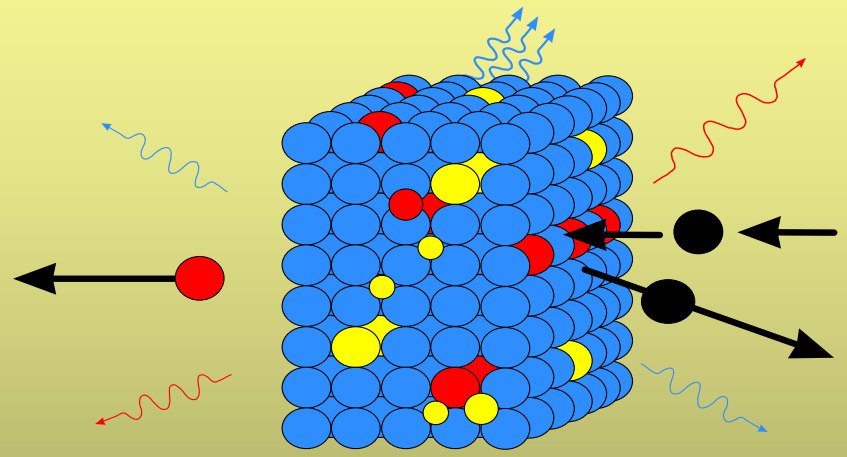
“Highly Efficient Thermoelectric Materials: Nanolayered Nanoclusters”



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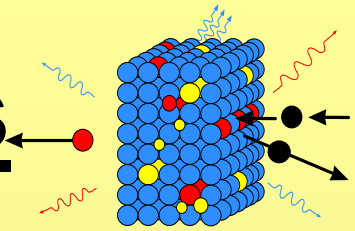
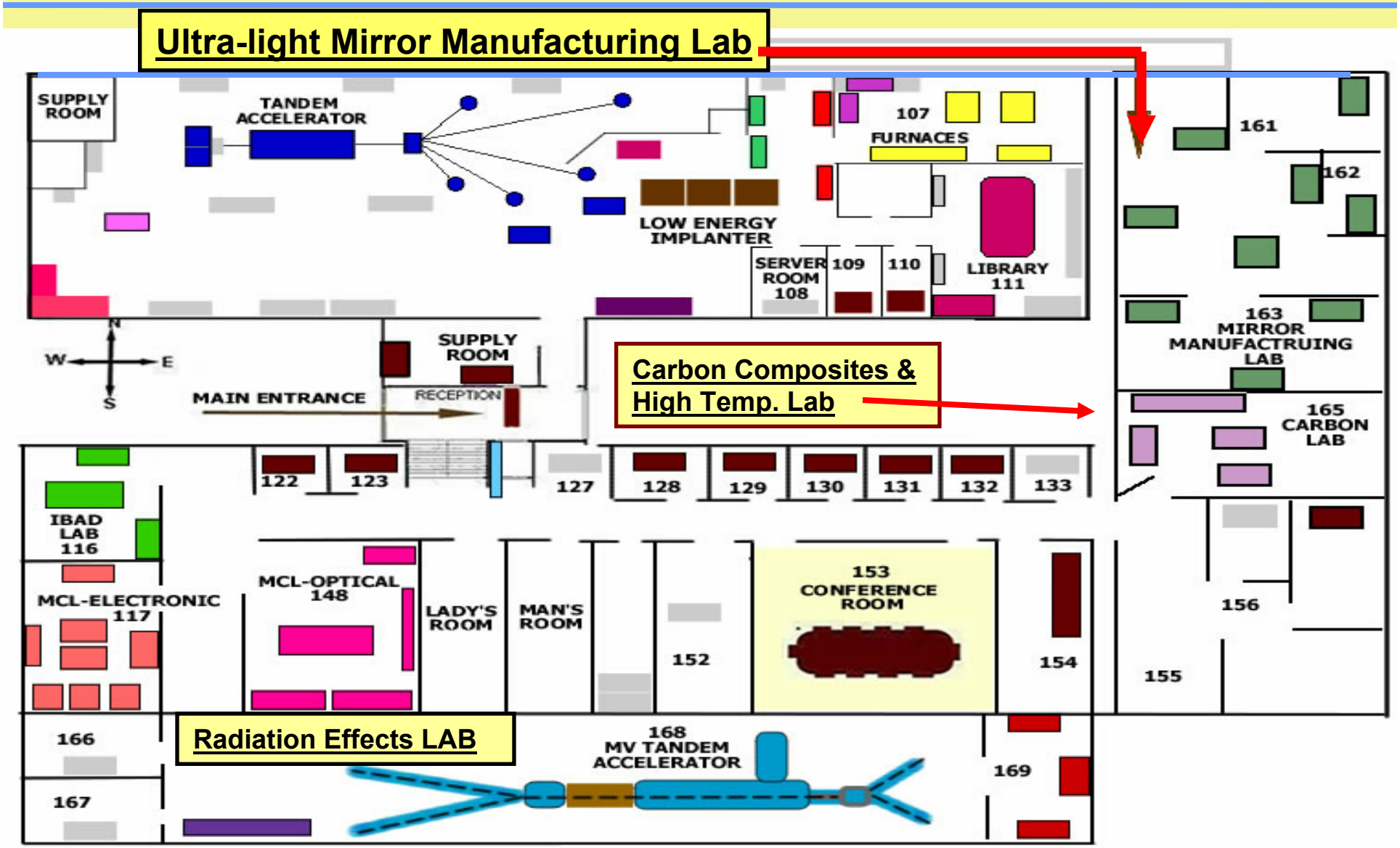
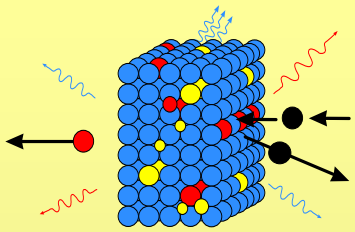
Ctr. for Irrad. of Materials



