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

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KM3NeT Collaboration

40 Institutes
Volume: ~5 km³

KM3NeT Neutrino Telescope

640 strings
18 DOM/string
11520 DOMs

~ 860 m

100 m
Deployment Of KM3NeT Detection Units

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

Pressure (bars)

Pressure vs. Time (hh:mm:ss)
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

![Laser Stability](Image)

- [Graph showing laser stability over time](Image)

![Energy Distribution](Image)

- [Histogram showing energy distribution](Image)
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 attenuator 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
New laser head. More powerful 25 µJ per pulse versus 3.5 µJ of previous head.
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