THE BEPICOLOMBO LASER ALTIMETER. N. Thomas[1], T. Spohn[2], L.-M. Lara[3], U. Christensen[4], K. Seiferlin[1], H. Michaelis[2], J.-M. Castro[3], R. Kallenbach[4], T. Bandy[1], T. Beck[1], L. Gambicorti[1], U. Geissbühler[1], K. Ghose[1], J. Gouman[1], A. Peteut[1], D. Piazza[1], A. Servonet[1], T. Behnke[2], W. Bresch[2], H. Hussmann[2], A. Lichopoj[2], K. Lingenauber[2], H.G. Lötzke[2], F. Lüdicke[2], R. Schrödter[2], K. Wickhusen[2], M. Herranz[3], J. Rodrigo[3], H. Perplies[4]
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Introduction: The BepiColombo Laser Altimeter (BELA) is slated to fly on Mercury Planetary Orbiter (MPO) component of ESA's BepiColombo mission to Mercury with a current launch date of June 2016. The instrument is designed to perform topographic measurements and participate in the mission-wide geophysics experiment to study the interior of the planet. The instrument development is close to completion. It contains a series of novel solutions to the requirements arising from the mission and spacecraft design.

BELA is the first European laser altimeter to be built for inter-planetary flight. A key element has been the development of a European high-power (50 mJ) pulsed Nd:YAG laser allowing instrument operation at distances of > 1055 km from the target. The nadir-pointing geometry of Mercury Planetary Orbiter (MPO) necessitated the use of baffles to reject the incoming thermal load (when MPO is over the nightside hemisphere but still illuminated by the Sun). The strict mass constraints combined with the expected large temperature excursions (arising in large part from the eccentricity of Mercury's orbit) drove the selection of a beryllium telescope as receiver. In addition, the competences within the participating countries led to adoption of a digital rangefinder concept. We discuss in a more detail each of these elements below.

System: For financial reasons, it was necessary to divide the BELA instrument into sub-elements which were manufactured and integrated in different countries. The transmitter section of the instrument was manufactured in Germany under the responsibility of DLR while the receiver was manufactured in Switzerland under the responsibility of the University of Bern. DLR produced the on-board computer and software while UBE integrated the Tx-Rx elements and performed all system level testing.

The instrument performance was driven by the need to observe at least half a hemisphere of Mercury during each 2.3 h, 400 km x 1500 km orbit of the MPO. The thermal environment demanded a series of hard decisions at instrument level. In particular, the required telescope aperture – laser pulse energy product (a figure of merit for laser altimeter performance) was constrained by the need to maintain a small aperture for the telescope as this aperture produces a significant heat leak into the interior of the spacecraft. Approximately, 300 W enters the telescope (worst case for a 20 cm diameter telescope) with the instrument being required to reject >90% of this heat back to space.

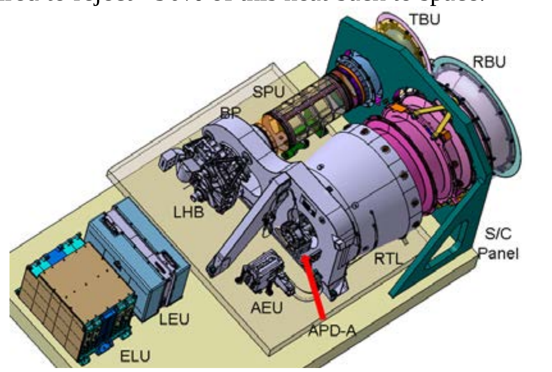

Figure 1 CAD/CAM of BELA. A common baseplate (BP) supports the laser head box (LHB), the receiver telescope (RTL) and the Rx focal plane (APD-A). [A transfer optic which sits within the BP is not seen here] The LHB optics are protected by a sleave (SPU) and a baffle unit (TBU). The RTL is protected from sunlight by the RBU. The two elements are driven by a common electronics unit (ELU) which also drives a laser electronics unit (LEU) which containing capacitor banks. The ELU contains a power converter module developed in Spain.

The system mass and power requirements were 12.0 kg (14.2 kg achieved) and 49 W (39 W achieved).

At instrument level, these issues were addressed by using a common baseplate for the Rx and Tx with the Rx being pre-mounted on the baseplate (i.e. having the baseplate as part of the Rx) and then mounting the laser head using 3 isostatic mounts (Figure 1). A sophisticated alignment procedure [1] with a novel pentaprism group was then used to bring the laser into alignment with the receiver. Both Rx and Tx apertures are protected by lightweight reflective baffles (RBU, TBU).

Components of note:

Laser. The laser is a fully redundant 1064 nm Nd:YAG with 5 ns pulse duration and a nominal 50 mJ pulse energy. A beam expander collimates the beam to a 60 µrad width. The system can operate at up to 10 Hz, consumes 20 W and weighs < 5 kg (including MLI, cabling, beam expander, and drive electronics) [2,3].

Baffles. The RBU follows a Stavroudis concept [4,5]. It is an aluminium structure combining ellipsoidal and hyperbolic surface machined with 4 nm roughness. The internal diameter is 204 mm and an extremely thin wall thickness has been achieved to minimize mass. Although the TBU is smaller, it must also hold a thermal filter to prevent the beam expander focussing reflected light from Mercury on to the laser. A narrow band filter transmits the laser wavelength but rejects light outside a band around this wavelength.

Figure 2 The laser head box (LHB) of the transmitter section of BELA (from [3]).

Telescope. The receiver telescope is two-mirror on-axis design with a 20 cm primary. The telescope is an all-beryllium design and only about 600 g. The primary mirror is just 2 mm thick. The telescope surfaces have been produced using diamond-turning of a deposited copper layer (250 micron thick) followed by gold coating. The aperture at the vertex of the primary mirror is close to the focus of the telescope and supports the instrument straylight rejection concept.

Figure 3 The receiver baffle unit undergoing vibration test at the University of Bern. The baffle is mounted to an aluminium support which simulates the spacraft interface.

Rangefinder Module. Unlike previous planetary laser altimeters, the rangefinding of BELA is performed using a digital approach where the signal is digitized and the return pulse detected using software in an FPGA. The resolution is limited by the digitization frequency and the bandwidth but tests indicate that in optimum conditions, accuracies of the order of 20 cm over the (typically) 500 km range can be achieved. The rangefinder can also detect fairly low return pulse energies. Testing also indicates that a return pulse containing just 6 photons can be detected.

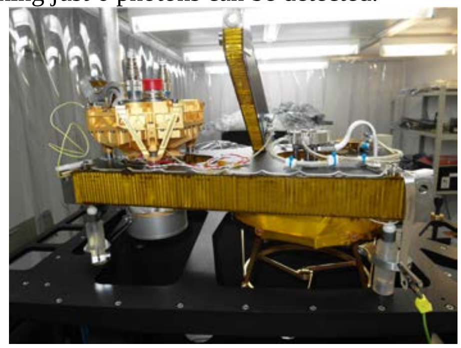

Figure 4 The integrated BELA FM.

Conclusion: The flight model of the BELA instrument system has just been integrated at the time of writing (August 2014). The system contains a number of novel technologies which have required significant development. On the basis of this work, new solutions for specific space-related issues are now available. At least two new industrial companies have been initiated on the basis of this program and several others have been able to optimize and improve their manufacturing capabilities by their participation. ESA now has access to a European source for this type of instrument for future missions.

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