Photonics-oriented data transmission network for the KM3NeT prototype detector

Jelle Hogenbirk, Nikhef)*

On behalf of the KM3NeT consortium

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Presentation Lay-out

- Description of the prototype KM3NeT detection unit
- Network block diagram of the optical network
- Optical Test bench
- Results
- Next steps

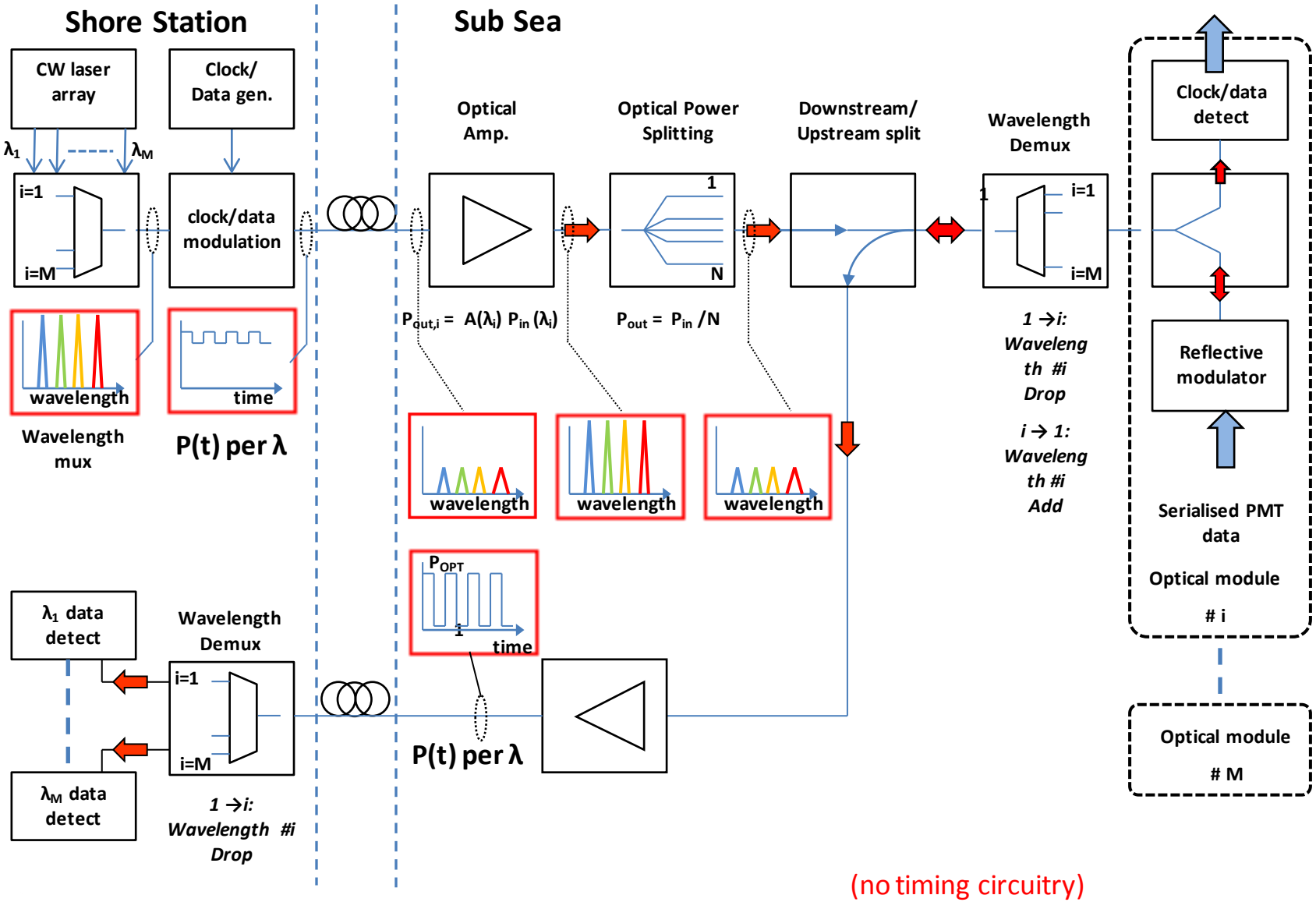
Configuration prototype KM3NeT detection unit

- Detection unit with 20 storeys
- Two storeys equipped with Digital Optical Modules (DOMs)

