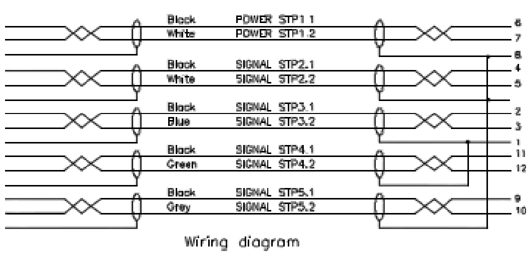


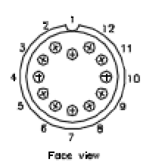
**Inner mechanics:**

- ✓ Provides the structure where the different devices of the laser beacon are integrated
- ✓ Internal mechanics developed in aluminum
- ✓ two aluminum rings joined together by two aluminum beams



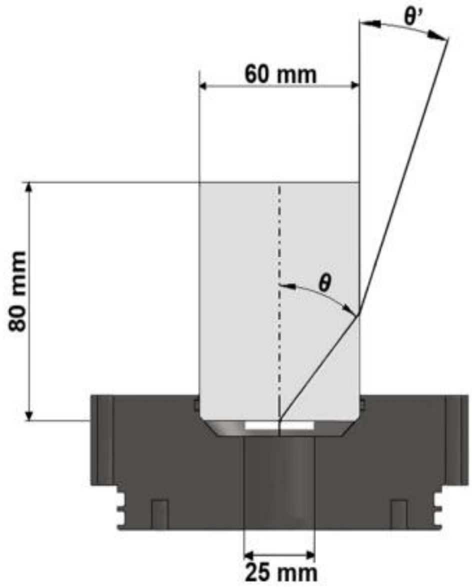



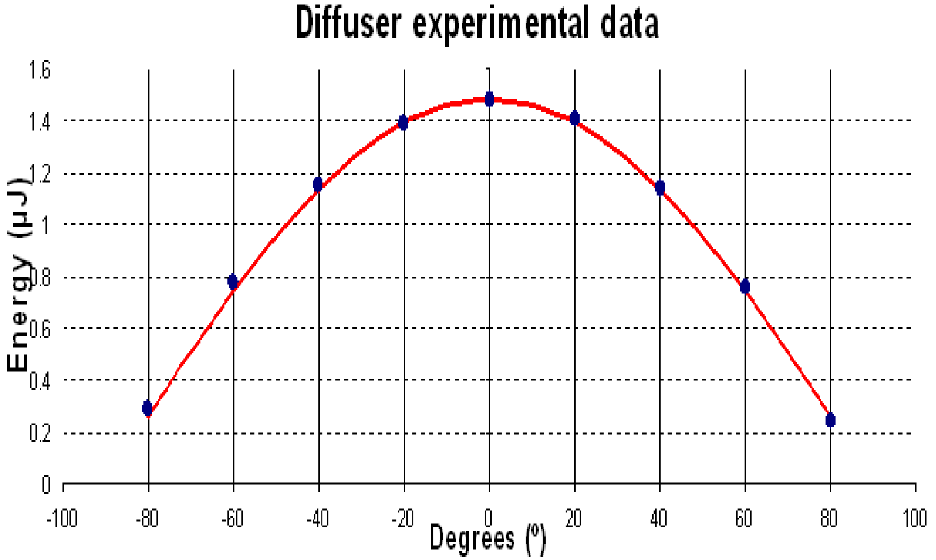




**Connector :**

- ✓ Made in titanium grade 5 from MacArtney
- ✓ Allows connection between the LB and the D.U

# The Anti-Biofouling System




**The cylinder quartz**

- ✓ pressure-resistant quartz
- ✓ refractive index 1.4585
- ✓ 60 mm x 80 mm
- ✓ Inserted 10 mm into the upper titanium cap

