ALTIMETRY SESSION SUMMARY

Chair: Frank Lemoine

With the successful return of data on missions such as Mars Global Surveyor, Clementine, Near Earth Asteroid Rendezvous (NEAR), and ICESAT, laser altimeters have been revealed as an essential tool for planetary exploration and Earth monitoring. This session included three papers on aspects of laser altimetry and a fourth paper demonstrating laser communications. Michaelis et al. reviewed the design for BELA, or the Bepi-Colombo Laser Altimeter. This instrument, onboard the Bepi-Colombo spacecraft would globally map Mercury with a 1 m /10 Hz instrument (100 m footprint, 300 m spacing) starting in 2019. Degnan et al. discussed second-generation photon counting imaging lidars. Second generation systems have flown on aircraft (1 km altitude) providing 15-20 cm resolution and contiguous coverage. Future systems could provide high-resolution topographic mapping even from orbital altitudes. Jirousek et al. presented the design of a timing system technology demonstration with sub ns resolution. The range gate delay width was 40 ns; the repetition rate was 24 Hz max, and the unit mass was 2.5 kg. The system was based on tested technology and developed in less than 3 months. Burris et al. presented the results of a demonstration of laser communications at sea. Live video and other data were transmitted on a 125 Mbps fast Ethernet ship-to-ship link over distances of up to 11 nautical miles.

Second-Generation, Scanning, 3D Imaging Lidars Based on Photon-Counting

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Abstract

Sigma Space is building a new generation of 3D imaging/polarimetric lidars based on photon-counting for use in small aircraft or mini-UAV's. The most recent system is designed to provide contiguous, high resolution (15 cm horizontal, 3 cm vertical) 3D volumetric images of the underlying terrain on a single overflight from an altitude of 1 km. Based on prior experiments with a first generation NASA prototype system and significant technological improvements, the second generation instruments are expected to have greatly enhanced spatial resolution, areal coverage, and ability to penetrate atmospheric haze, tree canopies, and even water columns for underwater imaging.

Introduction

In 2001, a prototype photon-counting laser altimeter was developed by NASA Goddard Space Flight Center [Degnan et al, 2001]. This first generation NASA system flew at altitudes up to 6.7 km and, using single photon returns in broad daylight, successfully recorded high resolution images of the underlying topography including soil, low-lying vegetation, tree canopies, water surfaces, man-made structures, ocean wave structures, and moving vehicles. The lidar was able to see the underlying terrain through trees and thick atmospheric haze (even when onboard cameras and personnel could not) and performed shallow water bathymetry to depth of a few meters over the Atlantic Ocean and Assawoman Bay off the Virginia coast. An external conical scanner, combined with the aircraft motion, allowed the generation of 3D images as in Figure 1.

Second Generation Lidar

Sigma Space Corporation is presently developing a more compact and higher capability second generation 3D imaging and polarimetric lidar for high resolution

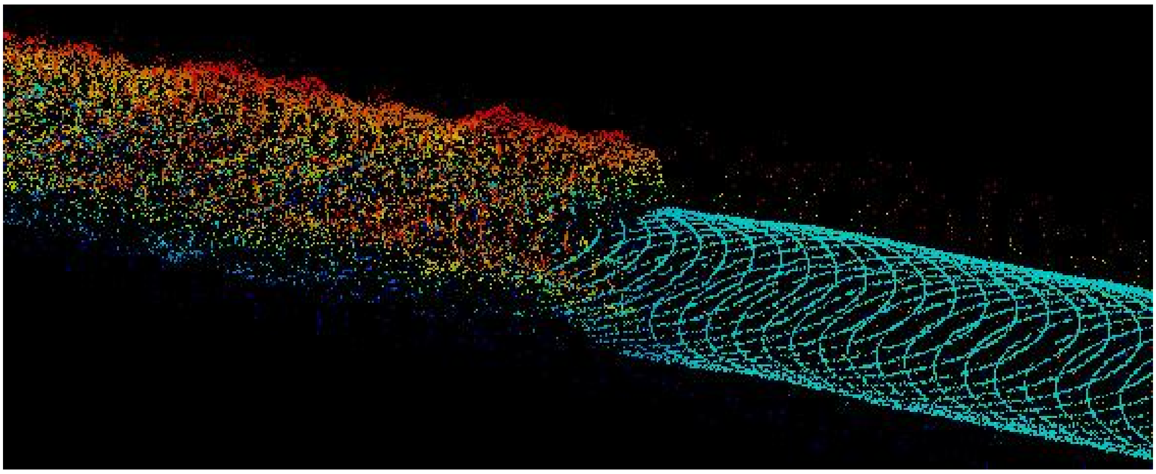


Figure 1: *3D image of a forest edge obtained in daylight by the 1st generation NASA photon-counting microlaser altimeter. (Courtesy Jan McGarry, NASA/GSFC)*

surveying and surveillance from a low altitude, mini-UAV. The shared transmitter is a passively Q-switched Nd:YAG microchip laser oscillator operating at a nominal fire rate of 20 kHz and producing 380 mW of output power at 1064 nm. The photon-counting imager operates at pulse rates up to 22 kHz with approximately 142 mW of frequency-doubled output power at 532 nm; the 238 mW of residual 1064 nm power

