HELENA – HERA LIDAR ENGINEERING MODEL ALTIMETER DESIGN

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LIDAR and rangefinders are among the most important instruments for an asteroid mission, a consequently a critical technology for planetary defence. They support spacecraft navigation, from fly by to landing operations and can also provide scientific data, such as relative velocity, falling velocity and reflectance measurements at laser wavelength.
Low mass compact spacecraft missions to asteroids is an increasing trend, including small landing spacecrafts. This fact tends to drive instruments design, namely miniaturization and flexibility maintaining its performance. New compact rangefinder technologies are therefore needed for future asteroid missions.

HELENA (HERA LIDAR ENGINEERING MODEL ALTIMETER) design is based on a Laser Landing Altimeter Engineering Model developed by EFACEC, Portugal in the frame of an ESA project. The laser source of this altimeter is a compact low power consumption microchip laser that emits 1.5 µm light pulses. This laser technology enables rangefinder compact designs. The EM of this altimeter has a mass below 1.4 kg, dimensions of 12 cm x 15 cm x 10 cm and was designed to measure distances up to 3 km and to endure a TID of 100 krads.
The previous altimeter design is now being adapted to HERA mission requirements. HELENA main design requirements are a measurement range of 14 km to 500 m, an accuracy of 0.5 m and mass below 1.5 kg. These new requirements have an impact mainly in the rangefinder optical front end, demanding a design update.
In this work, a new instrument design is reported that will be used in the HERA mission during operations near the binary asteroid Didymos; it can be used in future asteroid missions.