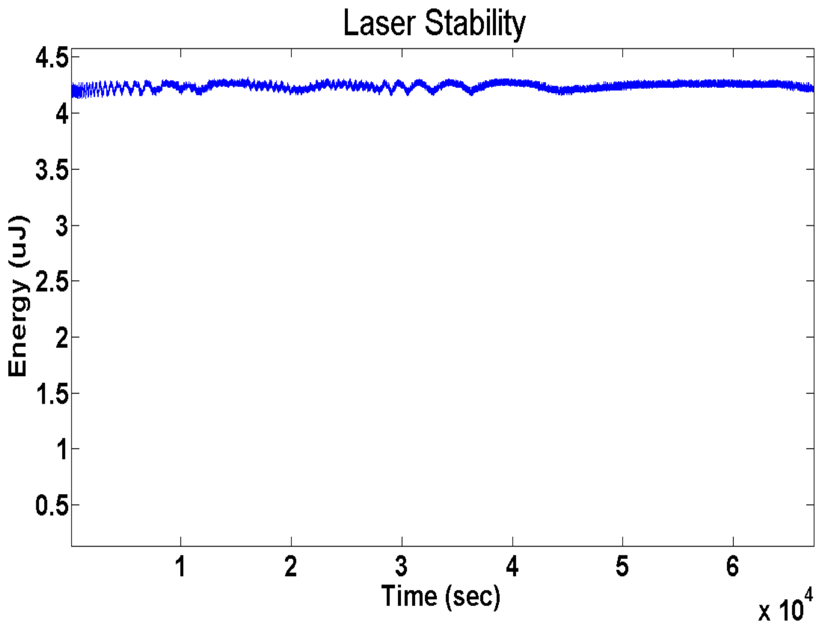
Possible to illuminate photo-sensors located at a horizontal distance of **200 m and 50 m** above the seabed.

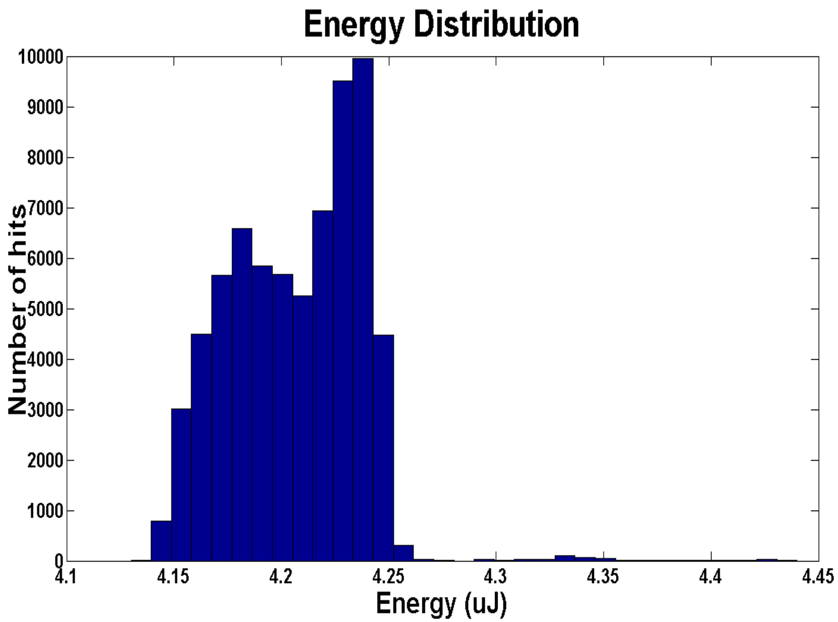
**Diffuser**

- ✓ model 48010 from ORIEL (Flashed opal diffuser)
- ✓ Thickness of 2.2 mm
- ✓ Diameter of 25 mm.
- ✓ Lambertian distribution