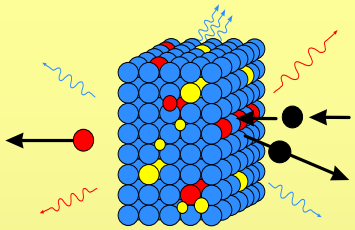


Introduction to CIM



- **Ion Beam Modification of Materials (IBMM)**
- **Materials Characterization**
- **Materials Processing/Synthesis**
- **Nanoscale Materials processing**
- **Device Fabrication/Prototyping**
- **Environmental Remediation (R&D)**

Center TEAM



AAMU:

Faculty and staff:

D. ILA, R. L. Zimmerman, G. M. Jenkins, A. L. Evelyn, L. R. Holland, C. I. Muntele, D. Nisen (R), I. C. Muntele, M. Schilloff, S. Sarkisov, Z. Xiao, H. Bowman, S. Budak, M. Saafi, A. Batra, A. Sharma, R. Taylor, M. Alim, T. Montgomery, T. Kukhtareva, J. Wang, J. Campbell, H. J. Caulfield, J. Fisher (Ind), G. Terry (Ind), S. Celaschi (Ind), J. Williams (Ind),

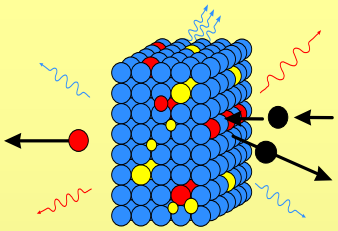
Students:

B. Chhay, R. Ichou, G. Deceprit, J. Chang, D. Walker, R. Minamisawa, S. Wu, B. Zheng, C. Smith, (Eight more)

Others:

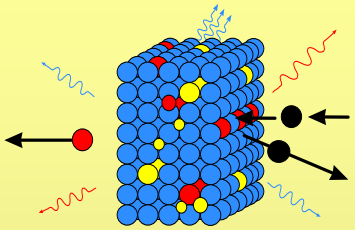
R. Mu (Fisk), I. Ozen (Sabanci Univ. Turkey), A. Elsamadicy (+ UAH Students), I. Gurhan and A. Ozterhan (Ege U, Turkey + students), P. Thevenard (+ UCB Students), A. de Almeida (+ USP Students),

Objective



Produce Highly Efficient Thermoelectric Materials (Operate from 300K to 1000K)

Project TEAM I



AAMU:

D. ILA, R. L. Zimmerman, L. R. Holland, S. Budak, C. I. Muntele, and Z. Xiao

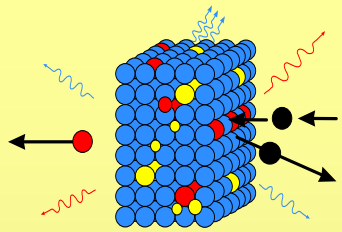
Students:

B. Zheng (Ph. D.), C. C. Smith (Ph. D.) , and (Four Undergraduate Students)

Others:

NRL, ARL/ARO, DOE, NASA (MSFC/Support), NSF (Support), *UAH*, *UA*, *TU*,

Figure of Merit



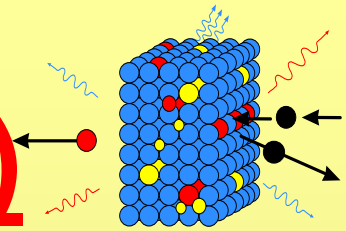
Thermoelectric devices performance quantified by the dimensionless figure of merit **ZT**

$$ZT=(S^2\sigma T)/\kappa$$

- S is the Seebeck coefficient
- σ is electrical conductivity
- T is temperature
- κ is thermal conductivity

