Univerza v Ljubljani
Fakulteta za elektrotehniko

LSO
Laboratorij za sevanje in optiko

SOK 2021
25th Seminar on Optical Communications

# Optical technologies on modern ships


<u>**Mladen Radovanović**</u>
**Boštjan Batagelj**

**5. 2. 2021**

# Challenges of optical technologies on a passenger ship

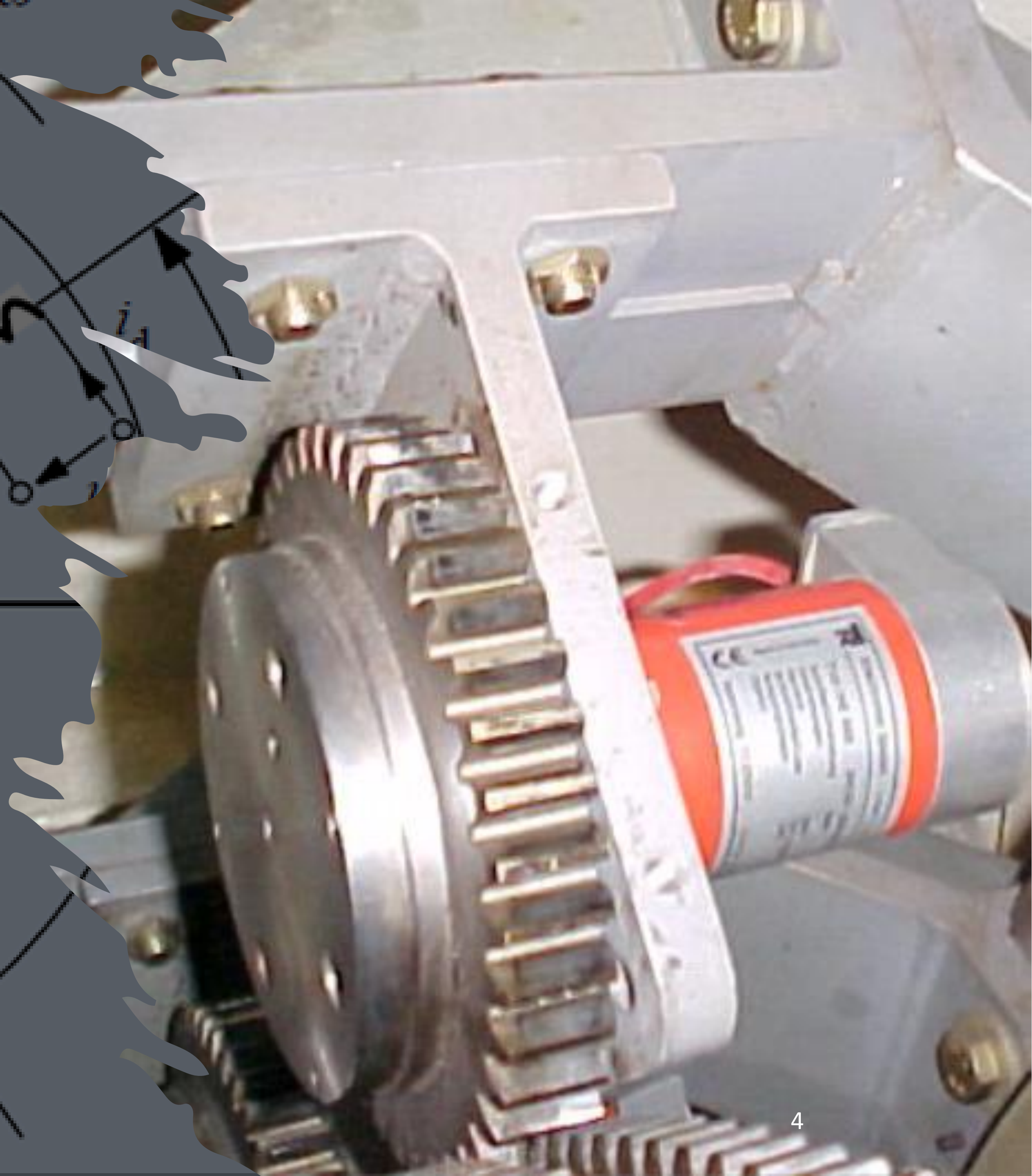
- Ship propulsion reliability: synchronous motor rotor position feedback to cycloconverter controller
- Sagnac phenomenon triaxial optical gyroscope: influence of SLD (SuperLuminescent Diode) aging on gyroscope operation
- Optical loop in a distributed automation system
- Measuring the temperature of a ship's electric drive synchronous motor using Bragg's Fiberg Bragg Gratting (FBG) sensors
- Hull stress measurements using FBG sensors

# Use of optics on a ship propulsion system

- three 15 MW marine drives, two 360 ° and one fixed (center)
- Synchronous motors are driven by PSR (Programmierbar Schnell Rechner) ABB cycloconverter
- operates in the range 0..1570 V, 0..15 Hz, with a working range of -150..150 rpm, rated current 2x2626 A and water cooling of power electronics with an efficiency of 96.7%.
- Each drive has a six-pole synchronous motor with double armature, two three-phase windings are mechanically offset by 60 °, they are driven by two electric drives with an electric offset of 120 °

# Rotor position feedback

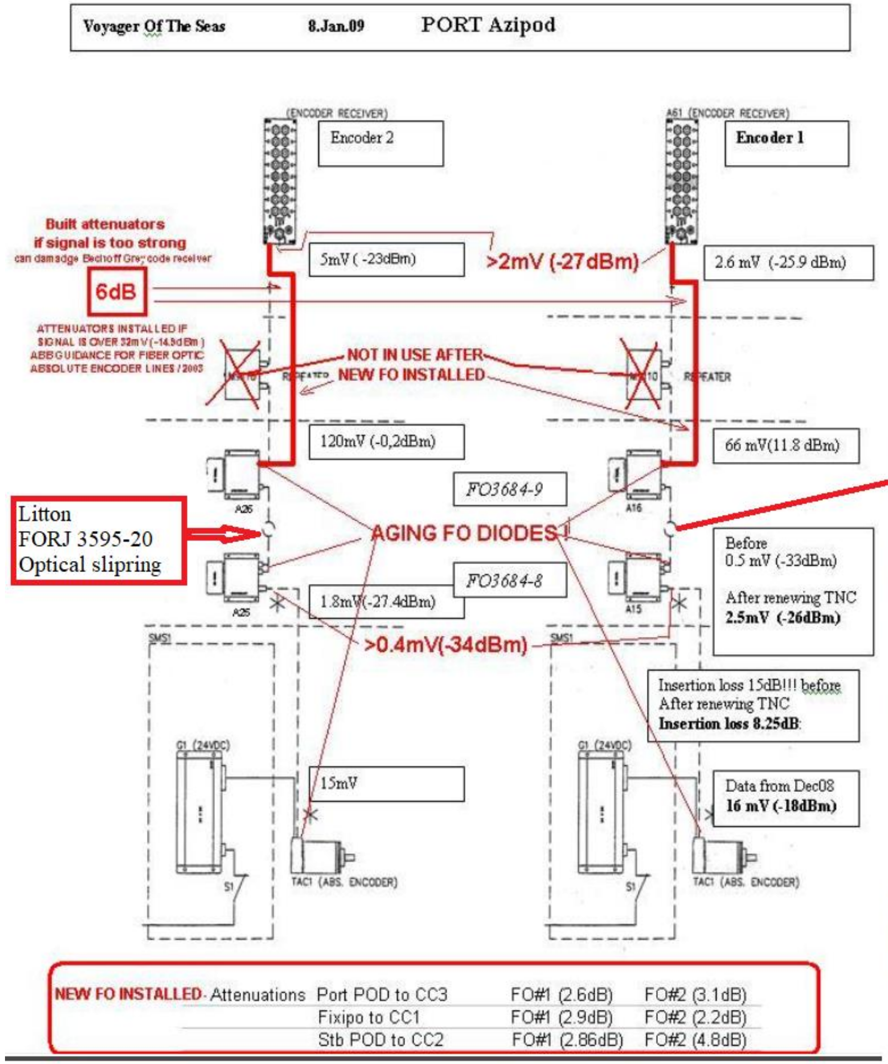
- The position feedback, angle λ of the rotor of the propeller electric motor in the cycloconverter is used to transform the coordinate systems from a 3-axis R, S, T stator to a two-axis rotor d, q vector system. The resolution of the 13 bit Gray code encoder TR HE-65-S LWL is 0.044 °. The Gray code is used because changes between two angles are present on only one bit, thus reducing the possibility of an error in the transmission of the angle.

