Numerical and Experimental Study of an Annular Pulse Tube Used In The Pulse Tube Cooler

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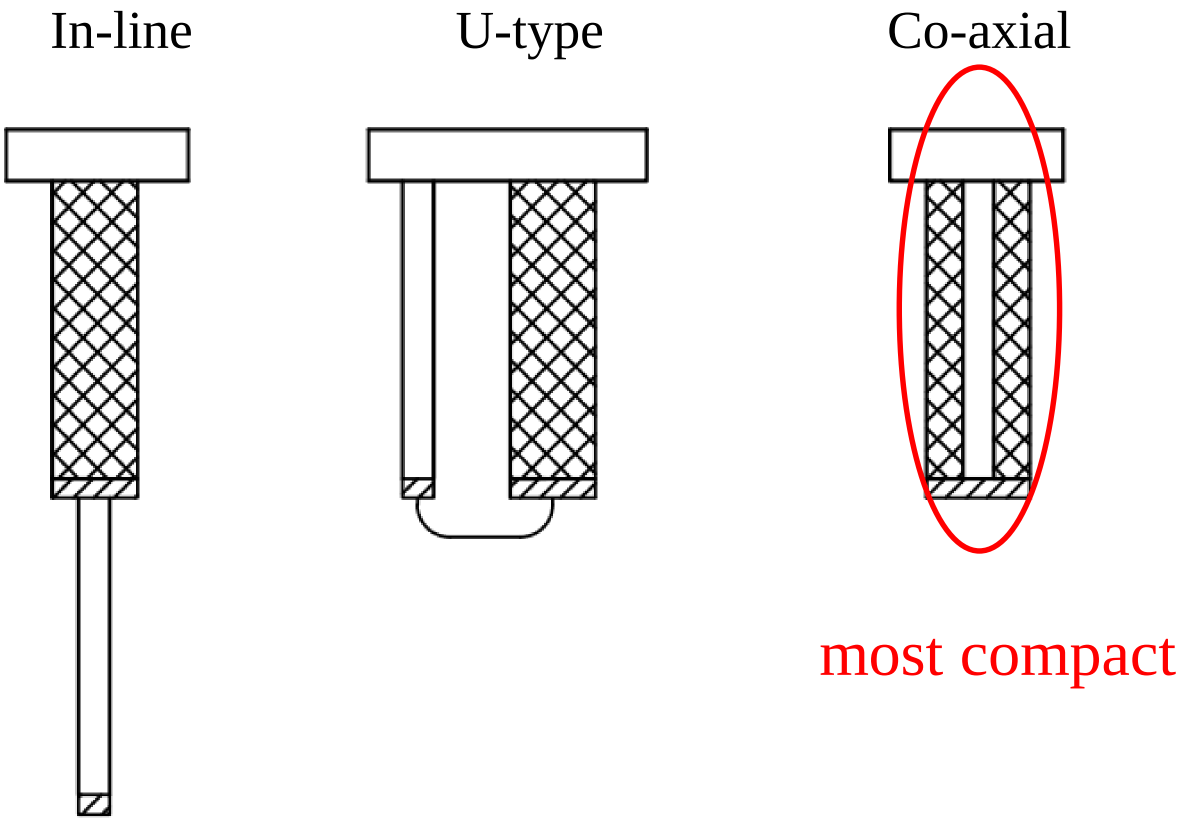
CONTENTS

- Introduction
- Physical model and CFD simulation
- Experimental setup and results
- Conclusions