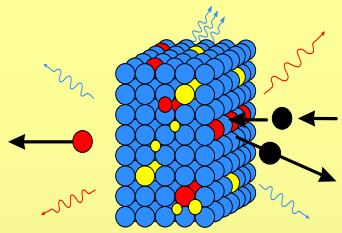
High ZT & High Efficiency

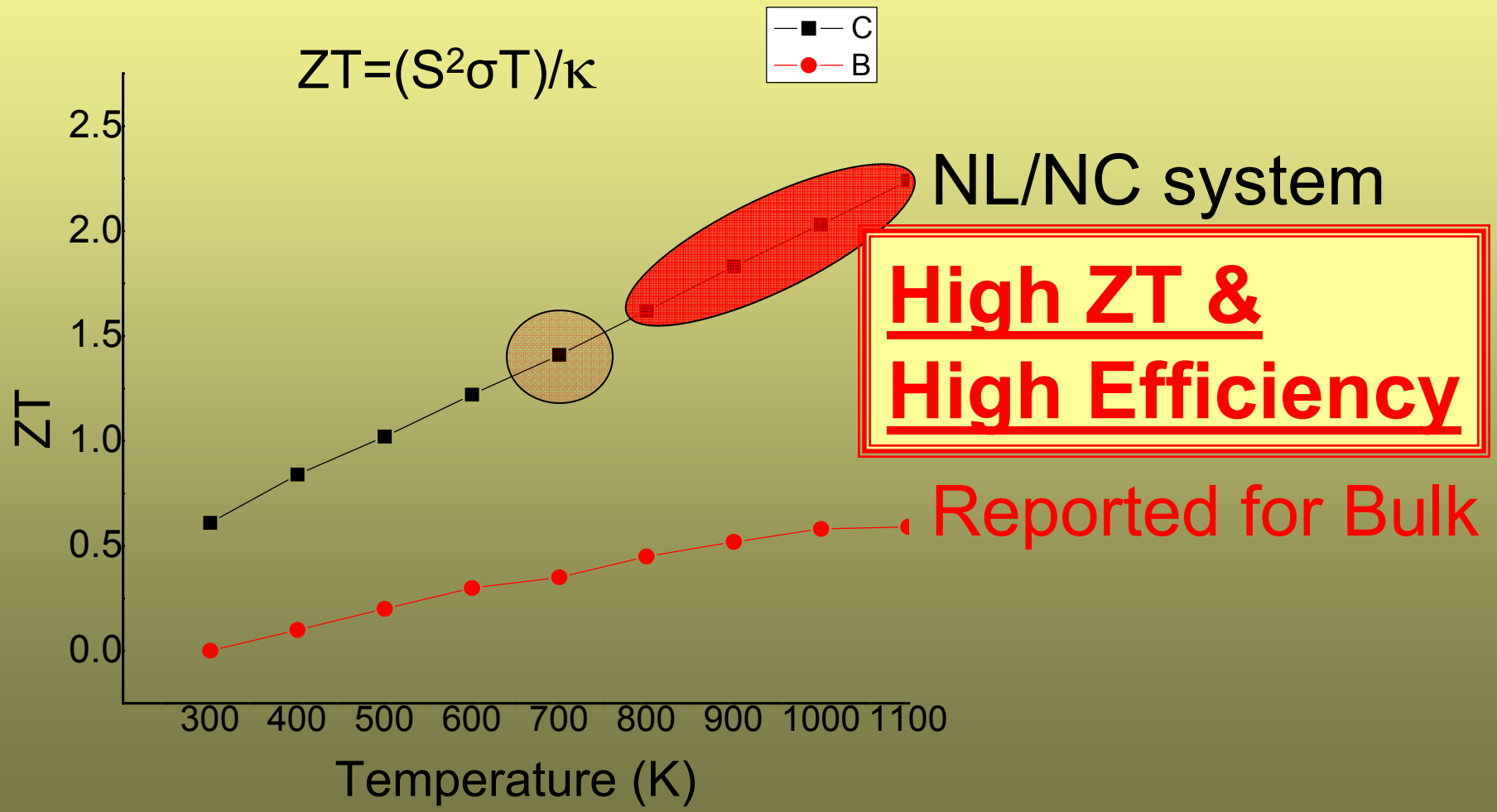
TEM Results (June 2k7)



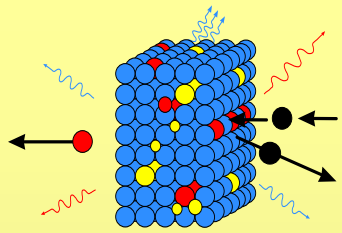
Materials	Reported ZT/Temp	AAMU ZT/Temp	Potential ZT/Temp $ZT=(S^2\sigma T)/\kappa$
SiO_2Au/SiO_2	0	2.52 @ 360K	> 2.52
Bi_xTe_3/Sb_2Te_3	1.1 @ 350K	2.6 @ 350K	> 2.6
SiO_2 Ag/SiO_2	0	0.085 @ 300K	Under Investigation
Zn_4Sb_3	0.50 @ 300K	0.53 @ 300K	Under Investigation
$CeFe_2Co_2Sb_{12}$	0.05 @ 300K	3.07 @ 300K	> 3
SiO_2/Zn_4Sb_3		0.28 @ 300K	Under Investigation
$Si_{1-x}Ge_x/Si$	1.@ 300K 0.6 @ 1200K	0.61 @ 300K	>> 0.61

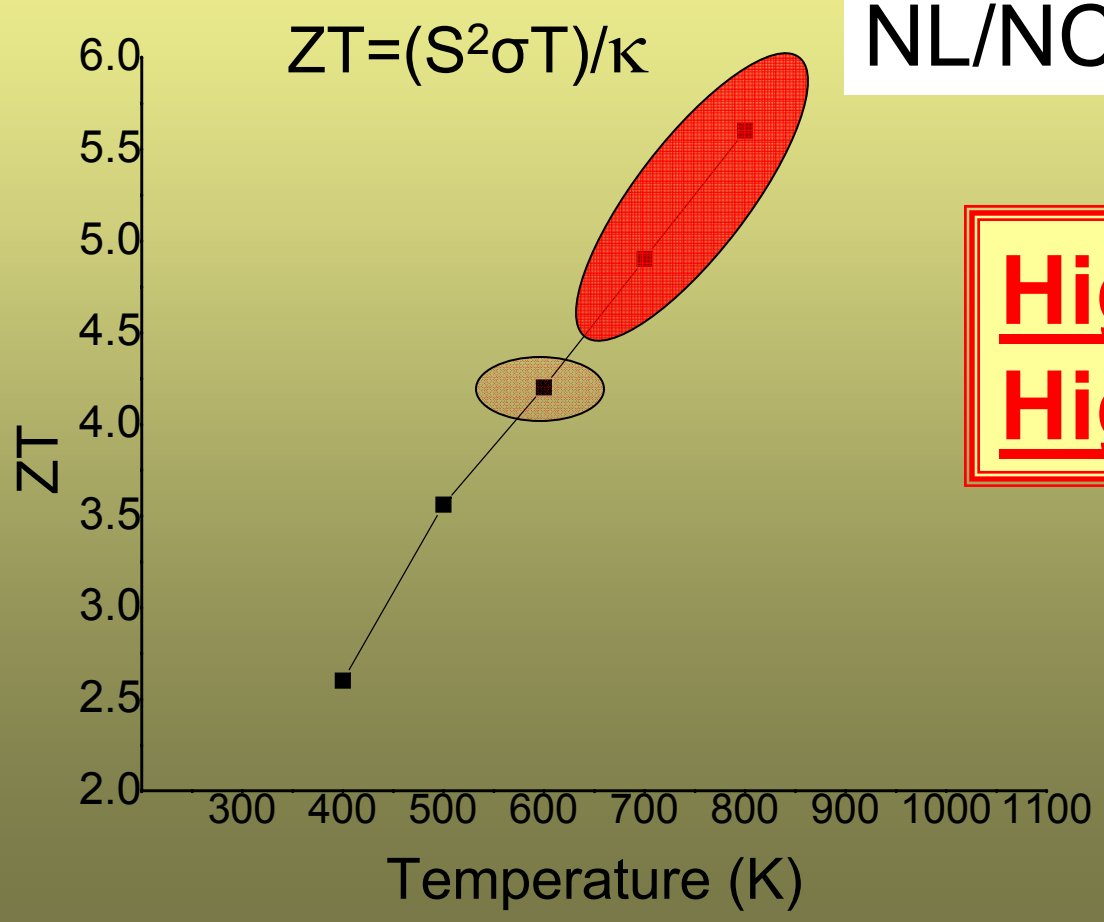
Predicted ZT for SiGe at Higher Temperatures