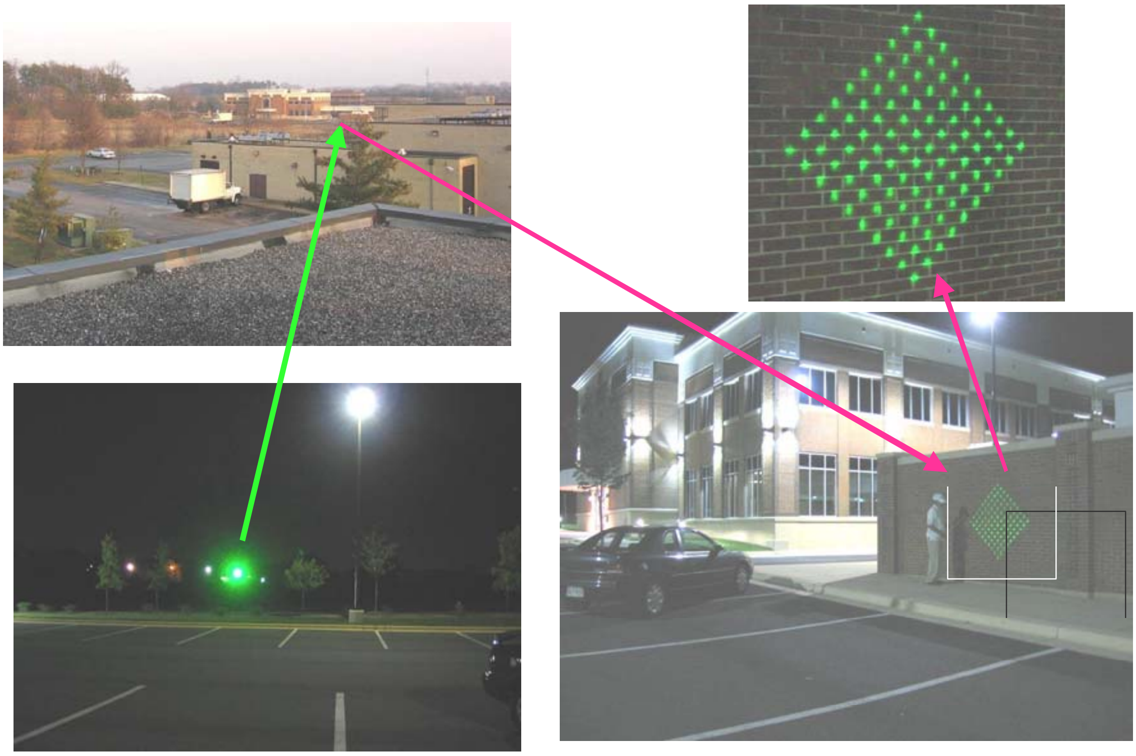


Figure 2: *Counter clockwise from top left: View of target area (most distant building) from the Sigma rooftop; lidar beam as viewed from the target area; projection of holographically altered Gaussian beam on a brick wall at a distance of 250 m; closeup of 10x10 array of beamlets on the brick wall.*

is allocated to polarimetry. Since the green wavelength is near the peak transmission of water, it is suitable for undersea imaging applications. The imager is designed to provide a contiguous, high resolution 3D topographic/volumetric map during a single overflight of the ground scene. From 1 km altitude, the scanner has a swath width of 150 m, a horizontal resolution of 15 cm, and an expected vertical (range) resolution of less than 3 cm. A Holographic Optical Element (HOE) breaks the spatially Gaussian laser beam into a 10x10 array of quasi-uniform eyesafe spots at the target (see Figure 2). The 100 individual far field spots from the HOE are then imaged by the receive optics onto individual anodes of a 10x10 GaAsP segmented anode microchannel plate photomultiplier. The output of each anode is input to one channel of a 100 channel, multistop amplifier/discriminator/timer. Presently, 50 multiple-stop timing channels can be accommodated by one amplifier/discriminator and one Time-of-Flight (TOF) Printed Circuit Board (PCB). The prototype timer has a demonstrated ±100 picosecond timing (± 1.5 cm range) resolution, a multistop capability with a 2 nsec recovery time per channel (corresponding to a capability to resolve objects separated by 30 cm or more in a single pixel for a single laser fire), and an ability to transfer up to 2.2 million ranges per second to onboard memory for long term storage and post-flight processing. Thus, each laser pulse produces a 100 pixel 3D volumetric image of a 1.5 m x 1.5 m ground area. The individual images are then mosaiced together via the platform velocity and the action of a highly flexible dual wedge optical scanner synchronized to the laser pulse train.

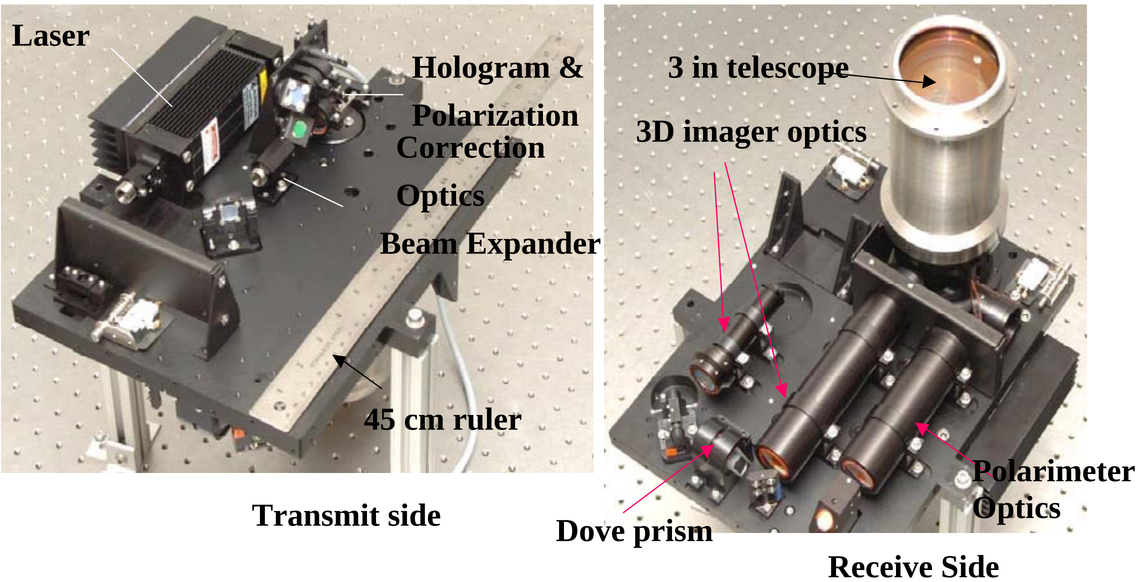


Figure 3: *Optical bench and telescope for second generation 3D imaging and polarimetric lidar. An 18 inch (45cm) ruler is shown for reference*

The transmitter and two receivers (imaging and polarimetry) share a common, 3 inch diameter afocal telescope and optical scanner. This allows the transmitter and receiver to have a common, but narrow, field of view (FOV) to aid in noise rejection and ensures that the imaging and polarimetric data are geographically coregistered. The polarimeter uses the residual laser power (~238 mW) at 1064 nm and two single element detectors to detect two polarization components (although the optomechanical design can accommodate up to 4 NIR detectors for a full determination of the Stokes parameters). Thus, the polarimeter has a nominal horizontal spatial resolution of 1.5 meters. A photo of the lidar optical bench (excluding scanner) is shown in Figure 3. The swath and scan frequency of the dual wedge optical scanner in Figure 4 are tailored to provide contiguous coverage of a ground scene in a single overflight [Degnan and Marzouk, 2003]. The highly flexible servo controller is capable of independently locking the phase and rotation rate of each wedge to the multi-kHz laser pulse train for an infinite variety of precision patterns. These include linear raster scans at various angles to the flight path and conical scans of varying cone angle as well as 2-dimensional rotating line or spiral scans, which might be useful for slow-moving aircraft, helicopters or hovering UAV's. Examples of a 1D linear scan at 45° to the flight path and a 2D rotating line scan are shown in Figures 5a and 5b respectively. The phase locking capability causes the laser beam to be laid down in precisely the same positions with each scan, thereby eliminating the need to record, store, and transfer the scanner wedge positions on each laser fire and greatly reducing data storage and handling. The measured scan repeatability is about 0.07 pixels or about 1 cm at an altitude of 1 km.

