Conceptual Design of a Small-scale Travelling-Wave Thermoacoustic Stirling Cryocooler

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Thermoacoustic machines have received increased interest since the initial investigation into 'thermoacoustic oscillations' by Sondhauss in 1850, due to their diminished environmental impact, and high reliability resulting from the omission of moving parts. These machines rely on the Stirling cycle which the gas performs by the propagation of acoustic waves through a differentially heated regenerator, and the direction of this propagation determines whether the energy conversion will be of thermal energy to acoustic energy (engine) or vice versa (refrigeration). There are two types of waves that can be produced: 'standing' or 'travelling', but research has shown that a travelling wave provides higher efficiencies due to the timing of the pressure and velocity peaks which occur such that there is no 'thermal delay' in the heating/cooling processes. These thermal delays are vital for a standing-wave device to convert any energy, but they also reduce the effectiveness of the regenerator resulting in poor efficiencies.

The construction of a travelling-wave Thermoacoustic Stirling cooler by Ueda in 2003 illustrated the potential for achieving low temperatures with a simple design, however the size of these machines has always been restricted by the length of the resonator, meaning small-scale versions are still unexplored.

In this paper, a numerical model of a small-scale travelling-wave Thermoacoustic Stirling cryocooler based on the design presented by Ueda will be developed in DeltaEC – a free software package created by Los Alamos National Laboratory for modelling thermoacoustic devices. The primary goals of this model will be to reduce the overall size of the cryocooler by minimizing the length of the resonator and looped tube as well as maximise the cooling capacity by varying parameters such as the working gas and frequency. The results obtained will provide initial geometric estimates required to later construct an experimental prototype.