Investigations of hypervelocity impact flashes using commercially available recording equipment (final year undergraduate project)

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Introduction

Hypervelocity impacts occur when the speed of impact exceeds the speed of the compression waves in both the target and in the projectile. Because the energy of the impact is delivered faster than it can be dissipate, the impact causes extreme transient densities and temperatures at the impact site [1]. This can cause vapourisation of the impactor and the target material involved, and such impacts produce luminous phenomena. Measuring light flashes in hypervelocity impacts have been investigated previously; for example Eichhorn in 1975 observed impact flashes using iron projectiles on gold and tungsten targets [2]. However, there is a renewed interest in the subject. At the European Planetary Science Congress in 2012, various observational programs of the Lunar surface detecting impact flashes have been introduced [3, 4] It is hoped that the results from this project can be used as a starting point for anyone who is interested in setting up a own monitoring program as well as a source for calibration data for national space agencies like NASA, ESA or JAXA etc.

Project

This projects aims are to measure the colour temperature of the impact flash in order to infer the speed of impact, and to measure the impact flash intensity in order to calculate the impactor size. To achieve these aims, two newly procured digital single-lens reflex (DSLR) cameras (a Nikon D3200 and Nikon 1 V1) will be characterised. The pixel colour response will be measured by photographing a calibrated spectrum, the pixel intensity response will be shown by plotting the recorded intensities versus attenuation with neutral density filters. The pixels' relative sensitivity will be measured by photographing a test screen of equal brightness and finally the cameras' infrared sensitivity will be tested by comparing the dark, IR portion to the visible portion of the calibrated spectrum.

Figure 1: Equipment used for data recording. (left) Nikon D3200 (24.2 million pixels) with HD video recording at 50 fps, (centre) Nikon 1 V1 (10.1 million pixels) with slow- motion movie recording at 1200 fps and (right) Red Tide USB650 Spectrometer by OceanOptics.

Camera calibration: Photographing a calibrated spectrum turned out to be more difficult than anticipated. Several setups were tried and did not work. These included several spectroscopes from the teaching laboratory, as well as some low cost spectroscopes. However, a new setup is currently being tested, and is working, comprising a light box with a rheostat for adjusting the light intensity, a measurement grid, an overhead projector and a 600 lines/mm grating on loan from the teaching laboratory. This idea was originally published by Dr. Philip M. Sadler in the article "Projecting Spectra for Classroom Investigations," *The Physics Teacher*, 29(7), 1991, pp. 423-427, [5].

Figure 2: Some low-cost spectroscopes which were tested and did not work, as well as an early attempt to photograph a spectrum of a Cadmium emission lamp.

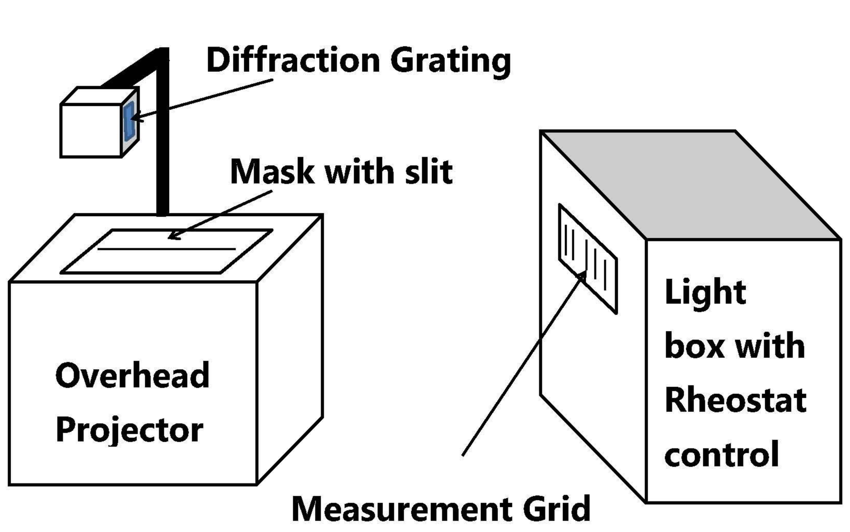

Figure 3: Modified experimental setup after Dr. Philip M Sadler for photographing spectral lines.