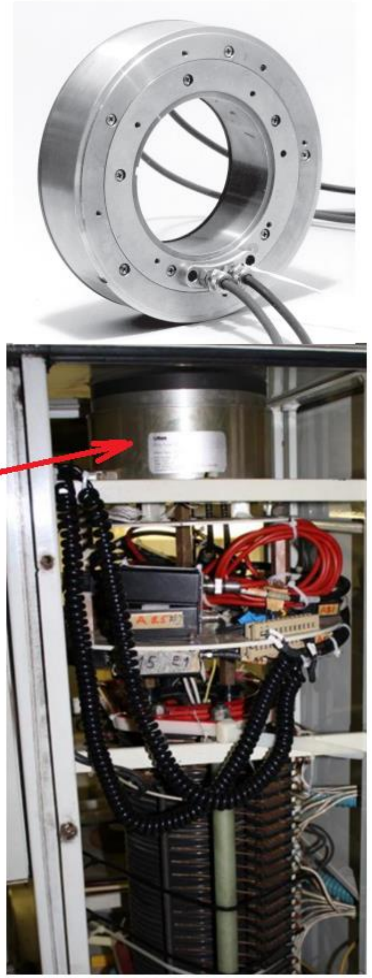



# Drive failure due to transmission path error

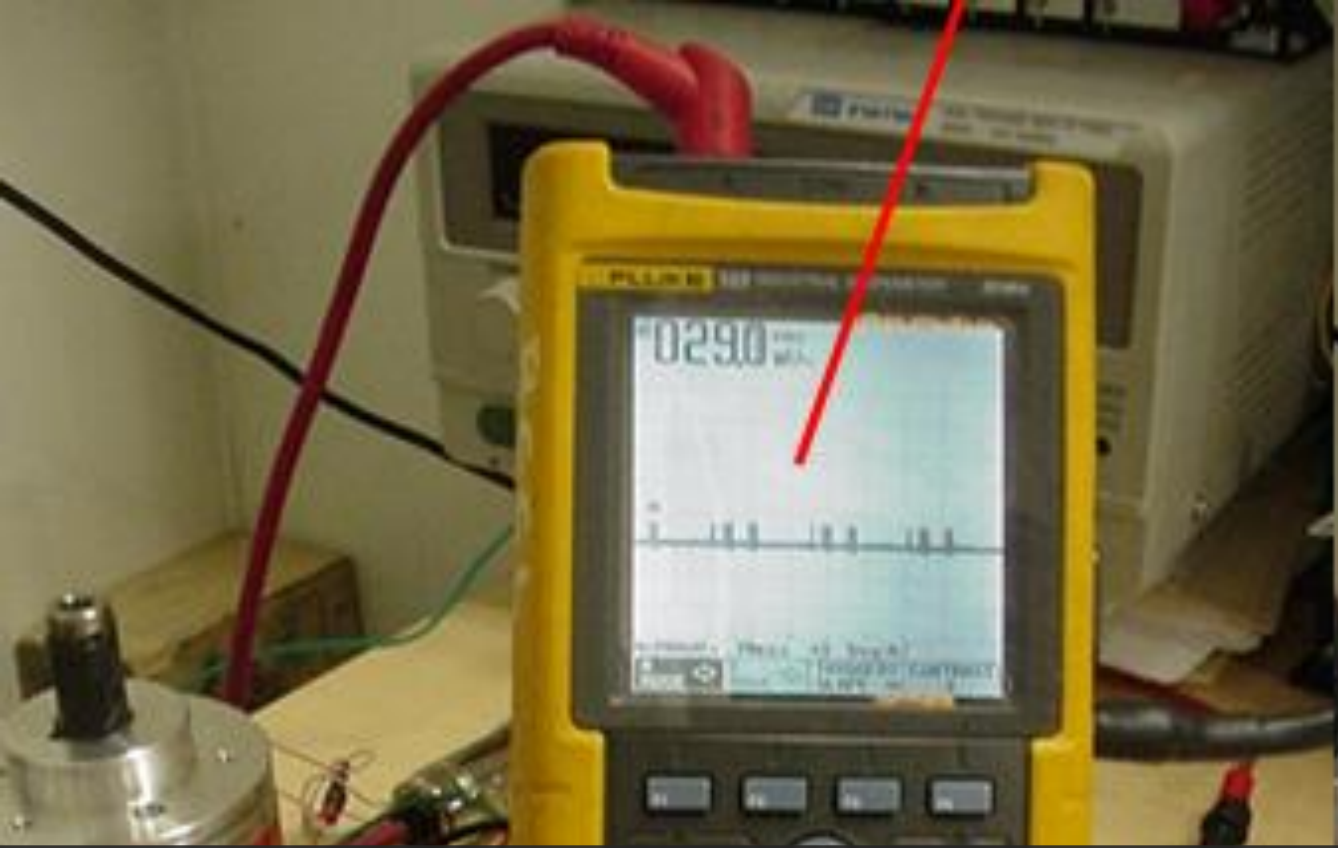
- If the rotor angle information is not available, the drive is switched off. This most often happens due to a fault in the transmission path from the rotor encoder to the Beckhoff M110 decoder in the cycloconverter. Switching off the drive is an extremely dangerous navigation event, especially if the ship is in maneuver (navigation in rivers, canals, entry or exit into port, narrow navigation corridors with a lot of traffic).

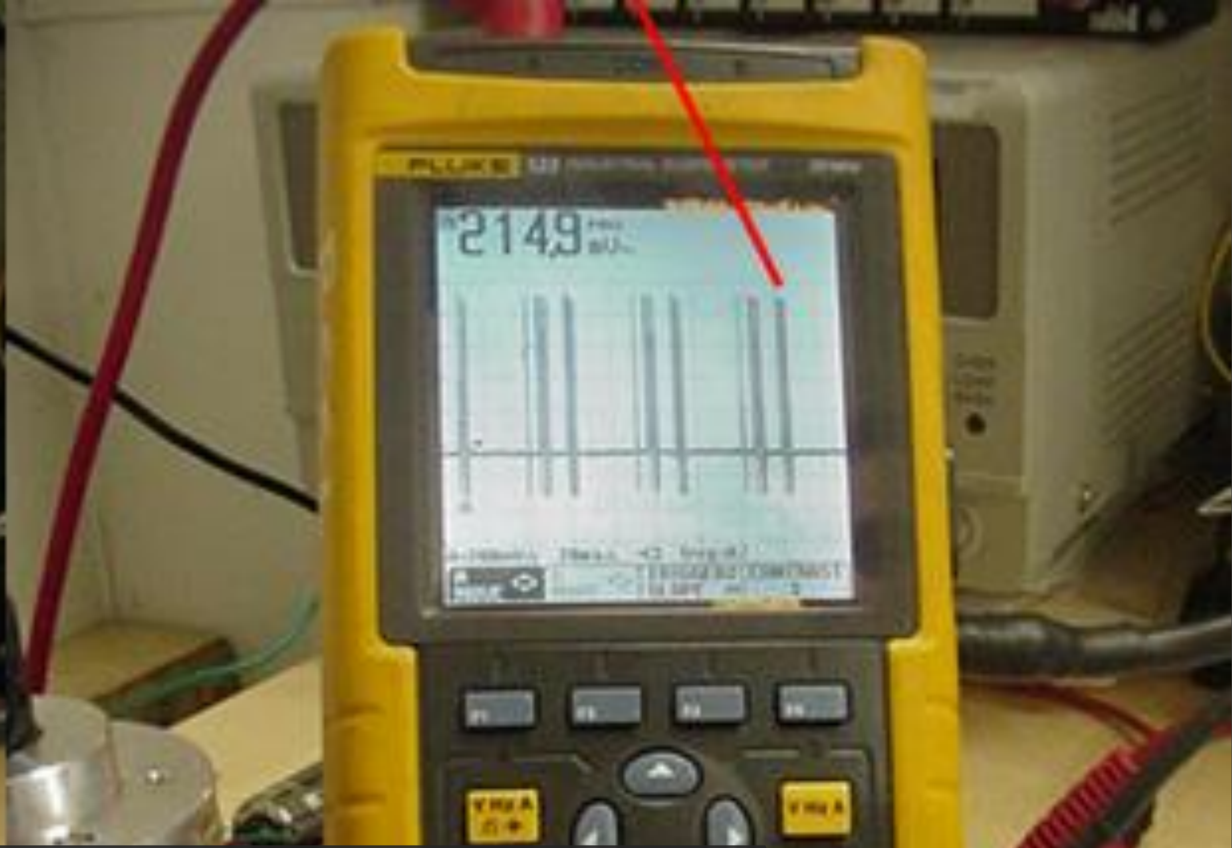
# Optical path from position encoder to decoder in cycloconverter electric drive controller



Poškodovan drseči prsten za 24Vdc napajanje tranceiverja A25,A26,A15,A16-->začasno uporabljen prašičji rep kabel (Ang. pigtail)



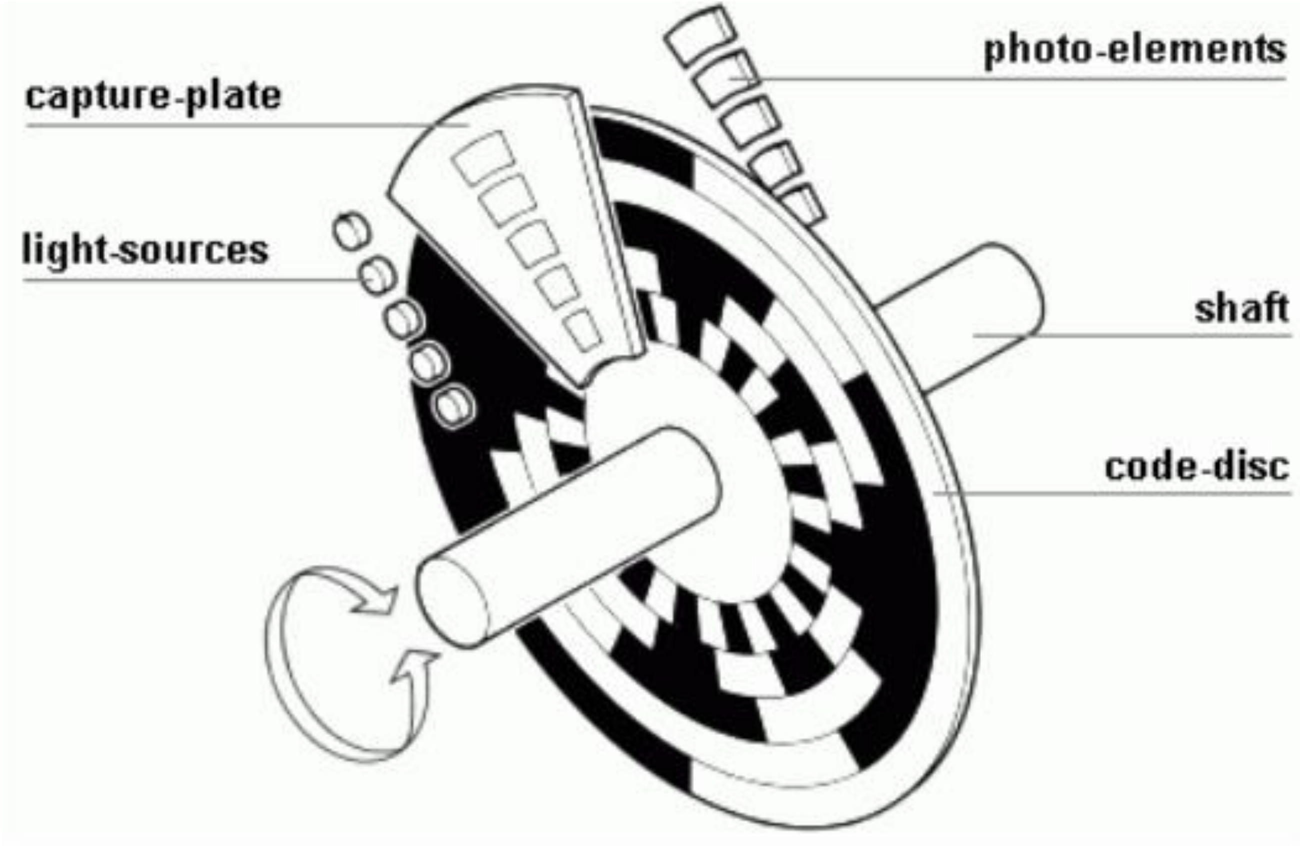




# The cause of the error

- Encoder optical signal modulation was lost due to a fault on the sliding rings (24 Vdc power loss for transceivers A25, A26, A16, A16 used to change the wavelength of the optical signal due to adjustment to the optical rotating ring). To determine the cause of the fault, the tranceiver was processed and on / off modulation was observed on the oscilloscope.

# Angle encoder building

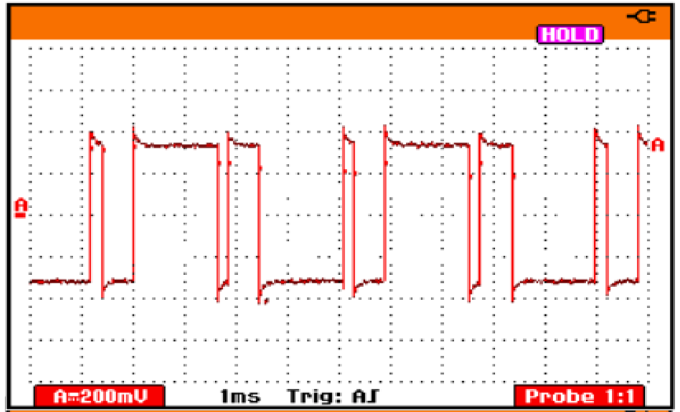
- The error in measuring the angle can also be due to the aging of the bearings or the vibration of the encoder, which is made as an optical disk with 13 Gray code rings.