→ In total 4 DOMs connected to shore

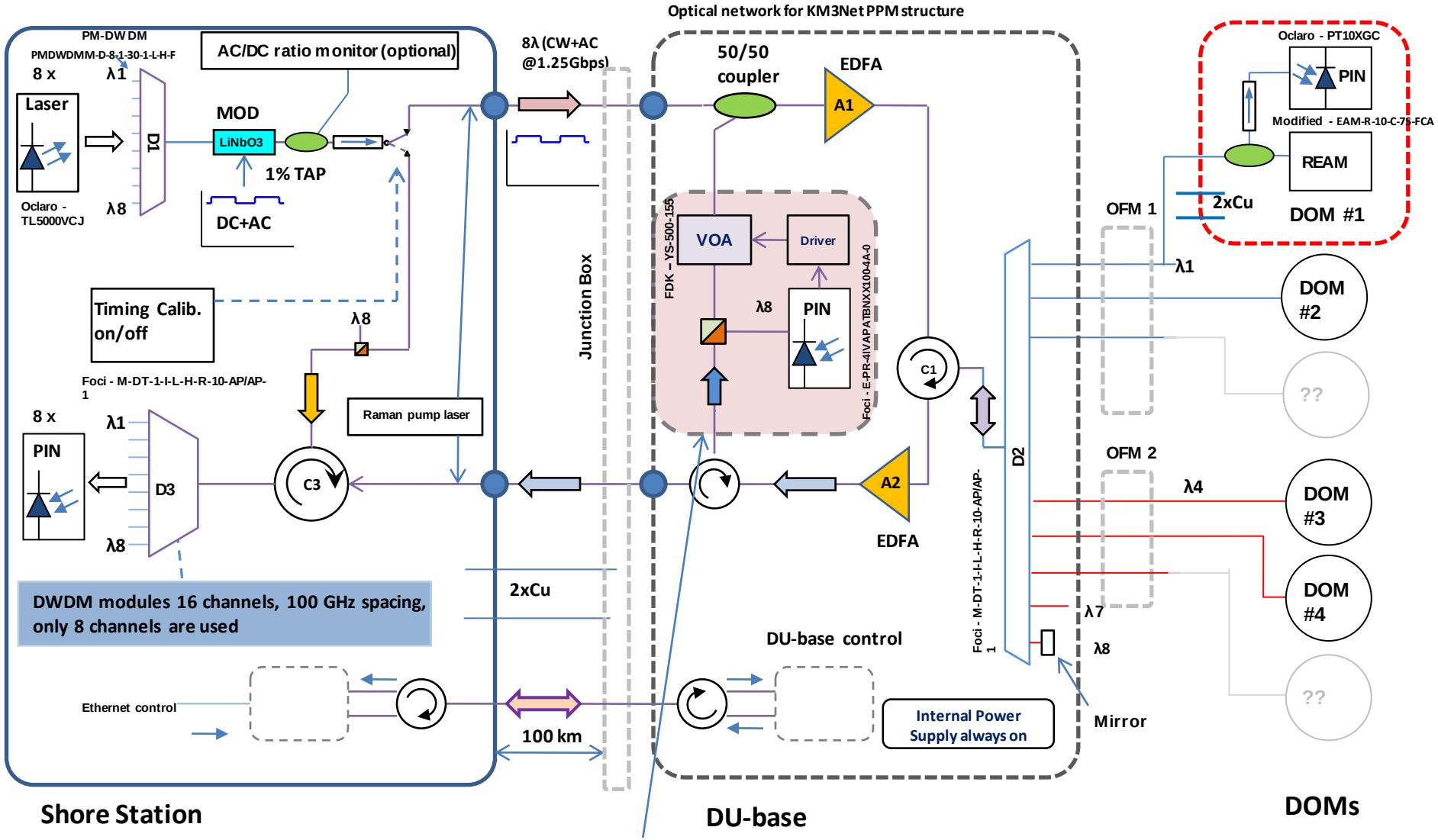
The prototype optical network will provide unique point-to-point optical connections between the shore and each DOM

Optical Network data flow



(no timing circuitry)

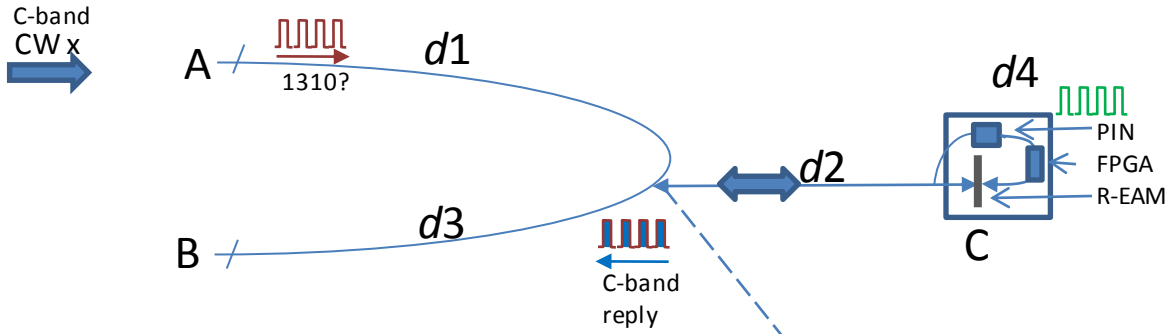
Optical Test Bench



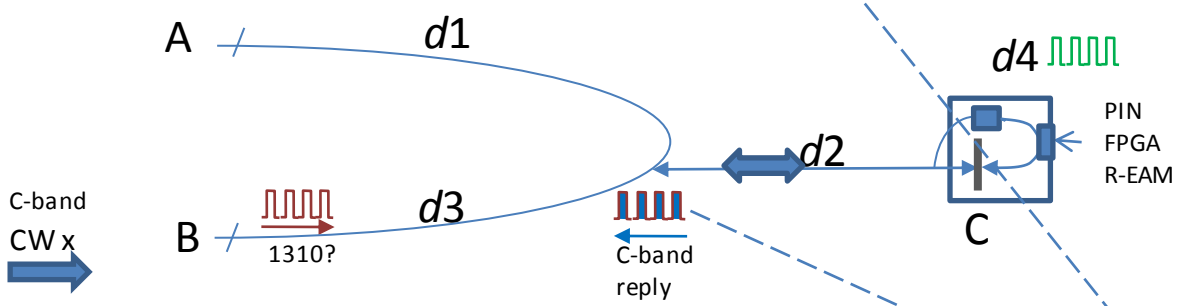
Enabling Signal Propagation Time Measurements