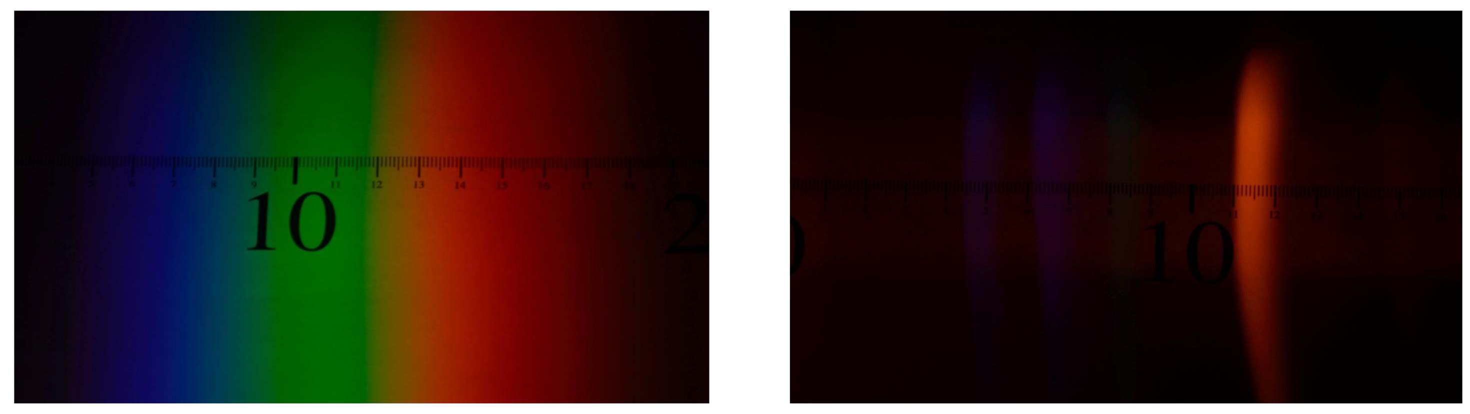

Figure 4: Continuous spectrum and Helium emission lamp spectrum recorded with the above setup.

Hypervelocity impact flash recordings: An observational program of hypervelocity impacts was run for collecting data. These impacts varied in speed and target/impactor compositions. The preferred material combinations of impactor and target was chosen to be basalt on basalt or iron-nickel analogue on basalt. This programme is running well and, to date well over 20 target impacts have been successfully recorded. Most of these shots were done in conjunction with students Mr. Ricky Hibbert and Miss Kathryn Styles (see other posters) and their respective projects, and therefore a mix of target/impactor composition were used, and a database of spectra and flashes is being built. Three basalt on basalt impacts were completed and previous imaging was helpful in determining optimal exposures times and improved the overall quality of the extracted images. However, the video footage remains slightly over exposed. Introducing the new camera Nikon 1 V1 to the project was a boost to the quality of recordings, since this camera is able to record video with 1200 fps maximum, but has not proven very fruitful to date. So far only one recording was managed with questionable outcome and more work needs to be done to determine the optimum exposure time and aperture settings.

Figure 5: Extracted images from video footage: **Left:** 1 mm diameter stainless steel projectile impacting sandstone at 5.16 kms^{-1} (shot ID G051012#3). **Right:** Solid sabot projectile impacting Aluminium plates at 5.38 kms^{-1} (shot ID G141212#2).

Spectral recordings: Additional use of the third porthole of the impact chamber allowed the setup of both cameras for the same shot, while using the spectroscope on loan from the teaching laboratory. 10 spectra have been successfully recorded so far. The Red Tide USB650 spectroscope has a wavelength range from 350 nm to 1000 nm and utilises a detector with 650 pixels. Most of the spectral recordings show a blackbody like curve with spikes at around 400, 480, 520, 580 and 750 nm. To interpret these results, the Atomic Spectra Database of the National Institute of Standards and Technology is used. To improve the quality of the spectra and the range of spectral recordings a new setup is planned. To allow any other radiation to be recorded the spectroscope needs to be updated and new porthole window needs to be installed according to the wavelength range required.

