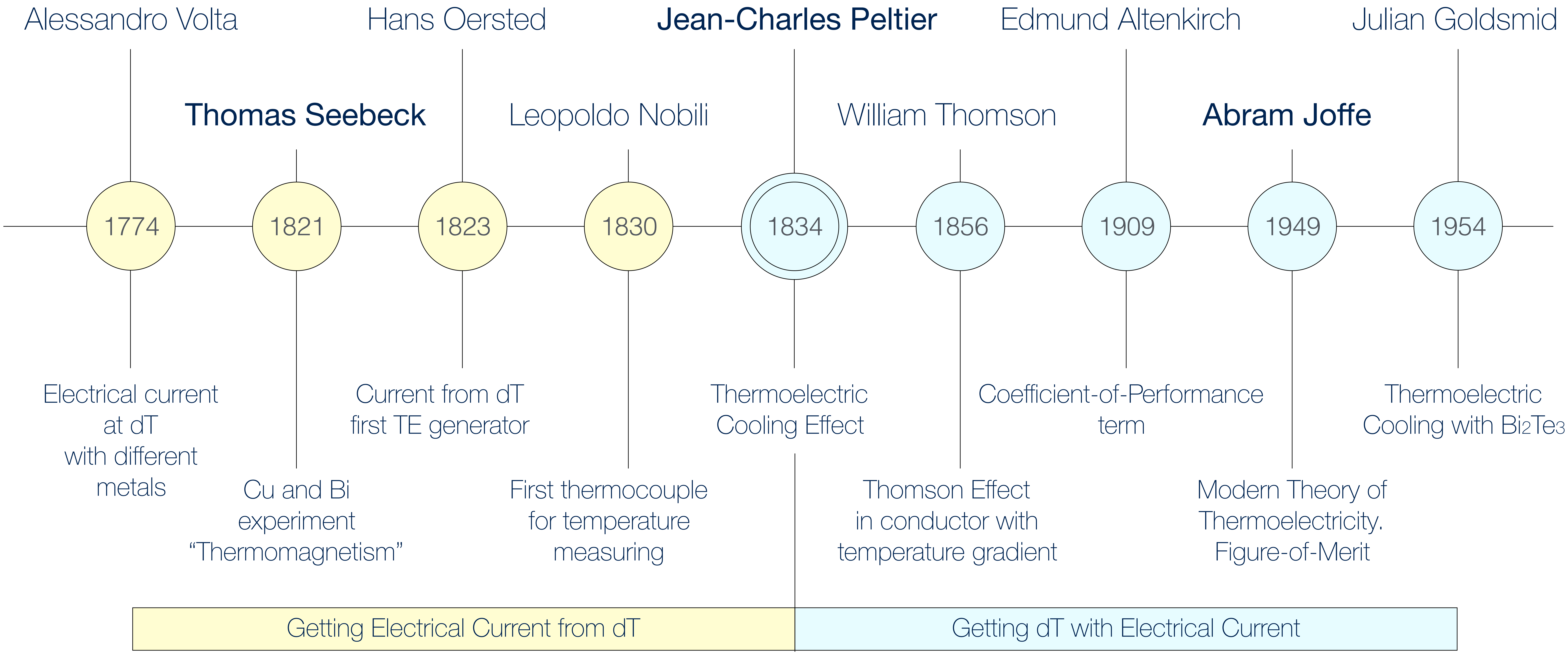
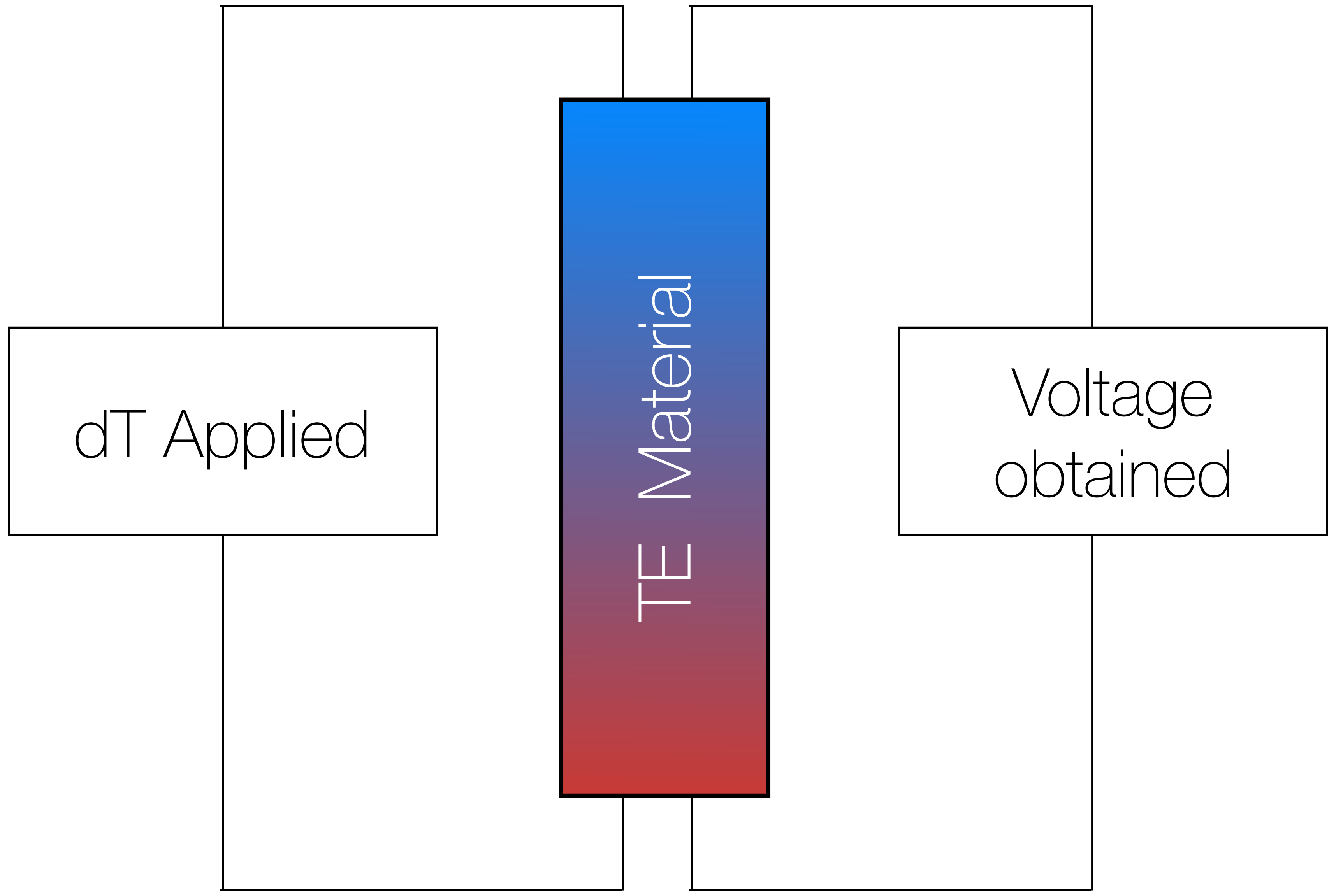
Thermoelectric Coolers FAQ

Brief History of Thermoelectricity



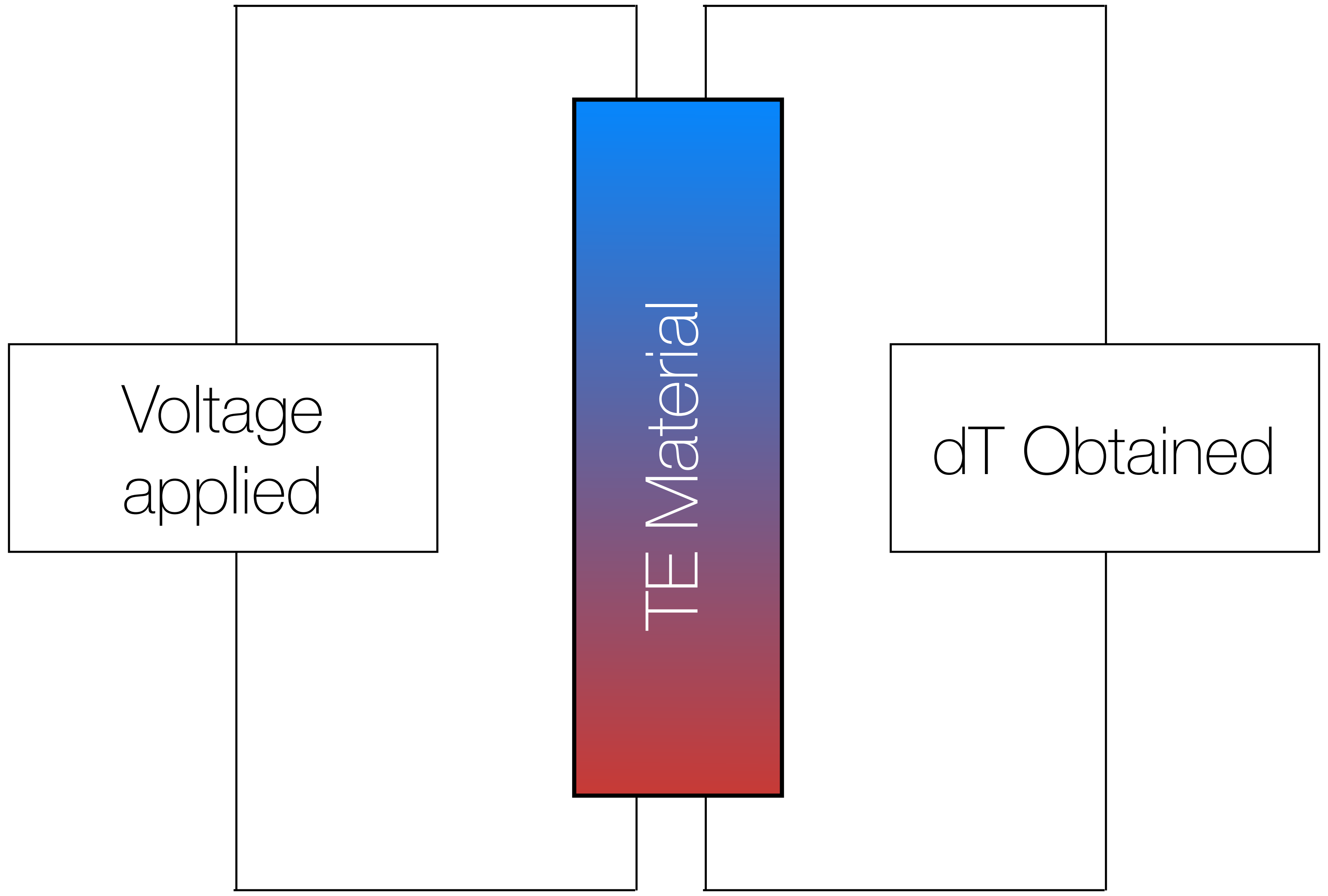
How does it work - Thermoelectric Pellet

Seebeck Effect - TE Generating



Apply Temperature Difference (dT) to get Voltage

Peltier Effect - TE Cooling

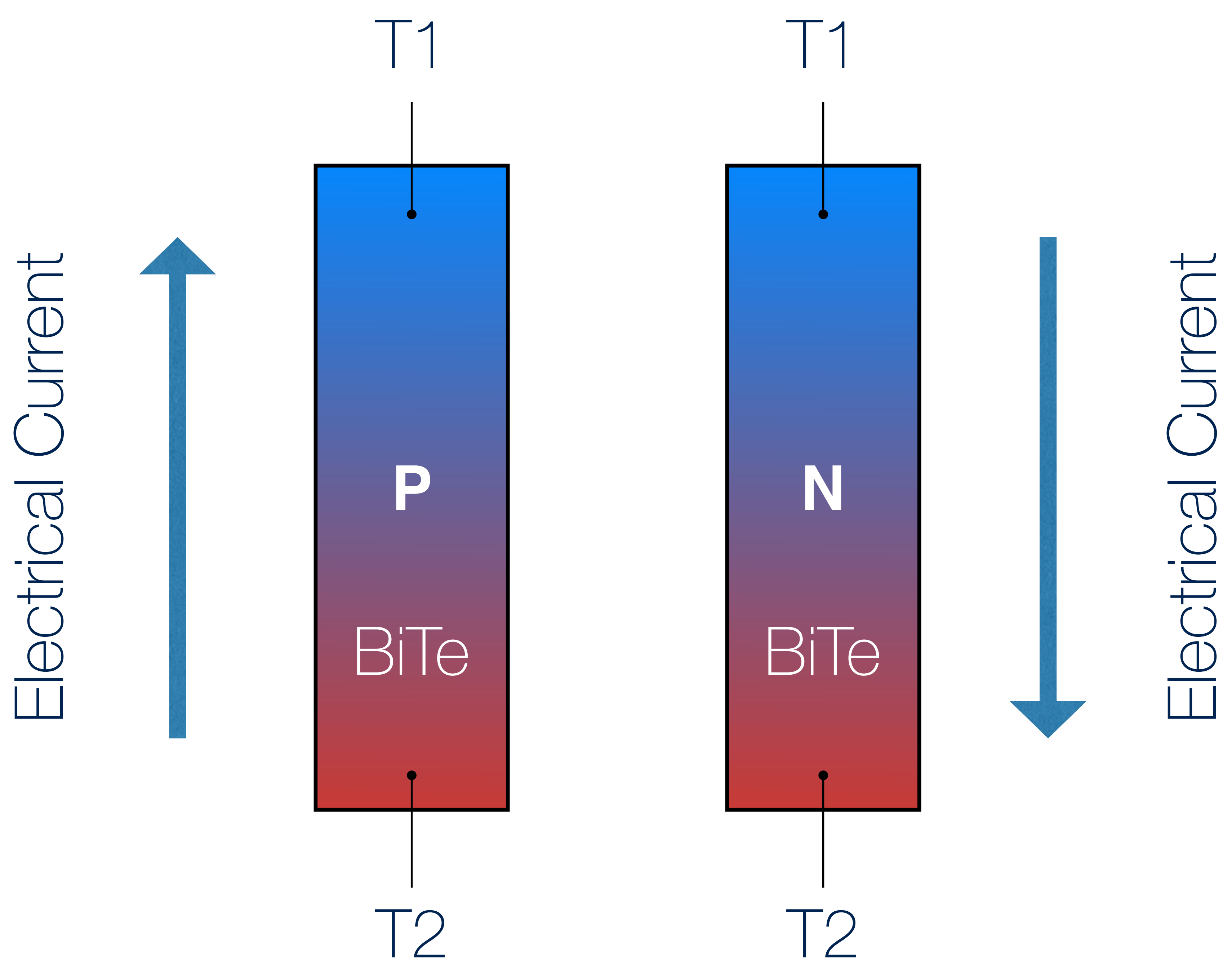


Apply Voltage to get Temperature Difference (dT)

BiTe Material is the most common for TE Coolers manufacturing

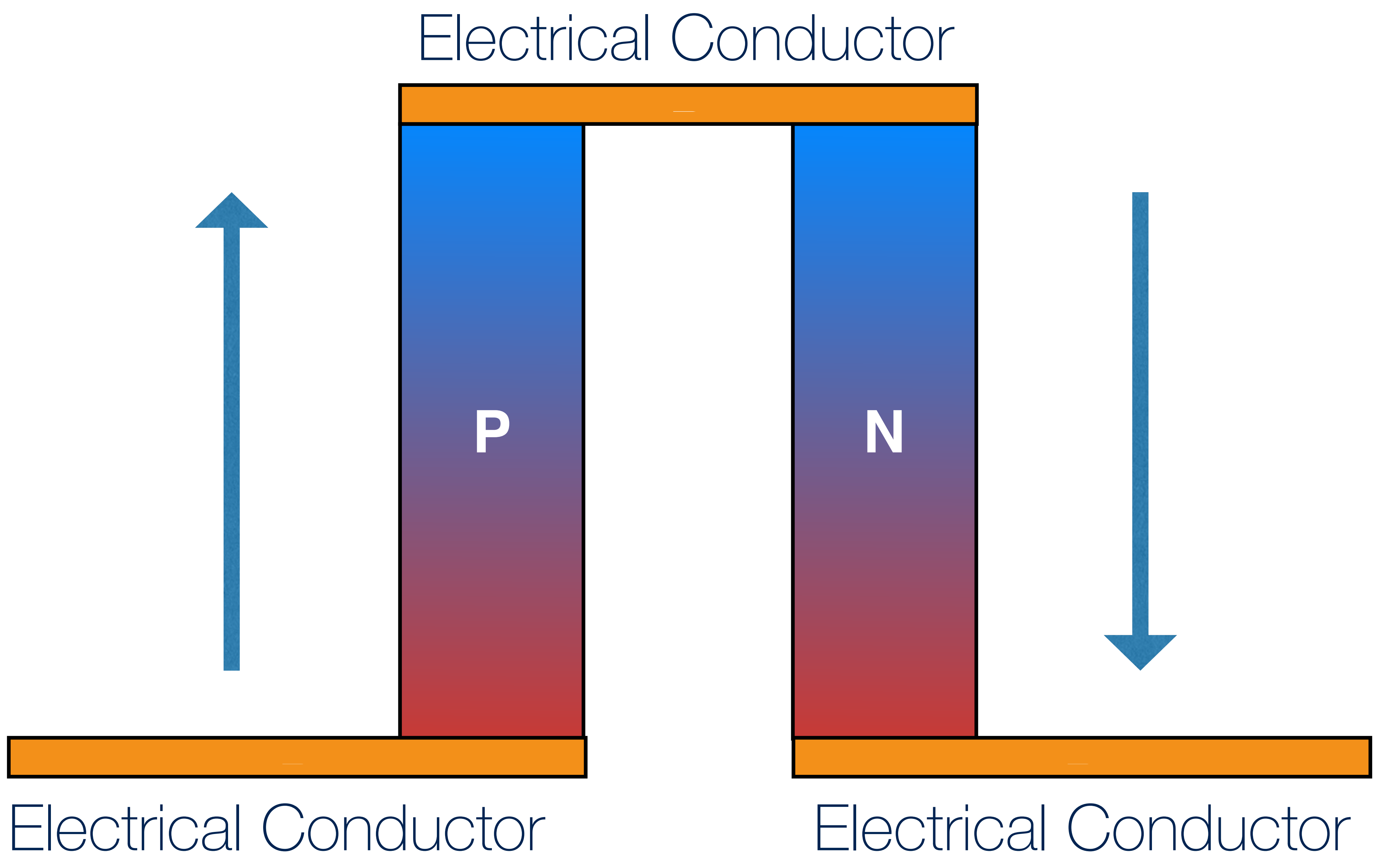
How does it work - Thermoelectric Couple

Understanding P and N pellet types



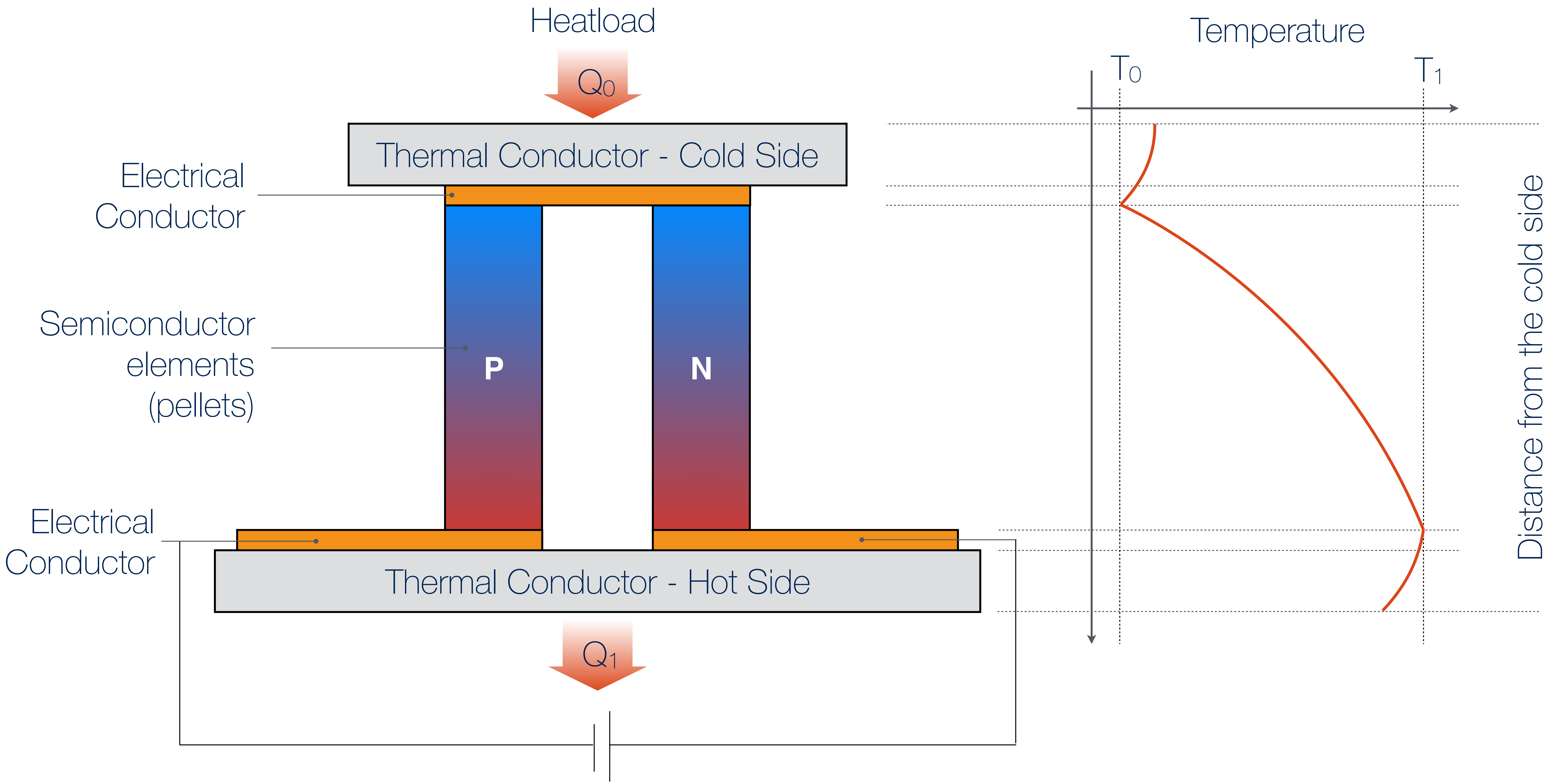
The difference between P and N pellets is in cold-hot side orientation under Electrical Current applied

Forming TE Couple

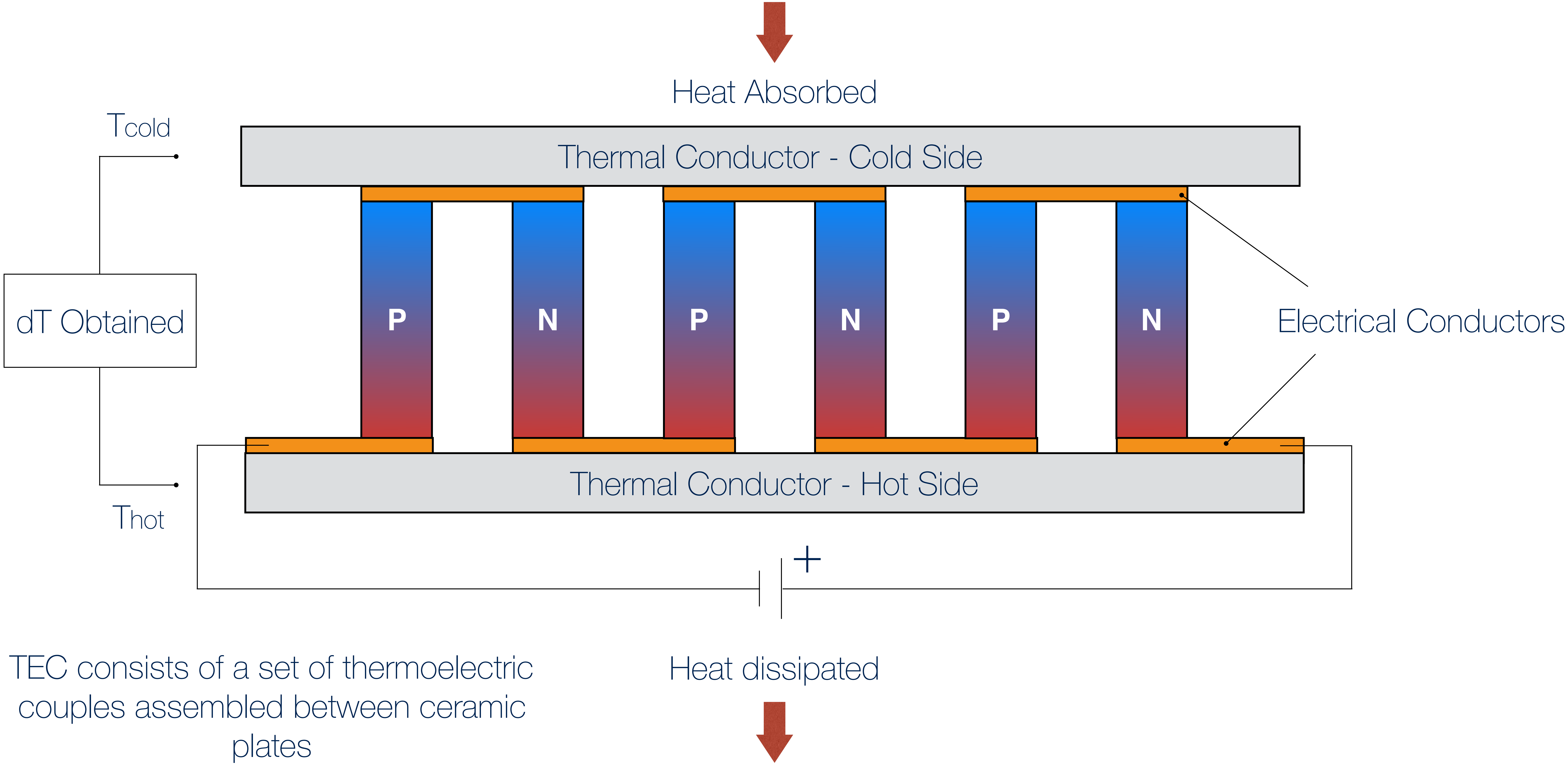


P and N pellets form a thermoelectric couple - the core of TE cooler construction

How does it work - Thermoelectric Couple

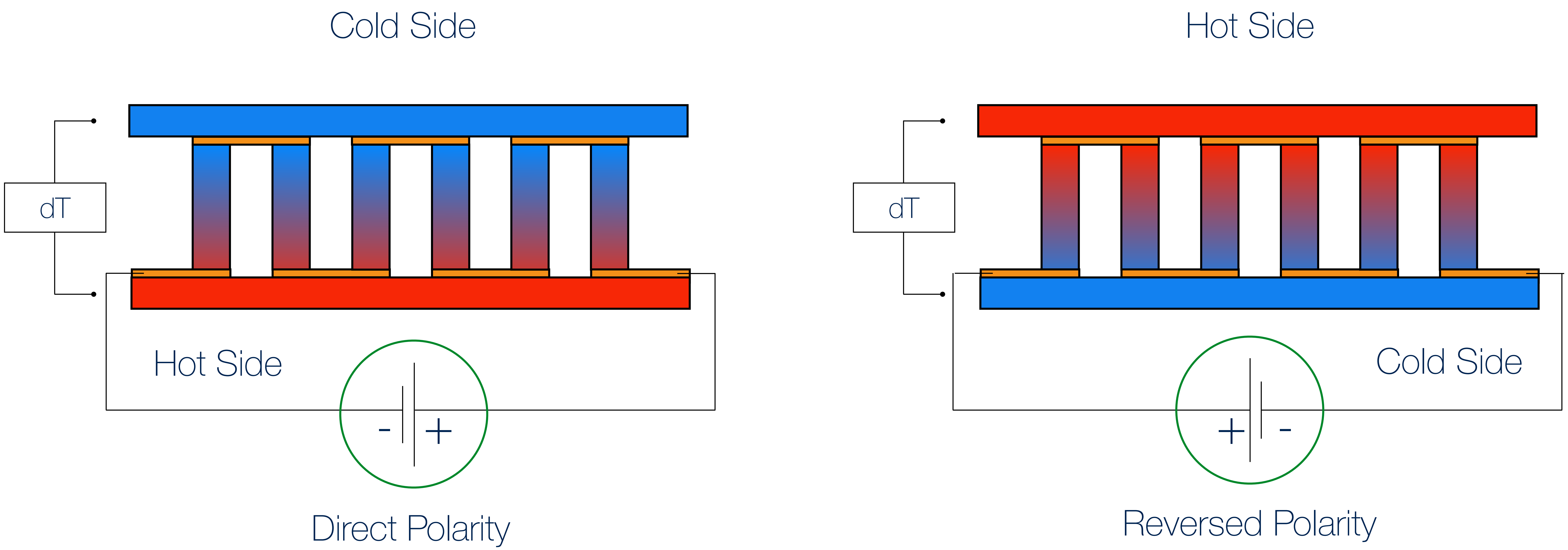


How does It work - Thermoelectric Cooler (TEC) Construction



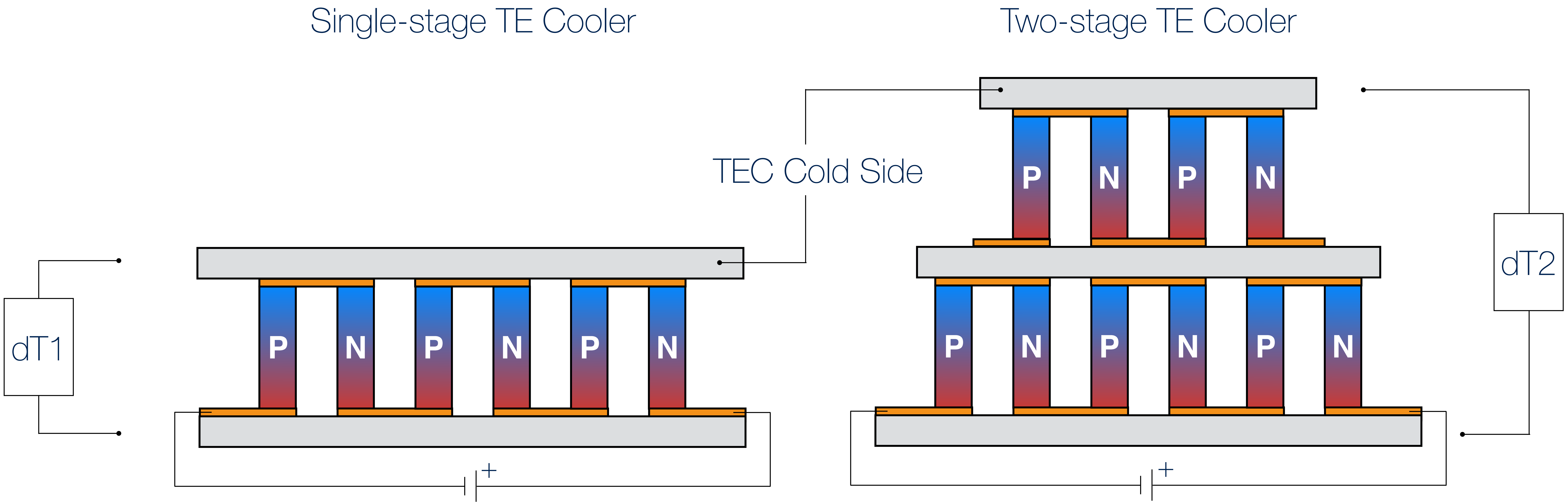
TEC consists of a set of thermoelectric couples assembled between ceramic plates

TE Cooler is bidirectional Device for use in Cooling and Heating Modes



Electrical Current polarity reverse turns TE Cooler (TEC) from Cooling Mode into Heating Mode.
This property makes TECs optimal for accurate Temperature Stabilization

How does It work - Single- and Multistage TE Coolers

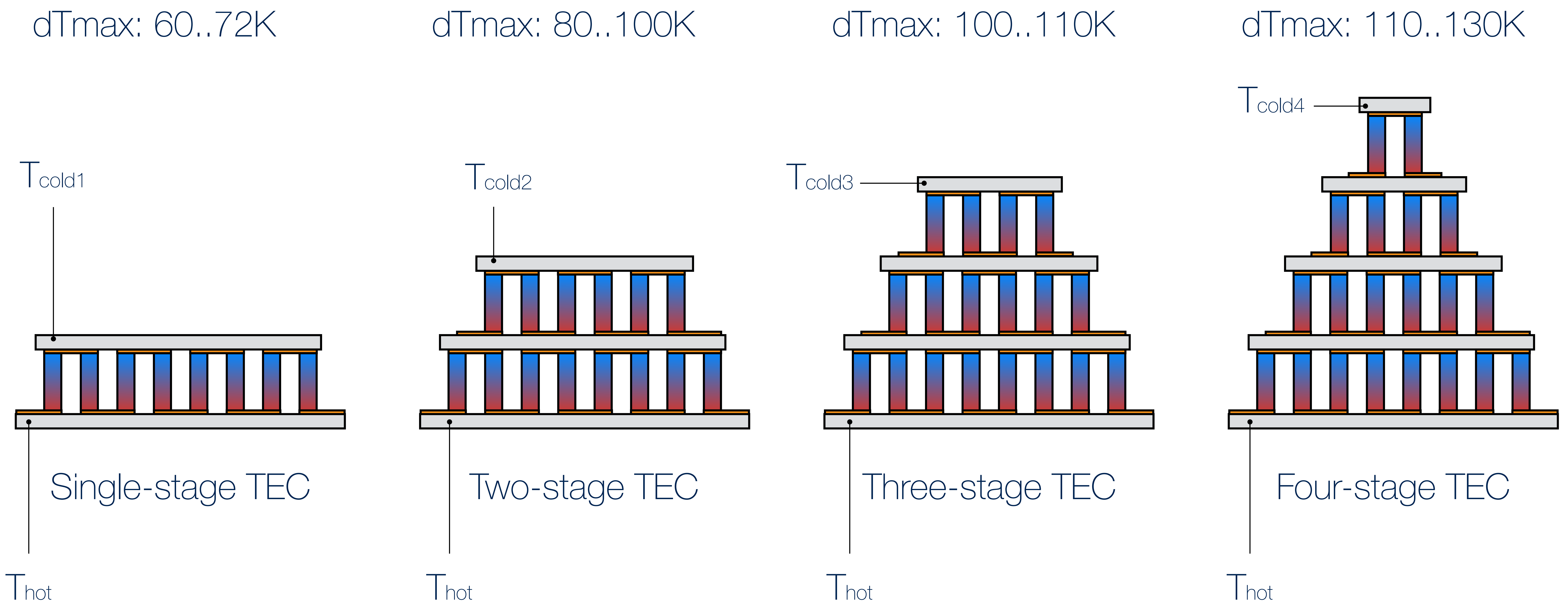


dT1< dT2

Multistage TE Coolers allow obtaining higher temperature difference between Cold and Hot sides

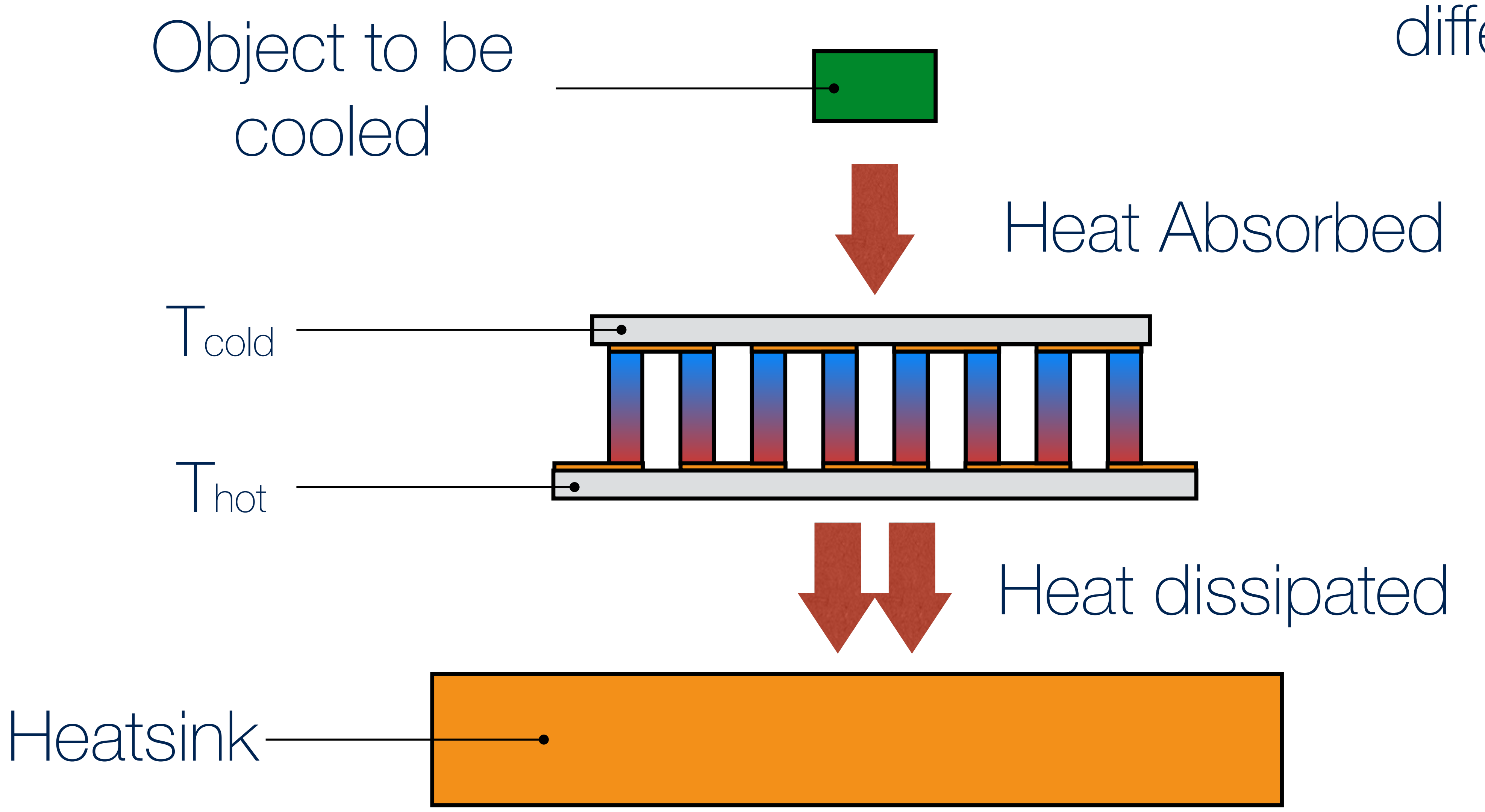
How does It work - Single- and Multistage TE Coolers

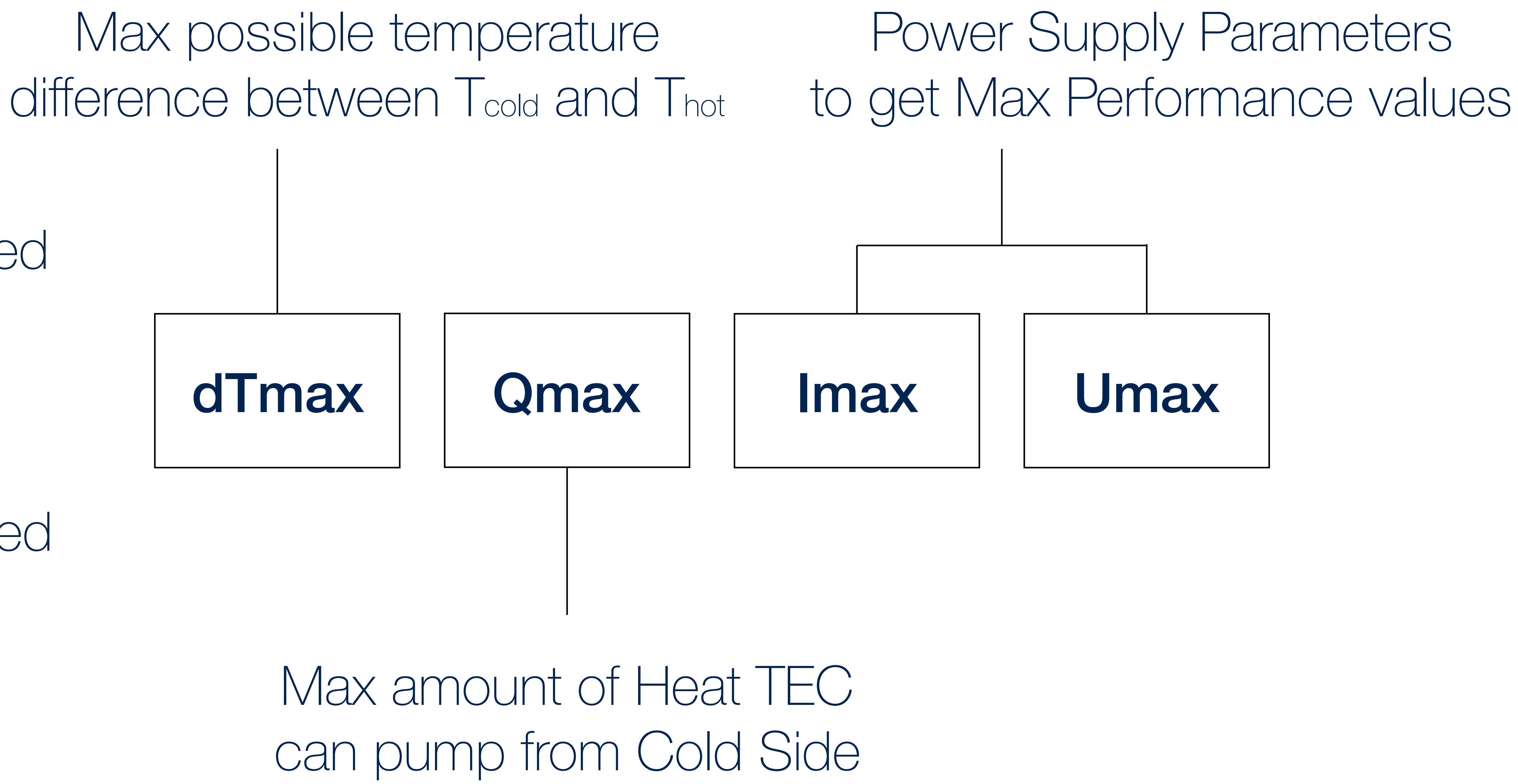
Maximum Temperature Difference between Cold and Hot Sides (dTmax) at +27ºC Ambient



Multistage TEC construction increases max possible dT in application, but the opposite effect may be in less amount of heat to pump from TEC cold side.

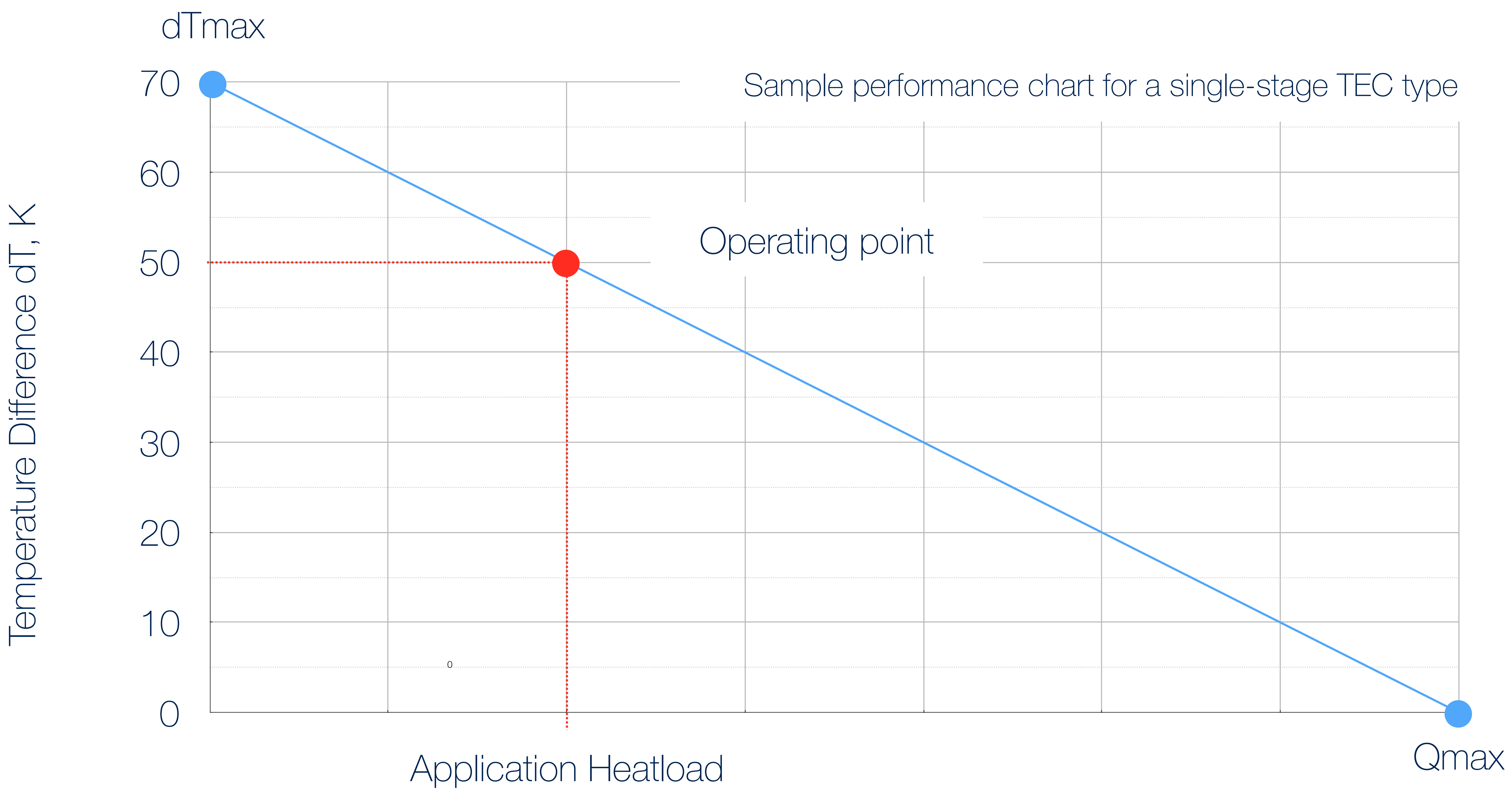
How does It work - TE Cooler Key Parameters





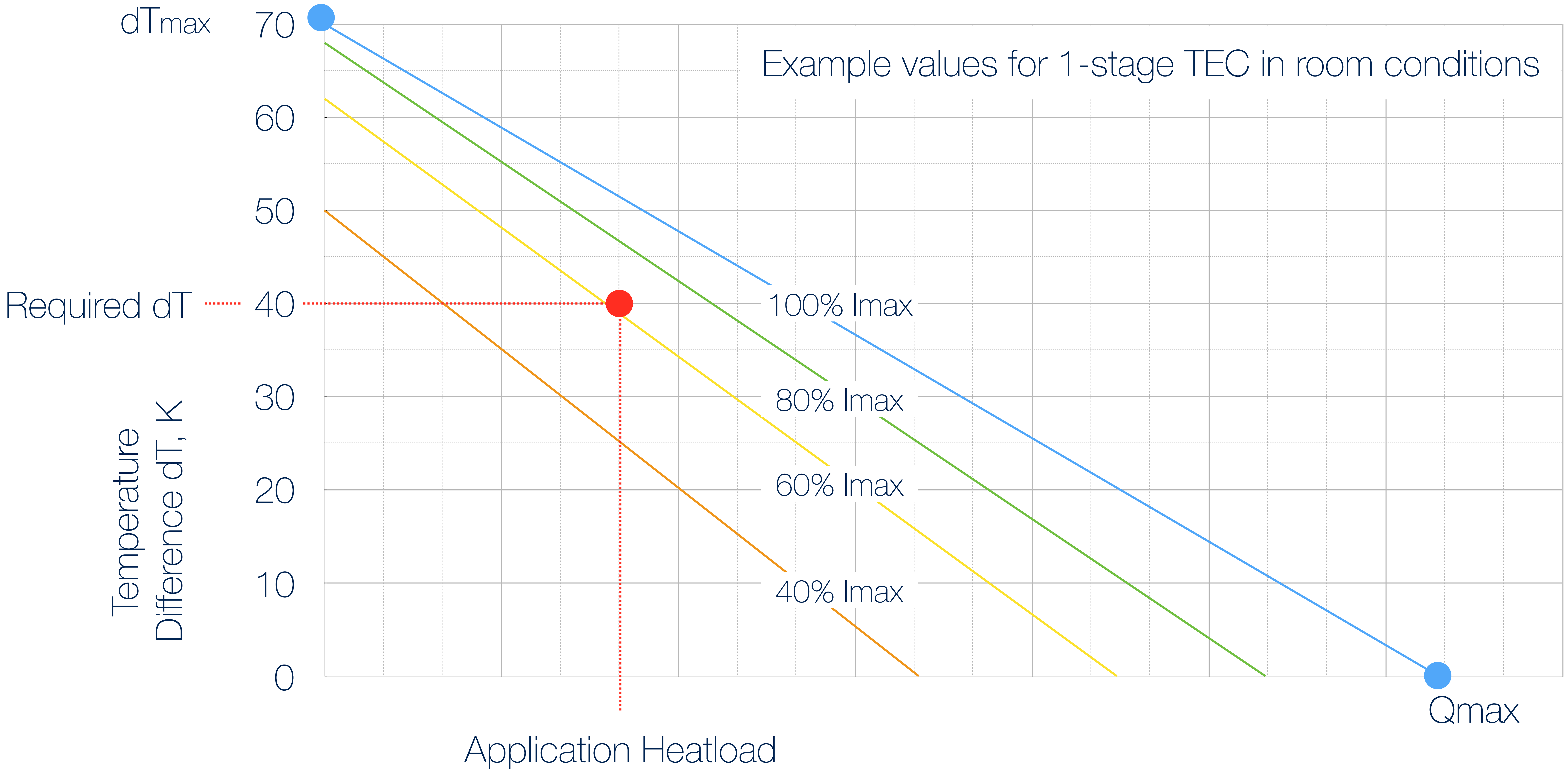
TE Cooler operates as a Heatpump. It transfers the Heat from Cold side to Hot Side and provides dT if required

Understanding TE Cooler General Parameters, dTmax and Qmax



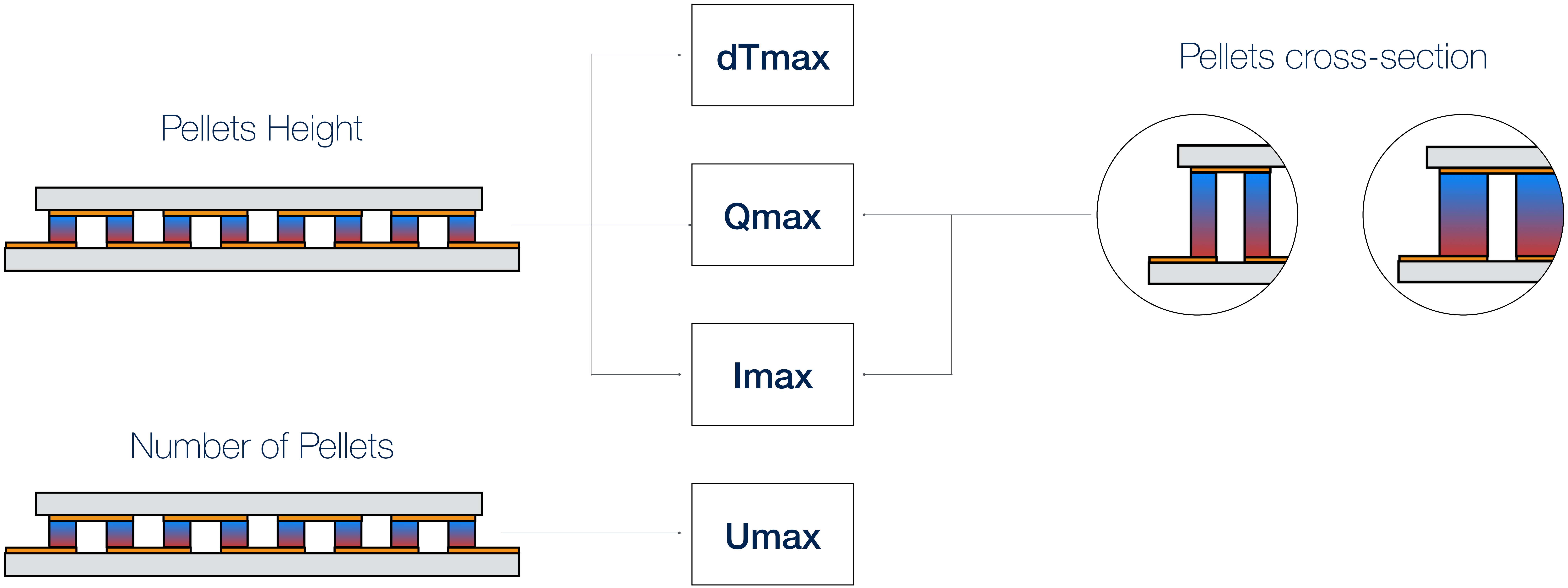
dTmax for TEC is specified without Heatload. Qmax is specified at dT=0. The application point is in between.