Predicted ZT for SiO_2Au/SiO_2 @ High T

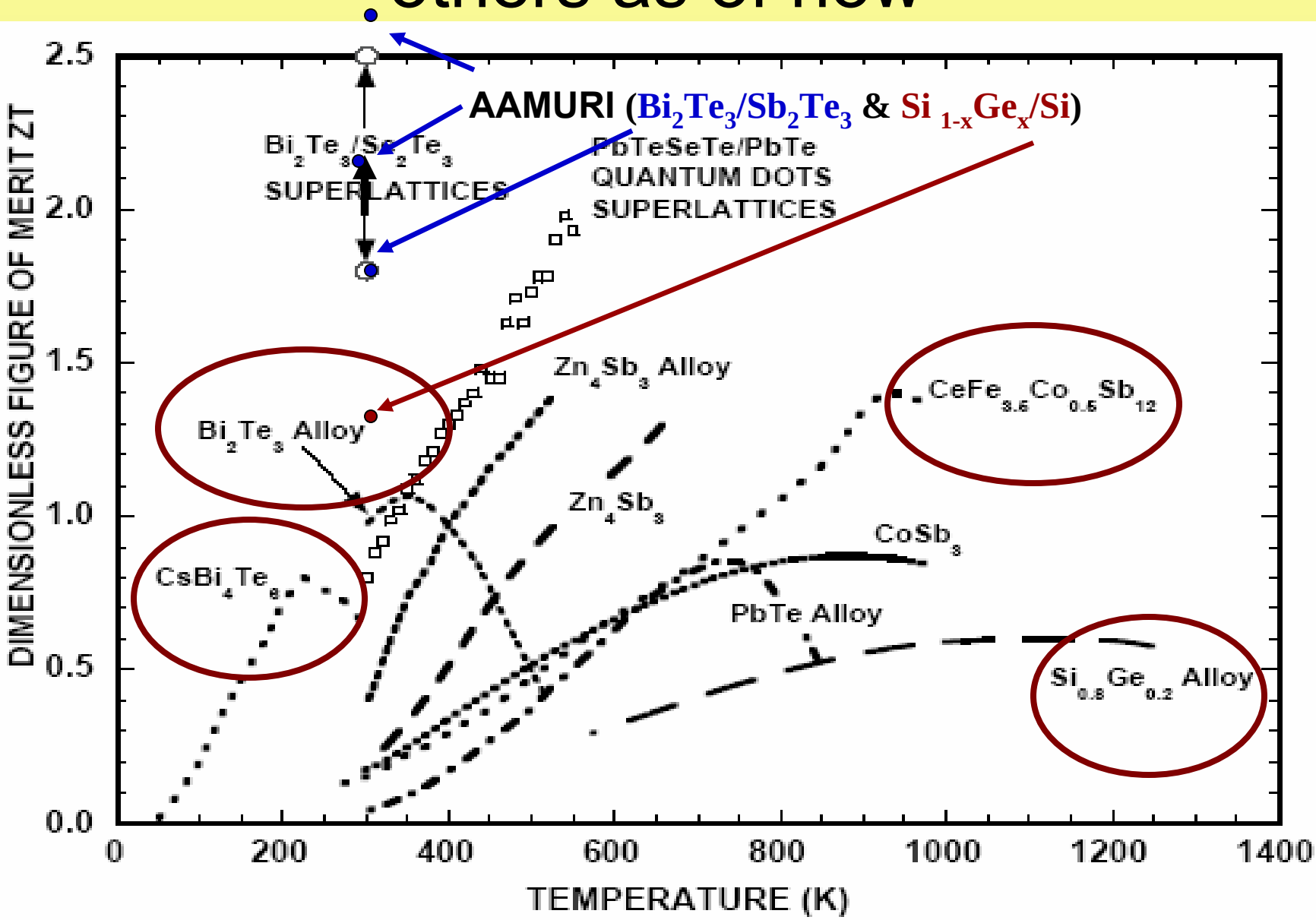




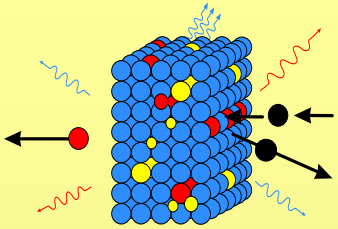
NL/NC system

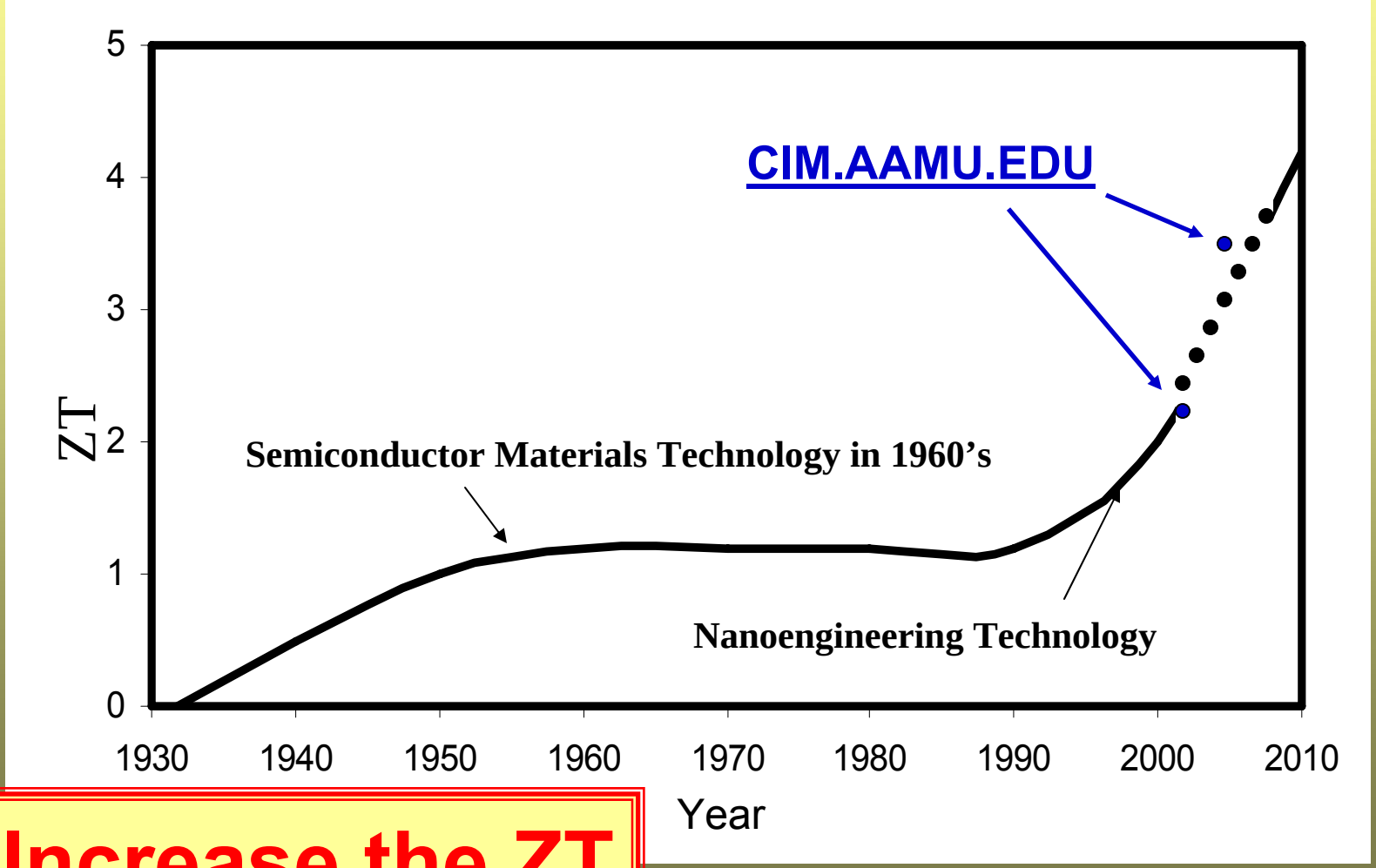
High ZT & High Efficiency

Results obtained by AAMU and others as of now



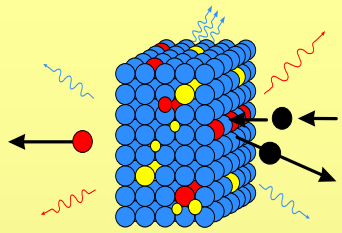
History





