Recent developments from experiments on HMX reactions

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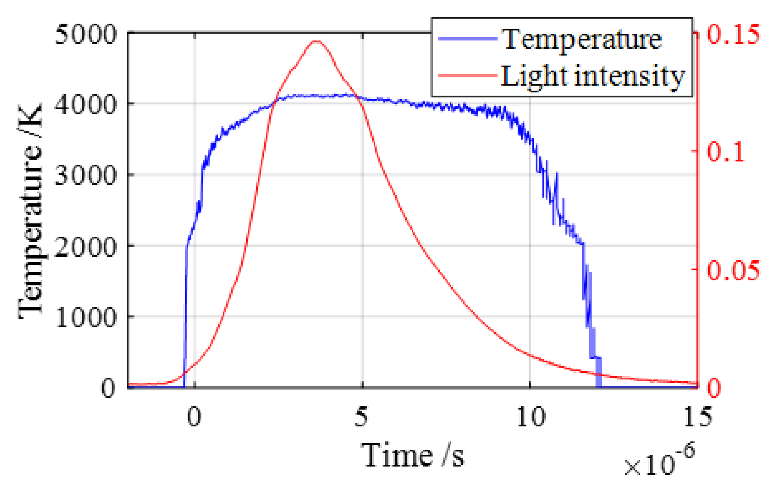
Abstract

Reactions of energetic materials are complex, but need to be well understood in order to safely handle these materials. Our research focuses on the secondary explosive HMX, and many of its reactions, from simple burning, to different types of deflagration, to detonation. Numerous new diagnostic methods were developed in order to investigate the conditions of these reactions, providing data to better understand the underlying science. Additionally, original measurement techniques, such as using optical light for pressure measurements, or a Hopkinson bar for deflagration initiation, provide a new avenue in which such reactions can be investigated in the future.

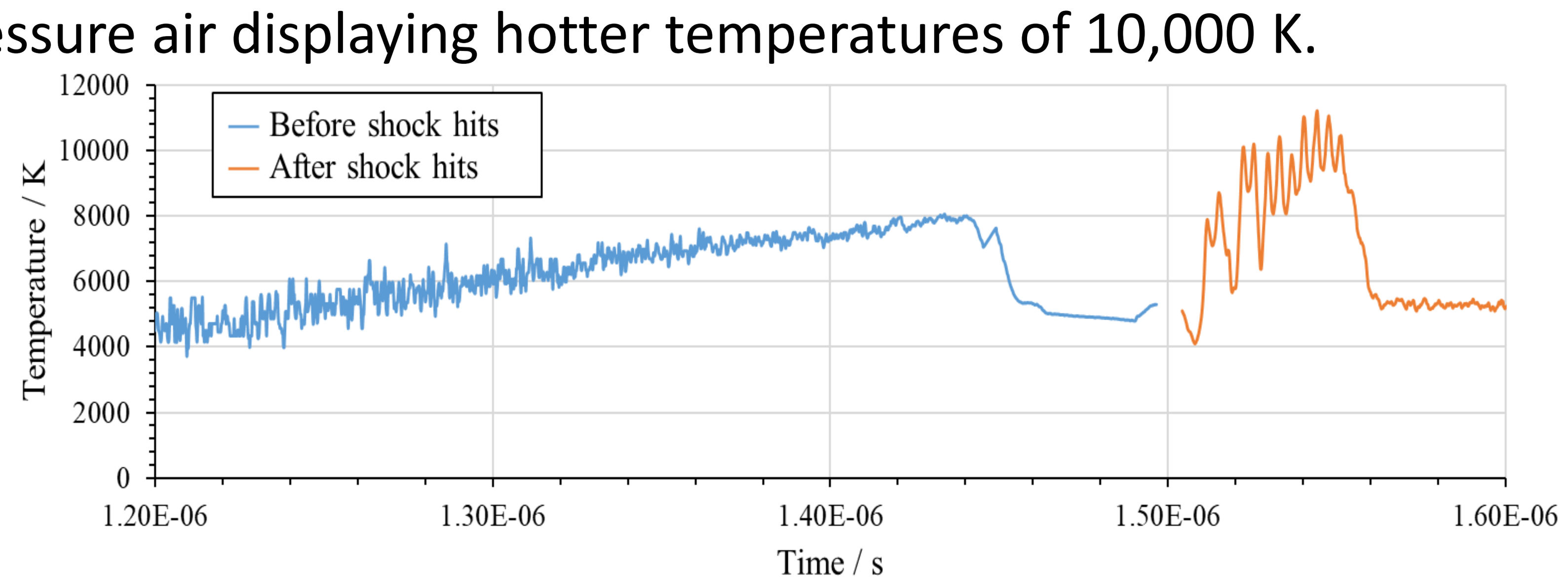
Fast 4-channel pyrometer

A simple diagnostic built to measure the temperature from the light collected by a single fibre optic, with the ability to be able to distinguish between a hotter reaction, and a brighter one.

