Development of LIDAR for deep space mission HAYABUSA

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ABSTRACT

LIDAR (LIght Detection And Ranging) is an important navigation sensor for the asteroid probe "HAYABUSA" to measure distance with an asteroid. Since it is carried in a planetary exploration spacecraft, the weight of LIDAR is very lightweight at 3.6kg. Furthermore, in order to realize landing missions, range finding ranges are 50km - 50m.

The composition and basic performance of LIDAR are explained and this paper also reports the ranging data at the time of landing to asteroid ITOKAWA of the autumn of 2005.

INTRODUCTION

In recent years, many planetary exploration missions have been carried out in the word. As typical planetary exploration missions, HAYABUSA of the world's first Japan which succeeded in landing to an asteroid, NEAR of the U.S. which performed many asteroid flyby observations, the comet exploration program ROSETTA of ESA, and U.S. Mars exploration programs, etc. are raised.

HAYABUSA launched in May, 2003 is an engineering test satellite aiming at establishment of planetary exploration technology, such as an autonomous cruise by an electric propulsion organization and optical apparatus, landing, a sampling, and sample retuning. HAYABUSA succeeded in landing to asteroid ITOKAWA in November, 2005. LIDAR has an important role as the science observation device like the presumption of the mass of the asteroid and the presumption of shape and the surface reflectivity distribution of the asteroid, etc.[1] The photograph LIDAR is shown in Fig.1

APPROACH AND LANDING SEQUENCE

The explorer approaches an asteroid by Range & Range Rate (R&RR) method with earth stations, and then catches the asteroid by ONC (optical navigation camera) .

In distance of 50km or less, the orbit of the asteroid is determined from the ranging data with LIDAR and R&RR from ground stations.

In the position (Home position) which is the several km distance which the influence of the gravity of an asteroid can be negligible, global mapping with LIDAR using rotation of the asteroid. And candidates of landing points are determined and landing plan are formed. After departure from Home position, HAYABUSA descents to 100m altitude by LIDAR and ONC, and release a Target Marker above a sampling point. In 100m or less, it lands with the automatic navigation using Target Marker the laser altimeter (LRF) for short distances. [2]

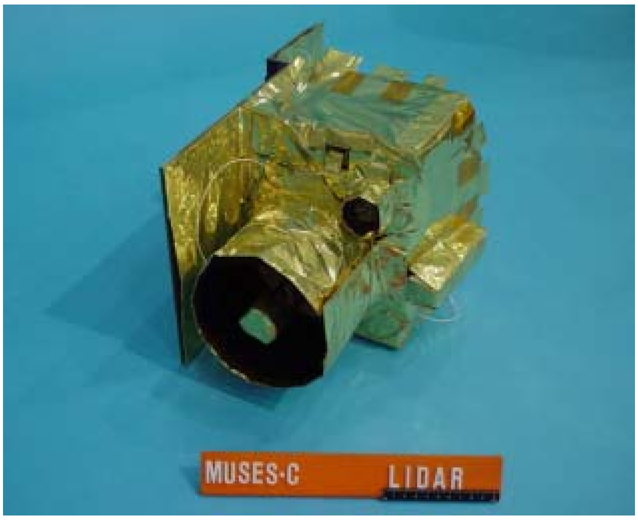

Fig.1 HAYABUSA LIDAR

LIDAR SYTEM

LIDAR is an altimeter which measures distance by carrying out laser pulse shot towards the asteroid, and measuring the both-way time of a light pulse. LIDAR consists of a transmitting laser part, a receiving telescope, a pulse detector circuit, and a control circuit. Specifications and functions are shown in Table 1.

The range of LIDAR is as wide as 50m - 50km, and the ranging accuracy is 1m in the short distance side. It operates synchronizing with 1pps signal from the attitude control system (AOCS). Both a transmitting laser shot rate and the data rate are 1Hz.

