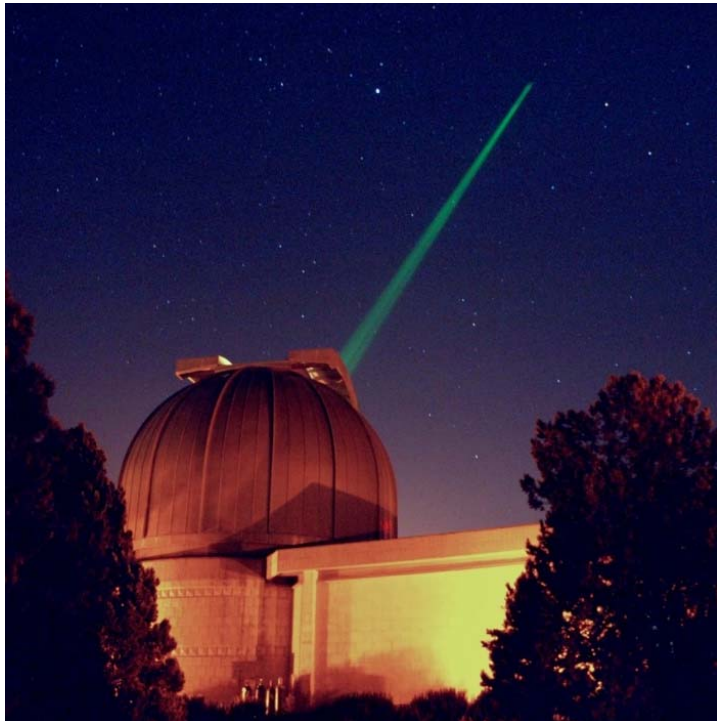# Matera Laser Ranging Observatory Upgrade

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MLRO specs

- ➢ Diffraction limited Cassegrain/Coudé telescope, 1.5 m aperture, 1" pointing accuracy (static & dynamic), 20°/s Az, 5°/s El tracking speed

- ➢ Nd::YAG active-active pulsed laser, originally dual wavelenght (green & UV),100 mJ, 40 ps, 10 Hz pulses. UV removed to add a new infrared channel for quantum communication

- ➢ Cesium/H-Maser frequency standards, GPS/UTC synchro, 1-ps event timing capability, sub-mm calibration (internal&external)

- ➢ Day & night, 1-color (and 2-color) ranging capability to cooperating targets (CCR arrays) from 400 km orbit to the Moon

- ➢ Single-shot ranging RMS jitter
  - $\leq$ 5 mm on LAGEOS ($\leq$ 1 mm NP)
  - $\leq$ 5 mm on Starlette, ERS ($\leq$ 1 mm NP)
  - $\leq$ 15 mm on Etalon, Glonass ($\leq$ 3 mm NP)
  - $\leq$ 15 mm on Moon ($\leq$ 10 mm NP)

MLRO upgrade project

➤ <u>Rationale</u>: MLRO system design made in the 90' and is nowadays using technology not available anymore on the market

➤ Replacement of the station controller hardware

➤ Porting of the controller SW to the new HW platform

➤ Device replacement using COTS
  - Constant Fraction Discriminator device
  - Event Timer
  - Peak Amplitude Detector
  - Motion Master
  - SPAD receiving chain
  - Laser source