# KM3NeT Laser Beacon Tests Head (I)

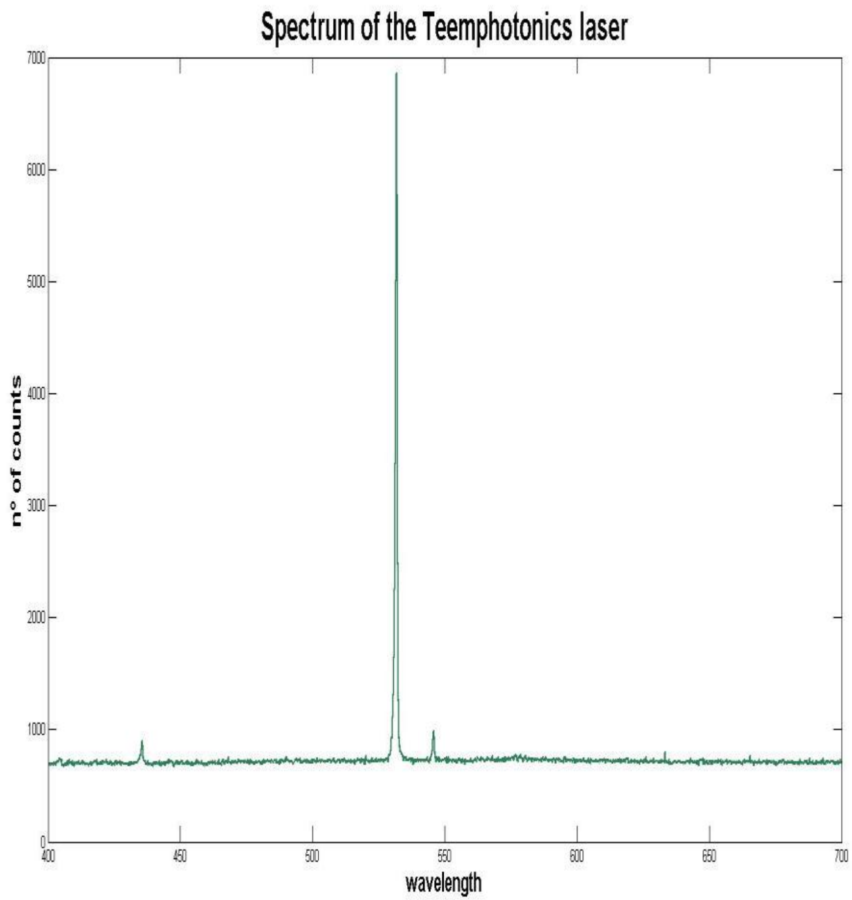
- ✓ Diode pumped Q-switched Nd-YAG laser
- ✓ Short pulses. FWHM ~ 400 ps
- ✓ Energy per pulse of 3.5 µJ (manufacturer)
- ✓ 4.15v – 4.25 µJ  measured in laboratory