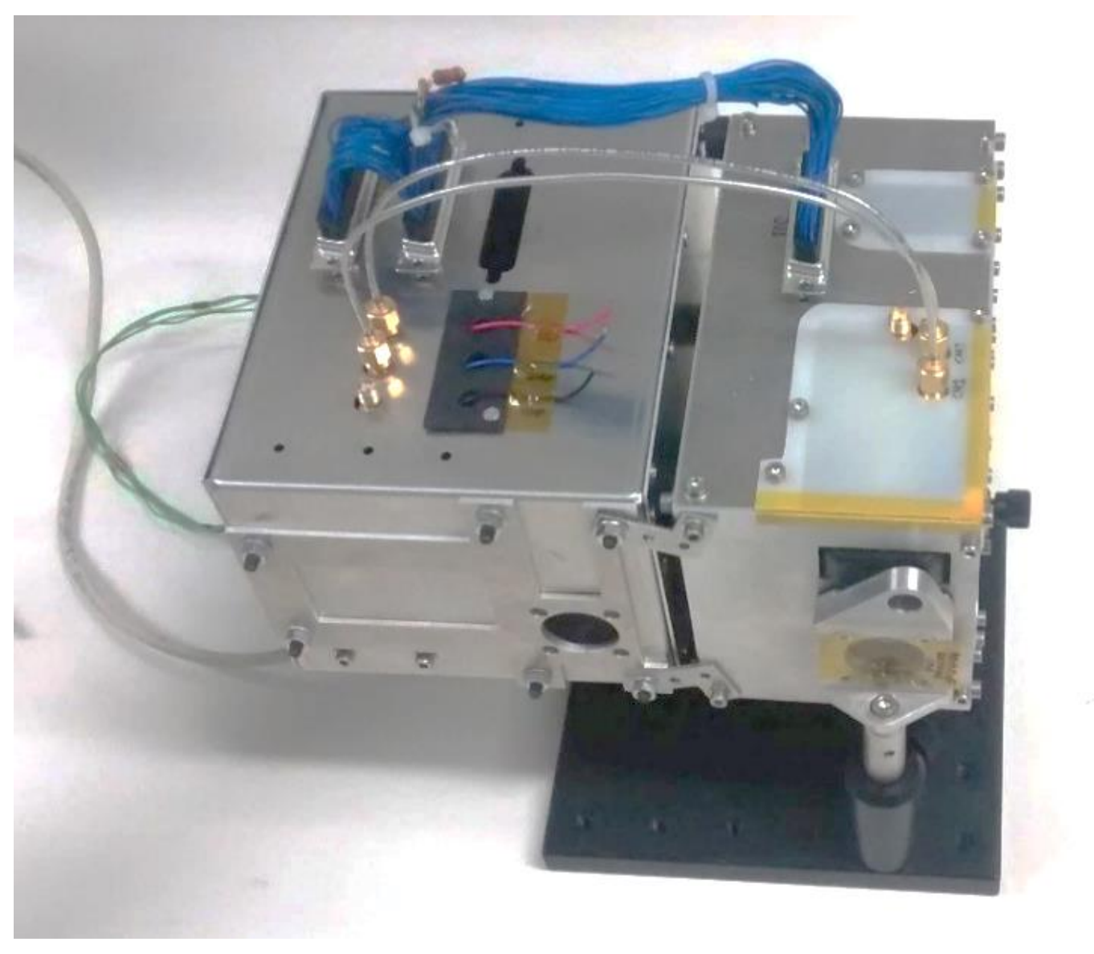
Hera mission and LIDAR requirements

AIDA (Asteroid Impact & Deflection Assessment) mission is a partnership of ESA and NASA, and aims to study asteroid deflection through a kinetic collision. This mission targets the binary Near-Earth Asteroid (NEA) (65803) Didymos (1996 GT). Didymos main body has a diameter value around 775 m and its secondary body (Didymoon) has diameter of 165 m. NASA provides the DART spacecraft that will impact Didymoon, while the orbit change is monitored by ground stations. ESA provides the HERA spacecraft that will study the post impact scenario. The HERA spacecraft is composed by the main spacecraft and two small CubeSats. HERA will study the asteroid with Cameras, Radar, Satellite-to-Satellite Doppler tracking, Lidar, Seismometer and Gravimeter. In this poster the focus is the LIDAR instrument HELENA.
HELENA is an TOF altimeter instrument that will measure the distances from HERA spacecraft to asteroid, providing information for a 3D topographic mapping of the asteroid. The key design requirements for HELENA are provided in Table below.

Requirement specification	Value
Range	500m to 14Km (goal=20 Km)
Accuracy	0.5m
Emitter FOV	< 2000 µrad
Repetition rate	10Hz
Operational Wavelength	1535 nm
Operational temperatures	-40 to +60 ºC
Total mass	<1.5Kg

HELENA architecture

HELENA Electronics are based on an EFACEC LIDAR developed for Planetary landing in an ESA activity. The EFACEC LIDAR was developed to support small spacecrafts in landing operations (e.g. Mars landing). The EFACEC LIDAR is shown in Figure below.



The EFACEC LIDAR was designed to shorter distances that the HERA requirement. So its optical front end has to be redesigned. The maximum distance will be extended from 1 km to 20 km.
This will be done at the cost of a larger optical aperture (i.e. Larger receiver Telescope).

