

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

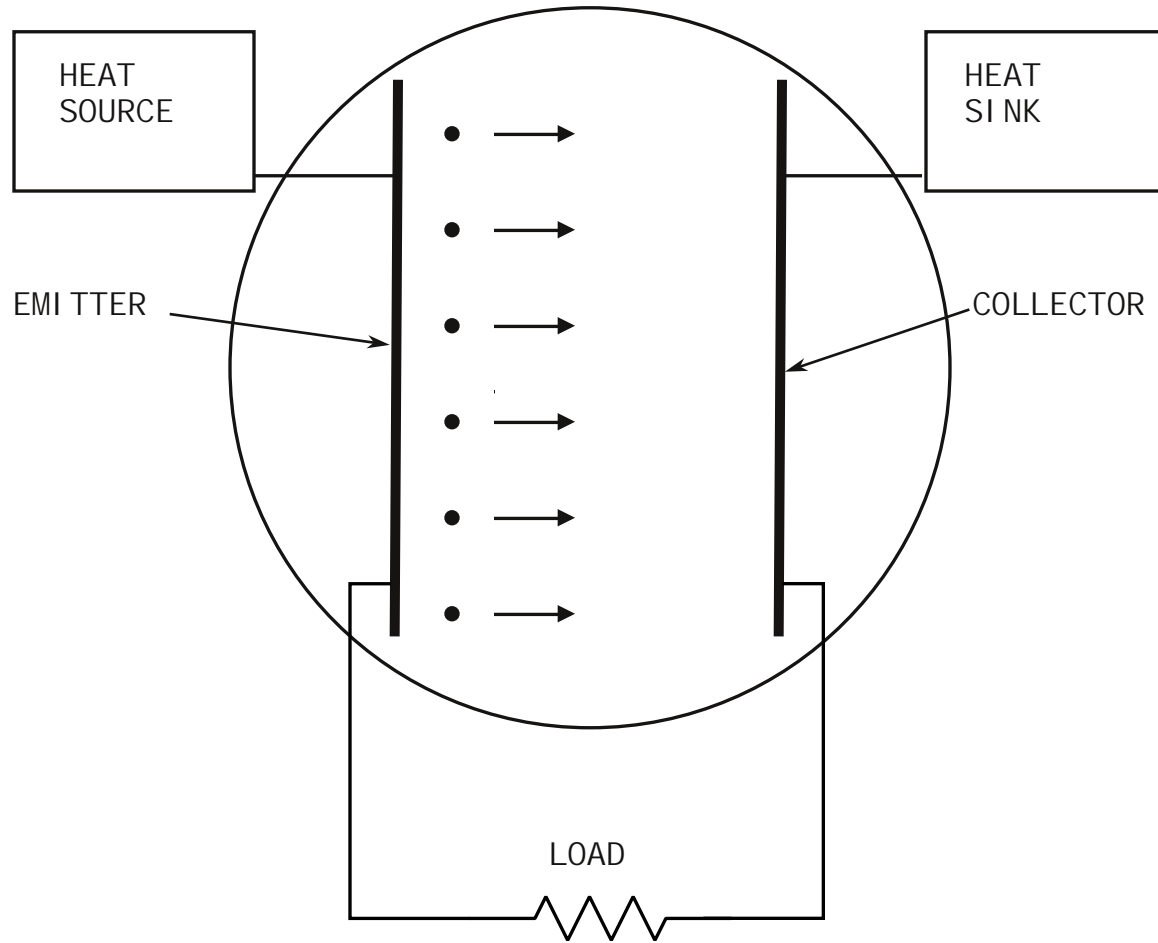
**ARL**

**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

Joshua Ryan Smith  
US Army Research Laboratory  
ORAU Senior Researcher

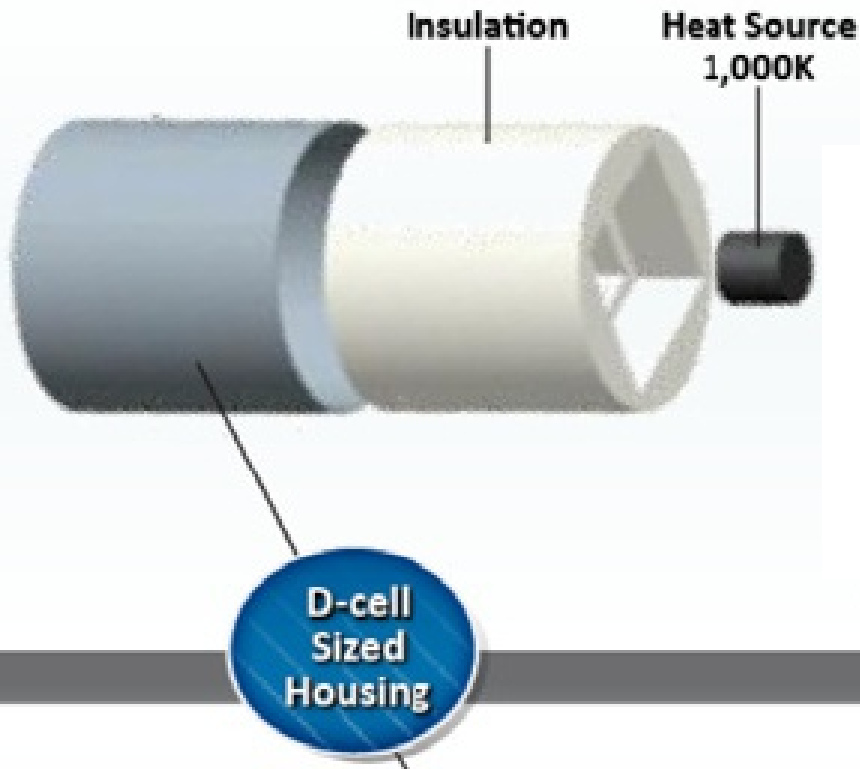
**TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.**

