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Investigation of the Reaction Zone of PETN initiated by a Laser Flyer

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Abstract

A laser flyer system has been built to launch aluminium/alumina flyers into small, low density pellets of pentaerythritol tetranitrate (PETN). The beam profile was homogenised by dispersive smoothing through a length of optical fibre and continuously analysed with a range of diagnostics. By varying the thickness and velocity of the flyer, experiments can be performed with a range of input shock magnitudes and durations. Microfabricated sensors to be used in conjunction with this system are under development – these are based on measuring the effect that the electrical conductivity of the reaction zone has on the resistance and capacitance of the sensors' electrodes. Without the electrical noise produced by a conventional bridgewire detonator, laser flyers offer a possible way to probe the electrical properties of the detonation reaction zone. Developing an understanding of the reaction zone will give more clues as to the mechanism behind initiation in different scenarios.

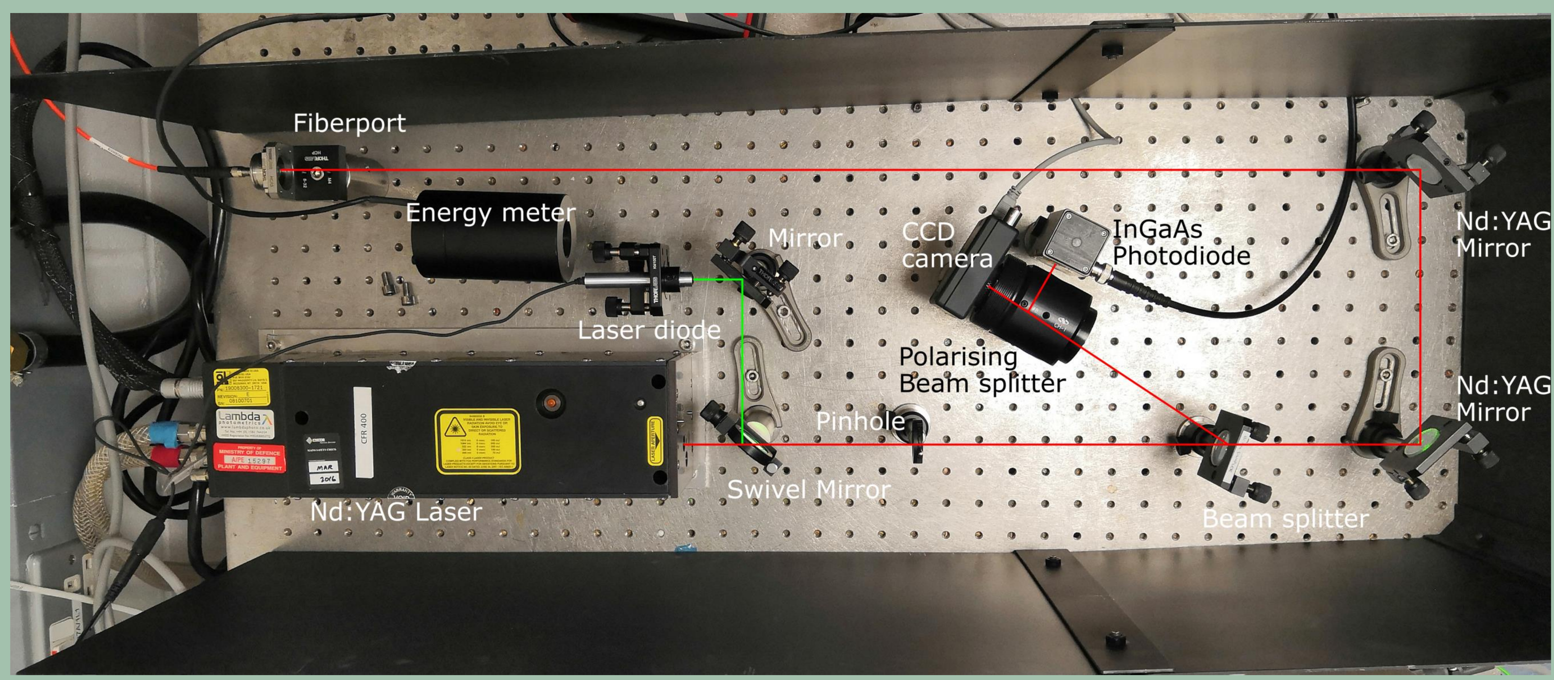

Figure 1. The delivery portion of the laser flyer system. The CCD camera and InGaAs detector allow continuous beam diagnosis in the spatial and temporal dimensions. The moveable energy meter can be used to monitor energy losses along the beam path. A 532nm laser diode is used to aid in alignment

