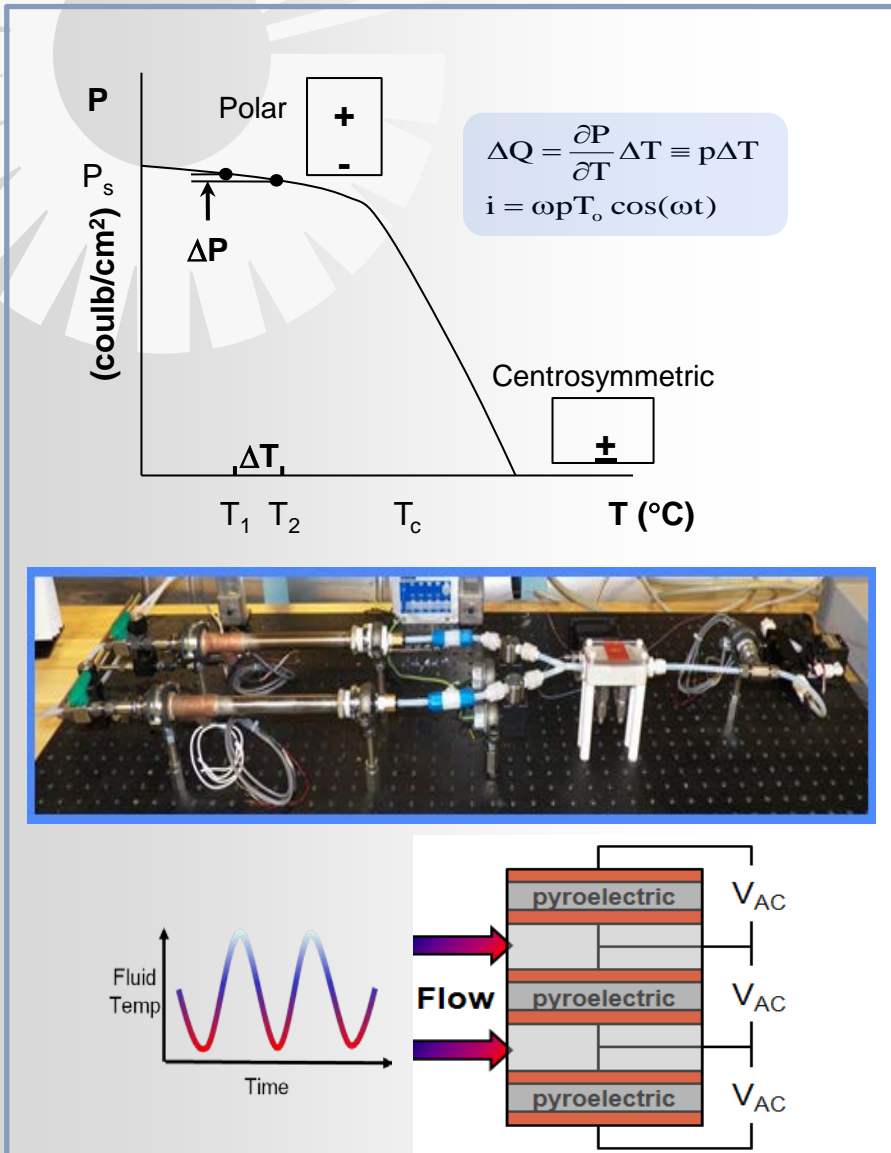


Pyroelectric Power Generation Technology



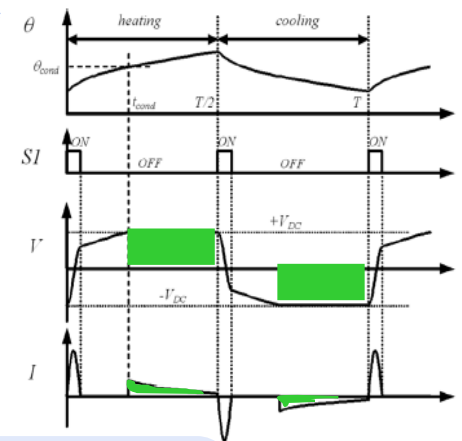
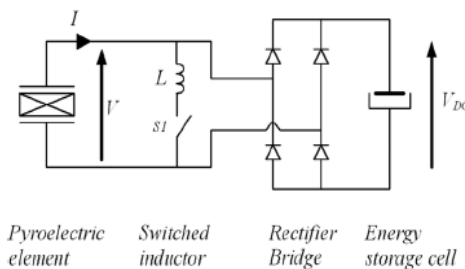
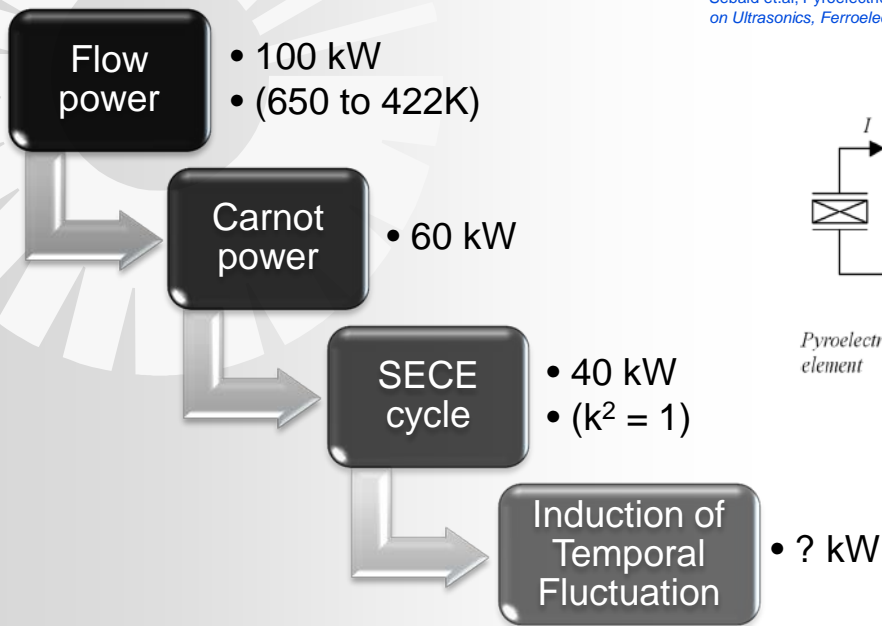
Pyroelectric power generation depends on temporal rather than spatial temperature gradients

Technical Details

- Potentially very light and compact **inherently large heat transfer surface**
- Scalable over a wide range of power and temperatures
- Efficiency is a function of cycle and materials
- No net emission, environmentally friendly materials
- Ceramic pyroelectric materials are mature and costs are understood

Pyroelectric Power Generation Cycles and Materials

Sebald et.al, Pyroelectric Energy Conversion: Optimization Principles, *IEEE Transactions on Ultrasonics, Ferroelectrics, and Frequency Control*, v. 55 n. 3, March 2008



SECE Cycle

$$k^2 = \frac{p^2 \theta_h}{\epsilon_{33}^{\theta} c_E}$$

$$\eta_{SECE} = \frac{|W_E|}{Q_h} = \frac{k^2}{1 + 0.5k^2} \eta_{Carnot}$$