➤ SW tailoring and new MLRO functionalities

System overview
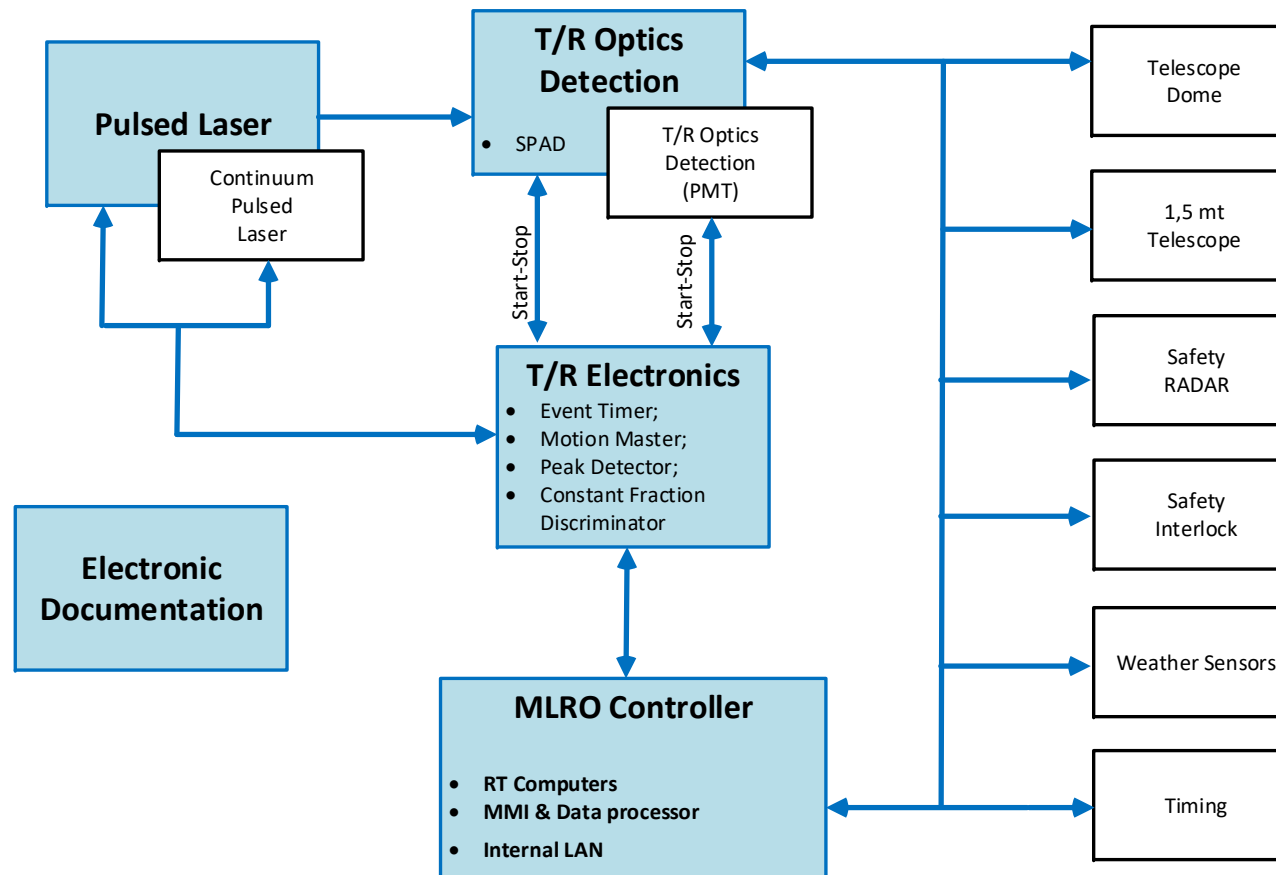
MLRO controller HW/SW upgrade

➢ MLRO controller HW by original design

Name	Description	Model
DDC (HP2)	Documentation and Database Computer	HP J200
DAC	Data Acquisition Control	HP743rt
PAT	Pointing, Acquisition and Tracking	HP743rt
ETP	Event Timer Processor	HP743rt
SCP	Streak Camera Processor	HP744rt

➢ New controller HW specs
- multi-core servers, 64-bit architecture
- I/O boards for the replaced devices
- SW licence for OS, compiler, DB, Versioning SW