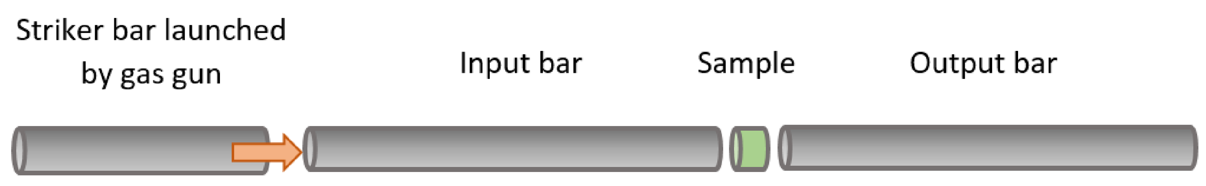


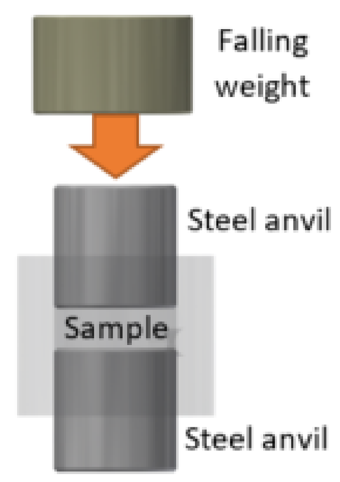
The figure on the left shows the light and temperature from a deflagration reaction. Despite getting brighter, the temperature stays constant at 4000 Kelvin throughout [1].

Below, the fibre optic collected light from the advancing detonation front. The detonation temperature of 8000 K is seen before the shock wave hits the fibre, with the air-shock due to high pressure air displaying hotter temperatures of 10,000 K.



Hopkinson bar initiation



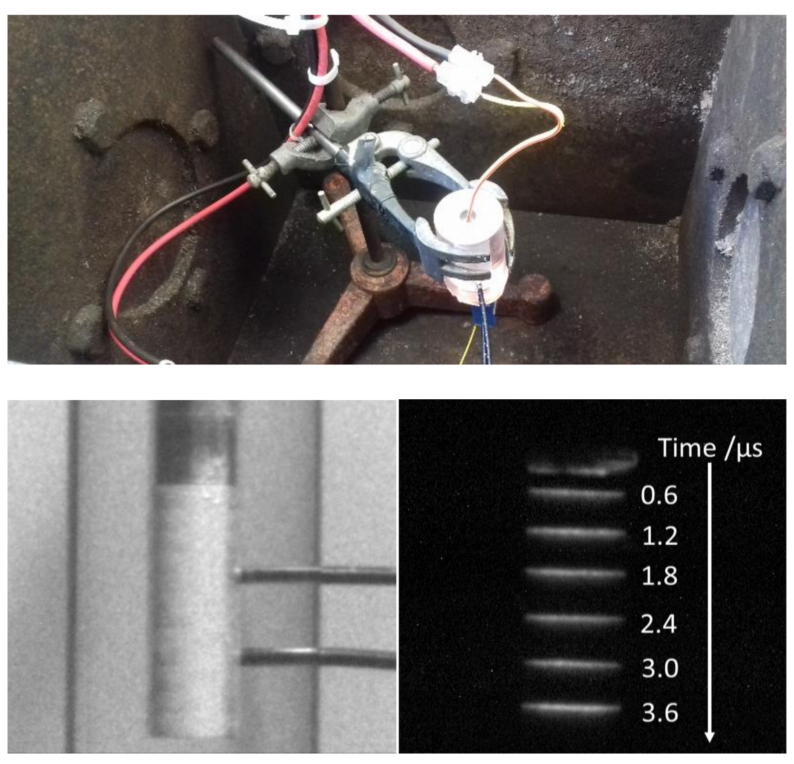


The Split Hopkinson Pressure bar (above) compared to the drop-weight impact test (right) which is a common test of sensitivity, and is a more well-known method of initiation.