# Thermoelectron engine



# Nuclear battery

[1]

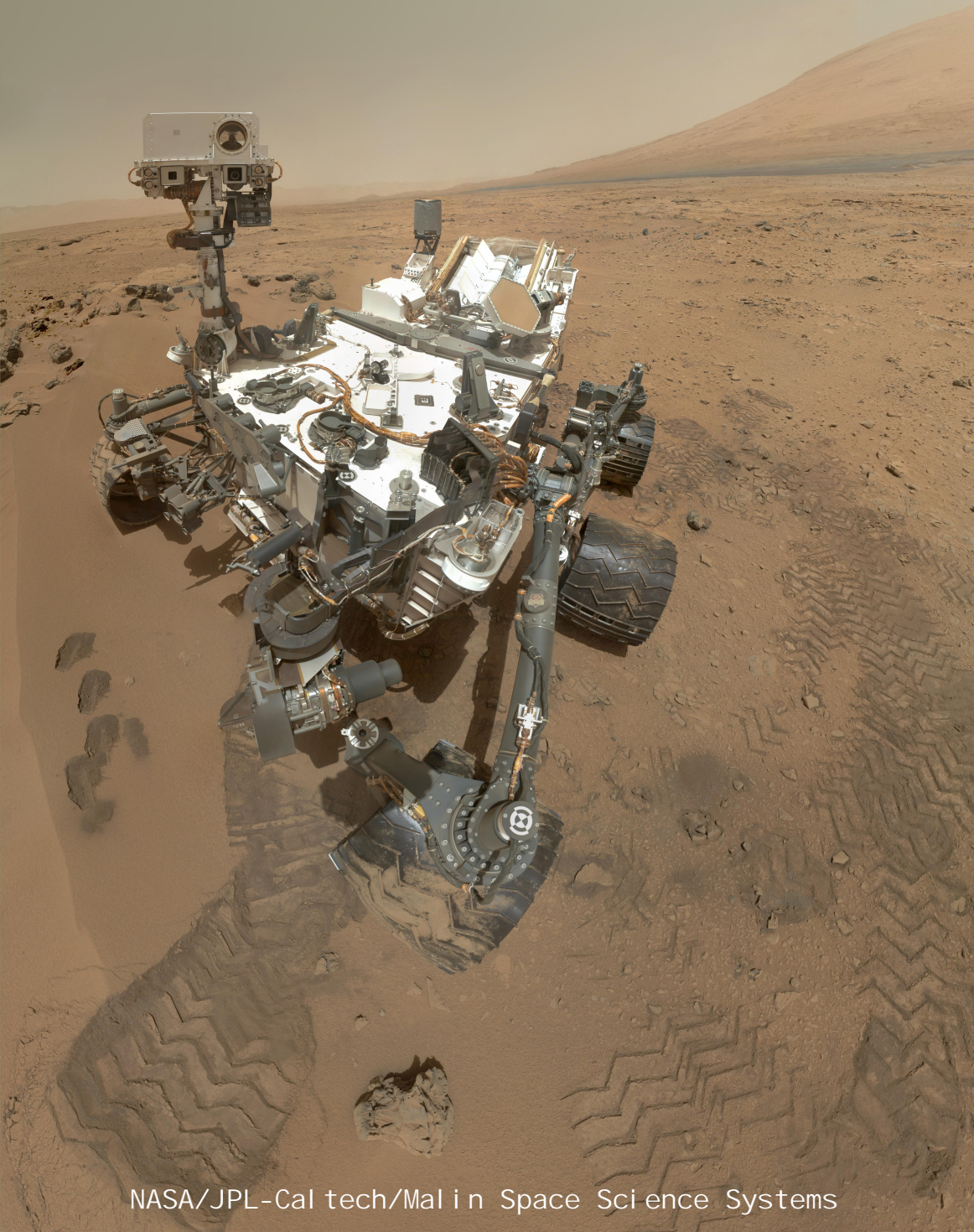


SOURCE: Institute for Soldier Nanotechnologies

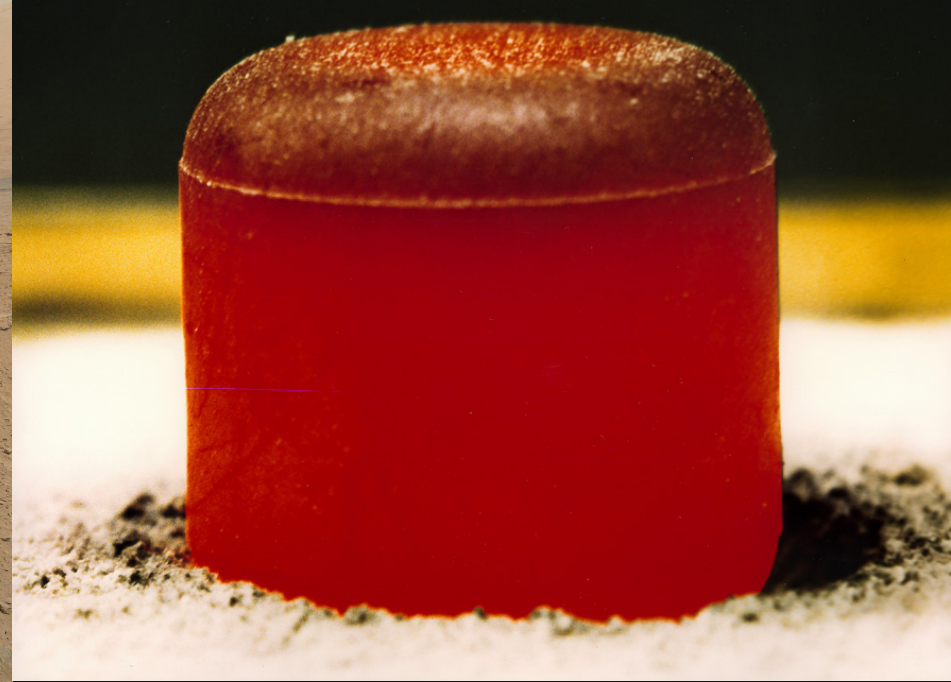
[1] Report of the Defense Science Board study on Technology and Innovation Enablers for Superiority in 2030, Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics



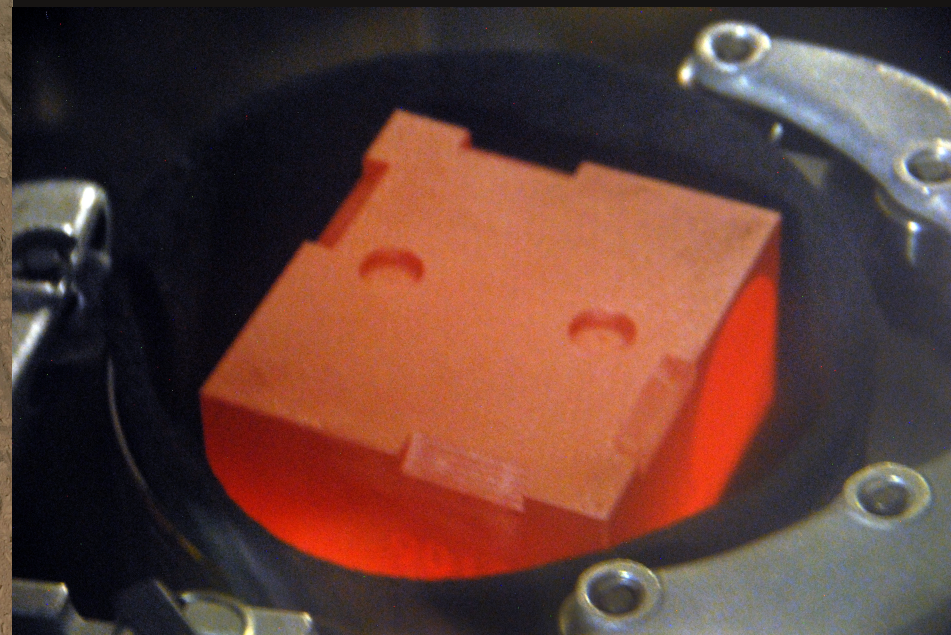
$^{238}\text{PuO}_2$  used in RTG for Galileo and Cassini spacecraft.  
Los Alamos National Laboratory via Wikipedia



NASA/JPL-Caltech/Malin Space Science Systems



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.



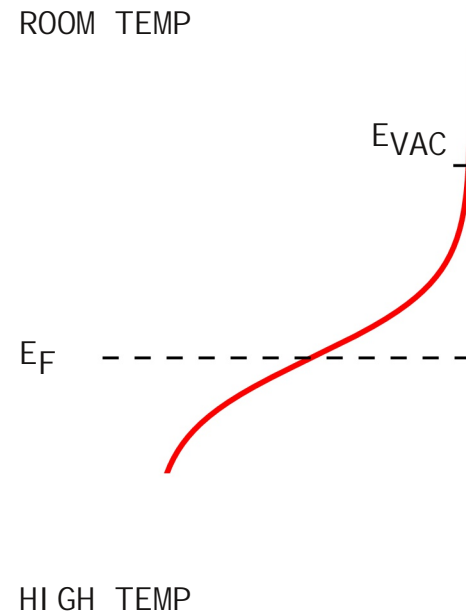
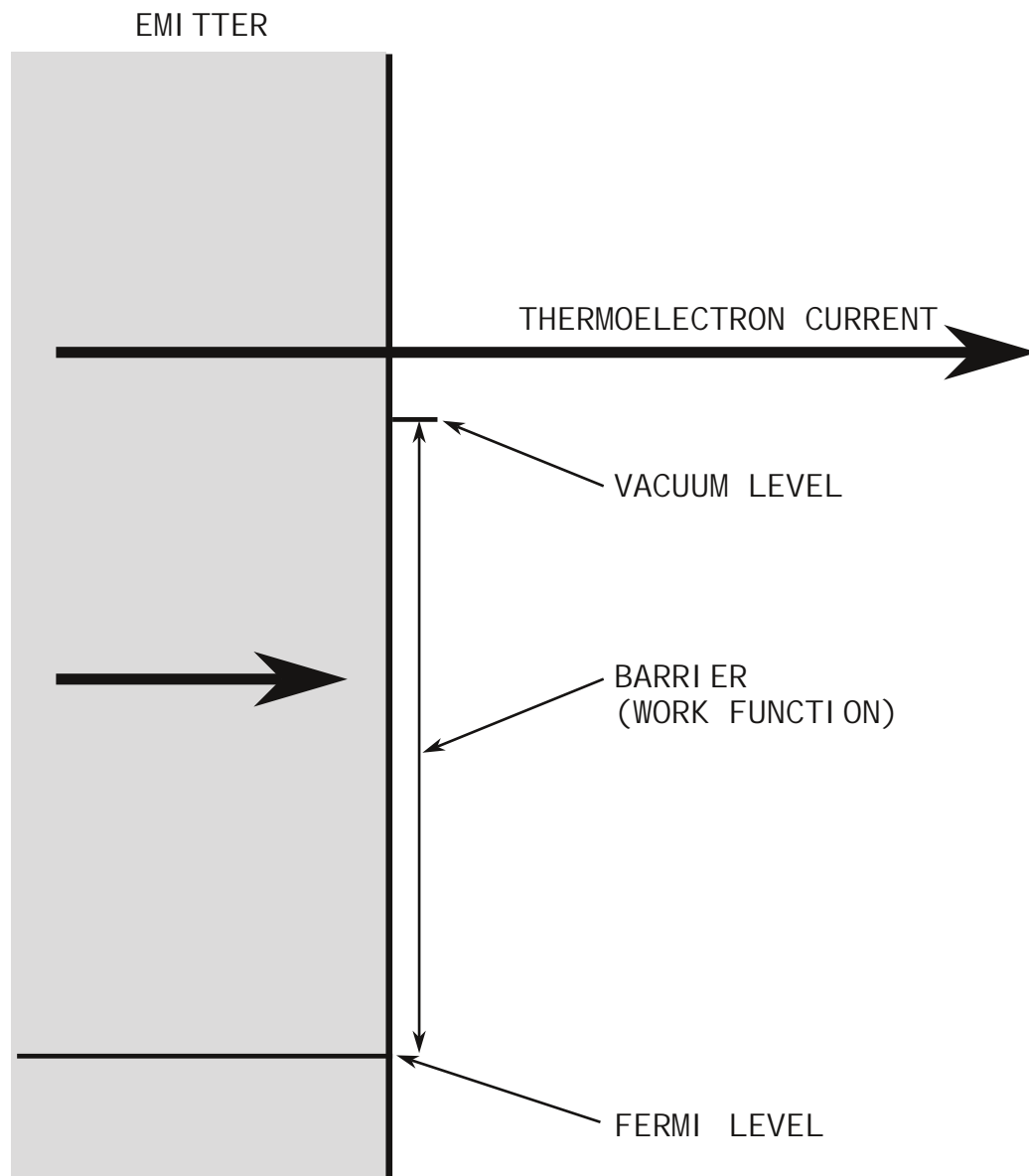
$$J = AT^2 \exp\left(-\frac{\phi}{kT}\right)$$