SW porting and upgrade

➢ Porting the MLRO SW not an easy job

➢ DiGOS Potsdam GmbH in charge of the SW porting and upgrade

➢ Use of a development platform to avoid SLR operation interruption

➢ Main tasks: C/C++ code Porting, Fortran code Porting, Database Migration

➢ SW tailoring

- Replacement of Obsolete Devices & Integration of New Devices
- Optimization of existing functionalities
- Adding new functionalities
  - One-way ranging
  - LLR prediction using CPF
  - Astronomical objects tracking

➢ SW porting completed in January 2023

MLRO MMI

MMI characteristics unchanged, optimized visualization and use of the windows

Event timer replacement

The main specifications of the available replacement equipment are reported in next table and compared to the current Event Timer specs

		HTSI EVT	EvenTech A033-ET/usb	quTAG HR
Computer Interface		Digital I/O	parallel/USB, ethernet (control)	USB 3.0
Channels		1 (12 input)	1 start + 1 stop	1 start + 4/8 stop
Input level		NIM	NIM/LVTTL	NIM/LVTTL
Input impedance	Ω	50		50
Sensitivity	mV			1.5
Min pulse width	ns		4	0.3
Resolution	ps	≤ 2.5	5	1
RMS Jitter	ps	≤ 10	< 7.5	< 10 (standard); < 5 (HR model)
Dead Time	ns	≤ 50	50	40
Measurement speed	meas/s	>100k (estimated)	12K	100M
Ref in	MHz	10	10	10
1PPS in			yes	no
10 PPS in		yes		

Event timer replacement
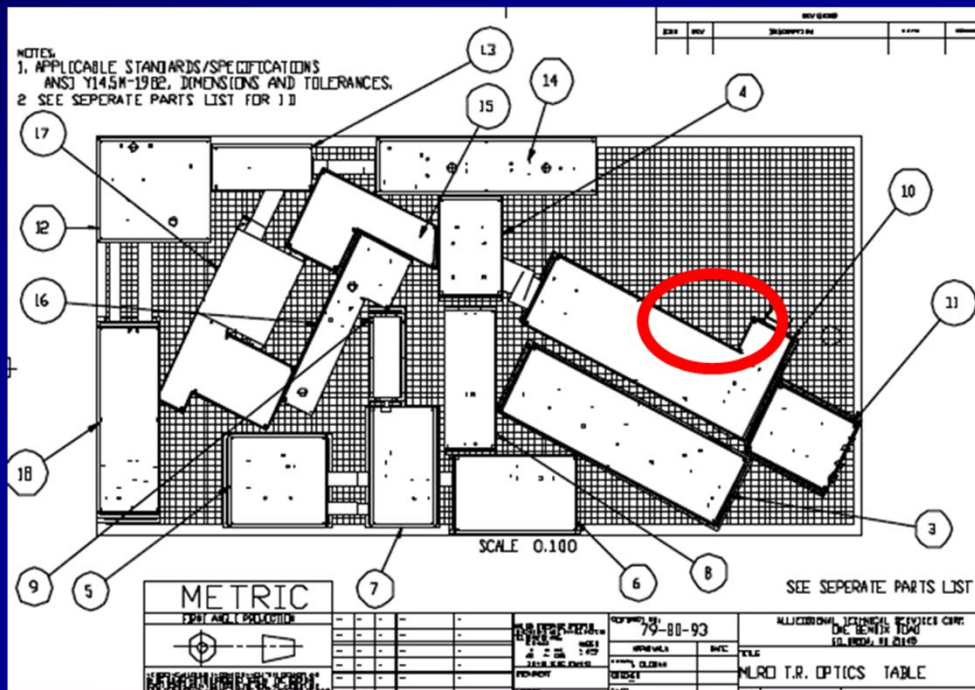

quTAG HR

HTSI EVT

Motion master replacement

- Newport Motion controller mod. esp302
- Hard to find linear and rotating actuators compatible with the existing devices
- Ad hoc adapters built by local manufacturer
- Both new and old actutators can be driven by means of proper configuration

