Circumasteroid dust monitor instrument for future missions. M. Kobayashi[1] (Kobayashi.masanori@perc.it-chiba.ac.jp), H. Senshu [1], K. Wada[1], N. Namiki[1], N. Hirata[2], and H. Miyamoto[2], [1]PERC/Chitech, [2]Univ. Tokyo.

Introduction: Dust particles may exist on the surfaces of or around asteroids. Their existence would reflect the evolution of the surface environment of an asteroid, which is important when interpreting terrestrial observations of asteroids. However, the role of dust particles on small bodies are not critically studied due to limited chances of observations.

The NEAR-Shoemaker spacecraft reveals that the surface of Eros hold enormous amount of dust particles, which appear to fill a crater to form smooth dust ponds [1]. On the other hands, the high resolution images of Itokawa obtained by Hayabusa spacecraft indicate that dust particles are deficient on the surface of the asteroid. However, interestingly, the returned samples of Hayabusa are generally dust particles [2], which raise the question if dust particles actually exist around the asteroid as a cloud, but are optically not detectable because the cloud is extremely thin. If this is the case, small asteroids may typically hold numerous numbers of dust particles as results of evolutional histories of asteroids. However, even so, no terrestrial observations can critically determine the existence of dust due to the above reason.

We are, therefore, planning a direct observation of circumasteroid dust with using the Dust Monitor (DM) instrument, which may be useful even for a flyby mission to an asteroid. In Japan, Hayabusa-2 mission, a successor of Hayabusa mission, is planned to be launched in 2014, aiming at a C-type asteroid, 1999JU3. In this study, we discuss the scientific advantage and the feasibility of the in-situ dust observation using Hayabusa-2 as a model mission.

Observation targets with the dust monitor: Observing the circumasteroid dust with DM has three principal significances. They are explained in detail below.

Levitating dust: Dust levitation phenomena have been observed repeatedly on the Moon [3]. There are some candidate mechanisms to make dust levitate from the surface: impact, seismic shaking, granular flow, photoelectric dust levitation, etc. Among them, photoelectric dust levitation is the most plausible mechanism to make dust levitate periodically on the Moon [4].

Surface of a resistive and airless body is positively charged on the dayside due to photoelectric effect to make an upward electric field. Since a dust grain on the surface is also positively charged, it would levitate from the surface if the electric field became strong enough. This process is called as photoelectric dust levitation and is expected to occur on asteroidal surfaces.

Dust grains up to ~100 μm could levitate and transfer laterally to make smooth deposit at the depressions [5]. Finer grains (< 1 μm) would defeat the gravity, resulting in partial evaporation of asteroids [6]. Such levitating dust grains around asteroids have not been directory observed so far. We are planning to observe them with DM and obtain their size- and velocity-distributions, which are required to reveal the surface evolution of asteroids.

Impact ejecta: An active impact experiment on the asteroid 1999JU3 is proposed in Hayabusa-2 mission (An impactor of 2 kg will be hit on 1999JU3 at 2 km/s). Detecting ejecta grains from such an impact experiment with DM is challenging but will give us meaningful information on the surface and the interior of asteroids.

Recording the position and the time when ejecta grains are detected with DM, we reconstruct the trajectories of the grains and obtain their ejection speed and angle. In particular, the ejection angle is informative since the ejection angle reflects the porosity around the impact site: The ejection angle tends to become high for fluffy target [7]. In addition, the trajectory reconstruction enables us to determine the speed of the ejecta at the moment of detection. Assuming that DM detects the momentum of colliding grains, the grain mass (or size) turns out with the colliding speed determined. We checked the possibility of ejecta detection with DM in the impact experiment of Hayabusa-2 mission as a test case. The preliminary results indicated that the amount of ejecta is enough to detect with DM. We will obtain key information about the porosity and the size-distribution of surface regolith of asteroids from detecting impact ejecta with DM.

Avoidance of debris collision: Hayabusa-2 mission plans to conduct an active impact experiment as described above. It is difficult to precisely predict the size and the ejection velocity of the ejecta. Hence, high risk “debris” as large as one can critically affect the spacecraft still can drift around the asteroid when the spacecraft is approaching the asteroid after the impact. Monitoring dust will be able to reduce such a risk.

Observation methods: When the spacecraft accompanies closely with the asteroid, the relative velocity and the number density of the circumference dust are extremely small. In addition, the speed of the majority of dust ejected at the impact experiment may be slow. For dust observation under such the environment, we propose two methods, direct method and indirect method.

