2.2.8

Impact light flash studies: Temperature, Ejecta, Vaporization

G. Eichhorn

Max-Planck-Institut für Kernphysik, Heidelberg/F.R.G.

Abstract

Impact experiments have been performed with the 2 MV dust accelerator; the dependence of the maximum light flash energy and intensity on the projectile mass and velocity has been determined experimentally. The temperature of the radiating gas and plasma was estimated to be in the range from 2500K to 5000K, depending on the impact velocity. The distribution of the maximum ejecta speed as well as the normalized distribution of ejected mass have been determined as a function of the ejection angle. A rough estimate of the degree of vaporization of the displaced mass was obtained.

In this paper we discuss measurements we have performed on the light flash produced during impacts of very high velocity projectiles. We also discuss information we have obtained in these experiments such as the temperature of the luminous material, distribution of secondary particles and the degree of vaporization of the displaced material. The measurements were performed with an electrostatic dust accelerator (particle masses between 10^{-15} g and 10^{-9} g) and a light gas gun (projectile mass 1.5×10^{-2} g).

In agreement with earlier studies (Friichtenicht (1965), Rollins and Jean (1968), and Eichhorn (1975)), the maximum impact flash intensity I and the total energy E were found to depend upon the projectile mass m and velocity v in the form $I = c_1 m^{\alpha 1} v^{ß1}$ and $E = c_2 m^{\alpha 2} v^{ß2}$. The parameters α_1, α_2, $ß_1$, and $ß_2$ were measured for different projectile-target combinations (projectile materials: Fe, Al, C, W, glass; target materials: Au, W, Fe, Rh, Al, glass). α_1 and α_2 were found to be $\alpha_1 = \alpha_2 = 1$ for all projectile-target combinations measured. A comparison of experiments with the light gas gun with those performed with the dust accelerator showed that the light intensity is proportional to the projectile mass over a mass range of ten orders of magnitude.

Values between 3.8 and 4.6 with an average of 4.1 were found for $ß_1$, while $ß_2$ ranges from 3.0 to 3.6 with an average of 3.2. These results yield the functions $I = c_1 mv^{4.1}$ and $E = c_2 mv^{3.2}$.

The absolute light energy of the impact flash was determined by measuring the spectral distribution of the light flash. Fig. 1 shows such a spectral distribution. The light energy measured with calibrated photomultipliers in different spectral ranges defined by interference

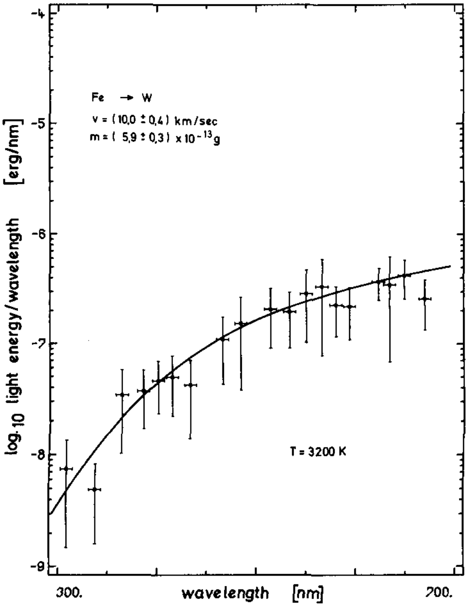

Fig. 1

The spectral distribution of the light flash. The curve is obtained from theoretical calculations on the basis of black body radiation with an initial temperature of the luminous material of 3200K.

filters is plotted there as a function of the wavelength. Integrating this spectral distribution over the wavelength yields the total light energy emitted in the range of the visible spectrum. Depending upon projectile and target material, the light energy varies from 2 x 10^{-6} (for iron impacting gold at 4 km/sec) to 10^{-2} (for carbon impacting gold at 7.5 km/sec) in units of the projectile energy.