Signal Propagation Time Measurement

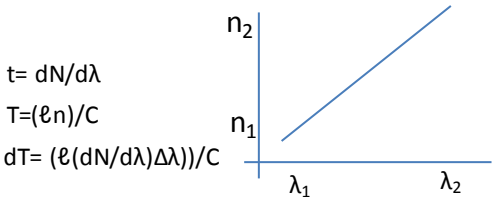
Assume fibre length: ℓ d1 < ℓ d3

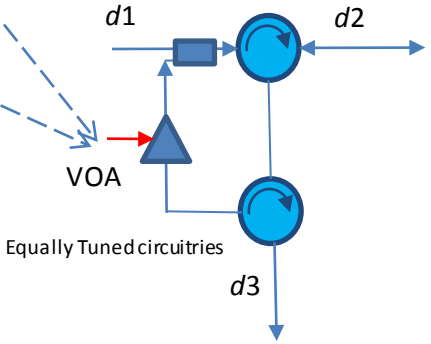


Total time T_{p1}=d1+d2+d4+d2+d3



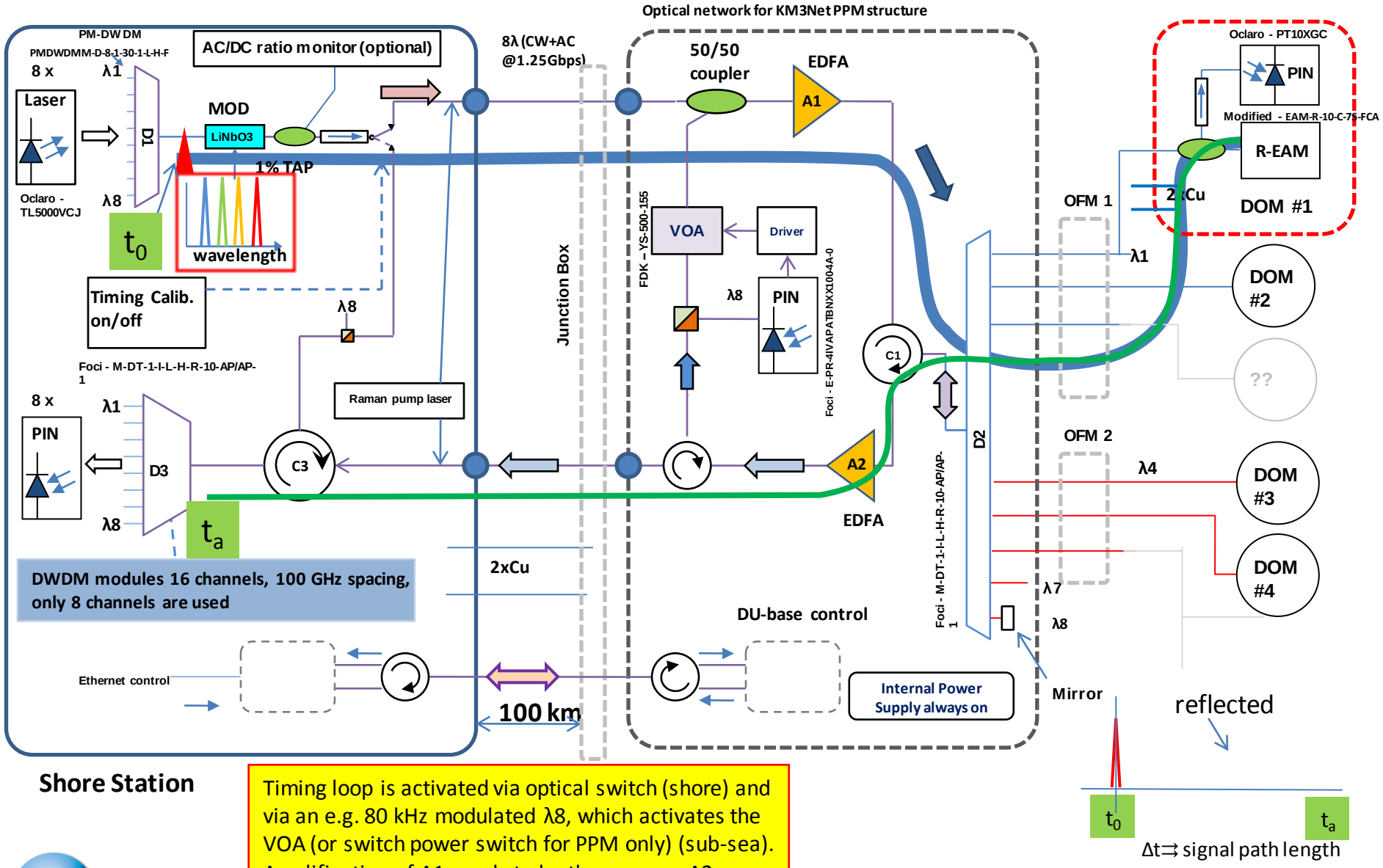
Total time T_{p2}=d3+d2+d4+d2+d3





ℓ = length
C = speed of light
N = numerical aperture
T = time

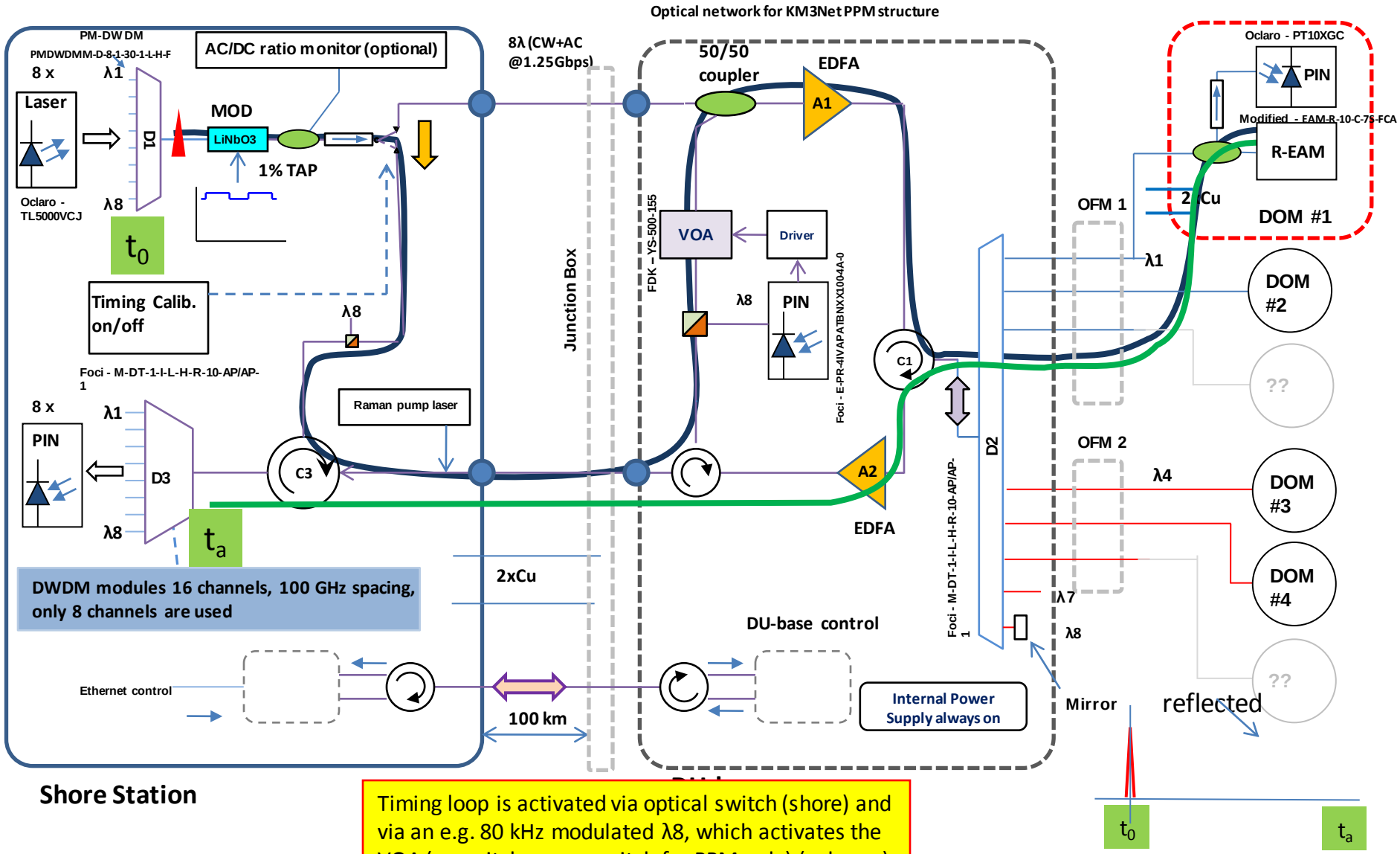
Signal Propagation Time measurement step 1