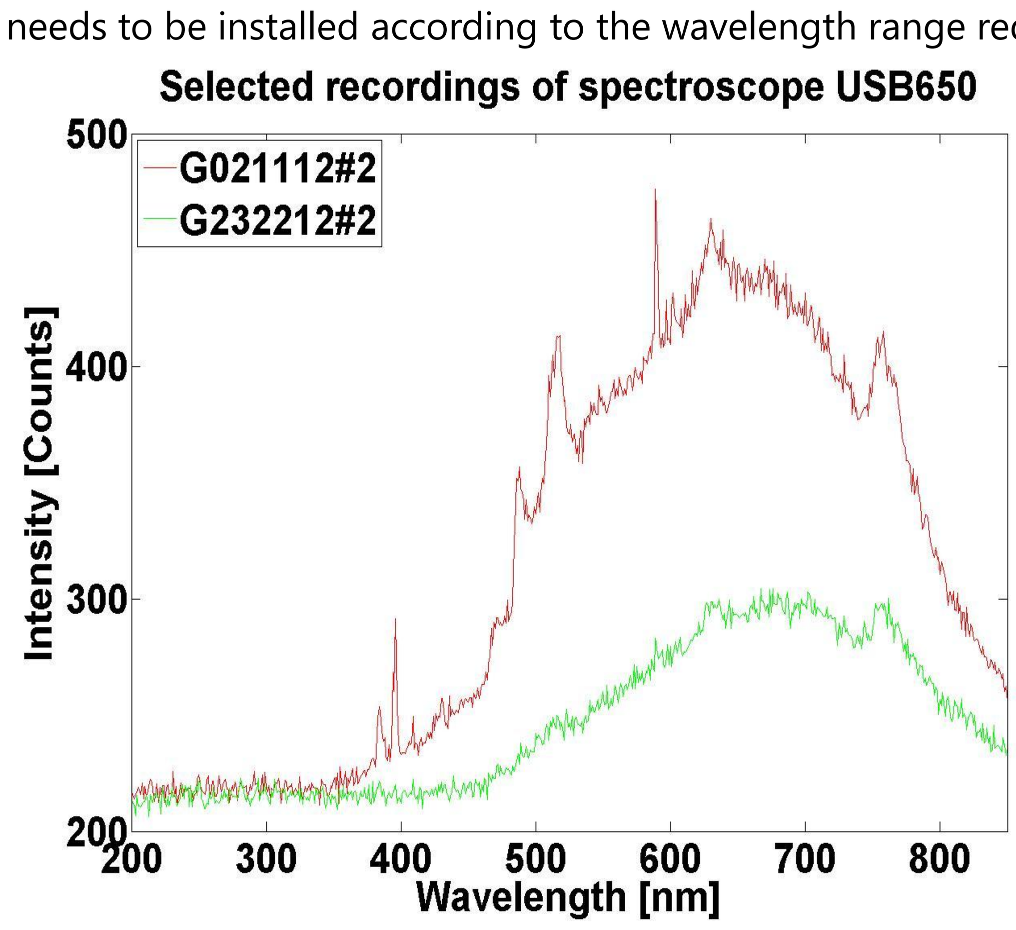

Figure 6: Impact flash spectra recorded with the Red Tide USB650 spectrometer.

(Red) **Shot ID G021112#2:** Solid nylon projectile impacting Aluminium plates at 6.32 km s^{-1}.

(green) **Shot ID G231112#2:** Solid nylon projectile impacting Aluminium plates at 6.65 km s^{-1}.

References

[1] Burchell et al. (1999), *Measurement Science and Technology*, 10 (1), 41 - 50. **[2]** Eichhorn (1975), Measurements of the light flash produced by high velocity particle impact. *Planetary and Space Science*; 23: 1519 - 1525; **[3]** Madiedo et al. (2012). *EPSC Abstracts*, 7, EPSC2012-59**.** **[4]** Margonis et al. (2012), *EPSC Abstracts*, 7, EPSC2012-562**.** **[5]** "Shedding a New Light on the Universe". Goddard Space Flight Centre. Available from http://heasarc.nasa.gov/docs/xte/learning_center/universe/prism.html (accessed Jan 31st, 2013).