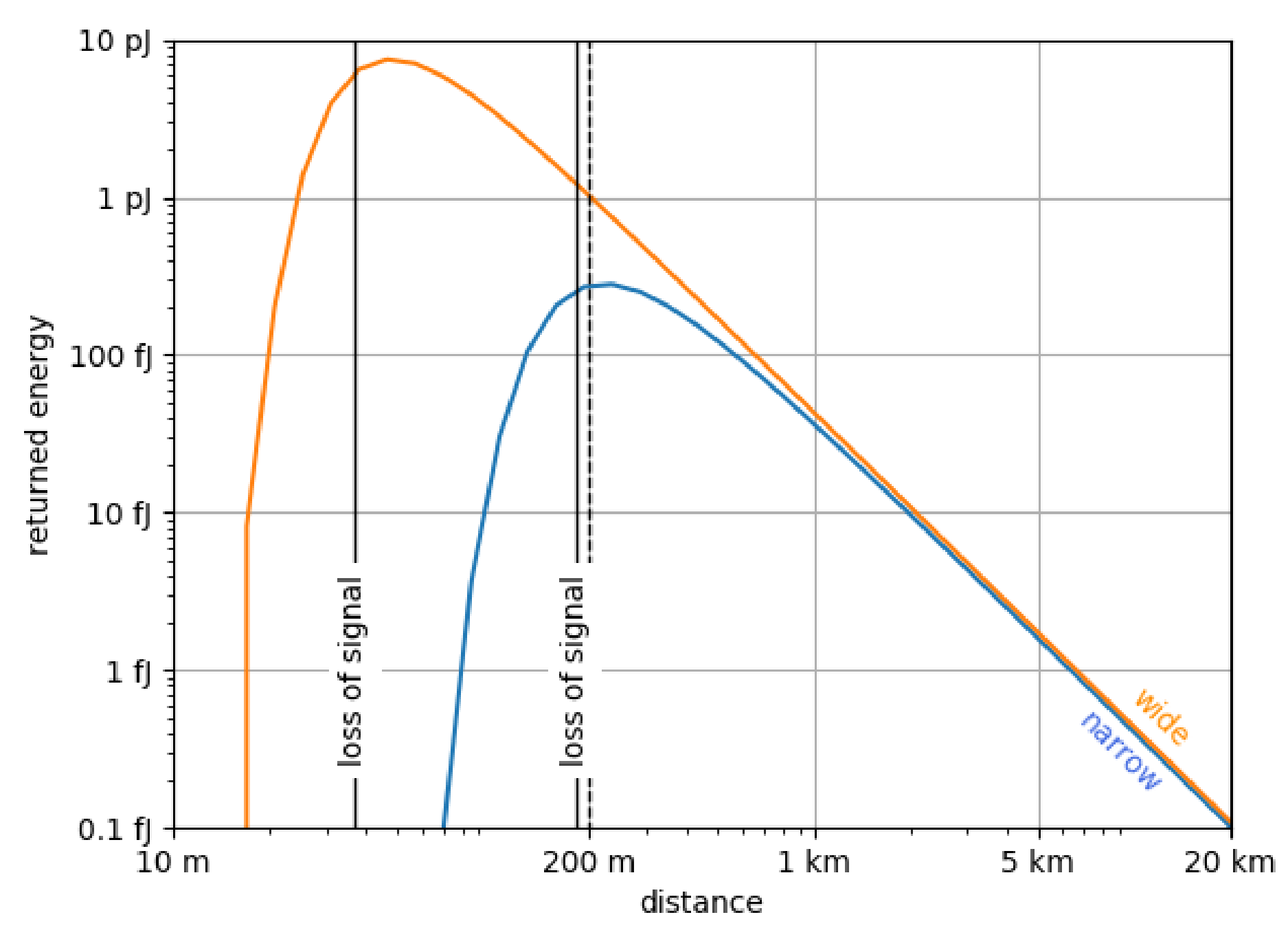
The digital interface will be made via USL link over an RS422 physical layer. HELENA main sub-systems are listed below:
1- Power Supply Board (PSU): responsible to generate the secondary voltages from the S/C power interface (unregulated 28V), and also for the Discrete interfaces (HPC, Status and TRP output);
2- Backend Electronics (BE): responsible for the instrument control, data acquisition and processing and for the serial interface with the S/C;
3- Frontend Electronics (FE): responsible for the Laser power supply and triggering, also for the Laser pulses digitalization;
4- Time of Flight (ToF): responsible to timestamp the pulses detected by FE;
5- Optical System (OS): the opto-mechanical concept of the unit, made by the Laser Telescope and APD telescope;
6- Mechanical Box (MB): the mechanical Box and structure responsible to hold the other sub-units.
HELENA will have two different acquisition modes: the first, called Burst Mode, where the instrument will output a measurement at a configurable periodicity (maximum 10Hz); the second, called Single Shot, HELENA will output only one measurement, with the value of the median of 9 measurement samples.
In both working modes HELENA, will also periodically send a housekeeping packet with the equipment health information.

Radiometric calculations

A Monte Carlo study of the returned pulse was performed. It was determined that only about 180 aJ reach the LIDAR sensor, for a measurement of 20 km distance. The dimming is mostly due to the geometric $1/d^2$ effect as light travels from the asteroid back to the spacecraft.
To calculate the returned energy we used the following equation:

$$E_r \approx E \times (\text{emitter transmittance}) \times (\text{asteroid reflectance}) \times \frac{\text{telescope area}}{\pi\,\text{distance}^2} \times (\text{receiver transmittance}) \times (\text{overlap})$$

ER – Receiver energy; E – Emitted energy; Overlap is a complex geometric formula that takes in account the LASER emitter angle and receiver telescope FOV.