Shore Station

Timing loop is activated via optical switch (shore) and via an e.g. 80 kHz modulated λ8, which activates the VOA (or switch power switch for PPM only) (sub-sea). Amplification of A1 needs to be the same as A2.

Signal Propagation Time measurement step 2

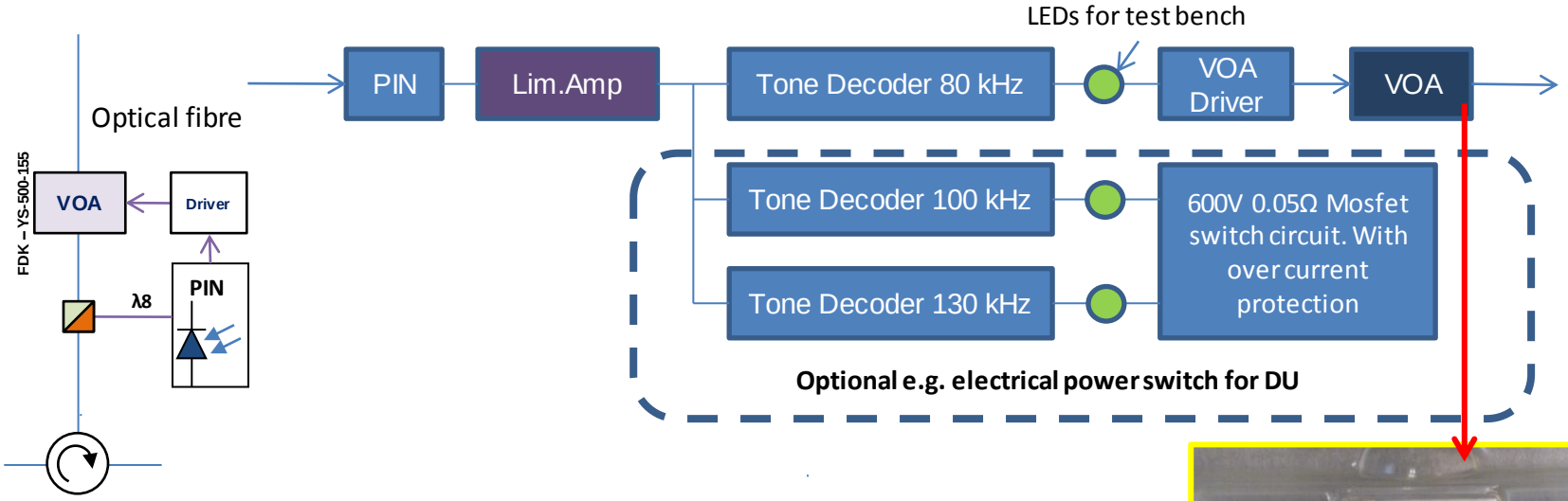


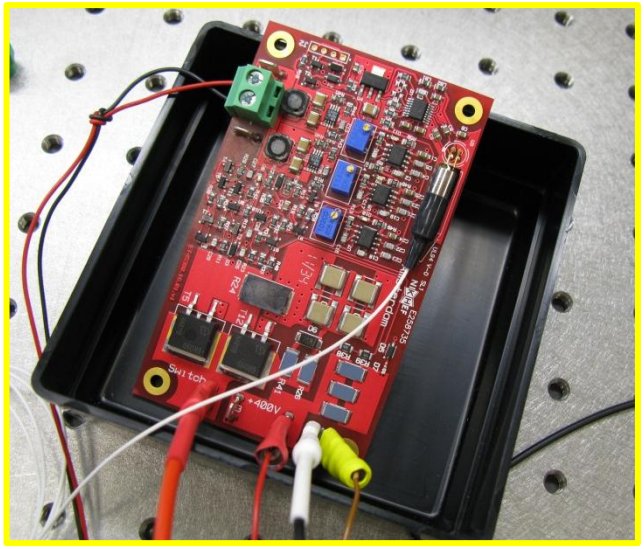
DWDM modules 16 channels, 100 GHz spacing, only 8 channels are used

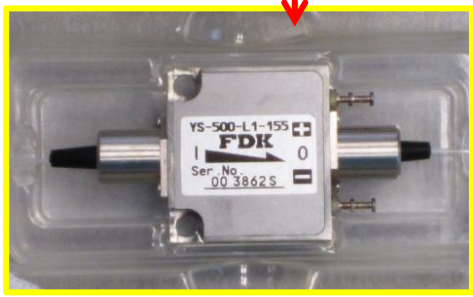
Shore Station

Timing loop is activated via optical switch (shore) and via an e.g. 80 kHz modulated λ8, which activates the VOA (or switch power switch for PPM only) (sub-sea). Amplification of A1 needs to be the same as A2.