Aside from providing a new deflagration initiation method, the Hopkinson bar is significantly less stochastic than the drop-weight, and also was designed for material testing. This makes it a more scientific test than the drop-weight, allowing energy, power-flux and compression of the material to be measured.

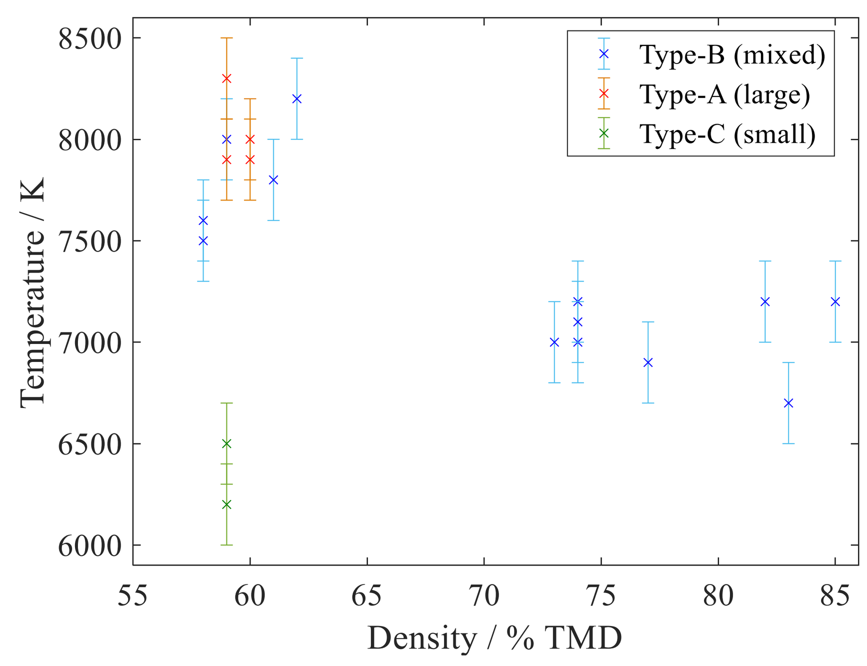
	Drop-weight	Hopkinson bar
Pressure of initiation /MPa	600	1030
Temperature of reaction /K	4000	3000
Rate of closure of anvils/bars /m·s^{-1}	3	50
Can account for all energy in system?	No	Yes

