U.S. ARMY RDECOM
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

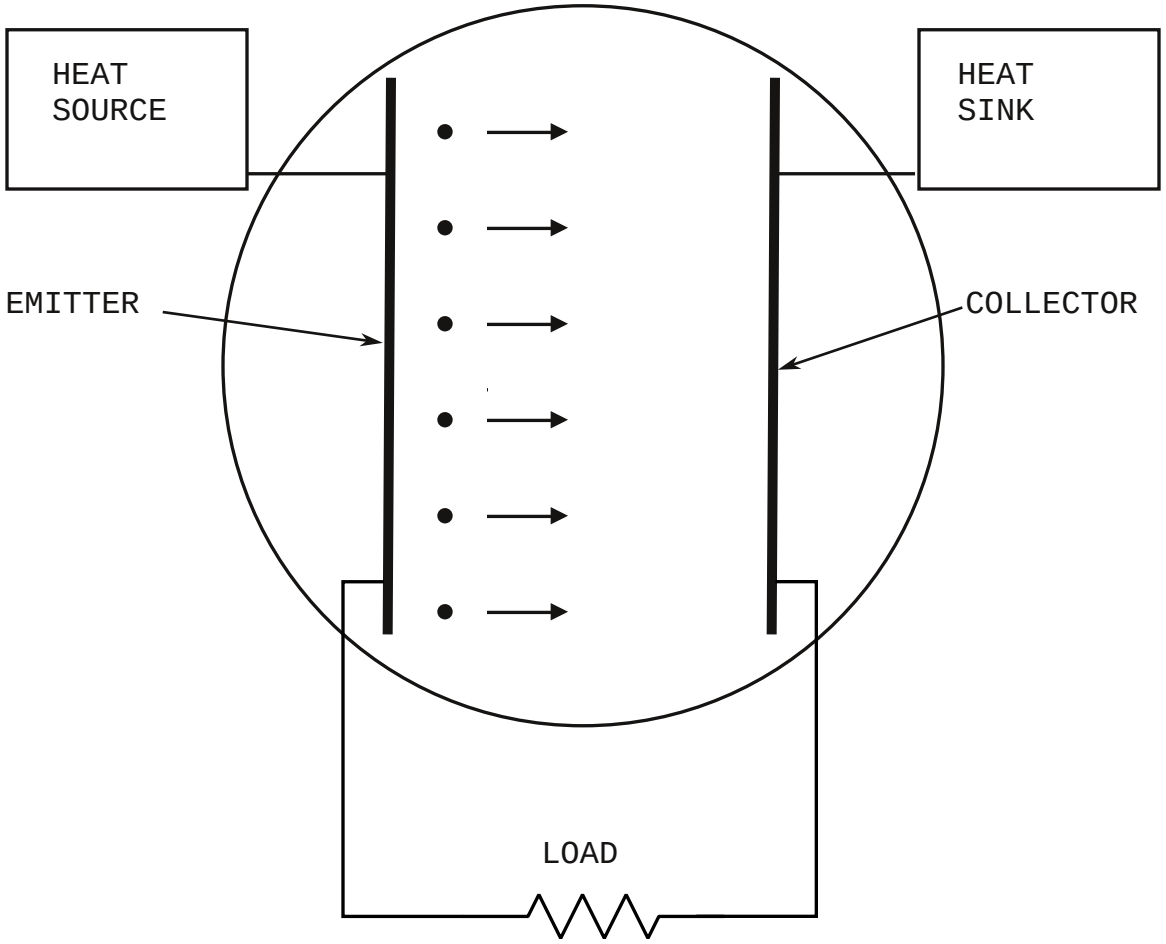
ARL

Achieving >20% efficiency using a vacuum thermionic energy converter featuring a diamond anode

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

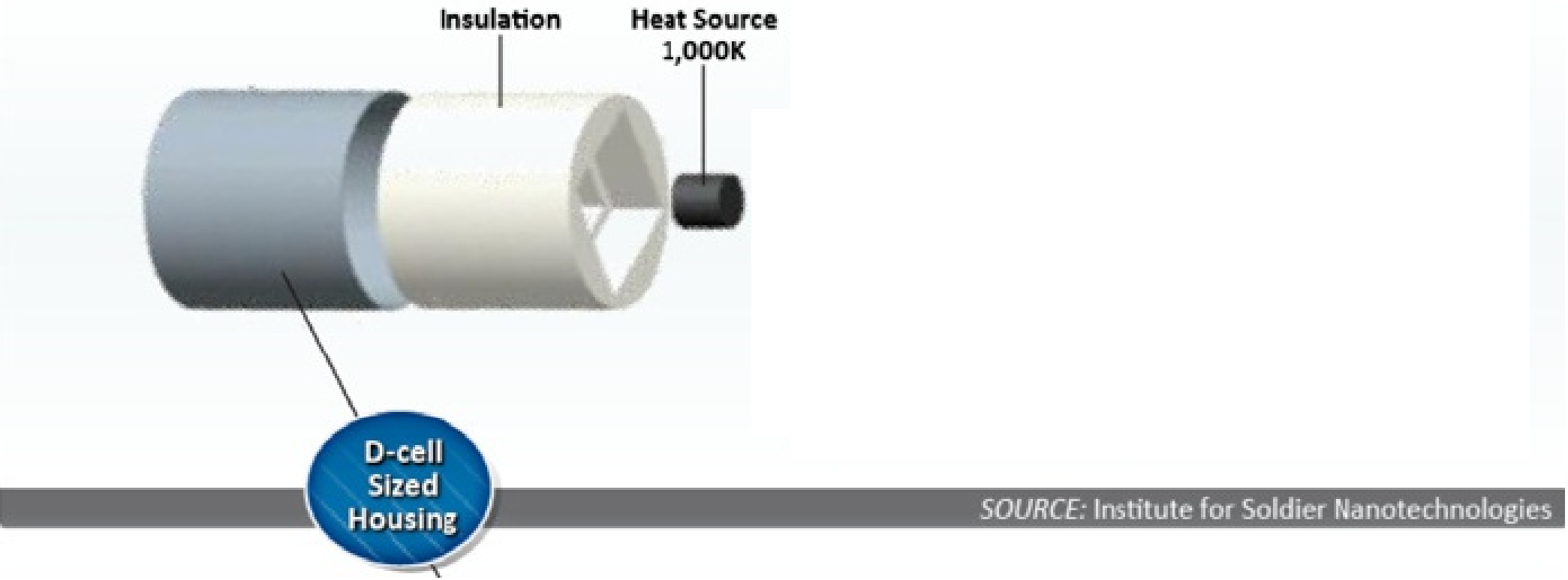
Joshua Ryan Smith
US Army Research Laboratory
ORAU Senior Researcher