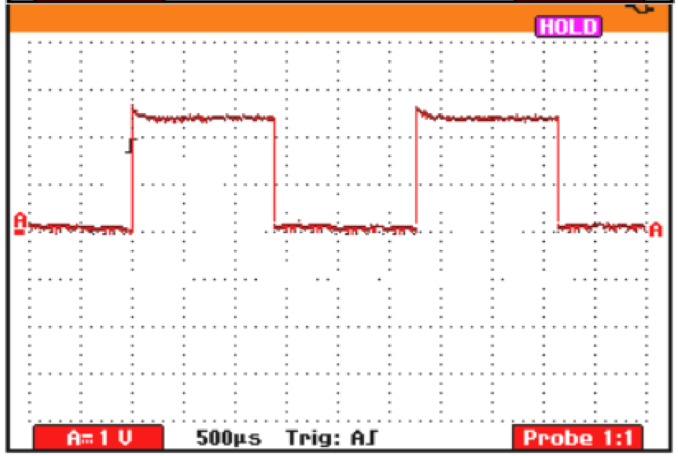


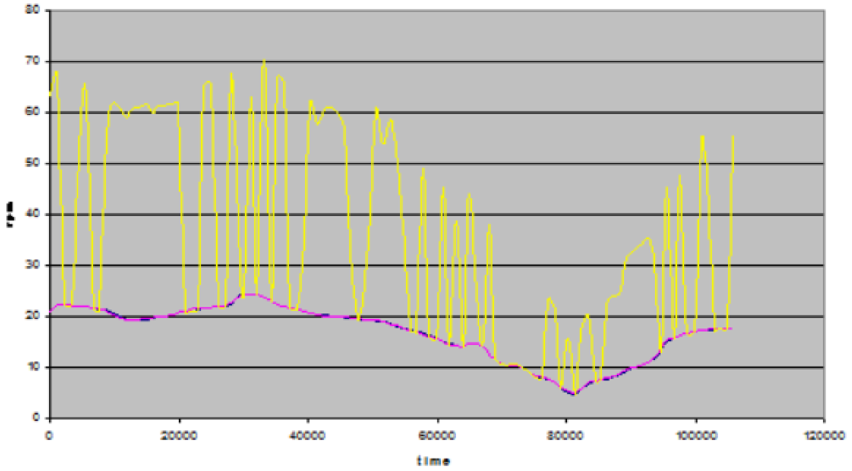

(https://tams-www.informatik.uni-hamburg.de)

# Encoder error

- The period of the fifth bit is equal to the rotation period of the synchronous motor rotor and is therefore used as feedback on the motor speed, together with the fifth bit of the second encoder and the voltage period of the cycloconverter (the drive has two windings mechanically offset by 60 degrees electric drive with 120 degree electric delay)Napaka na kodirniku pri petem (5) bitu in kodirnik brez napake
- An error in the fifth (5) bit results in an incorrect measurement of the rotation period and, in the worst case, the drive is switched off.
- Timely fault detection is part of the maintenance work and in this case, the incorrect encoder is replaced. After replacing the encoder, the initial calibration is performed: excitation of the synchronous motor with DC surges is done, until the rotor stops, the actual angle between mechanical and electrical zero measured by the new encoder is recorded in the controller of the cycloconverter.



### FIXIPOD – LINE 1

| ENCODER OUT ( mV | ENCODER OUT in dBm | BEFORE REPEATER IN ( mV ) | BEFORE REPEATER IN dBm | AFTER REPEATER IN ( mV ) | AFTER REPEATER IN dBm | BECKHOFF INPUT IN ( mV ) | BECKHOFF INPUT IN dBm | DATE WHEN MEASURED |
|---|---|---|---|---|---|---|---|---|
| 16,0 | -18,0 | | #NUM! | | #NUM! | 1,0 | -30,0 | |
| 16,0 | -18,0 | 2,3 | -26,4 | 114,0 | -9,4 | 8,5 | -20,7 | 26.Sep.09 |
| | #NUM! | 2,1 | -26,8 | 76,0 | -11,2 | 8,1 | -20,9 | 28.vlj.10 |
| | #NUM! | 1,0 | -30,0 | 37,0 | -14,3 | 2,5 | -26,0 | 23.lip.12 |
| | #NUM! | 1,0 | -30,0 | 31,0 | -15,1 | 11,1 | -19,5 | 23.lip.12 |
| | #NUM! | 1,0 | -30,0 | 27,0 | -15,7 | 8,0 | -21,0 | 1.vlj.14 |
| | #NUM! | | #NUM! | 22,5 | -16,5 | 5,6 | -22,5 | 19.July 14 |
| | #NUM! | | #NUM! | | #NUM! | | #NUM! | |
| | #NUM! | | #NUM! | | #NUM! | | #NUM! | |

### FIXIPOD – LINE 2

| ENCODER OUT ( mV ) | ENCODER OUT in dBm | BEFORE REPEATER IN ( mV ) | BEFORE REPEATER IN dBm | AFTER REPEATER OUT ( mV ) | AFTER REPEATER IN dBm | BECKHOFF INPUT IN ( mV ) | BECKHOFF INPUT IN dBm | DATE WHEN MEASURED | |
|---|---|---|---|---|---|---|---|---|---|
| 12,4 | -19,1 | | #NUM! | | #NUM! | | #NUM! | | |
| 12,4 | -19,1 | 1,3 | -28,9 | 28,2 | -15,5 | 2,4 | -26,2 | 26.Sep.09 | |
| | #NUM! | 1,2 | -29,2 | 22,4 | -16,5 | 2,0 | -27,0 | 28.vlj.10 | |
| | #NUM! | | #NUM! | 22,4 | -16,5 | 13,5 | -18,7 | 28.vlj.10 | |
| 16,0 | -18,0 | 1,3 | -28,9 | 20,9 | -16,8 | 4,2 | -23,8 | 23.lip.12 | |
| | #NUM! | 1,3 | -28,9 | 17,9 | -17,5 | 1,0 | -30,0 | 1.vlj.14 | |
| | #NUM! | | #NUM! | 164,0 | -7,9 | 4,2 | -23,8 | 1.vlj.14 | |
| | #NUM! | | #NUM! | 14,6 | -18,4 | 3,8 | -24,2 | 19.July 14 | Polished connectors line 2 |
| | #NUM! | | #NUM! | | #NUM! | | #NUM! | | |

### AZIPOD 1 STB – LINE 1

| ENCODER OUT ( mV | ENCODER OUT in dBm | BEFORE SLIPRING IN ( mV ) | BEFORE SLIPRING IN dBm | AFTER SLIPRING IN ( mV ) | AFTER SLIPRING IN dBm | BECKHOFF INPUT IN ( mV ) | BECKHOFF INPUT IN dBm | DATE WHEN MEASURED |
|---|---|---|---|---|---|---|---|---|
| 10,0 | -20,0 | 1,0 | -30,0 | 36,0 | -14,4 | | #NUM! | |
| | #NUM! | 0,9 | -30,5 | 29,0 | -15,4 | 1,3 | -28,9 | 22.sep.09 |
| | #NUM! | | #NUM! | | #NUM! | | #NUM! | |
| | #NUM! | 1,0 | -30,0 | 20,1 | -17,0 | 1,0 | -30,0 | 1.tra.10 |
| 17,0 | -17,7 | 3,0 | -25,2 | 9,1 | -20,4 | 3,6 | -24,4 | 19.lip.12 |
| 17,0 | -17,7 | 3,0 | -25,2 | 70,0 | -11,5 | 10,3 | -19,9 | 13.pro.13 |
| 22,5 | -16,5 | 2,5 | -26,0 | | #NUM! | | #NUM! | 5.tra.14 |
| | #NUM! | | #NUM! | | #NUM! | | #NUM! | |
| | #NUM! | | #NUM! | | #NUM! | | #NUM! | |

### AZIPOD 1 STB – LINE 2

| ENCODER SE 231 OUT ( mV ) | ENCODER OUT in dBm | BEFORE SLIPRING IN ( mV ) | BEFORE SLIPRING IN dBm | AFTER SLIPRING IN ( mV ) | AFTER SLIPRING IN dBm | BECKHOFF INPUT IN ( mV ) | BECKHOFF INPUT IN dBm | DATE WHEN MEASURED | |
|---|---|---|---|---|---|---|---|---|---|
| 12,1 | -19,2 | | #NUM! | 49,0 | -13,1 | 13,8 | -18,6 | | |
| 12,1 | -19,2 | 0,6 | -32,2 | 19,0 | -17,2 | 0,9 | -30,5 | 22.Sep.09 | |
| | #NUM! | 0,6 | -32,2 | 150,0 | -8,2 | 6,1 | -22,1 | 22.Sep.09 | Replaced A26 due to low signal |
| | #NUM! | 0,5 | -33,0 | 86,0 | -10,7 | 2,7 | -25,7 | 1.tra.10 | New fiber#1 connected |
| | #NUM! | 0,7 | -31,5 | 25,0 | -16,0 | 6,7 | -21,7 | 19.lip.12 | |
| | #NUM! | 0,5 | -33,0 | 13,1 | -18,8 | 3,9 | -24,1 | 13.pro.13 | |
| 17,0 | -17,7 | 0,9 | -30,5 | 13,1 | -18,8 | 3,9 | -24,1 | 6.vlj.14 | Need to polish both connectors in POD and LV slipring on line#2 |
| 16,5 | -17,8 | 0,6 | -32,2 | | #NUM! | 3,1 | -25,1 | 15.tra.14 | Polished connector before slipring, 3cracks found( cut 3cm) |
| | #NUM! | | #NUM! | | #NUM! | | #NUM! | | |

