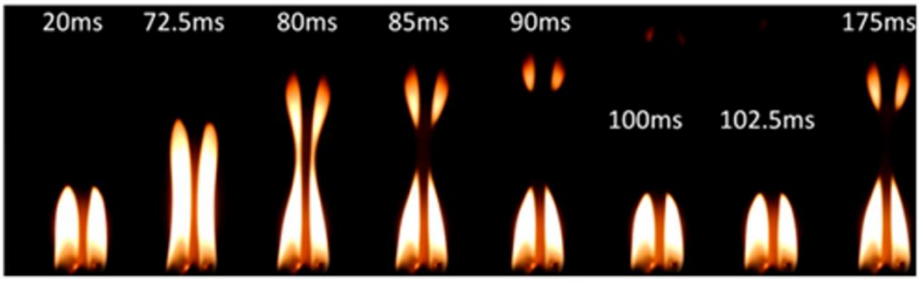
Synchronised flame dynamics

Derek Michael Forrester

Chemical Engineering Department, Loughborough University

For the first time, experimental evidence of the controlled synchronised motion, in phase and anti-phase, of large arrays of diffusive flames has been demonstrated[1]. Arrangements of candle flames, analogous to flames found in wild-fires, couple together through reaction-diffusion processes that lead to chemical oscillations due to periodic changes in the concentration of the reactants. Enhancement, suppression or redirection of a flame or group of flames can be imposed. For example, arranging eighteen oscillatory flames in groups of three around a central flame causes it to spiral in response to the slight out of phase oscillations of the groups. In other cases, lines of oscillator flames pump together or move with one up/one down sequences depending upon proximity and geometrical positioning. In phase motion of the visible luminosity also occurs with extension of the flame before collapse. Rings of flames "bow" and "arch" in phase or out-of-phase. In the situation of one-hundred flames arranged in lattice-like structures, domains of synchronised and incoherent oscillation appear together – chimera states. Thus, novel group effects in flames have been discovered and can be exploited for fire control and the development of novel devices.

(a)



(b)

Synchronised systems. (a) Hundreds of fireflies are able to synchronise their emission of bright light, pulsing on and off together. (b) In a similar fashion, arrays of flames can pulse in synchronisation. Shown above is the simplest case of two synchronised pulsations of candle flames. The candle flames can also exhibit anti-phase motions (e.g. one flame pumping up and one down), cessation of motion (oscillation death), and chaotic phenomena.

1. D. M. Forrester, Arrays of Chemical Oscillators, Scientific Reports, 5, 16994 (2015).