FREQUENCY ANALYSIS OF DUST SIGNAL FROM PIEZOELECTRIC PZT SENSOR. M. Kobayashi[1], T. Miyachi[1], M. Hattori[2], O. Okudaira[3], M. Fujii[4], N. Okada[5], and Ralf Srama[6], [1]Chiba Institute of Technology (2-17-1, Tsudanuma, Narashino, Chiba, Japan 275-0016; kobayashi.masanori@.it-chiba.ac.jp), [2]Tokyo Institute of Technology (Tokyo, Japan 152-8550), [3]JAXA (Tsukuba, Japan), [4]FAM science Co. Ltd. (Tsukubamirai, Japan 300-2435), [5]Honda Electronics Co. Ltd. (Toyohashi, Aichi, Japan, 441-3193), [6]University of Stuttgart (Stuttgart, Germany).

Introduction: Cosmic dust (mass of 10^{-18} to 10^{-6}g) is a basic component of the space and has been observed by space-borne missions since the 1960's, the number of observed dust particles. Most cosmic dust consists of interplanetary dusts and interstellar dust.

Dust-particle detector made of piezoelectric PZT sensor has been developed. Piezoelectric PZT sensor has an advantage of compact size, no high-voltage bias necessity, availability in high temperature (up to 150 ^{o}C), long-time sustainability and radiation hardness. The piezoelectric PZT sensor has been employed in Mercury Dust Monitor [1]. In a laboratory experiment, an output signal when a dust particle collides with the sensor is recorded by an oscilloscope in wave form. Previously, the signal wave form had been analyzed by measuring its amplitude that is proportional to the momentum transfer during the dust impact. "Measuring amplitude of the signal waveform" has ambiguities. For more objective way to measure the signal wave form, Hattori et al. [2] adopted a way to measure component at a resonance frequency of the sensor's thickness in a Fast Fourier Transfer (FFT) spectrum of the signal wave form.

Piezoelectric PZT sensor is an acoustic detector and very sensitive to mechanical vibration and an amplifier for PZT sensor has extremely high gain, therefore can easily detect noise as a false signal; small vibration duet to heat strain on ambient structure of the spacecraft, photoelectron due to solar UV irradiation to the sensor, solar wind plasma and energetic particle radiation on the sensor and/or its front-end electronics, and so on. The false signal can be visually identified by experience. Signal identification should be objective and systematic for onboard signal processing in space-borne instruments.

In this study, we studied an objective method to analyze dust signal waveform for true/false identification when piezoelectric PZT is used as a dust-particle detector.

Experimental Method: We had a dust particle acceleration on a PZT sensor as dust detector using Van de Graaf accelerator in Max Plank Institute for Nuclear physics in Heidelberg, Germany. The sensor has a size of 40 mm × 40 mm and a thickness of 2 mm. Iron dust particles ranging 1 pg to 100 pg were accelerated with 1.8 MV up to a speed raging from 1 km/s to 8 km/s. As experimental configuration, the PZT sensor was set at the end of accelerator beam port and a copper caliber which has the interior diameter of 18 mm and has the length of 41 mm was set in front of the sensor. The center of the sensor, the central axis of the caliber and the accelerator's beam port axis align in a straight line. Accelerated dust particles go through the inside of the caliber and collide with the sensor. Dust particles are irradiated to only 18-mm-diameter part in the center of sensor. When a dust particle collides with the sensor, the mechanical impact induces stress waves in the sensor and they are converted to charge signal by piezoelectricity. The signal from the PZT sensor is read out in waveform by a charge amplifier.

Charge signal induced on the caliber by a dust particle's charge is read out by a charge amplifier

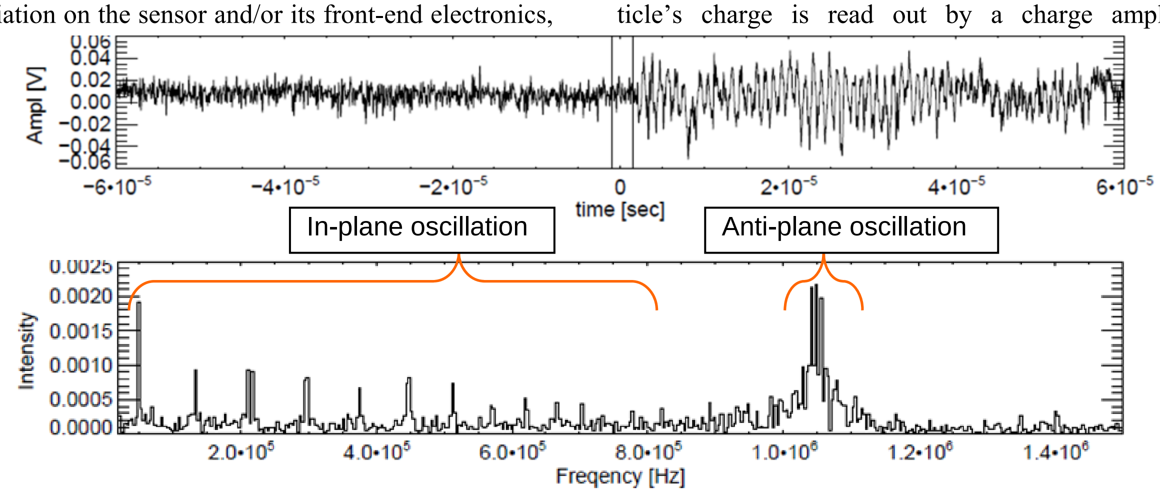

Fig.1 Signal waveform of dust impact on PZT sensor. Right vertical line shows impact timing. (top)
Fig.2 FFT spectrum transferred from signal waveform in Fig.1. (bottom)