$A$ : Richardson's "constant"

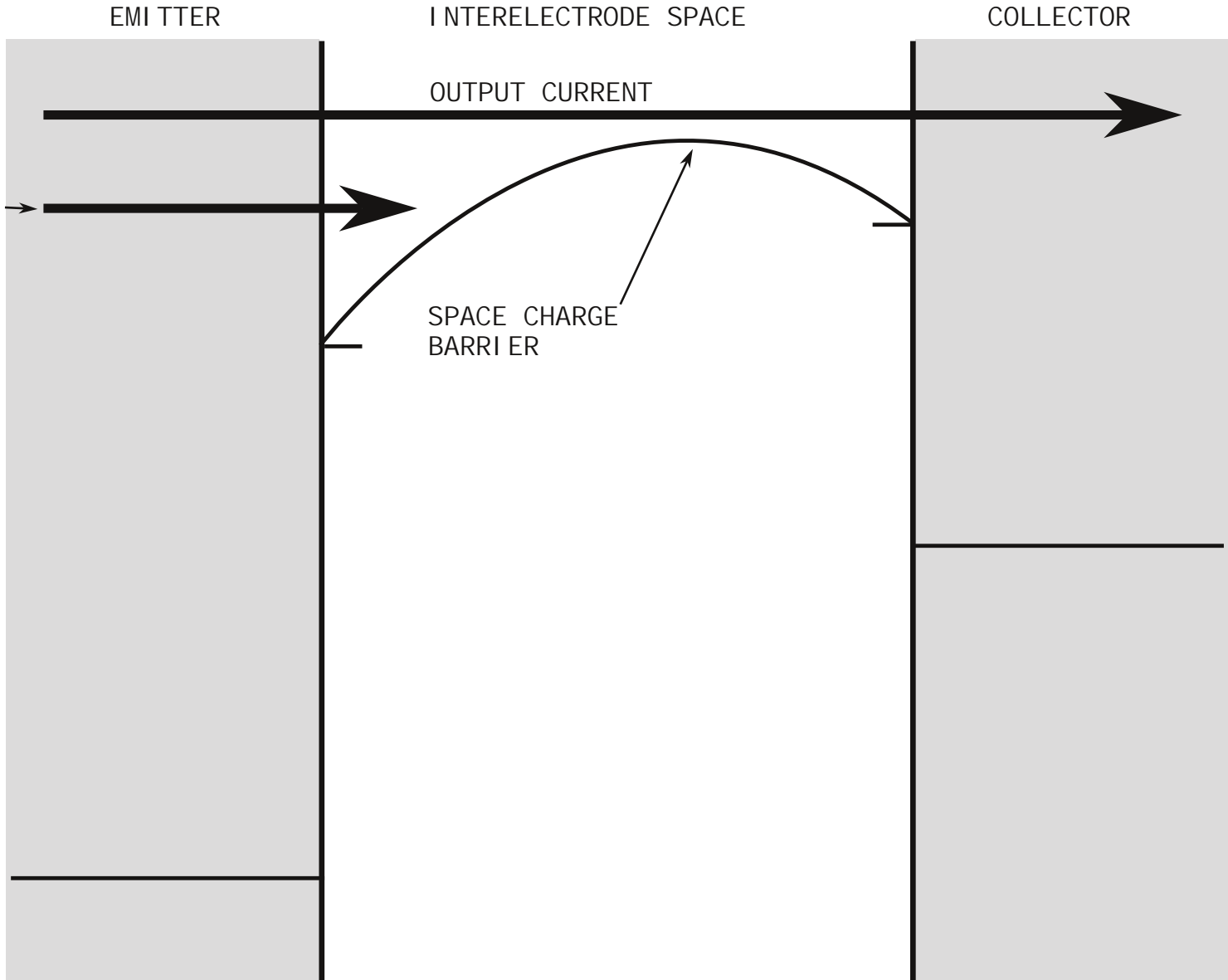
$T$ : temperature

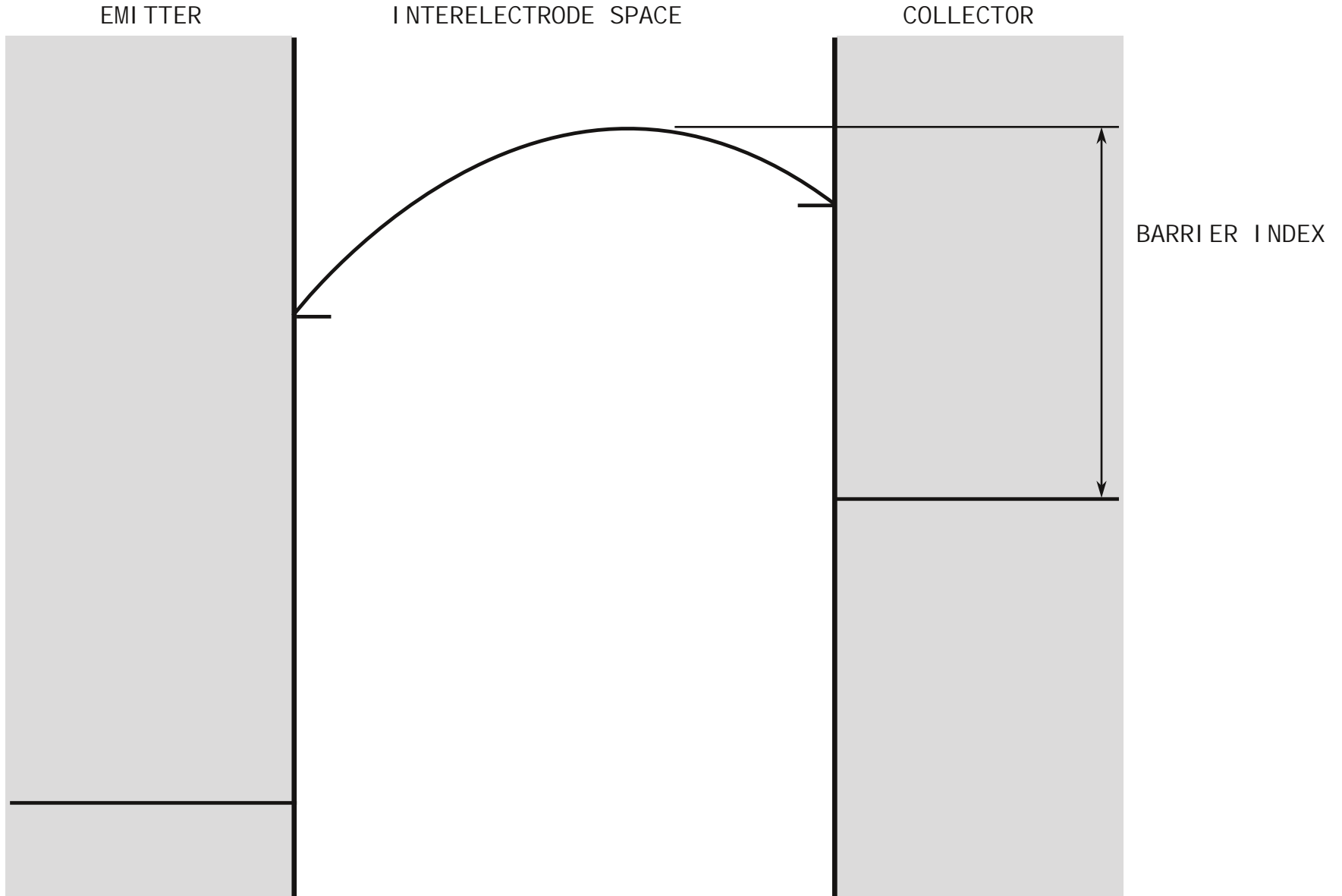