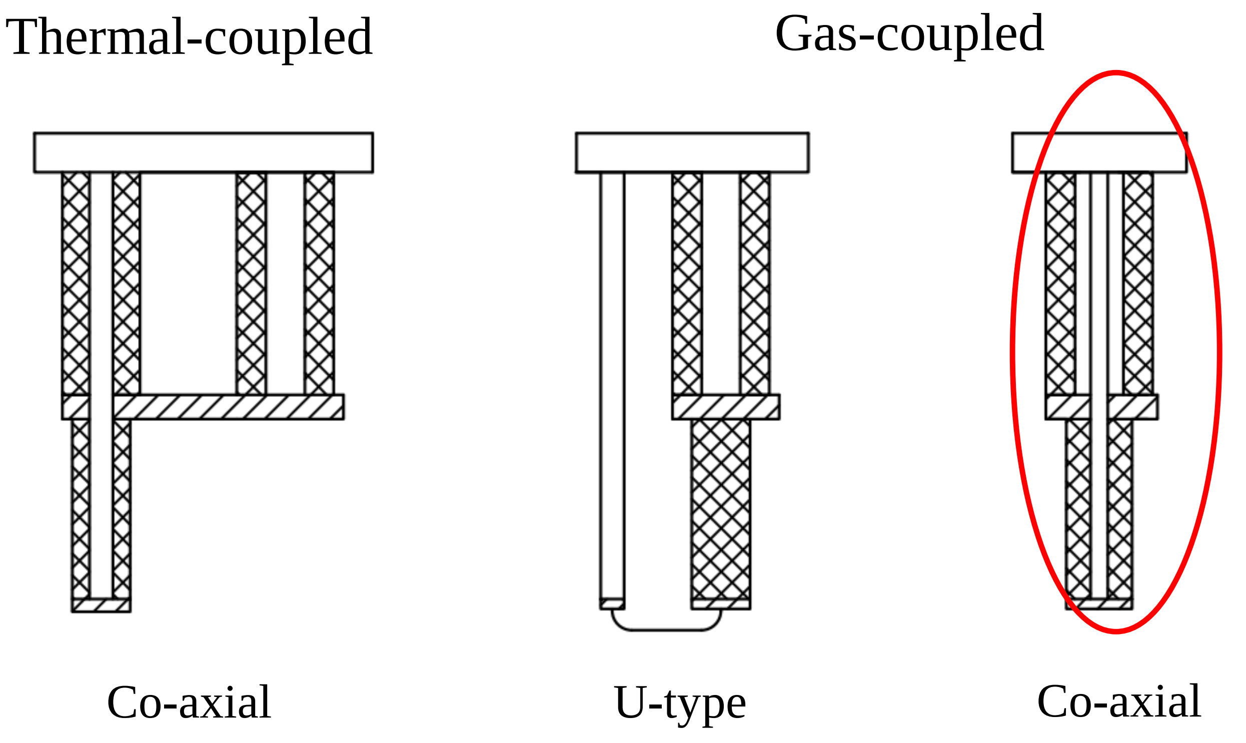
INTRODUCTION

- Single stage Stirling type pulse tube cooler configuration



INTRODUCTION

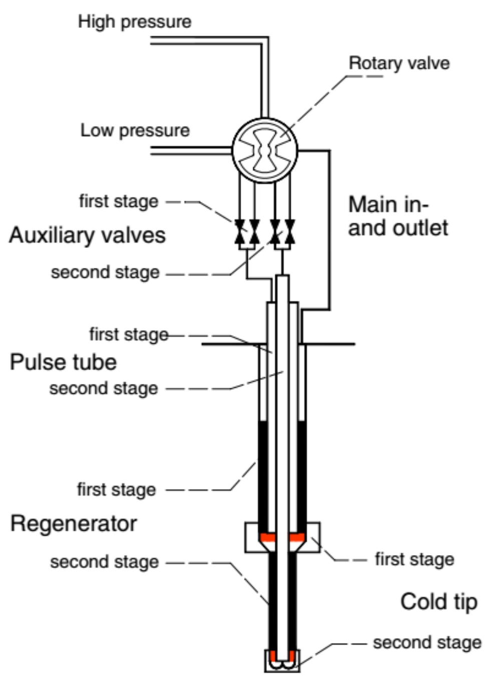
- Two-stage Stirling type pulse tube cooler configuration