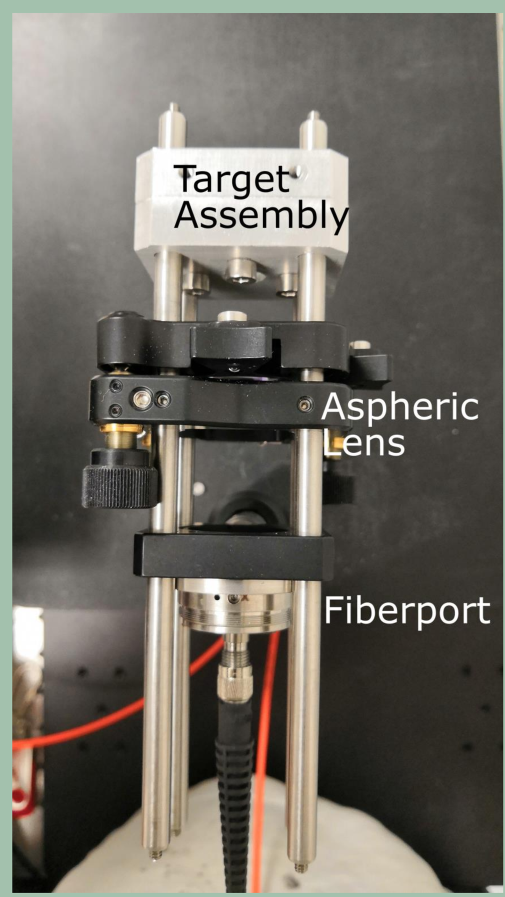

Figure 2. The target portion of the laser flyer system. The flyer substrate and column of explosive are held within the target assembly

LASER FLYER SYSTEM

- Built around a 400mJ Nd:YAG pulsed laser
- Laser pulse delivered to 600μm multimode fibre for smoothing the beam profile
- Flyer formed from foil glued to optical substrate
- Laser focused to spot of around $100\mu m$ diameter with the aspheric lens
- PETN pressed into cylindrical charge to density of $1gcm^{-3}$

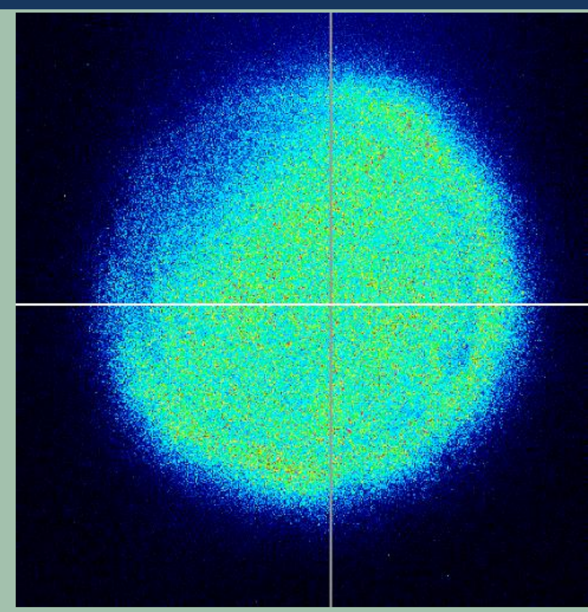

Figure 3. Profile of the Nd:YAG beam taken with a CCD camera. A homogeneous beam is important in this application as hot-spots can lead to premature plasma breakout and flyer disintegration.