Thermoelectron engine

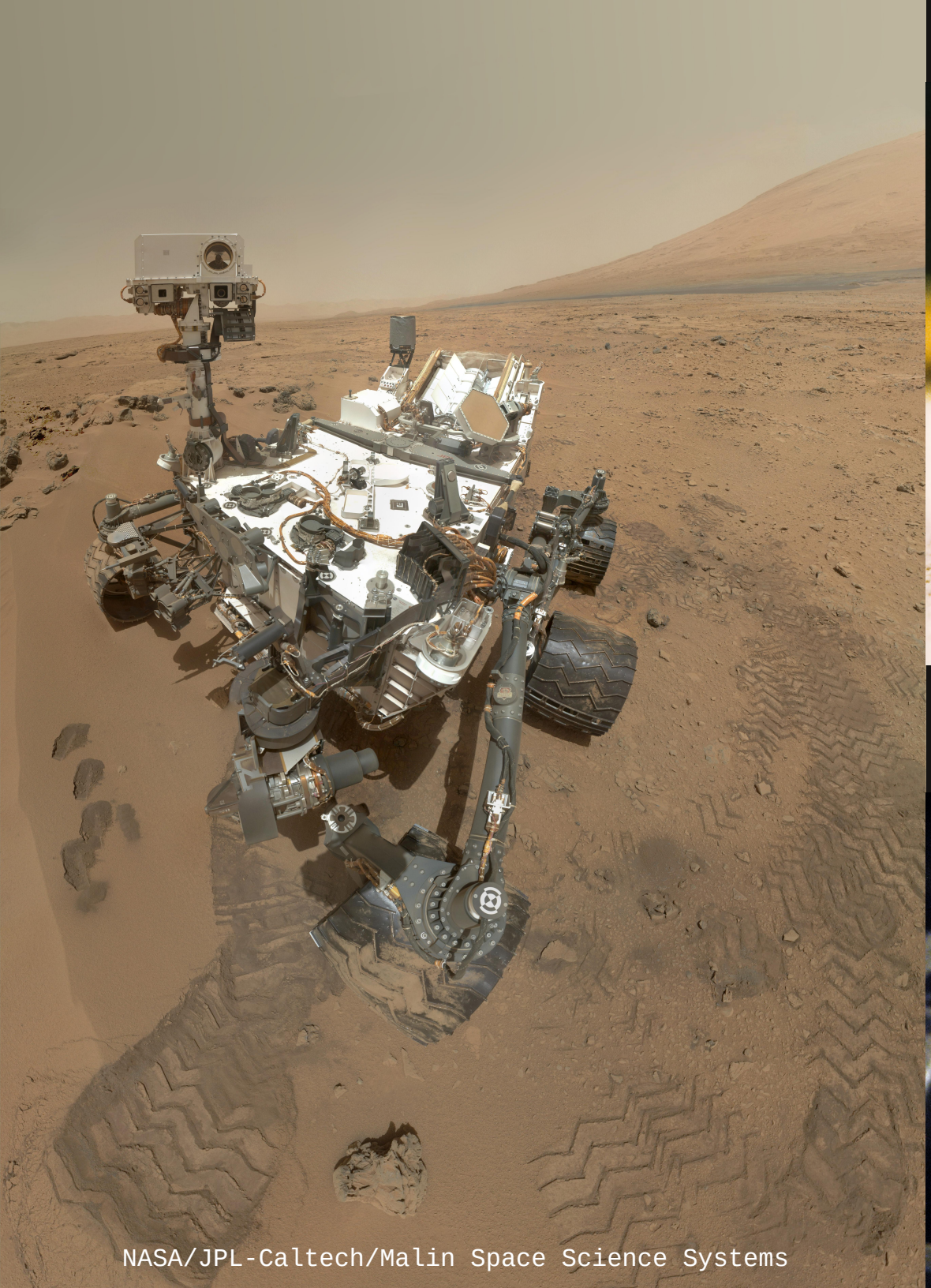


Nuclear battery

[1]