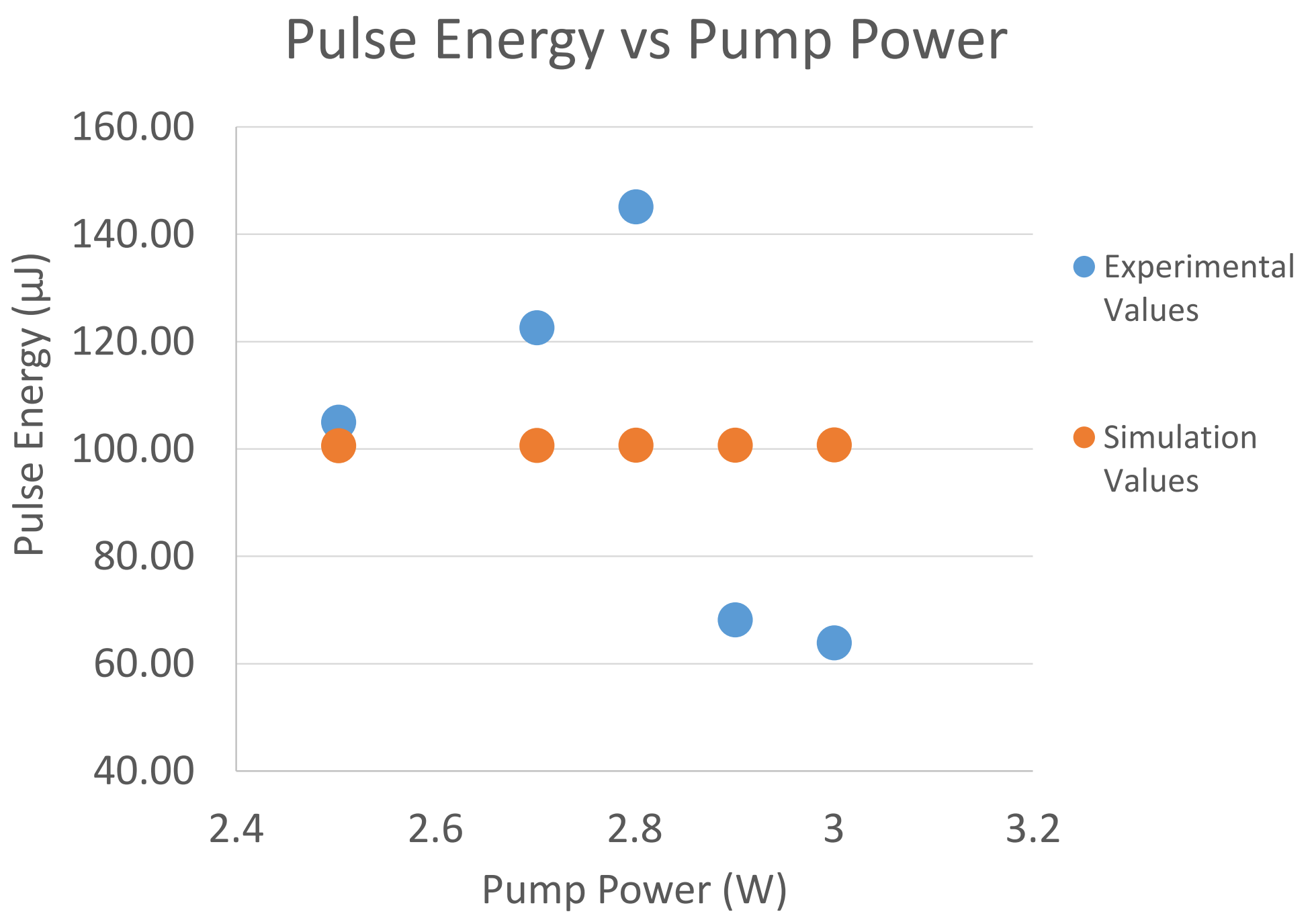
Two simulations with different emitter and receiver angles were performed:
1) Wide angles (Orange plot).
Receiver FOV = 2800 µrad;
Emitter angle = 2000 µrad.
2) Narrow angles (Blue plot).
Receiver FOV = 505 µrad;
Emitter angle = 495 µrad.
It can be seen that for the shorter distances the Narrow configuration receive less energy. This fact is manly due to the loss of signal caused by reduced emitter receiver footprint overlap.