The 3D imaging and polarimetric lidar consists of two parts – an optical head and a supporting electronics box. The optical head measures approximately 33 cm x 30 cm x 43 cm and houses the optical bench in Figure 3 (transmitter, imaging and polarimetric optics and detectors, telescope, laser gyros and inclinometer for attitude

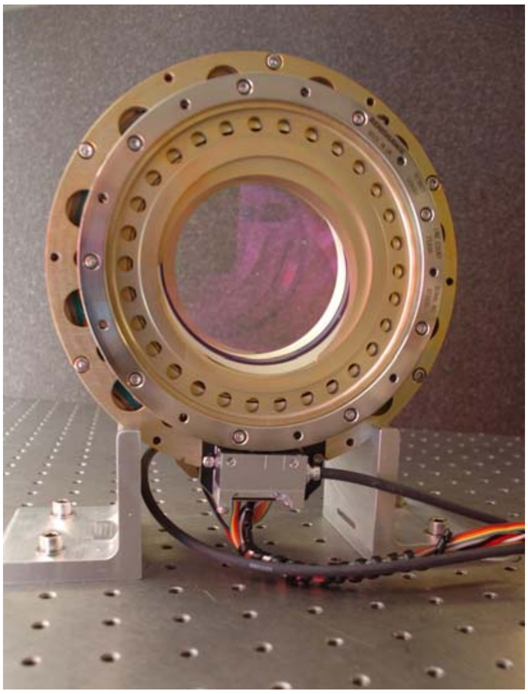


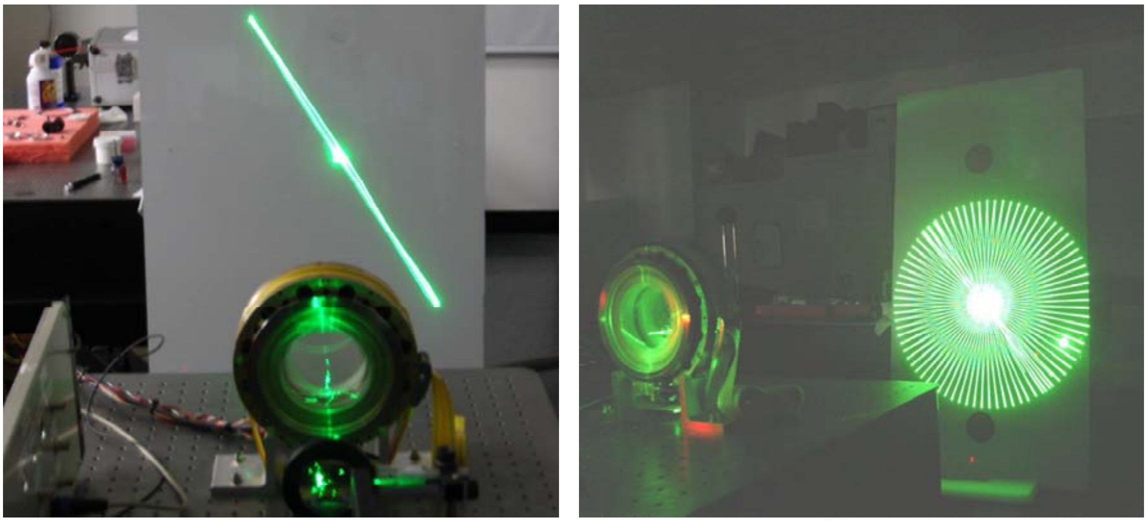
Figure 4: *Photo of the direct drive dual wedge annular ring scanner developed under the NASA JIMO program. The annular ring motors have cryogenic and vacuum compatible counterparts suitable for space use.*

determination, etc) plus the external dual wedge scanner in Figure 4, the MCP/PMT gating PCB, and the Amplifier/Discriminator/Timer PCB boards. The electronics box has a volume of 0.027 m^3 and houses the scanner electronics, GPS receiver, Reference Oscillator and Timing Distribution Circuits, Navigation and Imaging/Polarimeter Data Acquisition Modules, the laser power supply, and various DC/DC converters and voltage regulators. The manner in which the entire lidar system fits within the forward electronics bay of an Aerostar mini-UAV is illustrated in Figure 6.

Summary

Photon-counting altimeters are extremely sensitive and highly efficient, requiring only one photon per range measurement, and, with multistop capability, can be operated day or night with large temporal gate widths for monitoring large elevation changes or simultaneously detecting the tops of tall buildings and city streets or tall treetops and the underlying terrain. Post-detection Poisson filters easily extract the signal from the solar background [Degnan, 2002]. The ability to penetrate obscurants (ground fog, vegetation, water) on a single shot (i.e. without “staring” at a scene while multiple pulses are fired) was demonstrated in the NASA prototype [Degnan et al, 2001]. This penetration capability was the result of the single photon sensitivity and the rapid multiple stop capabilities of the range receiver and will be substantially enhanced in our second generation instruments due to a factor of 12 increase in the effective signal photoelectrons received per ground pixel (~3 pe vs 0.25 pe in the NASA prototype).

Since the laser fires at a rate higher than necessary for contiguous coverage, the 3 pe/pixel is accumulated during multiple interrogations of the pixel during the scan, i.e. typically 3 interrogations at 1 pe which results in a higher probability of detection (~99%) than 3 pe for one interrogation (95%). The integration of a dual wedge scanner in the 2nd generation systems will eliminate the gaps in coverage previously observed with a single wedge conical scanner (see Figure 1) and provide contiguous coverage on a single overflight.



(a) **(b)**

Figure 5: *NASA prototype Direct Drive Internal Scanner generating (a) a linearscan and (b) a rotating line scan on a near field screen. Both scan types were run at 18 Hz and synchronized to a nominal 9 kHz Q-switched microchip laser pulse train. The slight bowing of the linear scan in (a) is due to near field displacement of the beam in the optical wedges but collapses to a true line in the far field. The non-uniformity of the rotating line scan at the 4 o'clock and 10 o'clock positions is due to a slight overlap of two consecutive rotating line scans.*

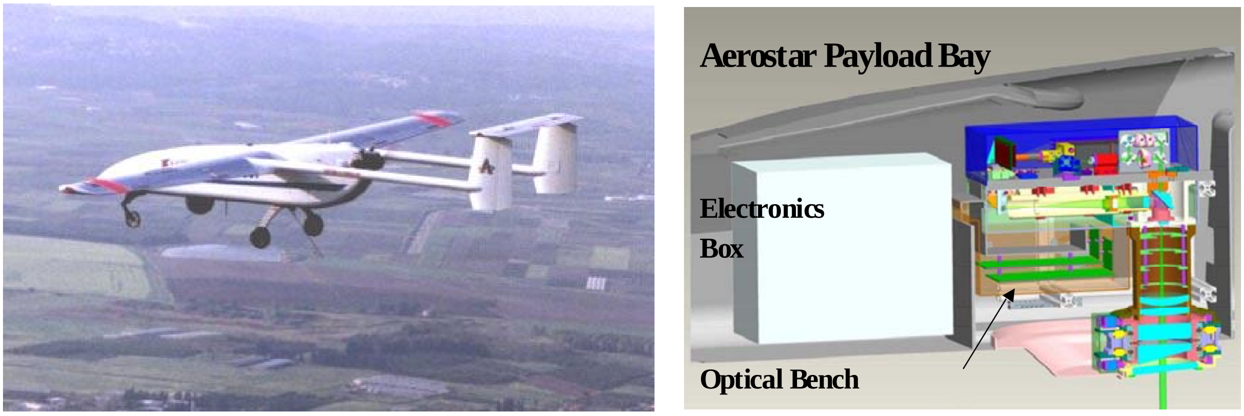


Figure 6: *(a) Aerostar mini-UAV in flight; (b) Packaging of the 3D imaging/polarimetric lidar within the nose electronics bay.*

Acknowledgement

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The BELA - The first European Planetary Laser Altimeter: Conceptional Design and Technical Status

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Abstract

The BepiColombo Laser Altimeter (BELA) is the first European laser altimeter for planetary exploration which has been selected by ESA for flight aboard ESA's Bepi Colombo mission to planet Mercury. A consortium led by the Physikalisches Institut Bern and Institut für Planetenforschung (DLR-Berlin, Germany) will develop a laser altimeter based on the classical principle of laser pulse time of flight measurement. The instrument is based on a longitudinally pumped Nd:YAG laser with 50mJ pulse energy and pulses of about 3ns duration, operating nominally at 10Hz repetition rate. The BELA requirements, the conceptional design, the technical development activities and their status are presented during the workshop.