Detonation temperature

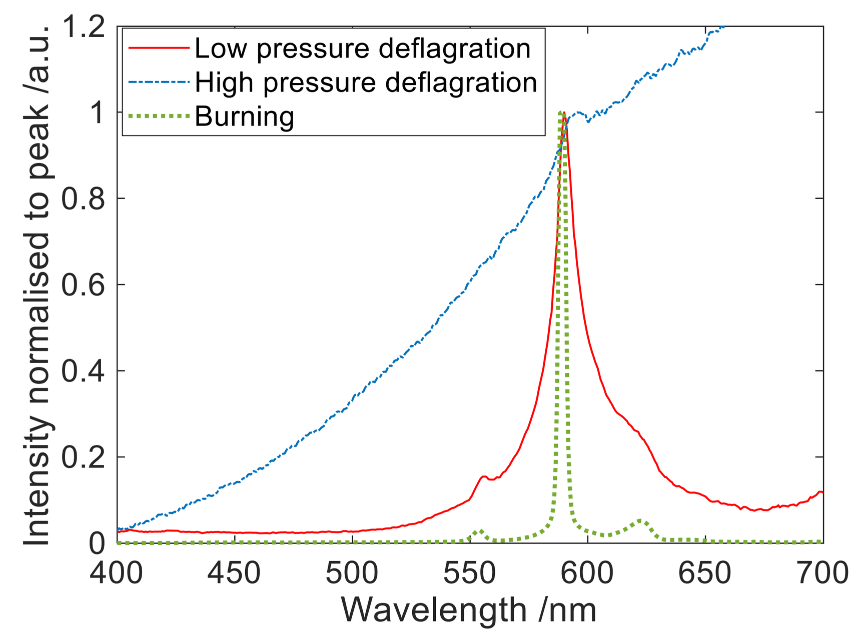


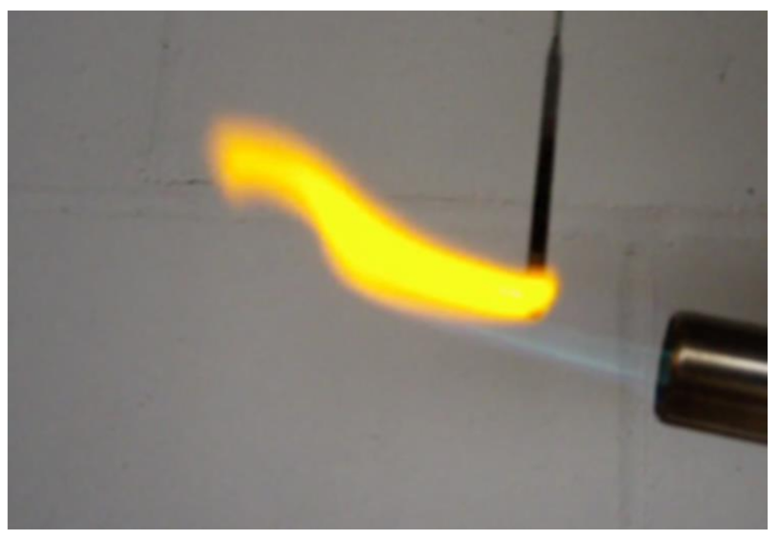
Detonation of HMX was achieved in a column setup, shown on the left. The granular HMX was pressed to a chosen density. The velocity and pressure were measured, as well as the temperature. This allowed the temperature dependence on particle size and density to be measured.

The graph on the right summarises the results. It was found that the temperature was dependent on the size of the voids present. When smaller particles were used, (or the large voids were crushed out by pressing to higher densities), the temperature decreased.



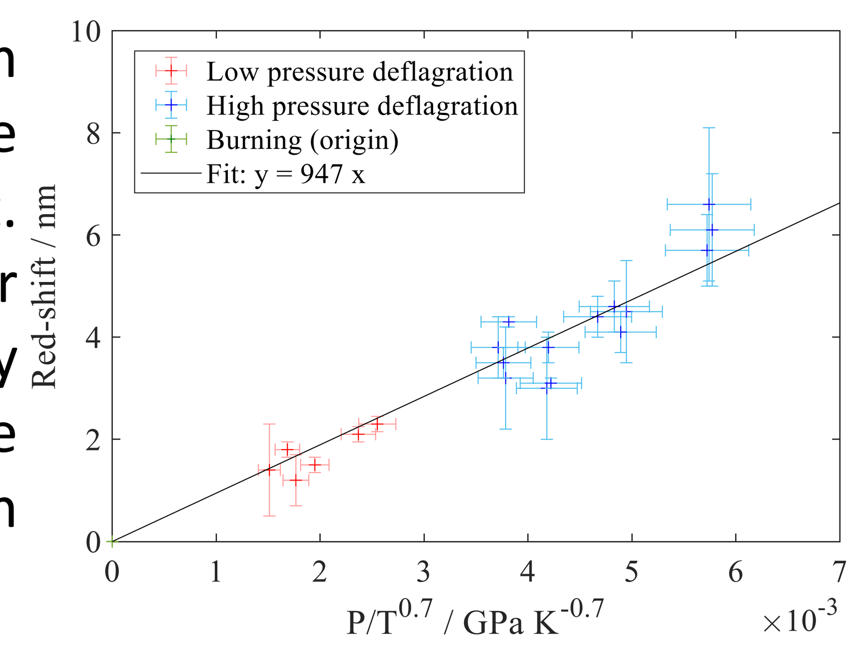
Measuring pressure using light





Light emission from energetic reactions is often dominated by sodium– as seen from the peak at 590 nm in the spectrum on the left. This sodium produces the distinctive yellow-orange observed in normal flames (right).

At higher pressures this sodium shifts more to the red, with the calibration shown on the right. Measuring the shift in colour therefore allows a fast, easy and simple pressure measurement of the reaction (see [2] for more information).



References

[1] O. Morley, D. Braund and D. Williamson. Time resolved pyrometry for deflagration. *NTREM proceedings* (2020).
[2] O. Morley and D. Williamson. Pressure and temperature induced red-shift of the sodium D-line during HMX deflagration. *Commun Chem* **3**, 13 (2020).