$\phi$ : work function/barrier

$k$ : Boltzmann's constant

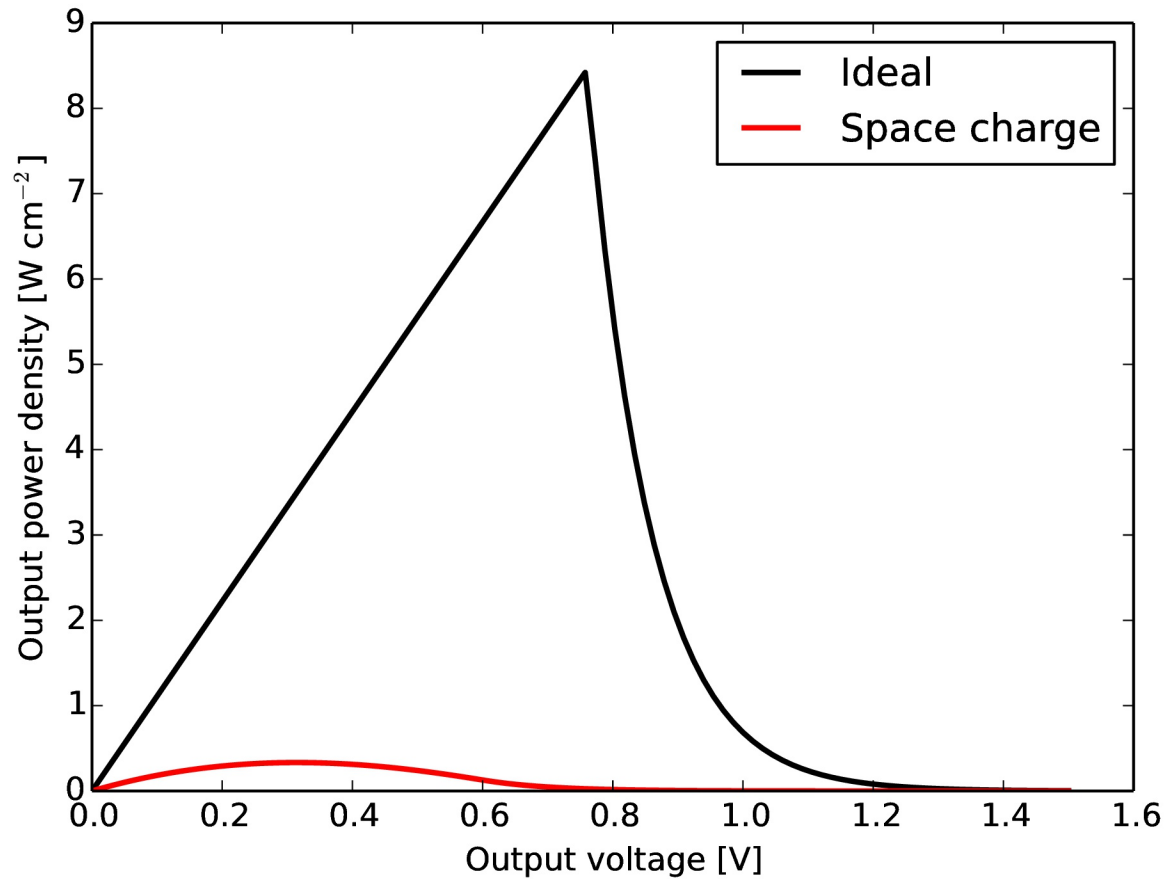












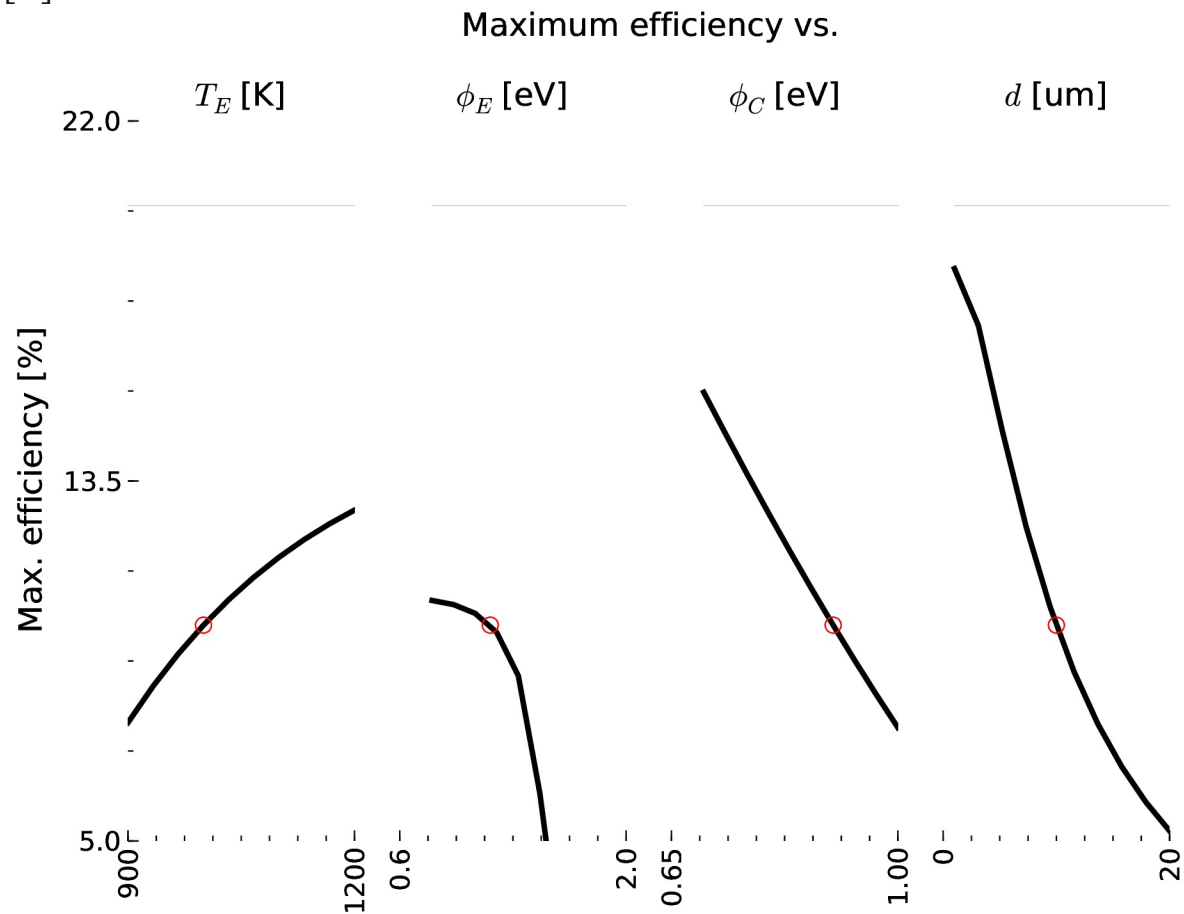
= EMITTER =  
 MATERIAL = SCANDATE  
 TEMP = 1000K  
 BARRIER = 1.16 eV [2]  
 RICHARD. = 7.8 A cm<sup>-2</sup> K<sup>-2</sup> [2]  
 EMISS. = 0.5