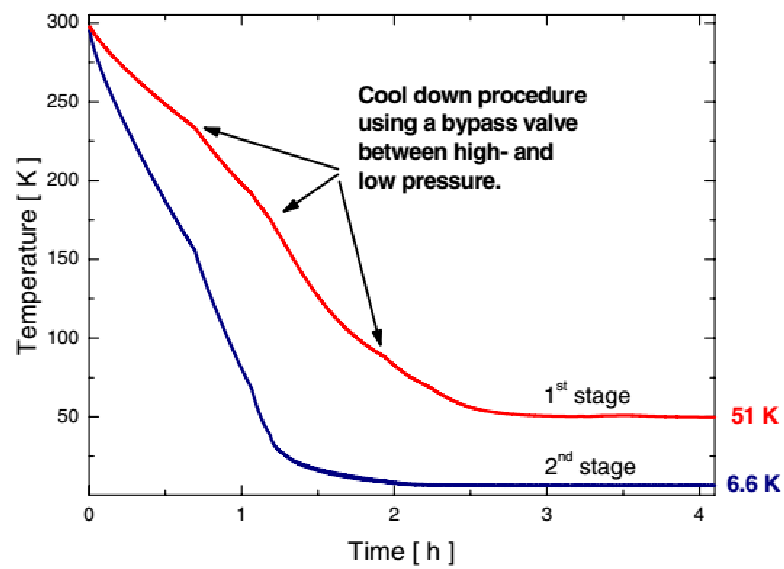


- Completely co-axial two-stage configuration is the most compact configuration

INTRODUCTION

➢ Co-axial configuration for two stage G-M type pulse tube cooler

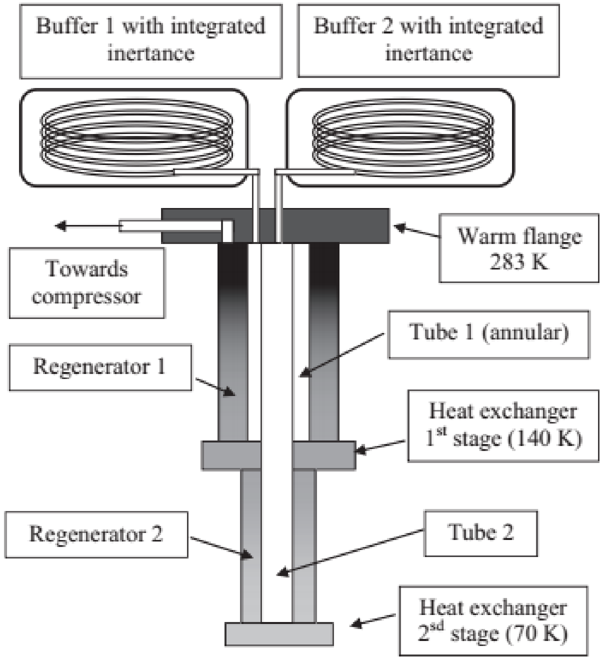


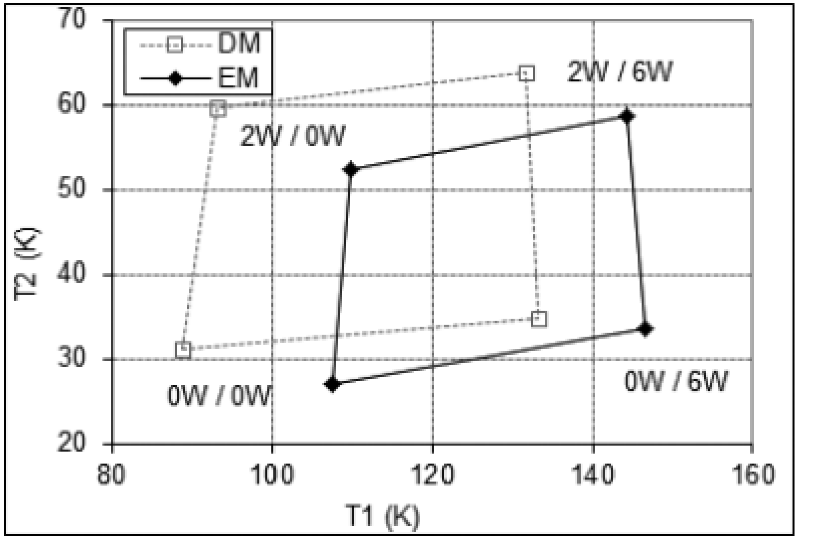


T. Koettig, S. Moldenhauer, R. Nawrodt. et.al. Two-stage pulse tube refrigerator in an entire coaxial configuration. Cryogenics, 2006, 46: 888-891

INTRODUCTION

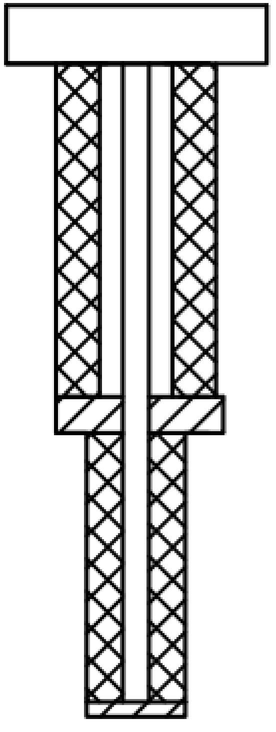
➢ Co-axial configuration for two stage Stirling type pulse tube cooler





I. Charles, E. Ercolani, C. Daniel. Preliminary thermal testing of a high frequency two stage coaxial tube for earth observation missions. [c]//Proceedings of ICEC24-ICMC 2012

INTRODUCTION



Annular pulse tube is inevitable in the completely two stage co-axial configuration

Comparison of Circular pulse tube and Annular pulse tube is present in this paper based on a single stage in-line type pulse tube cooler working in liquid nitrogen temperature.