TEC is DC Current regulated Device



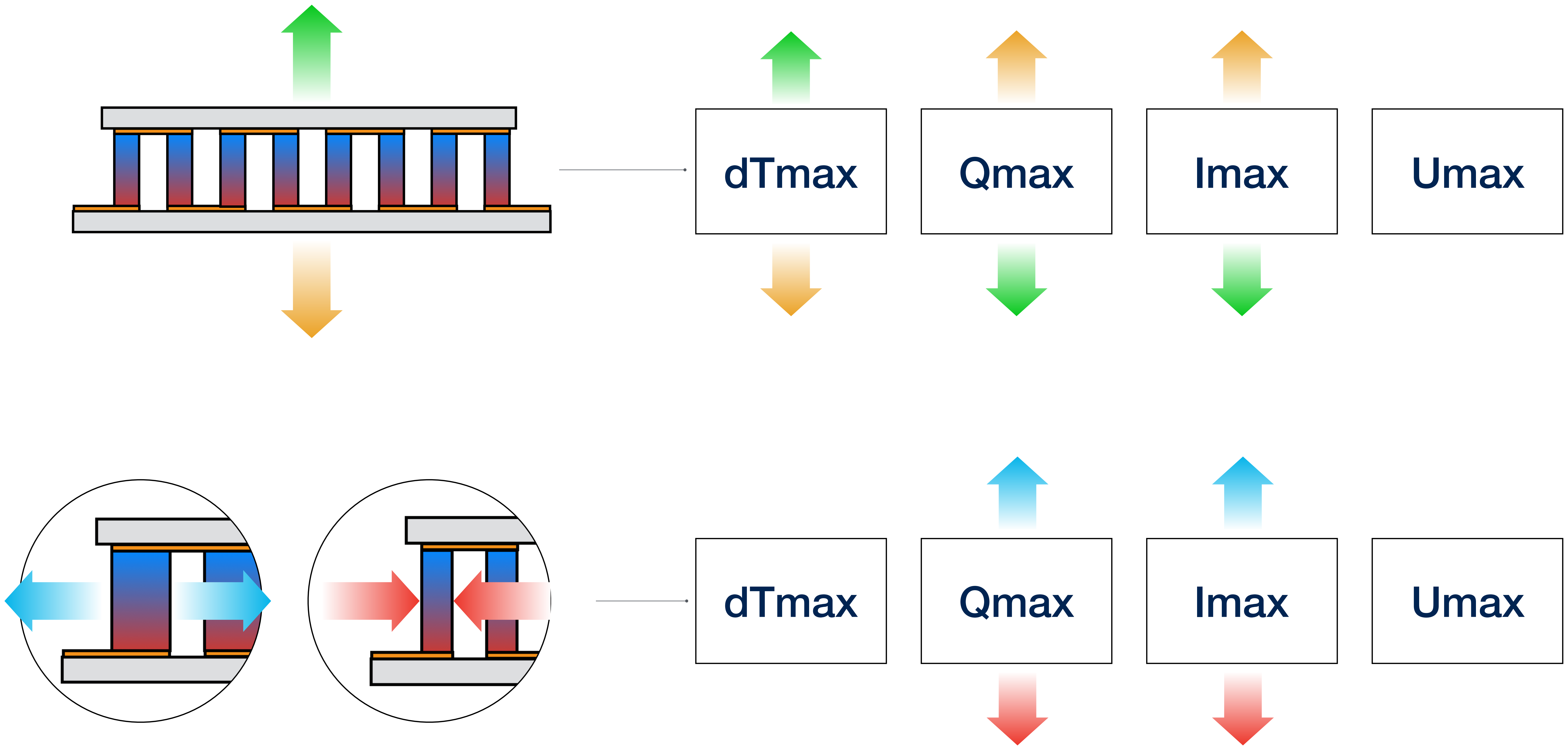
TEC Cold Side Temperature and Cooling Capacity in Application are regulated by applied electrical DC Current

TE Cooler Performance Parameters and Pellets Geometry



TEC General Parameters are directly connected to the number of pellets and pellets geometry

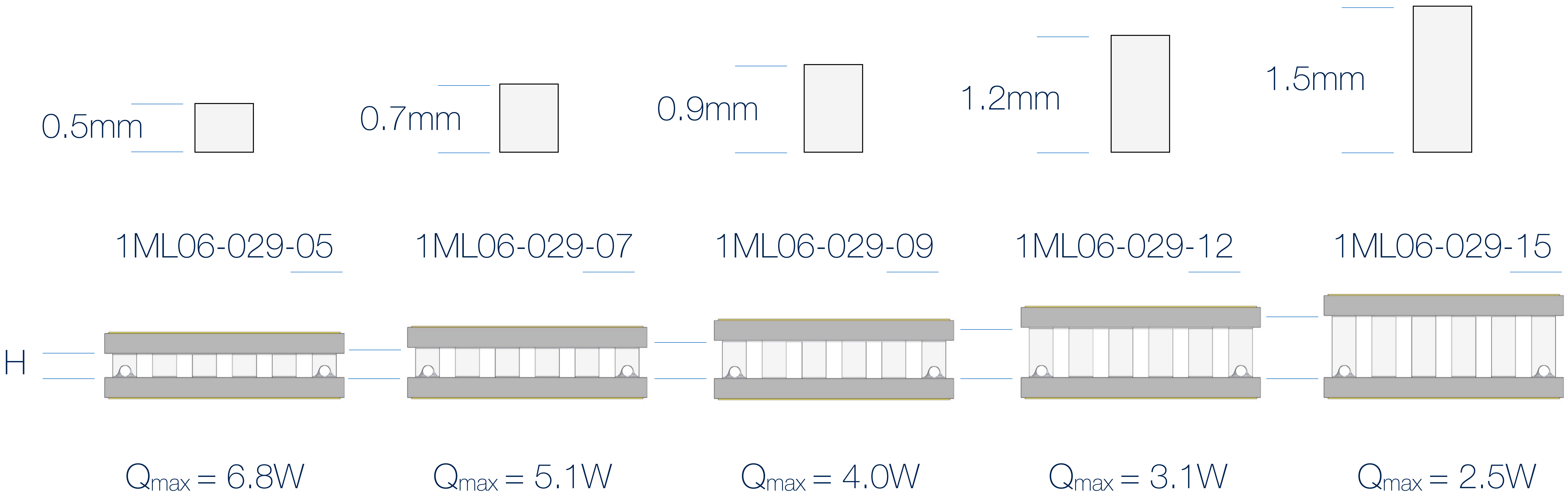
TE Cooler Performance Parameters and Pellets Geometry



Lower pellets make TEC cooling capacity higher, but increase the parameter Imax.
The same effect has pellets cross-section increasing (w/o height change).

TEC Microsystems TE Cooler Datasheet - Standard Pellets Height Variations

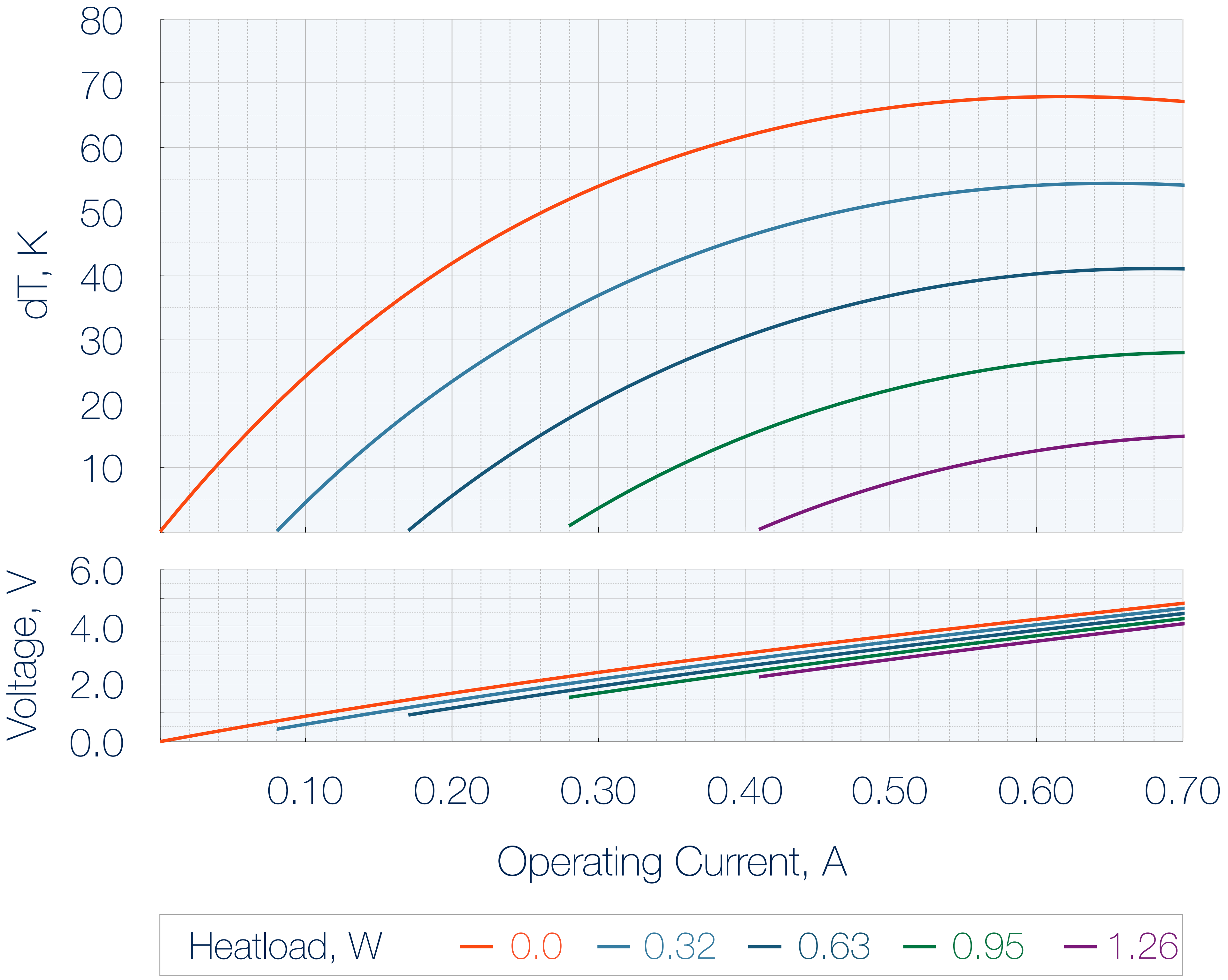
BiTe Pellets Height (H) is directly connected to TEC Cooling Capacity parameter



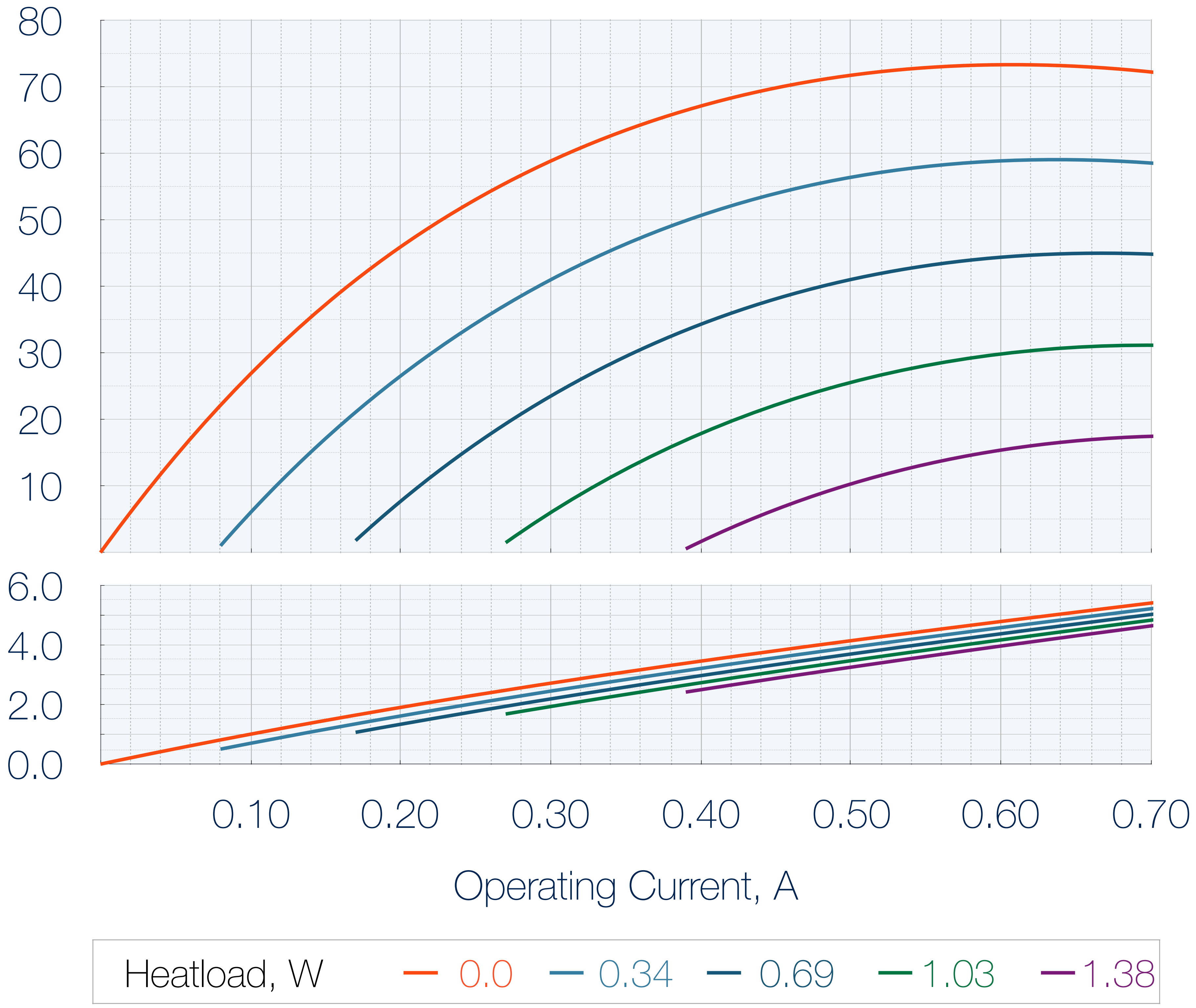
TEC Microsystems TE Coolers have several height and performance versions for one particular TEC type.

TEC Microsystems TE Cooler Performance Plots Example

@27ºC, Vacuum	ΔTmax K	Qmax W	Imax A	Umax V
TEC type	68	1.58	0.6	4.3

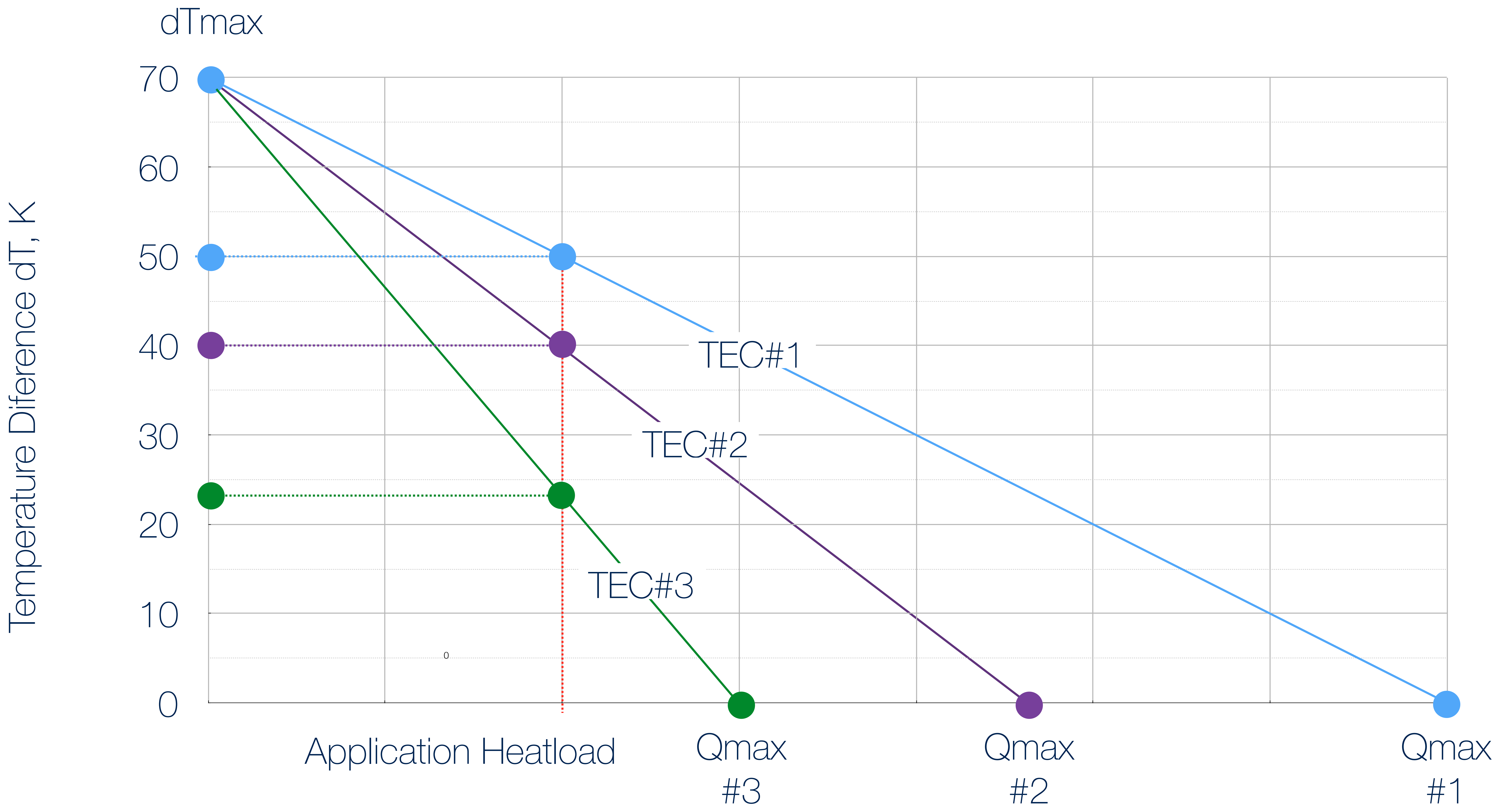


@50ºC, Dry N2	ΔTmax K	Qmax W	Imax A	Umax V
TEC type	73	1.72	0.6	4.8



TEC Microsystems Datasheets show standard TEC Performance in typical ambient condition modes.
TEC Performance plots can be recalculated for special ambient conditions by request.

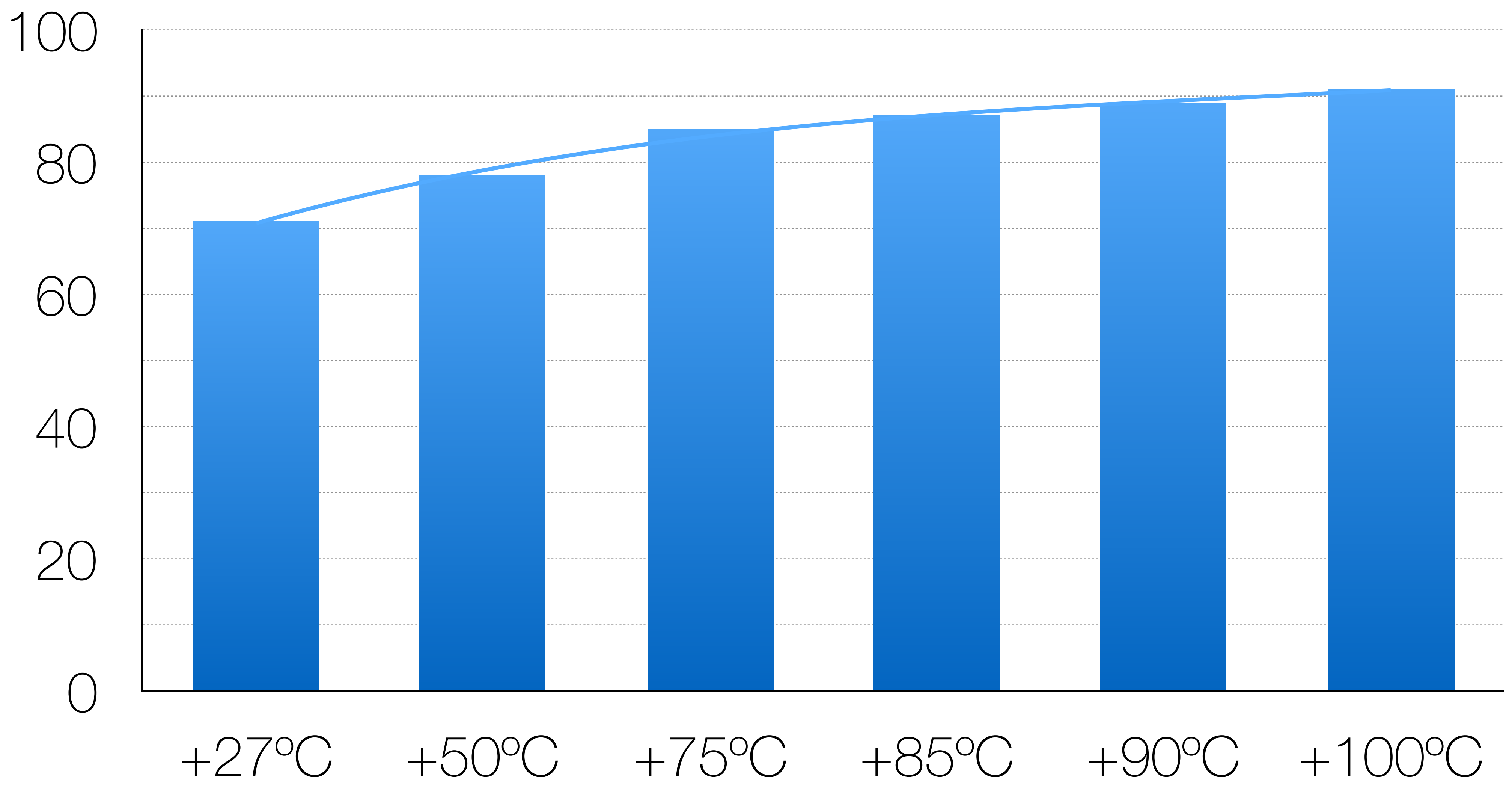
Understanding TE Cooler General Parameters, dTmax and Qmax



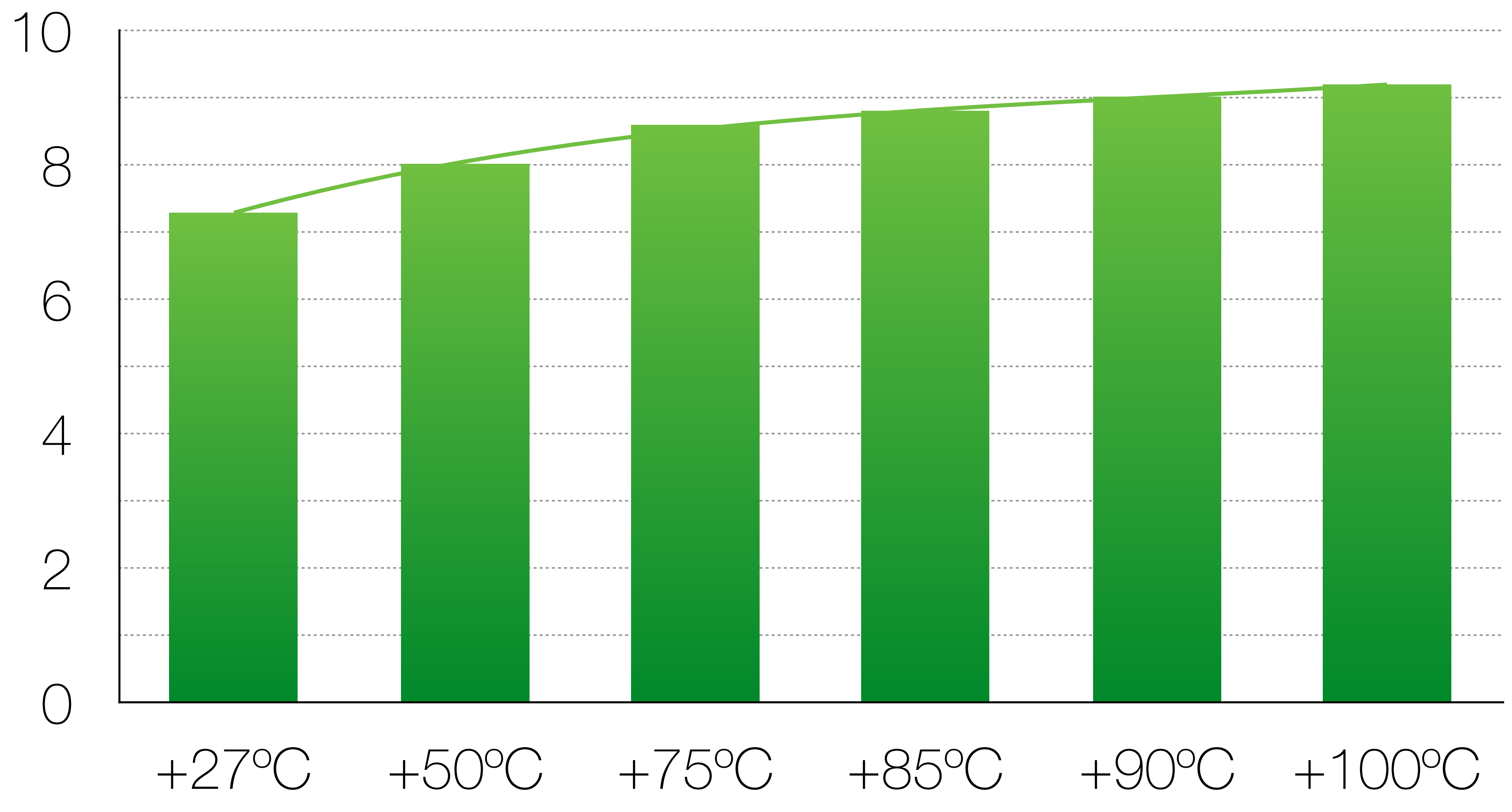
Different TEC types may have the same dTmax, but different Qmax. Thus the max achievable dT in application may vary.

TEC dTmax and Qmax parameters are connected to Ambient Temperature

TEC dTmax and Qmax grow with Ambient Temperature. Example data for a single-stage TEC.



TEC dTmax, K

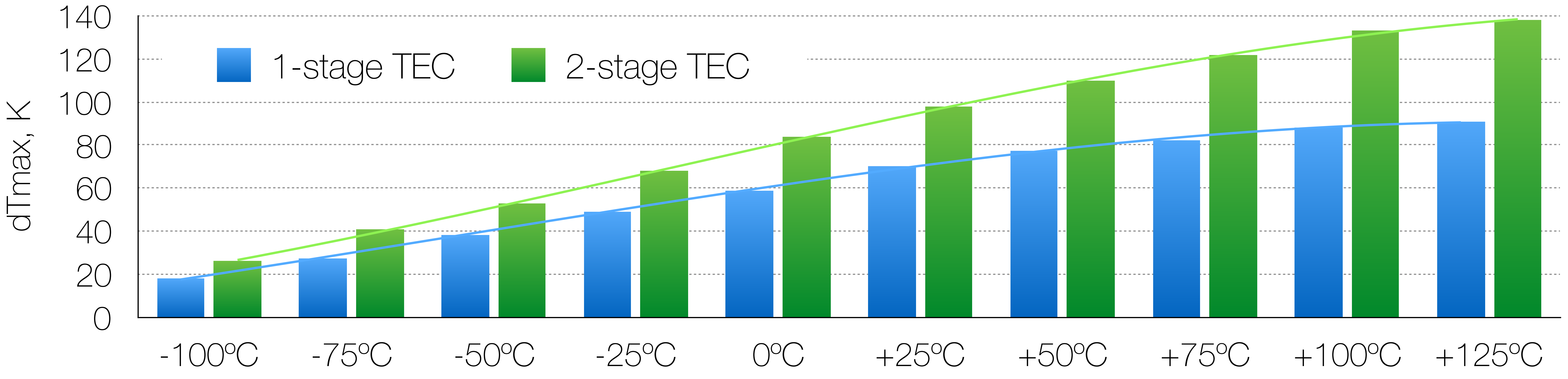


TEC Qmax, W

Qmax and dTmax values depends on ambient temperature. It's important to keep in mind.
Typical TEC datasheet has dTmax and Qmax values usually specified at +27ºC ambient and/or +50ºC

Ambient Temperature and TEC Performance

TE Cooler dTmax at specified Ambient Temperature

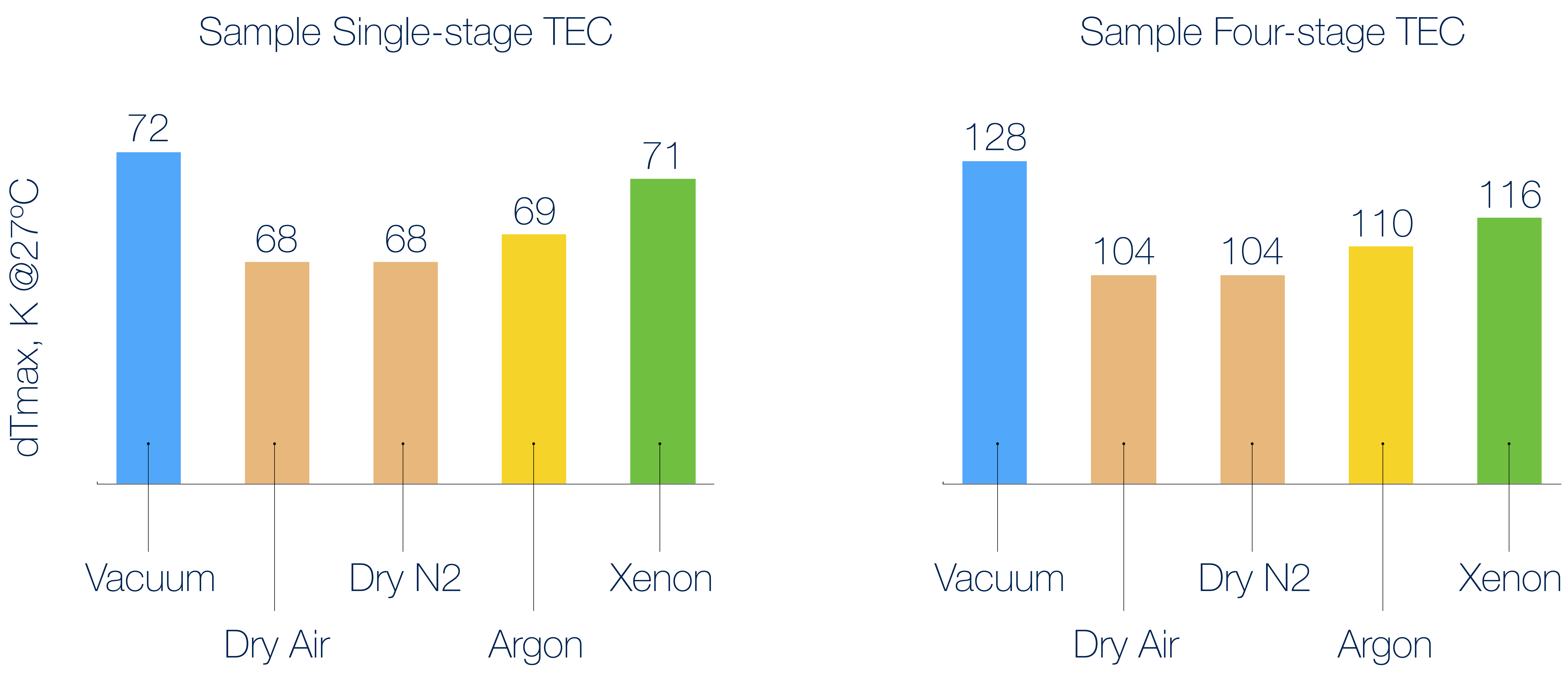


BiTe material in TE Cooler has the best performance at near room temperature and higher.

Lower temperatures reduce TE Performance. High temperatures (after +150ºC) affect TEC Lifetime crucially.

TEC doesn't work at CRYO-temperatures

TEC dTmax parameter is affected by Ambience



Multistage TE Coolers are more sensitive to convectional heatload from gas-filled Ambience.
For multistage TE Coolers best performance it's recommended to use Vacuum or inert gases Ambience.

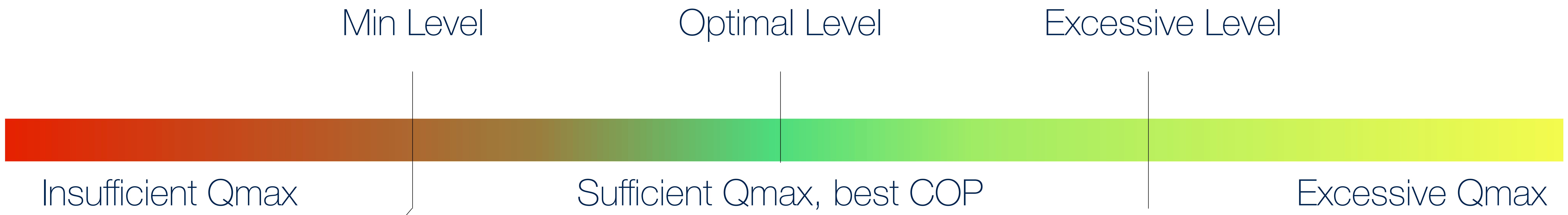
Typical Level of TEC dTmax parameter Reduction in Gas-Filled Ambience

Gas Type	Thermal Conductivity W/mK	Mean Level of dTmax Reduction (comparing to dTmax in Vacuum), K			
		1-stage	2-stage	3-stage	4-stage
Dry Air	0.026	-4	-9	-12	-18
Dry N2	0.024	-4	-9	-12	-18
Argon	0.016	-3	-6	-9	-14
Xenon	0.006	-2	-4	-5	-10

Additional Passive Heatload by Gas Convection affect TEC performance. The affect is usually not so critical for single-stage TE Coolers, but may be significant for multistage TECs.

Selecting TE Cooler for the required Application Parameters

TEC Cooling Capacity Qmax for Application



Min value for TEC Qmax to meet Heatload and dT requirements in application

$$Q_{max} = \frac{Q}{1 - \dfrac{dT}{dT_{max}}}$$

dT_{max} Standard Values

1- stage TEC	2- stage TEC	3- stage TEC	4- stage TEC
70	90	110	120

In application with required dT and heatload Q TEC must have Qmax at least meeting Min. level.
It doesn’t mean the optimal solution, but at least TEC can provide the required performance in application.

Selecting TE Cooler for Application, Example

Application Requirements

Heatload → $Q = 1.5W$

Required dT → $dT = 50K$

Estimations for a single-stage TEC suitable by Qmax parameter

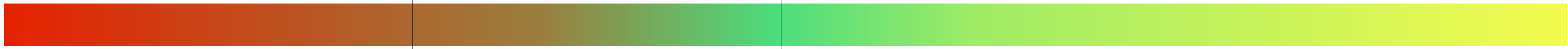
$$Q_{max} = \frac{1.5}{1 - \frac{50}{70}} = 5.25W$$

1- stage TEC	2- stage TEC	3- stage TEC	4- stage TEC
70	90	110	120

Qmax < 5.25W not sufficient

5.25W Min Level

Optimal Level to be defined



sufficient

optimal

The example of brief estimations: Application Heatload 1.5W, required dT=50K.

The suitable TEC that can meet the required dT in application must be with Qmax=5.25W at least.

Selecting TE Cooler for Application, Example

Application

Optimal TEC estimations are more complex and need PRO-level analysis

$Q = 1.5W$

$dT = 50K$

Optimal Q_{max} 5.7W … 11 W

Optimal TEC may have 4x .. 10x higher Qmax than Heatload

Qmax < 5.25W
not sufficient

5.25W
Min Level

5.7W

11W

Best COP results

Excessive Qmax

sufficient

optimal

Qmax=5.25W is the Minimum Level to meet application requirements. It’s sufficient, but it doesn’t mean TEC is the optimal one. Optimal TEC estimations are more complex and require experienced specialists.

The Balance of Powers - Optimal C.O.P. - Application Example

TE Coolers in testing

Most powerful by Qmax

TE Cooler	Qmax, W
TEC#1	6.7
TEC#2	4.3
TEC#3	1.9

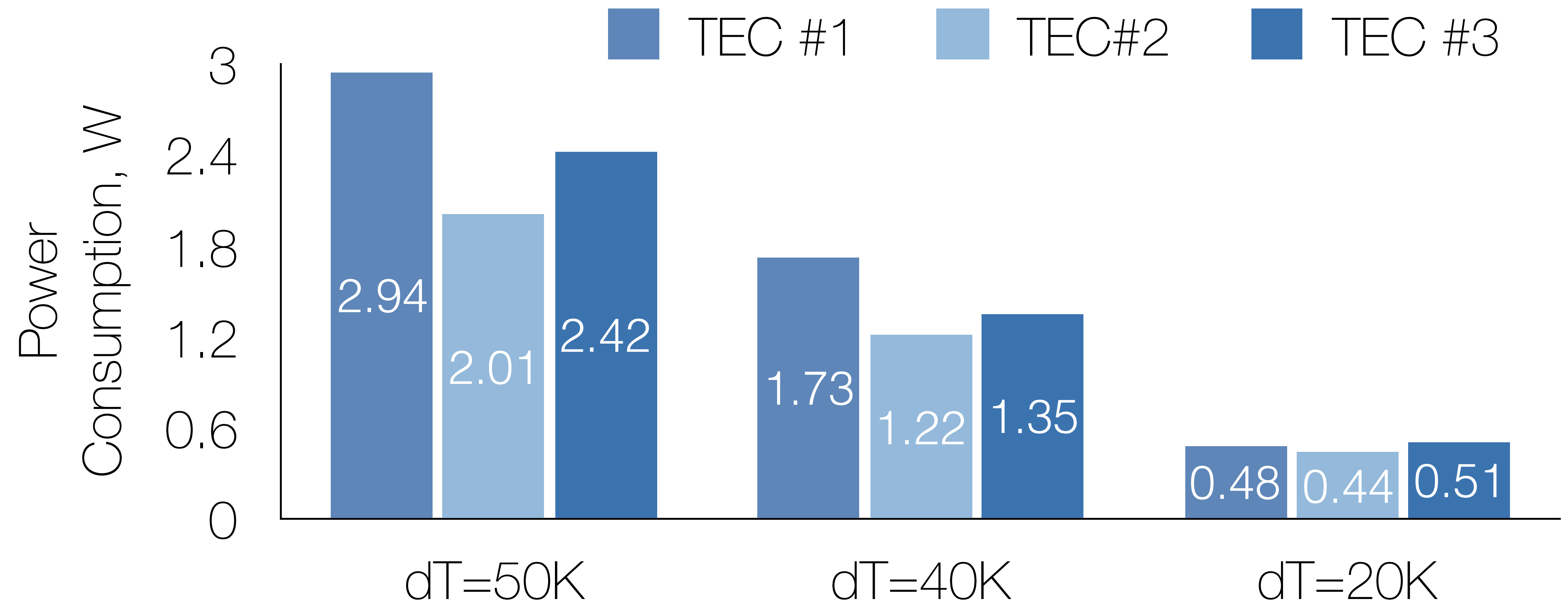
Application Conditions

Application Conditions (Example)	
Ambient Temperature	+75ºC
Heatload	800mW
Ambience	Dry N2

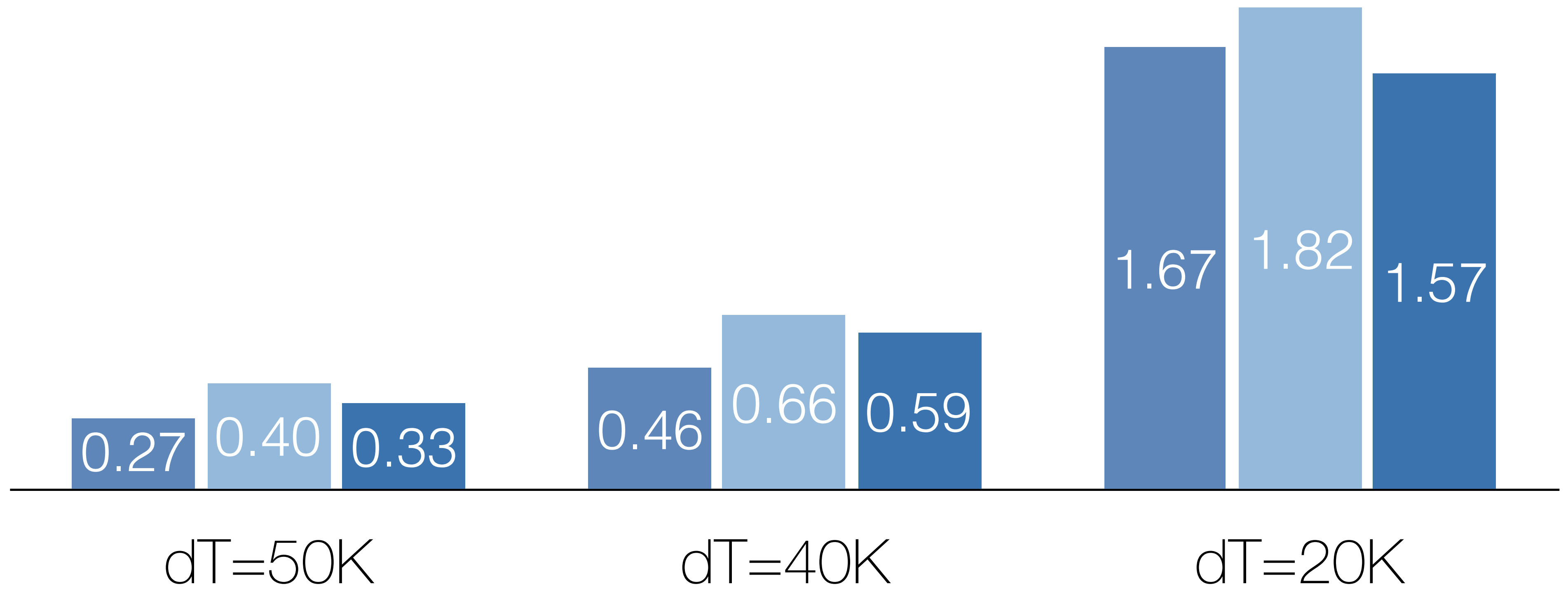
Required dT from Ambient

C.O.P.	dT=50K	dT=40K	dT=20K
TEC#1	0.27	0.46	1.67
TEC#2	0.40	0.66	1.82
TEC#3	0.33	0.59	1.57

Not optimal

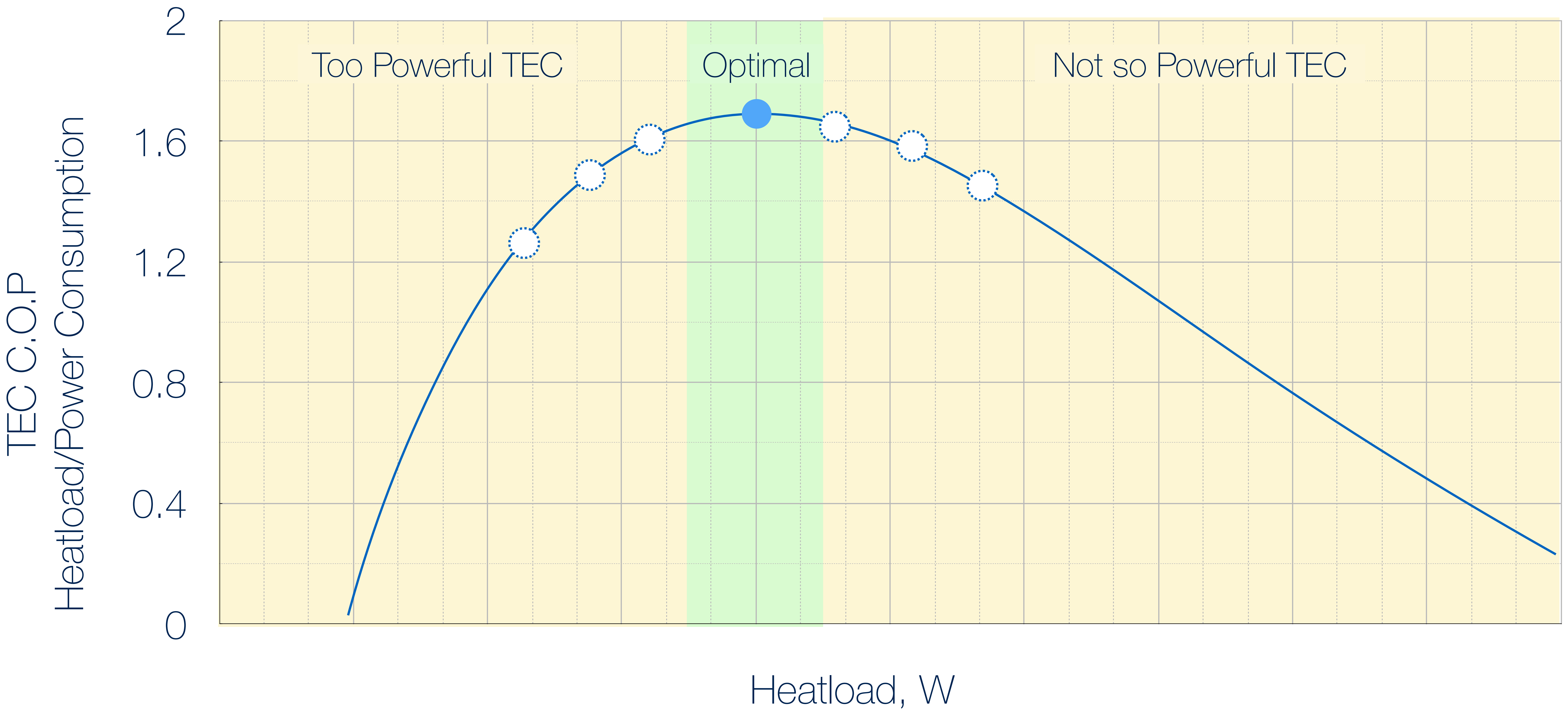


TE Coolers C.O.P.
Heatload / Power Consumption



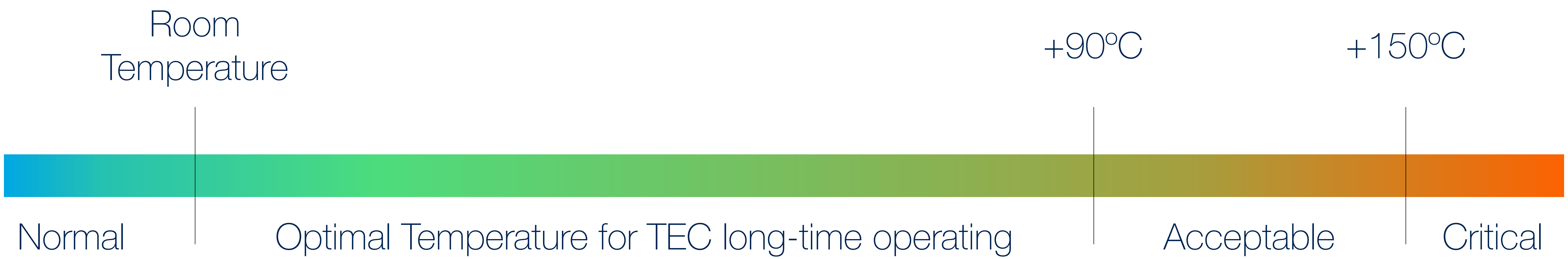
Bottom Line: the most powerful (by Qmax) TEC doesn't mean the most optimal one in the application

The Balance of Powers - Optimal C.O.P.



