

Polarization Analysis of Microwave Generated by Hypervelocity Impacts on Metal Targets

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1. Introduction

Space debris are moving at the velocity of 7-8 km/s in low Earth orbit. and may collide with artificial satellites or spacecrafts at an average relative velocity of 10 km/s or more depending on the trajectory inclination angle. Even tiny space debris can cause a significant damage. The structural damages caused by the collision, i.e. hypervelocity impact, generate craters on the surface of artificial satellite and space aircrafts and secondary debris. The electrical effects are the emissions of radio frequency (RF) signals, impact plasma, and light and the variation in electrical potential of an impacted target.

A fragment of the projectile and target materials is evaporated and ionized [1]. A plasma cloud that consists of an ionized gas of projectile or target material and electrons is generated instantaneously after the impact. RF emission associated with hypervelocity impacts was firstly confirmed by Bianchi et al. [2]. They observed that electromagnetic oscillation in low frequency and RF emissions originated from the impact-induced plasma when aluminum projectiles with the mass of approximately 1 g were collided with hard leucitite rock at approximately 10 km/s. Electromagnetic oscillation in low frequency was observed. RF emissions from hypervelocity impacts originate from the impact-induced plasma. Maki et.al observed

microwave emission from impacts of projectiles accelerated at the velocity of 2 to 6.7 km/s by using a rail gun [3]. Aluminum, alumina ceramic, red brick, and polyurethane rubber were used as targets. They suggested that the microwave emits when discharge occurs between microcracks. We conducted hypervelocity impact experiments using a two-stage light gas gun in the ISAS / JAXA and observed the polarizations of 5.8 GHz-microwave generated by hypervelocity impacts on metal targets.

2. Methods

Figure 1 shows an experimental setup. The experimental system consists of an accelerator, an acrylic vacuum chamber, and a measurement system. A two-stage light gas gun was used as the accelerator. A target was fixed in the chamber. A projectile of nylon sphere with a diameter of 7 mm was accelerated at the velocity of approximately 7 km/s and passed through a launch tube and then collided with the target in the chamber. The air in the chamber was evacuated to several pascals. Aluminum, copper, and stainless blocks were used as targets. Microwaves were measured by using two antennas and receivers. The horizontal and the vertical polarized microstrip antennas with the frequency band of 5.8 GHz were used. The antennas were located at the angle of 30 degrees from the direction of the projectile outside the chamber.

Figure 2 shows the schematic diagram of the receiver. The received signal was amplified by a low noise amplifier and then converted to lower frequency signals by using a mixer. The converted signal was recorded by using a digital storage oscilloscope. The light was observed by using a high-speed video camera and a photodetector. The high-speed video camera with a frame ratio of $2 \mu\text{s}$ was used for monitoring a spread of luminous cloud. The photodetector was used for measuring the intensity.

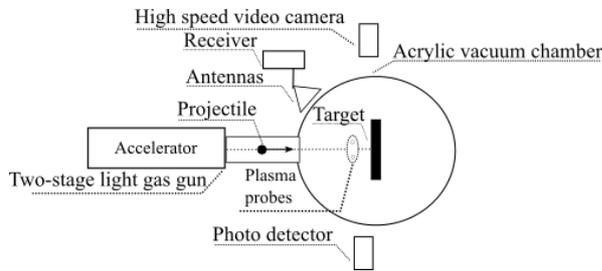


Fig. 1. The experimental setup.

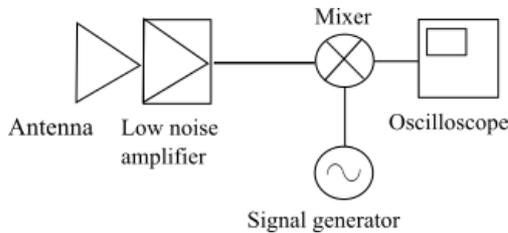


Fig. 2. The schematic diagram of the receiver.

3. Results & Discussion

When the nylon projectile was collided with the aluminum target, the intensity of light emission was observed by using the photodetector as shown in Fig. 3. The rise time of the waveform was defined as impact time. The images taken by the high-speed video camera are shown in Fig. 4. We can see propagations of luminous cloud from the aluminum target. The light propagates in the direction along the surface on the impacted target after the impact.