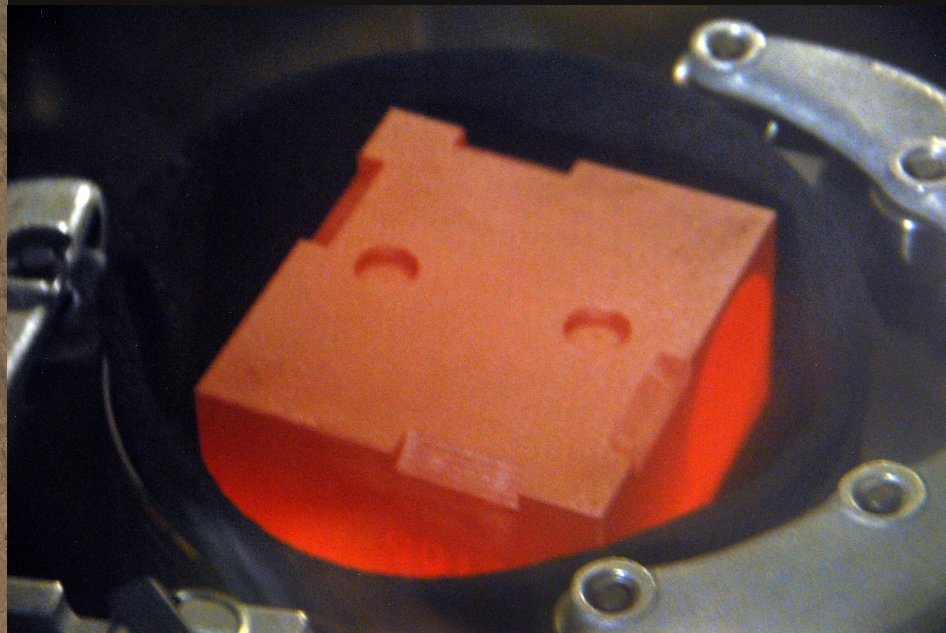
[1] Report of the Defense Science Board study on Technology and Innovation Enablers for Superiority in 2030, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics



NASA/JPL-Caltech/Malin Space Science Systems

$^{238}PuO_2$ used in RTG for Galilleo and Cassini spacecraft.
Los Alamos National Laboratory via Wikipedia

Mars Science Laboratory fuel module
Idaho National Laboratory



(Emitter) work function isn't everything.

Output current (power, efficiency) is limited by the largest barrier encountered by electrons.

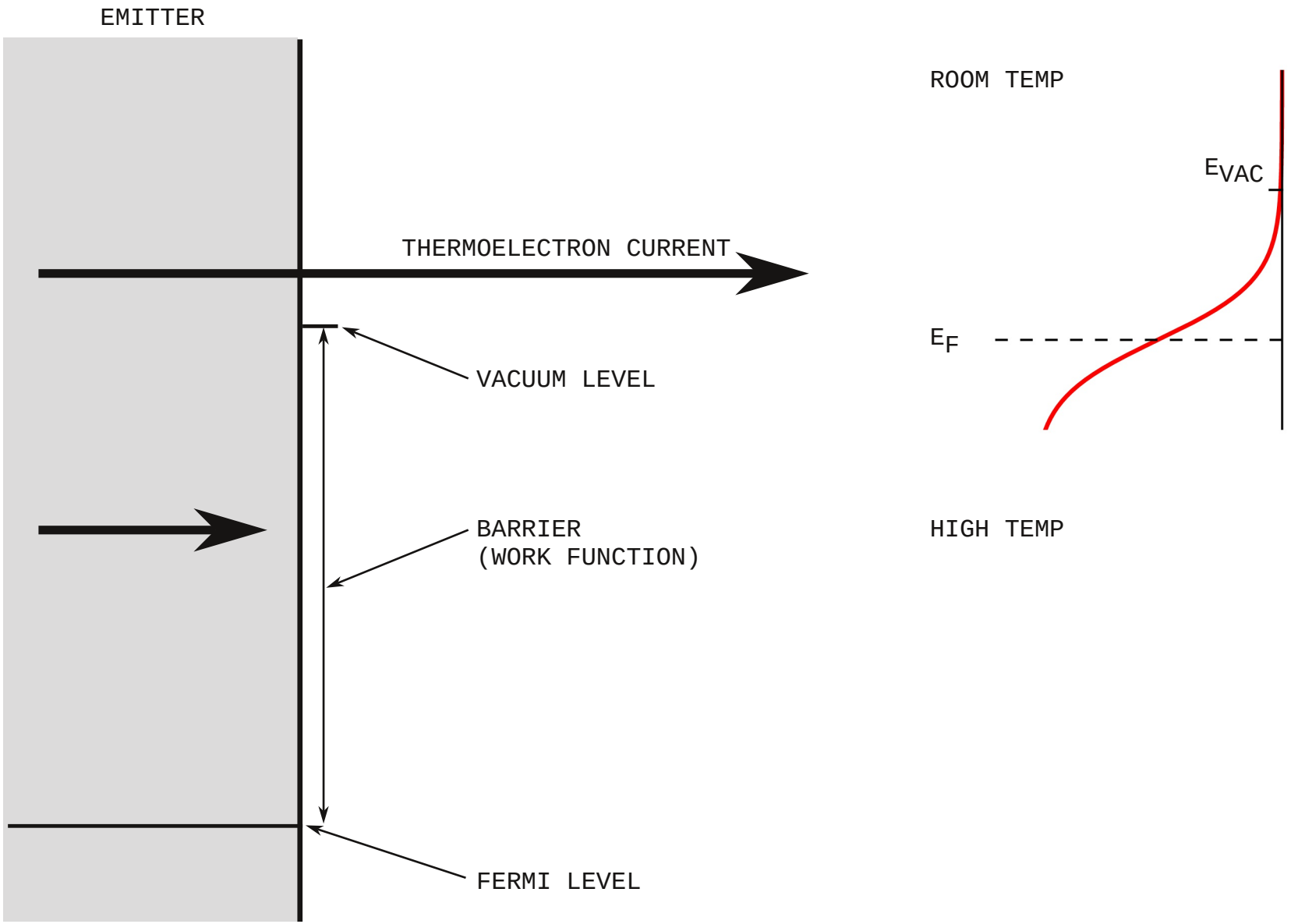
$$J = AT^2 \exp\left(-\frac{\phi}{kT}\right)$$