The parameters used in the simulations are presented in Table below:

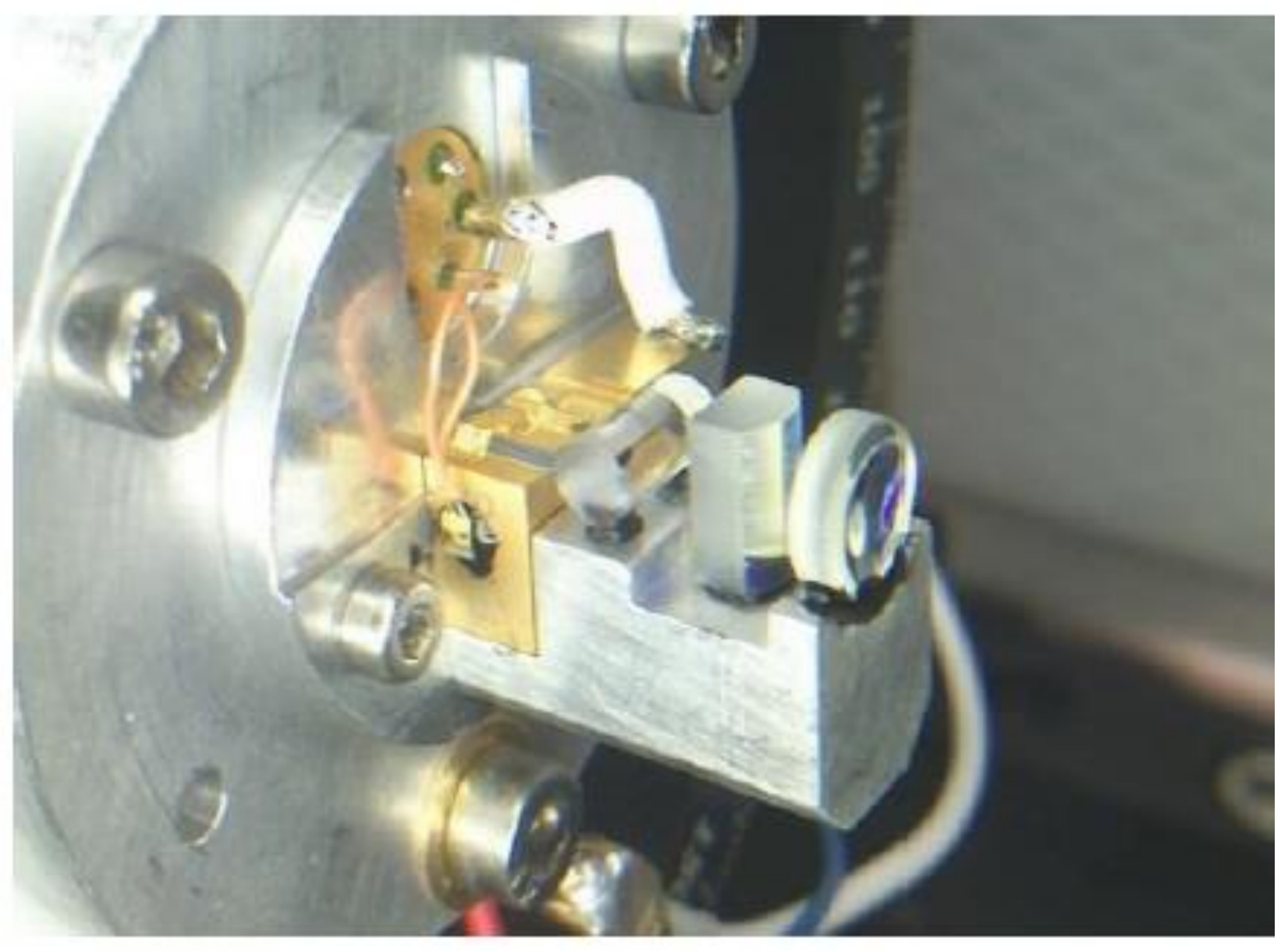
Telescope aperture	10 cm
Emitted energy	100 µJ
Wavelength	1535 nm
Pulse FWHM	2 ns
Emitter optics transmittance	0.93
Receiver optics transmittance	0.91
Asteroid surface reflectance	0.10
Telescope aperture	10 cm

Laser source

A possible LASER source for HELENA is currently being developed at Faculdade de Ciências da Universidade de Lisboa (FCUL).
The laser used as source is a diode pumped, passively Q-switched Yb-Er Microchip Laser that emits a 100 µJ pulse with a full-width half-maximum (FWHM) of 2 ns. A set of laboratory pulsed emission results and an integration photo of the laser source are presented below.



Pulsed Microchip laser preliminary results.



The laser pumping optical system.