1. The most powerful TEC doesn't mean the most optimal one. A lot depends on application.
2. For an application with specified Heatload and dT there is always an optimal solution by C.O.P.
3. Every TEC type has an optimal heatload range (with the highest C.O.P.) at required dT specified

Ambient Temperature and TEC Lifetime

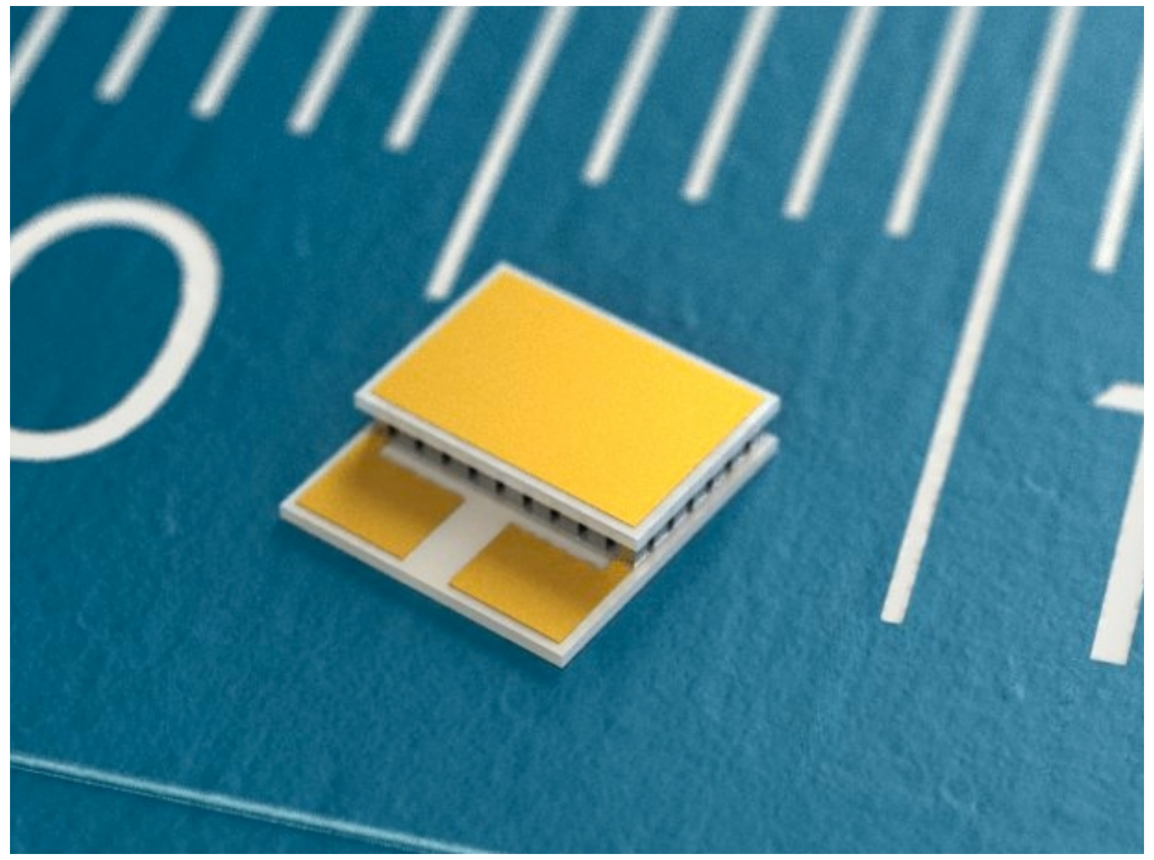


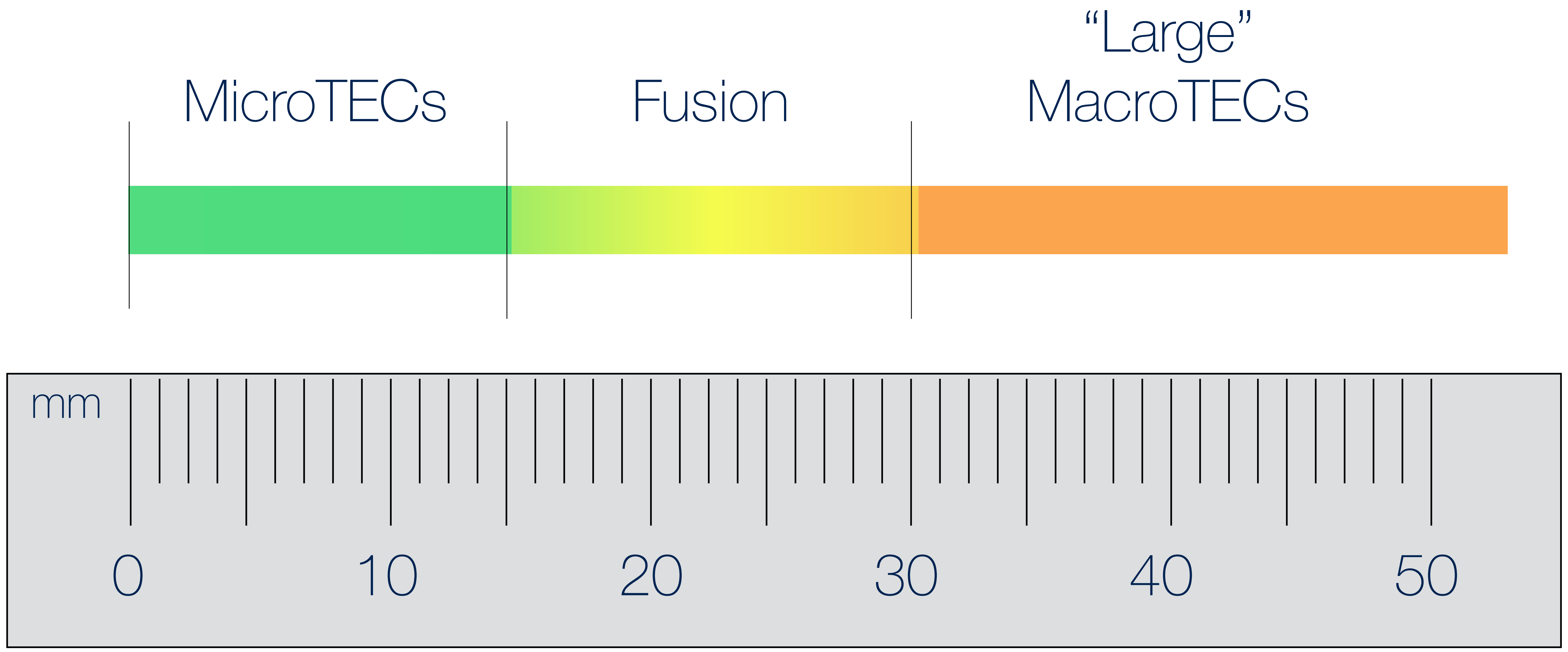
TEC Lifetime, hours

TEC Lifetime depends on Ambient Temperature
and can be estimated by Arrhenius equation

Term “Lifetime” for TEC is from Telcordia GR-468 Standard. The criteria of failure is TEC AC Resistance change for more than 5%. It doesn’t mean TEC stops operating, but certain performance degradation appears.

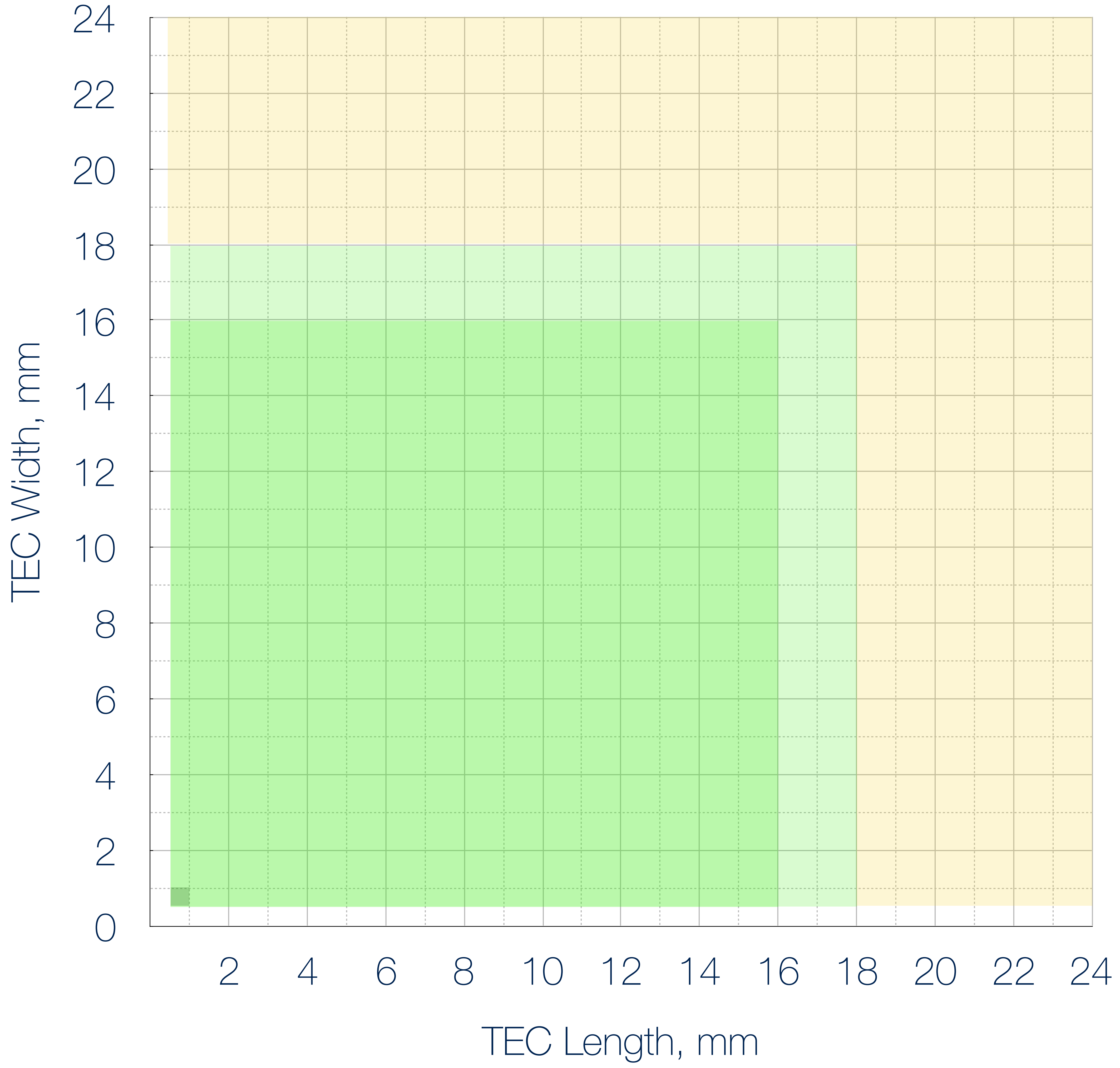
What means “Miniature" or “Micro” TE cooler

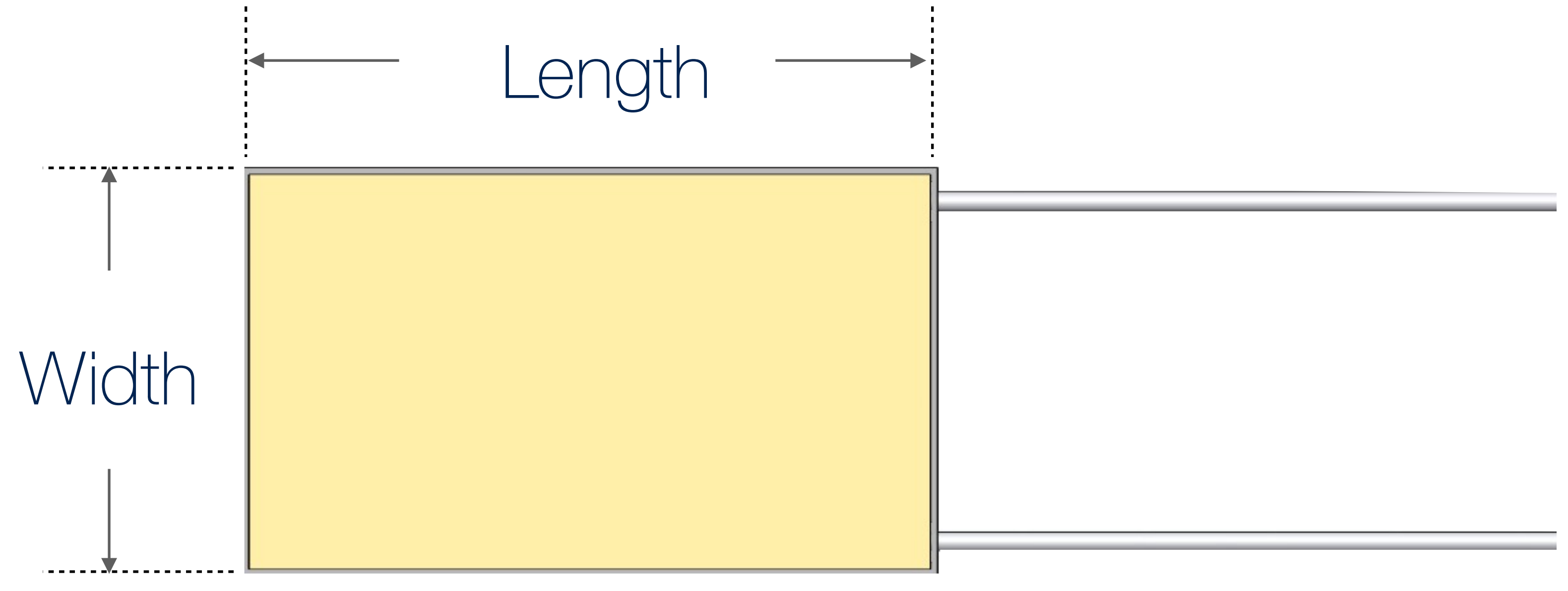




The main difference between miniature and large TE Coolers (besides the size) is in application areas and manufacturing technologies.

TEC Microsystems Standard TE Coolers Dimensions Coverage Map

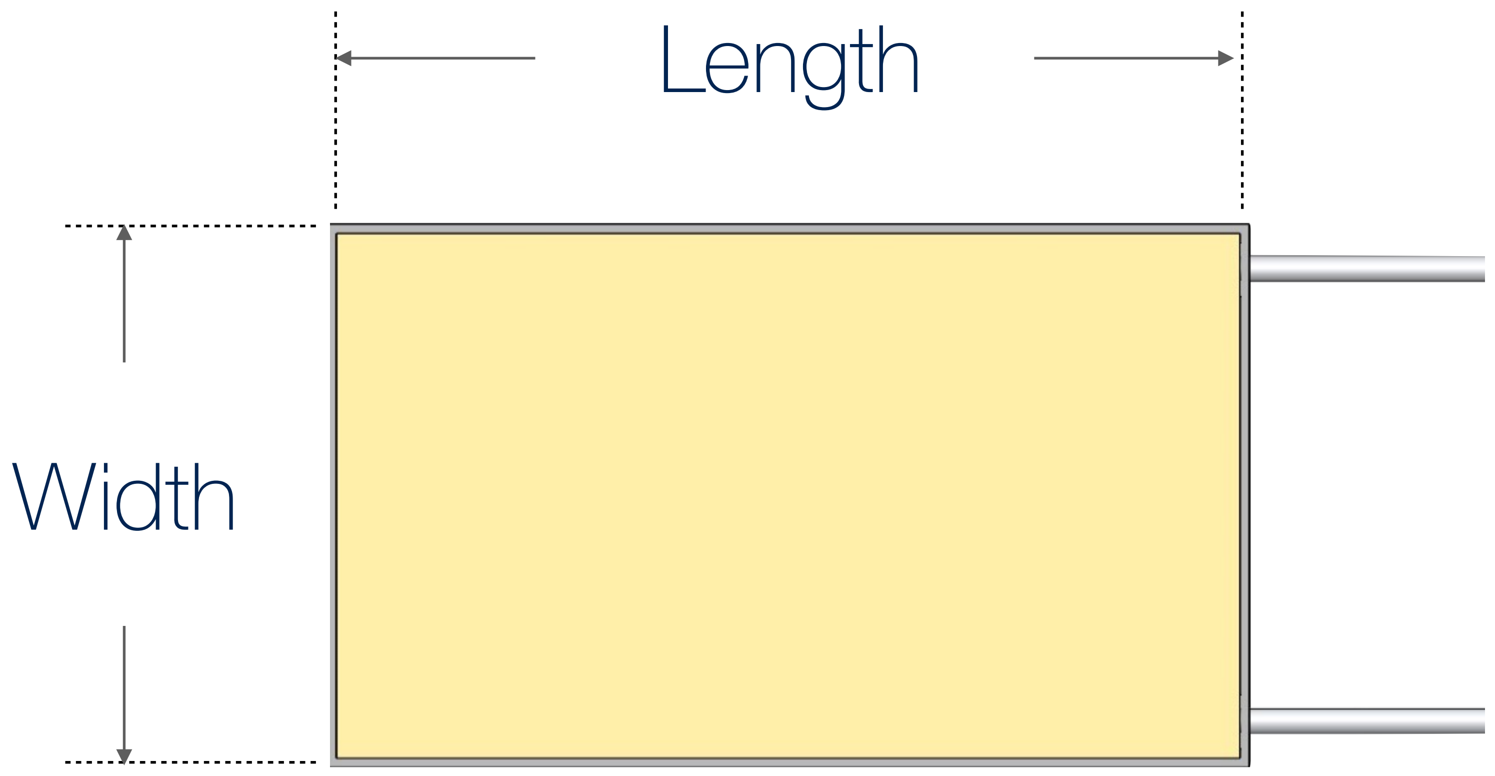




Dimensions	Width mm	Length mm
Min	0.5	0.5
Most Common	< 16	< 16
Available	18	18
Max	24	24

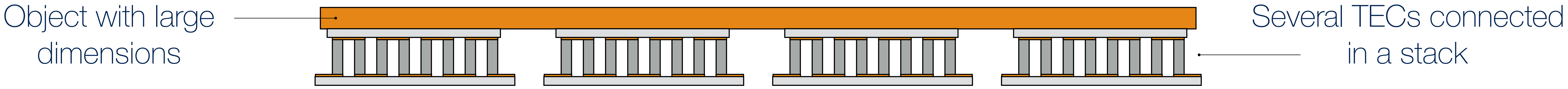
TE Cooler Length / Width Safe Proportions

TECs with elongated shapes have additional risks of mechanical strains due to thermal expansion



Recommended Safe Length/Width Ratio

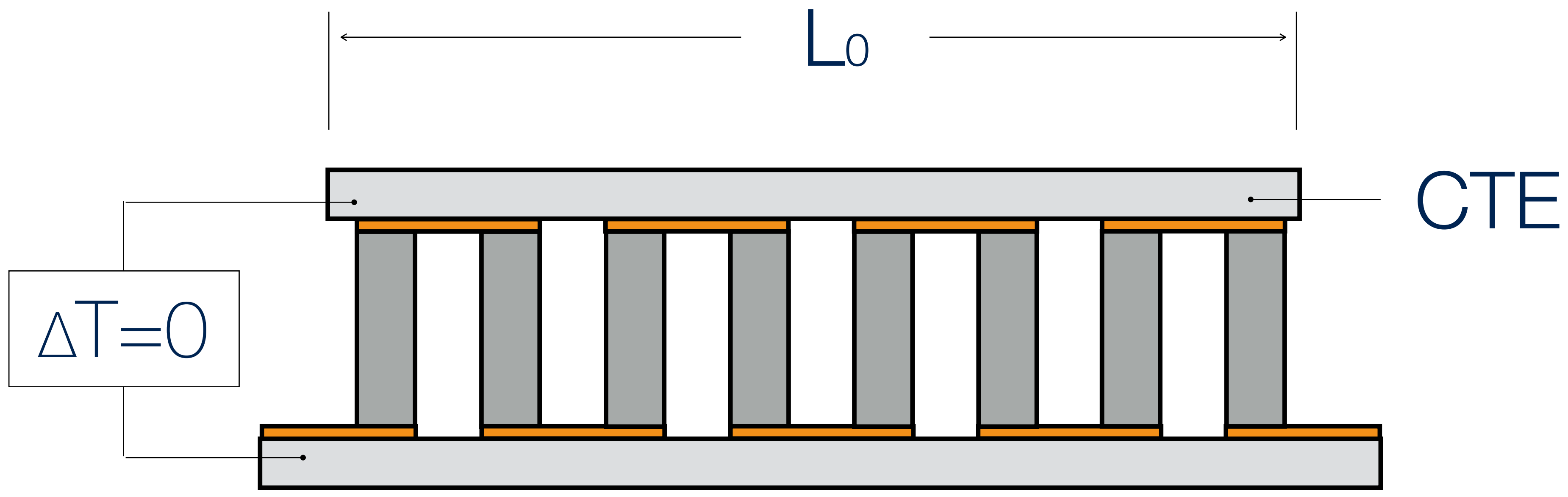
$\frac{1}{1}$ $\frac{2}{1}$ $\frac{3}{1}$ $\frac{4}{1}$

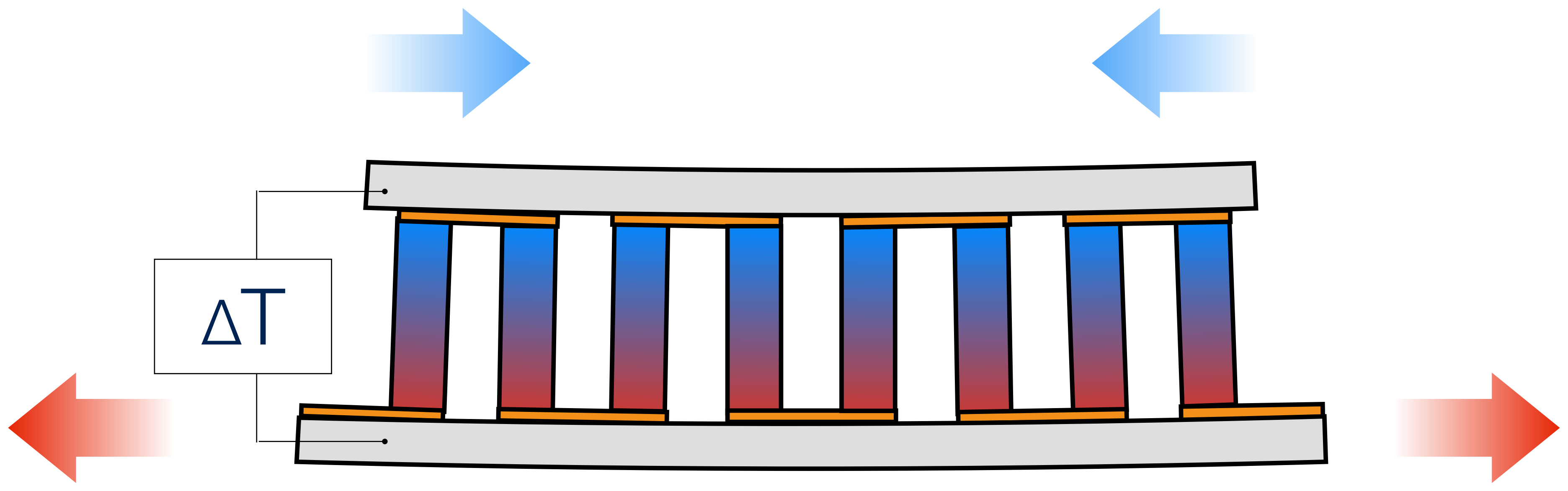


In case of large dimensions of object to be cooled it’s better to apply several TECs connected in a stack.

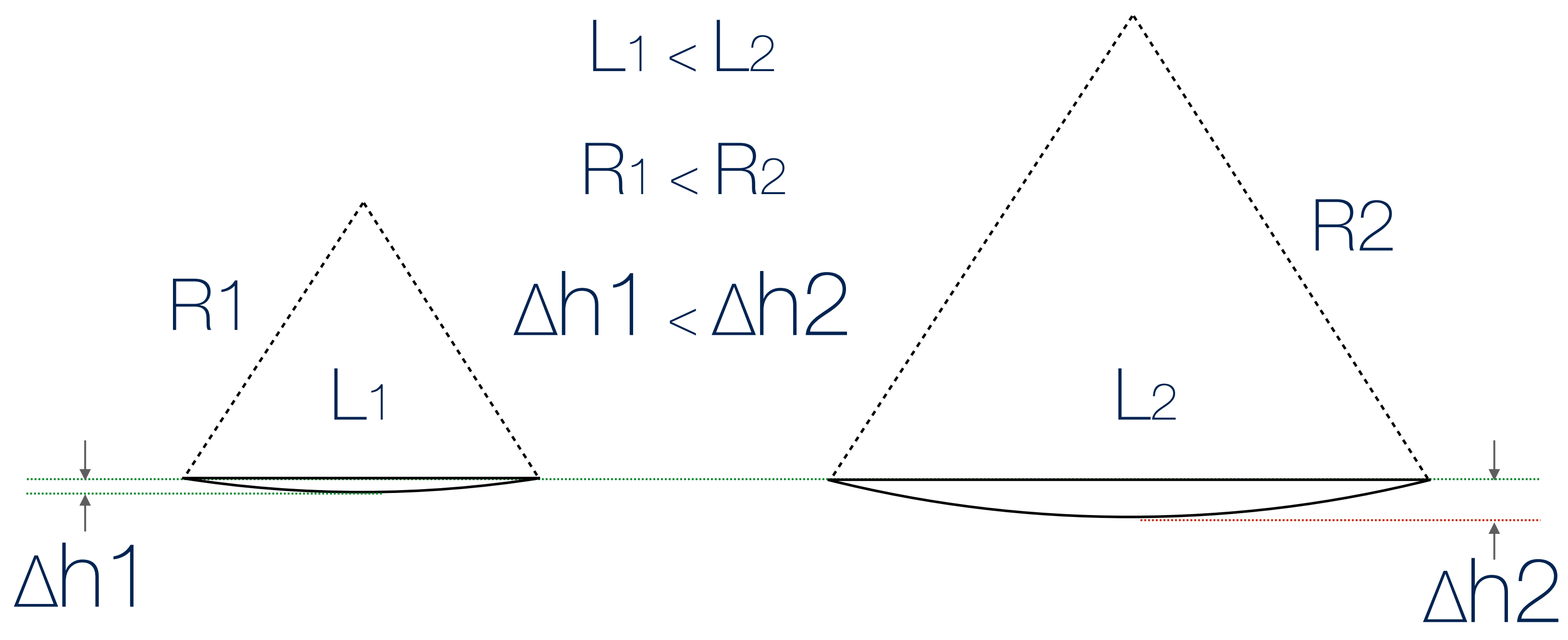
TEC Length / Width Safe Proportions

The larger TEC initial linear dimensions L_0, the more significant values of thermal expansions ΔL





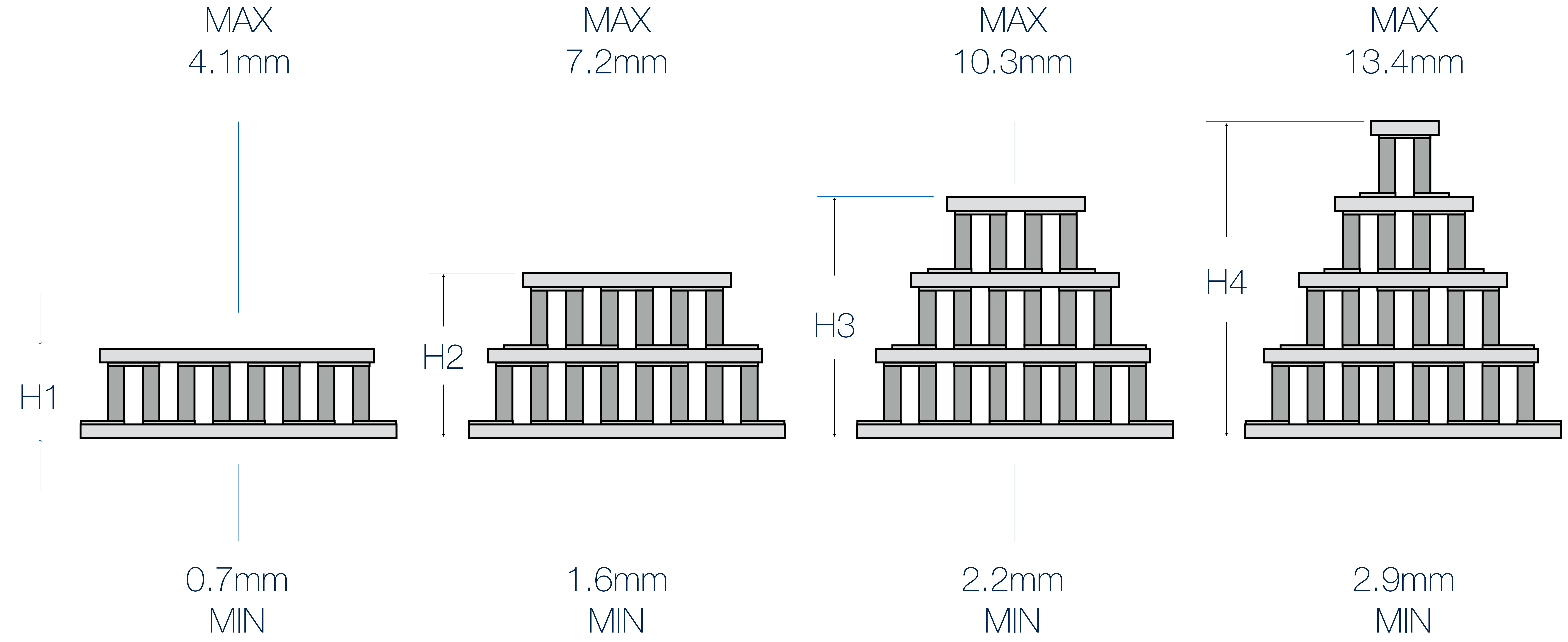
$$\Delta L = CTE \times \Delta T \times L_0$$



ΔL - Linear Dimension change due to expansion
CTE - Material Thermal Expansion Coefficient
ΔT - Temperature Difference

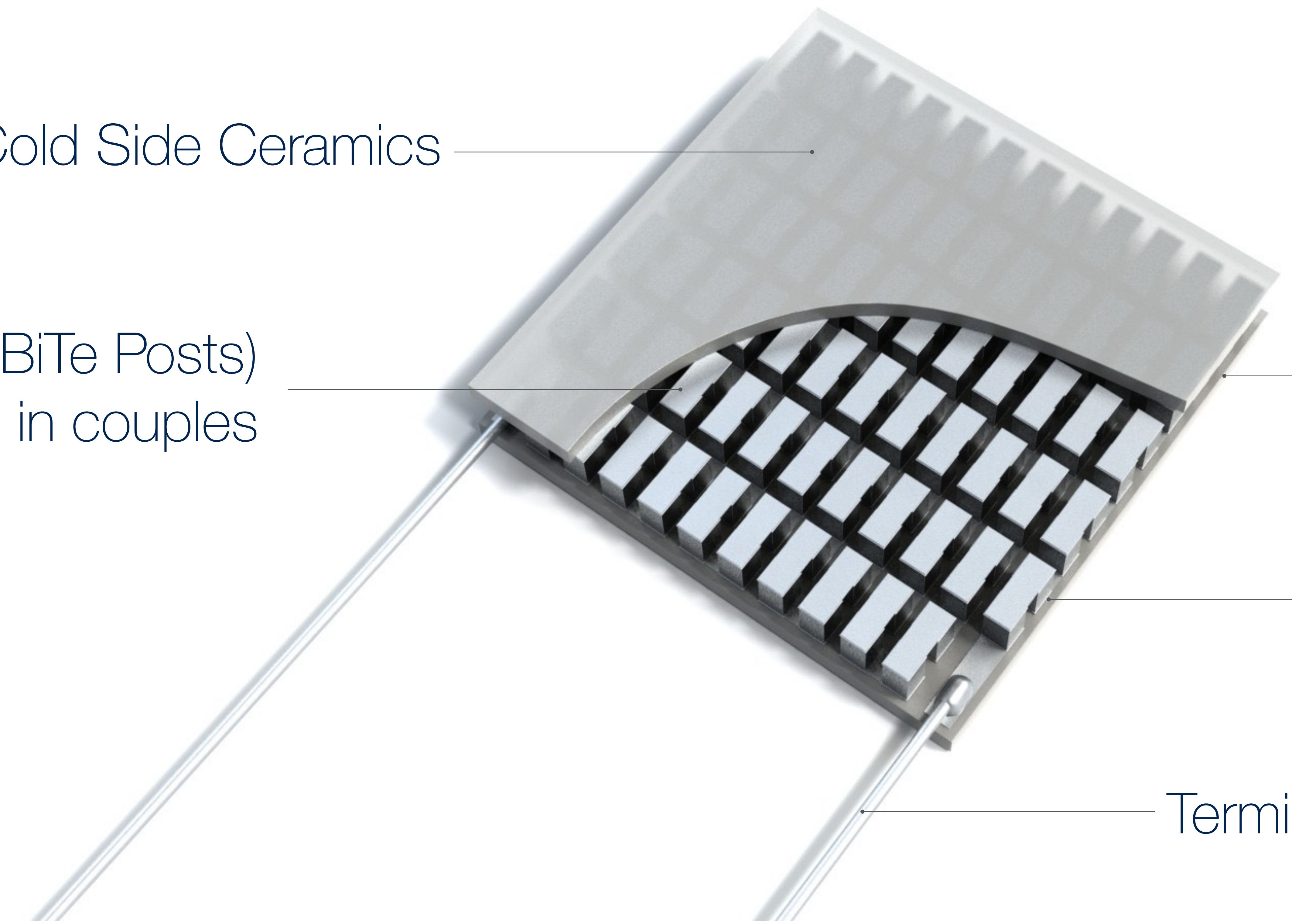
The bigger TEC linear dimensions L_0 is, the bigger is bending force affect and mechanical strains inside TEC

Minimum and Maximum possible TEC Heights for TEC Microsystems TE Coolers



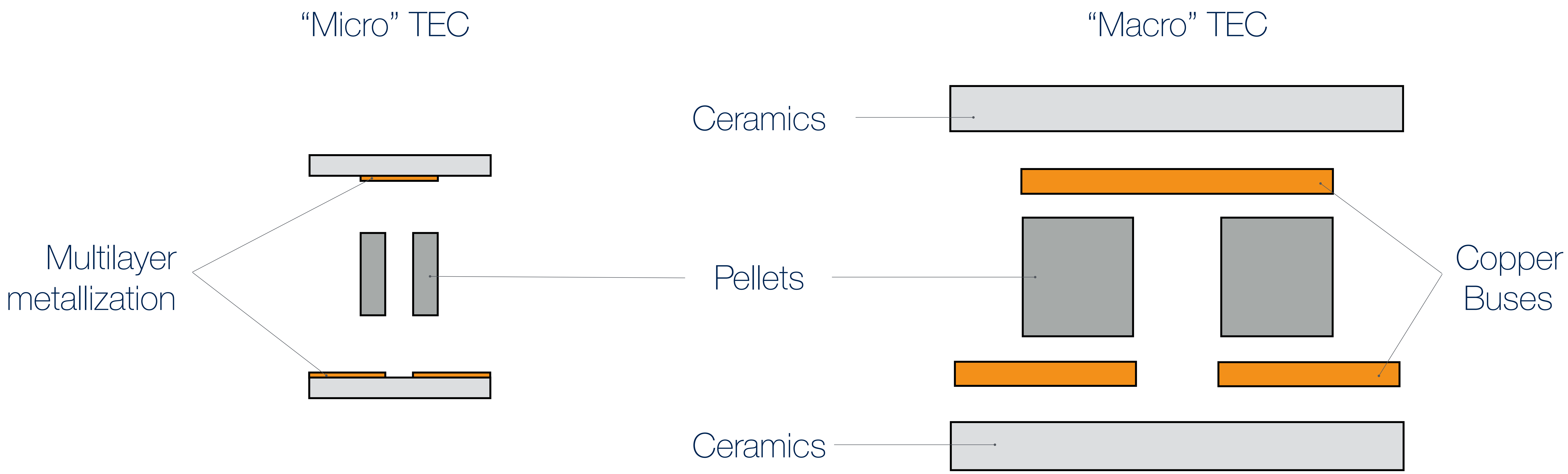
The values specified are absolute MIN and MAX Height values for TEC Microsystems TE Coolers.

“Micro” and “Macro” TE Coolers, Technologies and Differences



The differences between miniature “micro” TECs and large “macro” TECs (besides the size) are in assembly technology, pellets junctions methods and in BiTe material growing process

BULK Technology - “Micro” and “Macro” TE Coolers, General Technology Differences



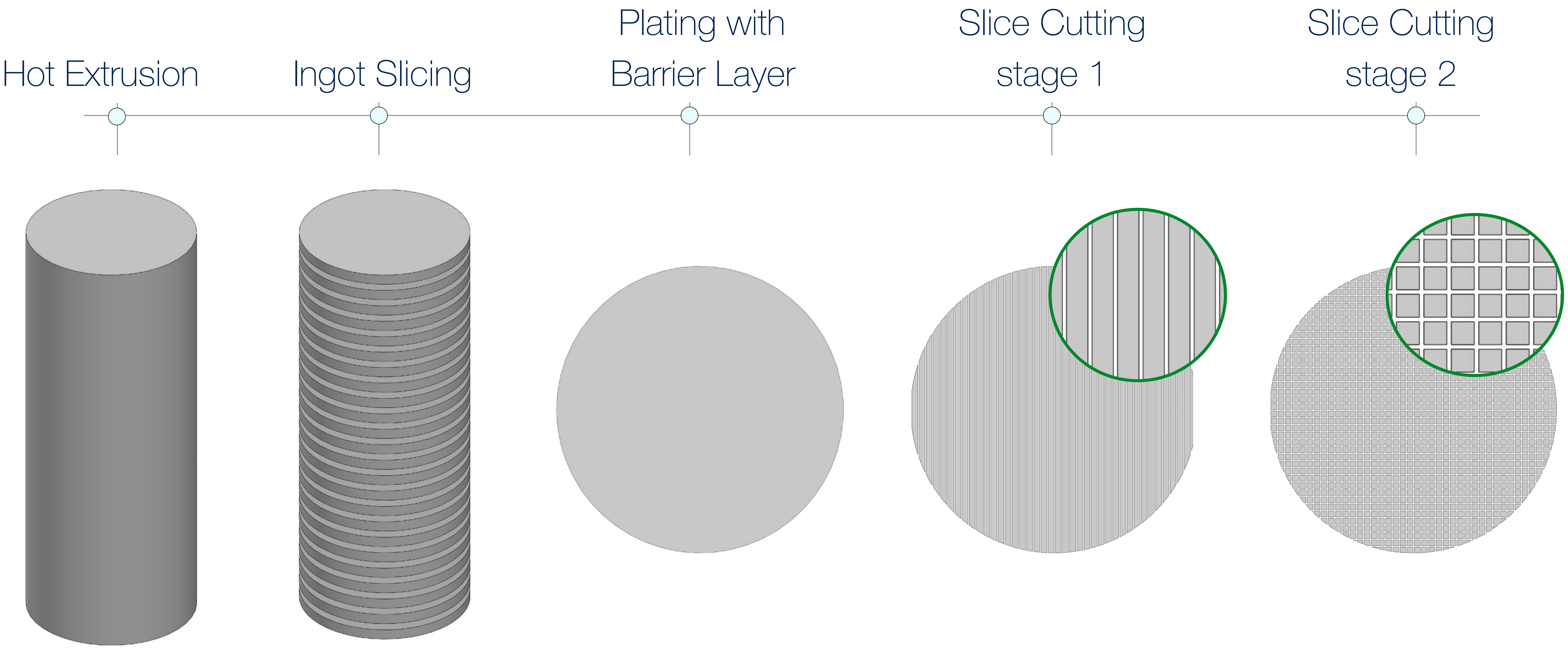
Junctions are created by metallization sputtering on ceramics

Junctions are created by Copper buses brazed onto ceramics with metallization

Small pellets, precise pellets positioning, small distances between elements

Large pellets, large distances between elements, high-precision is not required.