Coefficient Unit	p $\mu\text{C}\cdot\text{m}^{-2}\cdot\text{K}^{-1}$	$\frac{\epsilon_{33}^{\theta}}{\epsilon_0}$	$c_E (\times 10^6)$ $\text{J}\cdot\text{m}^{-3}\cdot\text{K}^{-1}$	$-p/\epsilon_{33}^{\theta} (\times 10^3)$ $\text{V}\cdot\text{m}^{-1}\cdot\text{K}^{-1}$	k^2 %
PZN-PT and PMN-PT single crystals					
111 PMN-0,25PT	1790	961	2.5	210	4.79
110 PMN-0.25PT	1187	2500	2.5	54	0.81
001 PMN-0.25PT	603	3000	2.5	23	0.17
001 PMN-0,33PT	568	5820	2.5	11	0.08
011 PMN-0,33PT	883	2940	2.5	34	0.38
Bulk ceramics					
PZT	533	1116	2.5	54	0.37
PMN-0.25PT ceramic	746	2100	2.5	40	0.38
Thin films					
PZT 700 nm	211	372	2.5	64	0.17
PMZT 700 nm	352	255	2.5	156	0.70

Pyroelectric coefficient, as well as dynamic material properties such as specific heat and dielectric constant, are important

Pyroelectric Power Generation Technology

Development Needs

- Develop technology to create pyroelectric material temperature fluctuations at high efficiency and low cost
- Material processing for:
 - Increased pyroelectric coefficient
 - Decreased dielectric constant and specific heat
 - Improved breakdown strength
 - Curie point tunability
 - Lower cost
- Identify and address issues of oxidation, corrosion, fatigue