### AZIPOD 2 PORT – LINE 1

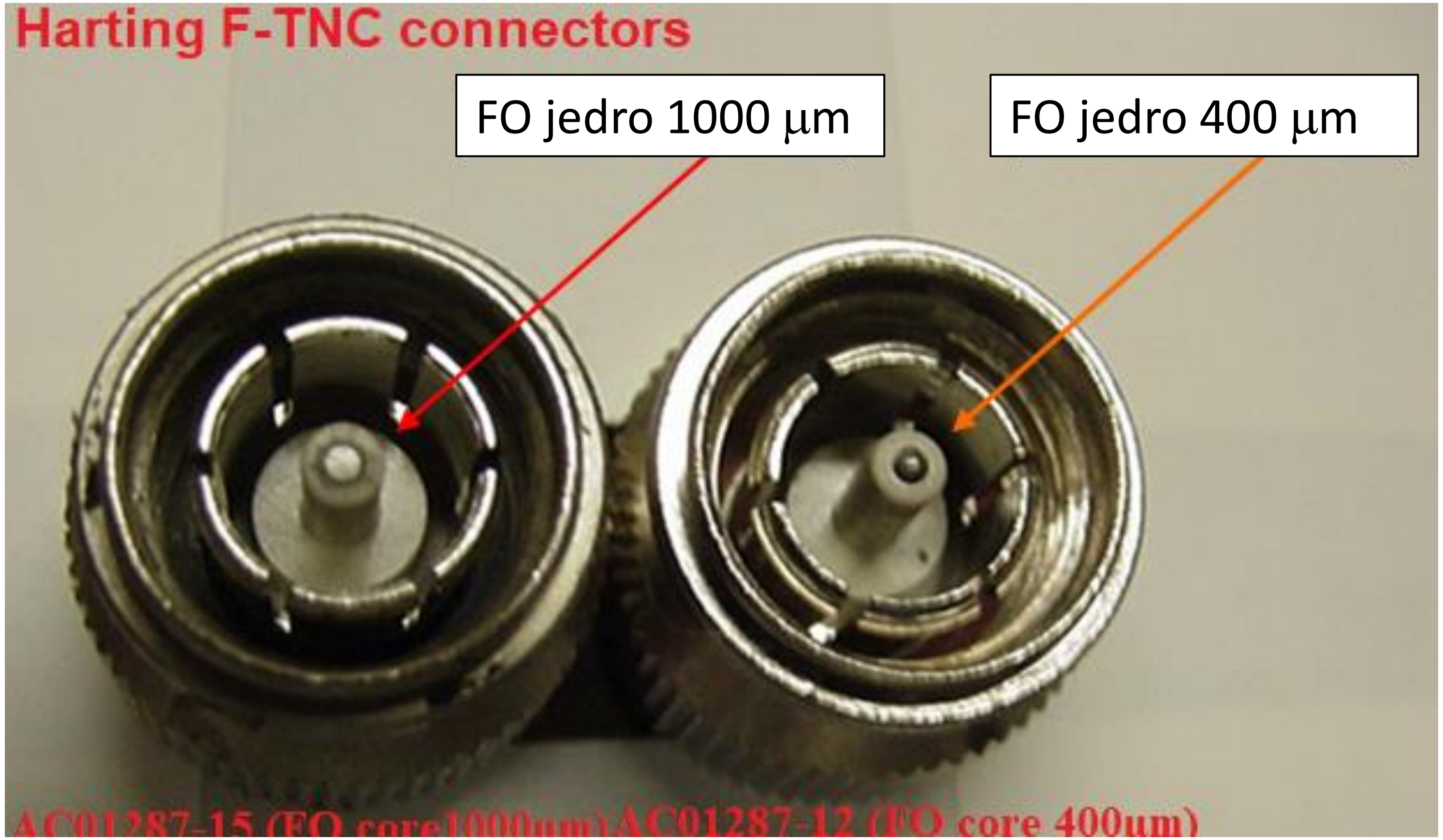
| ENCODER OUT ( mV | ENCODER OUT in dBm | BEFORE SLIPRING IN ( mV ) | BEFORE SLIPRING IN dBm | AFTER SLIPRING IN ( mV ) | AFTER SLIPRING IN dBm | BECKHOFF INPUT IN ( mV ) | BECKHOFF INPUT IN dBm | DATE WHEN MEASURED |
|---|---|---|---|---|---|---|---|---|
| 16,0 | -18,0 | 2,5 | -26,0 | 66,0 | -11,8 | 2,6 | -25,9 | 8.Jan.09 |
| 14,5 | -18,4 | 2,2 | -26,6 | 38,0 | -14,2 | 1,4 | -28,5 | 27.Sep.09 |
| | #NUM! | 1,9 | -27,2 | 28,0 | -15,5 | 3,3 | -24,8 | 30.ožu.10 |
| 15,0 | -18,2 | 2,4 | -26,2 | 11,4 | -19,4 | 4,0 | -24,0 | 24.lip.12 |
| | #NUM! | 2,6 | -25,9 | 7,6 | -21,2 | 2,3 | -26,4 | 6.vlj.14 |
| | #NUM! | | #NUM! | 19,5 | -17,1 | 5,5 | -22,6 | 10.Feb.201 |
| | #NUM! | | #NUM! | | #NUM! | | #NUM! | |
| | #NUM! | | #NUM! | | #NUM! | | #NUM! | |
| | #NUM! | | #NUM! | | #NUM! | | #NUM! | |

### AZIPOD 2 PORT – LINE 2

| ENCODER SE 331 OUT ( mV ) | ENCODER OUT in dBm | BEFORE SLIPRING IN ( mV ) | BEFORE SLIPRING IN dBm | AFTER SLIPRING IN ( mV ) | AFTER SLIPRING IN dBm | BECKHOFF INPUT IN ( mV ) | BECKHOFF INPUT IN dBm | DATE WHEN MEASURED |
|---|---|---|---|---|---|---|---|---|
| 15,0 | -18,2 | 1,8 | -27,4 | 120,0 | -9,2 | 5,0 | -23,0 | 8.Jan.09 |
| 14,8 | -18,3 | 1,7 | -27,7 | 93,0 | -10,3 | 2,5 | -26,0 | 27.Sep.09 |
| | #NUM! | 1,5 | -28,2 | 52,0 | -12,8 | 2,5 | -26,0 | 30.ožu.10 |
| | #NUM! | 0,9 | -30,5 | 18,0 | -17,4 | 7,3 | -21,4 | 24.lip.12 |
| | #NUM! | 0,8 | -31,0 | 9,2 | -20,4 | 3,9 | -24,1 | 6.vlj.14 |
| | #NUM! | | #NUM! | 19,6 | -17,1 | 6,5 | -21,9 | 10.Feb.2015 |
| | #NUM! | | #NUM! | | #NUM! | | #NUM! | |
| | #NUM! | | #NUM! | | #NUM! | | #NUM! | |
| | #NUM! | | #NUM! | | #NUM! | | #NUM! | |

Optical data transmition failure from encoder to cycloconverter can ocur: due to aging of p-i-n photodiodes (average 3 dB / 6 months)

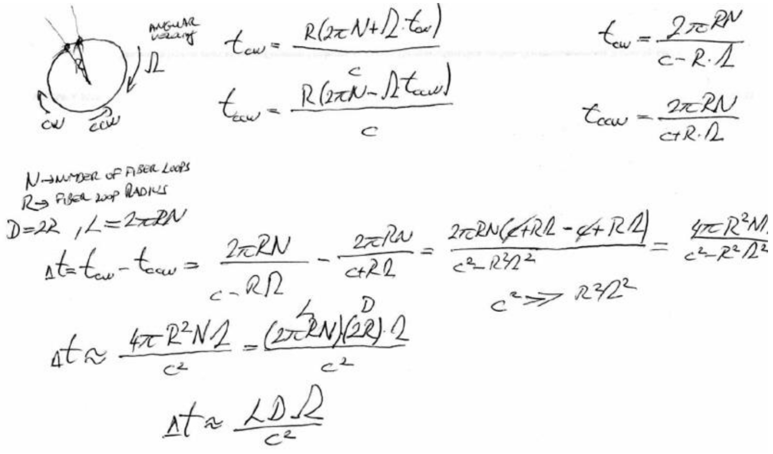
increased contact attenuation due to longitudinal displacement on fiber optic connectors spaced apart by vibration (1 mm longitudinal displacement approximately 3 dB attenuation)



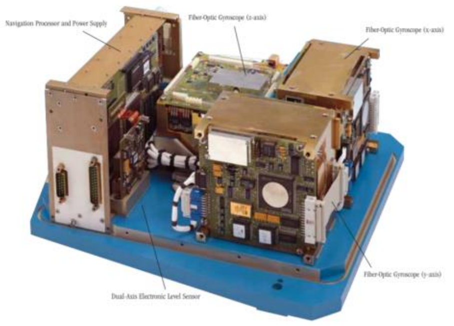

# Incorrect optical fiber placed with 400 μm core instead of 1000 μm

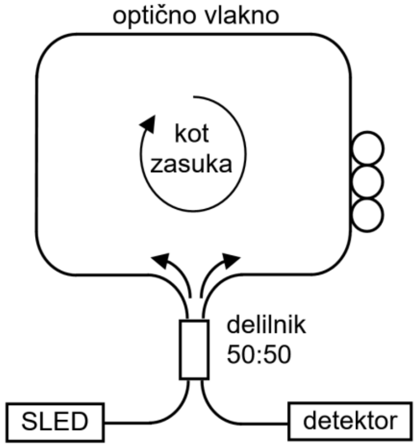
The optical fibers were placed through the same space. In the event of fire or mechanical damage (ship collision), all three drives may fail at the same time. In the picture below, the optical cables from the STB (right if looking towards the bow of the ship) and the fixipod go through the technical room of the PS drive (left if looking towards the bow of the ship).

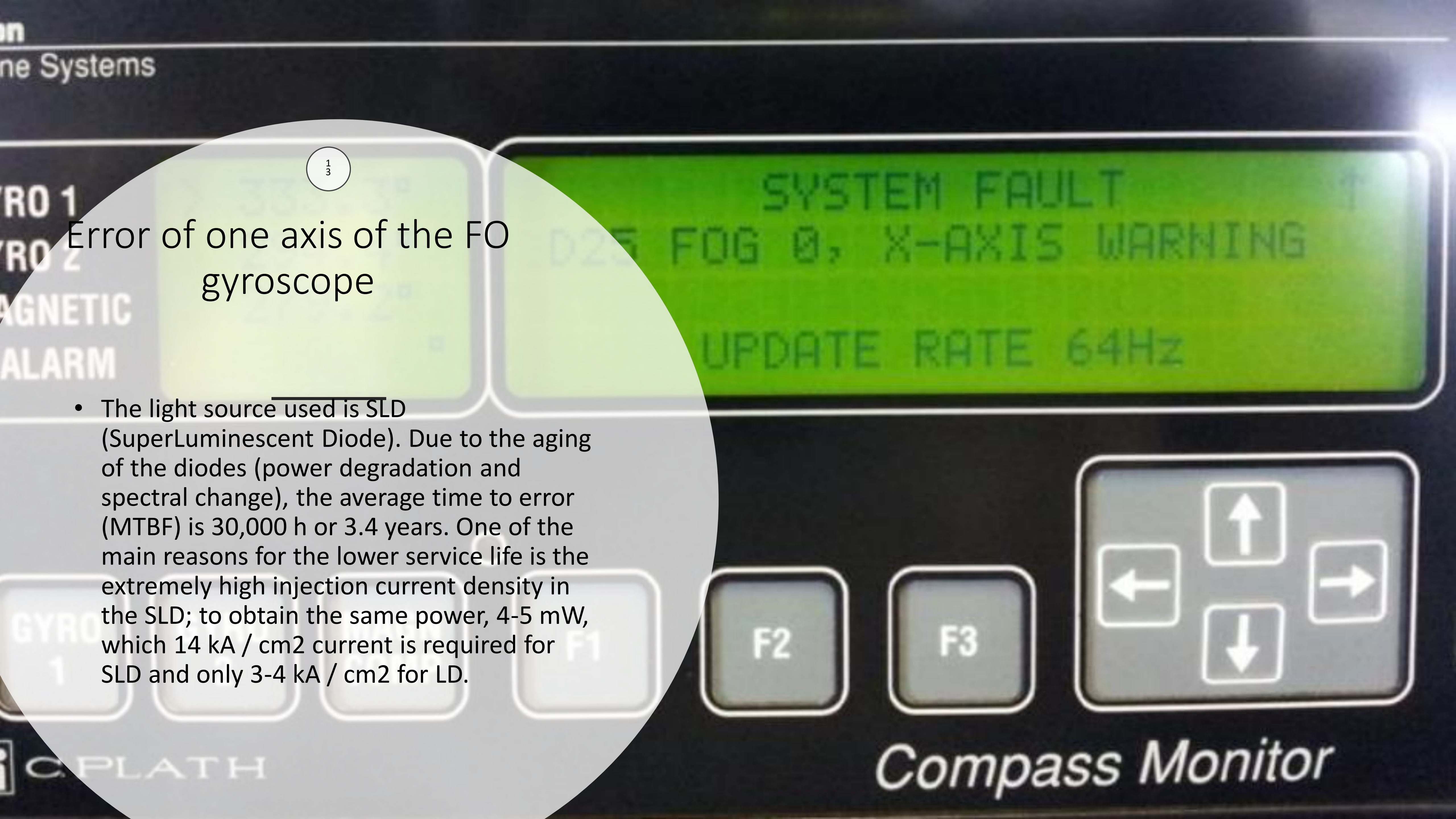
# Triassic optical gyroscope on the principle of Sagnac phenomenon