Increase the ZT

Increase ZT
Increase Efficiency



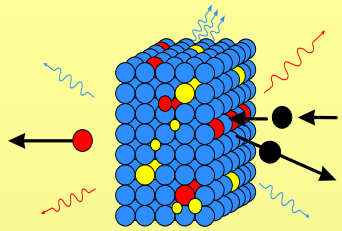
Three ways to increase Figure of Merit

$$ZT=(S^2\sigma T)/\kappa$$

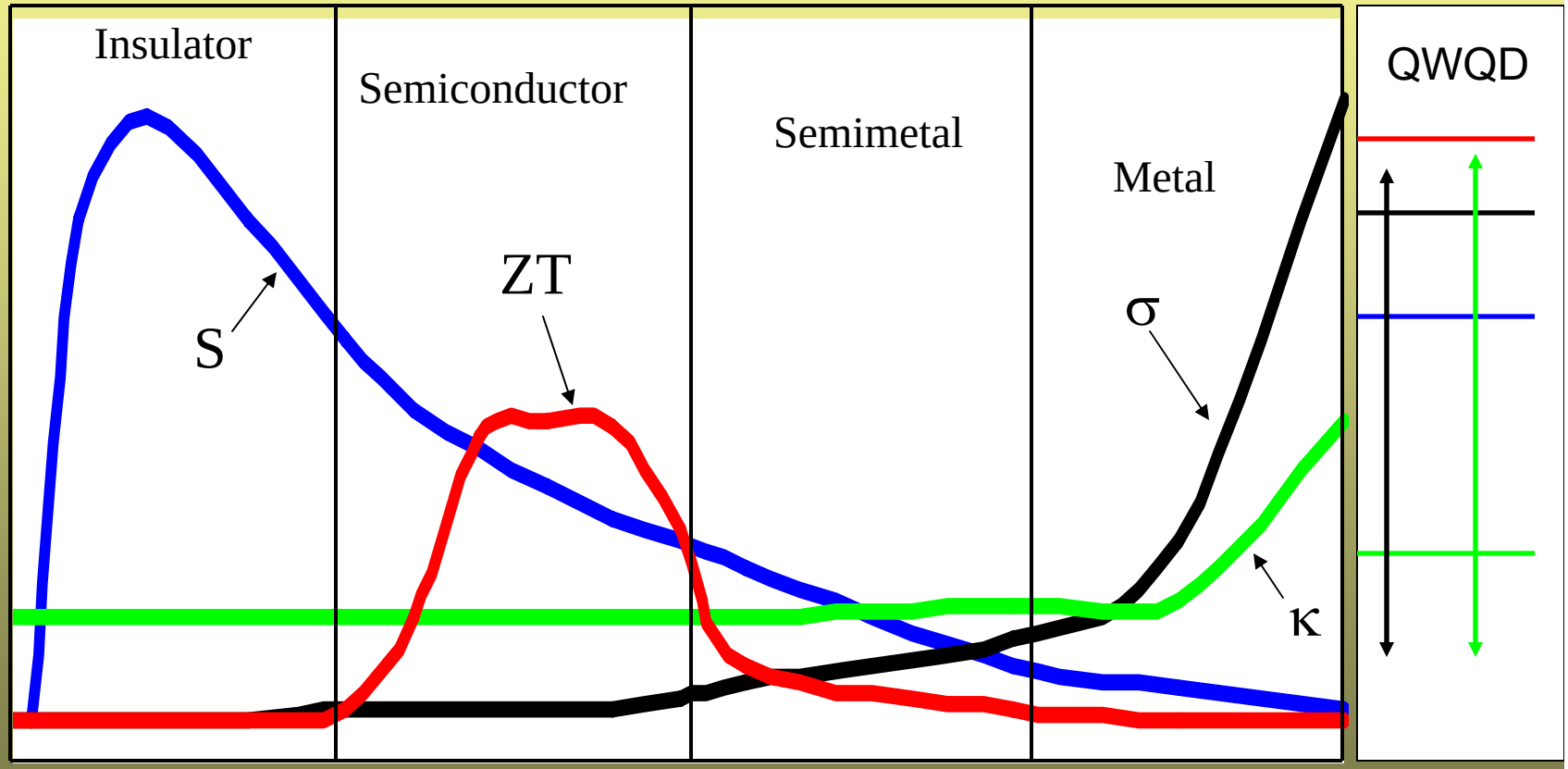
- Increase the Seebeck coefficient S
- Increase the electrical conductivity σ
- Decrease the thermal conductivity κ