Introduction

BepiColombo is the European Space Agencies (ESA) cornerstone mission to the planet Mercury. It consists of two orbiters, the Mercury Planetary Orbiter (MPO) and the Mercury Magnetospheric Orbiter (MMO). Among the instruments that have been confirmed is the Bepi Colombo Laser Altimeter (BELA). BELA's primary goal is:

- develop a full topographic map of the planet with an accuracy (goal) of 1m to support geomorphologic studies,
- explore Mercury's interior structure by joint analysis of topographic, gravity and rotation data,
- determine elastic properties of the planet by measurements of tidal deformation
- measure surface albedo and roughness,
- support spacecraft navigation.

Main Requirements

The instruments key requirements are:

- Global topographic mapping with height accuracy of 10m wrt. COM (goal: 1m),
- Surface spacing 300m (shot to shot),
- High detection probability (>70%) up to 1000km,
- Laser footprint <100m.

The detection probability is defined by the PFD, the probability that a random noise fluctuation in the pulse detection chain is misinterpreted as a laser echo.

These requirements have to be fulfilled under the harsh environmental conditions at Mercury. The main design drivers for the instrument are:

- high thermal- and solar flux,

- to guarantee an alignment stability of a few arc seconds
- cosmic radiation levels,
- low resources (e.g. mass)

The main demands come from the high thermal flux (that is as high as $10kW/m^2$) and the high Temperature of Mercury, which can reach surface temperatures of up to 700K. The total instrument mass must not exceed 12kg, which limits the size of the receiver and the laser transmitter.

Technical Approach and Design

The BELA instrument consists of the receiver and the transmitter part which will be developed by institutions from Switzerland, Germany and Spain. The architecture of the instrument is shown in Figure 1.

The receiver telescope with the detector, the laser head and the beam expanding telescope are assembled on the so called Baseplate (BP) unit. The laser head, (OAB), is fibre pumped by the pumped-diode unit (PDU) which is controlled by the laser electronics (LEU). The main electronics of BELA including rangefinder electronics, data processing electronics, transmitter electronics (START-pulse detection and digitization) and the power supply are accommodated in a common electronics box,(ELU).

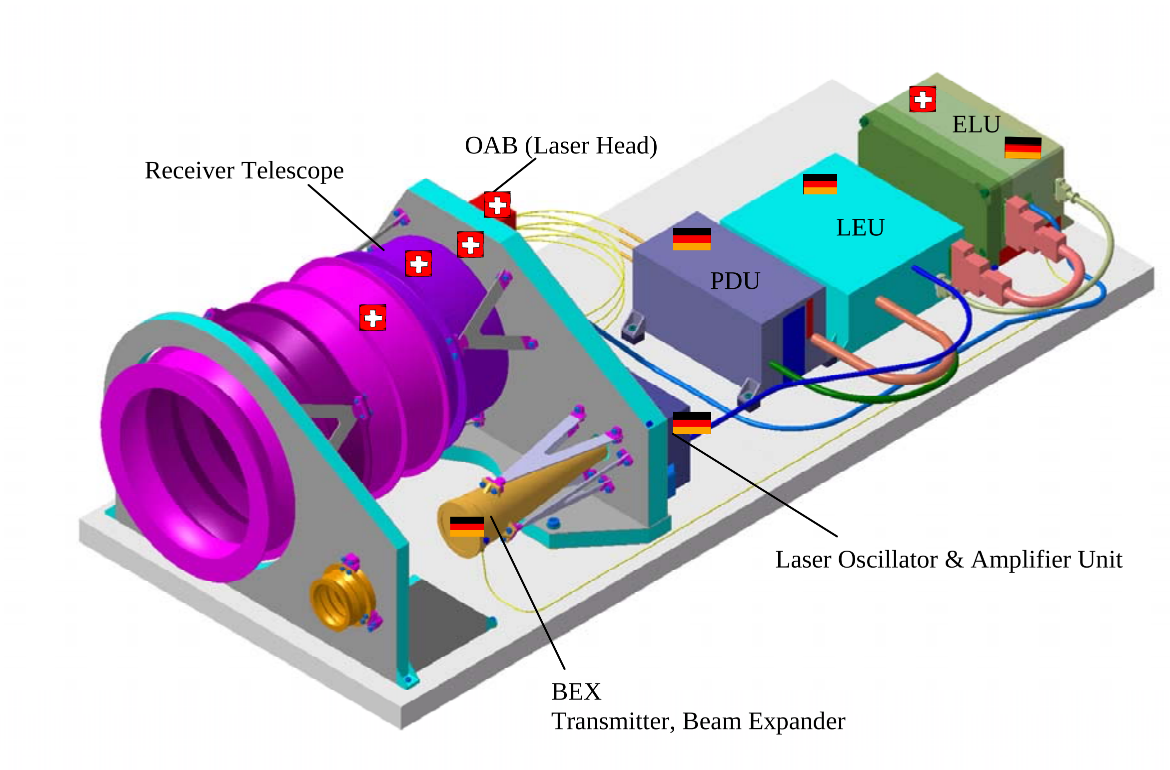


Figure 1: *Main Components of the BELA Laser Altimeter*

The main characteristics of the envisaged instrument are:

- 20-25cm lightweight telescope (1kg) with large baffle for thermal protection,
- backend optics with 1nm filter /FWHM) and >80% transmission,
- high sensitive (low noise) APD detector,
- 50mJ, 3ns diode pumped Nd:YAG laser, 10Hz nominal repetition rate,
- 50mm (20x) beam expander with ~50m footprint @1000km,

- common E box (ELU) with receiver-, START electronics and LEON-3 processor, power converter, thermal controller,
- 12kg, 33W (nominal).

The instrument's characteristics were derived by performance simulations according to the following parameter spreadsheet (see Table 1).