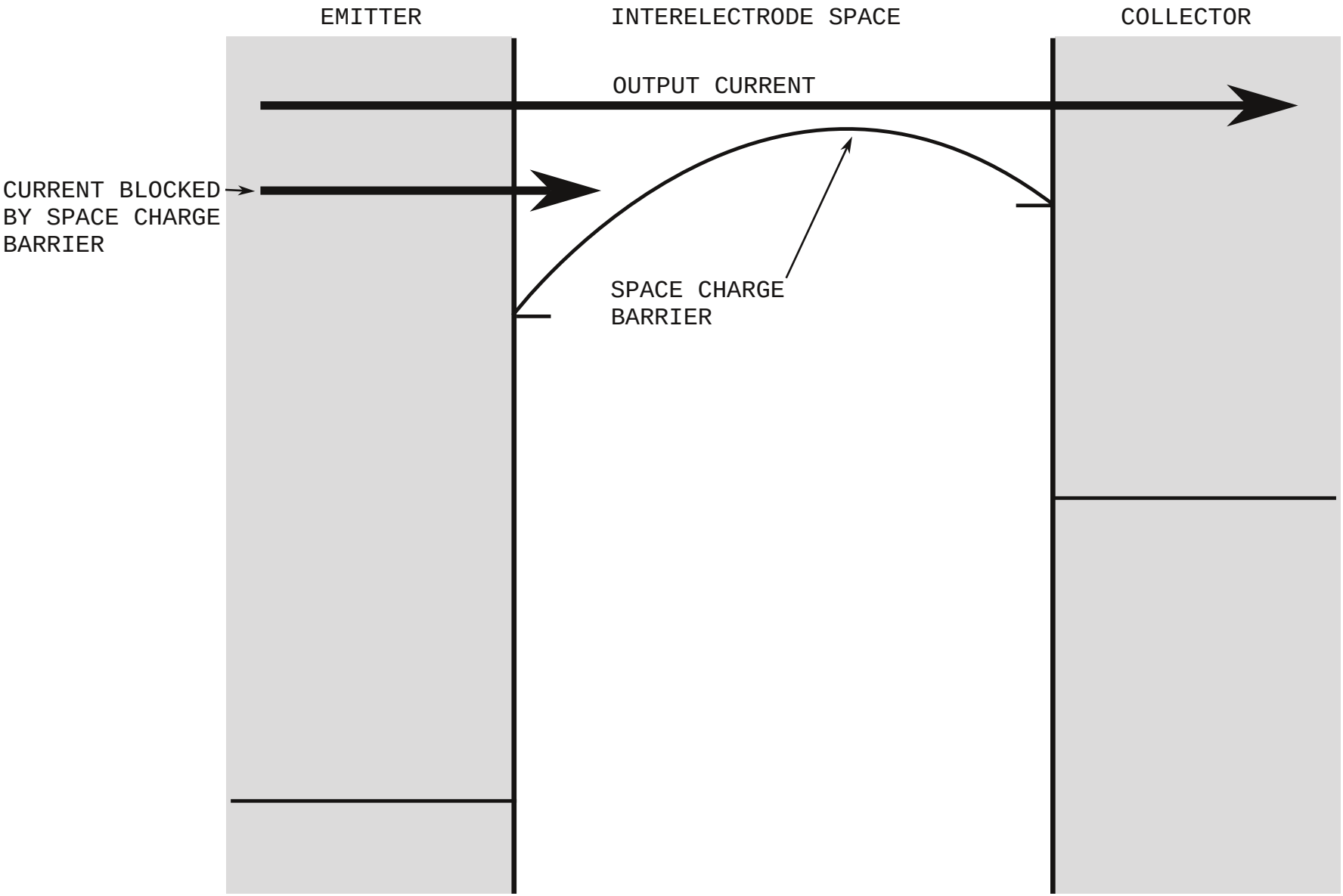
A: Richardson's "constant"