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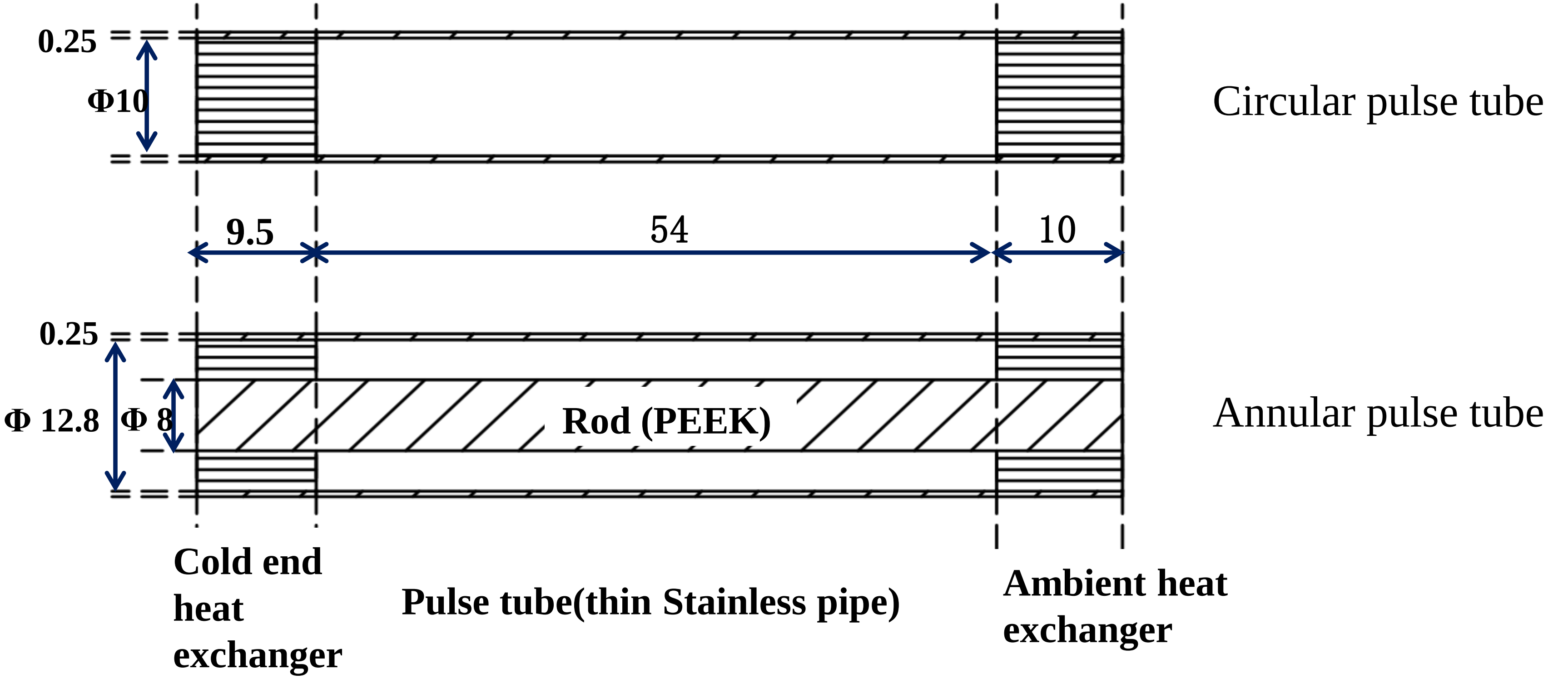
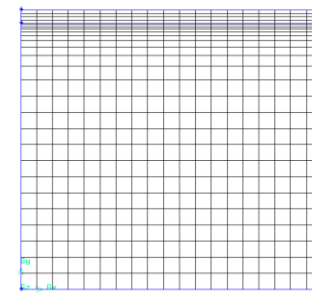
PHYSICAL MODEL

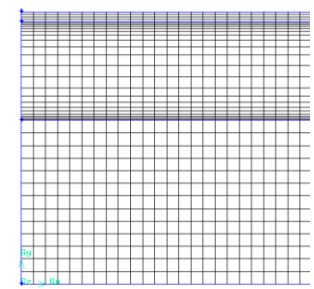
➢ Configuration and details of the model.



PHYSICAL MODEL

- Two dimensional axisymmetric model
- Grids and Boundary condition





Inlet : $\mathrm{m}_{\mathrm{in}} = m_a \sin(\omega t + \theta)$

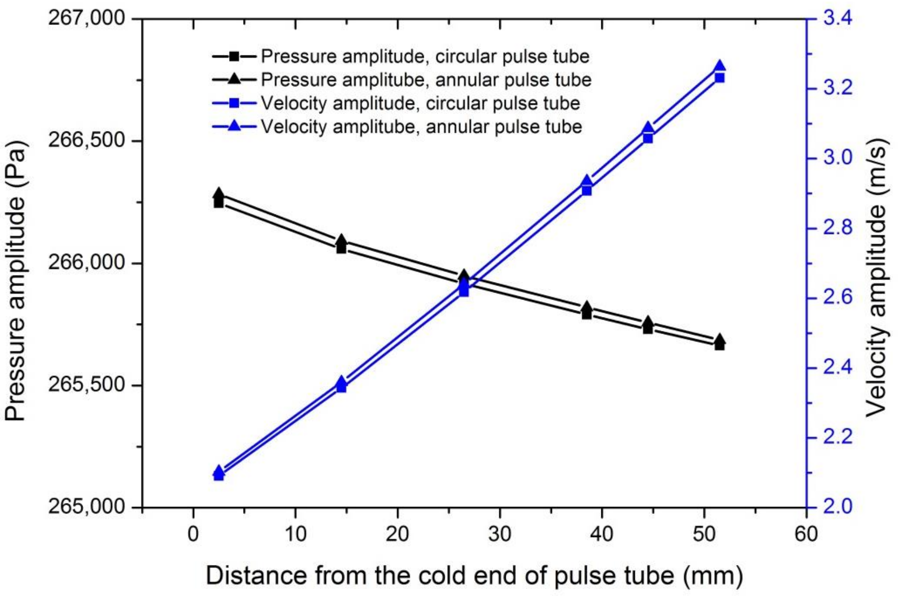
Outlet : $p_{out} = p_m + p_a \sin(\omega t)$