Thermoelectric Cooler Pellets Material - BiTe



TEC Microsystems TECs use the best method for BiTe manufacturing - Hot Extrusion with several know-how

High-Quality BiTe Material for Bulk Technology TE Coolers

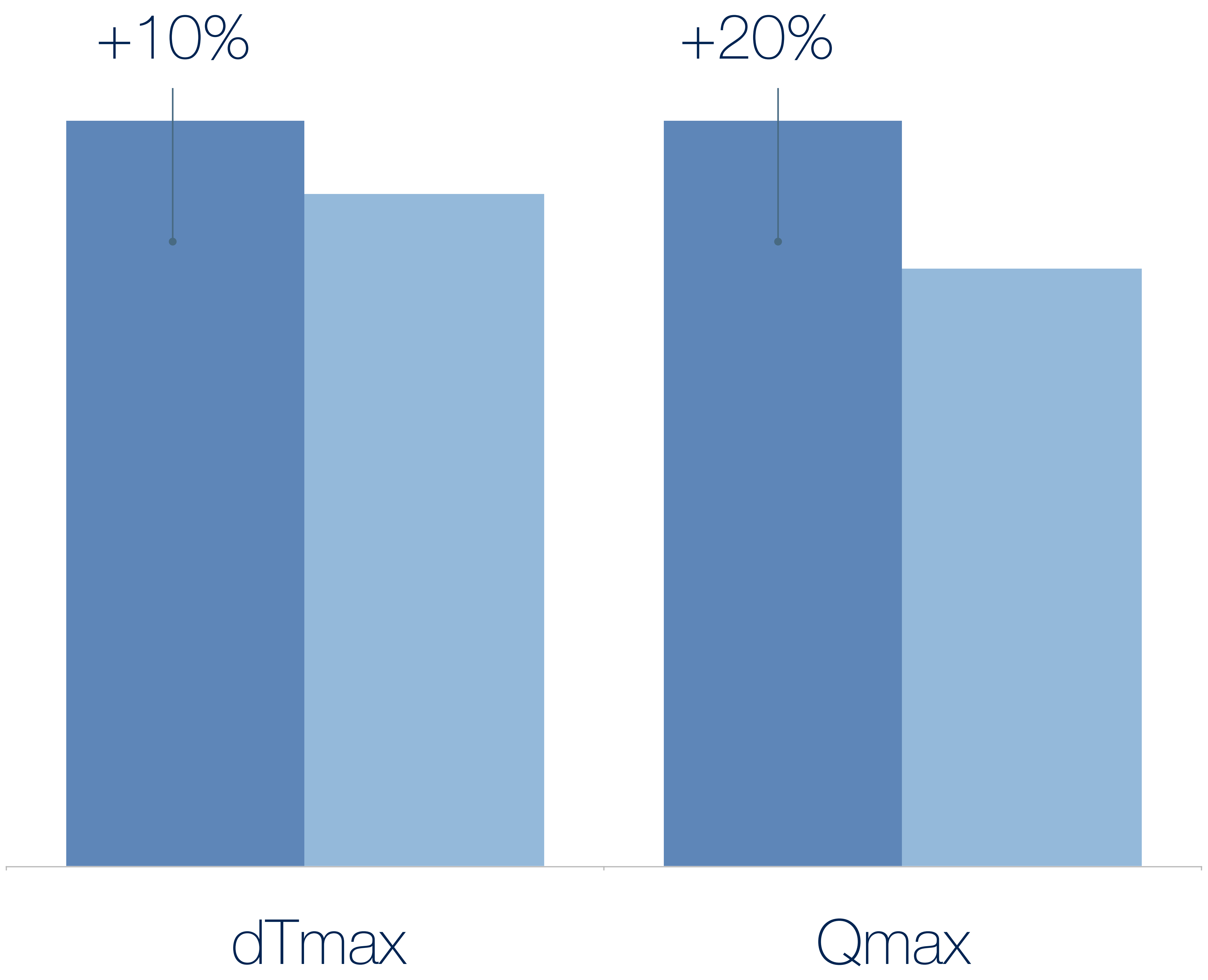
High-Quality BiTe Material

In-house Manufacturing

Hot Extrusion Process

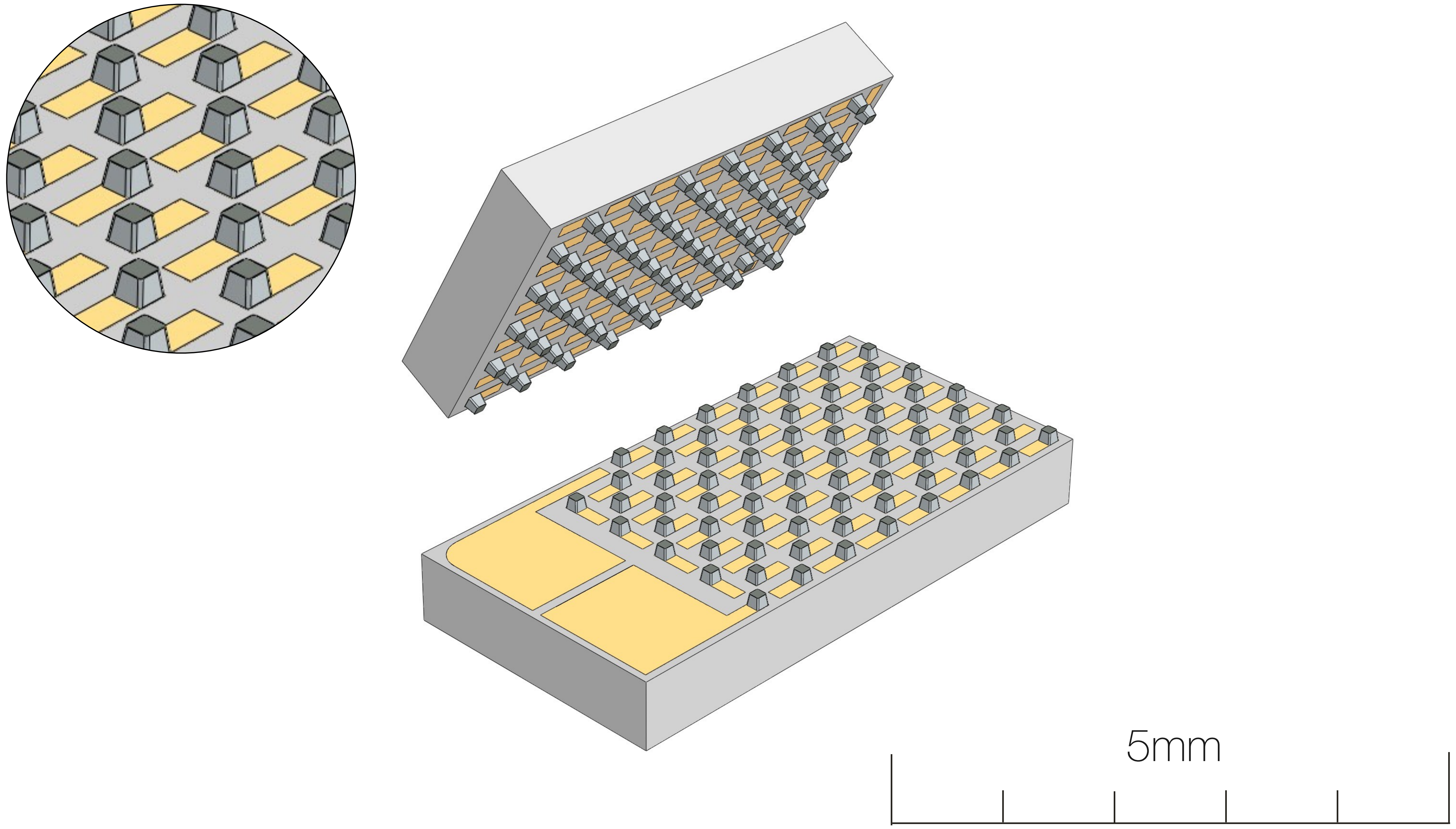
Advanced Performance

Processing with nanotechnology



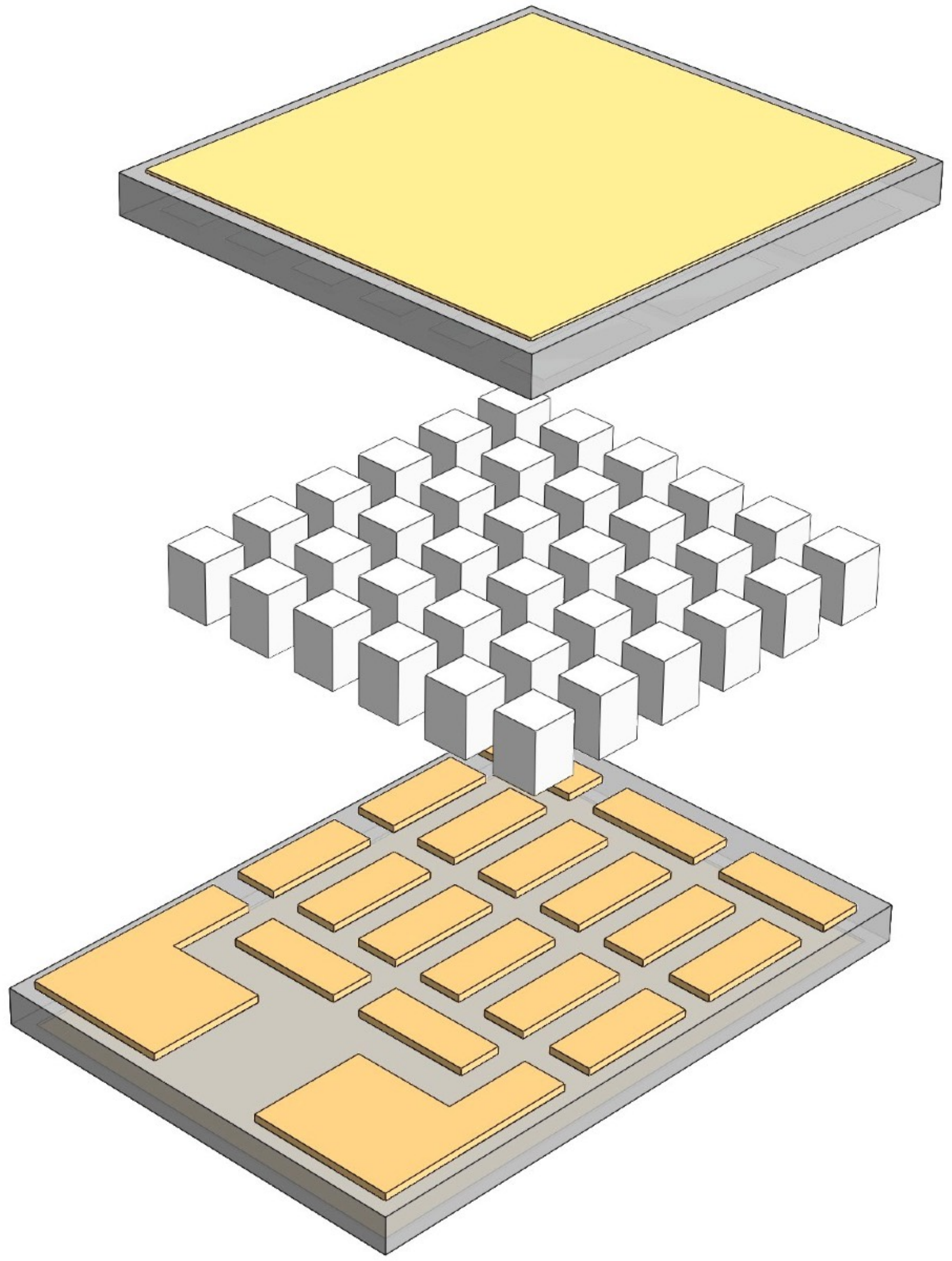
Miniature TE Coolers: BULK TECs and Thin-film TECs

Thin-film TE Cooler



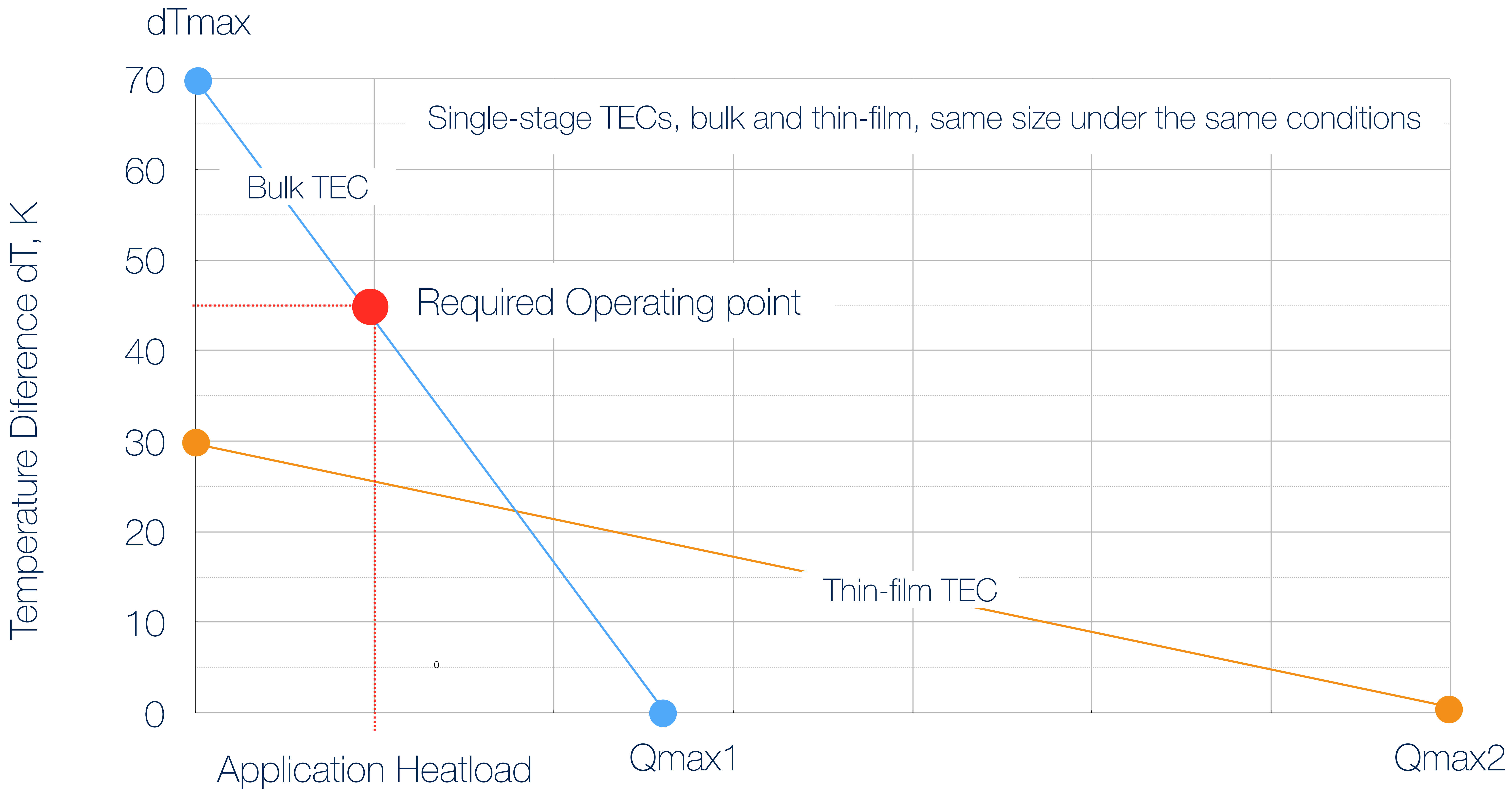
BiTe pellets are grown on a substrate
by thin-film process

Bulk Technology TE Cooler



BiTe material is manufactured in ingots,
cut into pellets and soldered to metallization on ceramics

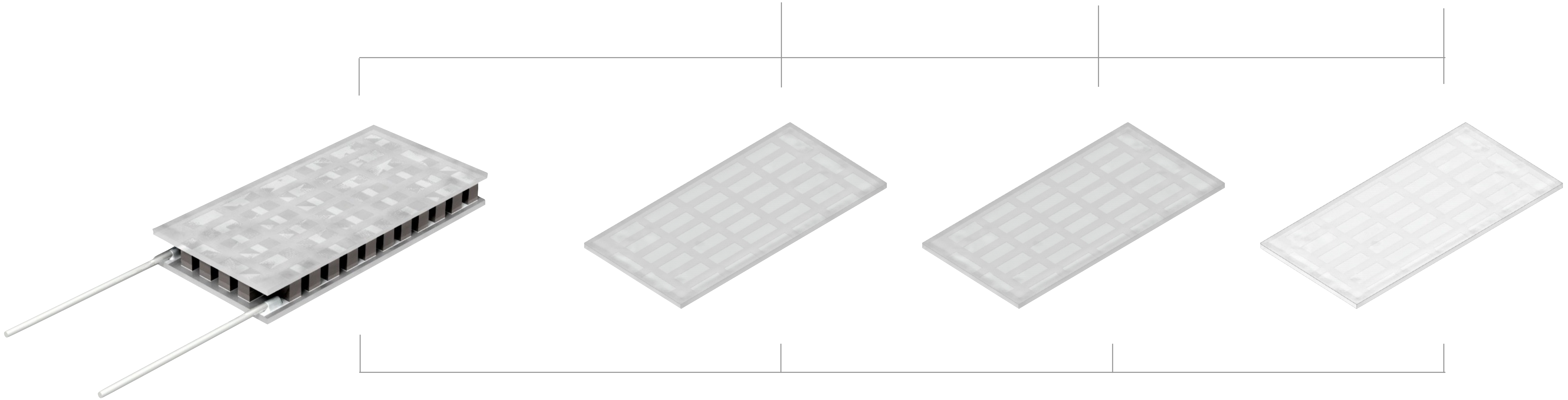
Thin-film and Bulk TECs Performance Differences



Thin-film TECs may have higher cooling capacity than bulk TEC on the same size, but way lower dT_{max}

Thermoelectric Cooler Ceramics Materials

Property	Units	AIN 100%	Al2O3 100%	Al2O3 96%
Thermal Conductivity	W/(m x K)	>170	30	24
Thermal Expansion	$10^{-6}K^{-1}$	4.8	7.2	7
Electrical Resistivity	Ohm x cm	$>10^{14}$	$>10^{14}$	$>10^{14}$



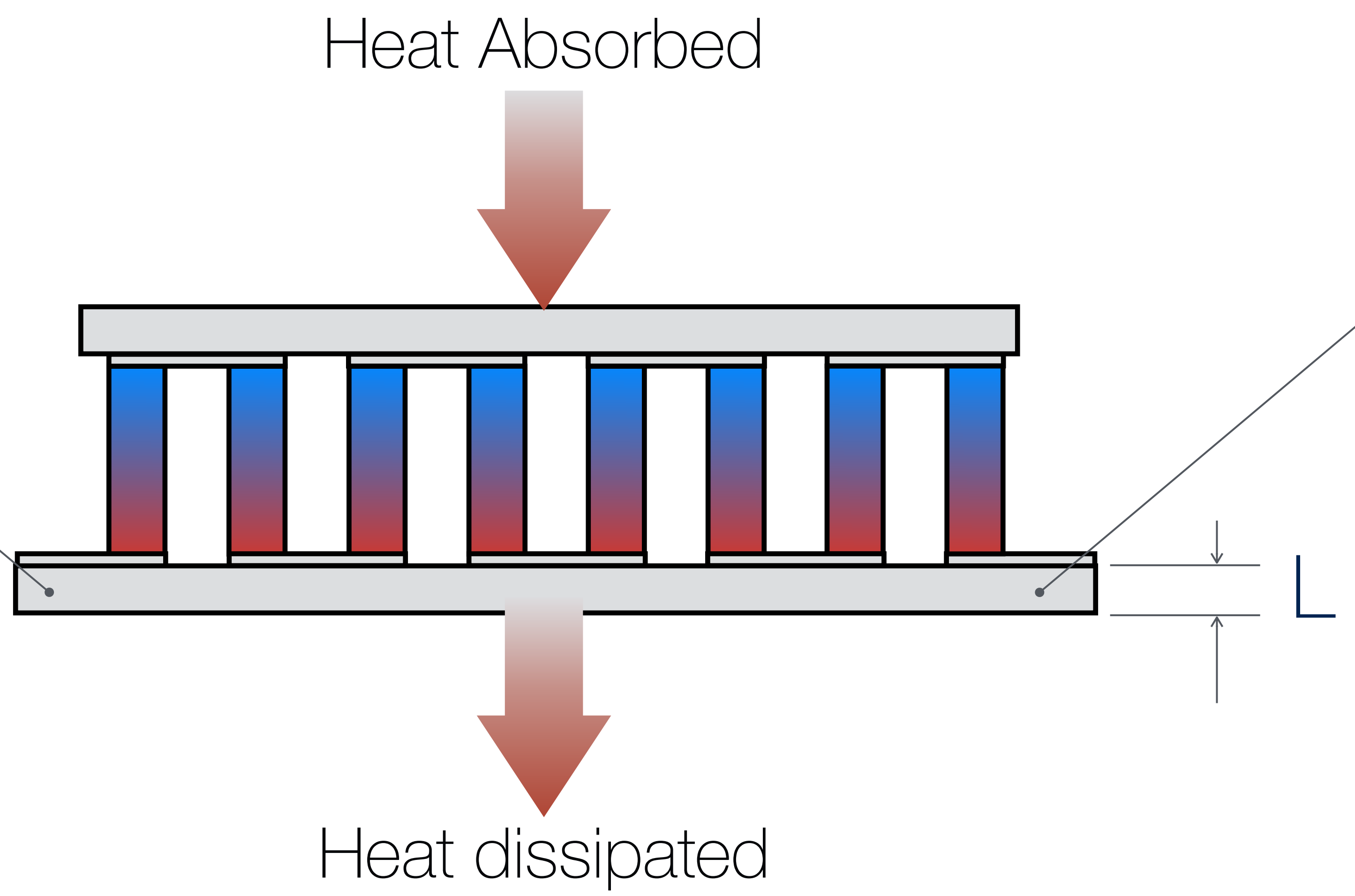
TEC Microsystems uses 100% A_2O_3 and AIN Ceramics for thermoelectric cooler manufacturing

TEC Ceramics Material and Performance Parameters

Ceramics

AlN 100%	Al_2O_3 (100%)
>170	30

Thermal Conductivity (k) , W/mK



Thermal Resistance

$$R_{th} = \frac{L}{k}$$

Parameters	1MD03-015-04		1ML06-023-05		1MC06-126-03	
Dimensions, mm2	2.5 x 3.9		6.0 x 8.2		16.0 x 18.0	
Ceramics Material	Al_2O_3	AlN	Al_2O_3	AlN	Al_2O_3	AlN
dTmax, K (@27ºC)	71	72	69	71	67	69
Qmax, W (@27ºC)	1.18	1.23	5.4	5.8	46.15	51.60
		+4%		+7%		+12%

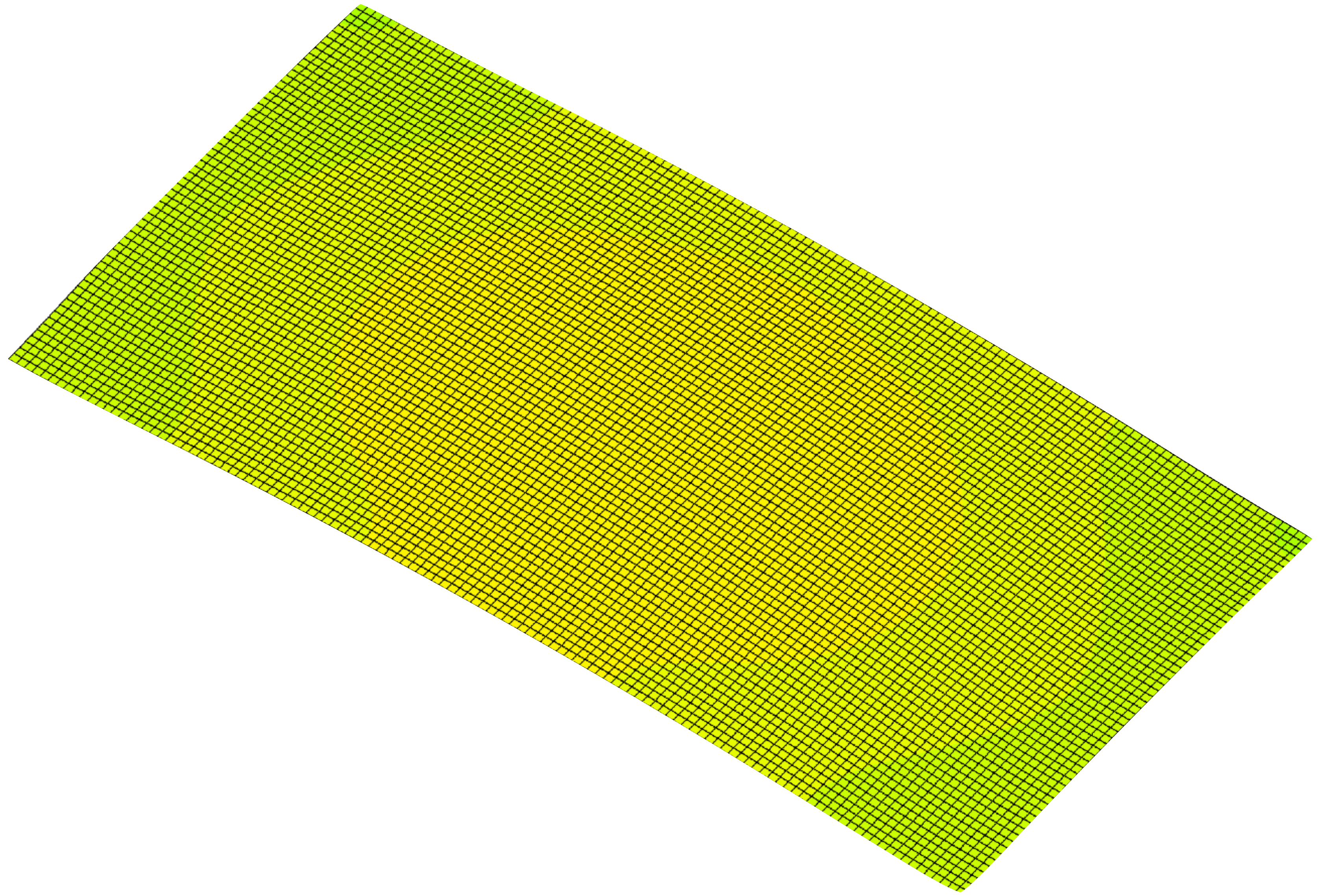
AlN Ceramics can increase TEC cooling performance, especially for powerful (by Qmax) TECs. In case of micro-TECs for low-power applications it' less visible.

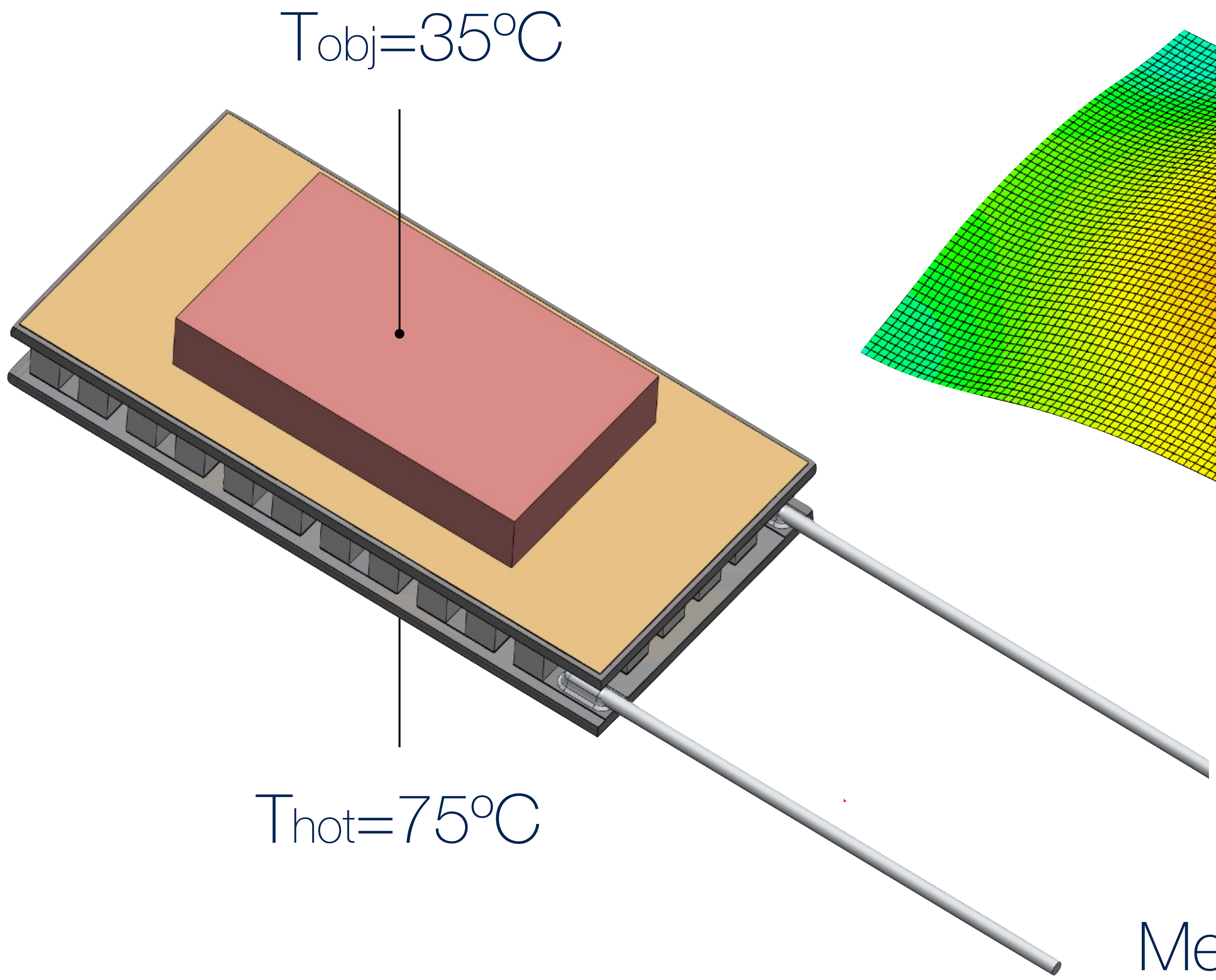
Ceramics Material and Temperature Uniformity (Example #1)

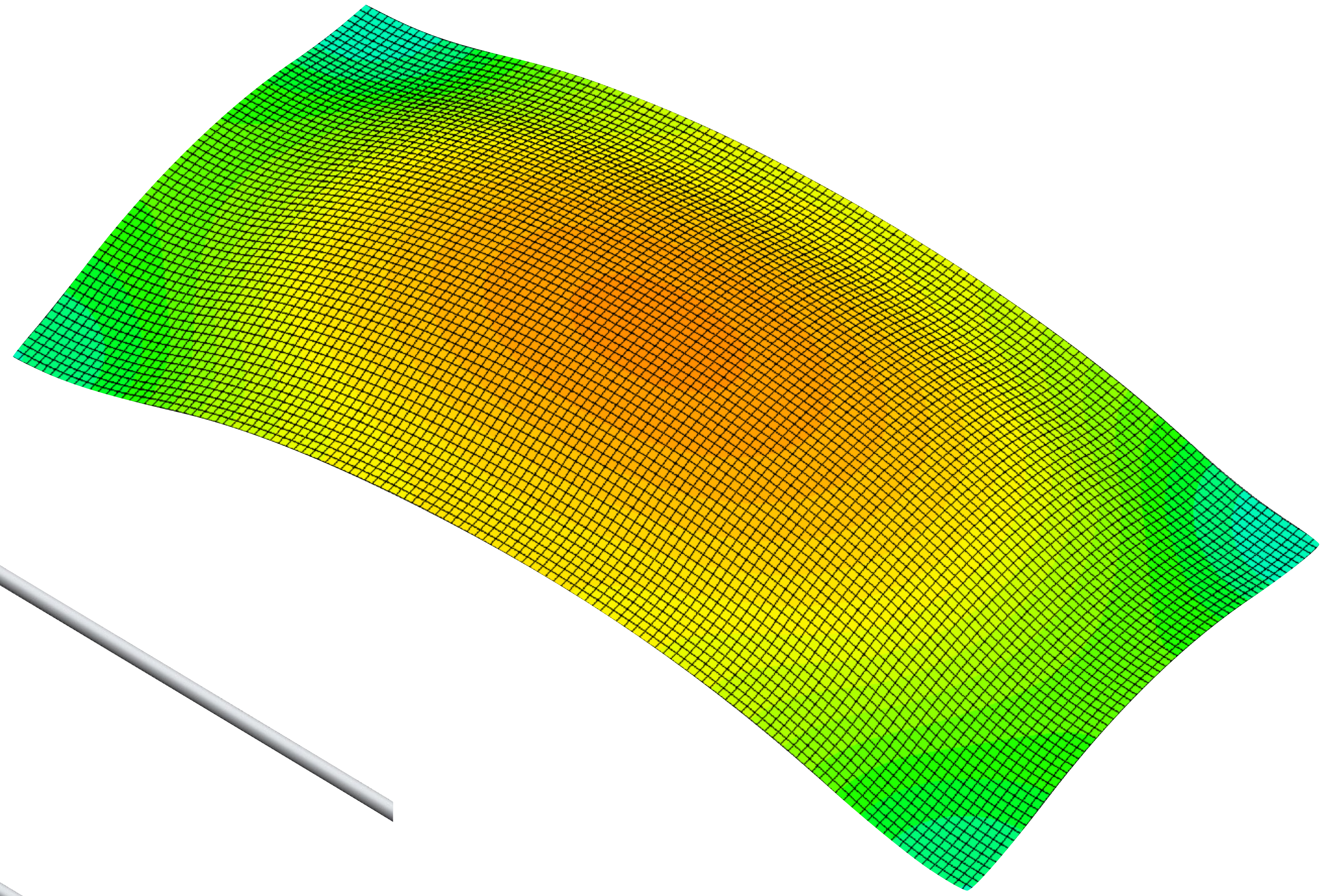
AlN 0.25mm Ceramics

Heatload 0.6W

A_2O_3 0.25mm Ceramics







Mean temperature difference
(among surface)

0.26 °C

Mean temperature difference
(among surface)

1.48 °C

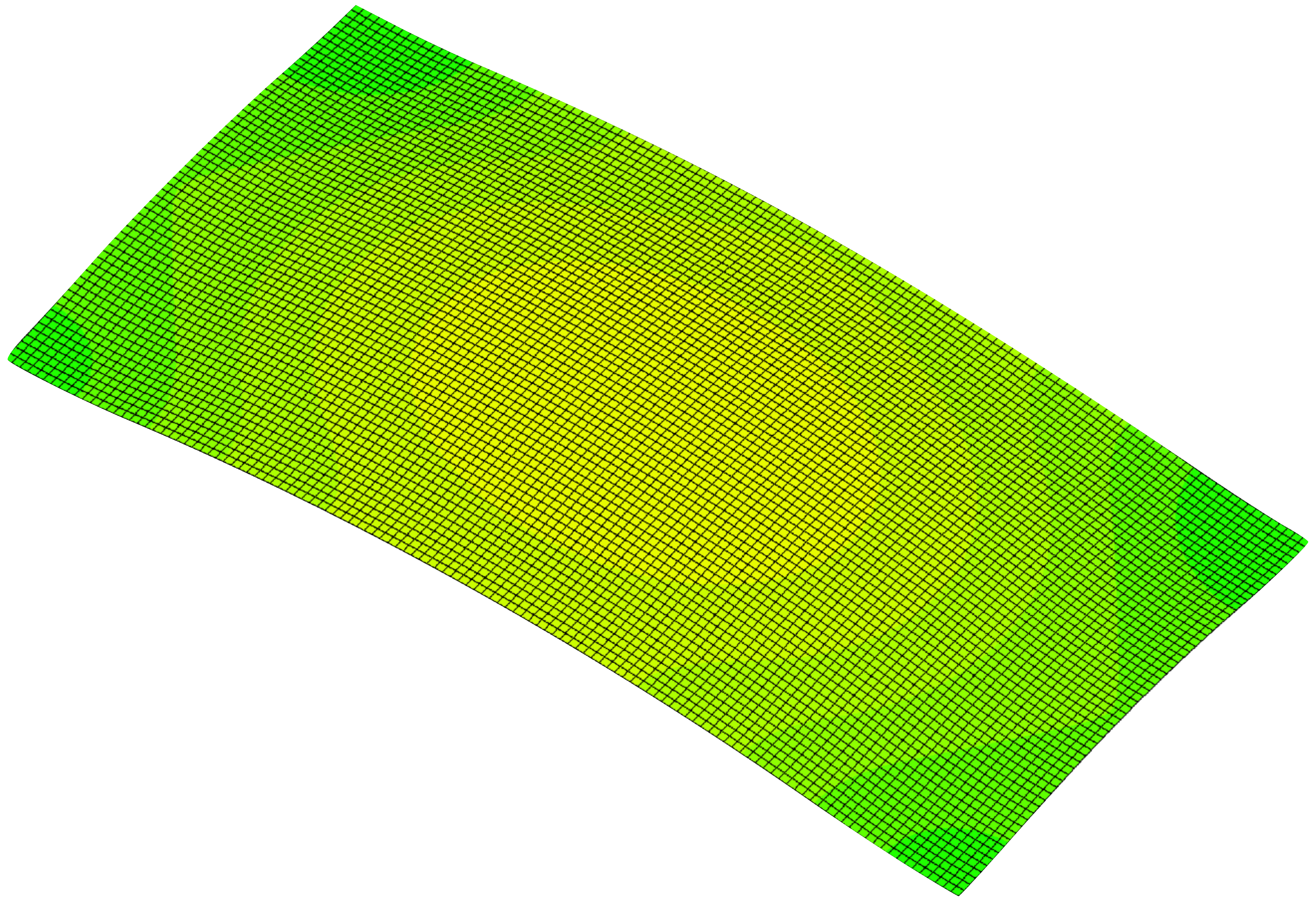
The difference in temperature uniformity among surface between Al2O3 and AlN ceramics may be valuable.

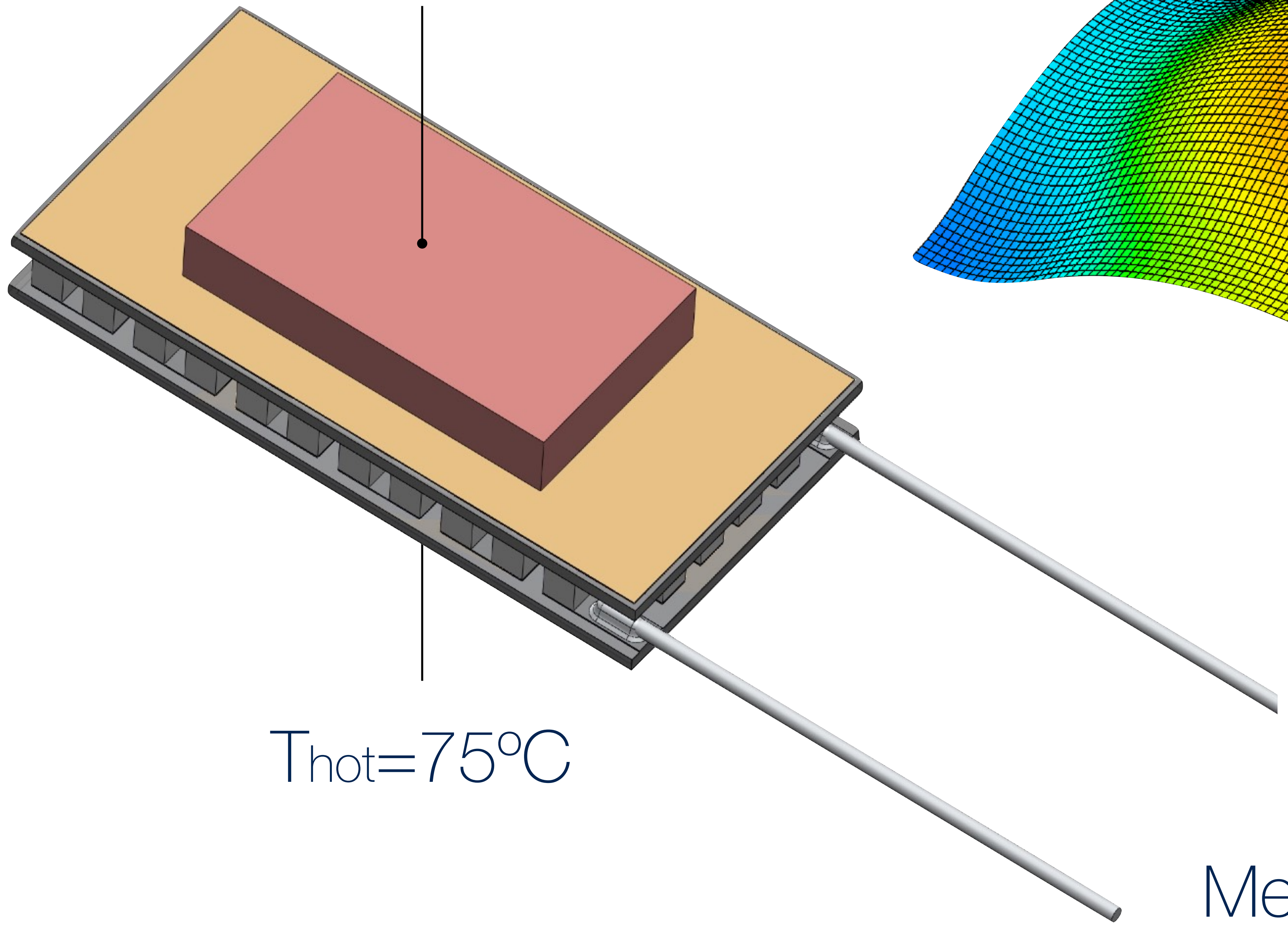
Ceramics Material and Temperature Uniformity (Example #2)

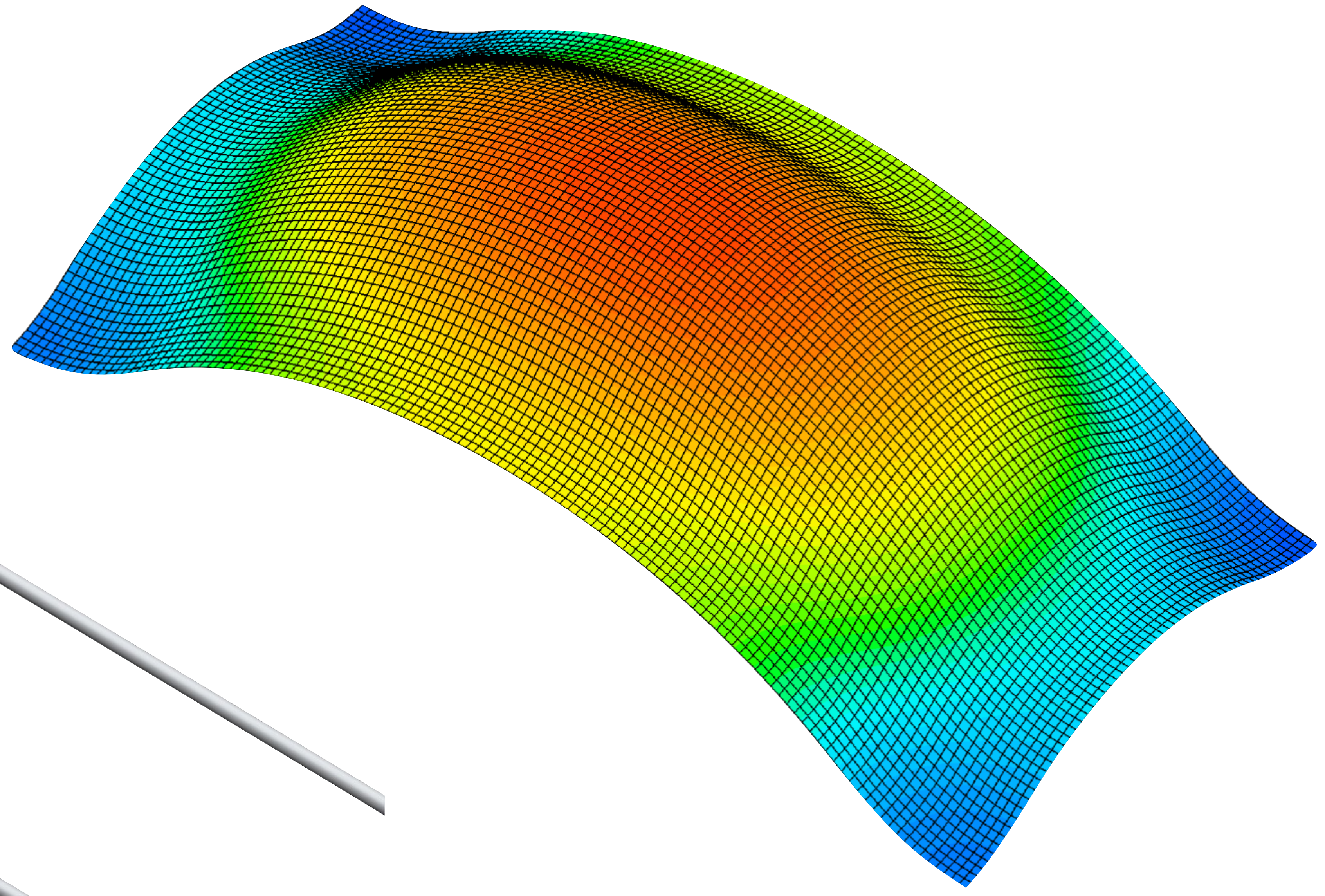
AlN 0.25mm Ceramics

Heatload 1.2W

A_2O_3 0.25mm Ceramics







Mean temperature difference (among surface)

0.53 °C

Mean temperature difference (among surface)

2.95 °C

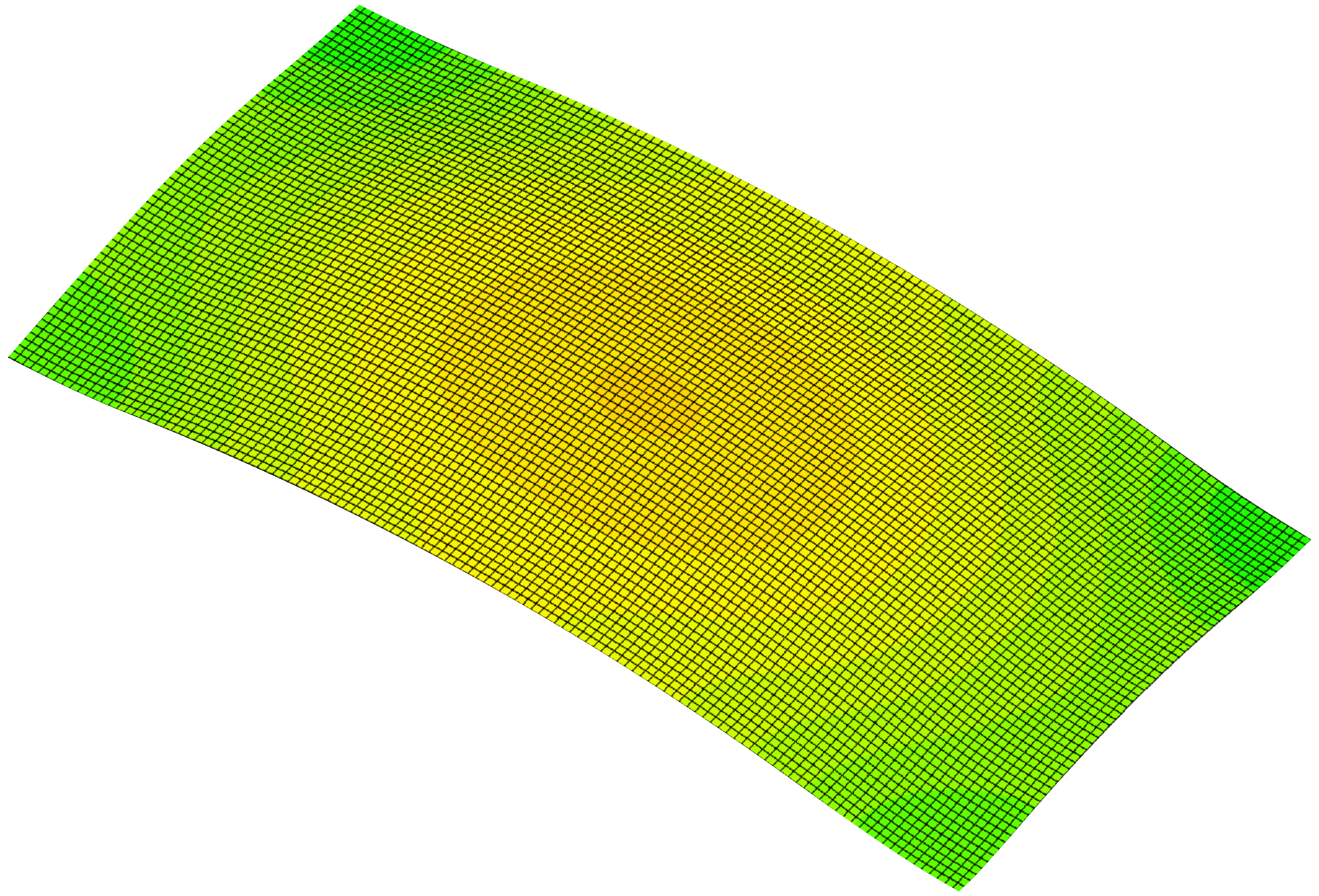
The difference in temperature uniformity among surface between Al2O3 and AlN ceramics may be valuable.