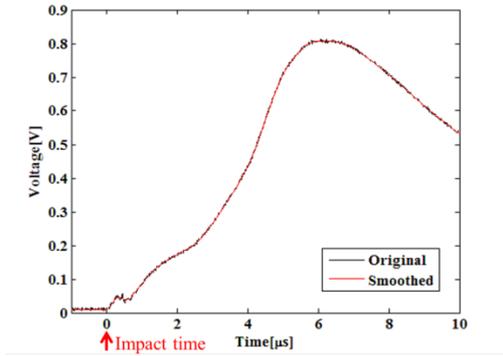


Fig. 3. The waveform of light emission observed by using the photodetector.

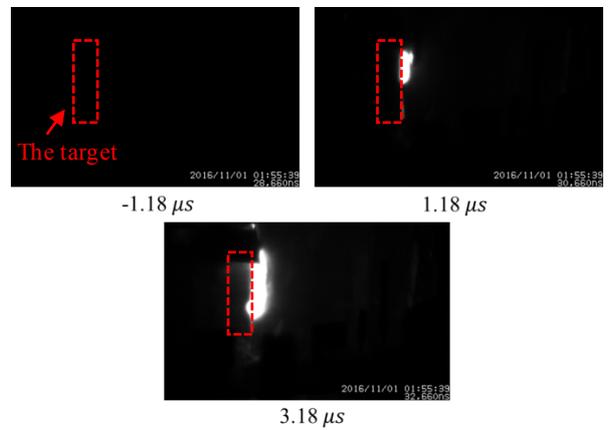
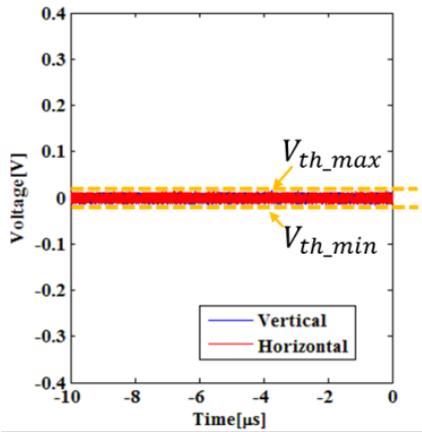


Fig. 4. Propagations of luminous cloud from the aluminum target.

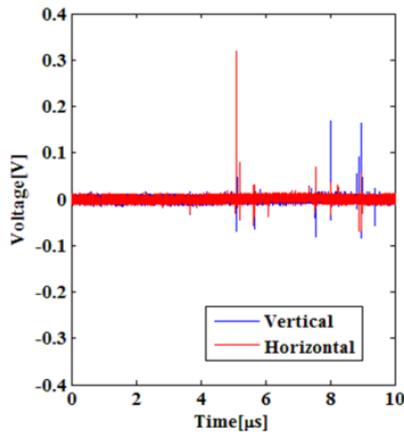
Microwaves were received by using the antennas and the receivers. Figure 5 shows the waveforms of background noise and the microwaves when the nylon projectile was collided with the aluminum, copper, and stainless targets. In the waveform of the background noise, the maximum voltage as V_{th_max} , and the minimum voltage as V_{th_min} are defined. The sharp pulse waves were received intermittently in all cases. It is shown that the first pulses in the case of aluminum, copper, and stainless targets were received at $3.680 \mu\text{s}$, $1.706 \mu\text{s}$, and $3.656 \mu\text{s}$ after the impact respectively.

Figure 6 shows the vertical and horizontal waveforms of the first pulse waves after removing

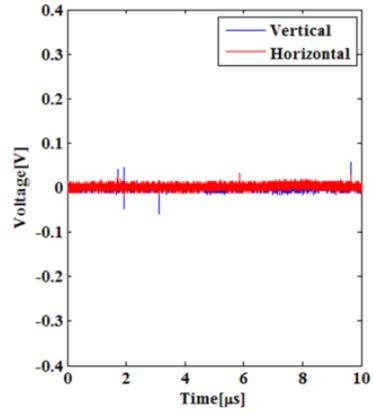
background noise based on the voltages of V_{th_max} and V_{th_min} . In the aluminum target, the peak voltages and shapes of vertical and horizontal waveforms are almost the same. In the copper target, the period of horizontal waveform is longer than that of vertical waveform. In the stainless target, the peak voltage of the vertical waveform is larger than that of the horizontal waveform.