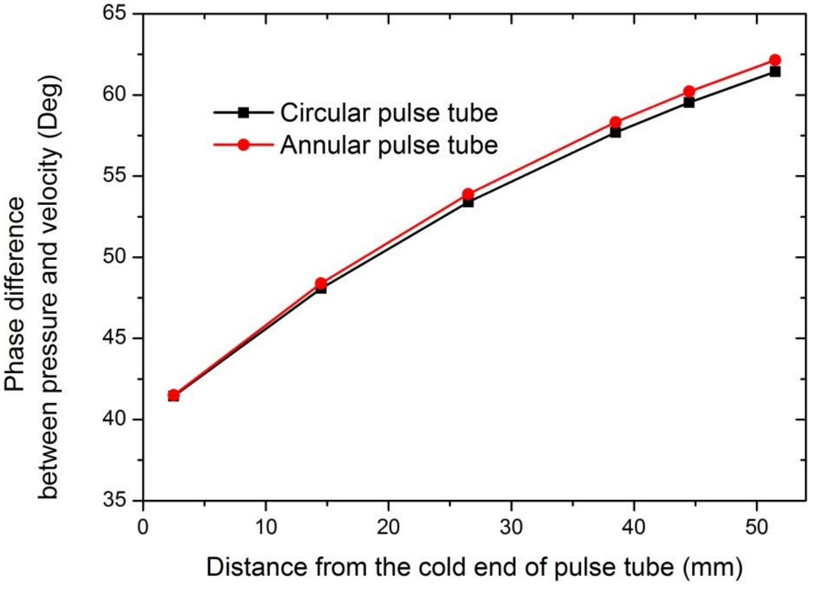
Mean Pressure: 3.5 MPa

Frequency: 100 Hz

SIMULATION RESULTS

- Influence of the pulse tube shape on the pulse tube impedance is small

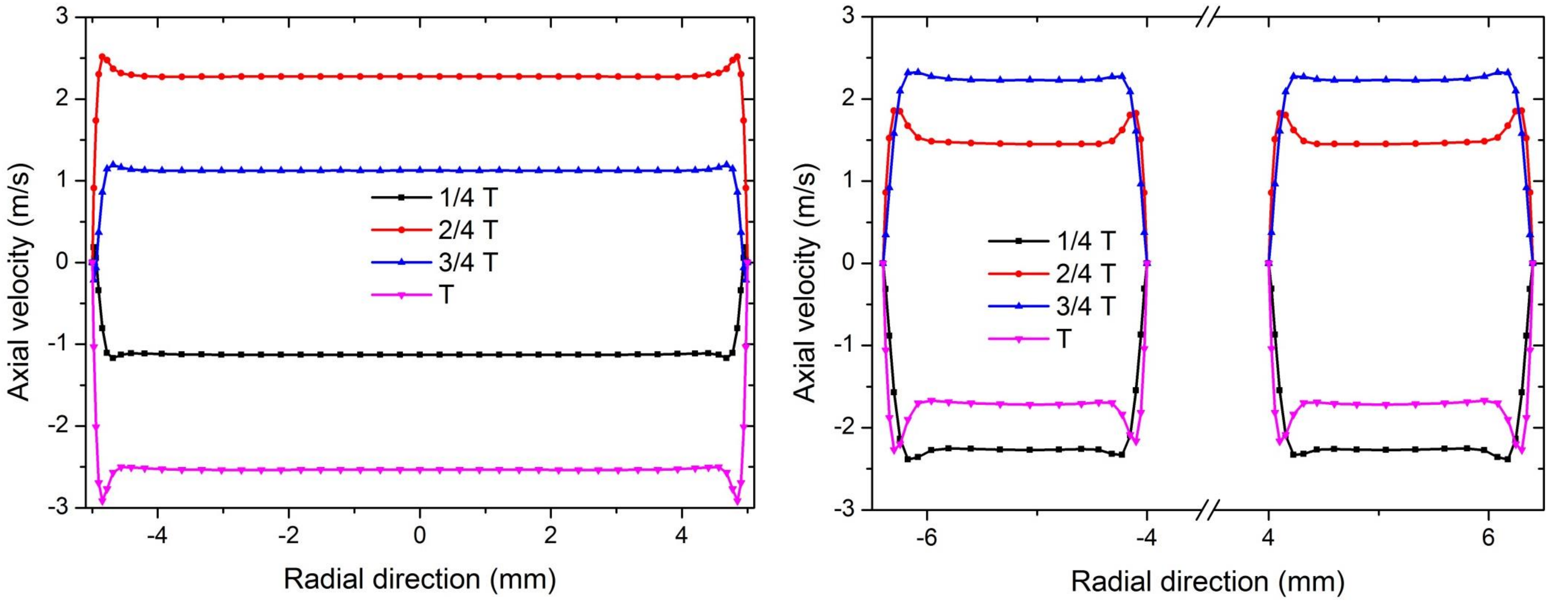




	Circular pulse tube	Annular pulse tube
Impedance amplitude (Pa.s/m2)	1.612E+9	1.612E+9
Impedance angle (Deg)	41.5	41.4