- Sperry Navigat 2100 fiber optics gyroscope
- Older mechanical gyroscopes, consist of a rotating wheel in gyroscopic fluid and exploit the principle of maintaining the rotational speed, began years ago to be replaced  with modern 3 axes optical gyroscopes
- They works on Sagnac phenomen measuring the change in phase of a light in the fiber coil traveling in oposite directions due superposition of  Earth rotational speed.
- Optical gyroscopes do not require annual servicing as mechanical (gyroscopic fluid replacement and calibration)







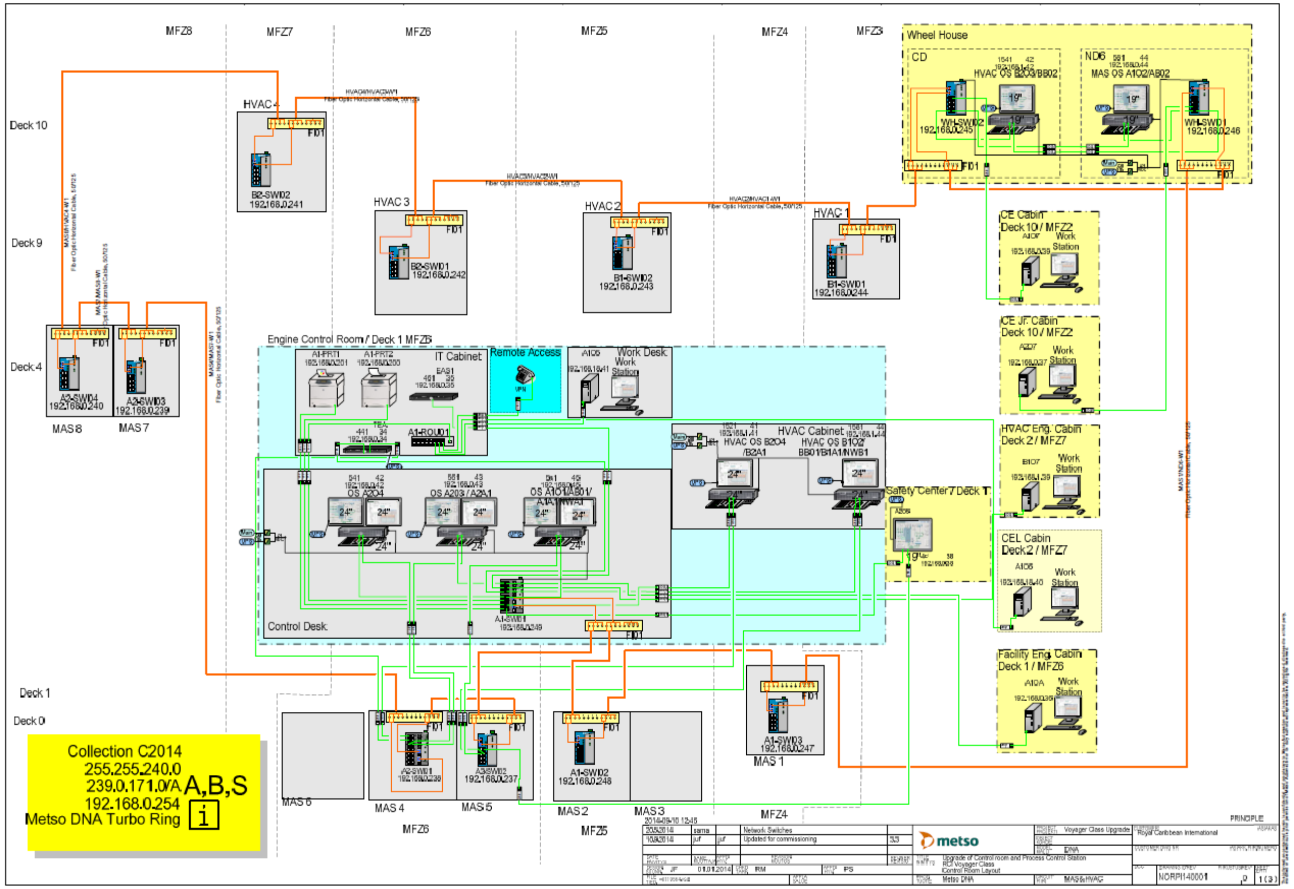



# Error of one axis of the FO gyroscope

- The light source used is SLD (SuperLuminescent Diode). Due to the aging of the diodes (power degradation and spectral change), the average time to error (MTBF) is 30,000 h or 3.4 years. One of the main reasons for the lower service life is the extremely high injection current density in the SLD; to obtain the same power, 4-5 mW, which 14 kA / cm2 current is required for SLD and only 3-4 kA / cm2 for LD.

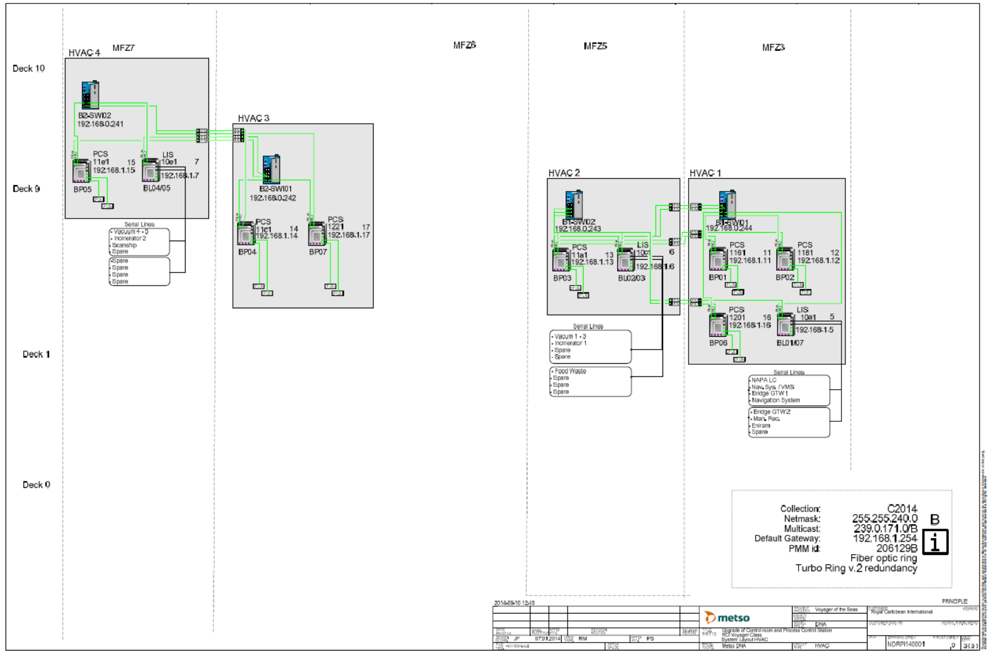
# Optical loop in a distributed automation system

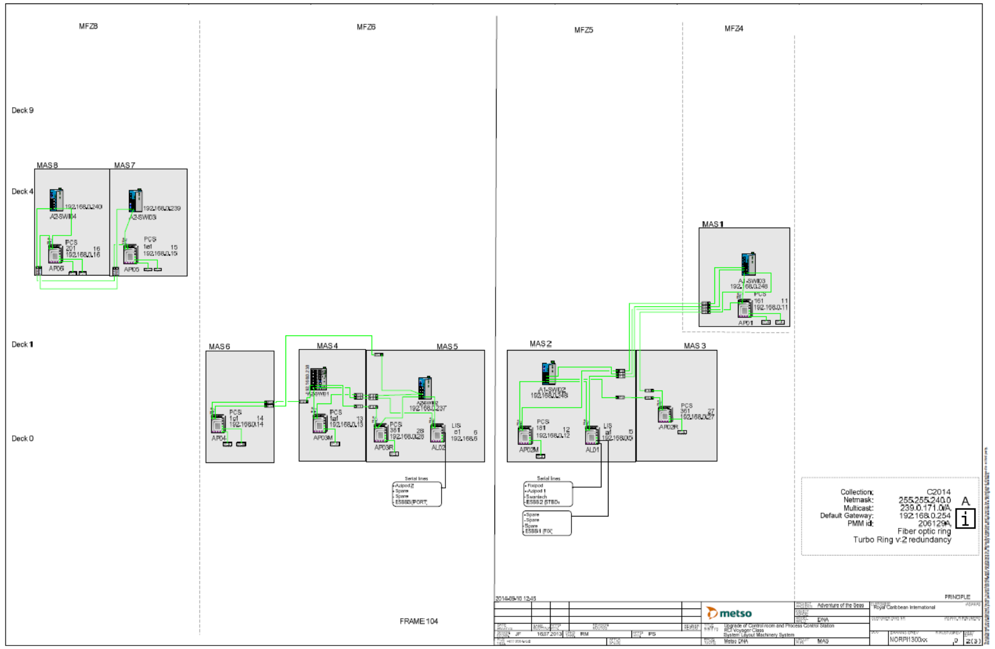
- On the Voyager of The Seas, the distributed Valmarine Damatic XD automation system with 15,200 input / output channels was replaced in 2014 by a Metso system. The author led the project in all phases. The core of the system, ie transmission paths, industrial computers, industrial routers, workstations and software have been replaced. Switching between old and new system is done without blackout




| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6 | | Upgrade of Control room and Process Control Station | | | | | | | |
| 7 | | RCI Voyager Class | | | | | | | |
| 8 | | NORPI140001 Control Room Layout | | | | | | | |
| 9 | | 2014-08-28 07:45 | | | | | | | |
| 10 | | | | | | | | | |
| 11 | Name | Revision Comments | | Rev number | | | | | |
| 12 | sama | Network Switches | | | | | | | |
| 13 | | | | | | | | | |
| 14 | | | | | | | | | |
| 15 | | | To | | | | Cable | | |
| 16 | Cabinet | Connector | Room | Cabinet | Connector | Connector Type | Identifier | Type | Length |
| 19 | HVAC 1 | 1 - 4 | | HVAC 2 | 5 - 8 | | HVAC2/HVAC1-W1 | Fiber Optic Horizontal Cable, 50/125 | 70 |
| 21 | HVAC 1 | 5 - 8 | Wheel House | CD | 1 - 4 | | HVAC1/CD-W1 | Fiber Optic Horizontal Cable, 50/125 | 120 |
| 26 | HVAC 3 | 5 - 8 | | HVAC 2 | 1 - 4 | | HVAC3/HVAC2-W1 | Fiber Optic Horizontal Cable, 50/125 | 135 |
| 29 | HVAC 4 | 1 - 4 | | MAS 8 | 1 - 4 | | MAS8/HVAC4-W1 | Fiber Optic Horizontal Cable, 50/125 | 280 |
| 30 | HVAC 4 | 5 - 8 | | HVAC 3 | 1 - 4 | | HVAC4/HVAC3-W1 | Fiber Optic Horizontal Cable, 50/125 | 45 |
| 33 | MAS 1 | 9 - 12 | Wheel House | ND6 | 1 - 4 | | MAS1/ND6-W1 | Fiber Optic Horizontal Cable, 50/125 | 340 |
| 36 | MAS 2 | 1 - 4 | Engine Control Room / Deck 1 MFZ6 | Control Desk | 5 - 6 | LC double | MAS2/Control Desk-W1 | Fiber Optic Horizontal Cable, 50/125 | 115 |
| 37 | MAS 2 | 9 - 12 | | MAS 1 | 1 - 4 | | MAS2/MAS1-W1 | Fiber Optic Horizontal Cable, 50/125 | 115 |
| 40 | MAS 4 | 1 - 4 | | MAS 7 | 5 - 8 | | MAS4/MAS7-W1 | Fiber Optic Horizontal Cable, 50/125 | 135 |
| 49 | MAS 5 | 1 - 4 | Engine Control Room / Deck 1 MFZ6 | Control Desk | 1 - 2 | LC double | MAS5/Control Desk-W1 | Fiber Optic Horizontal Cable, 50/125 | 30 |
| 50 | MAS 5 | 9 - 12 | | MAS 4 | 9 - 12 | LC double | MAS4/MAS5-W1 | Fiber Optic Horizontal Cable, 50/125 | 5 |
| 56 | MAS 7 | 1 - 4 | | MAS 8 | 5 - 8 | LC double | MAS7/MAS8-W1 | Fiber Optic Horizontal Cable, 50/125 | 5 |
| 125 | ND6 | 9 - 12 | Wheel House | CD | 9 - 12 | | CD/ND6-W1 | Fiber Optic Horizontal Cable, 50/125 | 10 |

- optical loop plan consisting of 13 sections of optical cables with four multi mode fibers (Tx / Rx + 2 reserve fibers) manufactured by Drake G4-50 / 125 AICI-I / O / RM-W with a total length of 1405 m




- the most important processes such as PMS (Power Management) are managed by redundant computers. Distributed fieldbus input / output cabinets, where most analog / digital input / output channels are connected, are connected to process computers via industrial Ethernet, or core system. Through serial buses, industrial computers are additionally connected to: controllers of three (3) drives, navigation system, AWP system for wastewater treatment (Adwance Waste Treatment plant), incinerator, Computer for ship stability, VDR black box (Voyage Data) Recorder), a controller for measuring the vibrations of propellers

# OTDR meassurements (angl. Optical Time Domain Reflectometer )

- The critical phase of the project after laying the cables and mounting connectors the are OTDR measurements (attenuation, dispersion, numerical aperture, location of possible damage or fiber breakage)
- OTDR measurements were performed with the Anritsu MT9083A2-06 instrument at two wavelengths of 850 n in 1300 nm.
- The measured values are used as a reference in further measurements at system start-up and future maintenance work (SPF monitoring of optical system core: monitoring PIN diodes aging, fiber damadges, FO connector issues, etc)

File : bridge-mas 1-1300-0001.sor
Device : MT9083A2-06 Num. 0
Date : 22/10/2014 5:06:42 PM
Module : 6C00028709

Configuration

Technic. :
ORIGIN
Cable :
Fiber : 1
Color : ---
END
Cable :
Fiber : 1
Color : ---

Way : O-->E
Origin :
End :
Wavelength (nm) : 1300
Index : 1.491000
Pulse (ns) : 50
Range (km) : 1.006
Average : 2048
Resolution : -

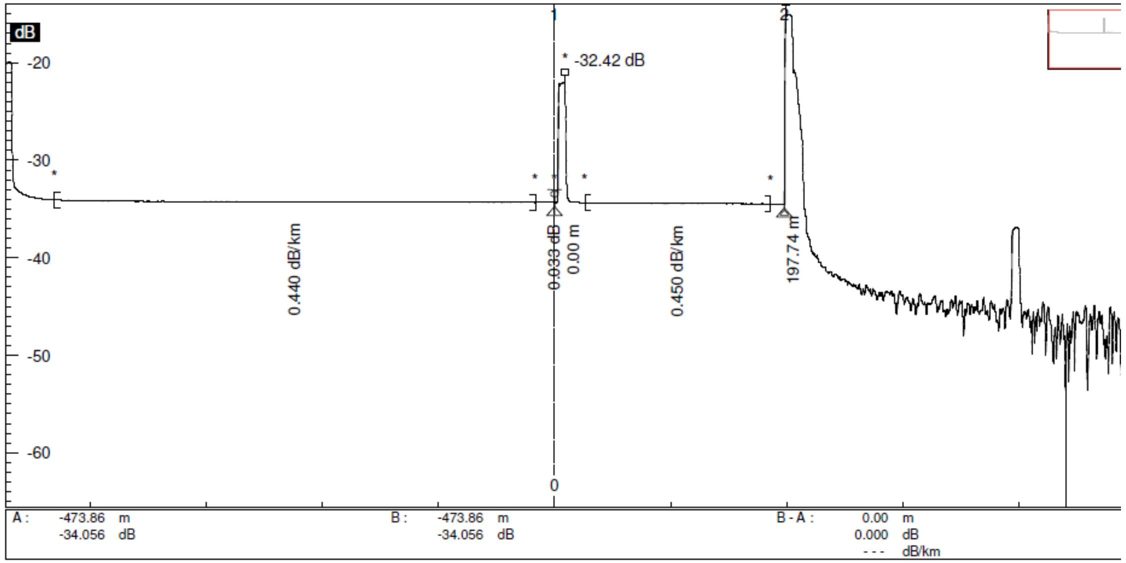
Backscatter coeff.: -74.00 dB
Event detection threshold
Splices : No
Slopes : 0.000 dB/km
Reflectances : All
Alarm threshold
Connectors : 1.000 dB
Splices : 0.300 dB
Reflectances : -40.00 dB
Slopes : 0.800 dB/km

Comment

Comment :

Job

OTDR Trace




Table

| | Event (2) | Distance (m) | Loss (dB) | Reflectance (dB) | Slope (dB/km) | Rel. Dist. (m) | Total loss (dB) | Uncertair |
|---|---|---|---|---|---|---|---|---|
| 1 | | 0.00 | 0.033 | ! -32.42 | 0.440 | 473.86 | | Manual measu |
| 2 | | 197.74 | | >-17.94 | 0.450 | 197.74 | 0.120 | |

# Built-in optical power measurements in Moxa industrial switches

## Monitor SFP

### SFP Status

| Port No. | Model Name | Temperature (°C) | Voltage (V) | Tx Power (dBm ) | Rx Power (dBm) |
|---|---|---|---|---|---|
| G1 | SFP-1GEZXLC-120 | 51.3 | 3.3 | -6.6 | -0.9 |

| Parameter | Description |
|---|---|
| Port No. | Switch port number with SFP plugged in |
| Model Name | Moxa SFP model name |
| Temperature (°C) | SFP casing temperature |
| Voltage (V) | Voltage supply to the SFP |
| Tx power (dBm) | The amount of light being transmitted into the fiber optic cable |
| Rx power (dBm) | The amount of light being received from the fiber optic cable |

- Due to the experience with the aging of laser sources, it is important to monitor the optical power in the fiber. For this, the built-in SPF signal level measurement option Rx / Tx (dBm) in Moxa industrial switches is used.

# MOXA switch series unreliability due to 60 nm DRAM

- MOXA switches made in the period from April 2013 to October 2016 can randomly turn off the inputs / outputs of the switches, suddenly restart or even "hang" without any response. The cause is internal overload/EM interference on the 60 nm SDRAM, which leads to an error in the read / write cycles of the central processing unit.
- The author experienced failures of the ship's command of the propulsion, unreliable operation and failures of security systems (Main Fire Zones fire doors closing, accidental activation of the fire extinguishing system (Sprinkler system), integrated navigation system ECDIS failures, blackout in the PMS system (Power Management System).
- On one ship, it was replaced more than 130 industrial switches in various systems.

MOXA®

Moxa Inc.
Fl. 4, No. 135, Lane 235, Baoqiao Rd., Xindian Dist.,
New Taipei City 23145, Taiwan, R.O.C.
Tel: +886-2-8919-1230
Fax: +886-2-8919-1231
www.moxa.com

## Customer Communication Letter

Date of Issue: Dec 28st, 2017
Attention to: Customers of ABB Marine

**Impacted Product Lines**

| Model Name | Product Version | Production Period | Serial Number |
|---|---|---|---|
| EDS-405A<br>EDS-405A-MM-ST<br>EDS-405A-MM-ST-T | V1.2 & V1.2.1 | 2013/8/1~2016/7/1 | TACHxxxxxxxx~TAFGxxxxxxxx |
| EDS-408A | V1.4 & V1.4.1 | 2013/4/22~2016/10/14 | TACExxxxxxxx~TAFJxxxxxxxx |
| EDS-408A-MM-SC<br>EDS-408A-MM-ST<br>EDS-408A-MM-ST-T | V1.4 & V1.4.1 | | |
| EDS-408A-3M-ST | V1.4 & V1.4.1 | 2013/8/13~2016/8/02 | TACHxxxxxxxx~TAFHxxxxxxxx |
| EDS-G509 | V1.5 & 1.5.1 | 2013/9/9~2016/3/8 | TACbxxxxxxxx~TAFCxxxxxxxx |

**Problem Description**

After working for a while, sometimes the units of foregoing product lines may reboot by themselves abnormally, or even hang without any response. When the unit hangs, the customer will need to power it off and on again to recover that.