SPAD installation

Position for the SPAD installation

Micro Photon Devices -PDM series

Specifications @ 25°C	Min	Typ	Max	Units
Photon Detection Efficiency (free space)				
@ 400nm	21	24		%
@ 550nm	45	49		
@ 650nm	34	37		
Fiber Receptacle coupling efficiency (CE)				
20 μm active area diam. - (wavelength > 470nm)	70	≥ 80		%
50 μm and 100 μm active area diam. - (wavelength > 470nm)	80			
Single Photon Timing Resolution (FWHM)				
TTL Counting Output			250	ps
NIM Timing Output - (wavelength > 470nm)		35	50	
After-pulsing probability	0.1		3	%
Dead Time		77		ns
Supply				
voltage	5		12	V
connector		Standard 3.5mm supply socket		
Outputs				
Pulse rise and fall times		< 2ns		
Output pulse duration		20ns typical		
Required Termination		50 Ω		
Pulse Characteristics - TTL		Digital, Positive, 0 to +3.3V		
Pulse Characteristics - NIM		Digital, Negative, 0 to -700mV		
Gating input		5V CMOS control (0V, detector off) 50Ω AC terminated, Internal 10kΩ pull-up		
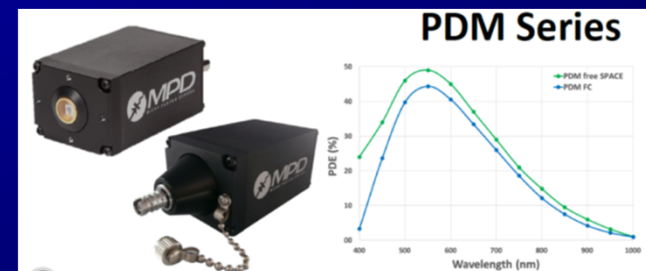
New laser source

Main characteristics of the available lasers on the market that could match the MLRO requirements

		current	EKSPLA 2105	EKSPLA 2206	INNOLAS MAGNA (II/III)	INNOLAS MAGNA EVO III	INNOLAS SpL DPSS EVO
PRF	Hz	10	10	up to 1k	20	up to 1k	100
pulse energy @532	mJ	100	250	7	200/500	150 (@100Hz)	up to 550
Pulse width	ps	50	90 (30 as option)	9	<600	<600	5000/3000
Beam diameter	mm	12	11		12	8	6.5 to 10
Beam divergence	urad	600	< 500	< 70	< 500	< 500	< 500
Temporal stability	ns	± 6	N/A	N/A	< ± 0.4	< ± 0.4	1
Pointing stability	urad	250	< ± 60	< 10	< ± 50	< ± 50	< ± 30
Pulse (energy) stability	%	± 5	± 2.5	± 1.5	< 1.6	< 2	< 1.7
Synch		yes	external trigger	external trigger	--	--	--

Head (WxLxH)	cm		60x150x35	(120x220x35) TBC	109x35x13	55x50x13	50x15x13 to 50x43x13
Power supply (WxLxH)	cm		55x60x110	(55x60x103) TBC	56x40x43	7 RU	
Chiller (WxLxH)				60x60x60			
Cooling type			water	water	water	water	water/air
Weight	kg						up to 40 (up to 50 P.S.)

- INNOLAS MAGNA II PSA-20Hz
- modified to reach the 50 ps pulse width

New laser source in place

CFD and PAD replacement

➢ Constant Fraction Discriminator

- CFD with similar characteristics to the TENNELEC TC454 in use not available as COTS

- another TENNELEC TC454 was procured as spare

➢ Peak Detector

- Replacement still an open point
  - Use of oscilloscope failed
  - Use of oscilloscope + event timer failed (Eventech)
  - Reuse of existing spare boards failed
  - Check with other SLR stations using PAD, no device available around
- Custom made device necessary

MLRO upgrade status

➢ All devices in place

➢ Tests undergoing

➢ Operation with new devices starting in December 2024

➢ SLR data release after the ILRS quarantine