RESISTIVE SENSING

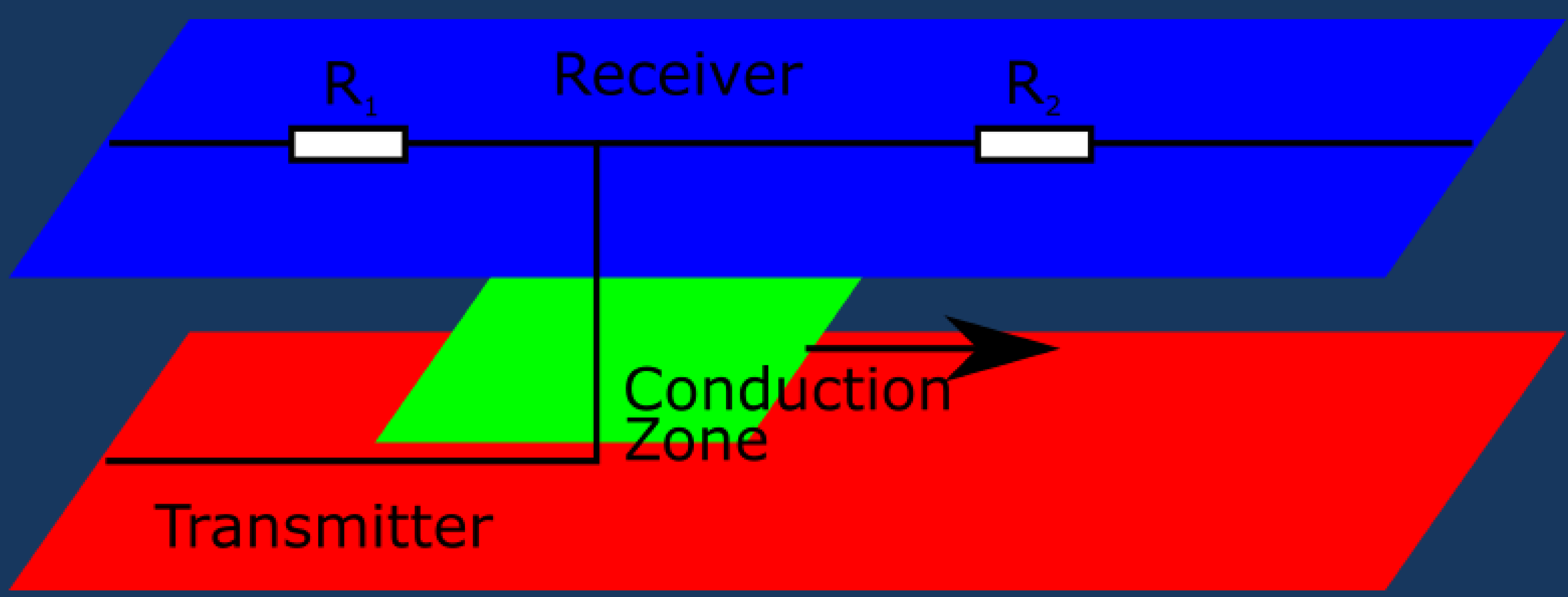

Figure 4. In resistive sensing the conduction zone acts as a potential divider of a receiver electrode. The relative sizes of the resistances behind and ahead of the detonation R_1 and R_2 gives the position of the rear of the conduction zone.

- Electrodes required to be constant width for method to work – else can be calibrated to account for resistivity variation
- A high pulsed voltage (kV) is required to see observable effects
- The voltage can alternatively be applied from ahead of the detonation to find the front of the conduction zone
- More channels gives a better resolution of the radial nature of the detonation but also requires more processing

Figure 5. Inside of a prototype resistive-type sensor cell at a 5x scale. There are eight pairs of electrodes to observe the degree of radial symmetry of the reaction zone. The difficulty in fabrication means different techniques (photolithography, etching) will be required to produce the sensor at smaller scales