# KM3NeT Laser Beacon Tests Head (II)

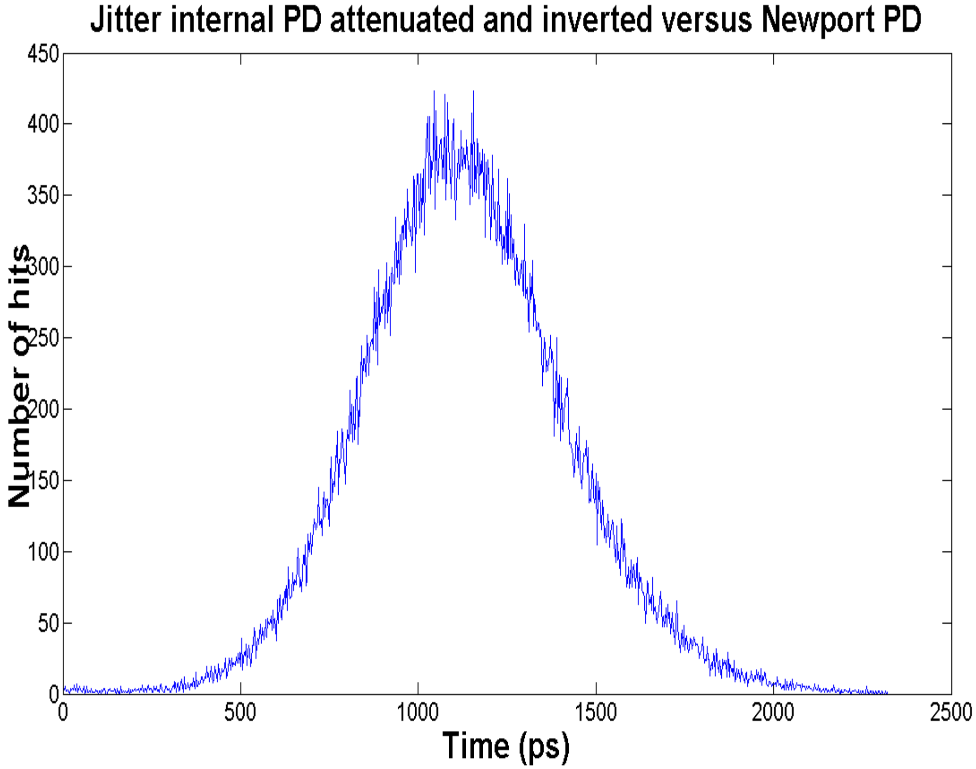
## Green @ 532 nm




Measurements carried out with the Spectrometer Ocean Optics HR4000

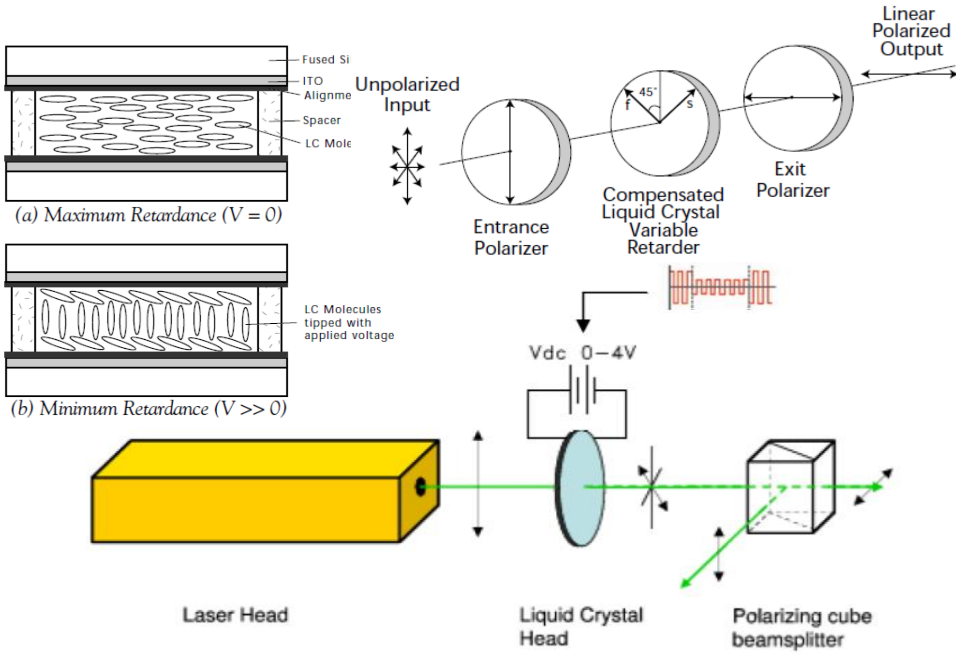
The laser presents the main spectrum at **532 nm** as expected

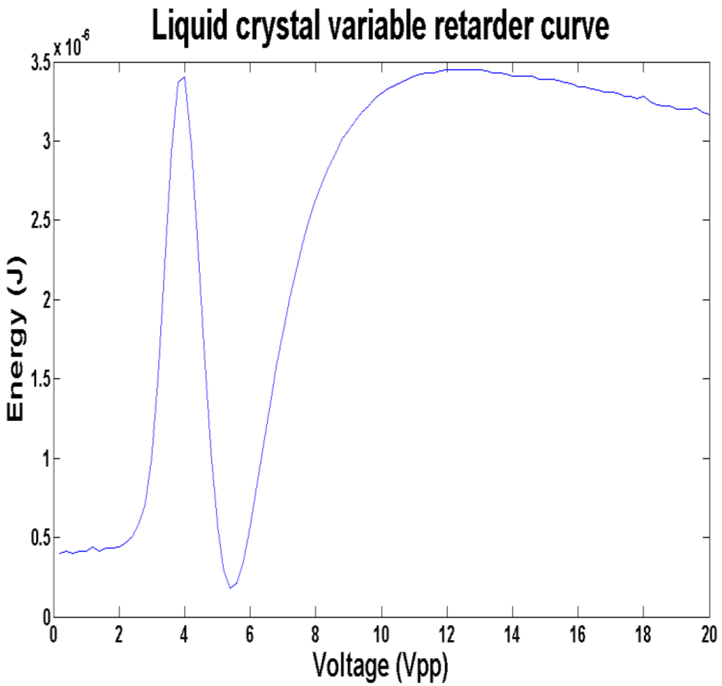
# Built-In Photodiode




- ✓ A jitter the laser pulse emission time of a **few hundred nanoseconds**
- ✓ **Internal Built-in photodiode** that provides the exact time of the laser light emission (0.5 ns)
- ✓ The read-out system to acquire the photodiode signal of the laser is not located in the laser container but in the D.U where the LB is connected
- ✓ The jitter of the internal photodiode has been measured using an external photodiode (Newport 812-20 photodiode with a rise time lower than 200 ps) directly illuminated by the laser beam
- ✓ The FWHM of the measured built-in photodiode **jitter is lower than 550 ps**