Hard to have all three cases (high S value, high σ value, low κ value) simultaneously.

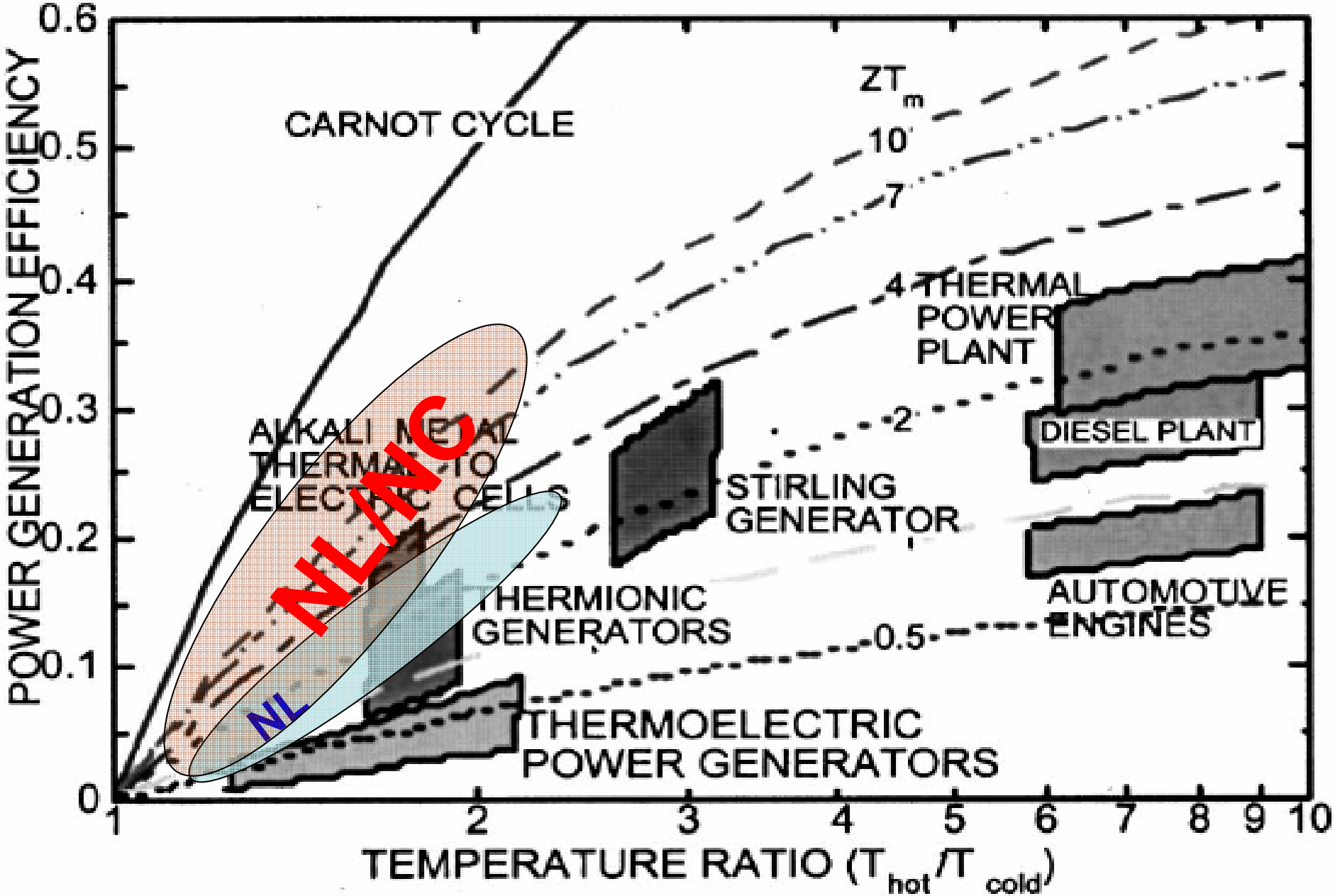
Introduction



$ZT=(S^2\sigma T)/\kappa$

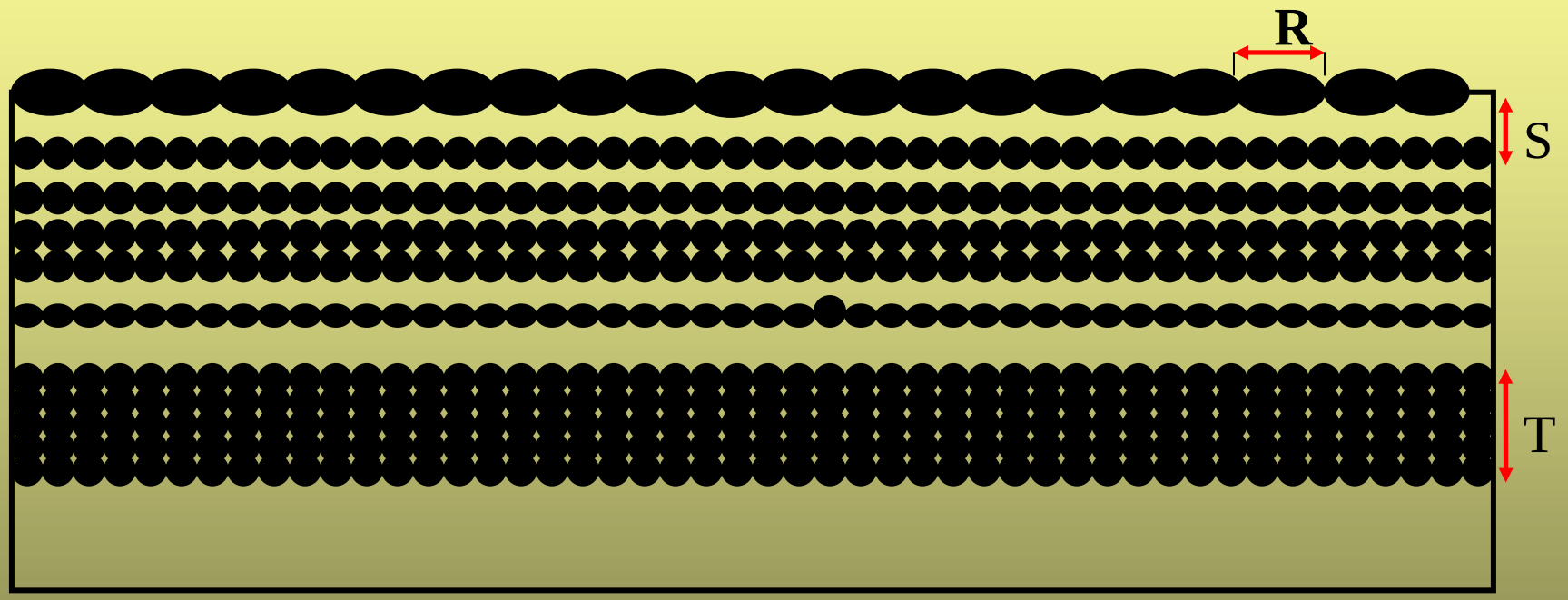


Power Generation Efficiency



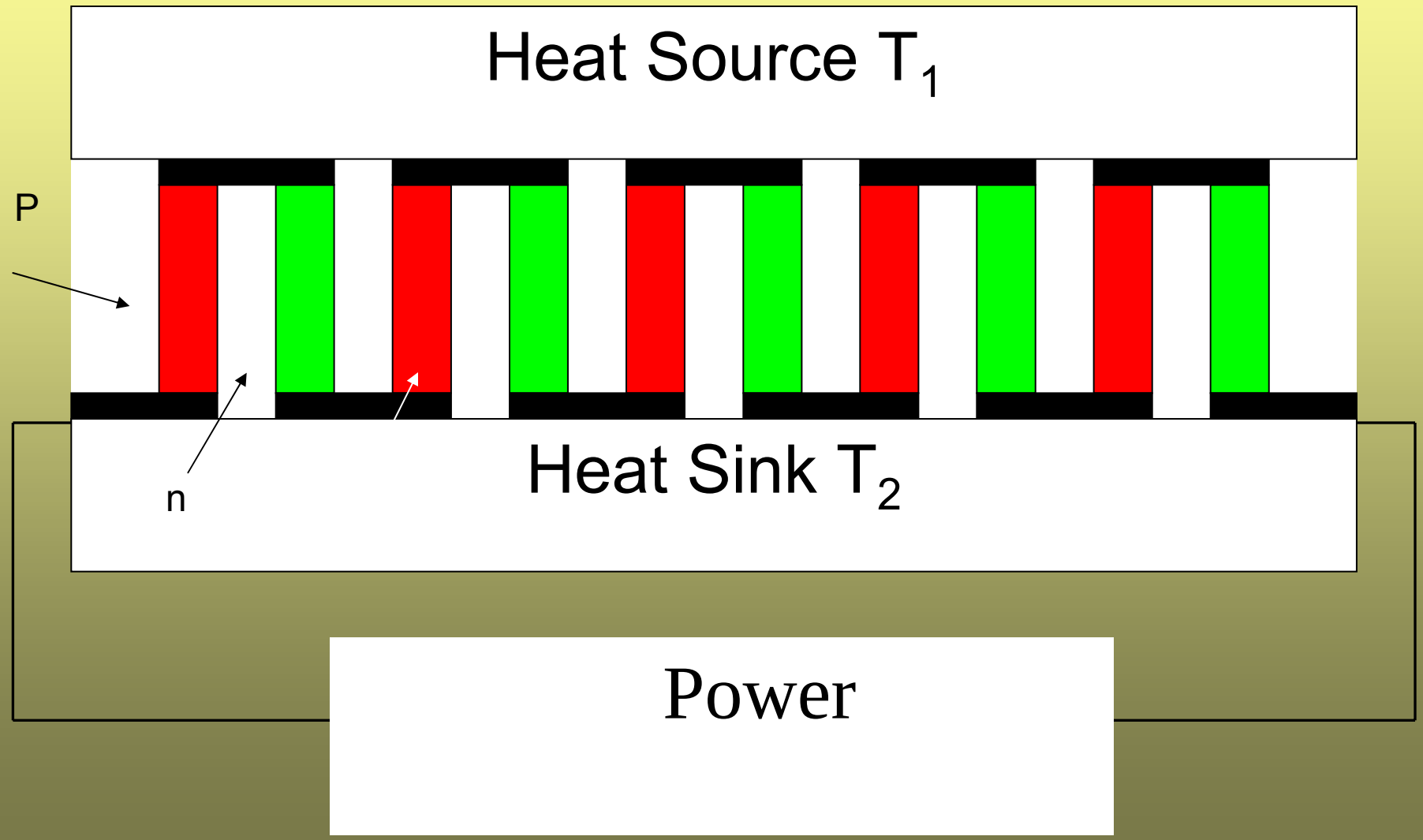
