Technion
Israel Institute of Technology

RAFAEL
ADVANCED DEFENSE SYSTEMS Ltd.

Miniature Piezoelectric Compressor for Joule-Thomson Cryocoolers

Sergey Sobol[a], Nir Tzabar[b], Gershon Grossman[a]

[a]*Technion – Israel Institute of Technology, Haifa, Israel 32000*

[b]Rafael, Haifa, Israel 3102102

Outline

- Motivation
- Design Concept
- Analysis
- Experimental Results
- Summary

Motivation

- Developing a compressor for Joule-Thomson Cryocoolers:
  - Low pressure = 0.1 MPa
  - High pressure = 2.5 MPa
  - Flow Rate = 5 slpm (~0.1 g/s)
- Long life
- Low vibrations

Design Concept

Second Stage

Small displacement

High pressure difference

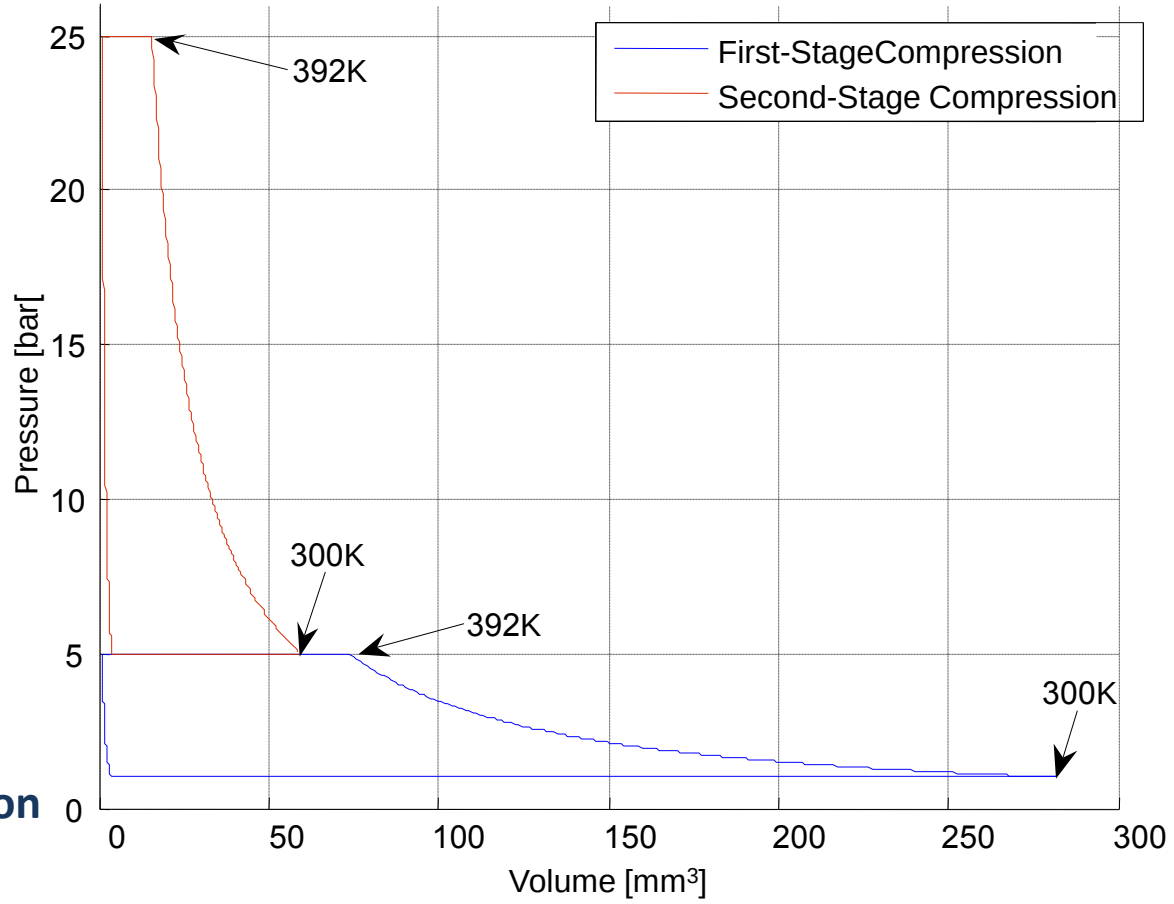
No amplification

First Stage

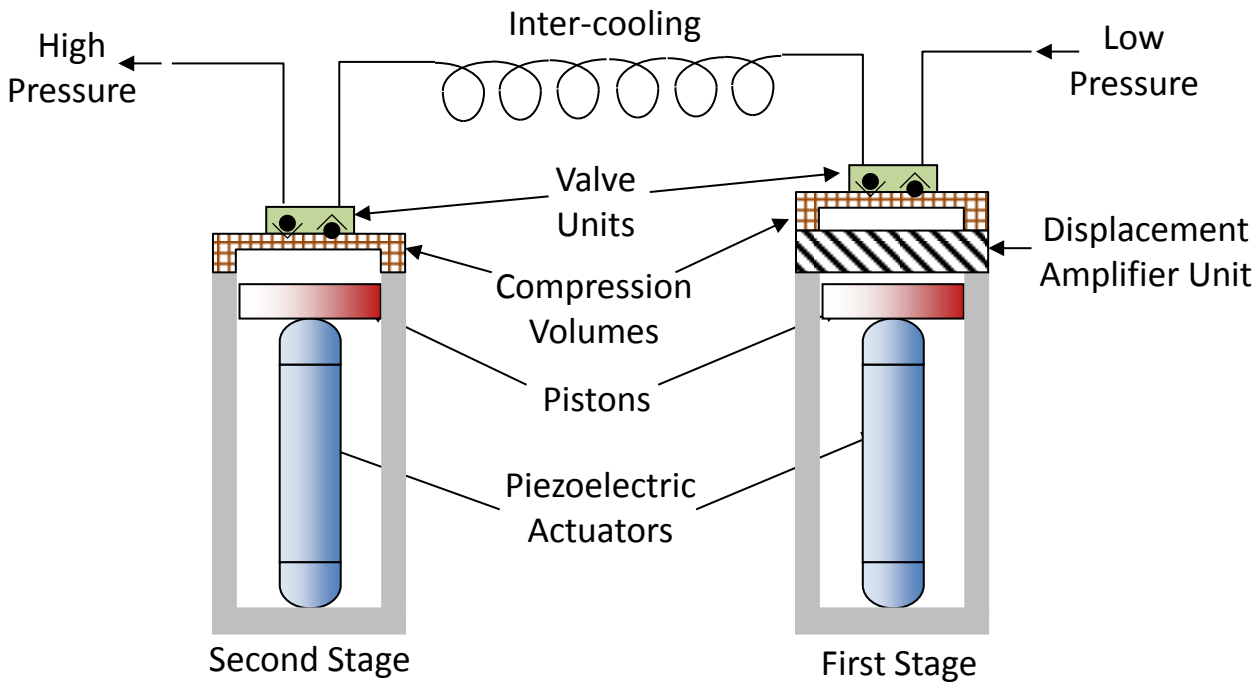