# The Voltage Controller Optical Attenuator



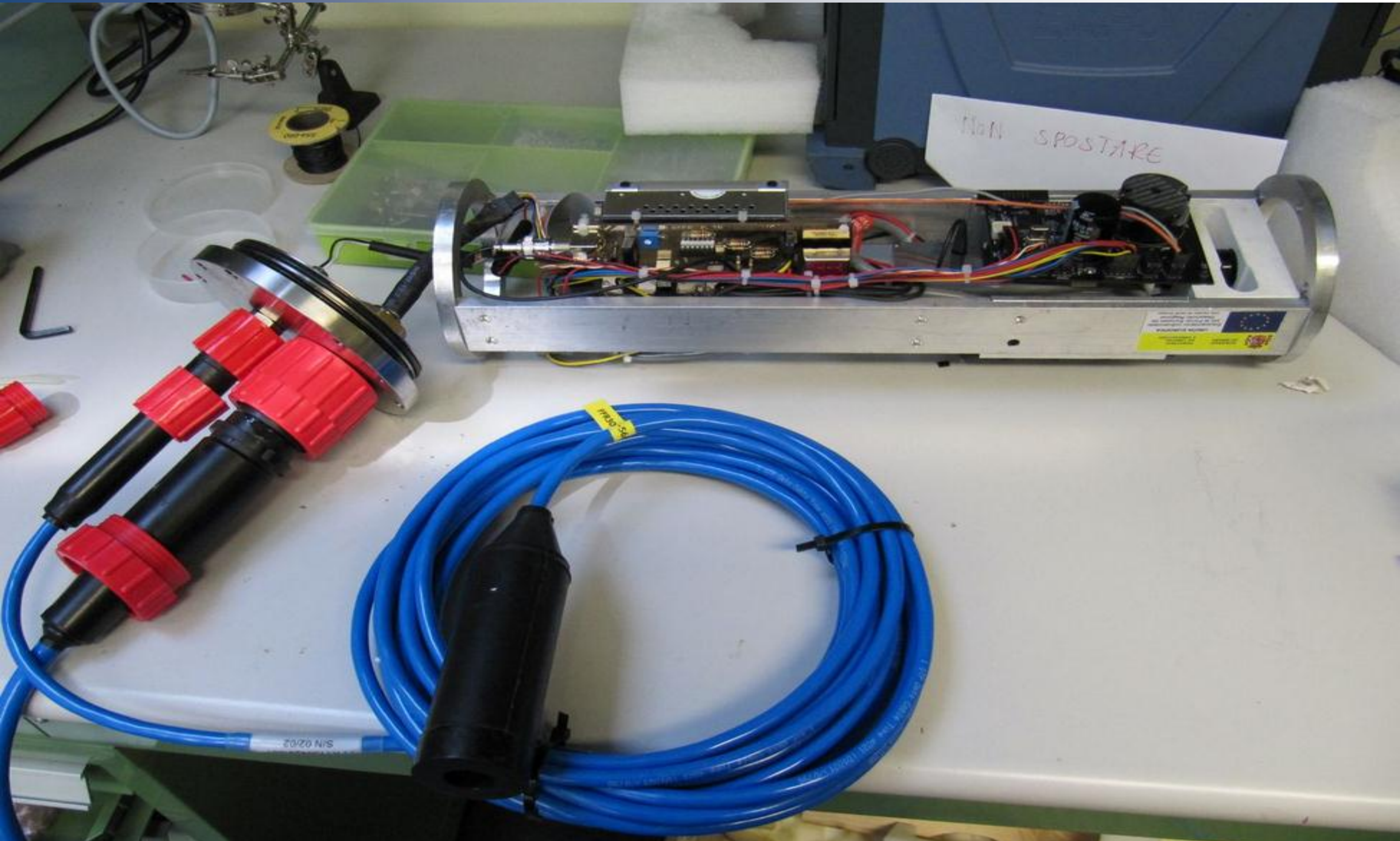

- ✓ Unlike LED sources **the amount of light emitted by the laser is fixed**
- ✓ A **voltage-controlled optical attenuato**r using a liquid crystal variable retarder located in the beam path is used
- ✓ a **beam-splitting polarizing cube** is used since they have a higher damage threshold to laser exposure than standard linear polarizer
- ✓ The model used is optimized to work in the **420 to 680 nm range**