(1)Direct method. The low speed (< 1m/s) dust grains are not able to produce ionized plasma for detection of impact ionization as used for hypervelocity dust. There are still detection methods for such low speed grains, for example, utilization of momentum transfer and electrostatic induction [8]. SESAME-DIM of Rosetta/Philae uses a momentum sensor of piezoelectric PZT for detection media and the target velocity range is 0.025 – 0.25 m/s [9]. The benefit of this type of detector is its mechanical simplicity, compactness, and light weight, e.g. about 500 g for the detector system unit of MDM to be onboard BepiColombo having 64 cm^2 of detection area [10], whose picture is shown in Figure 1.

Time-of-flight (TOF) sensor utilizes electrostatic induction while a charged particle passes through an electrode. LDM for the Selene-2 mission is designed to use two electrodes to detect the TOF signals electrically induced by the incident charged dust particle [11]. A schematic drawing is shown in Figure 2. The grain size can be inferred from the charge signal assuming the charge state of the incident particle is proportion to the size.

(2)Indirect method. The technique of the aerosol measurement by LIDAR (LIght Detection And Ranging) can be applied for the measurement of the drifted dust grains around asteroids (Figure 3). LIDAR must be equipped for ranging between the spacecraft and asteroids for its landing. The light-receiving system may be optimized for the scatted light from dust grains. The distribution of dust grains in depth can be derived from time-of-flight between the timings of the pulsed laser irradiation and the scattered-light receiving.

Summary: As described above, the asteroidal exploration needs dust monitoring device onboard. After the successful asteroidal mission Hayabusa, successive asteroidal missions are planned and studies. Dust monitors for circumasteroid dust should be seriously considered to be onboard upcoming asteroidal missions.

References: [1] Robinson, M. S. et al. Nature **413**, 396, 2001. [2] Yano, H. et al. Abst. of 37th LPSC #1596, 2006. [3] Gold, T. in “Photon and Particles Interactions with Surface in Space” (Ed. Grard, R. J. L.) 1973. [4] Wipple, E. C., Rep. Prog. Phys. **44**, 1197, 1981. [5] Colwell, J. E. et al. Icarus **175**, 159, 2005. [6] Lee, P. Icarus **124**, 181, 1996. [7] Schultz, P. H. et al. Space Science Reviews **117**, 207, 2005. [8] Auer S. in “Interplanetary Dust” (Eds. E. Grün et al.) 2001. [9] Seidensticker, K. J. et al. Space Science Reviews **128**, 301, 2007. [10] Nogami, K. et al. Planetary and Space Science **58**, 108, 2010. [11] Kobayashi, M. et al. Earth, Plants and Space, 2011, in press.

Figure 1. Engineering model of sensor unit and flight model electronics unit of Bepicolombo MDM (Mercury Dust Monitor).

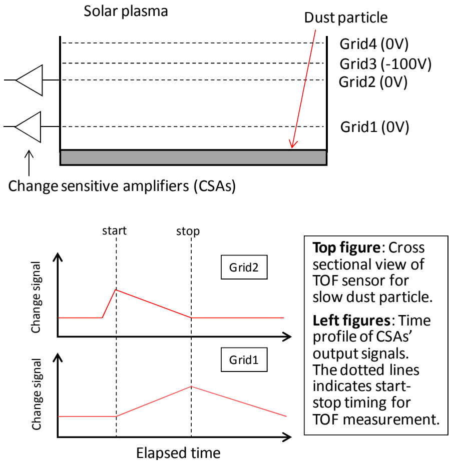

Figure 2. Cross-sectional drawing and signal time profile of a time-of-flight sensor.

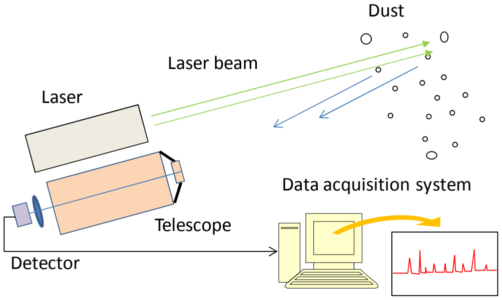

Figure 3. Measurement principle of LIDAR. LIDAR consists of the light-transmitting system, the light-receiving system and the data acquisition