= COLLECTOR =  
 MATERIAL = DIAMOND  
 TEMP = 300K  
 BARRIER = 0.9 eV [3]  
 RICHARD. = 1e-5 A cm<sup>-2</sup> K<sup>-2</sup> [3]  
 EMISS. = 0.5

INTEREL. DIST. = 10um

# Langmuir

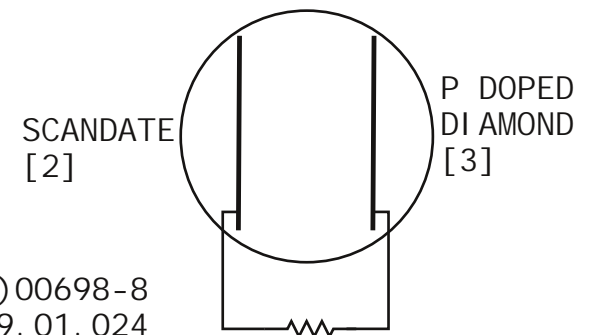
[1]



= EMITTER =  
 MATERIAL = SCANDATE  
 TEMP = 1000K  
 BARRIER = 1.16 eV [2]  
 RICHARD. = 7.8 A cm<sup>-2</sup> K<sup>-2</sup> [2]  
 EMISS. = 0.5

= COLLECTOR =  
 MATERIAL = DIAMOND  
 TEMP = 300K  
 BARRIER = 0.9 eV [3]  
 RICHARD. = 1e-5 A cm<sup>-2</sup> K<sup>-2</sup> [3]  
 EMISS. = 0.5

INTEREL. DIST. = 10um



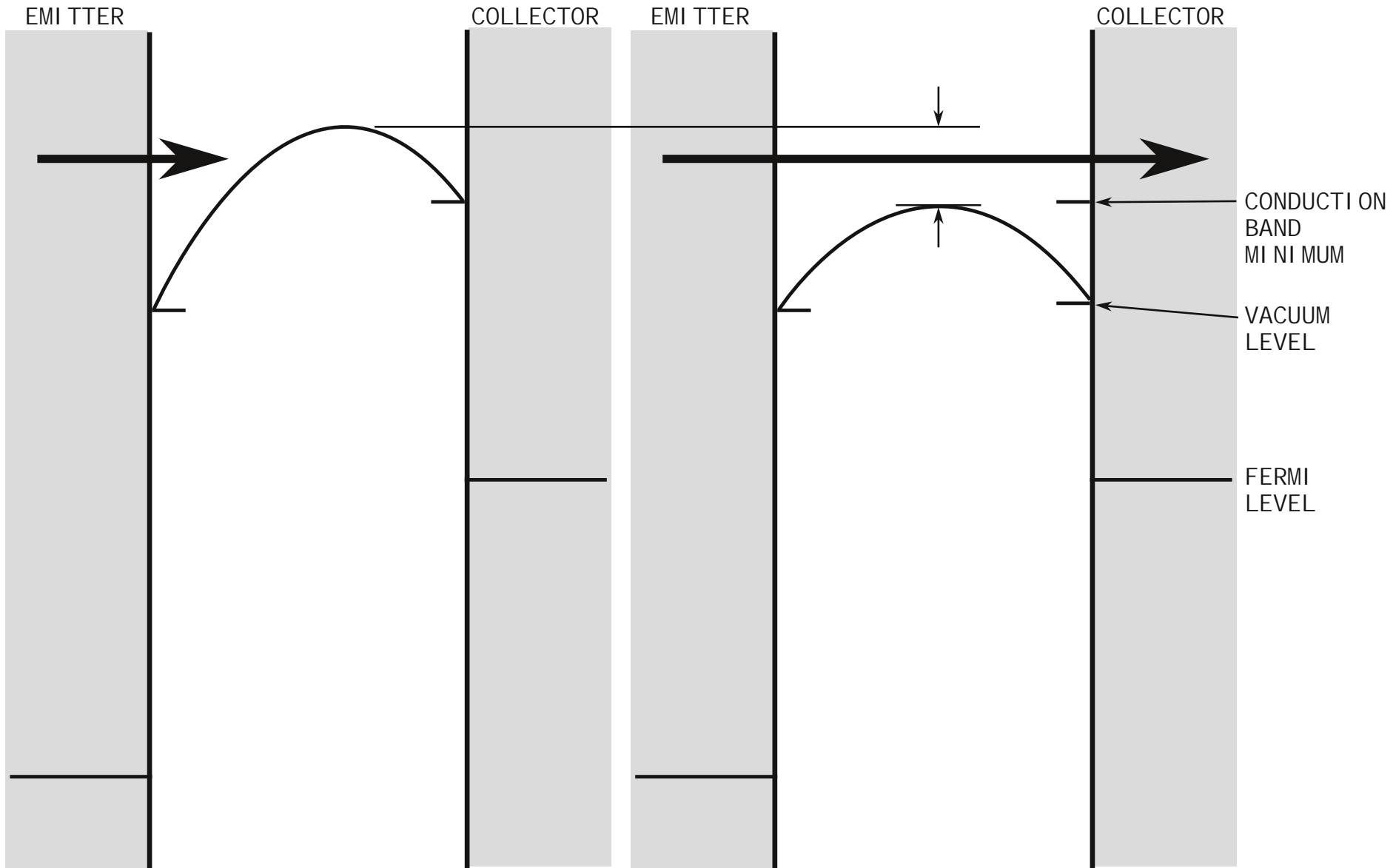
[1] Smith, JAP (2013), 10.1063/1.4826202