Table 1: *BELA parameter set for performance simulation*

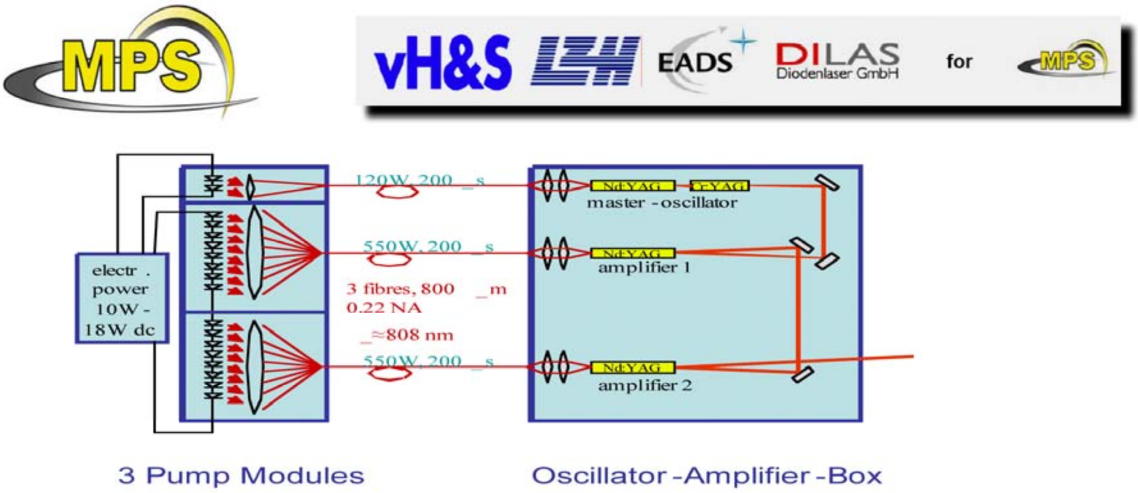
Parameter	Symbol	BELA
S/C		
Destination		Mercury
Altitude	H	400-1500 km
Pointing uncertainty	$\delta\varphi$	25μrad
Laser transmitter		
Pulse energy	E_r	50 mJ[a]
Pulse width	δ_0	3.4 ns[b]
Wavelength	λ_T	1064 nm
$1/e^2$ beam divergence	θ_T	25 μrad[c]
Repetition rate	ν_T	10 Hz
Collimator efficiency	ϵ_T	0.80
Receiver optics		
Arperture radius	r_R	125 mm
Focal length	f_R	1250 mm
Field of view	θ_{FOV}	200 μrad[c]
Optical efficiency	ϵ_{RO}	0.70[d]
Filter transmission	ϵ_{RF}	0.80
Filter bandpass	δ_{RF}	0.42 nm[b]
Detector		
Quantum efficiency	ϵ_{QE}	0.38
Gain	M	150
Excess noise index	χ	0.25
Surface dark current	I_{DS}	20 nA[a]
Bulk dark current	I_{DB}	50 pA[a]
Electronics		
TIA Bandwidth	B_0	20 MHz
ADC sample period	T_R	12.5 ns
Noise floor	δI_{NF}	1.0 pA $Hz^{-1/2}$

The most critical parameters are the laser pulse energy, the aperture of the receiver telescope and the performance characteristics of the detector (quantum efficiency, noise). It was estimated that the instrument will be capable of meeting the performance requirements, PFD<0.1 out to a height of 1050km and a height accuracy measurement of down to 1m for a reasonable set of observing conditions.

Key instrument components are presently in development for performance verifications and testing. One key component, the laser units has already been designed and fabricated by MPS and German industry (Laser Zentrum Hannover e.V., DILAS GmbH, Mainz, Von Hoerner & Sulger, Schwetzingen) as a prototype model, which is shortly described below.

The BELA-Laser

The optical design of the BELA laser is based on the concept of Nd:YAG laser crystals for the oscillator and the two amplifier stages, which are longitudinally pumped with GaAs diodes around 804 to 808 nm (@298K). The simplified block diagram of the laser head (OAB) and the pump diode unit (PDU) is shown in Figure 2.



The BELA instrument requirement is to have 3 fibre coupled pump sources (called modules); two of them shall deliver 550W ex fibre each for amplifier pumping while the third has to deliver 120W ex fibre for oscillator pumping.
The diodes for oscillator pumping shall be available in could redundancy, which means that two bars will be operated and two other bars can be used alternatively (not sketched).

Figure 2: *Block diagram of the laser head (OAB) and the pump diode unit (PDU)*

The OAB is optically pumped via three fibre optics cables between the OAB and the PDU. The output pulse energy of the laser is 50mJ at 3ns pulse duration (measured) and a firing of 10Hz (nominally). The control and the current supply of the laser are provided by the Laser Electronics Unit (LEU). The main parameters of the laser are summarized in Table 2.

Table 2: *Laser Main Characteristics*

Parameter	**Unit**	**Value/Description**
Material		Nd:YAG
Wavelength	nm	1064.x
Pulse Energy	mJ	50 (EOL)
Pulse frequency	Hz	10 (nominal)
Pulse Duration	Ns	3
M2		<1.6 (measured: 1.3)
Q-switch		Passive
Laser Pump		Longitudinal
Efficiency (electro-optical)	%	5.2 (measured)

The first Prototype Model of the laser is shown in Figure 3.

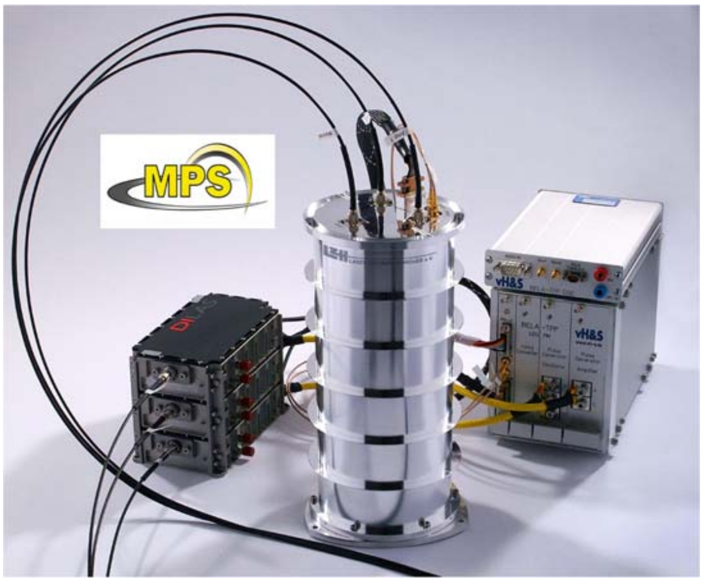


Figure 3: *BELA Laser Prototype Model-1*

Further key components that are presently in development are only shortly listed below:

Beam Expander (BEX)

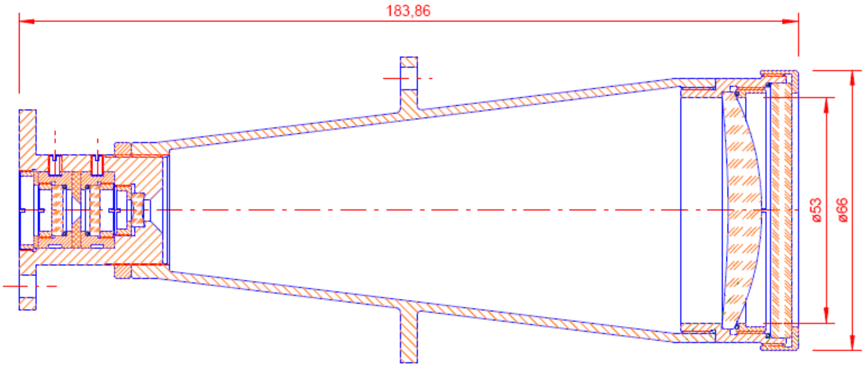


Figure 4: *Opto-mechanical layout of the BELA Beam Expander (BEX)*

The BELA beam expander (Prototype Model) is based on an aspheric lens design for the exit-lens in order to prevent a double-lens and to save mass. The beam direction can be slightly adjusted by wedge prisms at the entrance of the beam expander. The BELA-BEX has a nominal beam expansion ratio of 20. A fibre-optics interface is foreseen for optical detection of the START-pulse.