Switch for Propagation Timing



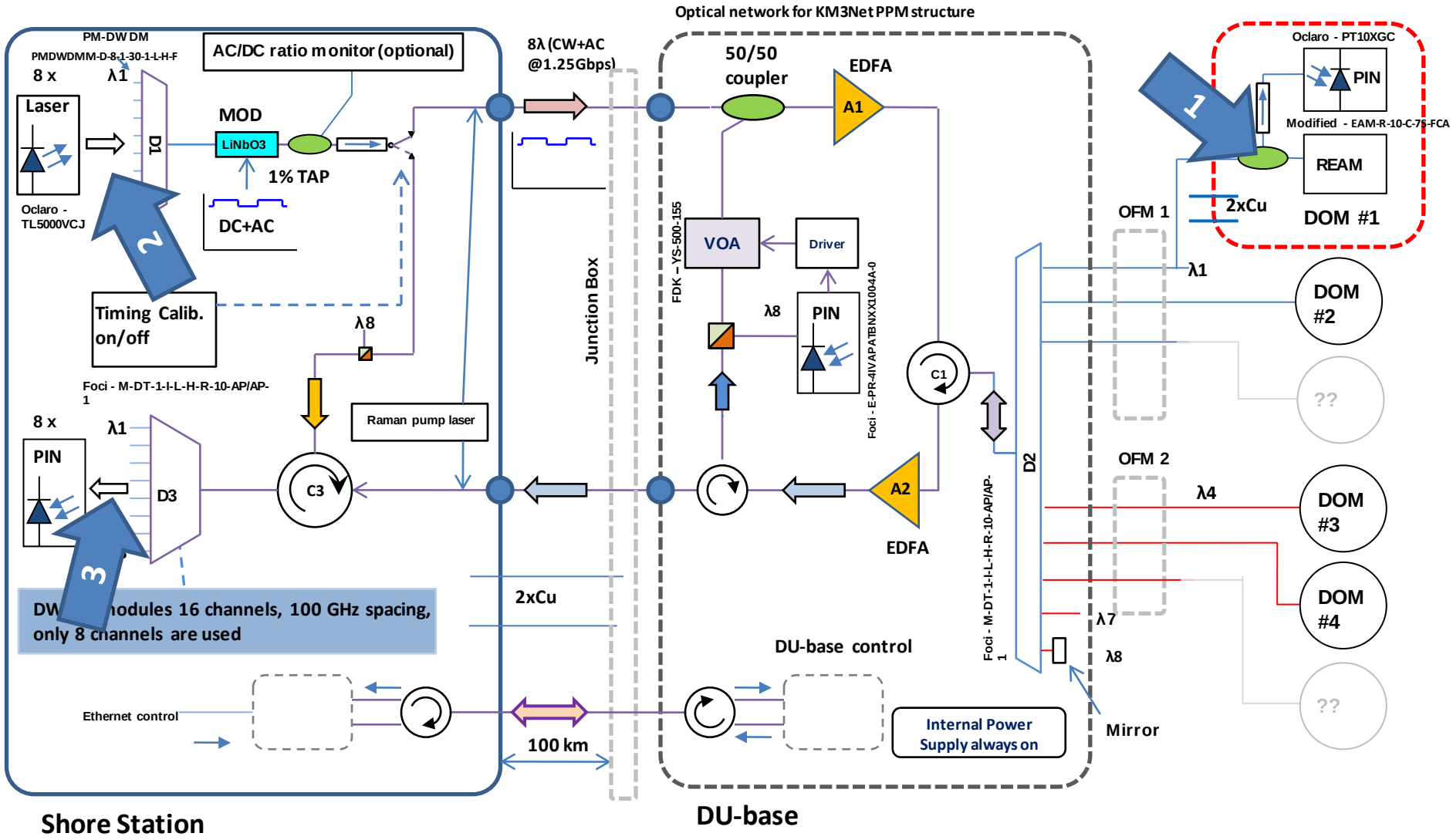




Variable Optical Attenuator

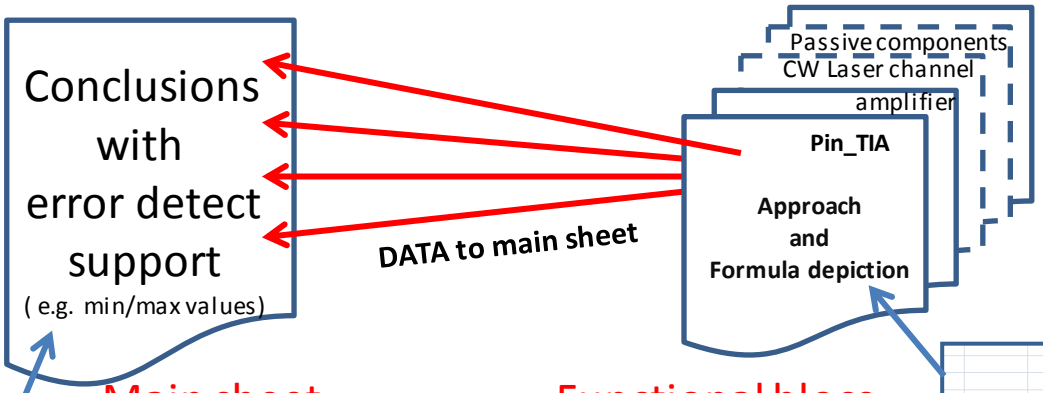
The optical AM modulated signal on λ8 is converted by the PIN diode to an electrical signal and directed to the limiting amplifier. When the frequency of the original signal matches the adjusted tone decoder frequency the VOA (used as a switch) is activated or deactivated.
Extra option: After power up the solid state switch is "on" after a minimum of 350 V. The switch is controlled by the 100kHz and 130 kHz tone decoders.
A power switch with over current protection is included.