Layered Nano-Structures

Cross section view

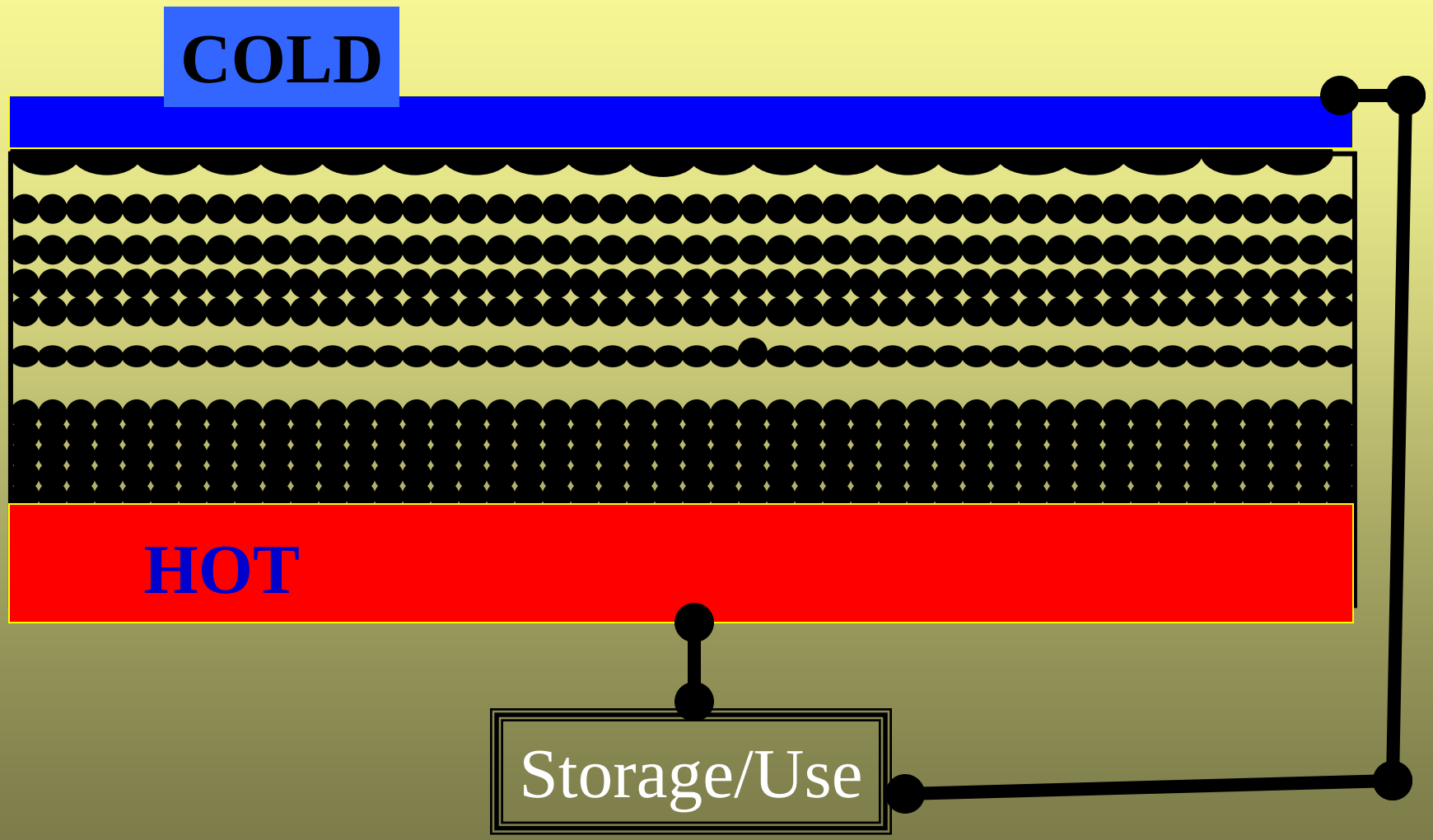


R: QD's Radius
S: Layer Spacing
T: Layer Thickness

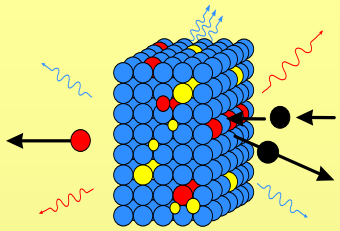
Schematic of thermoelectric module



Thermoelectric Generator using QDQW/NLNC



Summary



- 50 to 1000 NL/QD produced in house.
- NL/QD with
  - reduced thermal conductivity,
  - with increased electrical conductivity,
  - increased Seebeck Coefficient,
- ZT at higher temperature >3 since

$$ZT=(S^2\sigma T)/\kappa$$

High ZT & High Efficiency