START Electronics

The START electronics has two functions:

1. detection of the START-pulse, which will be fed to the rangefinder electronics
2. digitization of the START-pulse for energy and shape measurement of the outgoing pulse

The block diagram of the START electronics and the first prototype is shown in Figure 5 and Figure 6 respectively.

The components of the receiver: telescope (incl. base plate), baffle, detector and rangefinder electronics are presently in development in Switzerland, lead by the University of Bern (Nicolas Thomas and Karsten Seiferlin).

Conclusion and Outlook

The BELA team is in process to design the first European laser altimter for planetary exploration which has been selected by ESA for flight aboard of ESA's Bepi Colombo mission to planet Mercury. Numerical models have been developed to assist with design tradeoffs and definition of operational modes. Key components like the laser have been developed as prototype model and further units are in fabrication (beam expander, receiver telescope, detector electronics).

The Forschungseinrichtung Satellitengeodäsie der Technischen Universität München (Wettzell) and DLR are presently in process to design a first performance demonstrator which is based on the BELA prototype models and commercial components with a performance characteristics close to BELA. This performance demonstrator will be used for functional and performance verification of BELA by satellite laser ranging, and it will be used as a transponder demonstrator.

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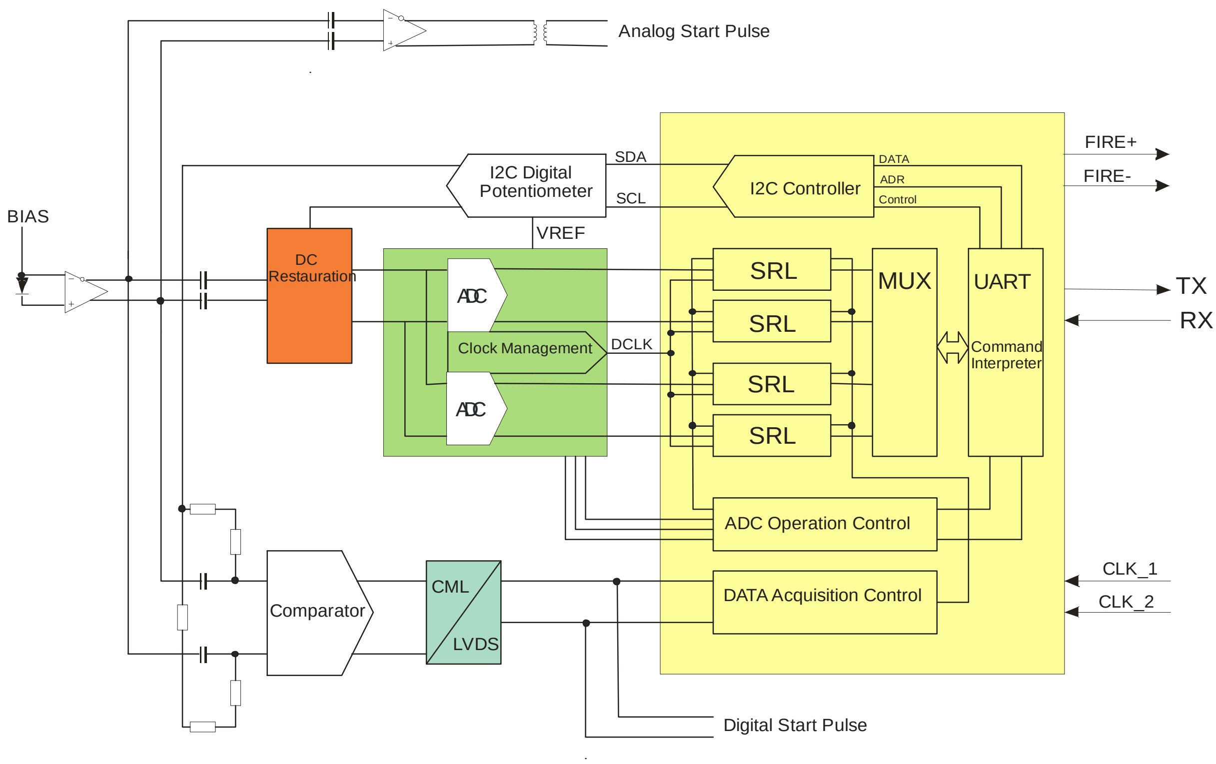

Figure 5: *Block Diagram of the START-Electronics*

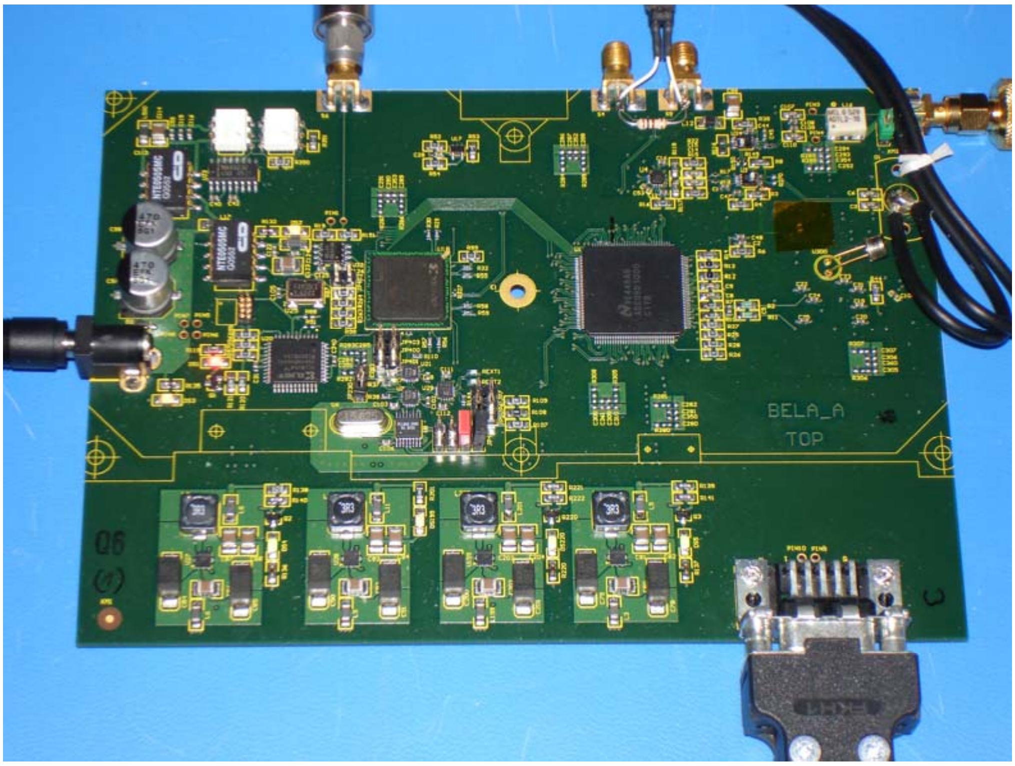

Figure 6: *Prototype of the START Electronics*

Timing System for the Laser Altimeter for Planetary Exploration Technology Demonstrator