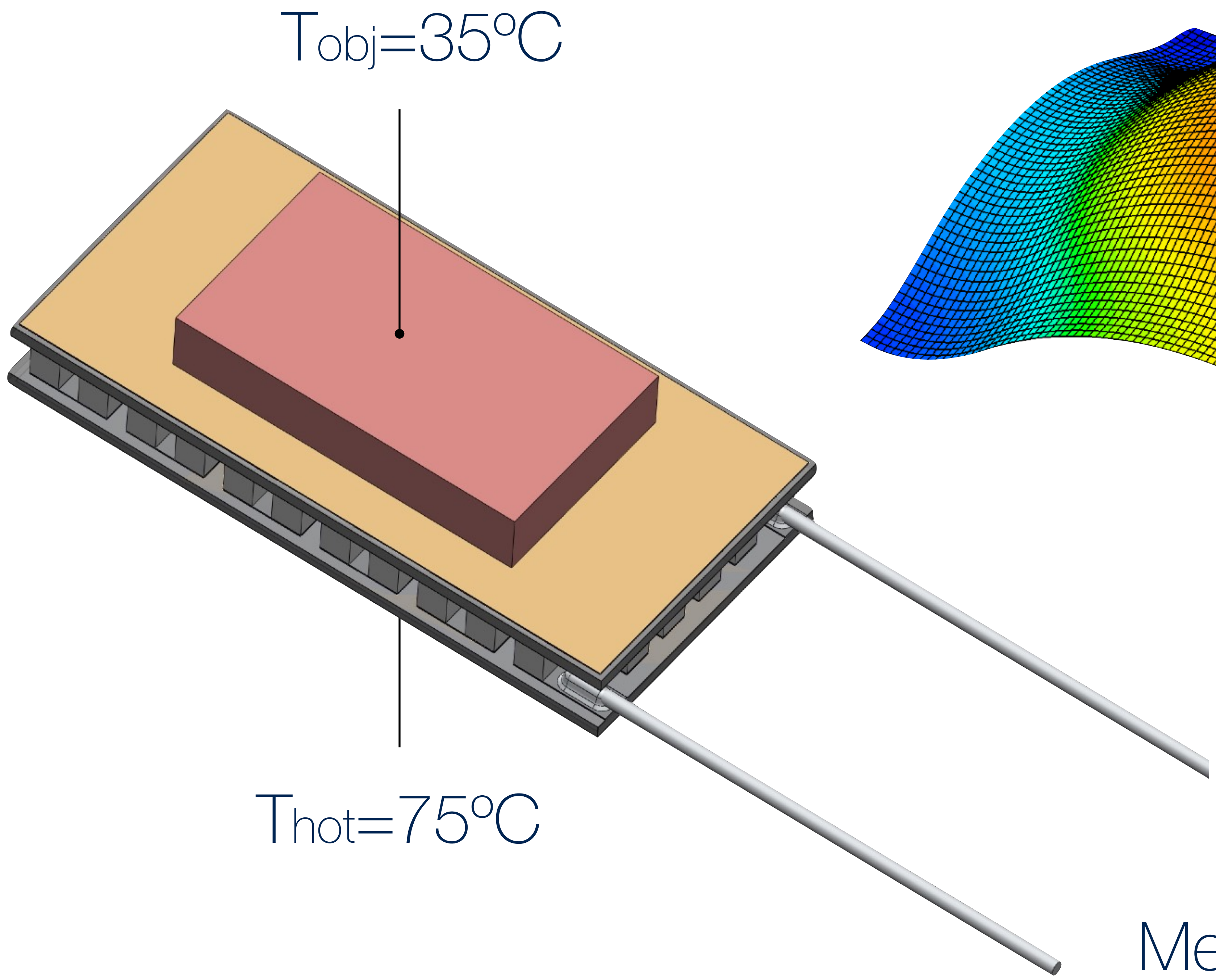
Ceramics Material and Temperature Uniformity (Example #3)

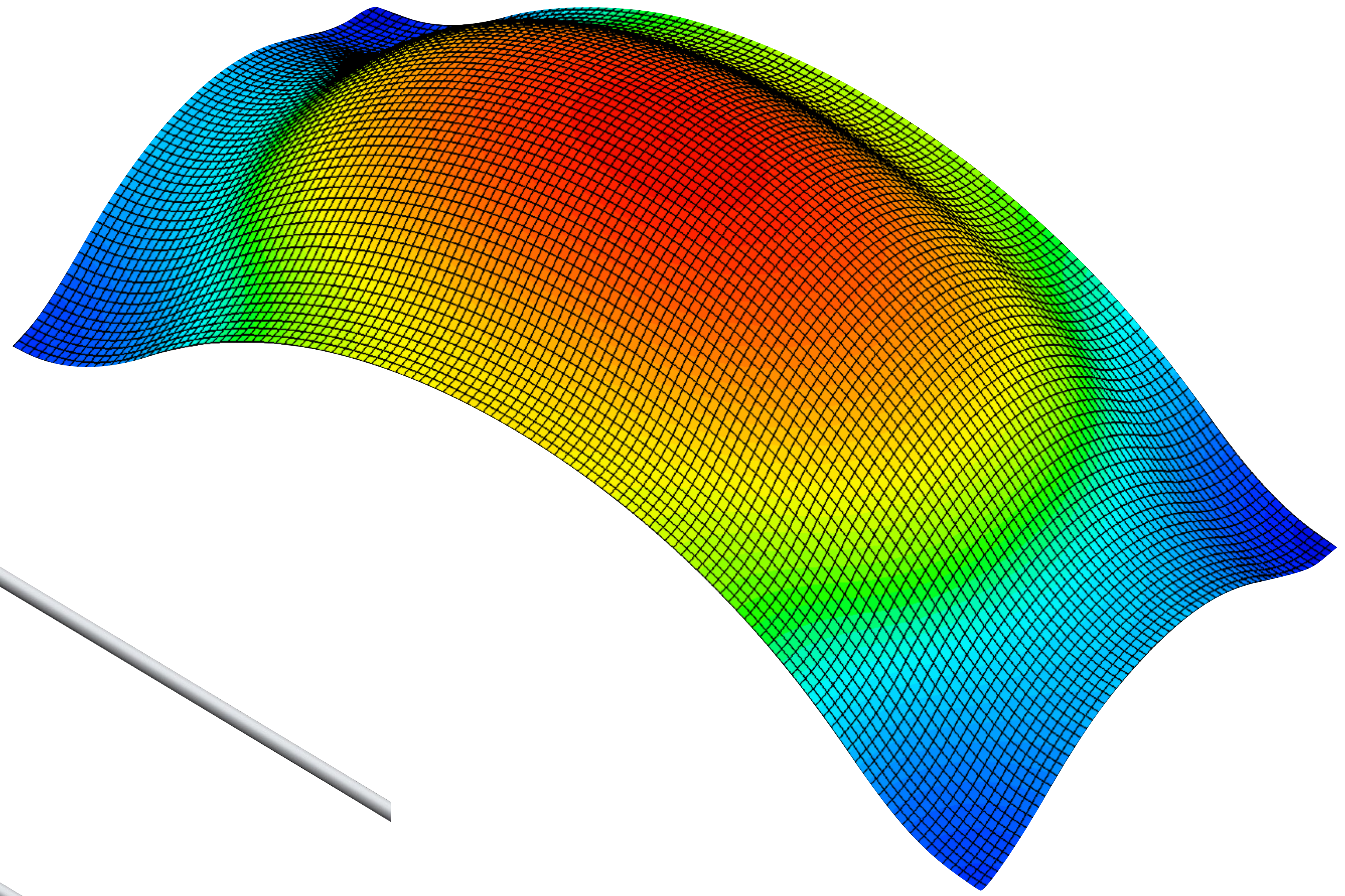
AlN 0.25mm Ceramics

Heatload 1.5W

A_2O_3 0.25mm Ceramics







Mean temperature difference
(among surface)

0.66 ºC

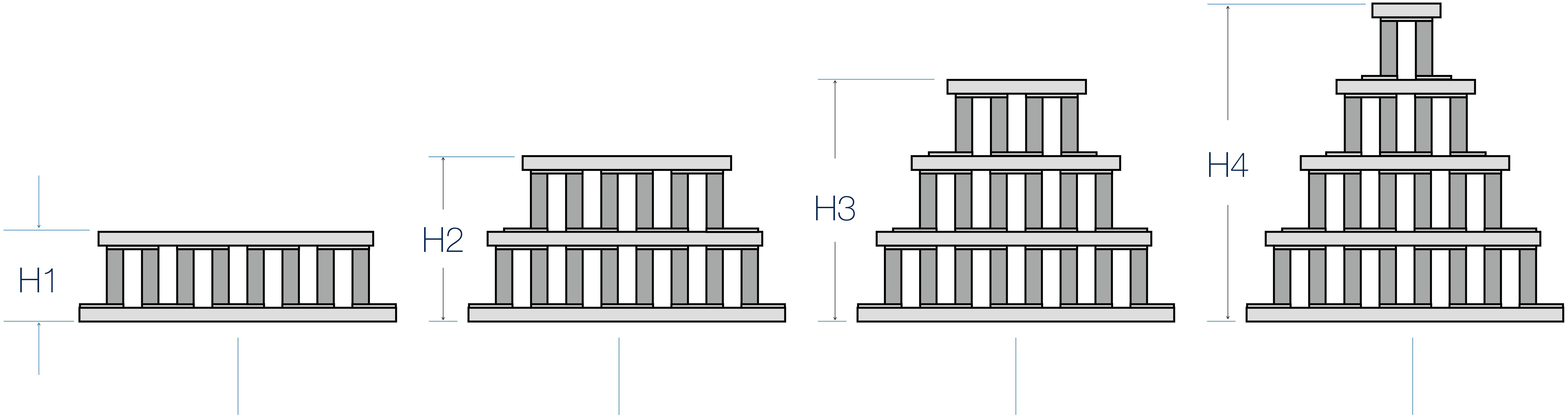
Mean temperature difference
(among surface)

3.67 ºC

The difference in temperature uniformity among surface between Al2O3 and AlN ceramics may be valuable.

Standard TEC Microsystems TEC Height Tolerances

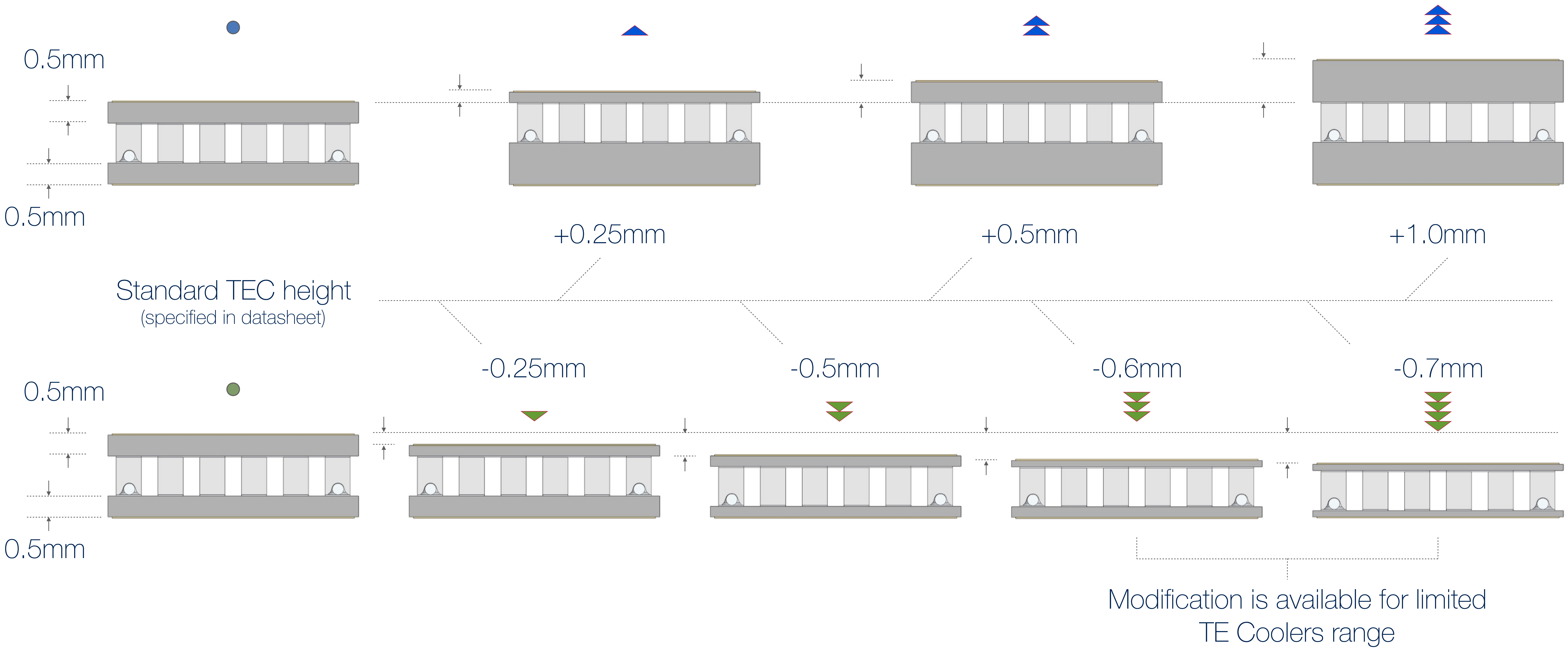
Single-stage TECs | Two-stage TECs | Three-stage TECs | Four-stage TECs



H1 ± 0.1mm | H2 ± 0.1mm | H3 ± 0.15mm | H4 ± 0.2mm

The specified Height Tolerances are provided by default for all TEC Microsystems TECs.
Advanced TEC Height Optimization and Tolerances enhancements are available if required.

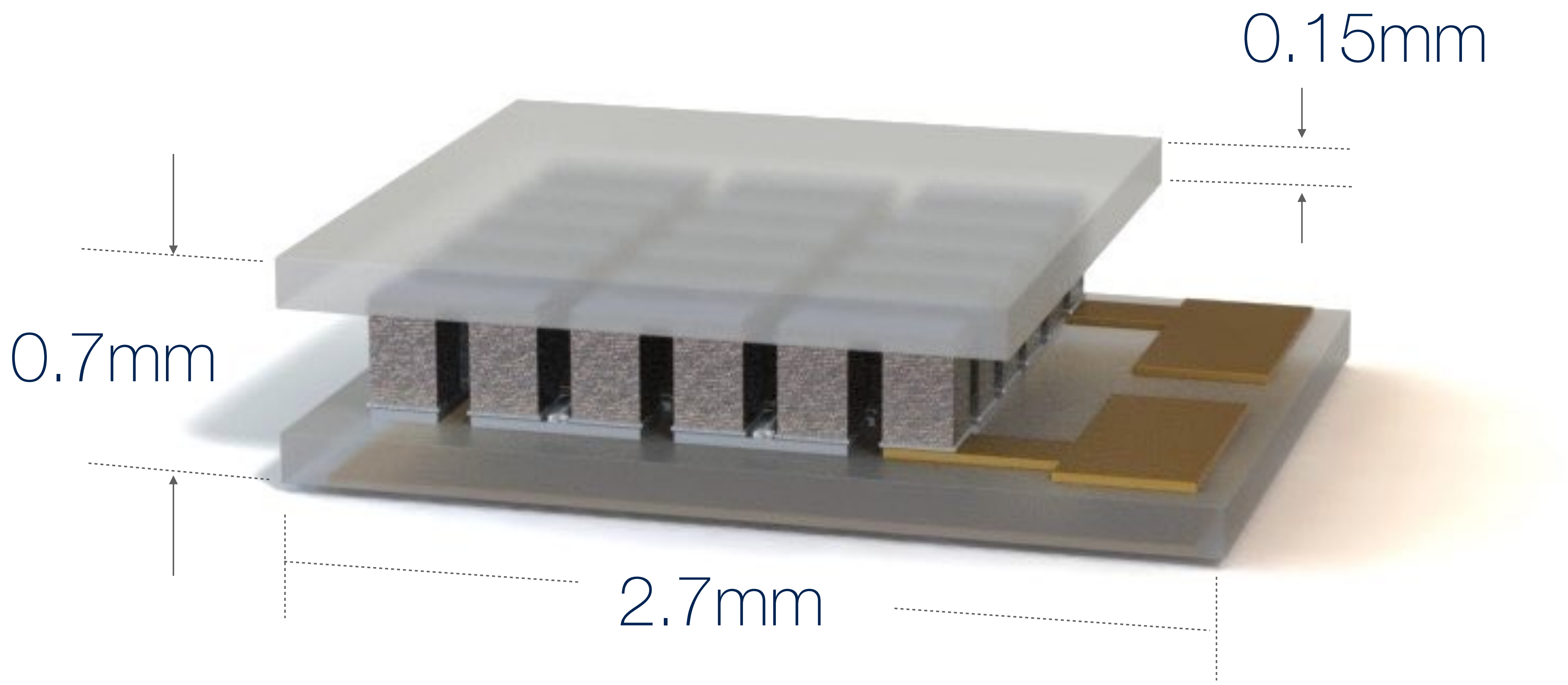
TEC Height Variation by Ceramics Thickness - Single-stage type



TEC Microsystems can change TEC height in a certain range by Ceramics Thickness without parameters changing

Miniature Ultra-thin TE Coolers on 0.15mm AlN Ceramics - “ANt”

Example:1MD02-018-03ANt - Index “ANt” indicates 0.15mm AlN Ceramics using

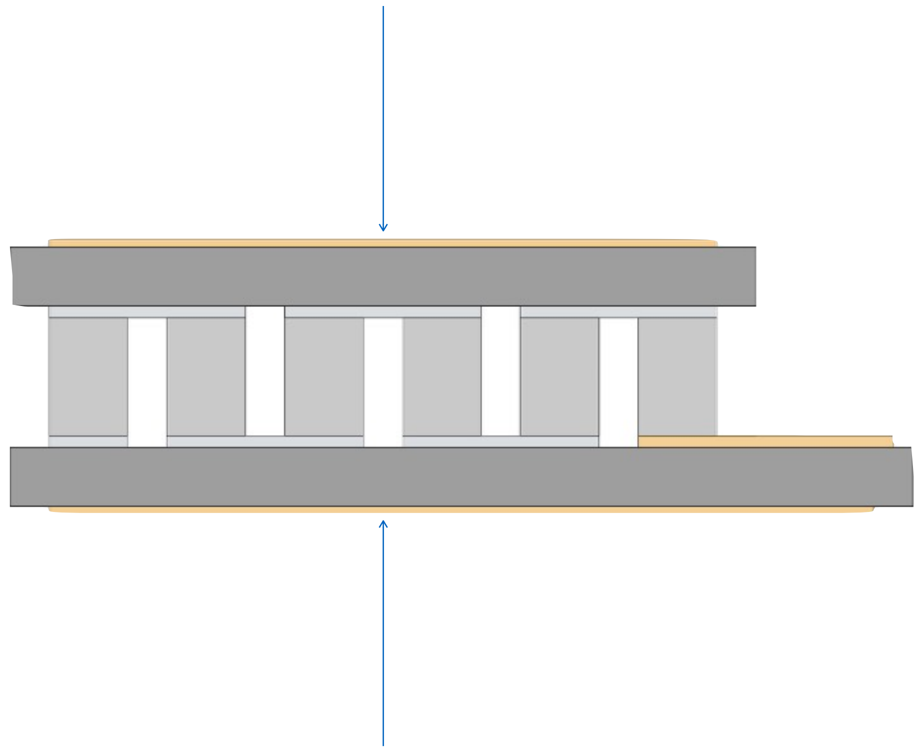


TEC Microsystems “ANt” Series of ultra-compact and ultra-thin TECs starts from 1x1mm^2 size and 0.7mm Height

TEC Microsystems “ANt” TECs - Ultra-thin TEC types with precise Height Control

Example with 1MD02-012-xx/1ANt TEC Type

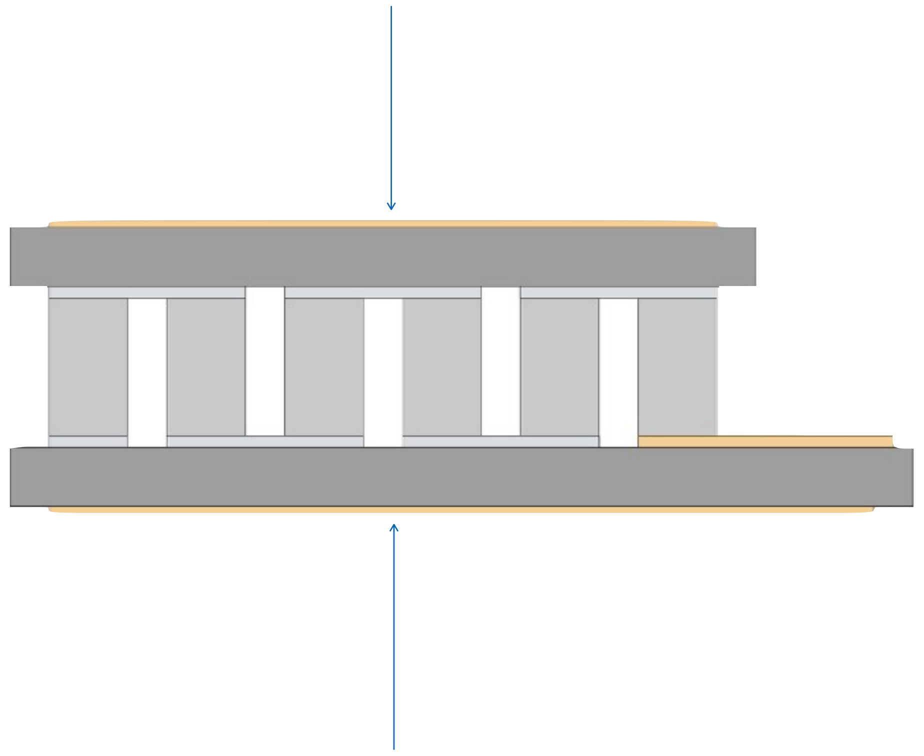
1MD02-012-03/1ANt



H=0.69 ± 0.05mm

± 0.03mm (optional)

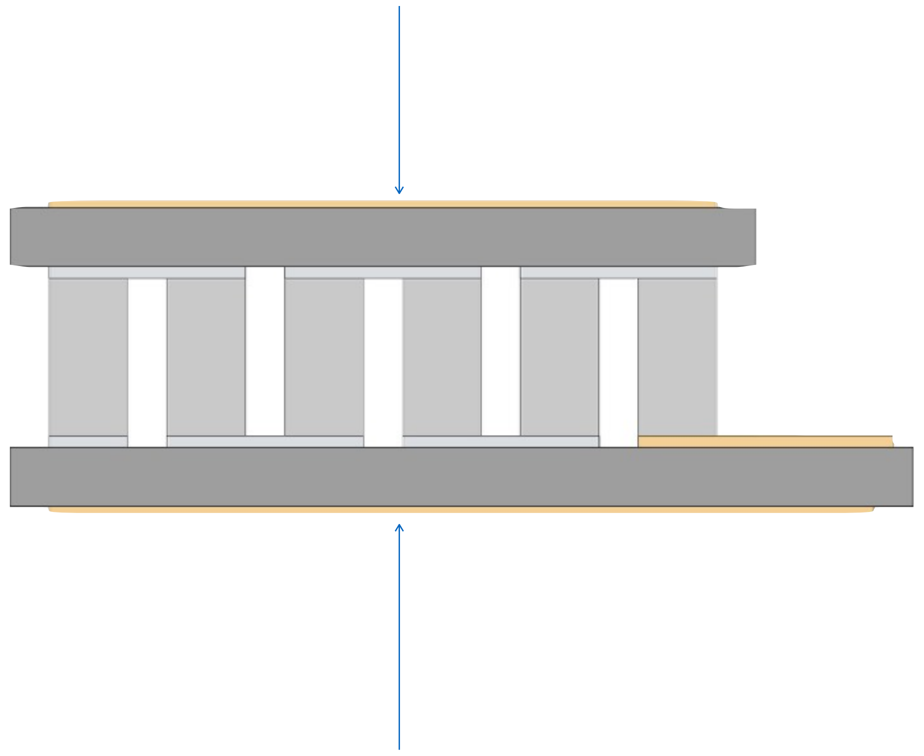
1MD02-012-035/1ANt



H=0.74 ± 0.05mm

± 0.03mm (optional)

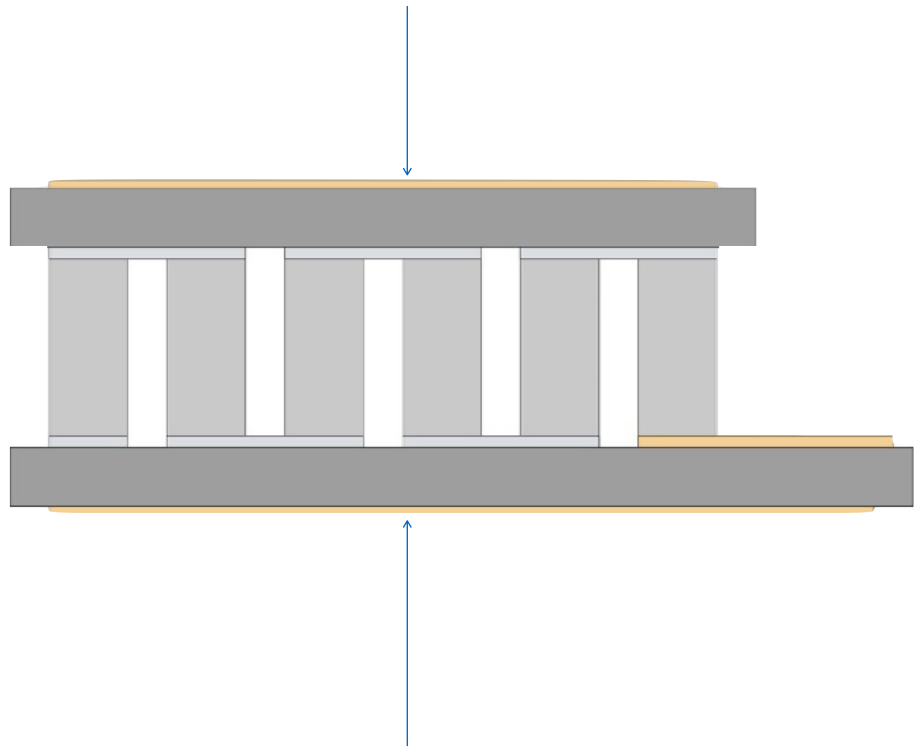
1MD02-012-04/1ANt



H=0.79 ± 0.05mm

± 0.03mm (optional)

1MD02-012-045/1ANt



H=0.85 ± 0.05mm

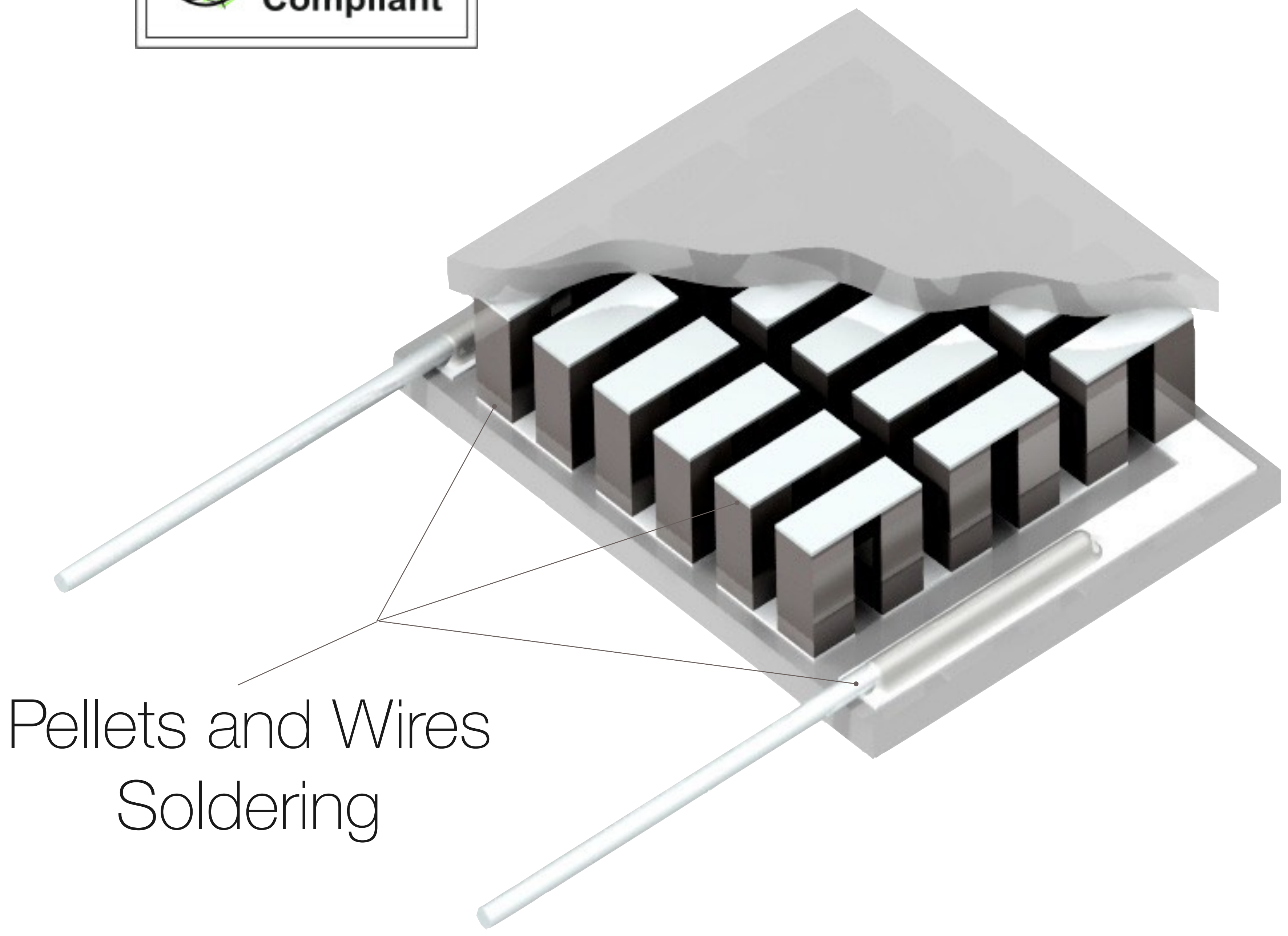
± 0.03mm (optional)

TEC Microsystems provides ultra-thin TEC Solutions from “ANt” Series - ultra-thin TECs with precise height control

TEC Microsystems Thermoelectric Coolers Assembly Solders

TEC Microsystems Standard TEC Internal Assembly Solder		
Antimony-Tin	Sn-Sb (95%-5%)	230°C

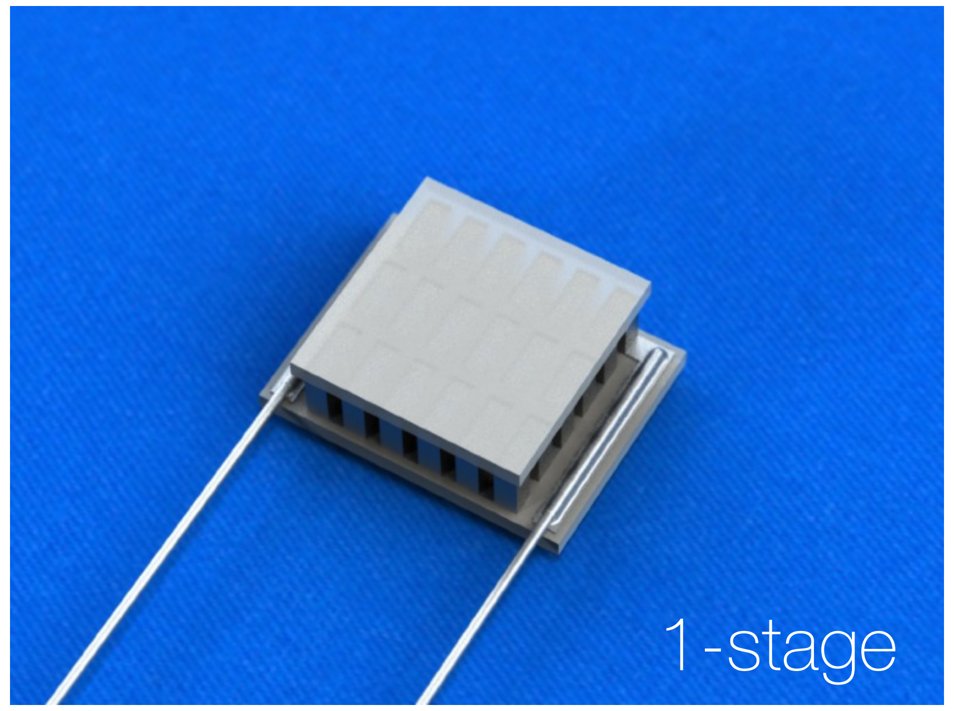
Optional TEC Internal Assembly Solders		
Gold-Tin	Au-Sn (80%-20%)	280ºC
Lead-Tin	Pb-Sn (37%-63%)	183°C
Bismuth-Tin	Bi-Sn (57%-43%)	138°C

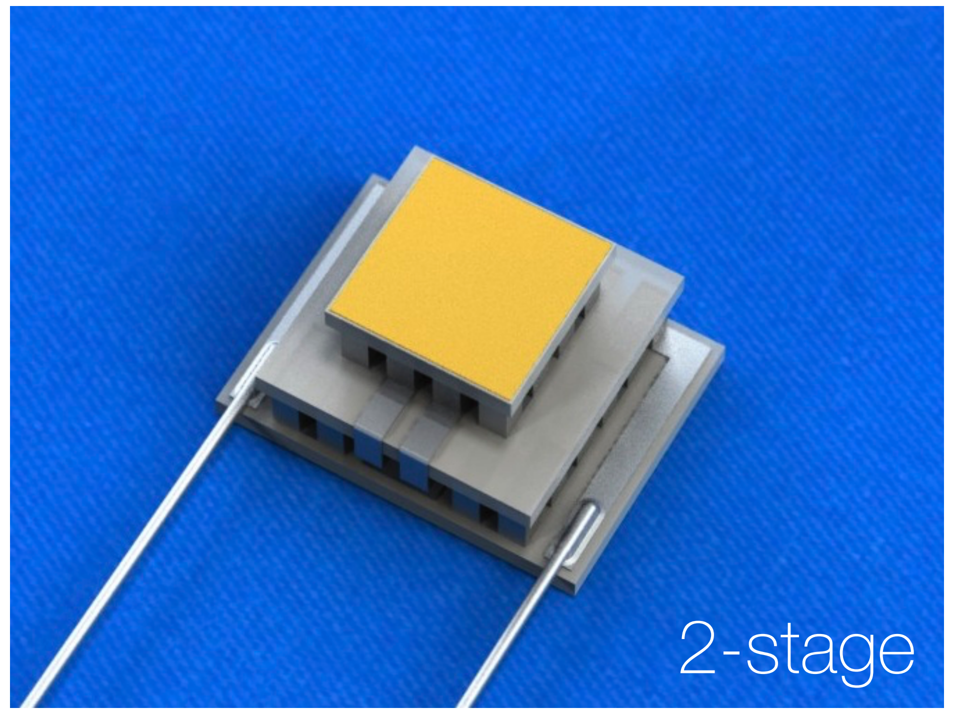


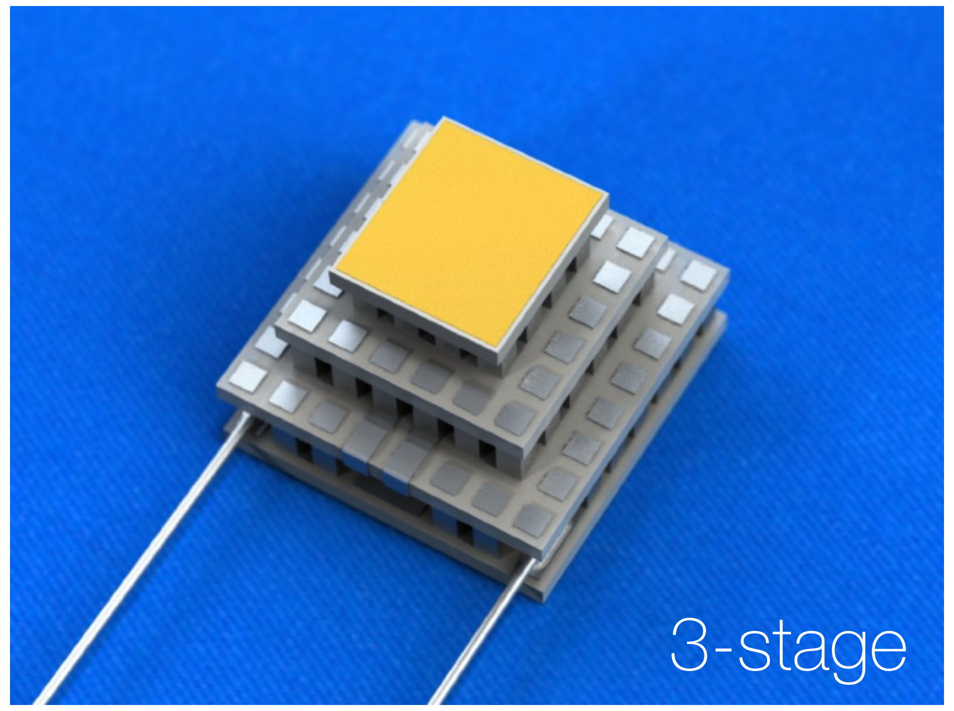
TEC Microsystems uses Solder 230 by default for TEC Assembly. Other solutions are available by request.

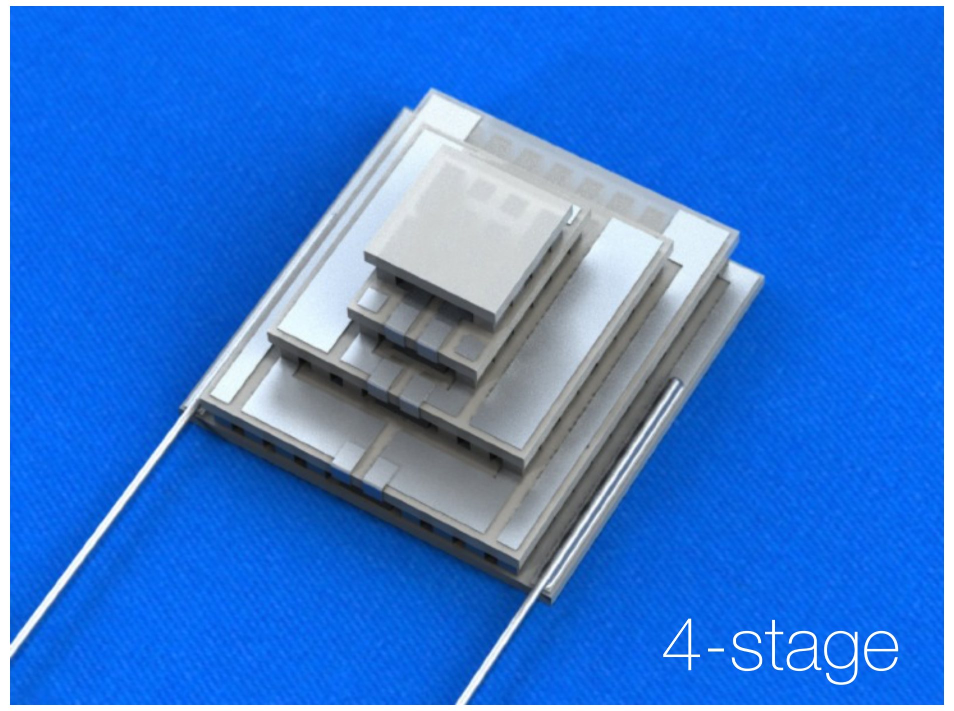
TEC Microsystems TECs are assembled with RoHS compliant Solder 230 by default

TEC Internal Assembly Solder		
Antimony-Tin	Sn-Sb (95%-5%)	230°C





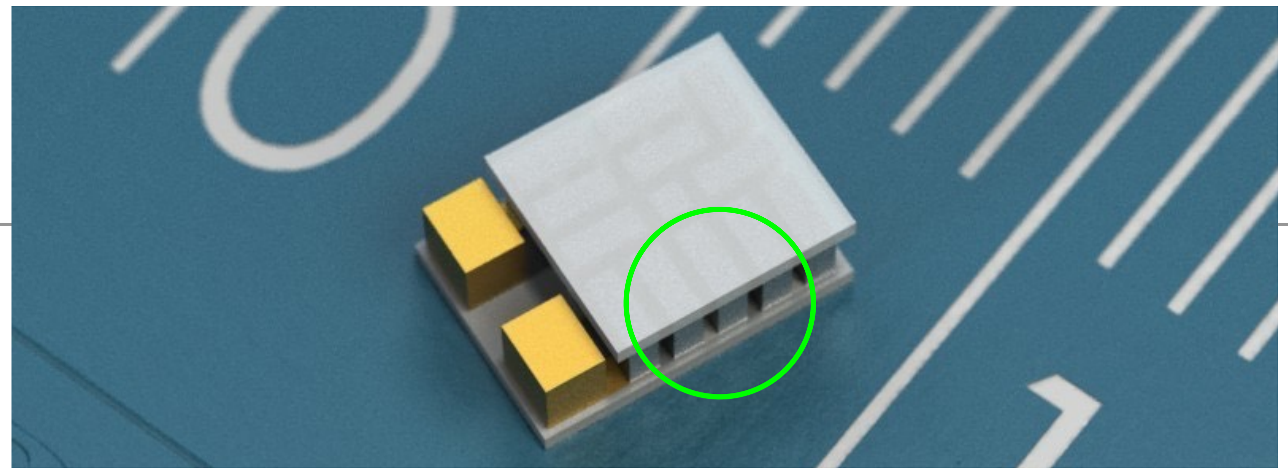




Solder 230 requires very high technology level in volume manufacturing, especially for multistage TE Coolers. Other vendors multistage TECs are assembled commonly with Solder 183 or Solder 138

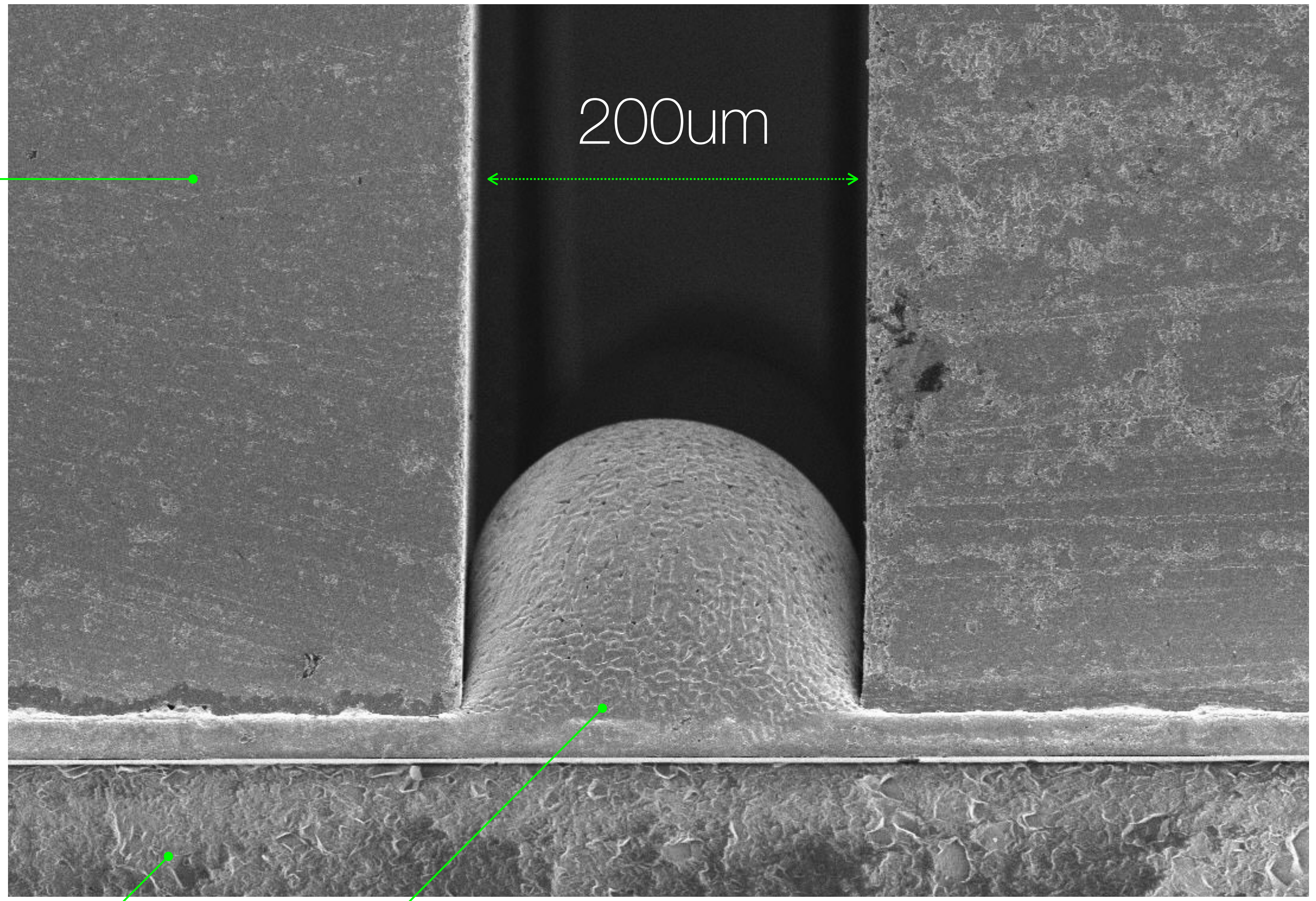
High-Quality Soldering Assembly for Thermoelectric Modules

TEC from
TEC Microsystems

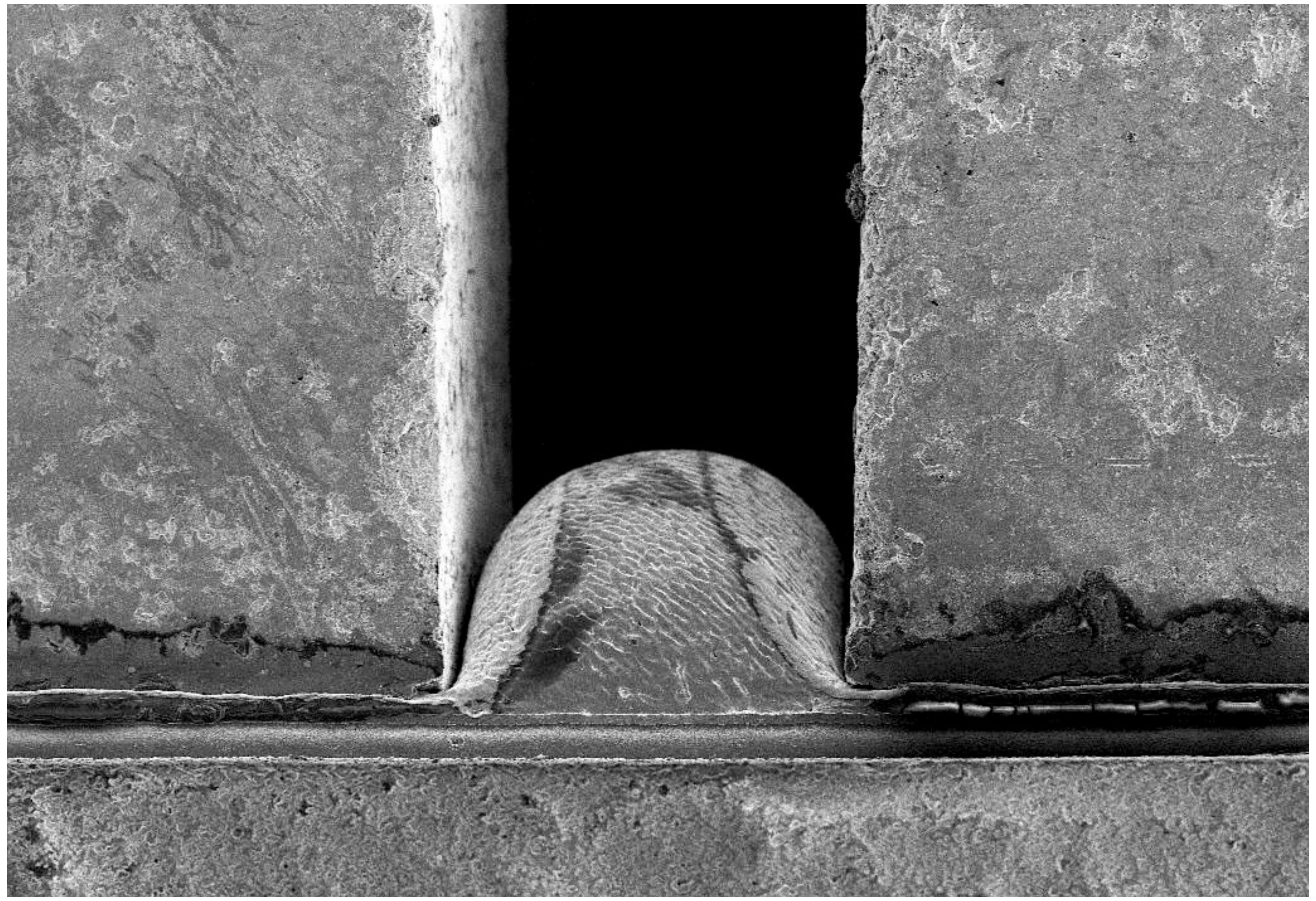


TEC from another vendor

BiTe Pellet



Ceramics   Solder   GOOD



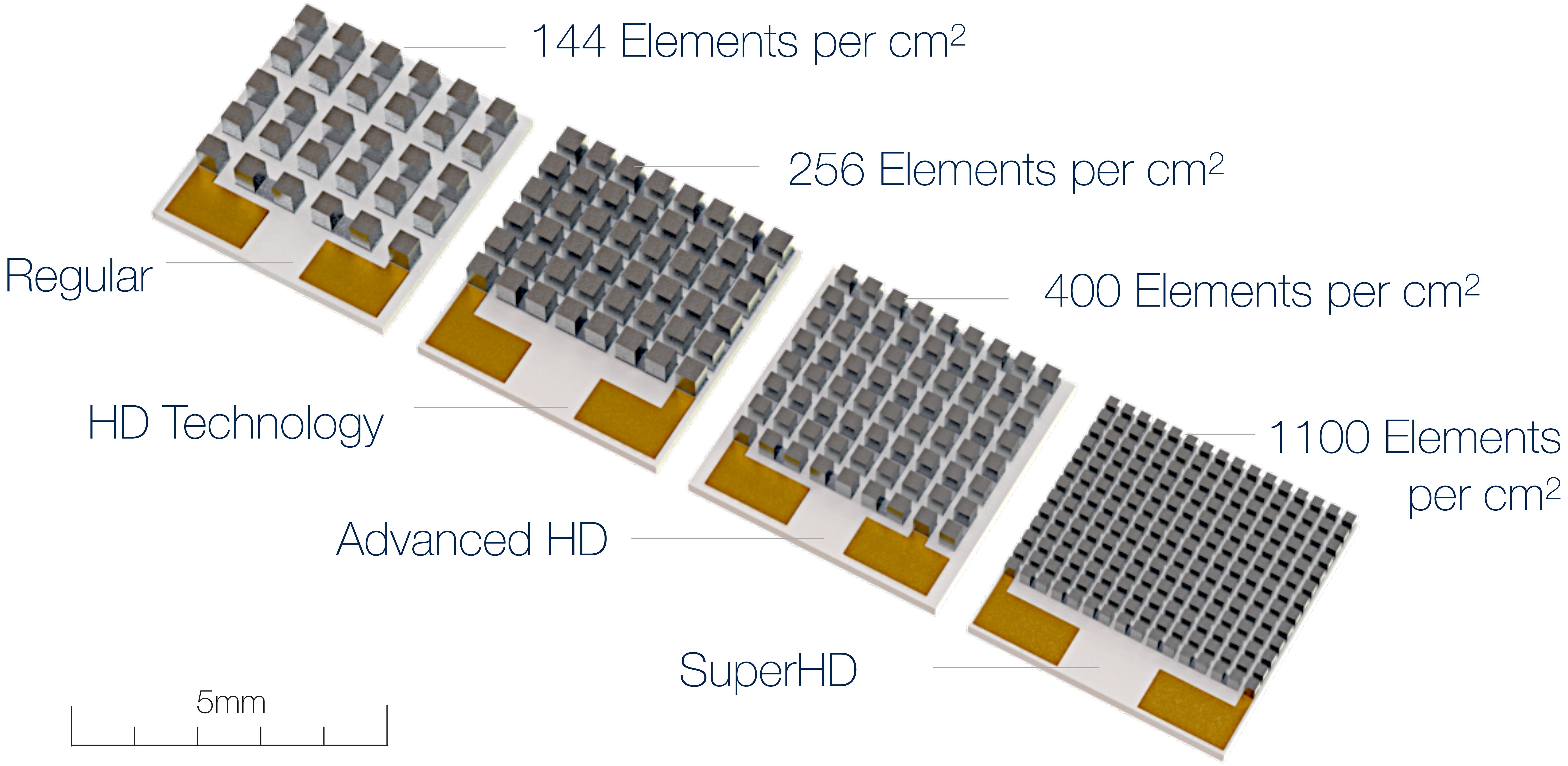
NOT GOOD

Max TEC Processing Temperature (short time) during mounting

100..120ºC	160..170ºC	**200..225ºC**	250..270ºC
Internal Assembly Solder 138 Bi-Sn	Internal Assembly Solder 183 Pb-Sn	**Internal Assembly Solder 230 Sn-Sb**	Internal Assembly Solder 280 Au-Sn