Large displacement

Low pressure difference

Displacement amplification

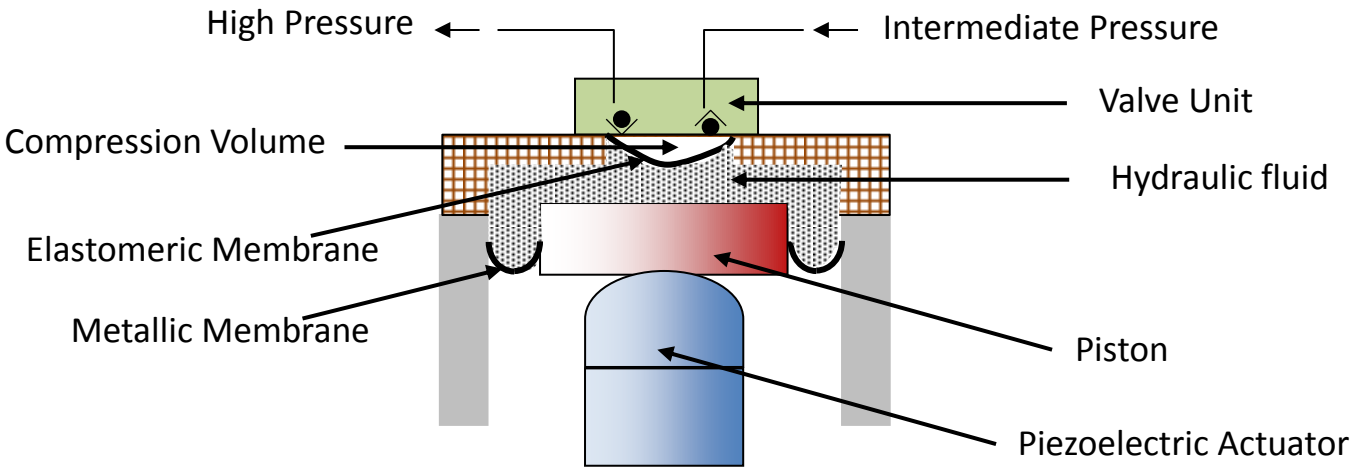


Design Concept



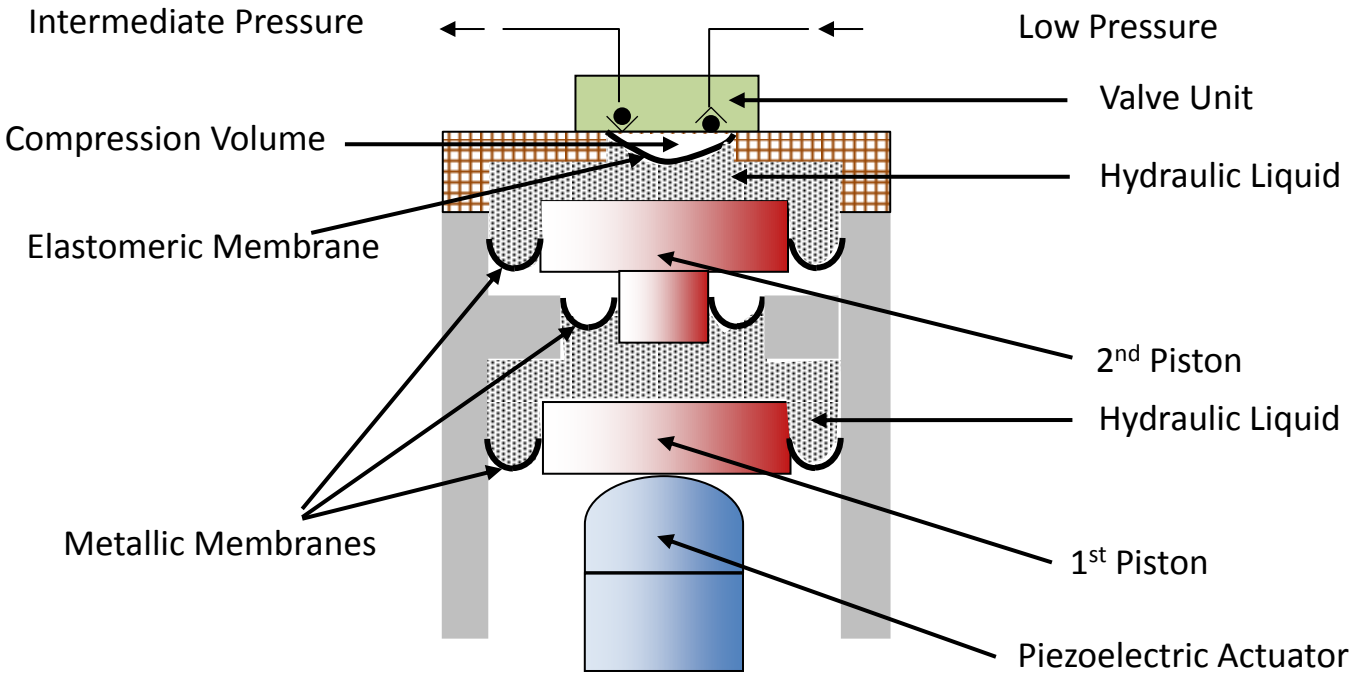
Design Concept

Compression volume



Design Concept

Compression volume + Displacement amplifier



Design Concept

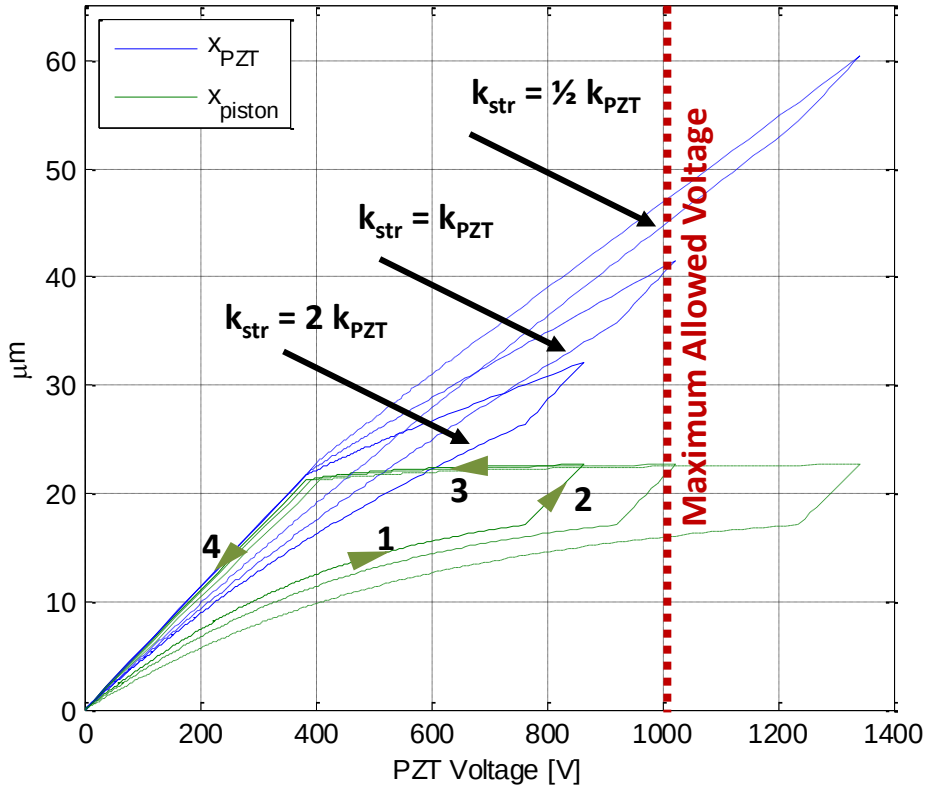
Structure stiffness

Structural deformations:

1. Housing cover deflection
2. Axial elongation of the housing
3. Deflection of the piston
4. Deflection of the membrane

Additional sources of elasticity:

5. Compressibility of the liquid
6. Mechanical contacts
7. Threads



Analysis

The quasistatic relation between the supply voltage to the piezoelectric element and the piston displacement