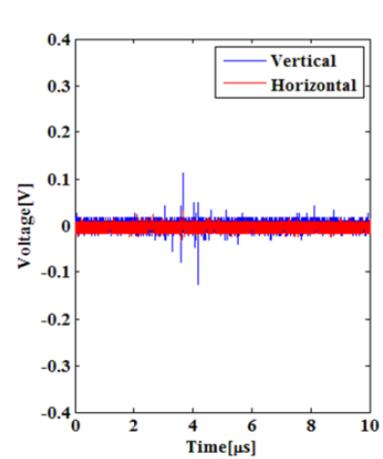
(a) Background noise



(b) Aluminum target

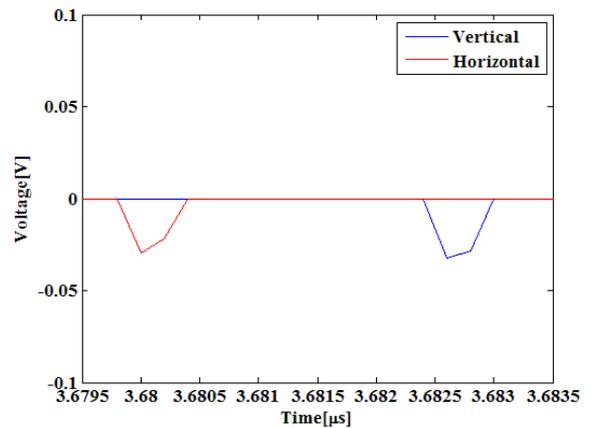


(c) Copper target

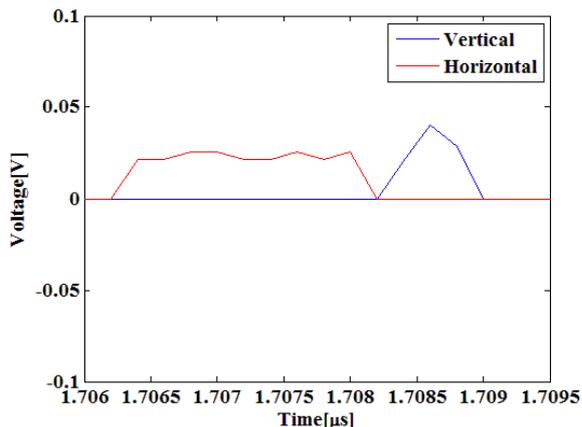


(d) Stainless target

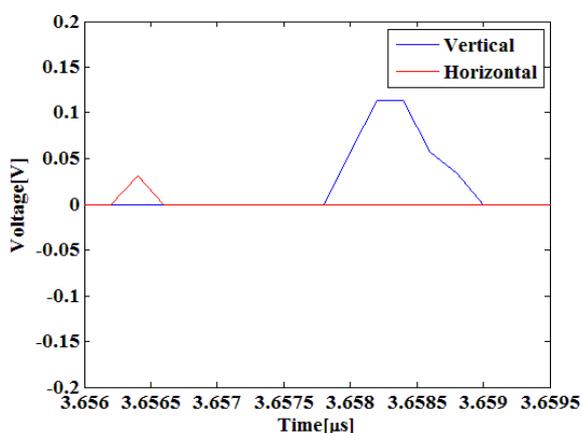
Fig.5. Waveforms of the background noise and the microwaves from the aluminum, copper, and stainless targets.



(a) Aluminum target



(b) Copper target



(c) Stainless target

Fig.6. Vertical and horizontal waveforms of the first pulses waves after removing the background noise.

4. Conclusion

Hypervelocity impact experiments using the two-stage light gas gun were conducted. Aluminum, copper, and stainless boards were used as the targets and a nylon sphere was used as the projectile.

The intermittent sharp pulses were observed by using vertical and horizontal polarized microstrip antennas with the frequency of 5.8 GHz. The peak voltages and the shapes of vertical and horizontal waveforms depended on the target materials.

Acknowledgments

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References

- [1] J. F. Friichtenicht, and J.C. Slattery, “Ionization Associated with Hypervelocity Impact,” NASA-TN-D-2091, 1963.
- [2] R. Bianchi, F. Capaccioni, P. Cerroni, M. Coradini, E. Flamini, P. Hurren, G. Martelli, and P.N. Smith, “Radiofrequency emissions observed during macroscopic hypervelocity impact experiments,” *Nature*, Vol. 308, pp. 830-832, 1984.
- [3] K. Maki, T. Takano, A. Fujiwara, and A. Yamori, “Radio-wave emission due to hypervelocity impacts in relation to optical observation and projectile speed,” *Advanced in Space Research*, Vol. 34, Issue 5, pp. 1085-1089, 2004.