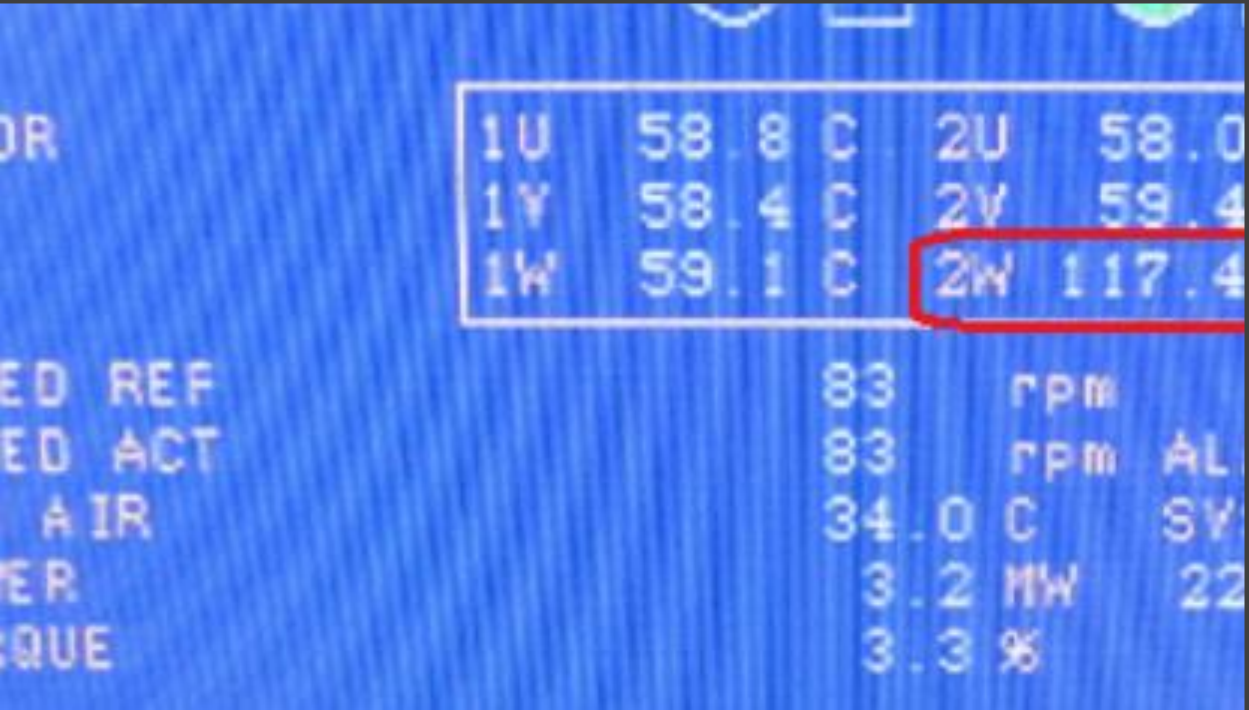
**Analysis and Conclusions**

After taking in-depth experiment and analysis, Moxa RD team verify that the unit's SDRAM will be impacted by higher electricity and caused malfunction happen. When that situation happens, the SDRAM malfunction could induce the CPU read data error to cause the unit hang and even reboot.
Considering the hardware architecture of foregoing product lines, their ESMT 60nm SDRAMs would be the weakest point, in terms of electrical immunity. This issue just happens on the ESMT 60nm SDRAM which Moxa started to use for production after 2013 April.

In sum, the main factors contributed to this issue is

**"Lack of expected electrical immunity on the ESMT 60nm SDRAM used within the period from April, 2013 to October, 2016."**





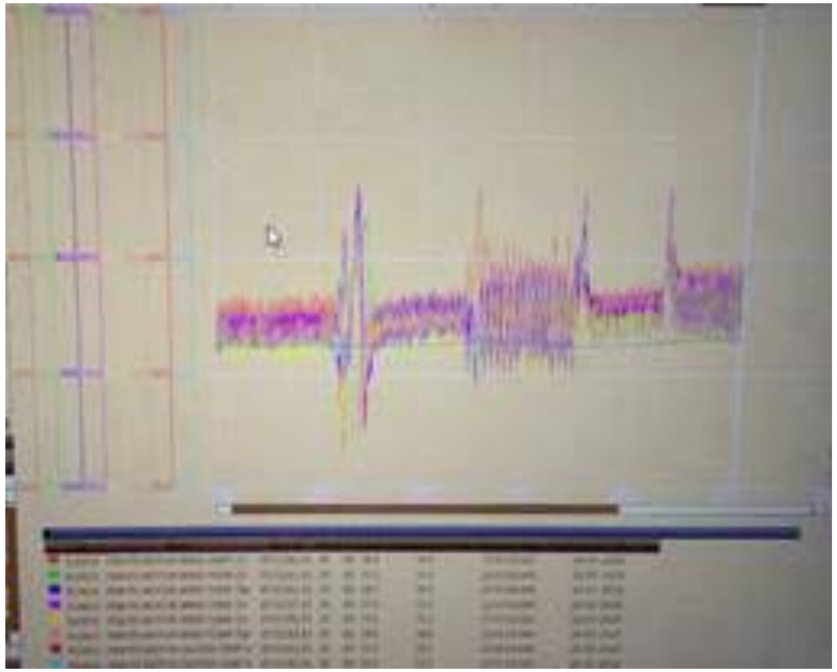

# Measuring the temperature of a ship's synchronous motor

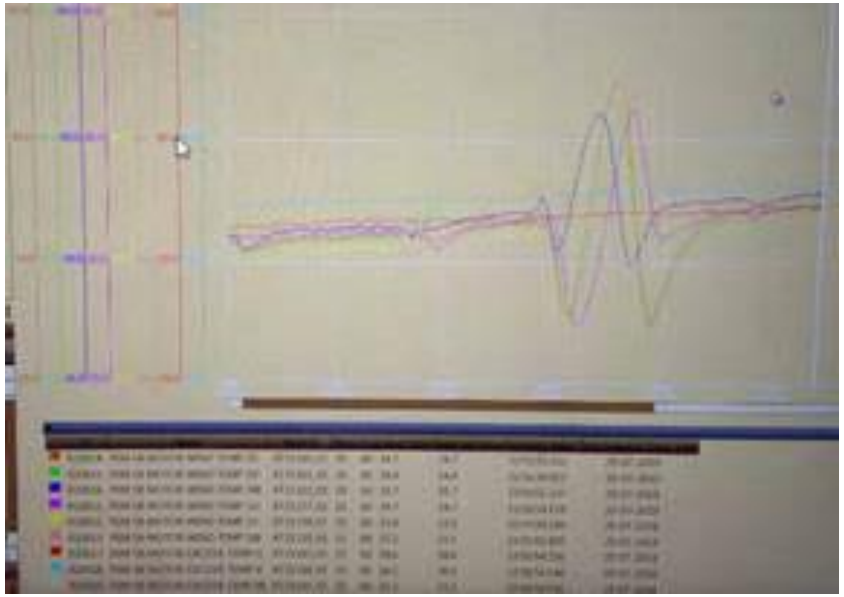
- The reliability of the temperature control of the synchronous motor of the electric propulsion is important due to the information on the thermal state of the ship's propulsion and timely navigational measures in case of approaching winding insulation breakdown temperature

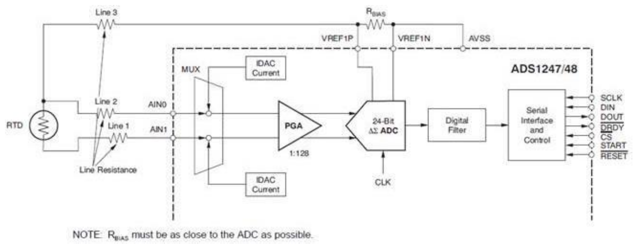
- Incorrect temperature measurements are extremely dangerous. The author experienced an increase in temperature measurements due to an unreliable ZMC-MIL connector in the ABB POD drive and prevented drive failure by activating Safety Overide in the Yang Ceng Yang River in a narrow navigation corridor. The failure of one of the propulsion moves the ship off the planned route due to the loss of thrust of the propeller.

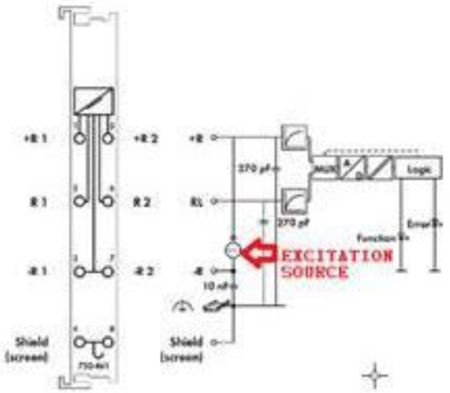
# Temperature fluctuations on 8.5 MW marine drive

- On the 8.5MW marine drive, a fluctuation in the temperature of the PEM electric motor (Propulsion Electrical Motor) ± 30 ° C with a period of several minutes was detected due to a system error and recalibration of the WAGO 750-461 module, which occurs with speed change of the electric motor and the effect of EM interference in PT100 three-wire measurements.
- The figure shows the motor temperature fluctuation and the temperature fluctuation with the implemented 60s digital filter in the drive controller.