Assuming, that the light is black body radiation, we calculate theoretical spectral distributions and fit them to the measured ones by adjusting the initial temperature of the radiating material. The curve in Fig. 1 is such a spectral distribution calculated with an initial temperature of 3200K.

The temperatures that have been estimated in this way for various measured spectral distributions are plotted versus the particle velocity in Fig. 2. The temperature increases with increasing particle velocity. The two curves represent measurements by Friichtenicht (1965) and serve as a comparison of the estimated temperatures at two different wavelengths of light.

In experiments with iron particles and a gold target, secondary particles with velocities greater than 1 km/sec were detected from the light they produce when they impact the entrance windows of the photomultiplier. Their velocity is calculated from data on the time between the primary and the secondary impacts and their locations. Fig. 3 shows the velocity of the fastest ejecta in different angular intervals plotted versus the ejection angle with respect to the target surface. At angles smaller than 20° the ejecta have velocities of up to 30 km/sec at an impact velocity of about 5 km/sec. The dashed curve represents measurements with high speed framing cameras of

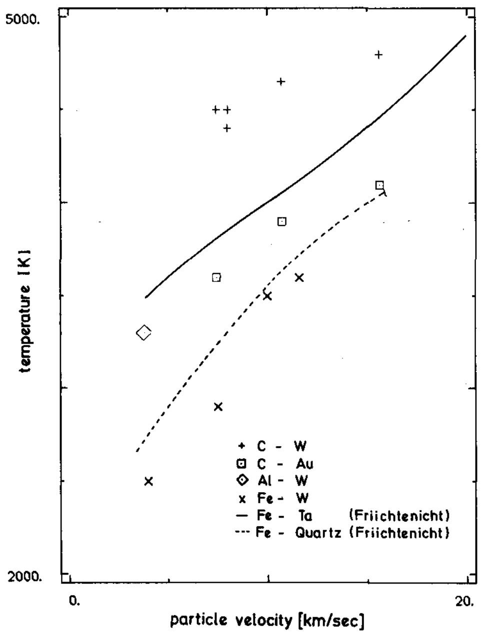

Fig. 2

The initial temperature of the luminous material estimated from the measured spectral distribution as a function of the impact velocity. The curves represent measurements by Friichtenicht (1965).

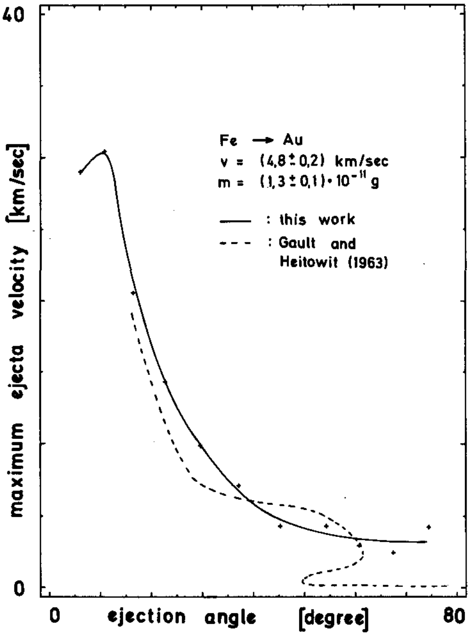

Fig. 3

The maximum ejecta velocity as a function of the ejection angle. The dashed curve represents measurements of Gault and Heitowit (1963) for iron impacting basalt.

Gault and Heitowit (1963) for iron impacting basalt. The light intensity produced by these ejecta is a measure of the mass ejected into a specific angular interval. This mass distribution is shown in Fig. 4. About 90 % of the ejecta are seen to be ejected at angles between 50° and 70°. The fastest secondary particles are ejected at angles below 20° and comprise only about 0.01 % of the total ejected mass.