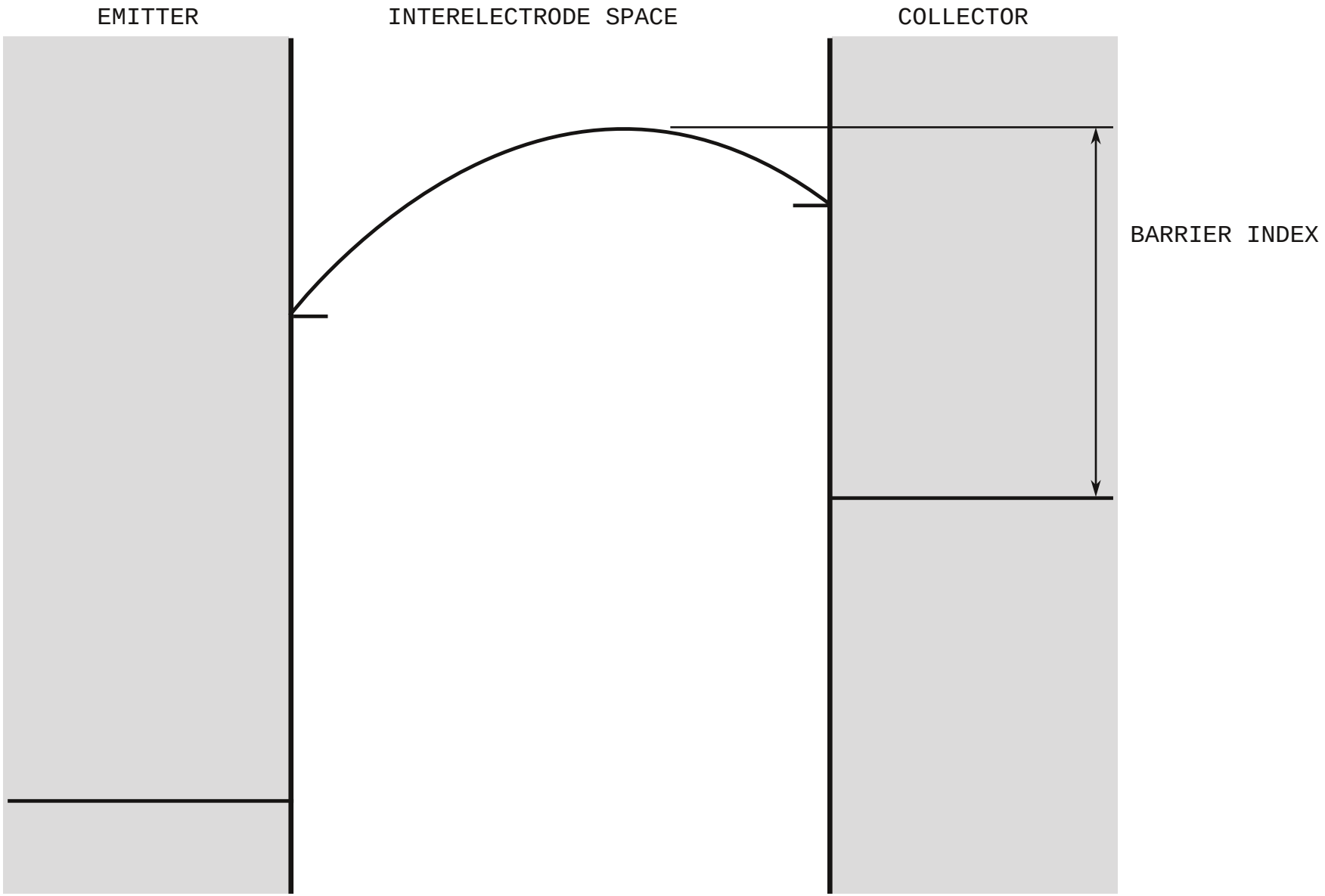
T: temperature

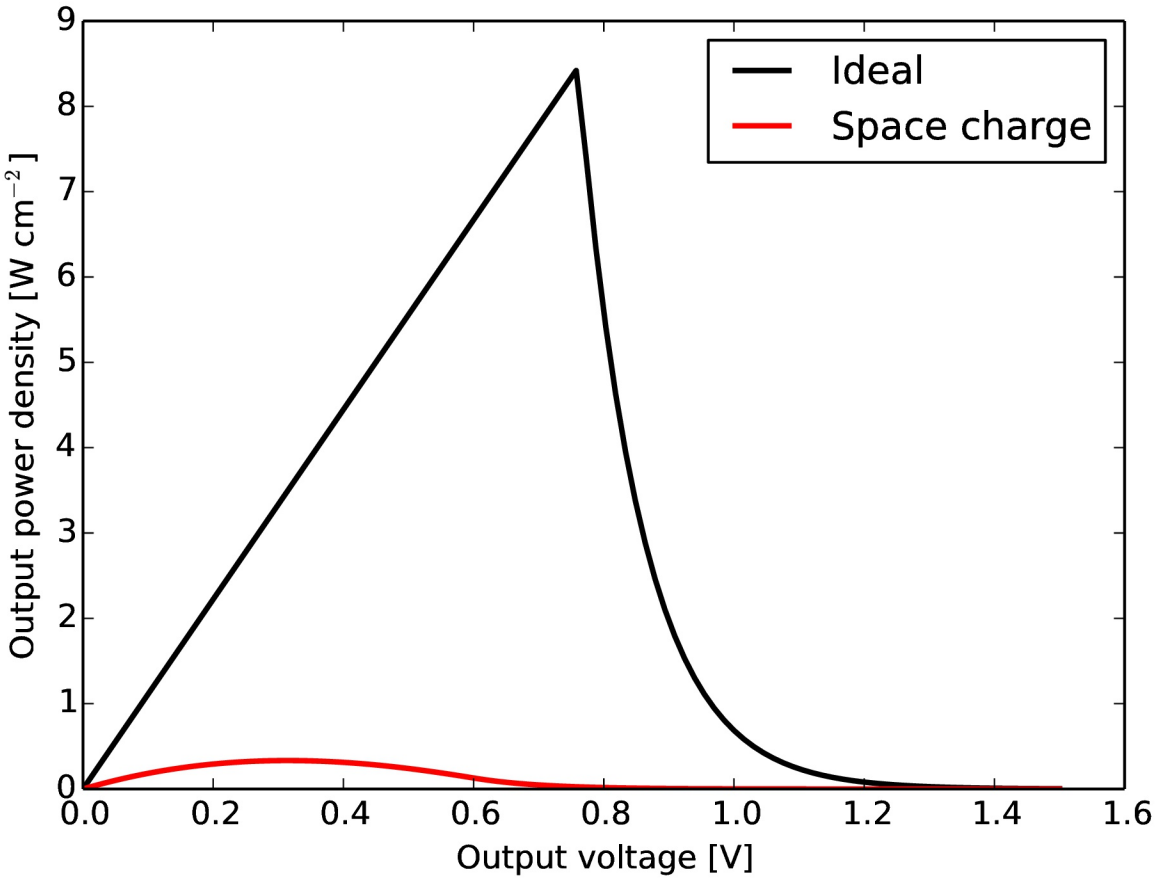
ϕ: work function/barrier

k: Boltzmann's constant