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Abstract

We are presenting the design, construction and tests of the timing system for the Bepi Colombo Laser Altimeter (BELA) technology demonstrator. BELA Timing System (BTS) is an universal timing system for laser ranging in ground-ground, air-ground and ground-satellite experiments. It is dedicated to measure precise time interval with subnanosecond resolution. The device for advanced range gating is included. The unit is interfaced to a host personal computer via a serial data link for control, two way data transfer and diagnostics.

The entire BTS has been designed and constructed on the basis of the Portable Calibration Standard (PCS) for satellite laser ranging, which has been developed in our labs within the last ten years. To reduce the complexity, costs, weight and power, considering the modest timing resolution requirements, the sub-nanoseconds instead of picoseconds resolution of the time intervals, the timing part of the original device has been replaced by the Mini counter. The overall design philosophy, the operational control software, the epoch timing, the range gate generation have been preserved along with the concept of the host computer software package for data acquisition, control and data analysis including the communication protocol, data and command formats etc. The use of well tested concept of both the HW and SW enabled to shorten the design, construction and testing phase of the final device down to several weeks.

The BTS consists of the Mini Counter module, the epoch timing and range gate generator module, the control processing unit, the input / output circuits and of the power supplies. The entire control logic hardware including the epoch timing and range gate generator and the input/output board logic is based on the FPGA (ispGAL) programmable logical arrays. There is a significant array capacity still available for future functional extensions and device upgrades, the arrays are field programmable. This fact ensures the maximum device flexibility and upgradability. The main parameters are : resolution 0.25 ns, linearity and stability better than 0.1 ns and 0.1 ns per K and per hour resp. The laser fire epoch resolution is 100 ns, the range gate is programmable in 40 ns steps. The device is small (2 kg), low power, it is capable to operate 3 hours on eight AA batteries.

Goals

- Technology demonstrator of a Compact Laser Rangefinder applicable in future space projects :
  - Mercury planet altimetry
  - Lunar altimetry and surface mapping
  - on-board optical transponder(s) for Earth orbiter(s)
  - airborne range finder
  - ground based Satellite Laser Ranging (SLR)

- Main altimeter parameters:
  - one meter ranging precision
  - multiphoton approach
  - diode pumped laser, ns pulses,
  - modular construction
  - existing / available technology

Philosophy

- Technology demonstrator of a Compact Laser Rangefinder
- modular construction
- existing / available technology
- test bench at the Satellite Laser Ranging site Wettzell, WLRS

- applicable in various ground and space projects :
  - Mercury planet altimetry
  - Lunar altimetry and surface mapping
  - on-board transponder for Earth orbiters
  - ground based Satellite Laser Ranging (SLR)
  - airborne range finding

Schedule & responsibilities

July 31 st	decision, proposal, quotation	CTU Prague
August 31st	DLR acceptance, contract	DLR
October 30	first version operational	CTU Prague
November	on-site testing	CTU / DLR
November 30	delivery	CTU
December 15	integration at DLR	CTU / DLR

Altimeter Timing System Requiremerets

- GENERAL
  universal timing system for laser ranging with sub-ns resolution

- FUNCTIONS
- determining the epoch of laser fire
- measuring the time-of-flight of the laser pulse
- generating the range gate pulse for the echo signal detector
- data acquisition and process control.

- PROPERTIES
- compact, low power (battery operated), low cost
- based on field - proved components HW & SW
- simple to integrate into final device

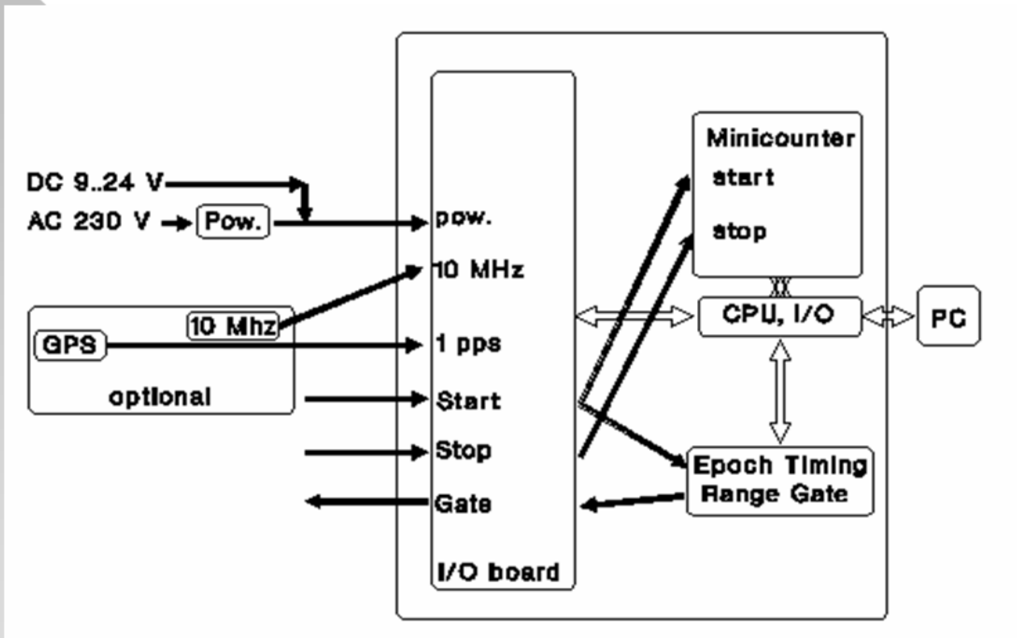
Altimeter Timing System Concept

- Based on P-PET hw and sw concept,
  the Dassault modules are replaced by integrated TDC chips .

- The timing system consists of the range counter module, the epoch timing and range gate generator module, the control processing unit, the input / output circuits and of the power supplies.

- The entire control logic hardware, epoch timing, range gate, and input/output board is based on the FPGA (ispGAL) programmable logical arrays.
  This ensures the maximum device flexibility and upgradability.