[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

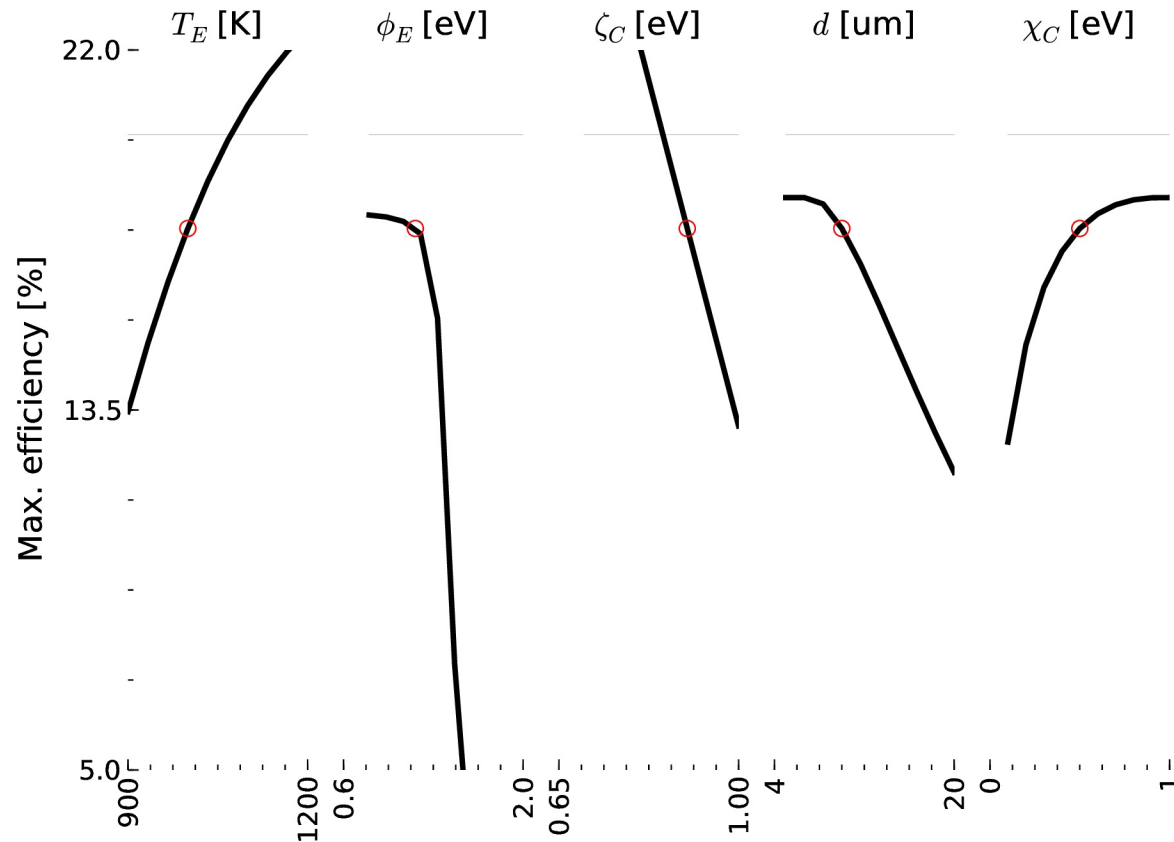
COLLECTOR WITH NEA



# Phosphorus doped diamond

[1]

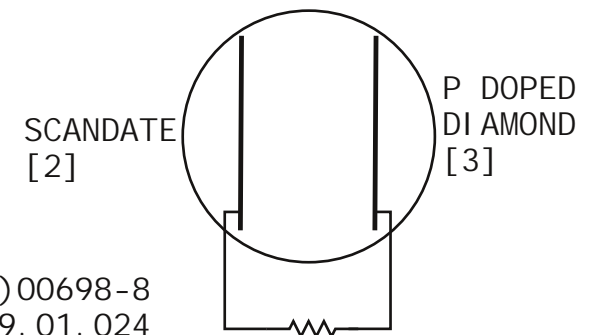
Maximum efficiency vs.



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

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

INTEREL. DIST. = 10um



[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

# Results

DoD nuke battery

=====

assumi ng:

r = 0.5 cm

h = 1 cm

output power at maximum effi ciency for gi ven si ze

Langmui r = 1.5 W

NEAC = 4.9 W

Curi osi ty rover

=====

assumi ng: 125W output

Size at maximum effi ciency to achieve power target

Langmui r (0.31 W cm<sup>-2</sup> \* 399 cm<sup>2</sup>): r = 4.6 cm, h = 9.2 cm

NEAC: (1.03 W cm<sup>-2</sup> \* 121 cm<sup>2</sup>): r = 2.5 cm, h = 5 cm

# github.com/jrsmith3/tec

jrsmith3/tec

247 commits 3 branches 5 releases 1 contributor

branch: master tec / +

Added CITATION file.

jrsmith3 authored on May 7 latest commit be85efa74e

File	Description	Time
doc	Bumped version number so that everything is consistant at the same time.	a year ago
tec	Code to display output voltage on motive diagram.	a year ago
test	Threw out the crap in numerics.	a year ago
trash	Note about throwing this crap out.	2 years ago
.gitignore	Now ignoring sphinx built documents.	2 years ago
CHANGELOG	Dropped .txt extension.	2 years ago
CITATION	Added CITATION file.	5 months ago
LICENSE	Finally explicitly licensed this thing.	a year ago
MANIFEST	Added setup.py for pip, etc. Closes #18	2 years ago
Makefile	Automatically commit gh-pages.	a year ago
README	Executed sphinx-quickstart.	2 years ago
klynen_langmuir.dat	Klynen's tabulated solution.	2 years ago
setup.py	Bumped version number so that everything is consistant at the same time.	a year ago

Code

Issues 20

Pull Requests 1

Wiki

Pulse

Graphs

Settings

SSH clone URL

git@github.com:jrs

You can clone with HTTPS, SSH, or Subversion.

Clone in Desktop

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