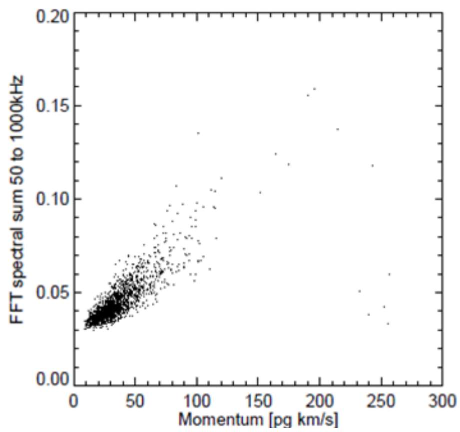

Fig.3 In-plane components.

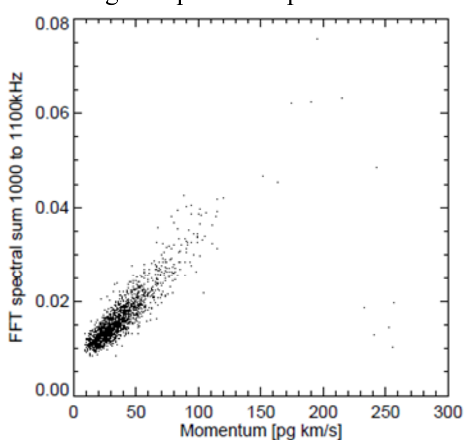

Fig.4 Anti-plane components.

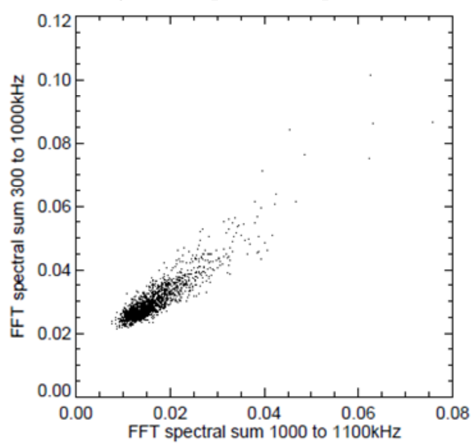

Fig.5 Relation btw in- & anti-plane compo-

connected to the caliber. The amplitude and the time width of the caliber signal during the dust particle pass are used to derive the speed and the charge of the dust particle. The caliber signal was also used as trigger for data acquisition. For data acquisition, we used a digital oscilloscope of LeCroy Wave Pro 7000.

Data Analysis and discussion: Out of 2000 events stored, 102 events have irregular shapes in waveform probably due to the incident dust particles contact on the inside of the caliber. The remnant events, 1898 events, were analyzed. In Fig.1, an example of the signal waveform from the PZT sensor is shown.

For individual events, a 300-μs part from the impact timing of the waveforms were converted to frequency spectra by FFT. Frequency resolution is 2.5 kHz. In Fig.2, an example of FFT spectrum transferred from the signal in Fig. 1 is shown. There is a strong peak around 1.0 - 1.1 MHz, while below 1MHz, small but clear peaks were found in the spectra, which were not seen in previous studies. Those peaks in the spectra correspond to frequency characteristics of PZT impedance. The 1 MHz peak corresponds to a fundamental resonance frequency of oscillation in thickness direction while 50 kHz corresponds to a fundamental resonance frequency of oscillation in in-plane direction and also its high harmonic frequencies are observed (Fig.2).

For in-plane oscillation component, intensities over 50 kHz through 1000 kHz are summed up and the sum has a correlation with the momentum transfer (Fig.3). The intensity of the 1 MHz peak of FFT spectrum has a strong correlation with the momentum transfer from the incident dust particle (Fig.4). Those results show that in-plane and anti-plane oscillation components have correlation with the momentum transfer independently. The impact energy from dust particle collision can be divided into the in-plane and anti-plane components.

Fig. 5 shows a relation between intensities of in-plane (300 - 1000 kHz) and anti-plane (1000 - 1100 kHz) oscillation components and it has a strong correlation. In this study, we used only “true” event that is not noise but real dust-impact-induced signal. When a impact applies on the detection plane, the energy can distribute into in-plane and anti-plane directions at a certain rate. As mentioned above, false signals can be detected in space operation and those events may have different rate from one of true events.

Concluding Remarks: We found some experimental results:

- In-plane oscillation components are contained in impact signal readout from PZT sensor.
- The in-plane components have a correlation with the moment transfer.
- The ratio between in-plane and anti-plane oscillation components has a certain value for true event.

From those results, we assume to be able to identify true event from false event by testing the shape of frequency spectrum of the signal waveform.

References: [1] Nogami et al. (2010) *PSS*, 108-115 [2] Hattori et al. (2012) *Jpn. J. Appl. Phys.* 51 (2012) 098004.