Timing System Technology Demonstrator Block scheme



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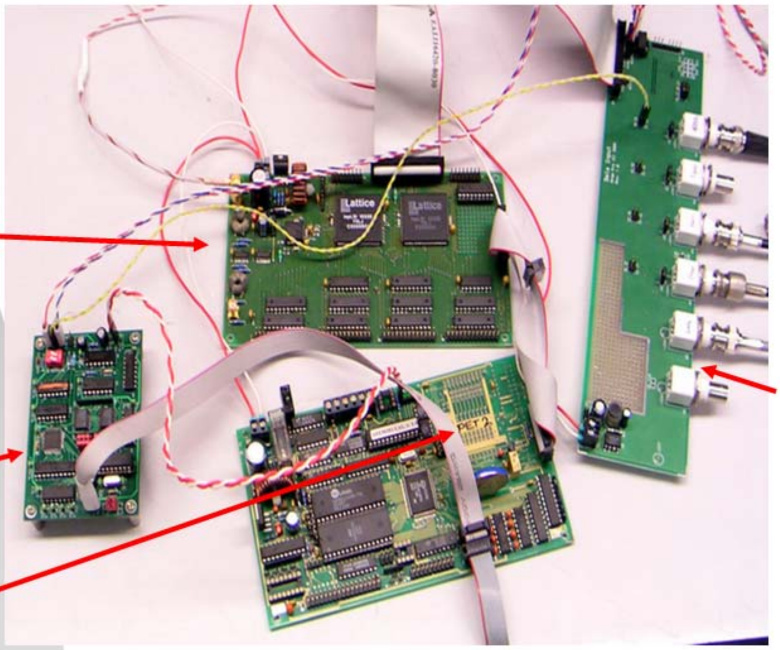
Timing System Technology Demonstrator Electronics boards

Range gate logic
PET 2 version

TDC timing board

CPU board
PET 2 version



I/O
board

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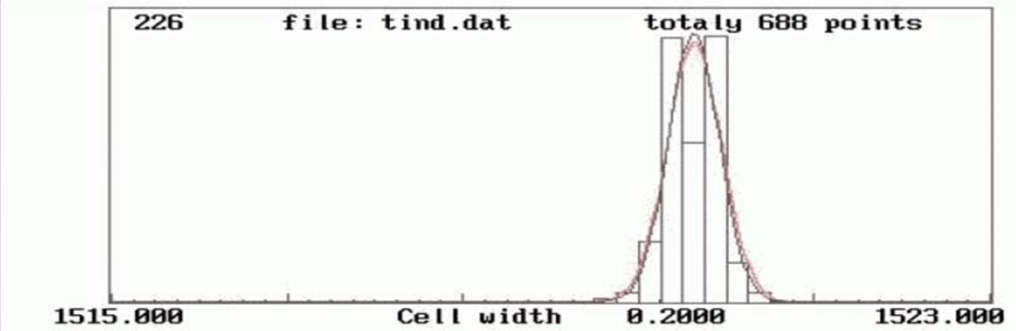
Timing System Technology Demonstrator
Temporal resolution



Criter.	MEAN	SIGMA	PT #
1515.000 / 1523.000	1520.304443	0.252117	688
3.0 * SIGMA	1520.304443	0.252117	688
2.5 * SIGMA	1520.304688	0.247236	684
2.0 * SIGMA	1520.298462	0.231441	660

measured time 1.52 μs
the timing resolution of 0.25 ns
normal data distribution

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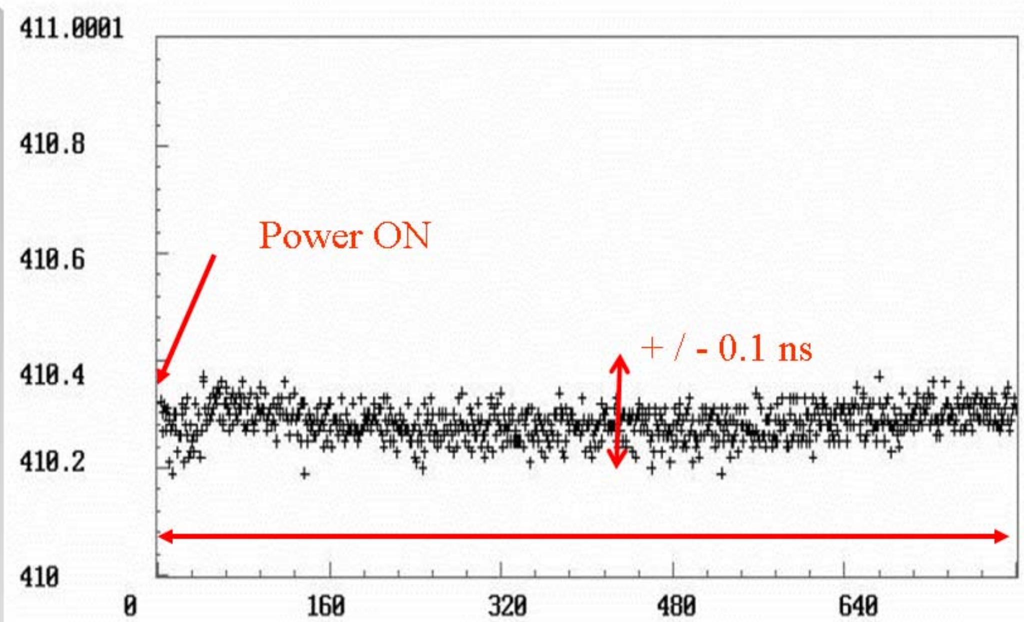
Timing System Technology Demonstrator
Long-term temporal stability



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Timing System Technology Demonstrator
Parameters

- universal timing system for laser ranging with sub-ns resolution

-

resolution, precision	0.25 ns, 0.25 ns rms
non-linearity, stability	< 0.1 ns, < 0.1 ns/hour
range gate delay,width	40 ns steps
repetition rate	24 Hz max.
mass	2.5 kg
power	DC 9-38 V, 7 VA > 3 hr operation on AA cells (8x)

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Altimeter Timing System Technology Demonstrator
Conclusion

- the universal timing system for laser ranging:
  ground-ground, air-ground and ground-satellite
  with sub-ns resolution has been developed and tested

- simple to implement:
  SW package identical to PET devices

- based on tested technology and components
  development period < 3 months :-)

- In perspective the Altimeter Timing System may be applied
  in deep space laser transponder experiments

Jirousek,Prochazka,Hamal,Fedyszynova,Schreiber,Michaelis,Yang,Huang,Canberra 2006

A Compact Low Power Altimetry Laser For Lunar Applications

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2. Fibertek Inc., 510 Herndon Parkway, Hendon, VA 20170

Abstract

A very compact 10 mJ, 10 Hz, 4ns laser with greater than a billion shots capability is being developed for lunar altimetry applications for a mission projected for 2008. The altimeter will complement other scientific payloads of the mission that includes Terrain Mapping Camera with stereo imaging capability, Hyper-Spectral Imager, and a Low Energy X-ray spectrometer. The laser design exploits the advances in technologies, capabilities, and lessons learned from the NASA Risk Reduction Laser program, Calipso, and others. The Engineering Model and Flight Model are discussed.