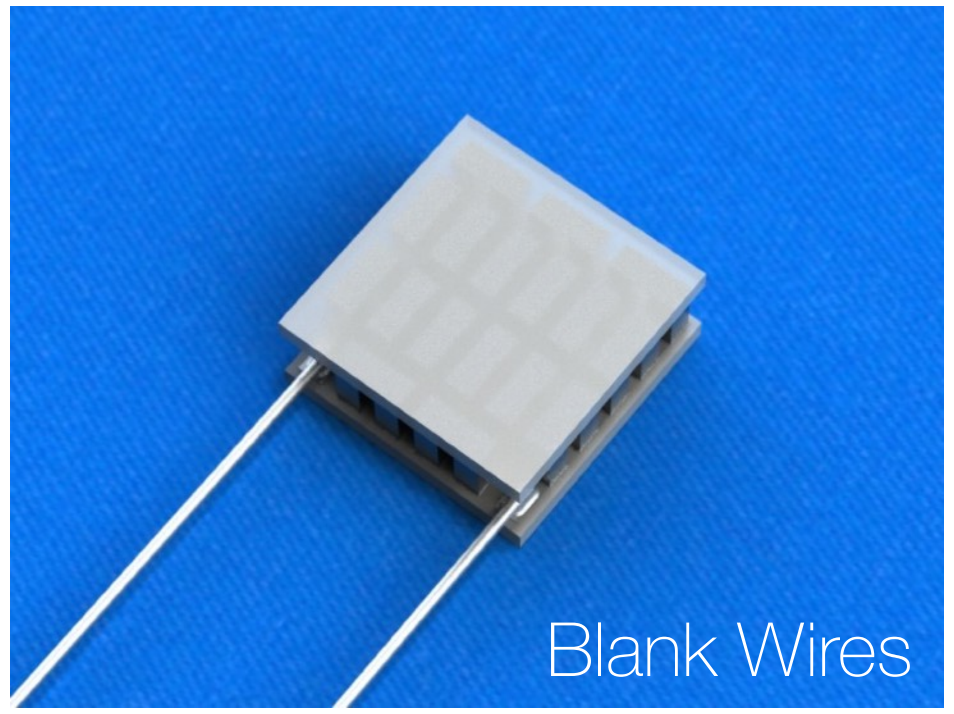
TEC Internal Assembly Solder is usually specified in datasheet or batch specification. It can be also identified by max recommended mounting processing temperature (short time)

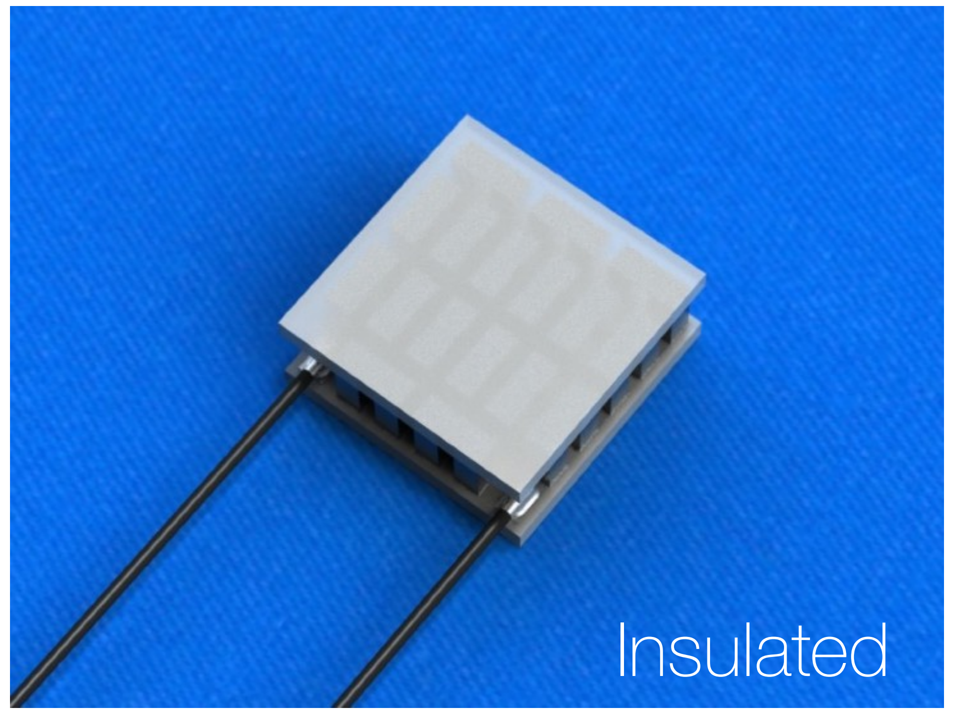
TEC Microsystems Bulk TEC Assembly - Pellets Placement Technologies

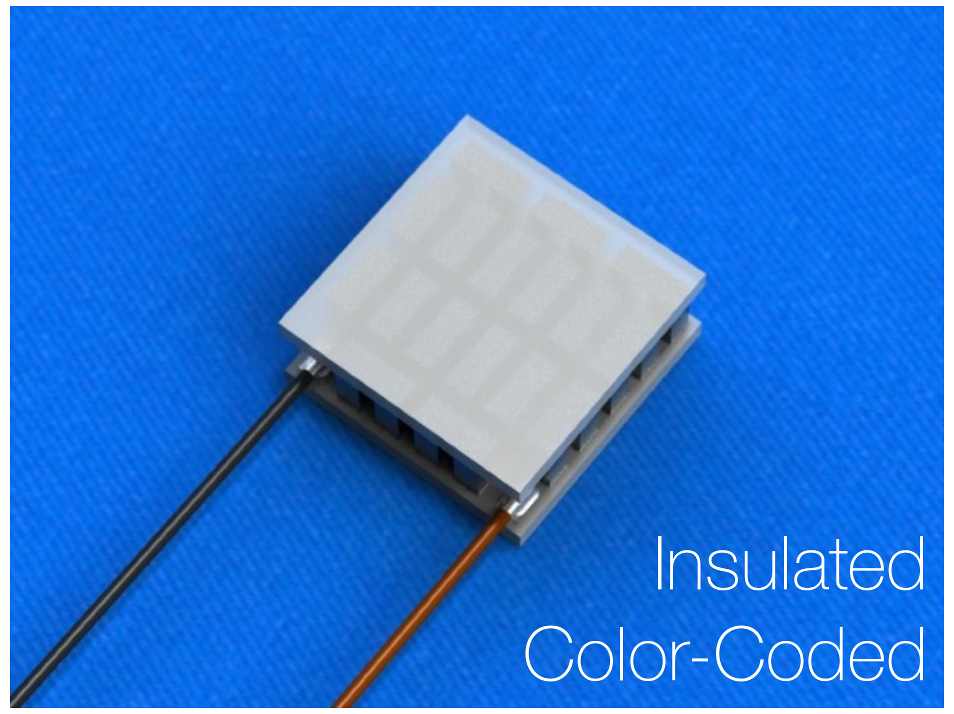


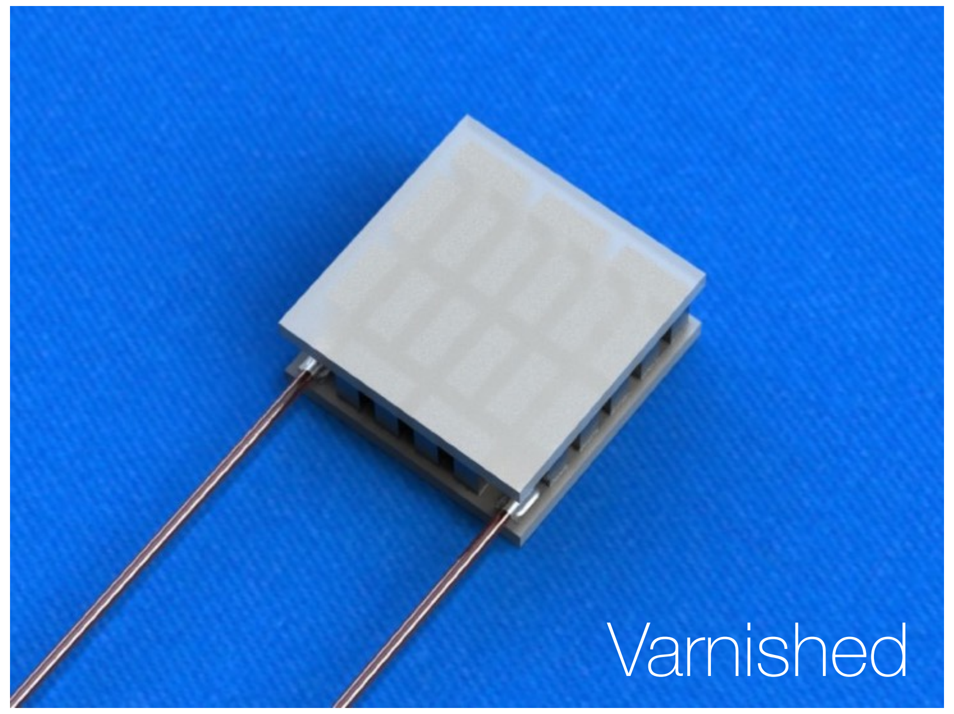
Unique HD technologies allow creating high-performance TECs with low power consumption.

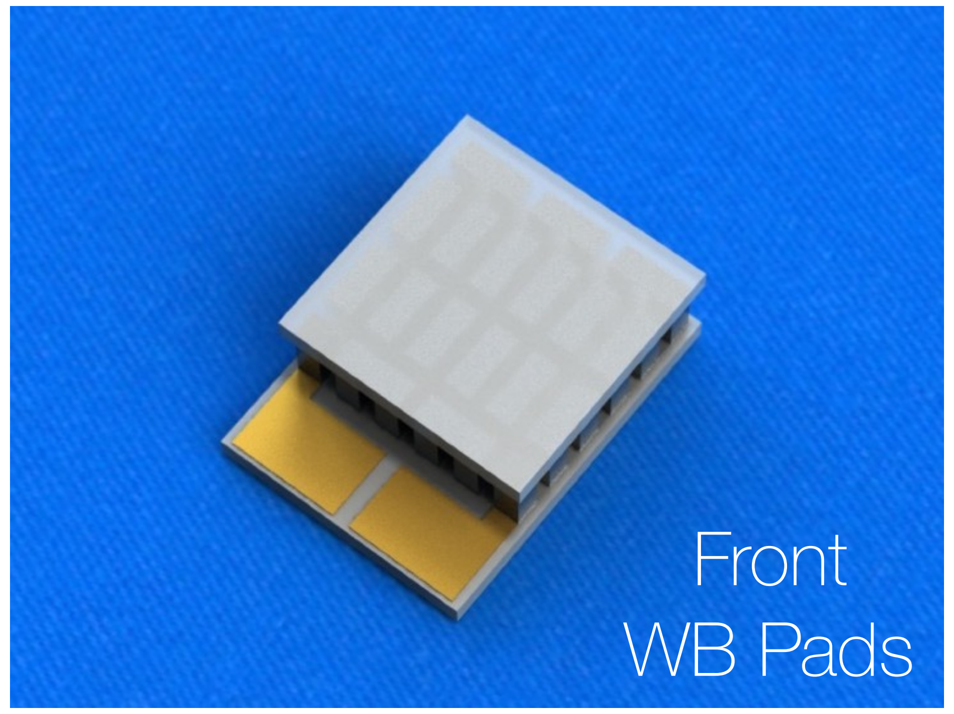
Terminal Connection Solutions for TE Coolers

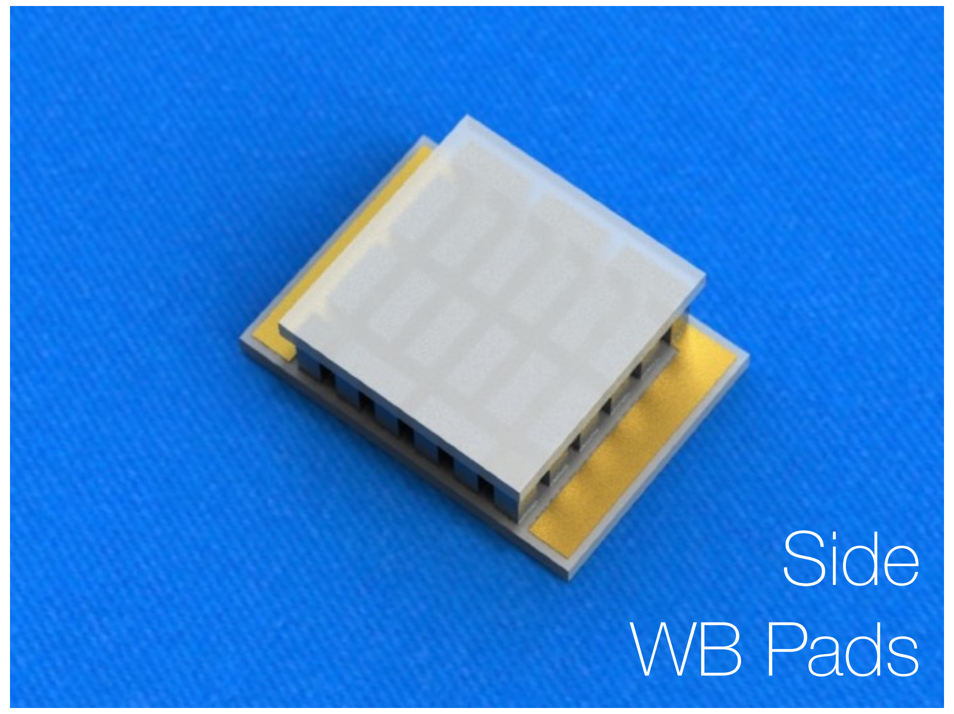


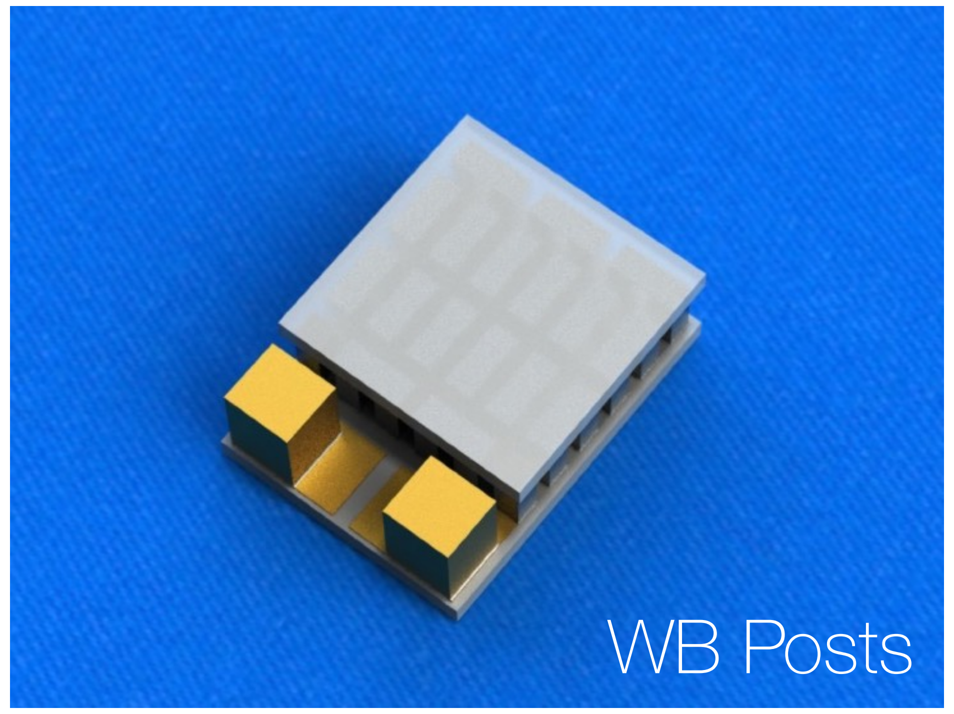


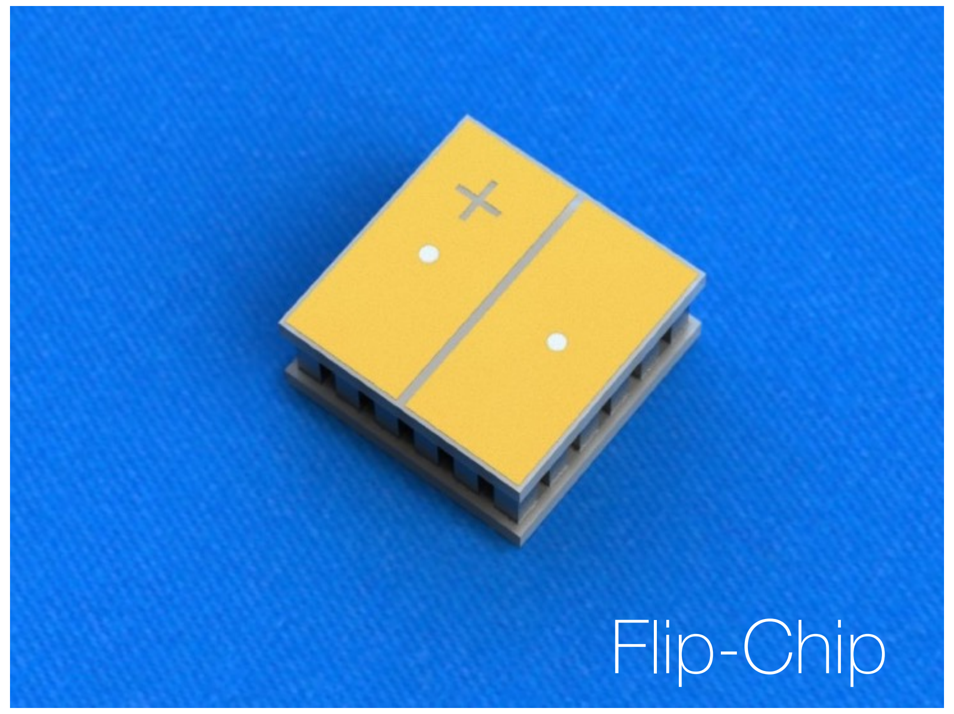








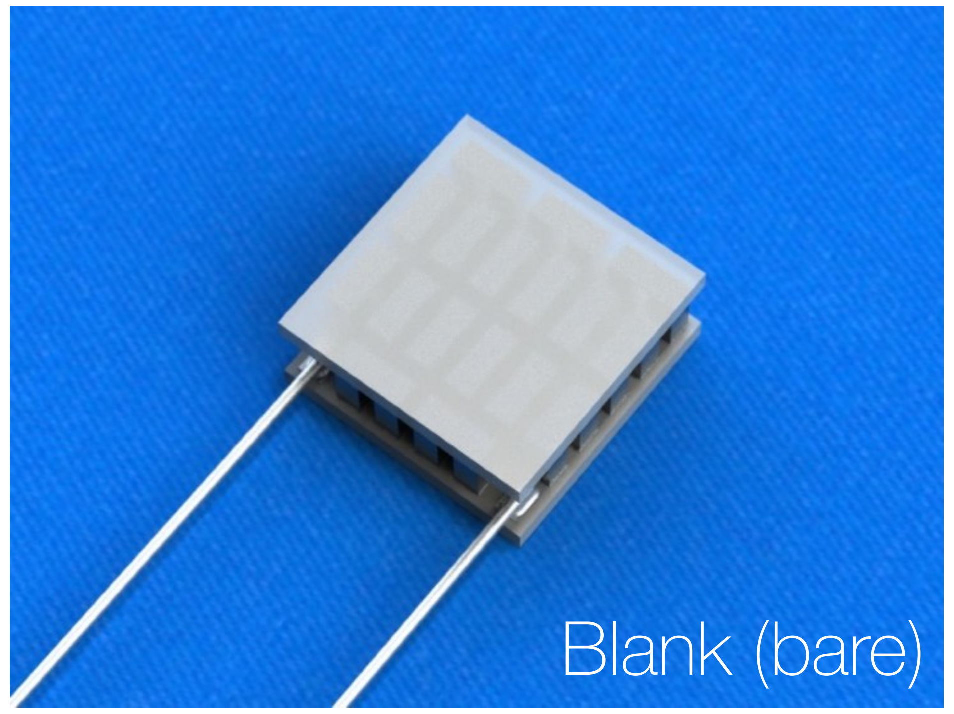


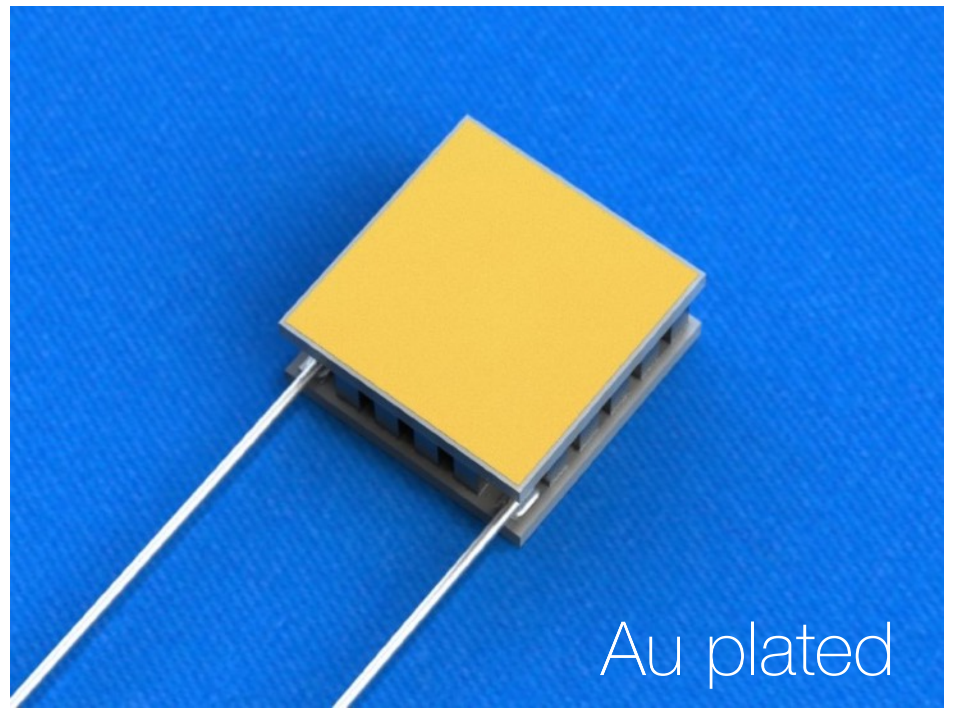


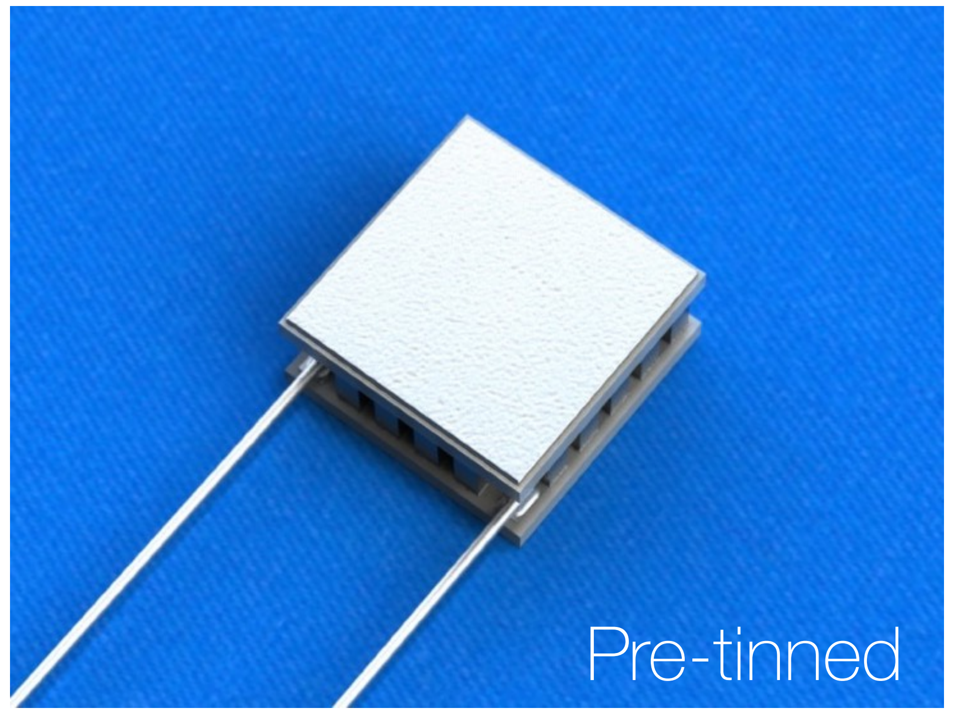
TEC can be manufactured with Wired terminal connection or optimized for Wire Bonding (WB) process. TEC Microsystems has a full flexibility with terminal connection solution for TECs. TEC Flip-Chip optimization is available.

TE Cooler Ceramics Surface Solutions

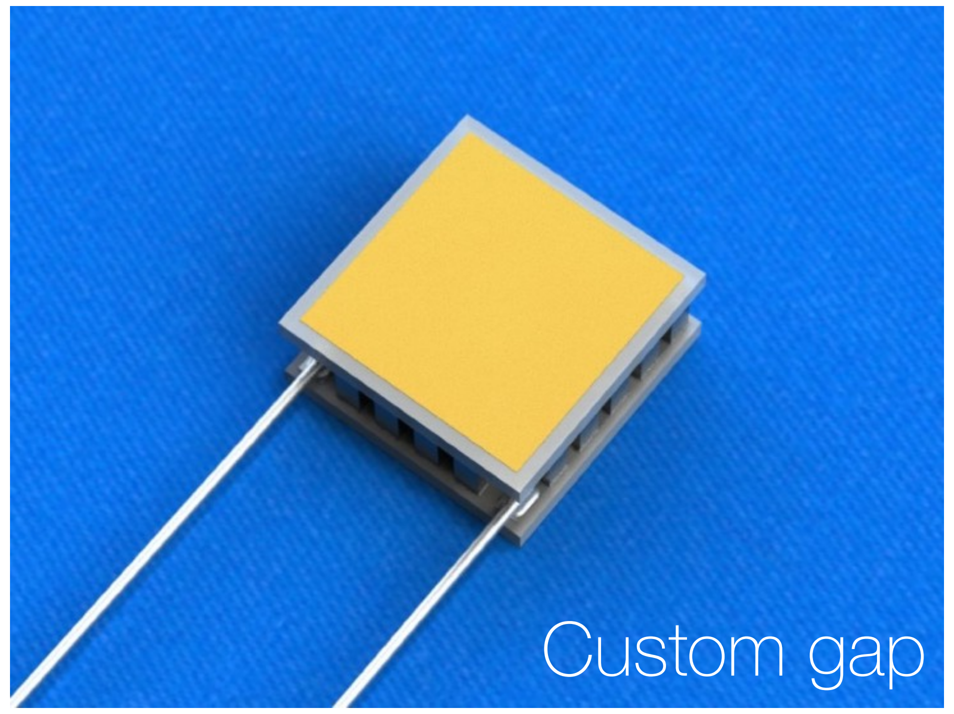
Standard
Surface Solutions

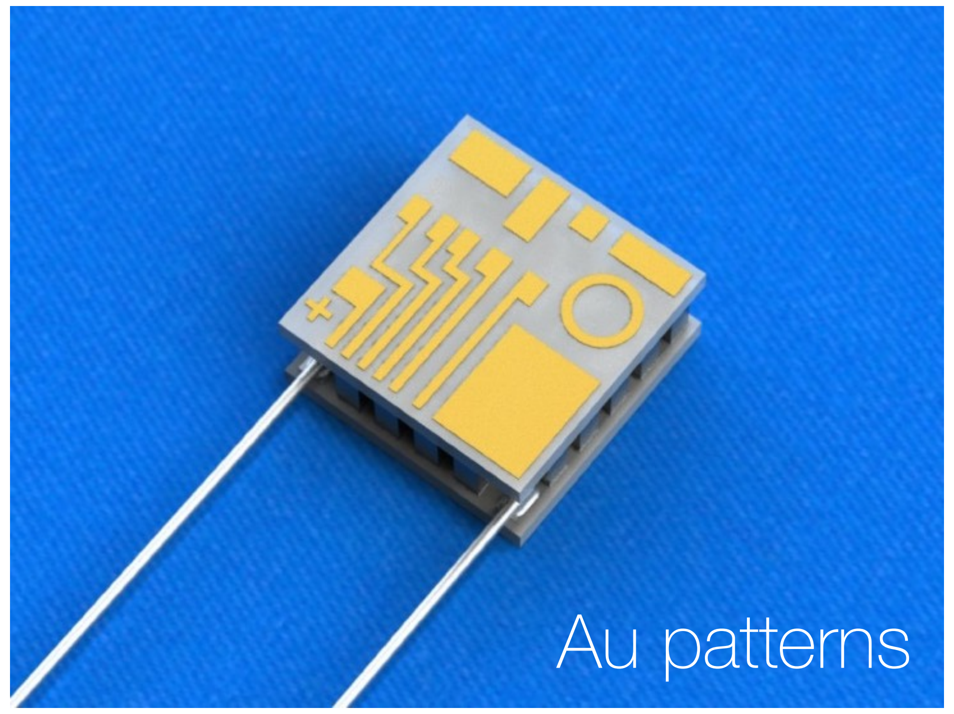


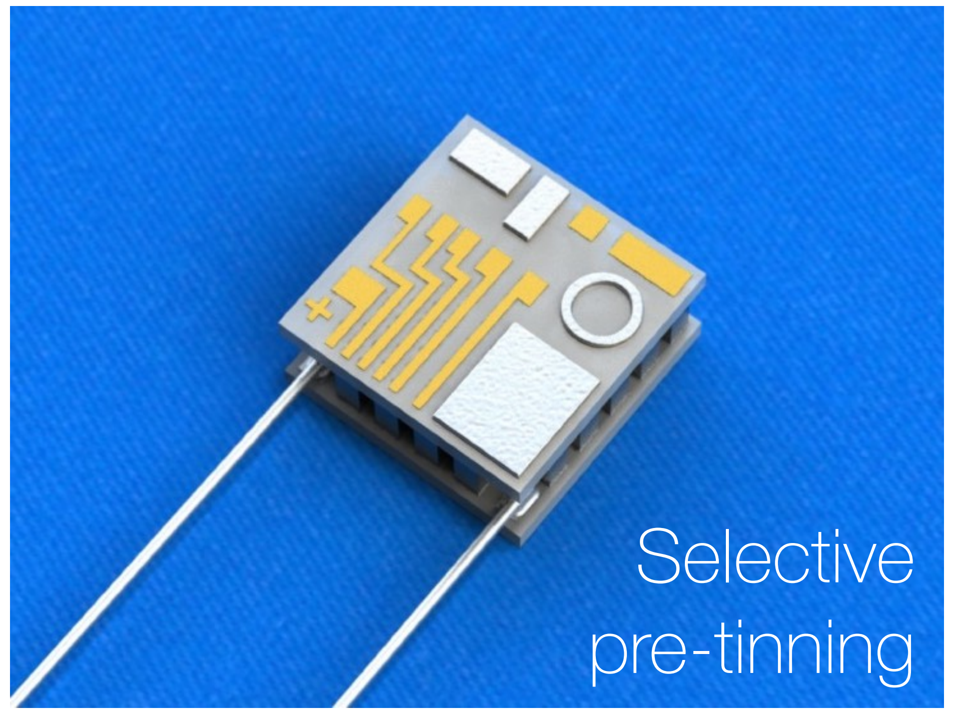




Advanced
Surface Solutions

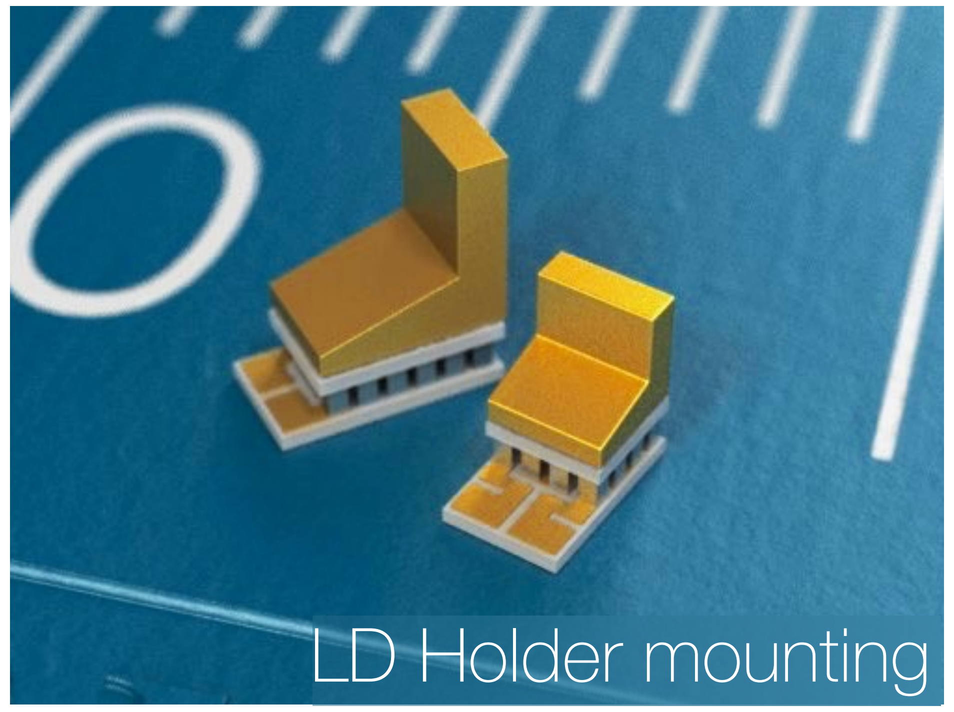


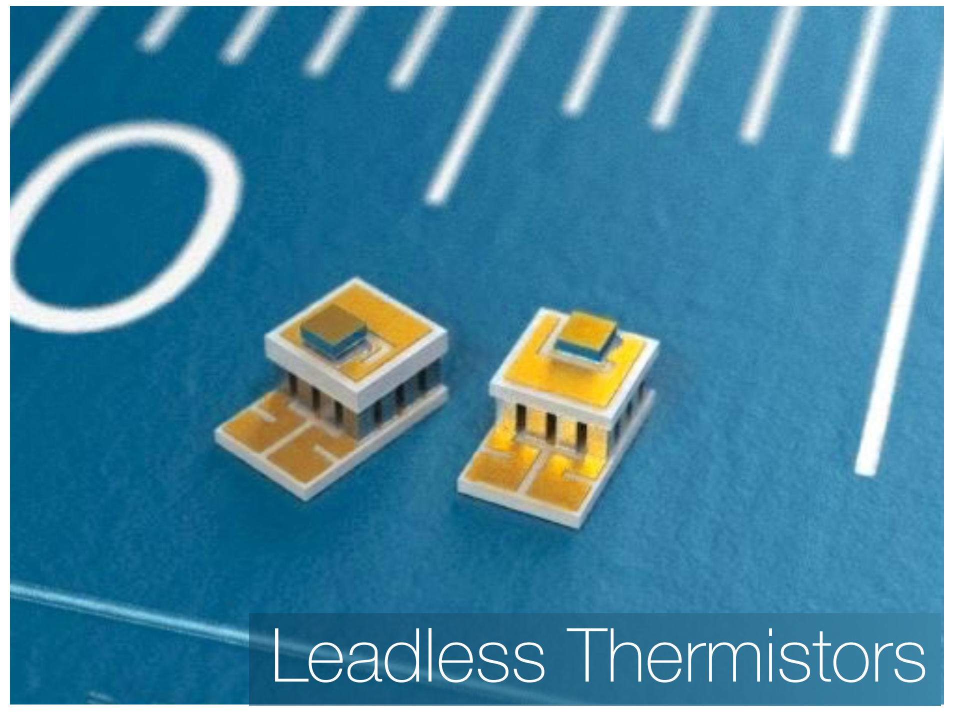


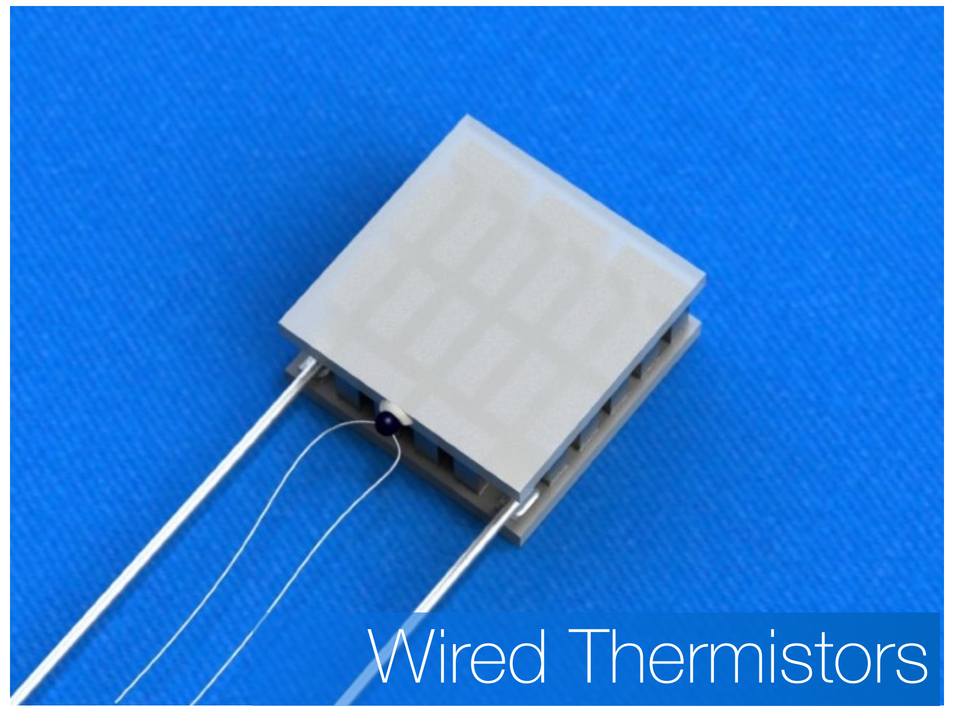


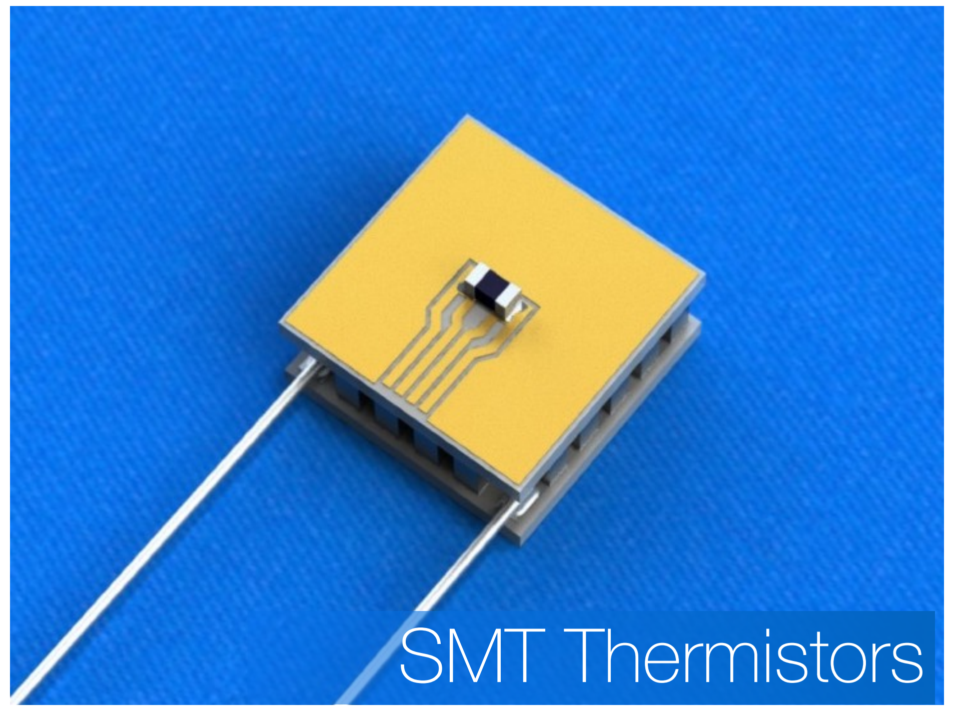
Ceramics surface solution can be the same for both TEC sides, or can be specified for each side separately.