Since the light emission is due to radiating gas and plasma (Jean and Rollins (1970)), information about the luminous gas can be gained by varying the pressure in the target chamber. The light intensity as a function of the pressure is shown in Fig. 5. Between 10^{-6} torr and 10^{-3} torr, the light intensity does not depend on the pressure. Increasing the pressure further, the light intensity also increases and reaches a maximum at about 0.1 torr. This increase is caused by collision of the vaporized material with the restgas. The number of atoms in the vapour can be calculated from the thermal energy of the

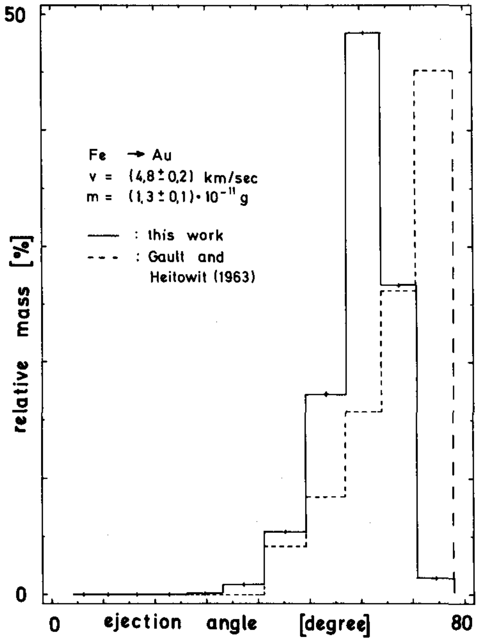

Fig. 4
The relative mass distribution of the ejecta.

gas when converted into light energy, and combined with the above estimated temperatures. Assuming, that all of the thermal energy is converted into light, 0.4 % and 1.6 % of the displaced mass are vaporized at impact velocities of 5 km/sec and 7.4 km/sec respectively. Since nothing is known about the degree of energy conversion, these values are to be considered as lower limit estimates.

Further experiments are expected to provide more informations about the partition of energy during the impact process.

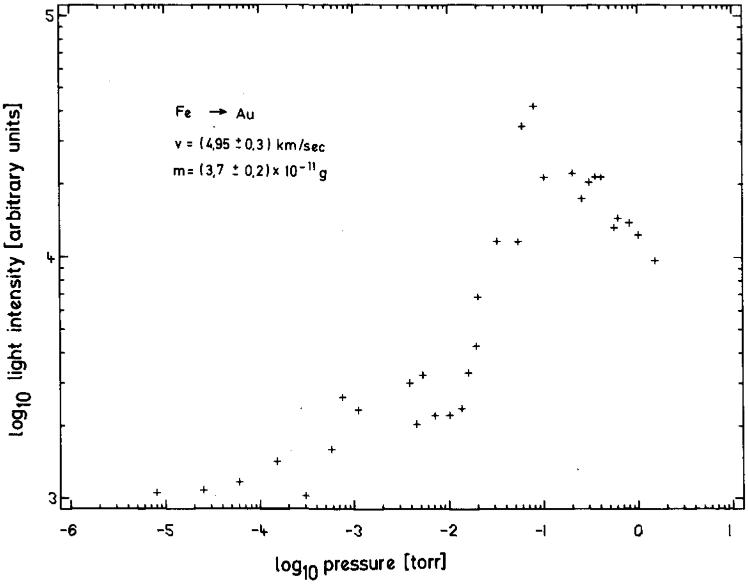

Fig. 5: The light flash intensity as a function of pressure in the target chamber.

References

Eichhorn, G. (1975), "Measurements of the Light Flash Produced by High Velocity Particle Impact", accepted for publication in Planet. Space Sci.

Friichtenicht, J.F. (1965), "Investigation of High-Speed Impact Phenomena", NASA Contr. No. NA Sw-936.

Jean, B., and Rollins, T.L. (1970), "Radiation from Hypervelocity Generated Plasma", AIAA Journal, Vol. 8, No. 10, p. 1742.

Rollins, T.L., and Jean, B. (1968), "Impact Flash for Micrometeoroid Detection", Com. Dev. Report 9899/FR1, NASA Contr. No. NAS 9-6790.