Determination of the Optical signal levels



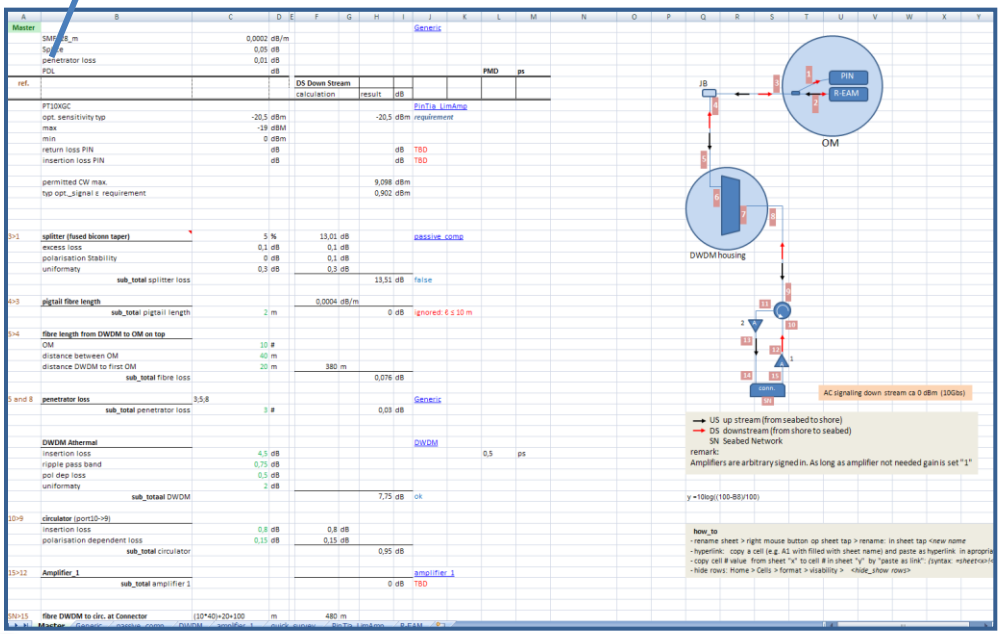
Sequence measurements for optical signal level determination

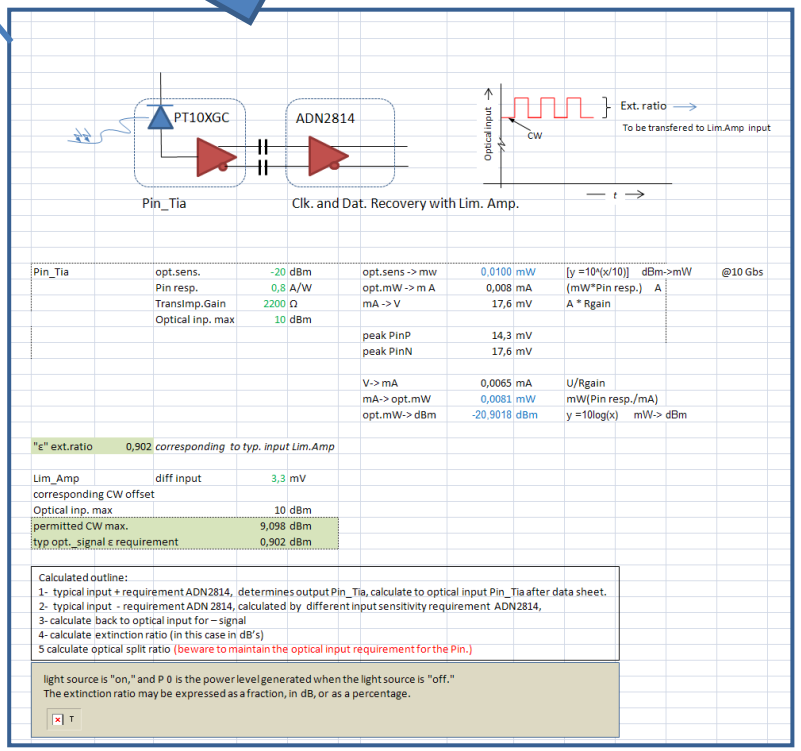
Attended Spread Sheet Overlay for design control



