PLAYING WITH FIRE

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OBJECTIVES
Build and test a focused ultrasound array and control algorithm for control of flames.

BACKGROUND
TinyLev, developed by the University of Bristol, is a single axis acoustic levitator and forms a basis for this project. Acoustic waves impact flame formation as shown in experiments such as Ruben’s Tube.

APPLICATIONS FOR FLAME CONTROL
Precise experimentation - Precision heating of specific regions of sample. Increased thermodynamic efficiency - Enable the development of more precise, more efficient thermodynamic machines. Visual effects - Manipulate flames to create stunning visual displays.

ALGORITHMS
Simulation software was produced using MATLAB; takes any transducer specification and generates the pressure field mapping, in any plane specified, and force graphs (horizontal and vertical), along any axis specified. The simulations were used to test the above array geometry design proposals and to analyse experimental results.

Optimisation algorithm took the desired antinode placement location, and optimised the transducer phases and voltages. Gradient ascent with a cost function that balanced the peak antinode pressure as well as the difference between all the antinode pressures was used.

REFERENCES

EXPERIMENTATION

METHOD 1 - ANTINODE PLACEMENT
Antinodes produce large, rapid pressure variation that is hypothesised to either ‘blow’ the flame away, or to increase the gas flow causing a ‘fanning’ effect - increase the flame intensity at these points. These effects were used to attempt to shape the flame.

After experimentation, it was found that large, inconsistent temperature differences vary the speed of sound inside the flame, causing dispersion that breaks down the pressure field, so complex shapes can not be formed.

METHOD 2 - COLLECTIVE PUSHING
A more direct approach; simultaneously activate all transducers opposite the desired flame direction, creating a ‘pushing’ effect that dynamically controls the flame.

CONCLUSION
Temperature differences in the flame cause too much dispersion to allow complex flame shapes, but using the ‘pushing’ method, the flame position in the xy plane of the control volume can be entirely controlled.

ACHIEVEMENTS: An array and control system, capable of controlling a flame to some extent was created, along with a simulation algorithm. Experiments were completed to determine the extent of control.

LIMITATIONS: Flame behaviour in a pressure field was not known before the array design process meaning that the array designed didn’t focus on the most critical features. Further developments could better utilise the ‘push’ method and produce a more effective outcome.