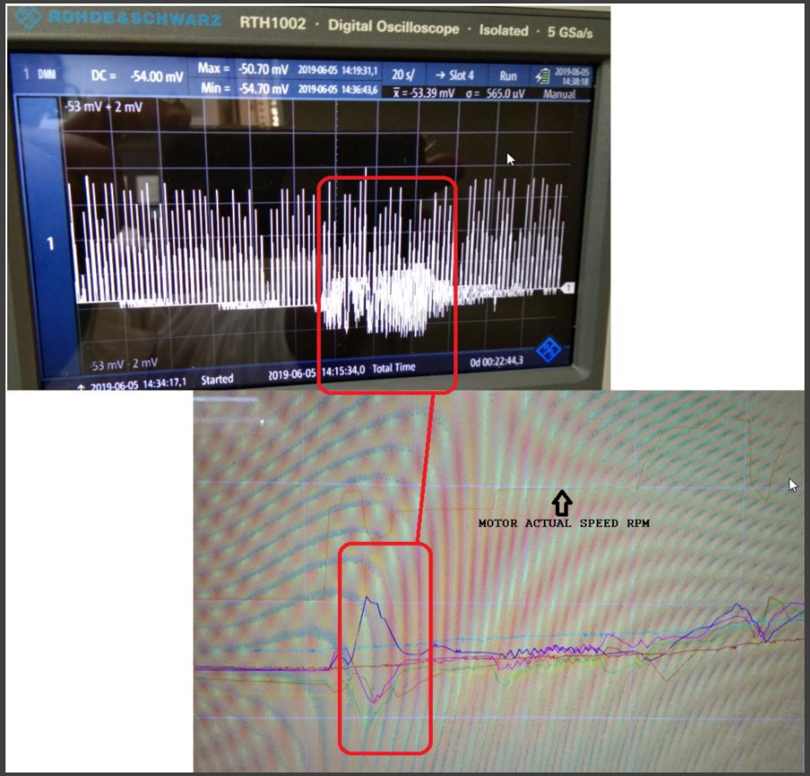



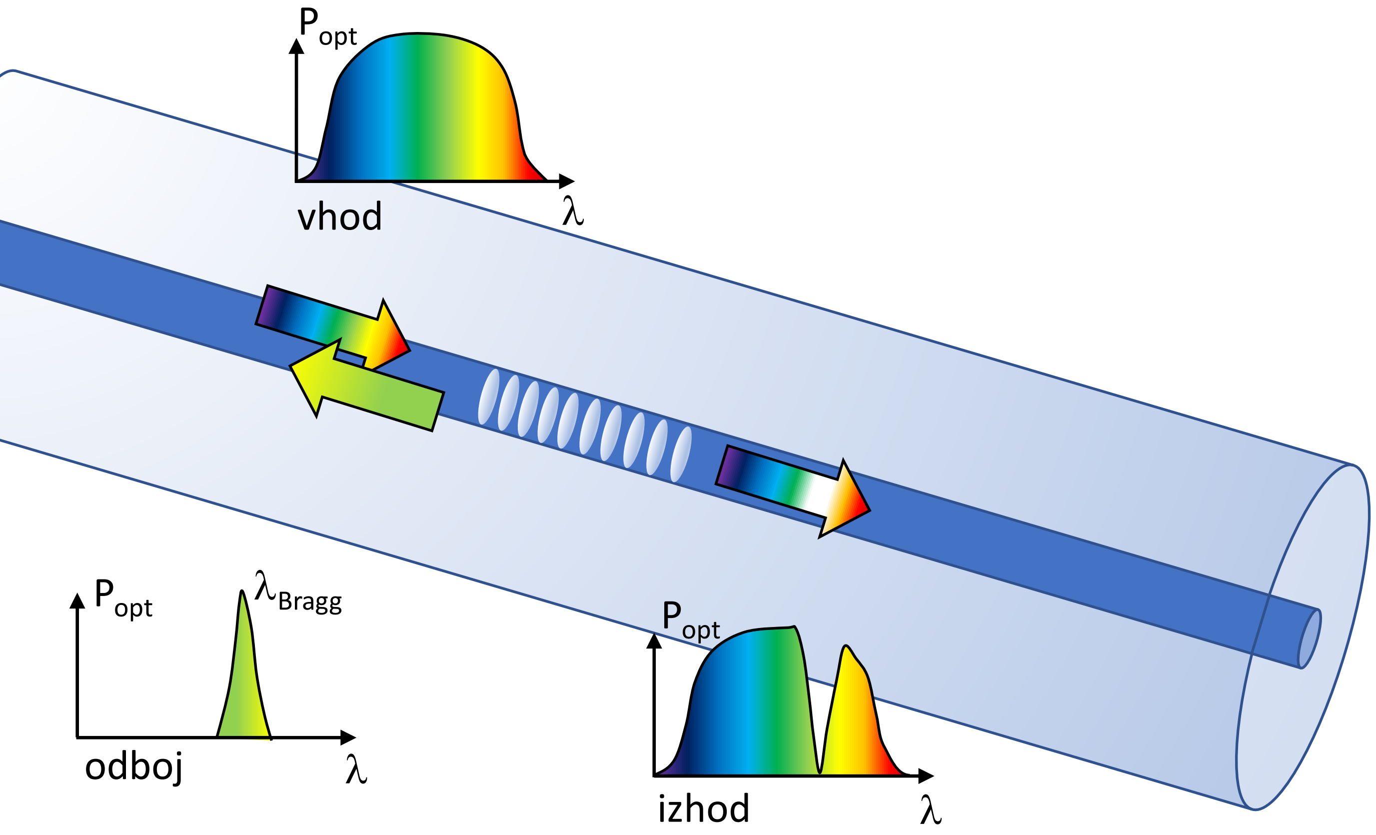

# Implementation of three wire measurements with TI ADS1247



modul WAGO 750-461

By measuring the voltage drop at terminals 2/3, it is shown that the module controller is recalibrated when the rotor speed changes and the effect of EM interference. Unfortunately, the recalibration cannot be turned off,






# Bragg‘s gratting grid

- To avoid EM interference in a synchronous machine, temperature measurement with optical measurements based on Bragg's Fiber Bragg Gratting (FBG) can be used.
- FBG is a type of distributed Bragg reflection made in a short segment of optical fiber that reflects certain wavelengths of light and transmits all others. This is achieved by adding a periodic change in the refractive index in the fiber core, which creates a dielectric mirror specific for the wavelength.

# Bragg fiber

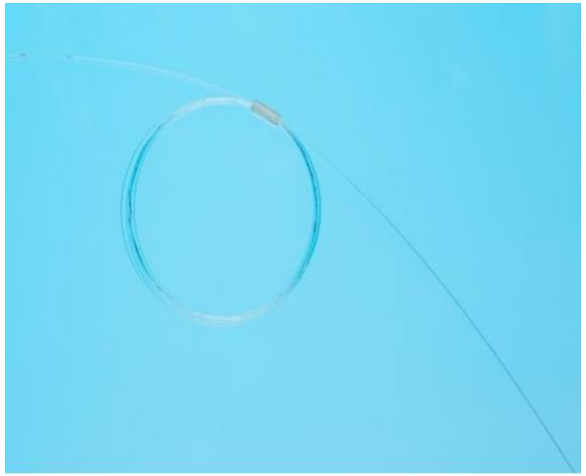
- The Bragg fiber diffraction mesh can be used as a built-in optical filter to block certain wavelengths or as a reflector specific to the wavelength. By changing the periodic properties of the core due to temperature or shrinkage / tension, an optical fiber with a Bragg structure can be used as a sensor to measure temperature, e.g. winding of a synchronous machine or strain on the hull of a ship
- Compared to PT100 Class AA sensors, defined in the range -50 … + 250 ° C (resistor with wire winding), 0… + 150 ° C (thin film resistor)] FBG fibers have twice the temperature resolution ± 0.05 ° C and a wider measuring range -270 ÷ 300 ° C

## Specifications

| Parameter | Standard | | | | Options |
|---|---|---|---|---|---|
| Centre Wavelength | 1528 to 1608 nm | | | | Alternative wavelength range |
| FBG Length | 1 mm | 2 mm | 5 mm | 10 mm | |
| Peak Reflectivity | >=50 % | >=50 % | >=70 % | >=80 % | |
| 3 dB Bandwidth | <1.5 nm | <1.2 nm | <0.7 nm | <0.3 nm | |
| SLSR Single Sensor | 15 dB | | | | >15 dB |
| Strain Range | ± 9,000 μstrain | | | | > ± 9,000 μstrain |
| Strain Sensitivity | 1.2 pm/μstrain | | | | |
| Strain Resolution[†] | 0.4 μstrain | | | | |
| Temperature Sensitivity[‡] | 11 pm/°C | | | | |
| Temperature Resolution[†] | 0.05 °C | | | | |
| Fibre Type | Single Mode SMF-28, 9/125 μm | | | | |
| Fibre Coating and FBG Recoating Options[*] | Acrylate | | Polyimide | | High temperature acrylate<br>Other custom coatings |
| Temperature Range[‡] | -270 to +85 °C | | -270 to +300 °C | | |
| Cable and Connections | To suit application | | | | |

[†] with 0.5 pm resolution interrogator
[‡] decreased temperature sensitivity below -170 °C - no temperature sensitivity below -220 °C
[*] Polyimide recoating recommended for strain applications

Specifications may change without notice

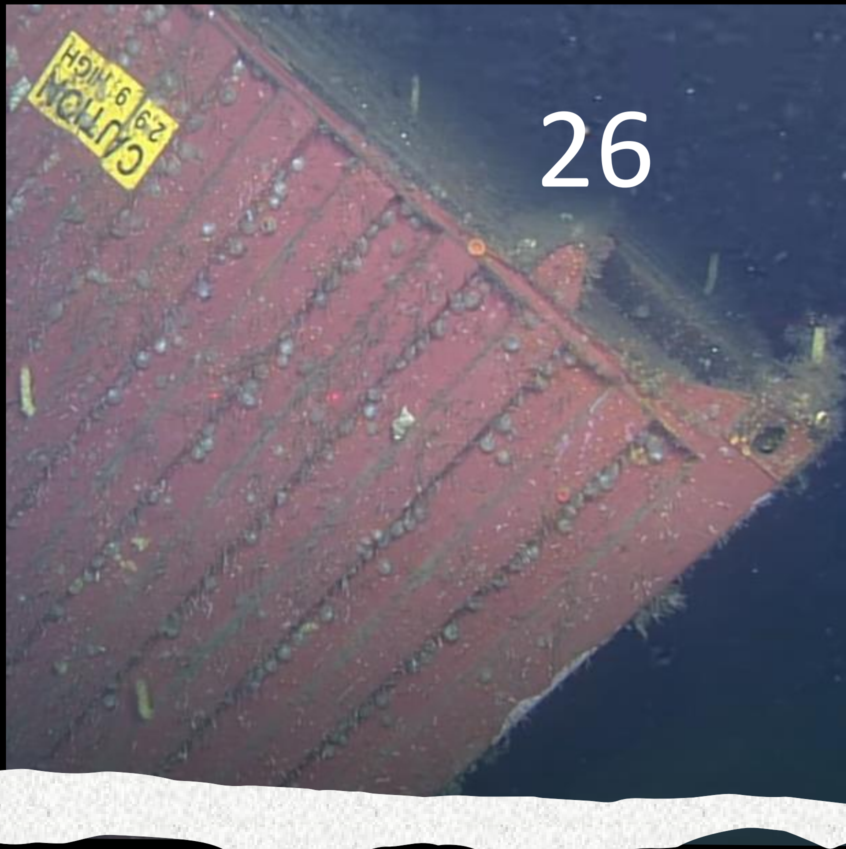


FBG Sensor in Acrylate Coated Fibre

# FBG hull strain meassurements and digital twin concept

- Consequences of ship hull overstress can be hull damadges or hull breakdown
- Increassed hull stres due to climate change and increase of Significant Wave Heigh
- The concept of a digital ship twin is used to monitor the state of a ship in real time
- The inputs to the twin model are state of the PMS, 3D state of the sea around the ship (use of low cost mmWave radars or FPB fibers) and in front of vesel (processing X band radar bacscatter reflections from the sea surface), the structural response or stress of the ship's hull using FBG sensors, vesel stability, weather conditions, current speed, wind direction, ship dynamics  and other vesel parameters
- Based on above inputs vesel Twin model can be offset in time and used for avoiding dangers such as extreme left-right oscillations (parametric roll), real time optimisation of PMS and fuell savings

Image Credits: fiveoceansalvage / Hasan Saad


# Fiber optic sea waves measurement

- an optical fiber with distributed FBS sensors around the ship can also be used to measure the thrust force of the sea buoyancy on the optical fiber, which depends on the wave height, the information is used as input to the digital twin model.
- frequent occurrence of parametric ship oscillations is safety and enviromental concern, in the last event in December 2020, 1900 containers were lost, of which 40 with dangerous cargo
- Monitoring the hull strain in real time contributes to safer navigation, along with the captured information on the state of the sea, the data can be used for timely measures in case of high hull stresses (inspections and repairs) and  improvements in ship design.

# SUMMARY

- Monitoring the hull strain in real time contributes to safer navigation, along with captured information on the state of the sea, the data can be used for improvements in ship design, and timely measures in the event of high hull stresses (inspections and repairs).
- The use of optical fibers for temperature measurements in an environment with strong EM interference is presented, where some new technologies prove to be unreliable
- The aging of laser sources is the main limitation of the reliability of operation in modern offshore systems, the lack of awareness of classification societies (DNV GL, RINA, etc ..), owners and crew is an even bigger problem.
- Insufficient testing of components and systems before installation (example of MOXA switches), rapid obsolescence of components, limited support due to market pressure.
- The solution is the standardization of hardware and software interfaces, similar to the OEM in automotive industry, which allows rapid upgrades of obsolete components and systems.
- Better sharing of information on technical errors and accidents is important to increase safety at sea
- existing AIRTS (Accident Incident ReporTing System) is insufficient