SIMULATION RESULTS

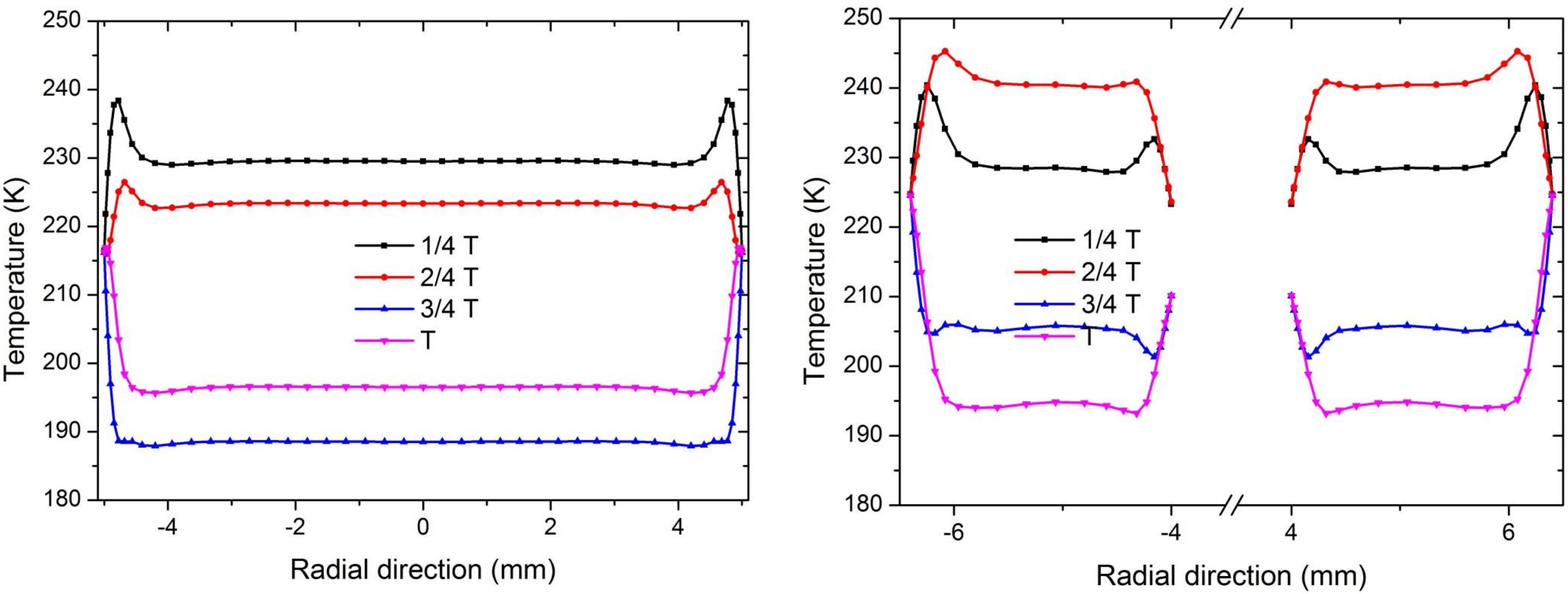
- The skin effect influencing area occupies a larger fraction of the total flow area in the annular pulse tube



Radial distributions of velocity at X=36 mm (middle of the pulse tube) at four moments