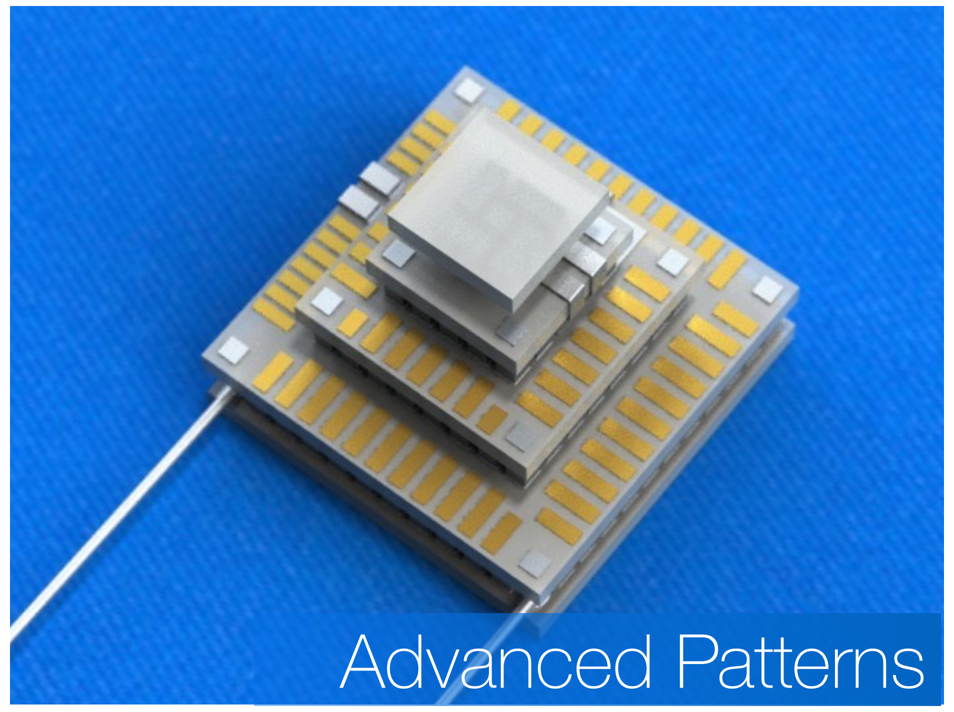
Additional Value-added Services for TEC Microsystems TE Coolers

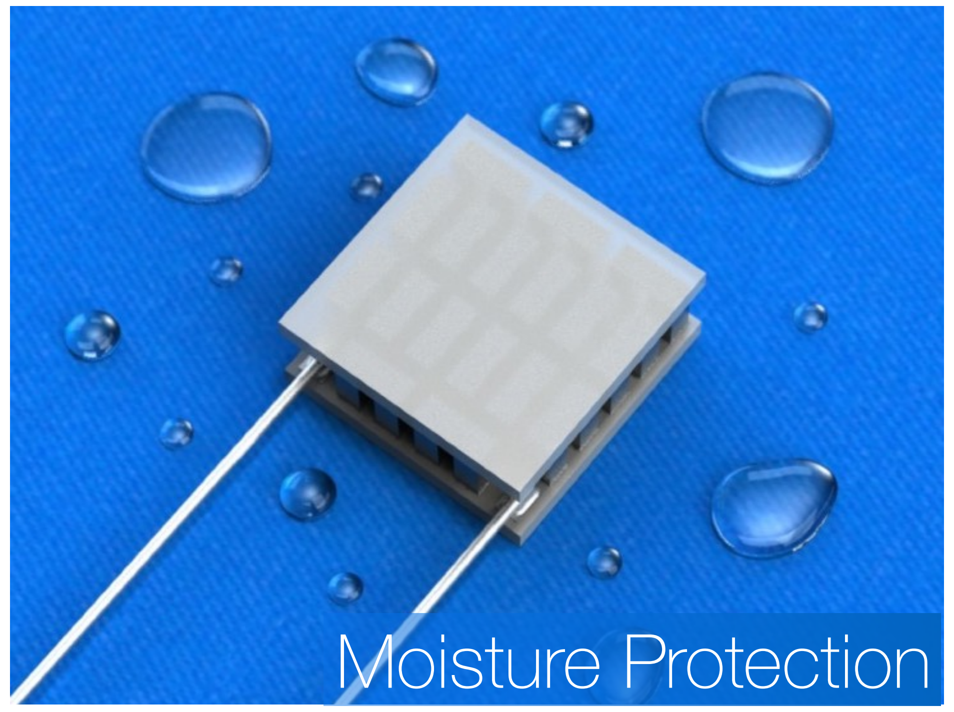


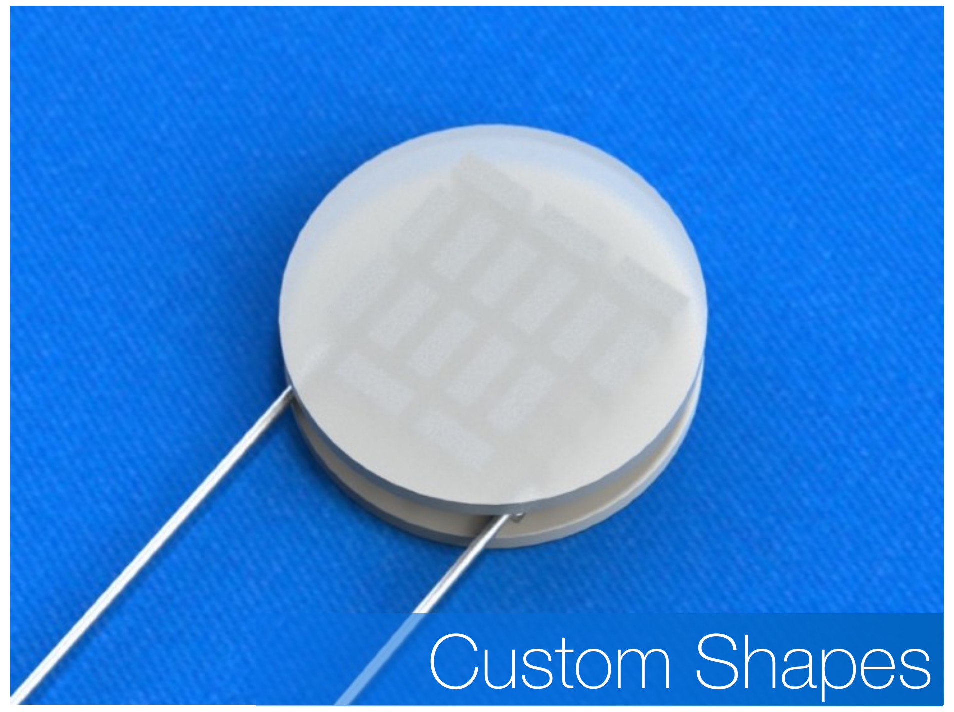


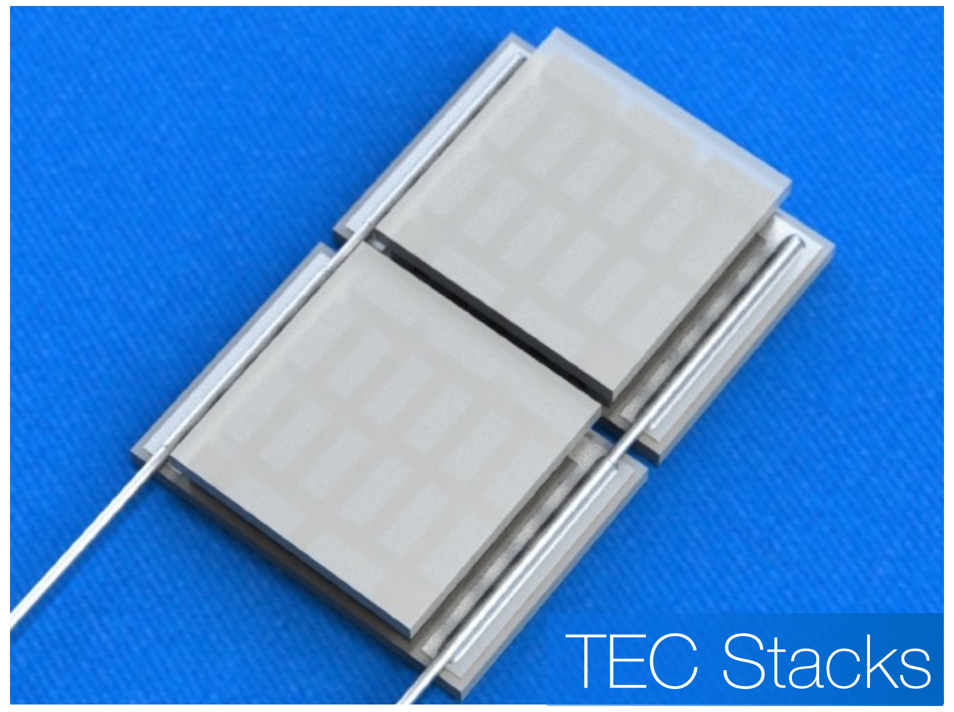






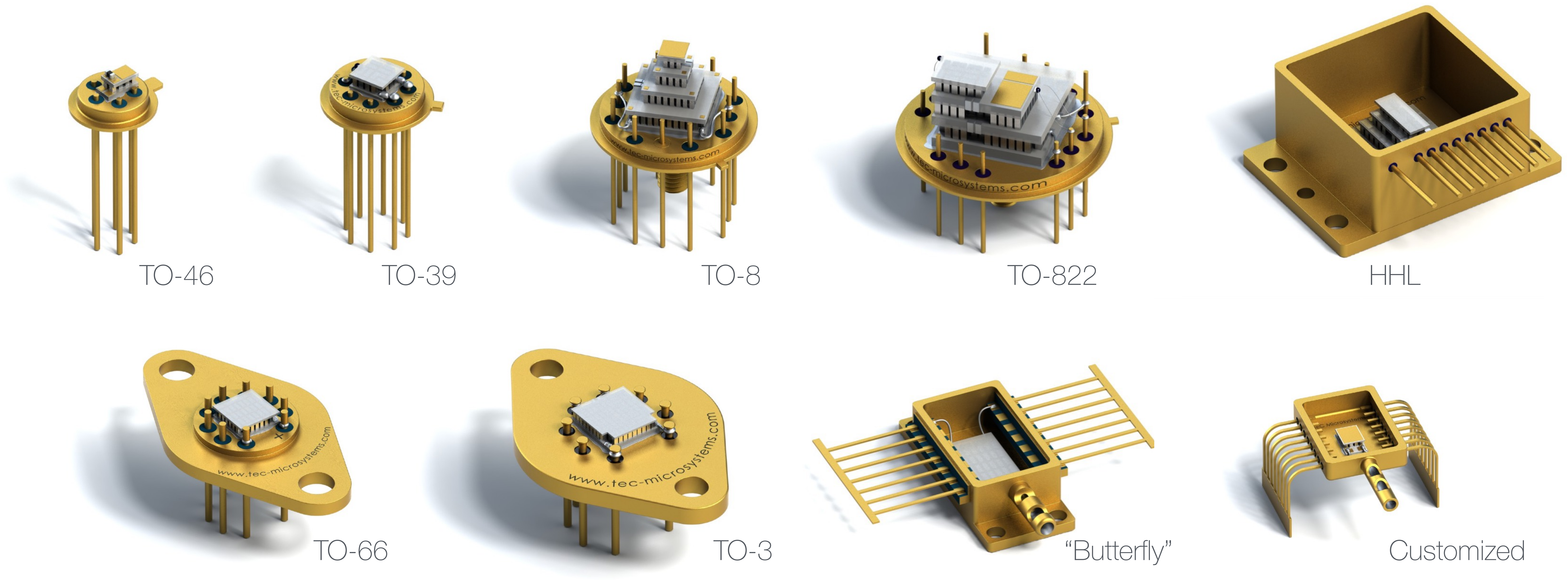






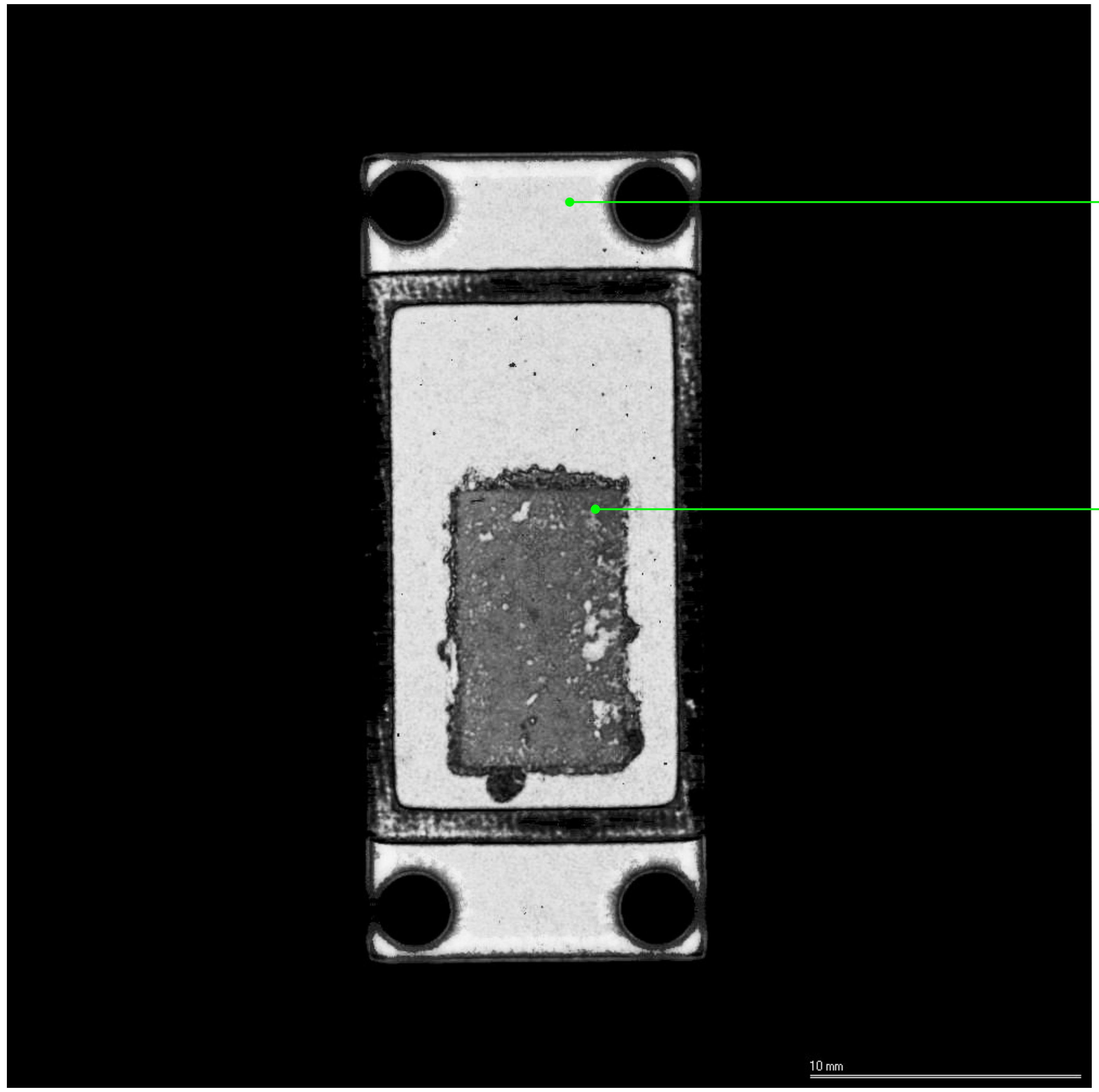
TEC Microsystems provides a wide range of additional modification and mounting services for TE Coolers.
It saves costs and simplifies TEC integrating into Customer application.

TEC Microsystems TE Coolers Mounting Service - Flux-Free Soldering in Vacuum



TEC Microsystems provides TEC mounting and Integrating Services. TECs can be mounted onto Standard or Customer provided headers/packages using flux-free RoHS compliant soldering process with 100% Quality Control

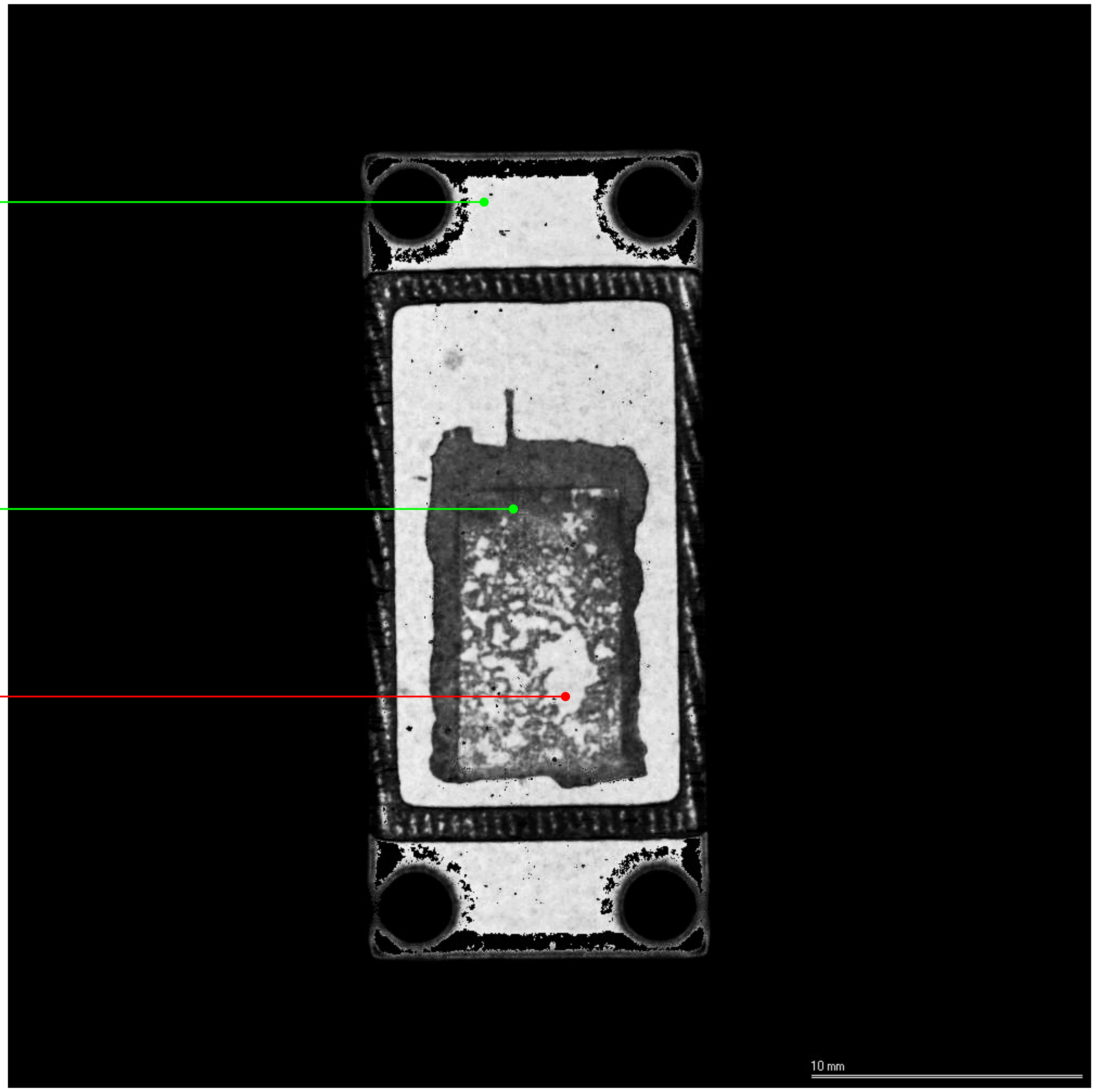
Acoustic Microscope Analysis Example - Internal voids and caverns in solder layer



BTF Package

Grey area is
the solder
under TEC

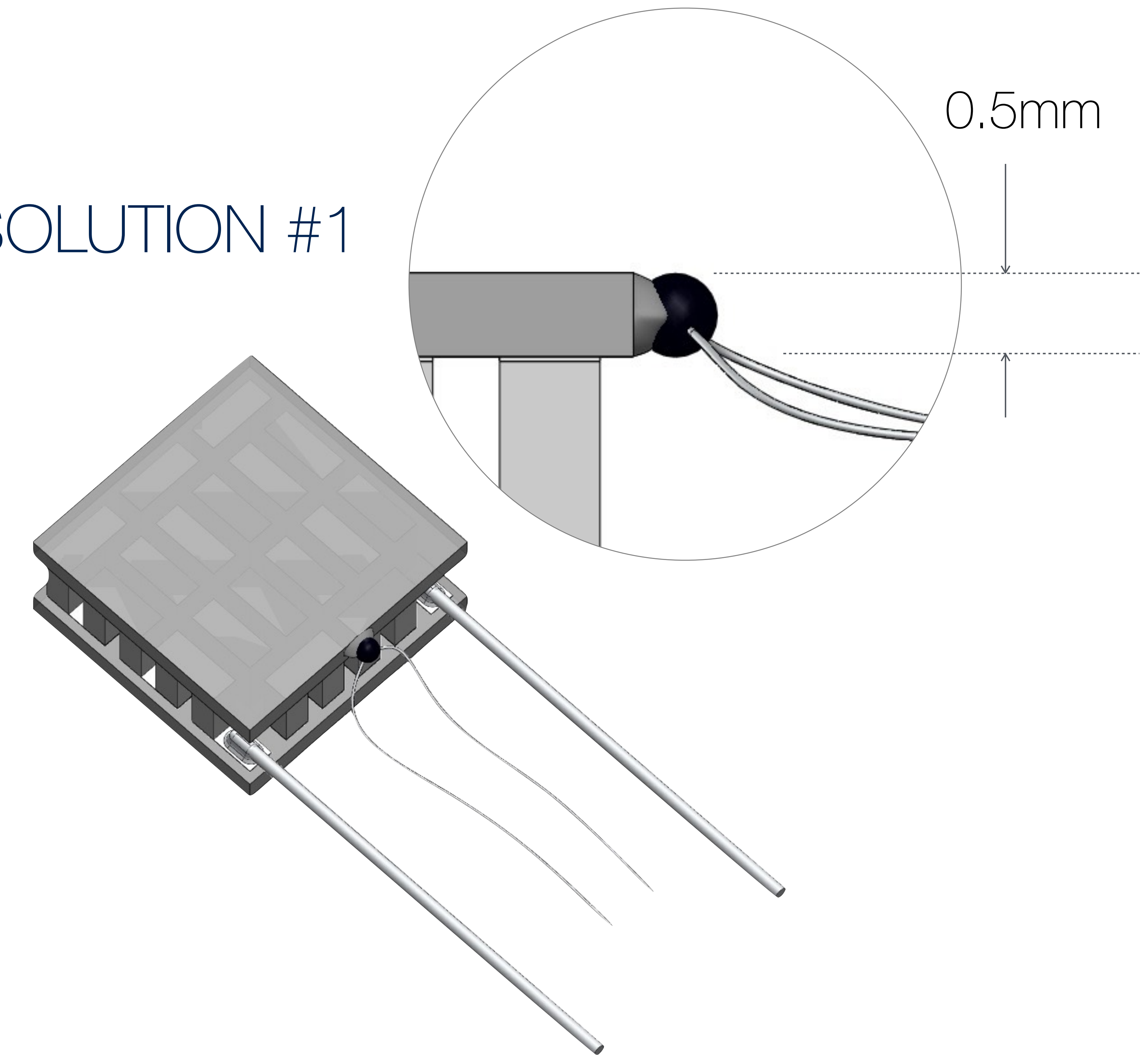
White areas are
voids in solder



Acoustic Microscopy analysis of soldering joint connection between TEC and BTF package

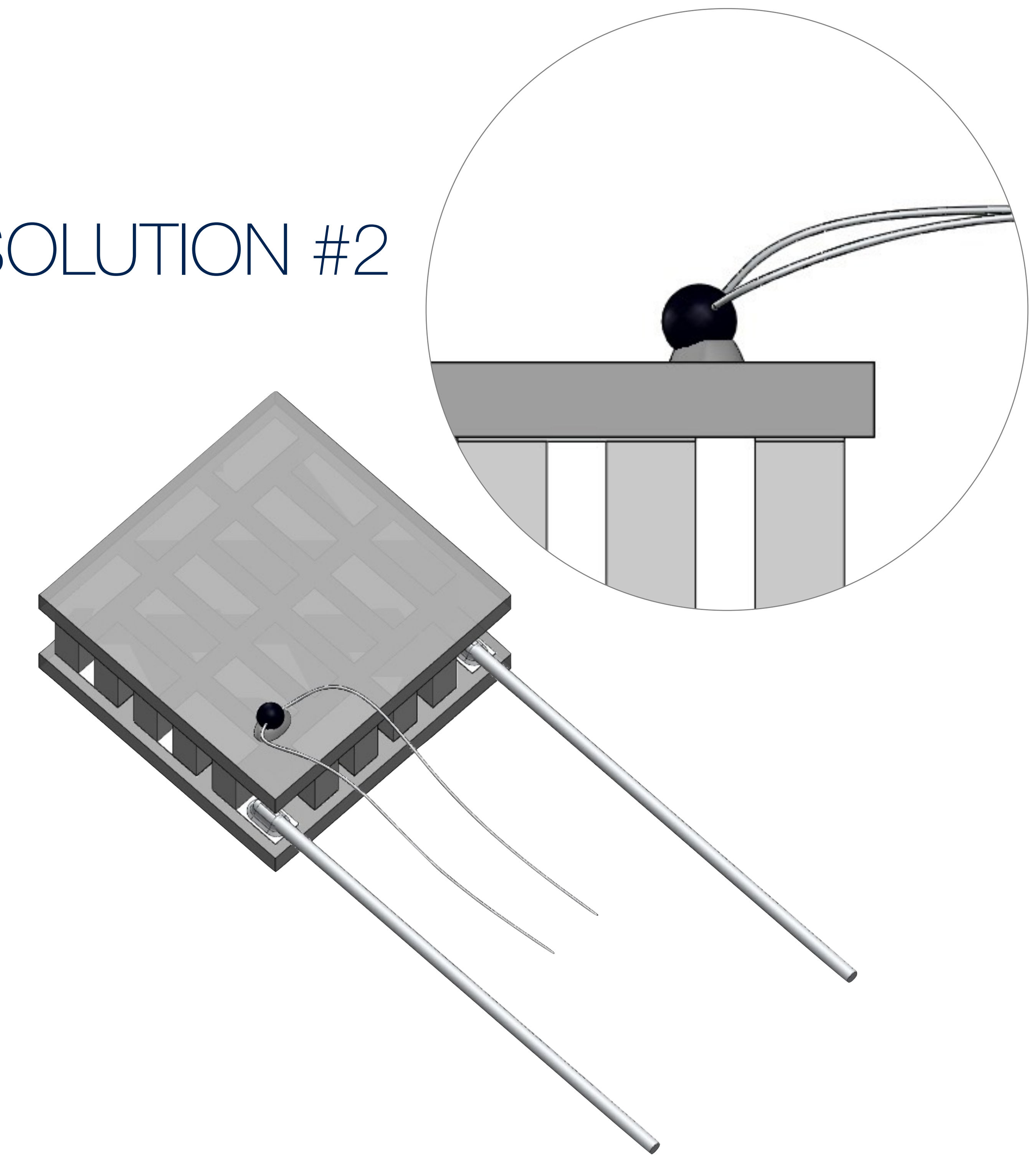
Thermistors - Glass-beaded NTC Solutions

SOLUTION #1



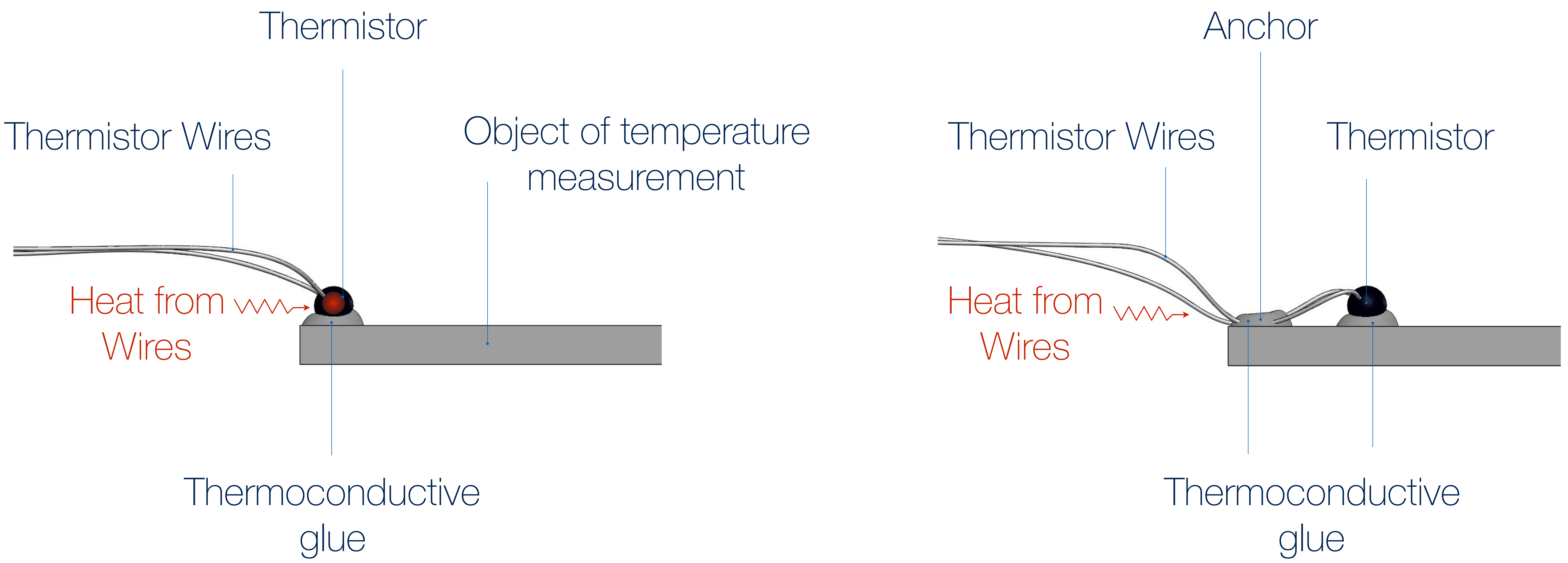
Mounting to TEC Cold Ceramics Edge

SOLUTION #2



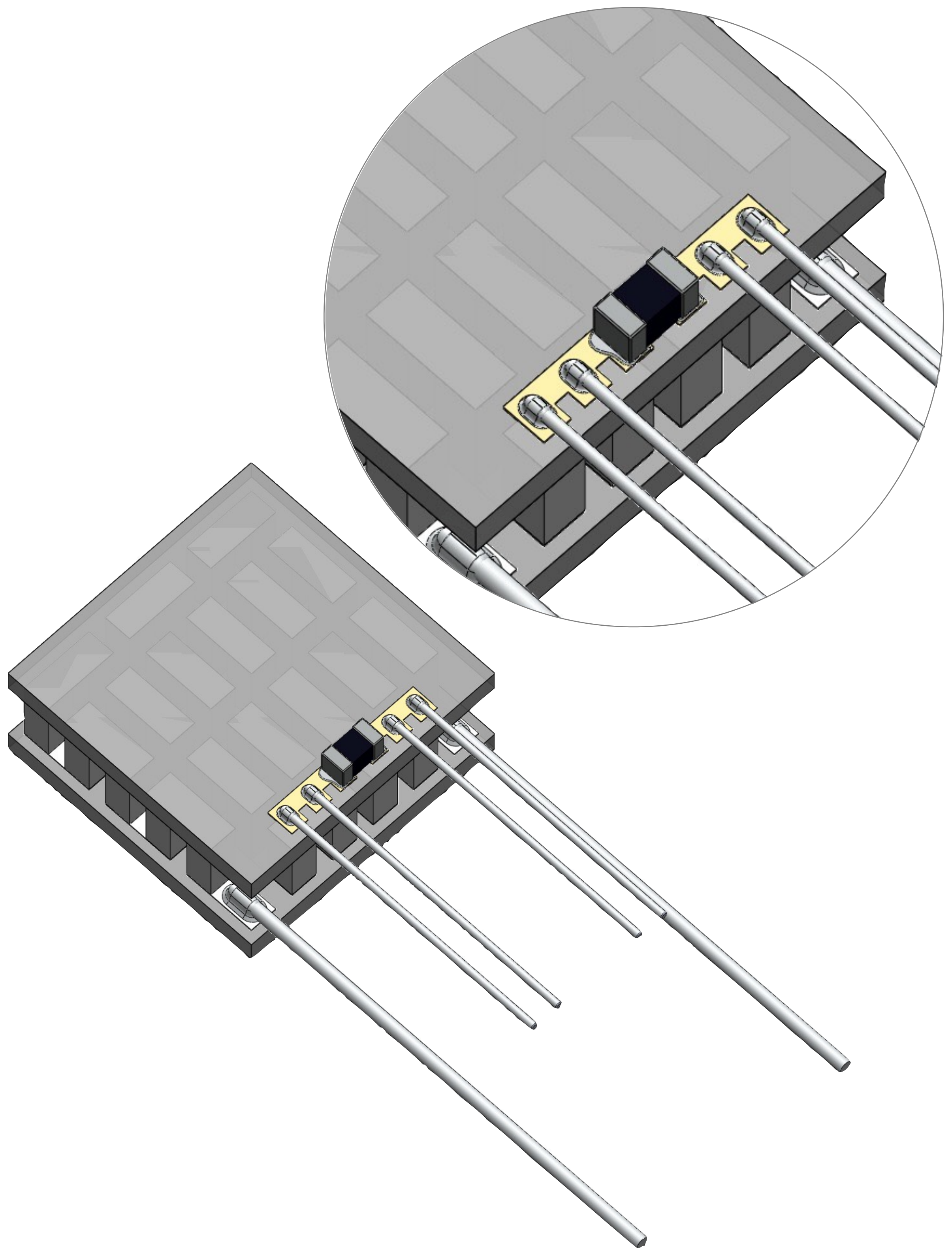
Mounting on TEC Cold Ceramics Surface

Thermistor Mounting - Anchoring Thermistor Wires (EXAMPLE)

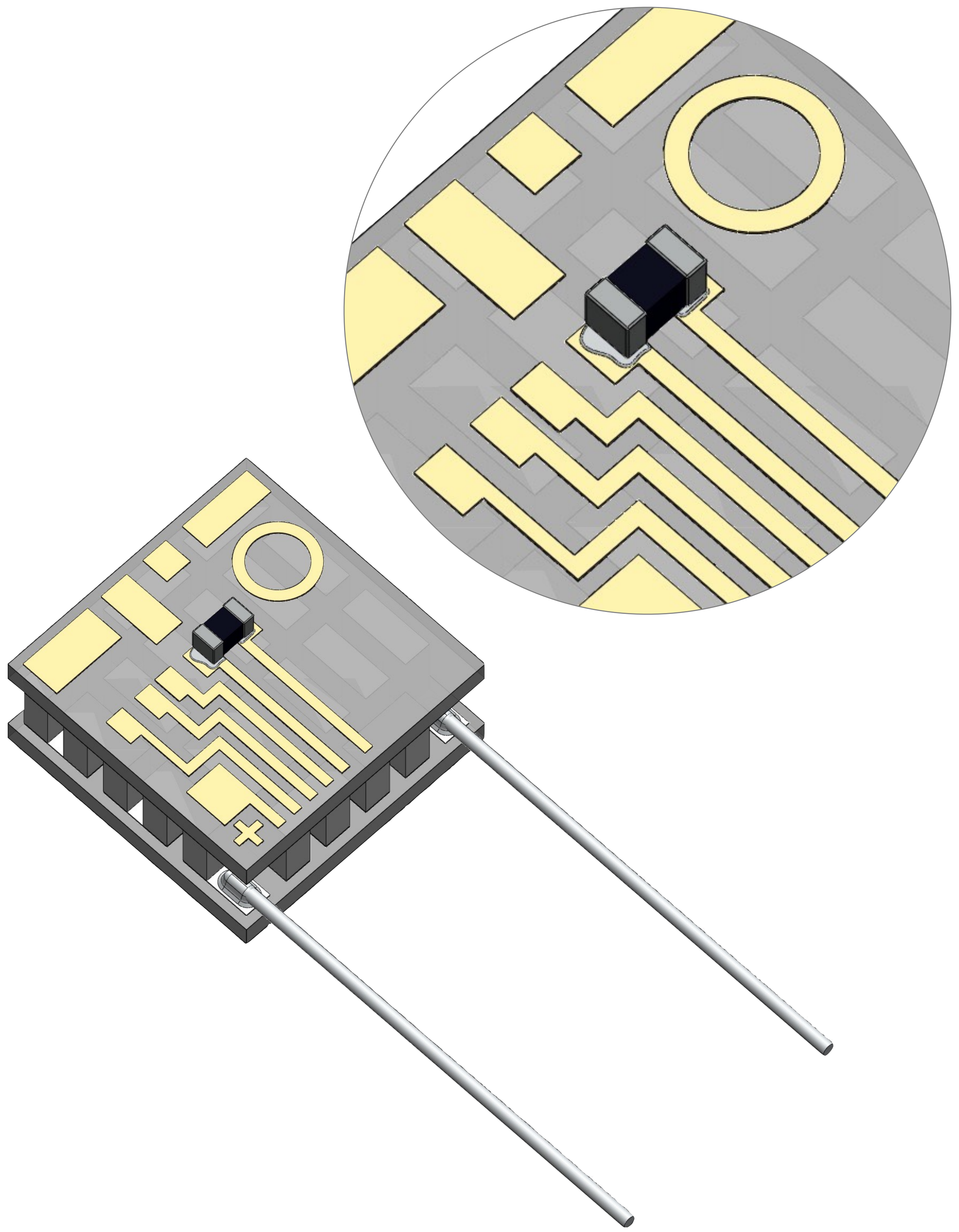


Certain amount of heat coming from thermistor wires may distort temperature measurement results.
It's recommended to anchor thermistor wires for better temperature measurement results.

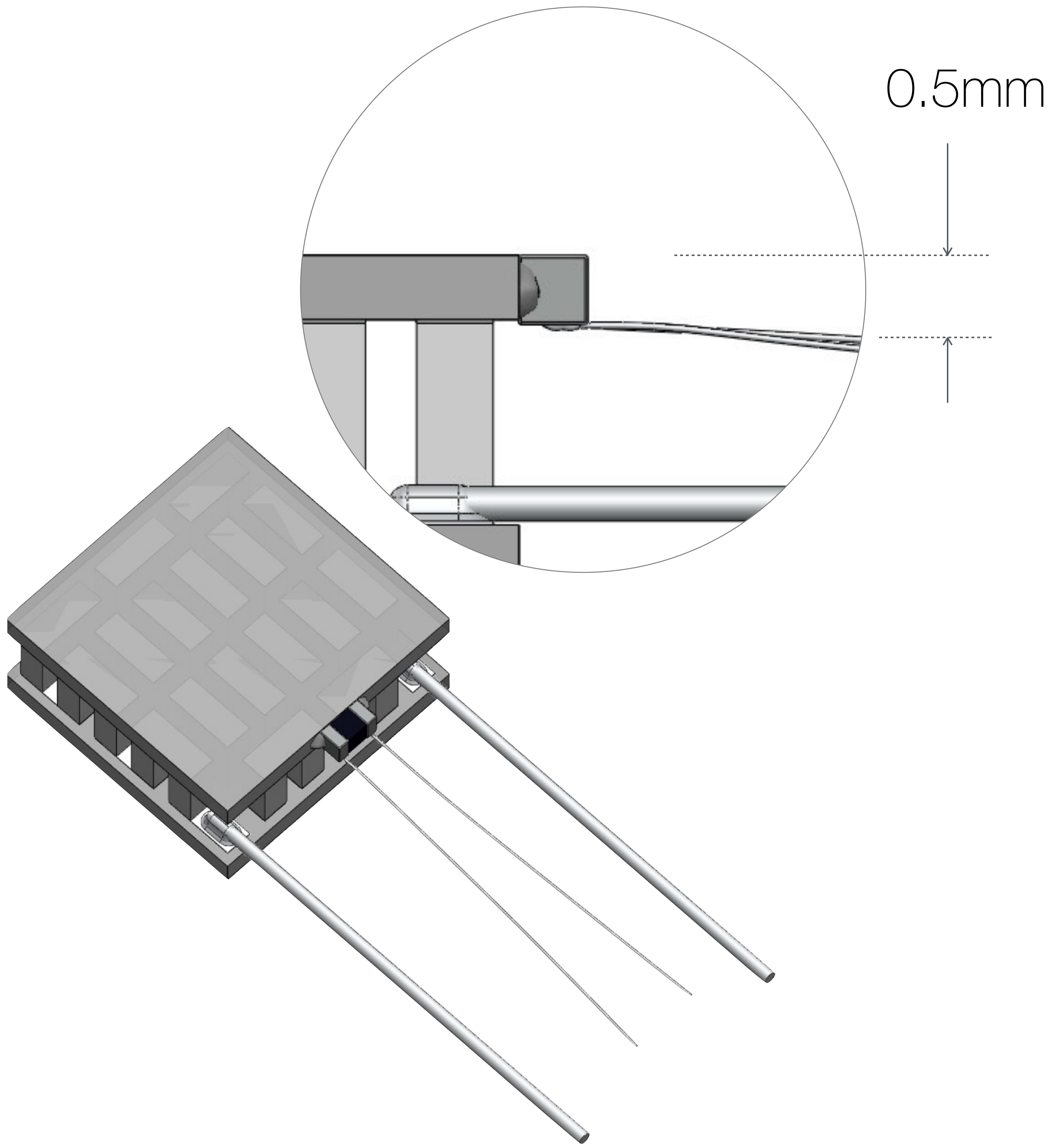
Thermistors - SMT-type NTC Solutions



SOLUTION #1
Soldering to TEC Cold Side
Au Pattern for thermistor

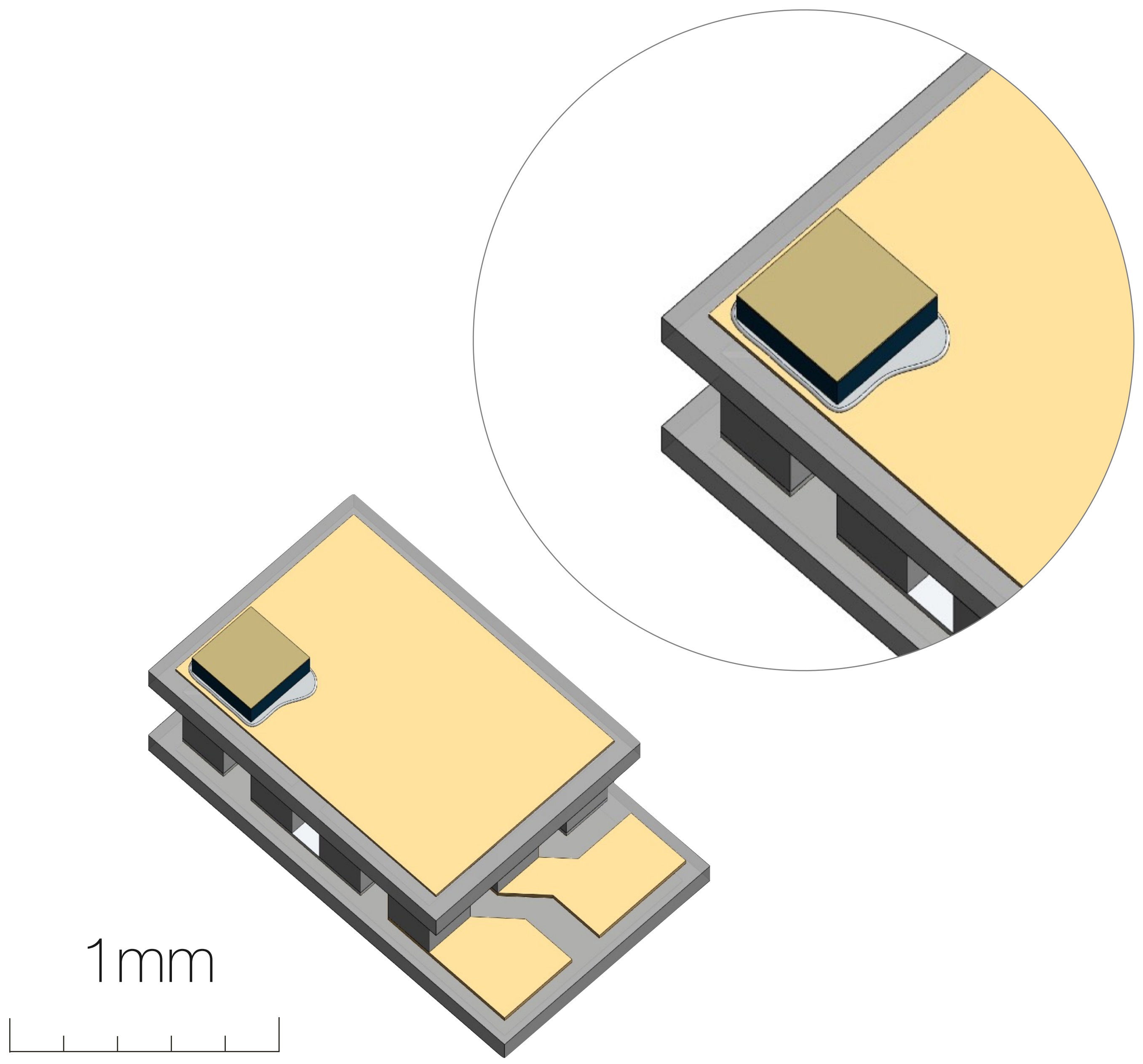


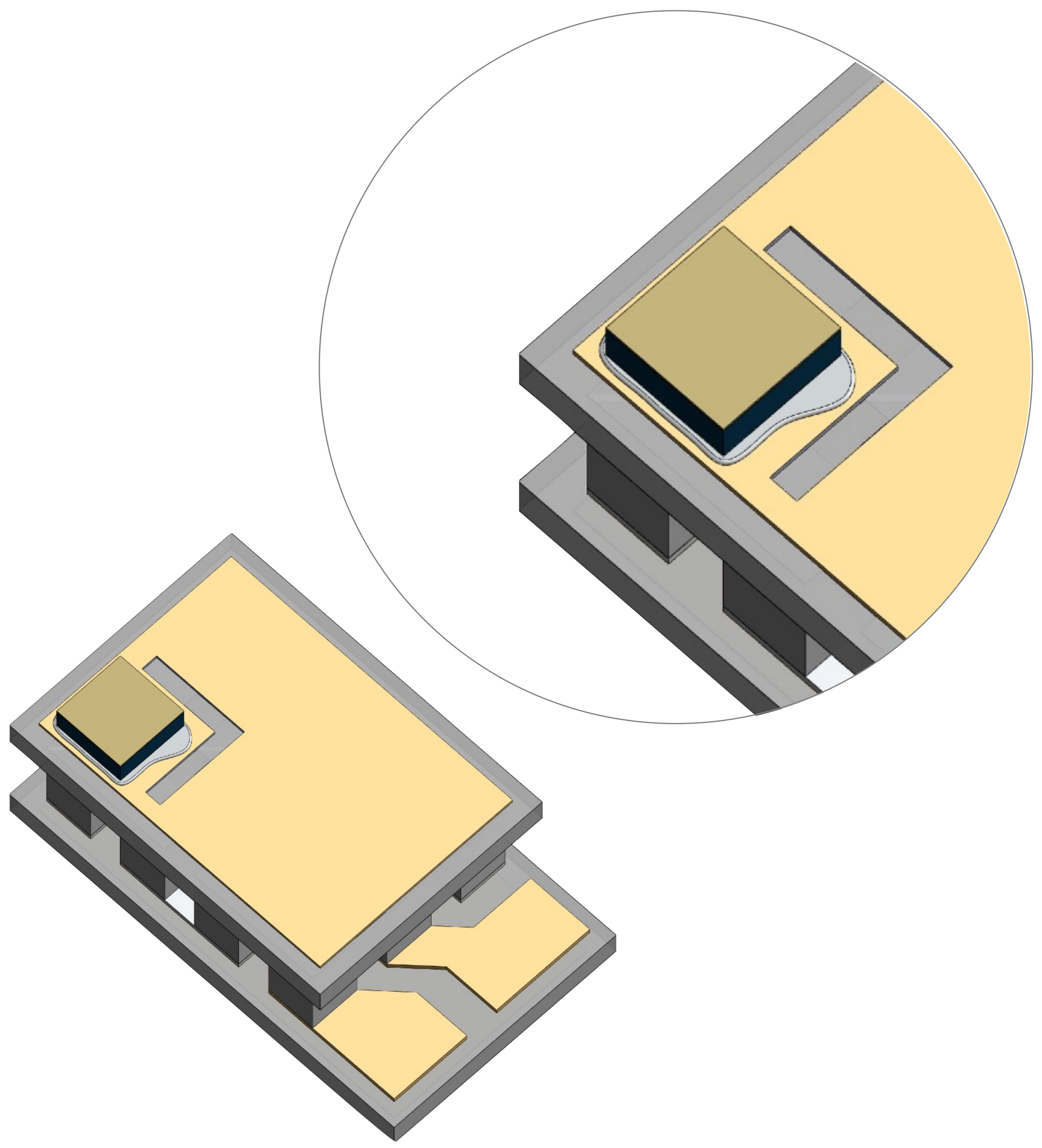
SOLUTION #2
Soldering to TEC Cold Side
Application Special Au pattern

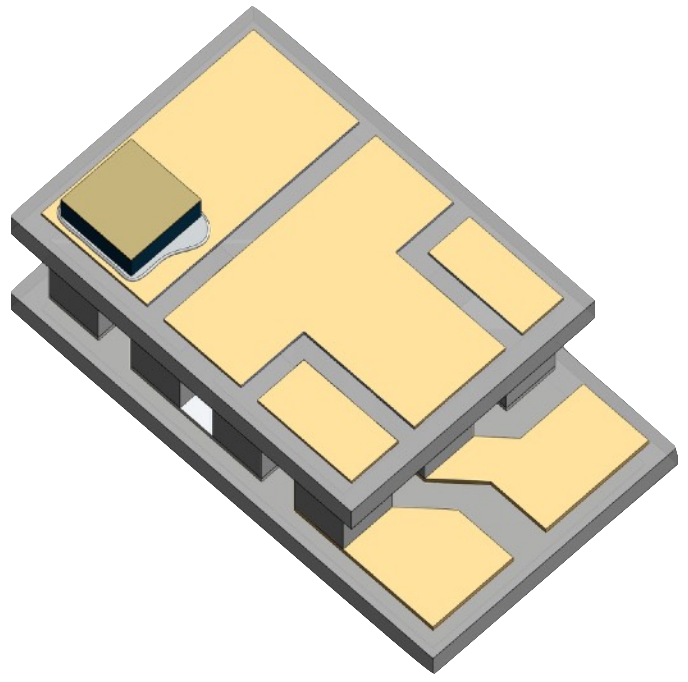


SOLUTION #3
Gluing Method with Wires
soldered to SMT Thermistor

Thermistors - Miniature Lead-less Thermistors for WB process





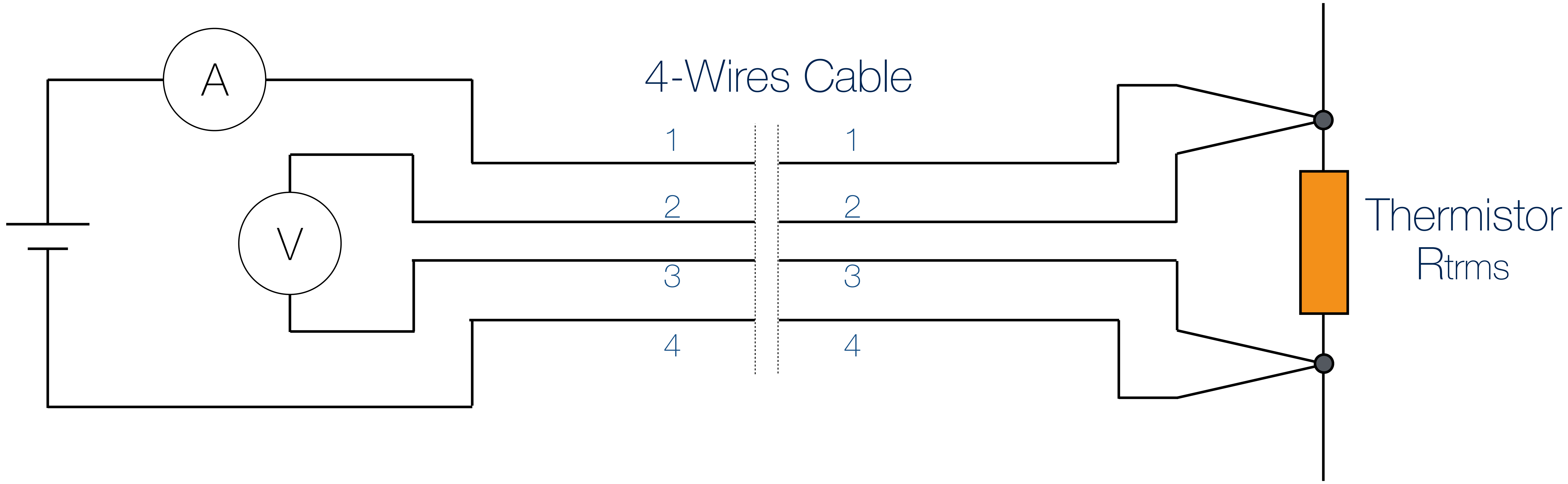


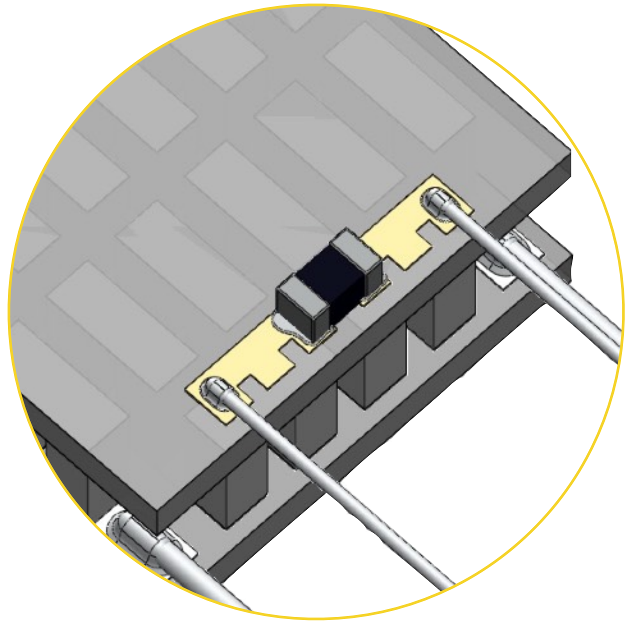
SOLUTION #1
Soldering to TEC Cold Side
Solid Au plating