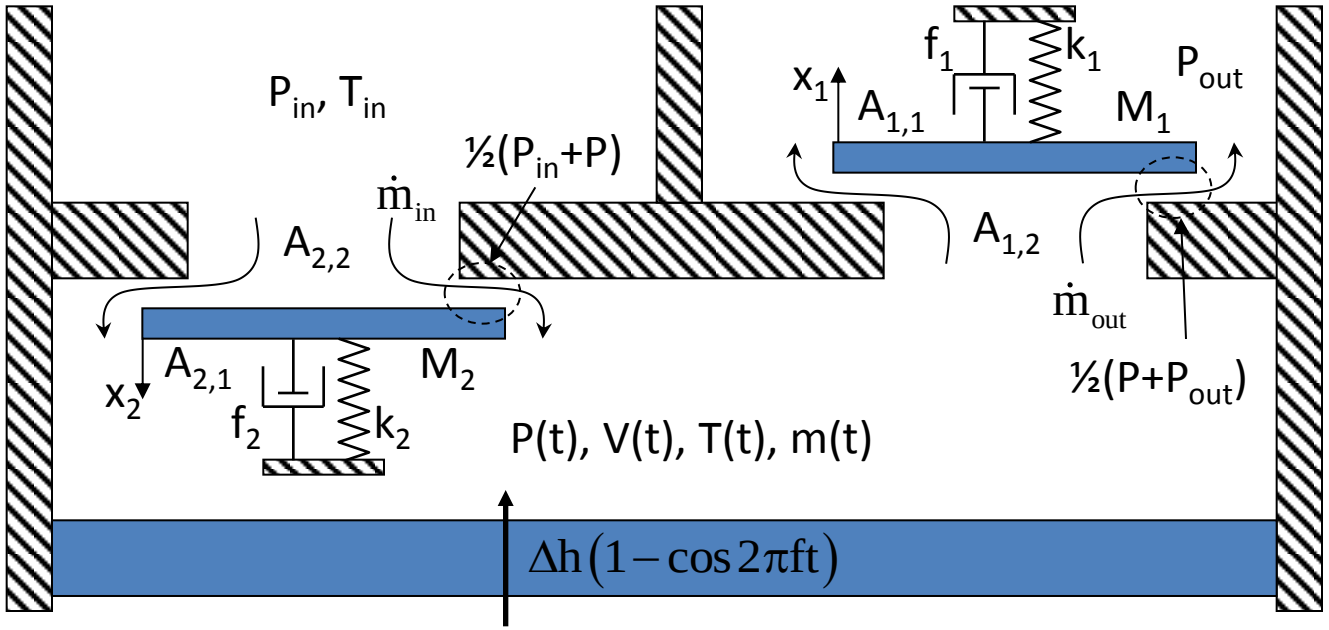
$$N \cdot V_{PZT} = \frac{k_{PZT}}{a} x + a\left(1 + \frac{k_{PZT}}{k_{str}}\right)\left[\Delta p(x) A + k_{prl} x\right]$$

The relation between the piezoelectric displacement and the piston displacement

$$x_{PZT} = \frac{x}{a} + \frac{\Delta p(x) A + k_{prl} x}{k_{str}}$$

Analysis

Check valves



Outlet valve:

$$M_1\ddot{x}_1 + f_1\dot{x}_1 + k_1x_1 = PA_{1,2} - P_{out}A_{1,1} + \frac{P + P_{out}}{2}\left(A_{1,1} - A_{1,2}\right) - k_1x_{1,0} + \frac{\dot{m}_{out}^2}{\rho A_{1,2}}$$

Inlet valve:

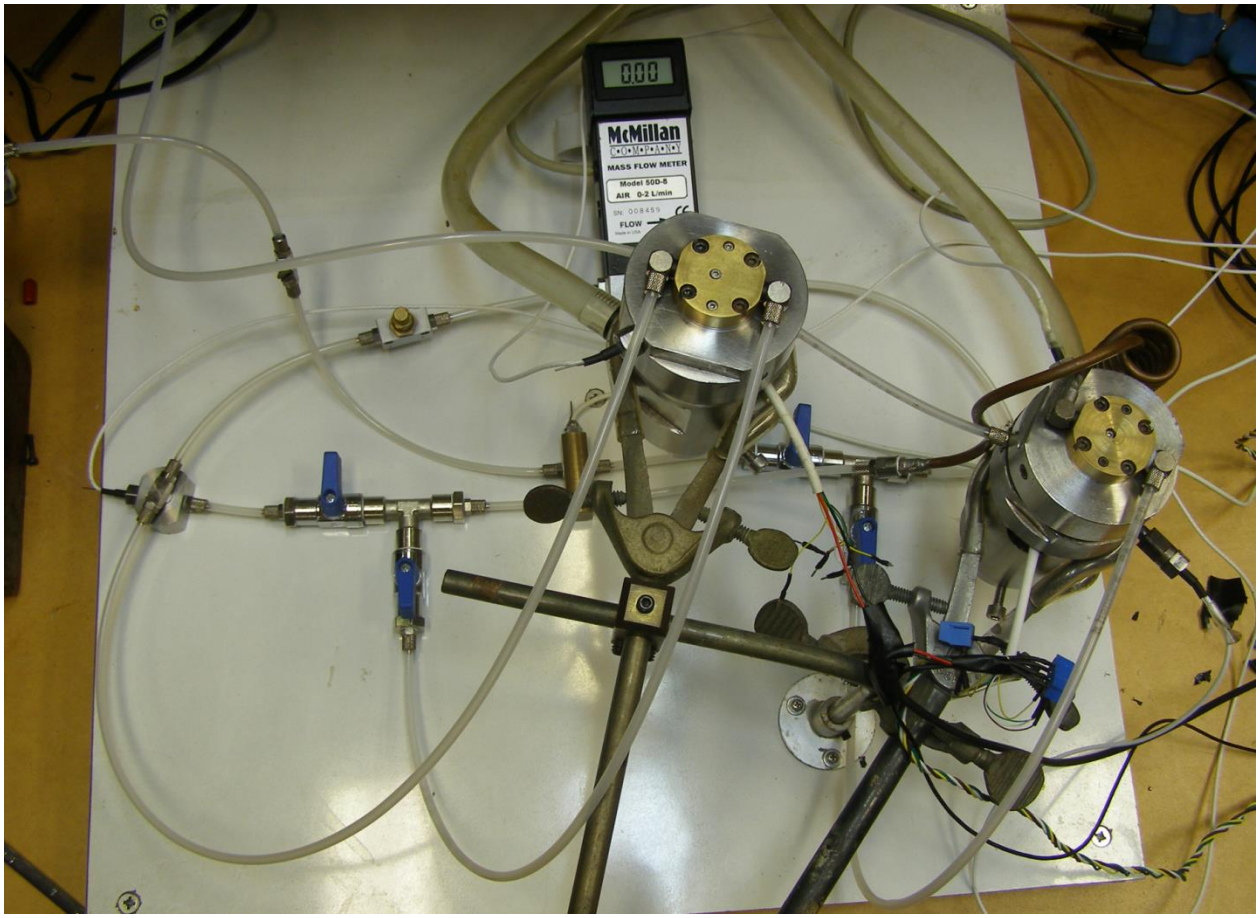
$$M_2\ddot{x}_2 + f_2\dot{x}_2 + k_2x_2 = P_{in}A_{2,2} - PA_{2,1} + \frac{P_{in} + P}{2}\left(A_{2,1} - A_{2,2}\right) - k_2x_{2,0} + \frac{\dot{m}_{in}^2}{\rho_{in}A_{2,2}}$$

Experimental Results

Experimental setups

Experimental Results

Experimental setups



Experimental Results

Compression Stage	Frequency [Hz]	Low Pressure [MPa]	Intermediate Pressure [MPa]	High Pressure [MPa]	Flow Rate [mg/s]
2	50	-	0.5	2.4	6
2	100	-	0.5	2.1	13.4
2	200	-	0.5	2.2	21
1	100	0.155	0.506	-	13.4
1	200	0.149	0.503	-	21.4
1+2	100	0.15	-	2.1	13.4
1+2	200	0.15	-	2.2	21
Requirements:		**0.1**		**2.5**	**100**

Summary

The compressor is designed to provide a relatively high compression ratio in comparison with other piezoelectric driven compressors described in the literature.

The design concept has been presented.

Preliminary results show a pressure ratio of 1:14.7 with a flow rate of 0.021 g/s.

Further development shall improve these results by increasing the pressure ratio and/or the flow rate.

Questions?

Prof. Gershon Grossman - grossmng@tx.technion.ac.il

Dr. Nir Tzabar - nirtzabar8@gmail.com