SIMULATION RESULTS

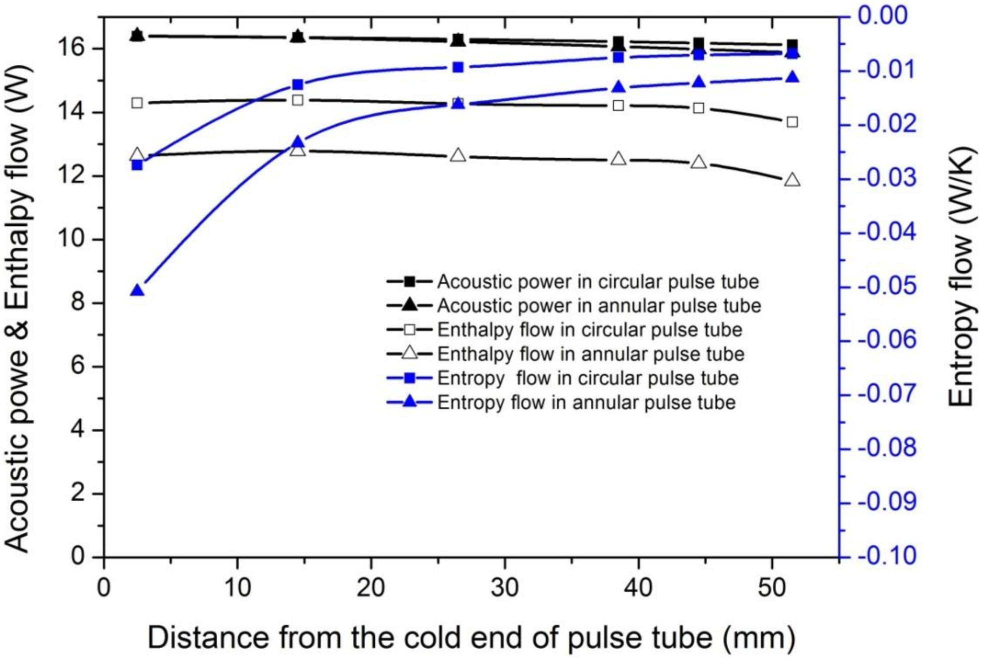
➢ The skin effect influencing area occupies a larger fraction of the total flow area in the annular pulse tube



Radial distributions of temperature at X=36 mm (middle of the pulse tube) at four moments

SIMULATION RESULTS

- The enthalpy flow in the annular pulse tube is lower by about 1.6 W (11%) compared to that in the circular pulse tube.
- The expansion efficiency of the circular pulse tube is 88%
- The expansion efficiency of the annular pulse tube is 78%



The distribution of energy flow in the pulse tube

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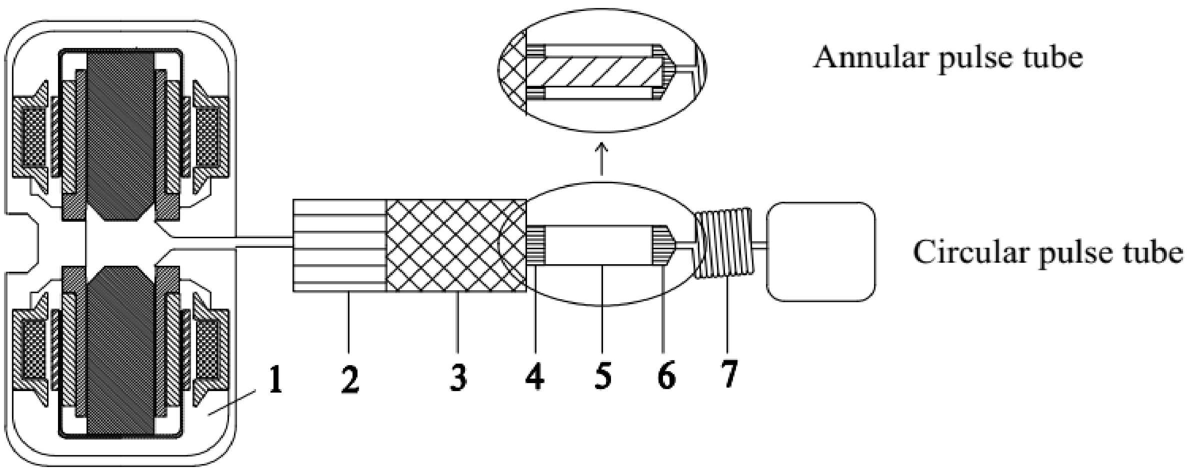
EXPERIMENTAL SETUP