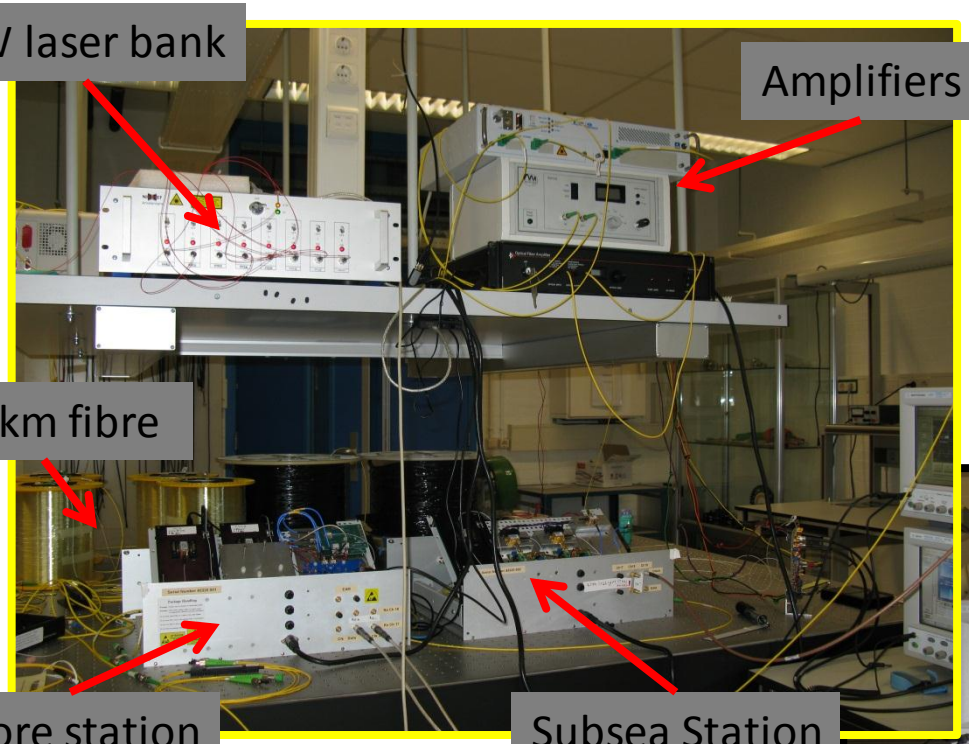
Main sheet

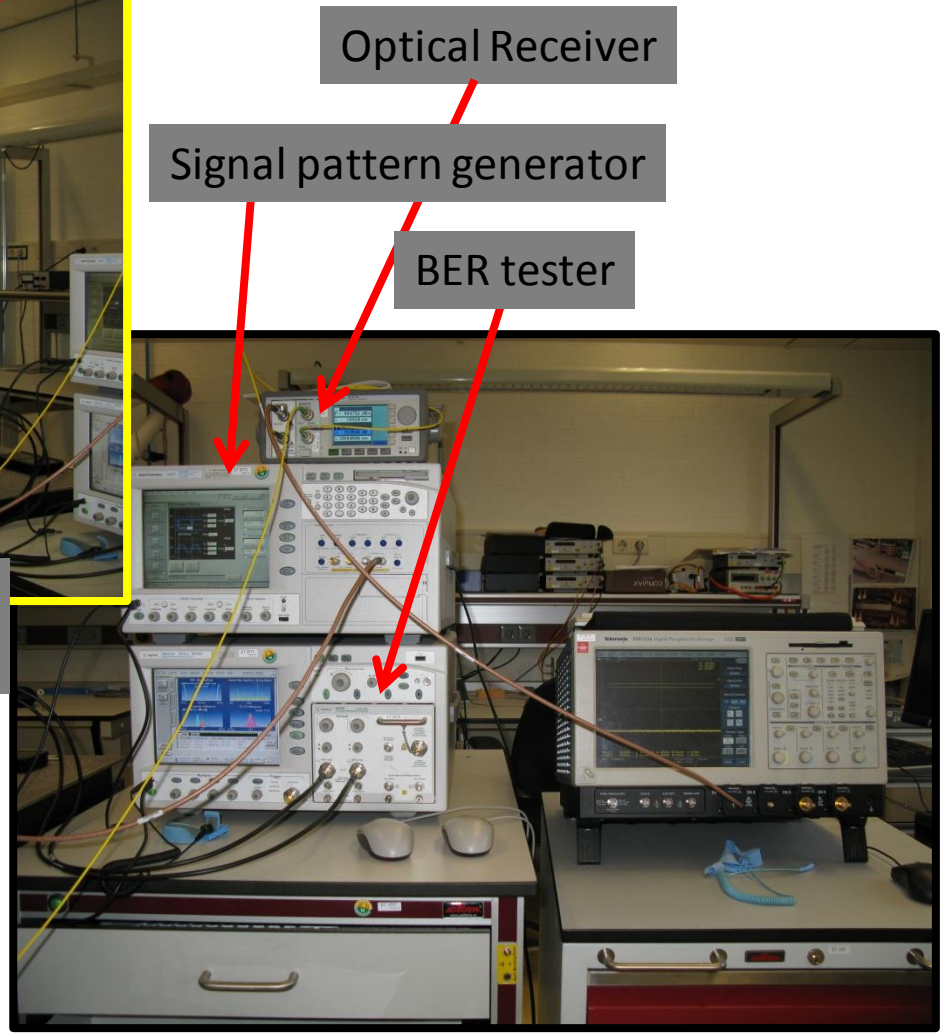
Functional blocs





Test Bench @ Nikhef





Joint forces with the engineers of LNS-INFN Catania

Results

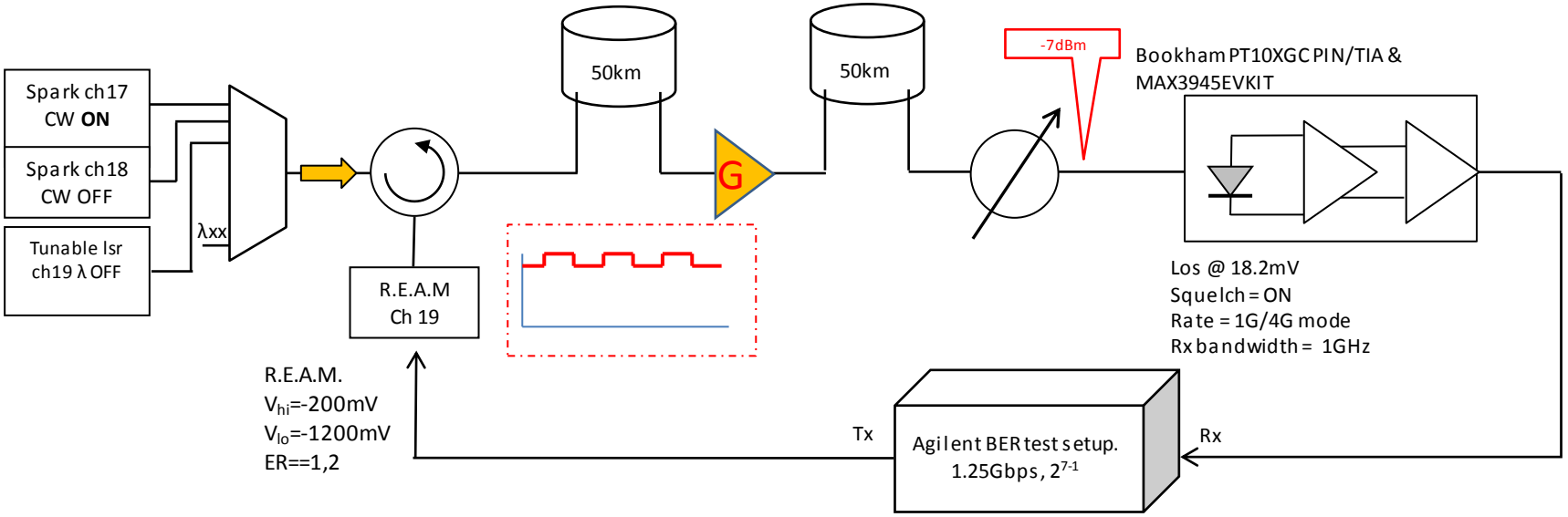
- The basic optical test bench setup compliant to a bidirectional data communication has been realized for 1 optical channel with an extinction ratio of 5% at the receiver. (Over a span of 100 km using optical amplifiers and the receiver is a PIN diode)