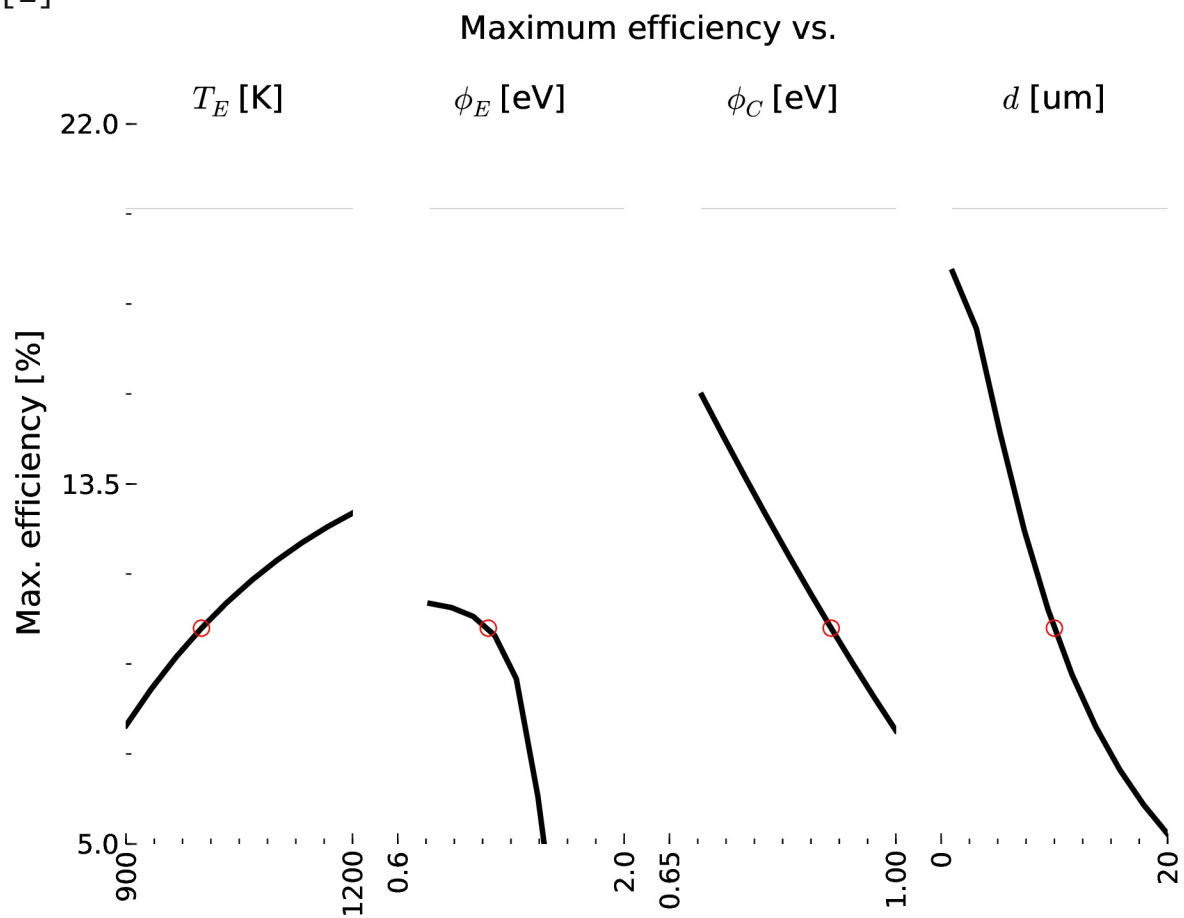
= EMITTER =
MATERIAL = SCANDATE
TEMP = 1000K
BARRIER = 1.16 eV [2]
RICHARD. = 7.8 A cm^{-2} K^{-2} [2]
EMISS. = 0.5