We did the weight saving thoroughly by using magnesium for many portions, such as laser part bases including a case cover. As a result, we were

Table 1 Specification of LIDAR

Item	Specification
Range Accuracy Repetition Rate TX Trigger	50m～50km ±1m(@50m)、±10m(@50km) 1pps External
Wave Length Pulse Power Pulse Width TX Beam Width RX Beam Width TX-RX Angle RX Optics	1064 nm 10 mJ 14 nsec φ0.5 mrad (1/e^2) φ1 mrad 0 mrad Casegren, φ126 mm、SiC
Reflection Index	0.05～0.2 (Lambert Plane)
Weight	3.56kg (Include DC/DC, Thermal Insulator and Radiator,)
Power	17.0W(+LD Heater max5W)
Size	240mm×228mm×250mm Radiator: 240mm×300mm

able to make whole LIDAR weight that include DC/DC converter and heat fin (900g) very light with 3.6kg.

Since the laser part is sensitive to thermal condition, 20-60 degrees C and a temperature of operation are as severe as 10-40 degrees C, and preservation temperature is restricted.

The Q switch Nd:YAG laser (wavelength of 1.064 micrometers) of LD (Laser Diode) excitation are used as transmitting laser. The pulse width, pulse energy, beam diameter and beam divergence are 14ns, 10mJ, 3mm and 1.7mrad, respectively. The YAG rod has doped Cr+ for improvement of radiation tolerance other than Nd. In order to extend the tolerance level of an alignment error, the prism is used for the laser resonator instead of the mirror. By adopting a prism, error tolerance level has increased about 10 times comparing with a mirror.

The receiving telescope is a Casegren type telescope and a diameter and a field of view are 126mm and 1mrad, respectively. SiC (Silicon carbite) is used for the material of the Casegren telescope. We considered aluminum, beryllium, SiC, and glass as a material of a receiving optical system. Since the thermal condition of the landing phase is greatly different from the cruising phase, we adopted SiC that has good thermal feature. When the roughness of the main reflector surface was measured by the laser interference system, it was 0.18micromp-v. The optical sensor which detects a reflective pulse is Si-APD (Avalanche Photo Diode).

ON ORBIT RANGING

In July, 2004 about one year after a HAYABUSA launch, the power supply of LIDAR was turned on for checking the laser transmission. As a result, we found that the laser oscillation was fine and the pulse detection system was also fine.

September 10, 2005 one more year after, HAYABUSA arrived to Asteroid ITOKAWA and LIDAR found the position of 48.6km from ITOKAWA. The ranging data after discovering ITOKAWA until it arrives at the home position of 2km of distance is shown in Fig.2. HAYABUSA approached ITOKAWA at the rate of about 0.3 m/s, and has reached HP in two days. Two of three sets of Reaction Wheels which HAYABUSA were out of order at the time of ITOKAWA arrival. In Fig.2, it is for this reason that the point of measurement on September 10 is several points. LIDAR operated completely for several months from arrival to landing. At the time of the first landing, HAYABUSA stayed for 30 minutes on the planet surface unexpectedly. However, after first landing, LIDAR was operated without the problem.

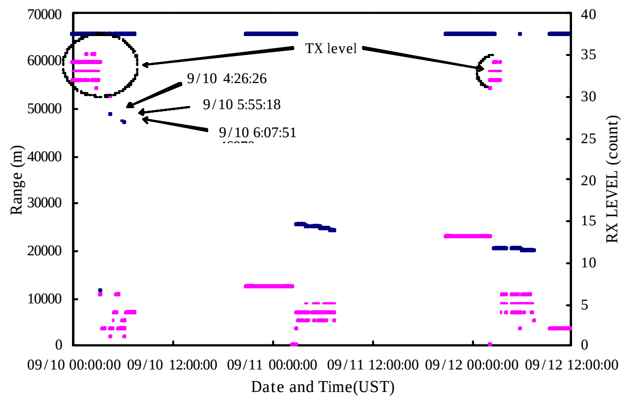

Fig.2 Ranging data at arrival

CONCLUSION

The basic composition and performance of LIDAR for HAYABUSA has been introduced and the ranging results of on orbit is explained. LIDAR achieved the big contribution, in order that HAYABUSA attained world's first asteroid landing. Not only this contribution, but also brought about many scientific knowledge, such as form measurement of ITOKAWA, and gravity model creation.

REFERENCE

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