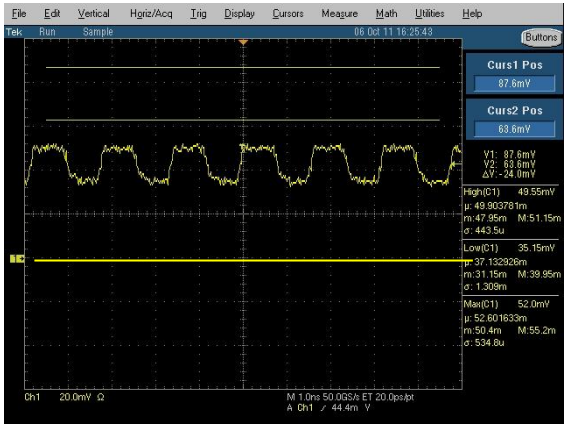
  The engineers from IRFU (Saclay) tested their standard 1000BASE-X ETHERNET system over a bidirectional span of 100 km over this test bench successfully. (however with a higher E.R.)

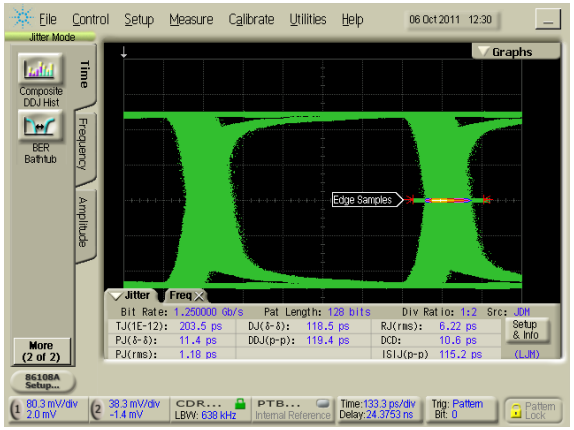
- Test bench is ready for "Synchronous command insertion and extraction" that can be implemented for accurate signal propagation time measurements

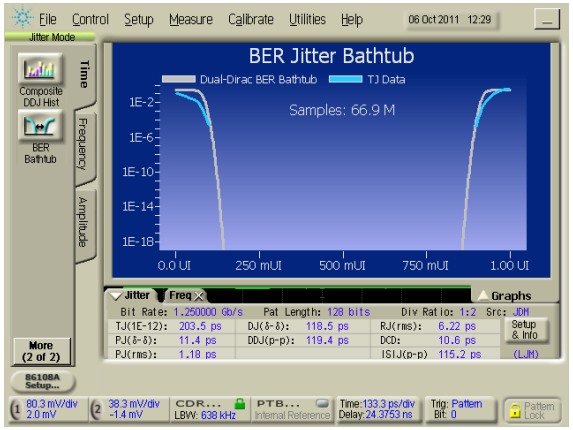
- The Raman Amplifier, EDFA and optical fibre, supplied by INFN Catania are successfully tested over a span of 100km. Some amplifier parameters are still to be optimized.

Optical Communication Setup









Component Inventory for prototype optical network

For the PPM of KM3NeT sufficient optical parts available for at least 6 DOMs	Present at Nikhef
8 Tunable Lasers Full C-Band with variable output power. Mounted in a case	Yes
PM Patch cords	Yes
Polarization Maintaining DWDM	Yes
LiNbO3 modulator: currently only an old type available. New type in research/ordered	Yes/ordered
Isolators	Yes
Couplers	Yes
Circulators	Yes
DWDM: Subsea and shore station	Ordered
VOA (Variable Optical Attenuator)	Yes
R-EAMs	Ordered/soon
PIN Diodes for DOM	Yes
Add/Drop filter λ8 for timing circuit	Yes
PCB: Timing Circuit with driver for VOA	Yes
Optical Amplifiers to be ordered (industrial contacts are established)	No

Next steps

- ✓ Test bench to be extended with the 8 channel laser bank and
  Tests of the individual optical channels. E.g. influences of crosstalk etc.

- ✓ Implementation and tests of the Timing Switch.
  The configuration control in the system and repeating the
  "Synchronous command insertion and extraction"

- ✓ When the functionality of the system is proven
  system reliability to be reviewed.

To be continued

Steve Jobs saying:

I skate to where the puck goes

I don’t stay where the puck is

DAQ optical network for KM3NeT

- Subsea compatible (subsea reliable design = position of active and passive components, single point failures etc.) RAMS criteria
  (additional ongoing benefits of this system: among DWDM colorless connections of DU's
- Top Overlay bidi data communication circuitry (system modules in scientific notation)
- Work document schematics + timing circuitry (the golden circuitry)
- Showcase Test Data and tested components
- Inventory of components at Nikhef (laser bank), ordered, to determinate (contacts with industries)
- Next steps, planning

Electronic and photonics,
Mar van der Hoek, Sander Mos, Jan Willem Schmelling, Jelle Hogenbirk, Gerard Kieft, Henk Peek, Peter Janswijer, Paul Timmer, Albert Zwart
Mechanics,
Gertjan Mul, Auke Korporaal, Edward Berbee, Hans Kok, Rene de Boer, Herman Boer Rookhuizen
Coordination,
Eric Heine

RAMS

Evaluation of the RAMS criteria applied to the KM3NeT **network**

RELIABILITY

During design:
- Perform fault tree analyses
- Perform MTBF calculations
- Single point failures

During construction:
- Stringent QA program
- Test systems

During deployment
- Monitoring assistance
  e.g. deploying the MEOC

During operation:
- Monitoring

AVAILABILITY

During construction:
- Purchase of components
- Availability of components
- Second source suppliers

During deployment:
- Monitoring assisted deployment

During operation:
- Observation time versus Calibration time
- Response time to failures
- Time to Repair
- Spare parts

MAINTAINABILITY

- Reduce the number of sub-sea components
- Modularity of design
- Implementation of monitoring functions

First attempt . . .

SAFETY

During construction:
- Laser safety
- High voltage safety
- Optical sphere aspects

During deployment:
- t.b.d (WP 5)

During operation
- Environmental impact

These RAMS criteria are also applied to the related mechanics!