= COLLECTOR =
MATERIAL = DIAMOND
TEMP = 300K
BARRIER = 0.9 eV [3]
RICHARD. = 1e-5 A cm^{-2} K^{-2} [3]
EMISS. = 0.5

INTEREL. DIST. = 10um

Langmuir

[1]



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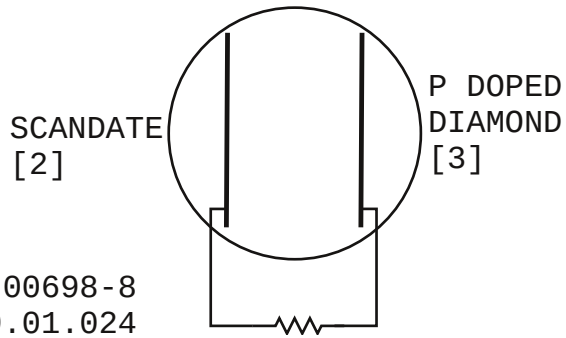
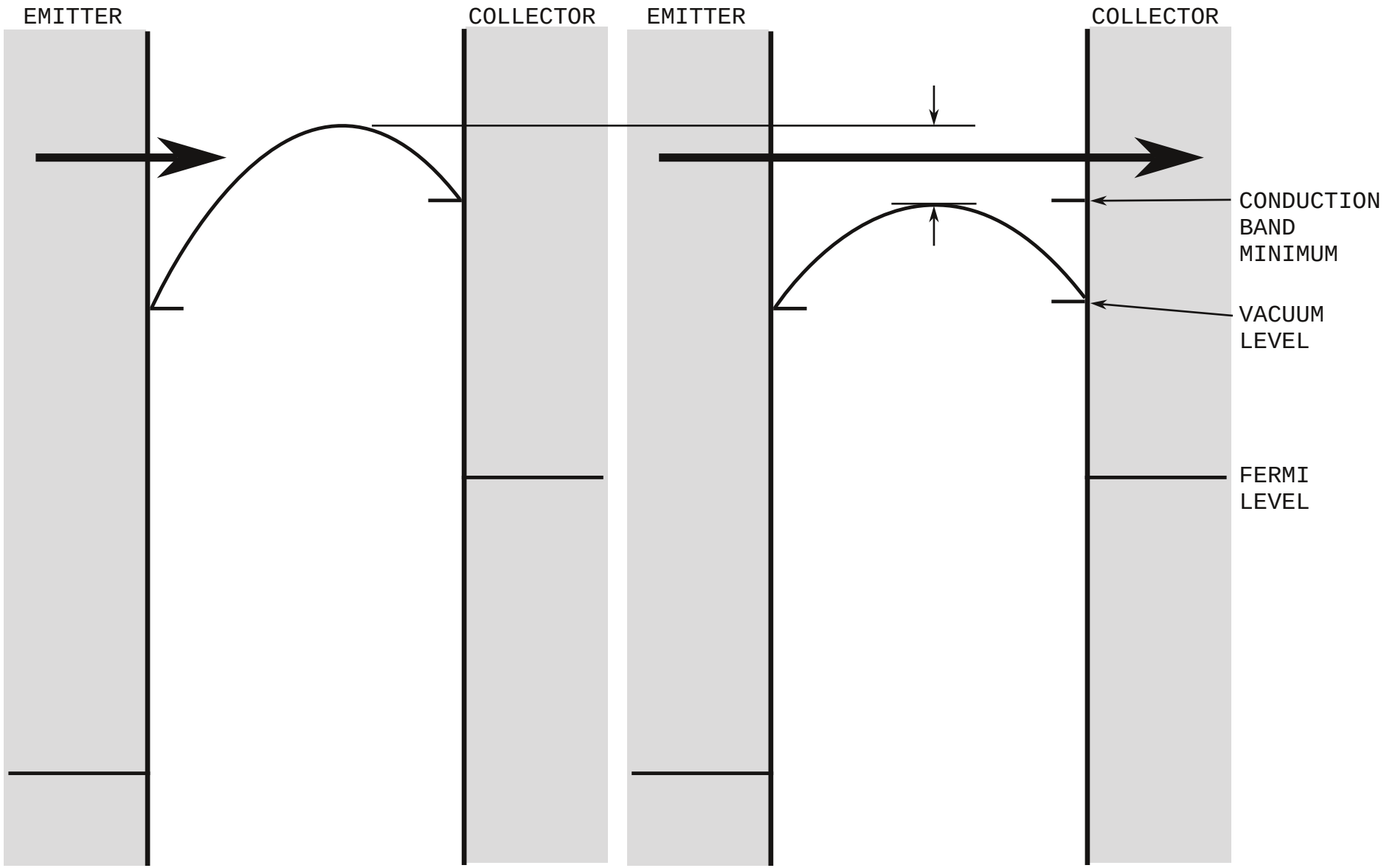


[1] Smith, JAP (2013), 10.1063/1.4826202
[2] Gaertner et.al., Appl Surf Sci (1997), 10.1016/S0169-4332(96)00698-8
[3] Koeck et.al. Diam Relat Mater, (2009), 10.1016/j.diamond.2009.01.024