# KM3NeT Laser Beacon Tests

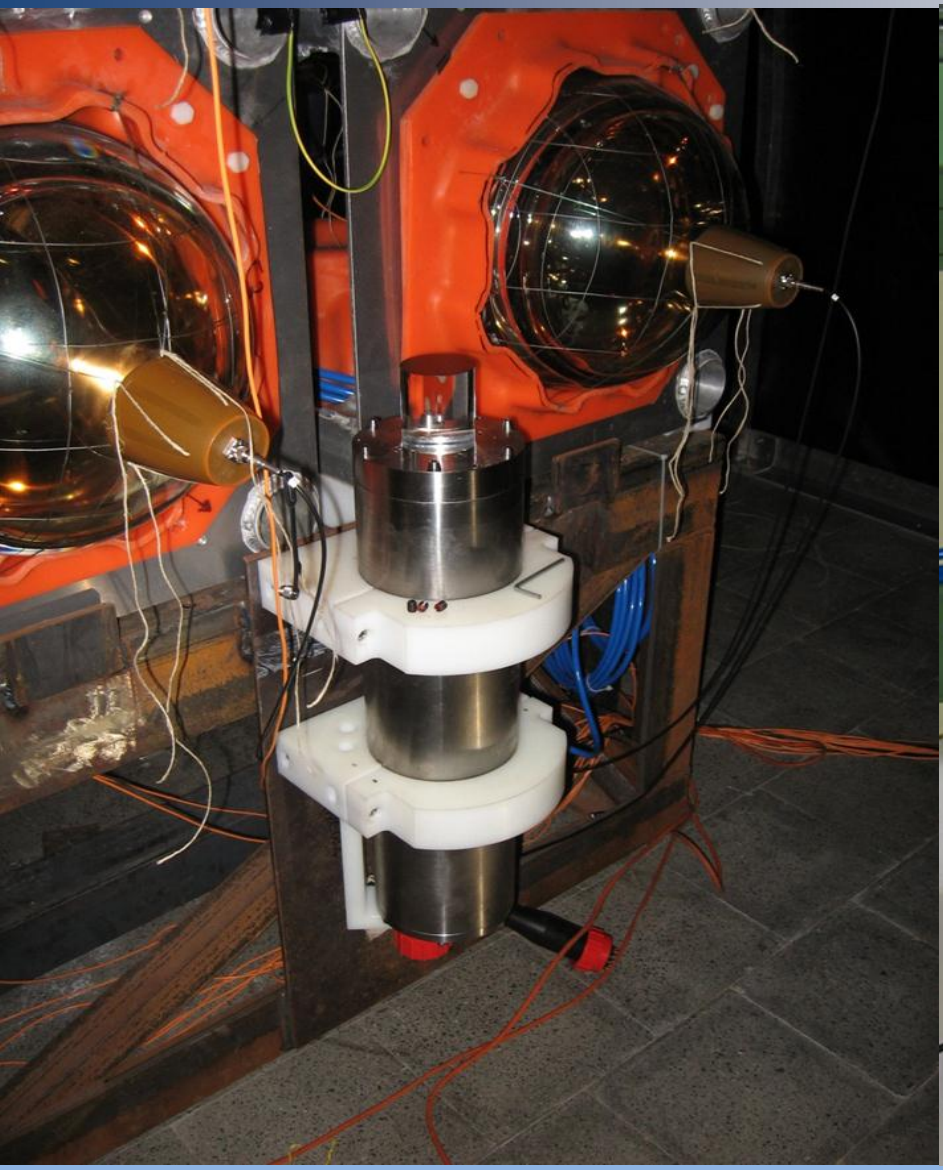
- **1 laser beacon integrated in the ANTARES IL13**
- **1 laser beacon integrated in the KM3NeT "Nemo Tower Phase II"**

**Both use a 3.5 µJ the laser head STG-03E-1S0 from Teemphotonics which emits light with a wavelength of 532 nm after frequency doubling of the original Nd-YAG wavelength of 1064 nm**

# KM3NeT Laser Beacon Developments



# KM3NeT Laser Beacon Developments



# KM3NeT Laser Beacon Developments

New laser head. More powerful
25 µJ per pulse versus 3.5 µJ of previous head.

| Model | PNP-B06010 | PNP-B08010 | PNG-B02010 |
|---|---|---|---|
| Energy/Pulse (µJ) | 70 | 90 | 25 |
| Pulse Width (ps) | 400 | 400 | 300 |
| Peak Power (kW) | 175 | 220 | 80 |
| Repetition rate (Hz) | 1,000 | 1,000 | 1,000 |
| Average Power (mW) | 70 | 90 | 25 |

Typical values

# Conclusions

- **1 laser beacon** integrated in the ANTARES IL13 **(3.5 µJ)**
- **1 laser beacon** integrated in " KM3NeT Nemo Tower Phase II" **(3.5 µJ)**
- Proposal to use a new laser head for KM3NeT.
  - More powerful with **25 µJ** per pulse