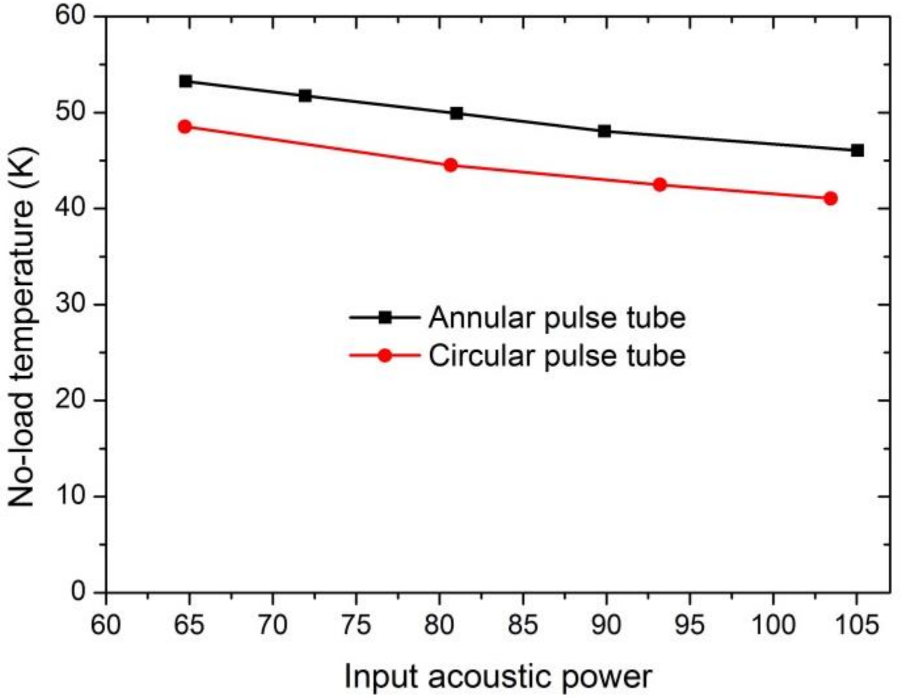
- Schematic of the experimental setup



1. compressor 2. Main ambient heat exchanger 3. Regenerator 4. Cold end heat exchanger 5. Pulse tube 6. Ambient heat exchanger 7. Inertance tube

EXPERIMENTAL RESULTS

- The no-load temperature increases by about 5.5 K when the pulse tube changes from circular shape to annular shape.

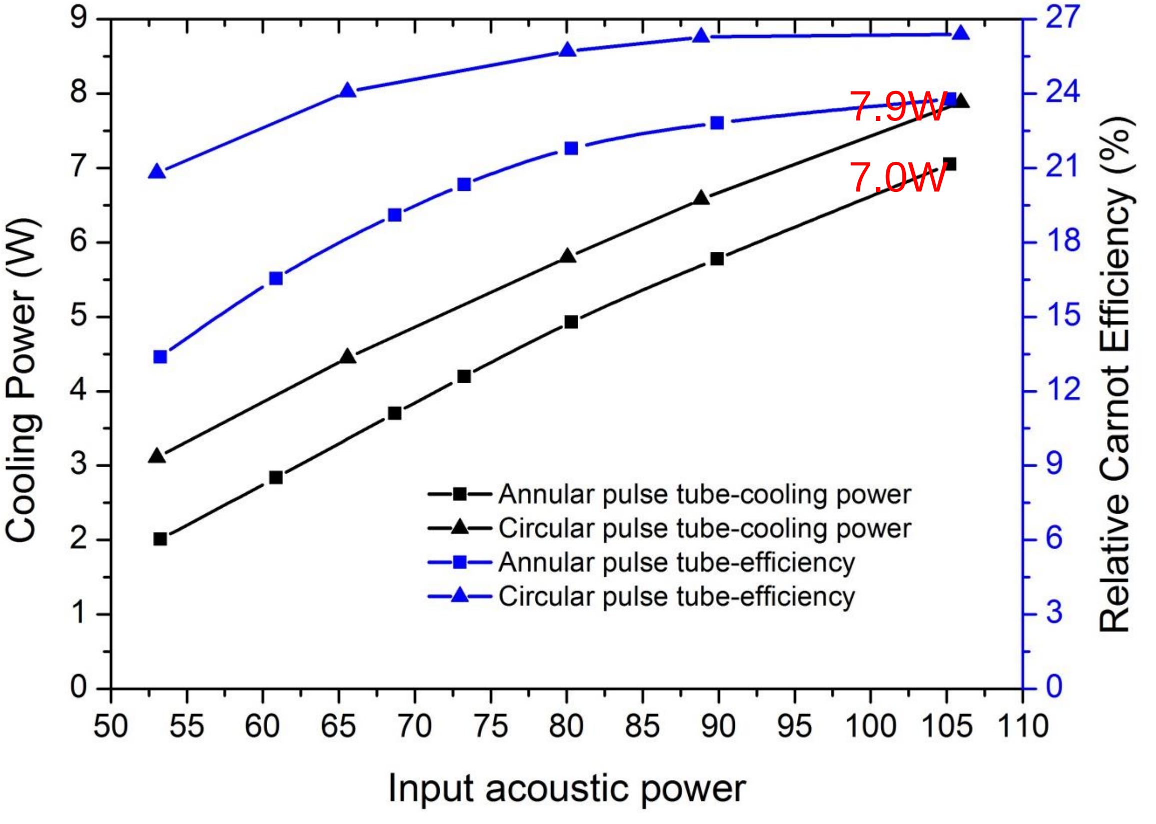


No-load temperature vs. Input acoustic power

Mean pressure: 3.5 MPa
Frequency: 100 Hz

EXPERIMENTAL RESULTS

- Cooling power difference is about 0.9 W (11.4%).



Cooling power & efficiency at 77 K vs. input acoustic power

CONTENTS

CONCLUSIONS

- Simulation results show that inhomogeneity of the velocity and temperature are stronger in the annular pulse tube.
- Simulation results show that the expansion efficiency:
  Annular pulse tube 78% vs. Circular pulse tube 88%.
- Experimental results show that the cooling power at 77 K:
  Annular pulse tube 7.0 W vs. Circular pulse tube 7.9 W.
- Set the basis for building a completely co-axial two-stage pulse tube cooler system

CONCLUSIONS

A Two stage completely co-axial pulse tube system has been set up.

THANKS

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