CAPACITIVE SENSING

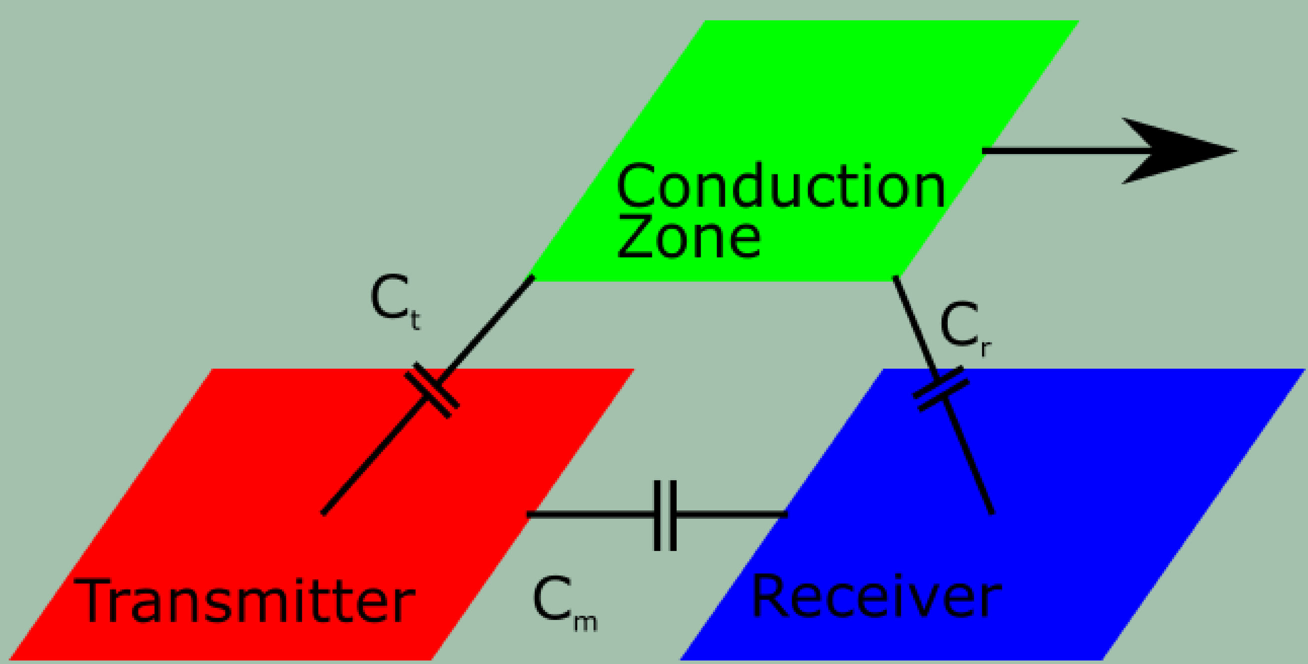

Figure 6. Any two conducting objects have a mutual capacitance between them. In (mutual) capacitive sensing the presence of a conducting zone in proximity to two electrodes alters the mutual capacitance C_m between them. The size of this change depends on the separation between them – therefore it can be used to calculate the position of the conducting zone.

- The charge on either the transmitter or receiver changes by an amount $\Delta Q_{t/r}$ in response to the conducting zone.
- The additional 'parasitic' capacitance between the two electrodes is:

$$C_m = \frac{C_t \Delta Q_r - C_r \Delta Q_t}{C_t V_t - C_r V_r}$$

- The transmitter and receiver electrodes should be different shapes to maximise this effect
- Interdigitating electrodes can improve sensitivity

MEASURING CAPACITANCE

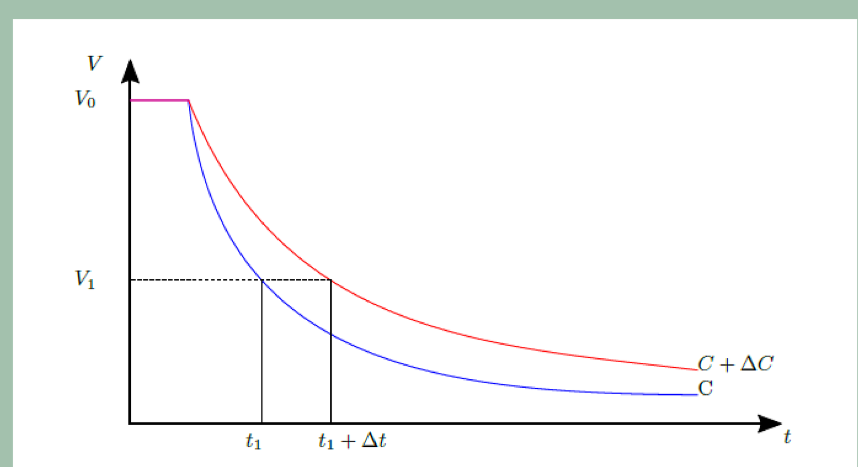

Figure 7. Comparison of two voltage decay curves of RC circuits with different capacitances

- Changes in capacitance can be measured by comparing the time taken for the voltage to decay to a threshold value V_1.
- The difference in times Δt gives the change in time constant RC and hence the change in capacitance
- High processing speed (GHz) is necessary to perform these calculations in the necessary time scale.

CONCLUSIONS

We have constructed a fibre-coupled laser flyer system to perform shock initiation of PETN without electrical noise associated with conventional detonators. Development of reaction zone microsensors is underway, exploiting the small changes in capacitive and resistive properties of surface electrodes that are caused by a conductive reaction zone.

References

Bowden, M., & Drake, R. (**2007**). *The initiation of high surface area Pentaerythritol Tetranitrate using fiber-coupled laser-driven flyer plates.* Paper presented at the Photonic Devices+ Applications.

Ershov, A. P., Satonkina, N. P., & Ivanov, G. M. (**2006**). *Reaction zones and conductive zones in dense explosives.* Paper presented at the Thirteenth International Detonation Symposium.

O Strand, D Goosman, C Martinez, T Whitworth, W Kuhlow, **Review of Scientific Instruments 77**, 083108 (**2006**)

Barrett, G., & Omote, R. (2010). Projected-capacitive touch technology. *Information Display, 26*(3), 16-21.

Tasker, D. G., Lee, R. J., & Gustavson, P. K. (**1993**). *The measurement of electrical conductivity in detonating condensed explosives.*

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