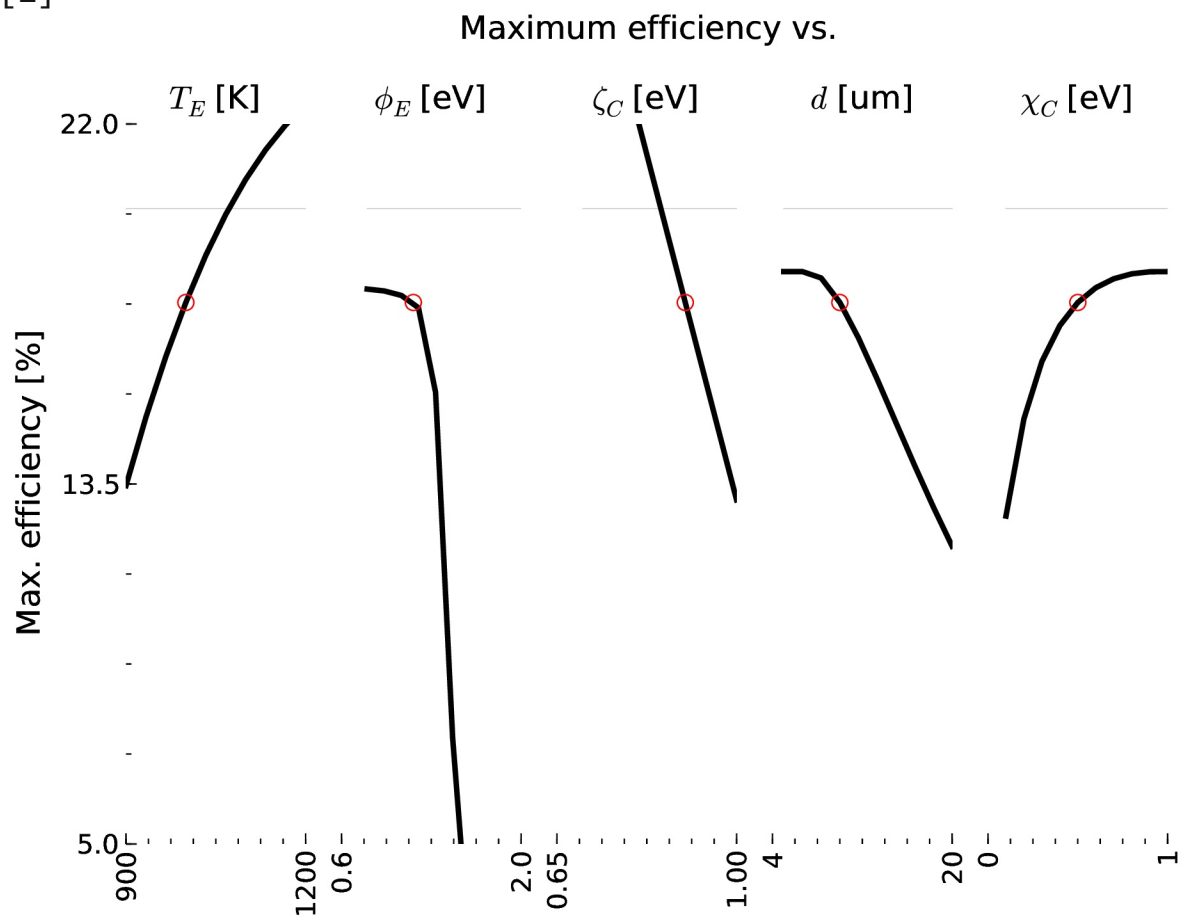
COLLECTOR WITHOUT NEA

COLLECTOR WITH NEA



Phosphorus doped diamond

[1]



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TEMP = 1000K
BARRIER = 1.16 eV [2]
RICHARD. = 7.8 A cm^{-2} K^{-2} [2]
EMISS. = 0.5

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MATERIAL = DIAMOND
TEMP = 300K
BARRIER = 0.9 eV [3]
NEA = 0.5 eV
RICHARD. = 1e-5 A cm^{-2} K^{-2} [3]
EMISS. = 0.5

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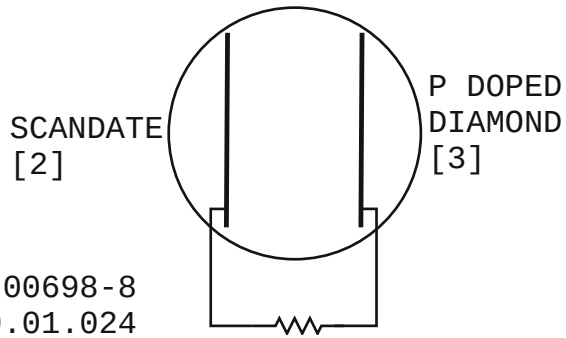

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Results

DoD nuke battery
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assuming:
r = 0.5 cm
h = 1 cm

output power at maximum efficiency for given size
Langmuir = 1.5 W
NEAC = 4.9 W

Curiosity rover
==========
assuming: 125W output

Size at maximum efficiency to achieve power target
Langmuir (0.31 W cm^-2 * 399 cm^2): r = 4.6 cm, h = 9.2 cm
NEAC: (1.03 W cm^-2 * 121 cm^2): r = 2.5 cm, h = 5 cm

github.com/jrsmith3/tec