SOLUTION #2
Soldering to TEC Cold Side
with Solder Stops

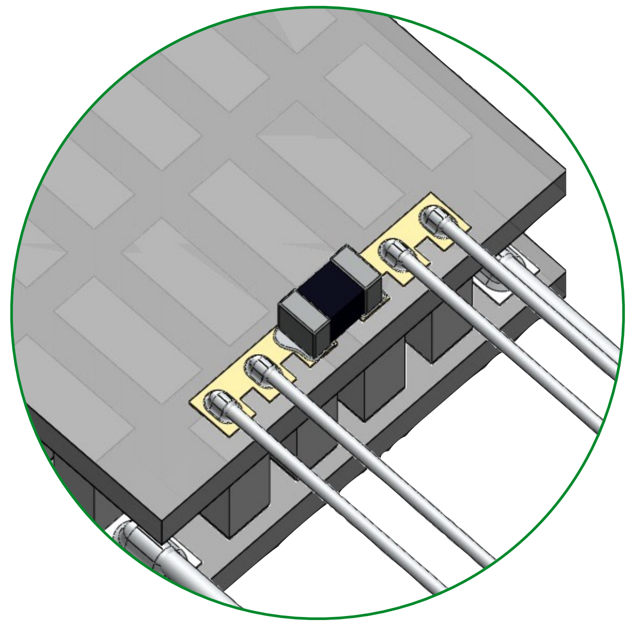
SOLUTION #3
Soldering to TEC Cold Side
Application Special Au pattern

Thermistor Resistance Measurement - 4-Wires Measurement Scheme





2-Wires Method

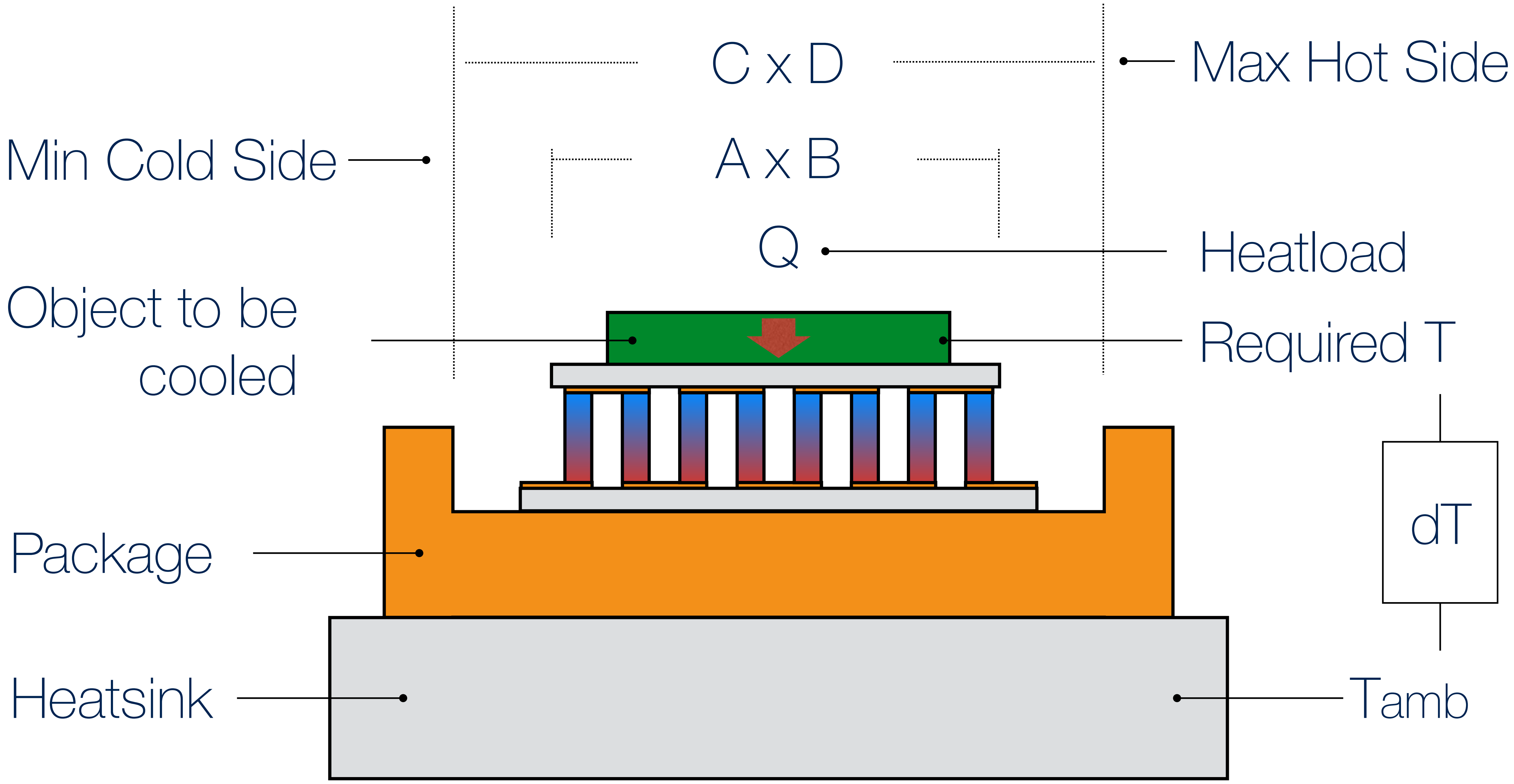


4-Wires Method

$$R_{trms} = \frac{\text{Voltmeter Indication}}{\text{Ammeter Indication}}$$

Long Thermistor Wires and Header pins may distort actual Thermistor Resistance value during measurements. 4-wires Measurement Method is recommended for the most accurate measurement results.

Finding the most optimal TEC - Application Parameters Required



In optimal case Heatsink is stabilized at Tamb

Primary Set

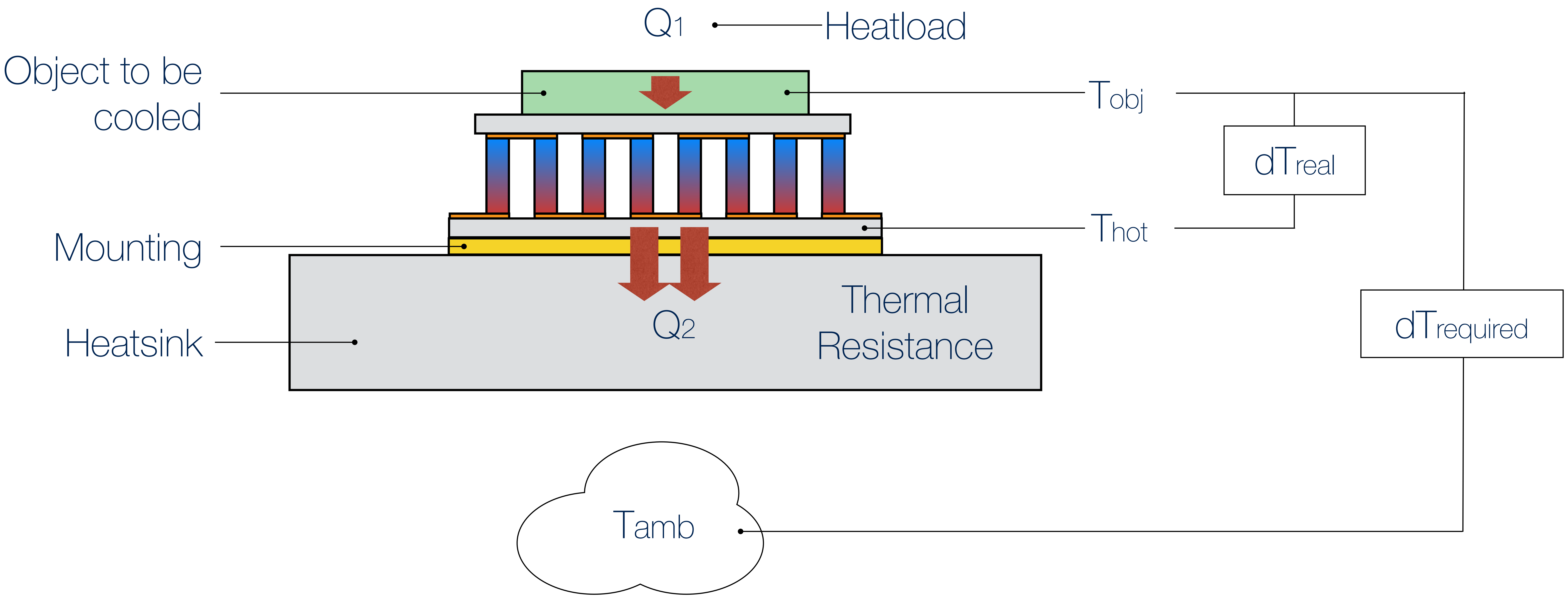
1. Max Ambient Temperature
2. Ambient Conditions (gas, vacuum)
3. Total Heatload in Application
4. Max required dT from Ambient
5. Min required Cold Side
6. Max available space for Hot Side

Secondary Set

7. TE Cooler Height Limit
8. Electrical Power limits (if any)
9. Heatsink Thermal Resistance
10. Package Type and Materials

Items 1-6 are the minimum set of application parameters to start finding the most optimal TE Cooler

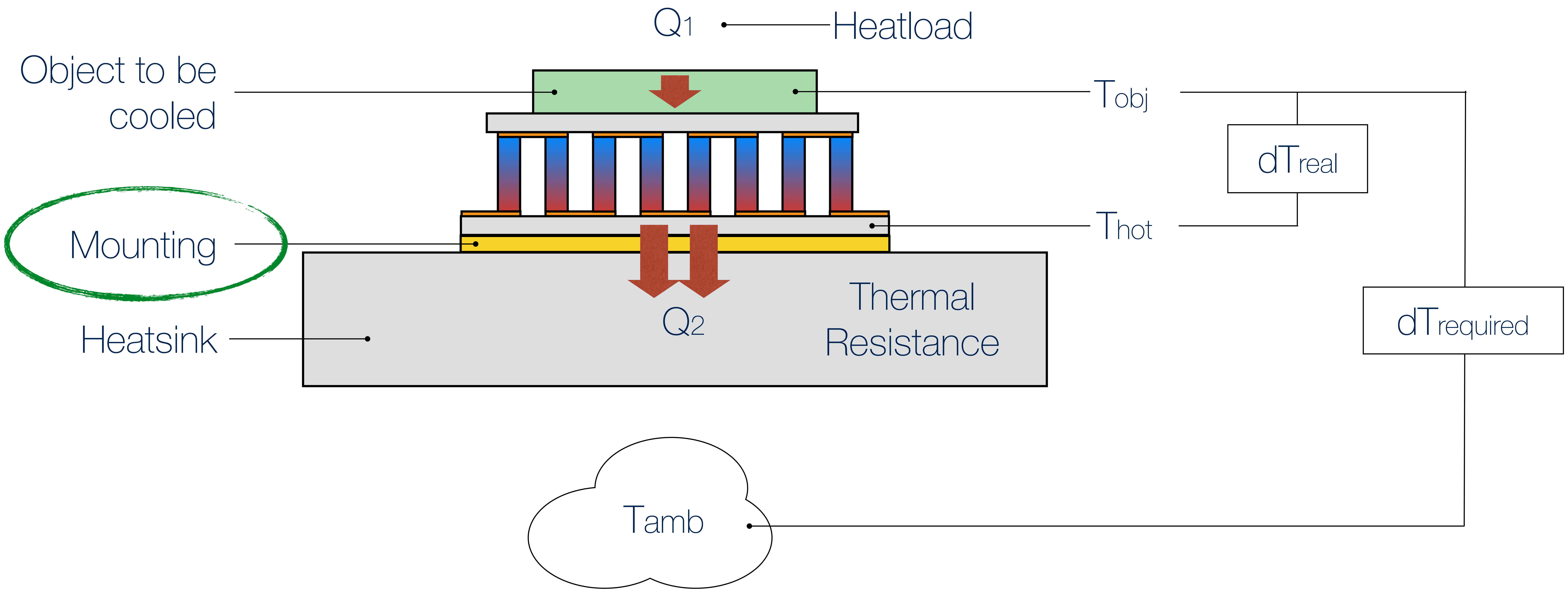
Optimal and Real Application Conditions - Hot Side Overheating Issue



Heat Q_2 from TEC Hot Side is Q_1 + TEC (I x U). Heatsink and Package have Thermal Resistances

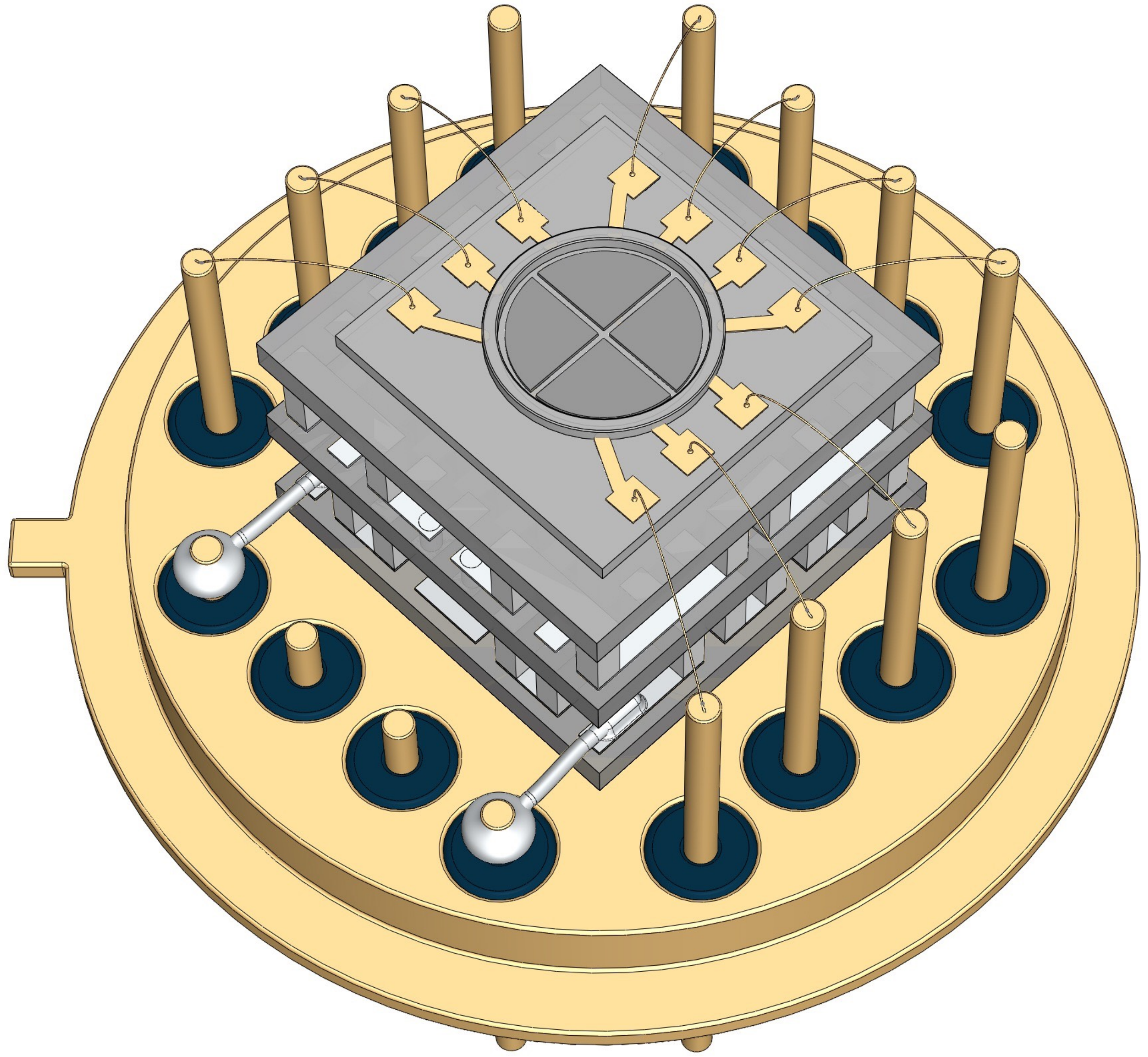
Thus in most cases: $T_{hot} > T_{amb}$ and $dT_{real} > dT_{required}$

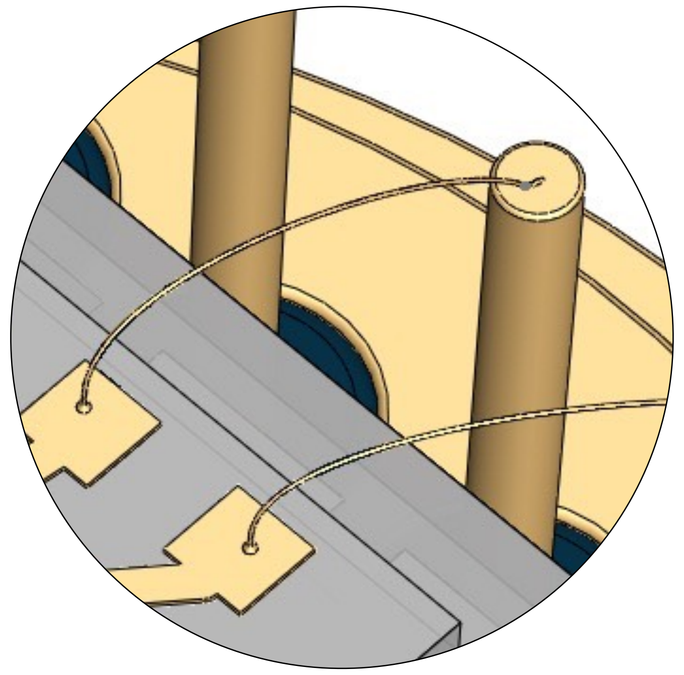
Application Conditions Optimal and Real - Hot Side Overheating Issue



Mounting method and materials are important to avoid overheating and low performance issues.
Soldering is usually the most optimal method by thermal conductivity and mechanical properties.

Extra Heatload Coming by Wires on TEC Cold Side





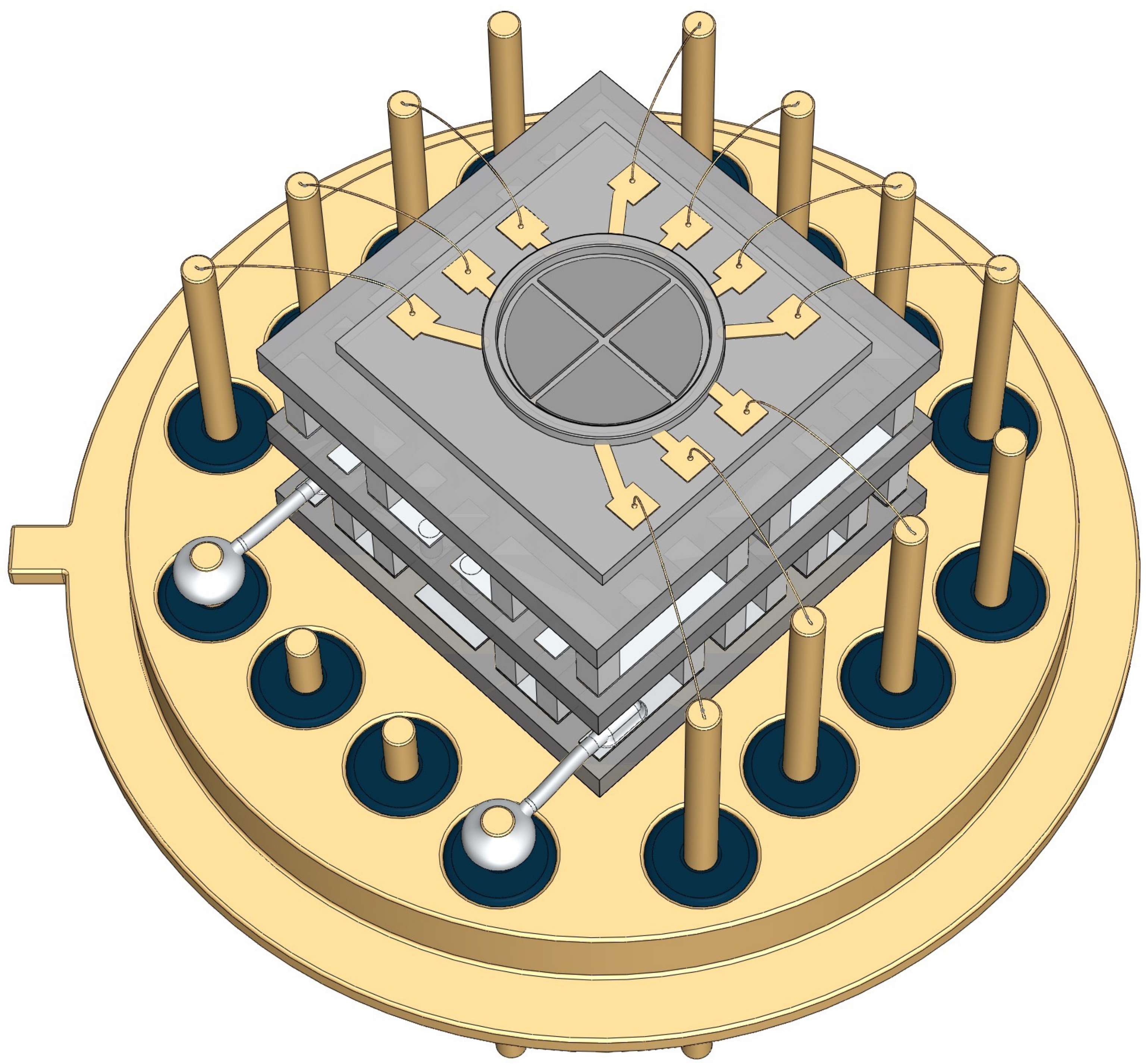
Heat coming by wires can be estimated by simplified formula

$$Q_{wires} = N \times K \times \frac{S}{L} \times dT$$

- N - Number of wires
- K - Wires Material Thermal Conductivity
- S - Wire Cross-section
- L - Wire Length
- dT - Temperature difference in application (between TEC cold side and header)

WB wires length, diameter and material are very important in minimizing passive heatload.
Improper WB wire type choice may lead to unexpected and significant heatload in final application.

Extra Heatload Coming by Wires on TEC Cold Side, Example

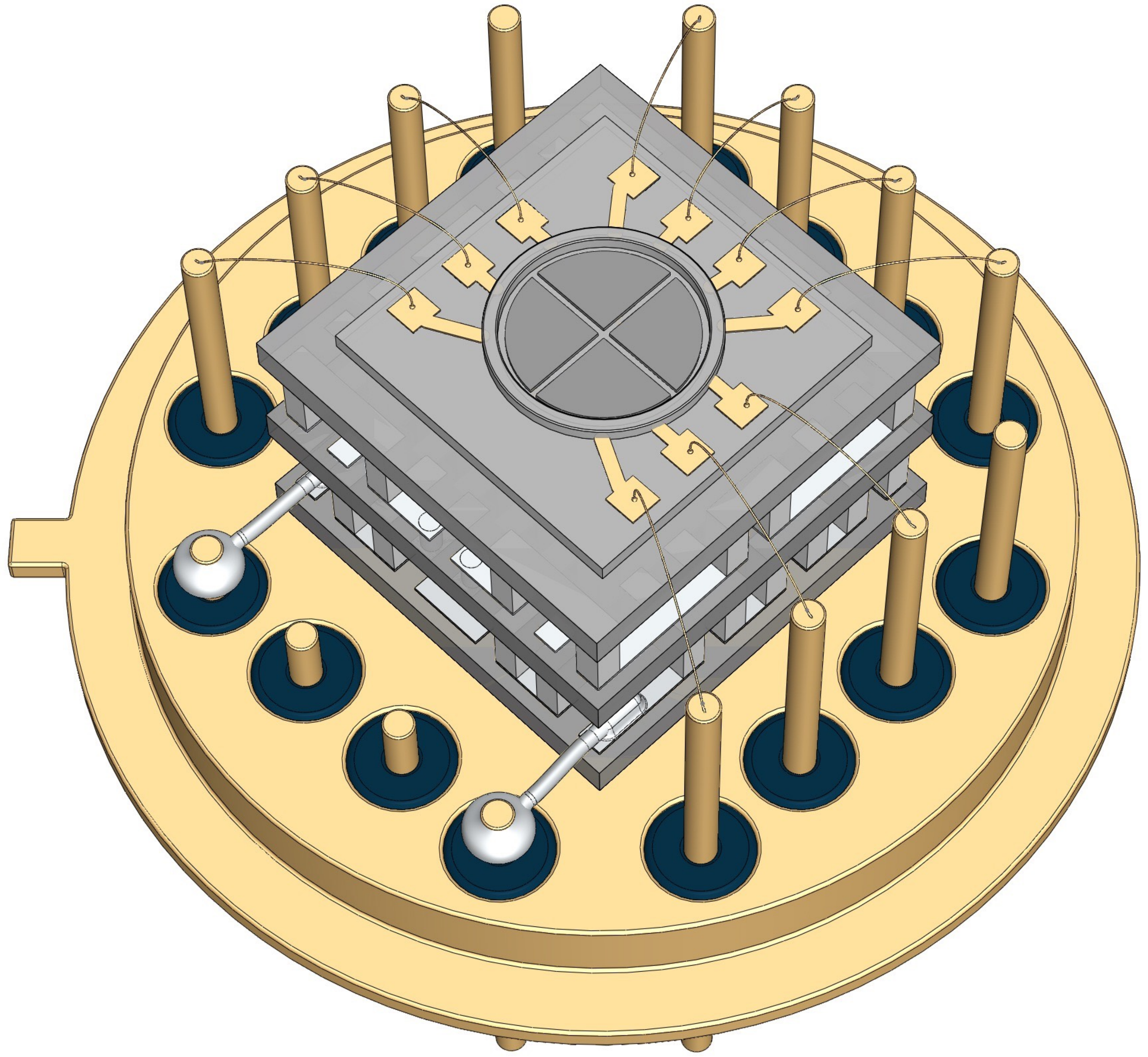


N = 10 (number of wires)
D = 50um (diameter) = 0.05mm = 0.5E-4 m
K = 317 W/mK (Gold wires)
S = $(\pi \times D^2)/4$ = 0.196E-8 m^2
L = 3.5mm = 0.0035m
dT = 80K (between TEC cold side and header)

$$Q_{wires} = 10 \times 317 \times \frac{0.196E\text{-}8}{0.0035} \times 80 = 0.142W$$

WB wires length, diameter and material are very important in minimizing passive heatload.
Improper WB wire type choice may lead to unexpected and significant heatload in final application.

Extra Heatload Coming by Wires on TEC Cold Side, Materials Comparison



Example #1: dT=80K, 10 WB Wires, 50um dia, 3.5mm Length

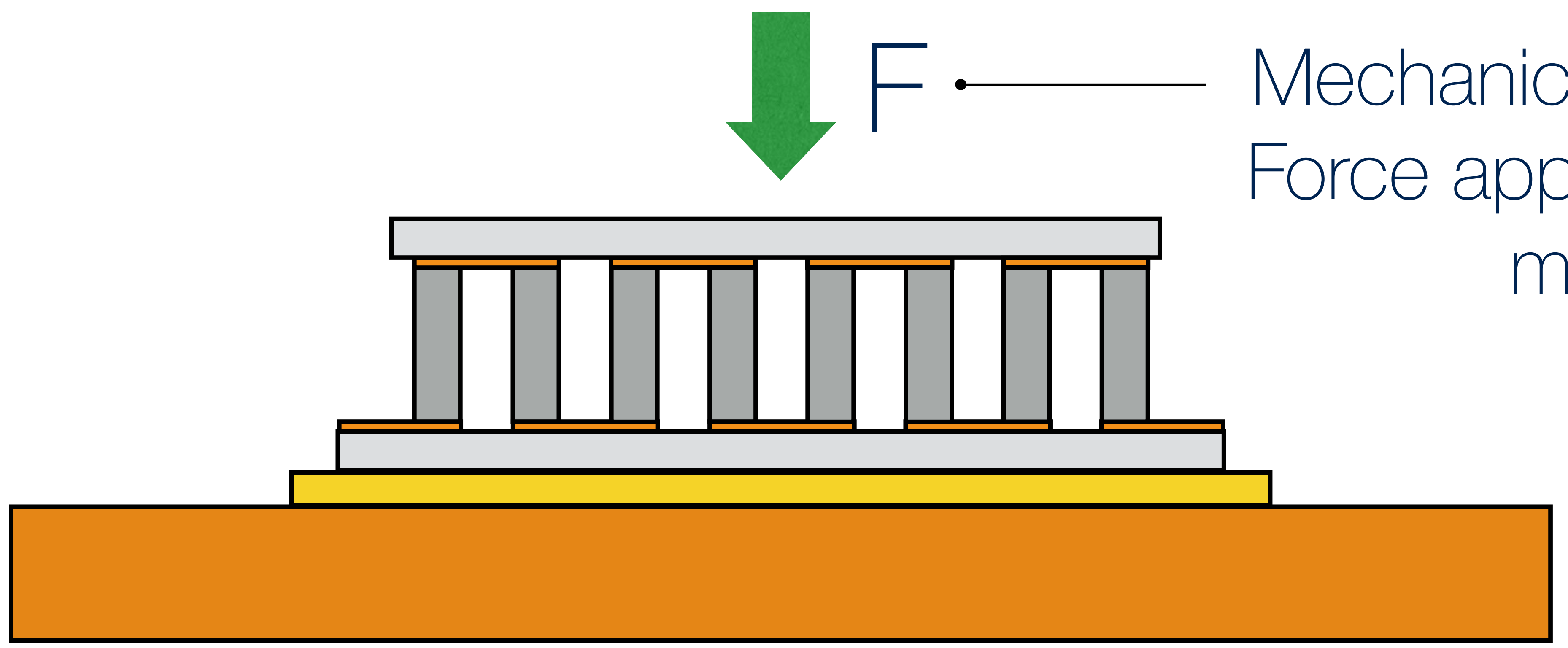
Property	Units	Au	Al	Pt
Thermal Conductivity	W/(m x K)	317	237	72
Resulting Heatload	mW	142	106	32

.. but if to apply **20um** dia wires (instead of 50um)

Resulting Heatload	mW	23	17	5

WB wires length, diameter and material are very important in minimizing passive heatload.
Improper WB wire type choice may lead to unexpected and significant heatload in final application.

Max Compression Force during TEC mounting



Mechanical compression Force applied during TEC mounting

Example with TEC*

1ML06-023-10

0.6x0.6mm² Pellets

23 pellet Couples

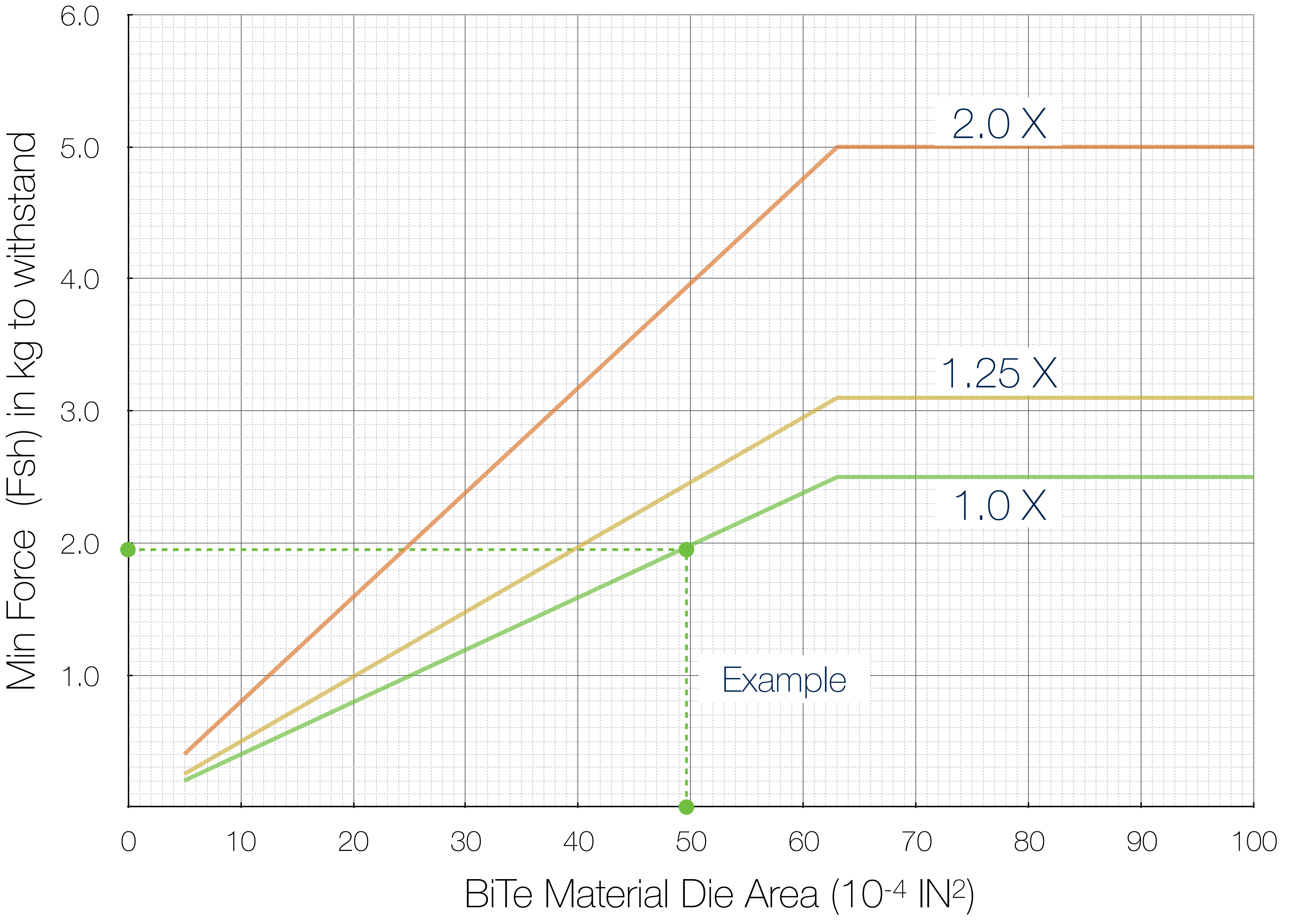
$F_{max} = 1\text{kg per mm}^2$

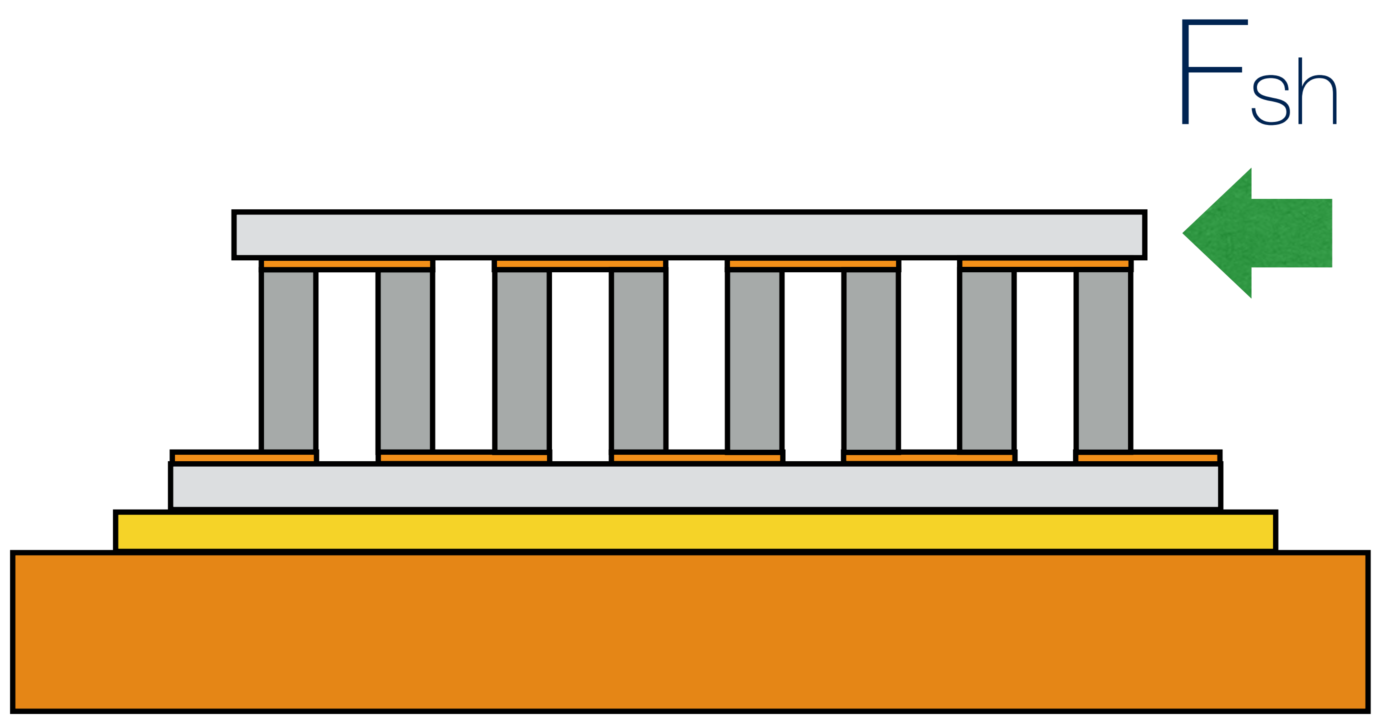
BiTe die area inside TEC

$F_{max} = 0.6 \times 0.6 \times 23 \times 2 = 16.5\text{kg}$

* TEC Microsystems uses the patented nomenclature system, where TEC type name describes TEC internal construction

TE Coolers and Shear Force





Example with TEC Microsystems TEC

1MC04-010-05

$0.4 \times 0.4 mm^2$ Pellets

10 pellet Couples

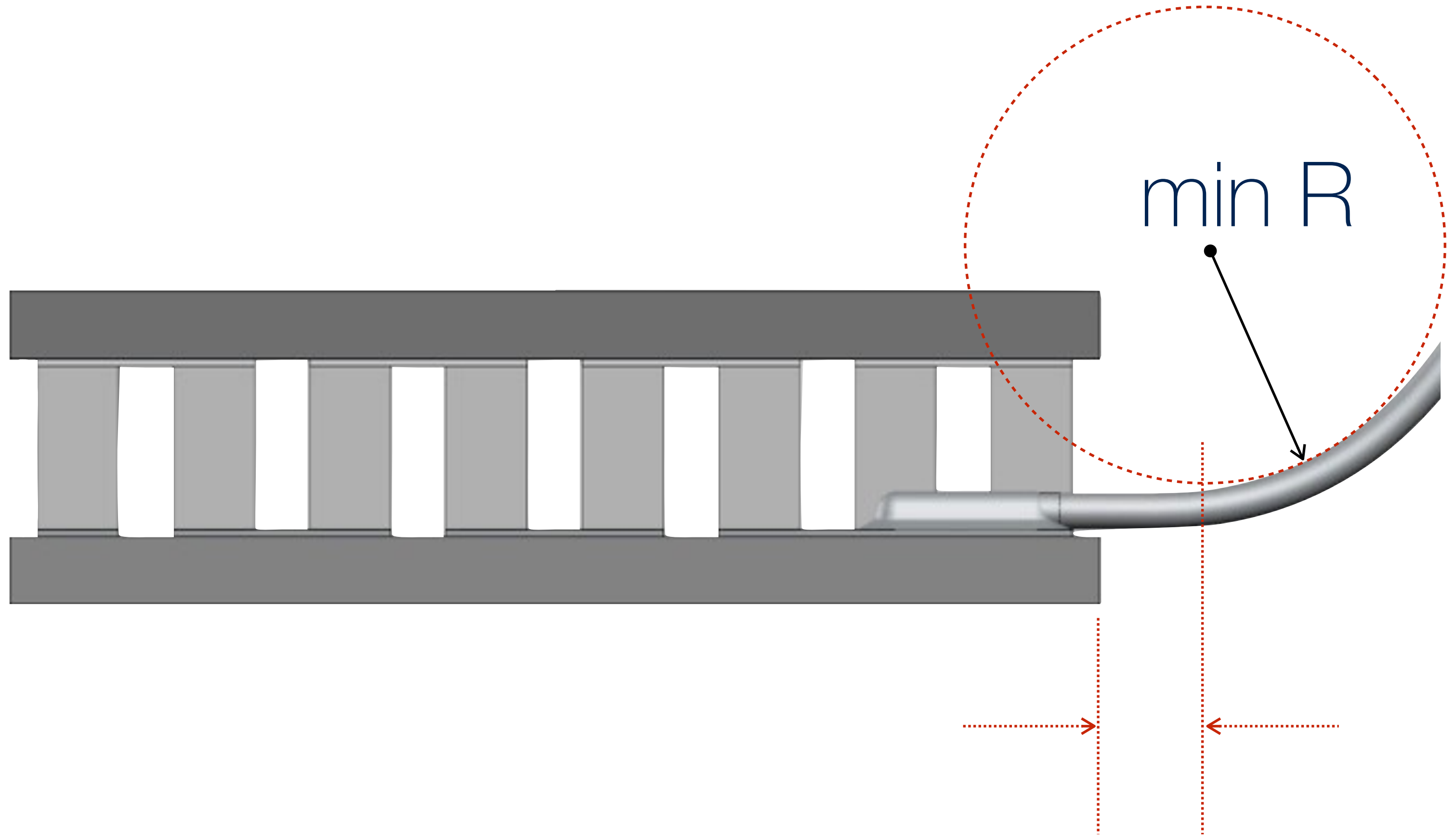
BiTe Die Area=$0.4 \times 0.4 \times 10 \times 2 = 3.2 mm^2 = 49.6 (10^{-4}$ IN$^2)$

MIN force (1.0X) to withstand is 1.95kg (per chart)

By Telcordia GR-468 Standard (based on MIL-STD-883F, method 2019.7) TEC must endure, at least, the minimal given effort to shift (1.0X)

Wire integrity and Bending

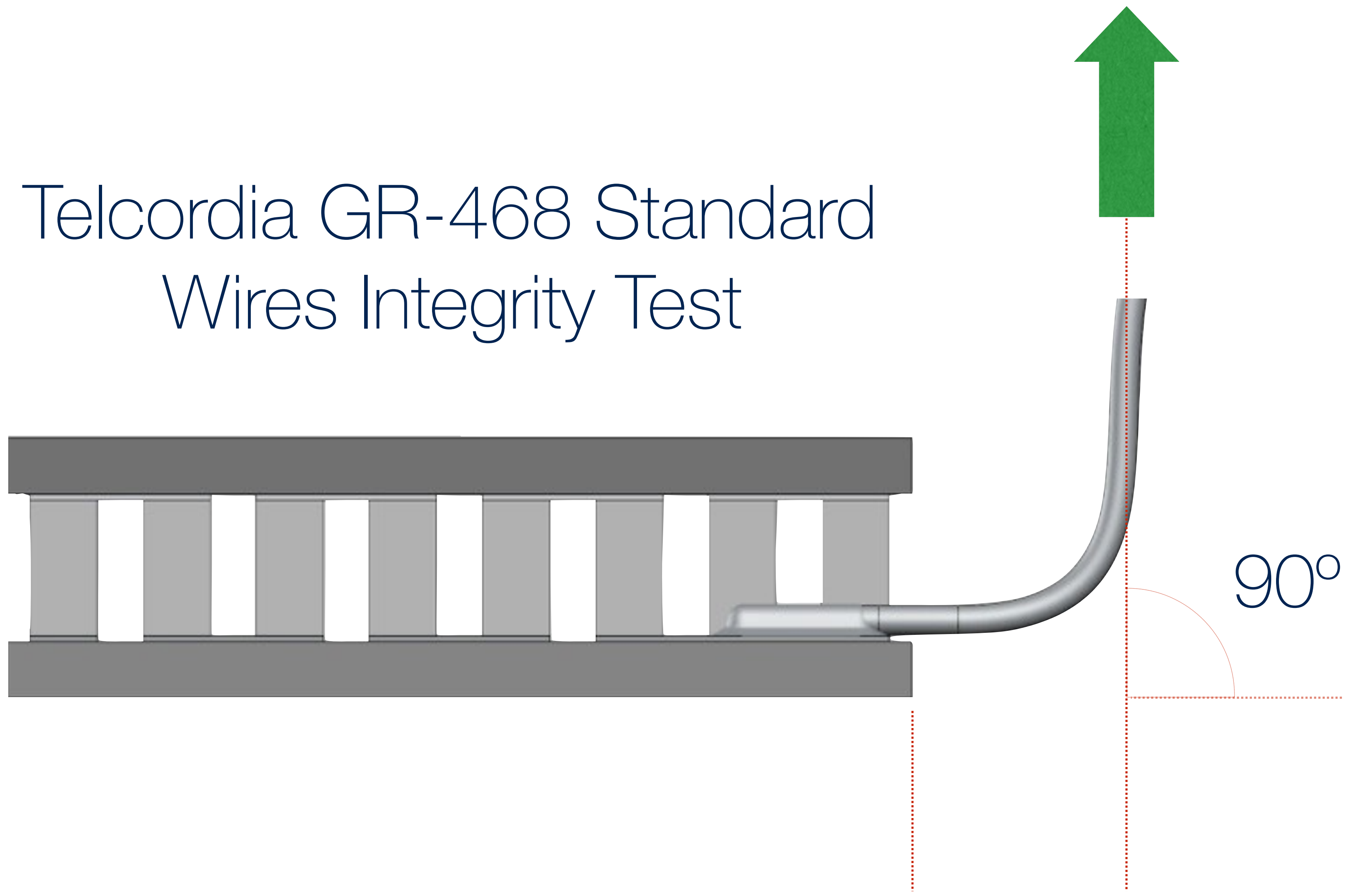
MIN bend Radius: 0.5mm
Recommended: 4x Wire Dia



1.0 mm MIN
Safe Area
(do NOT bend closer)

Max Pull 8 oz
(2.2N)

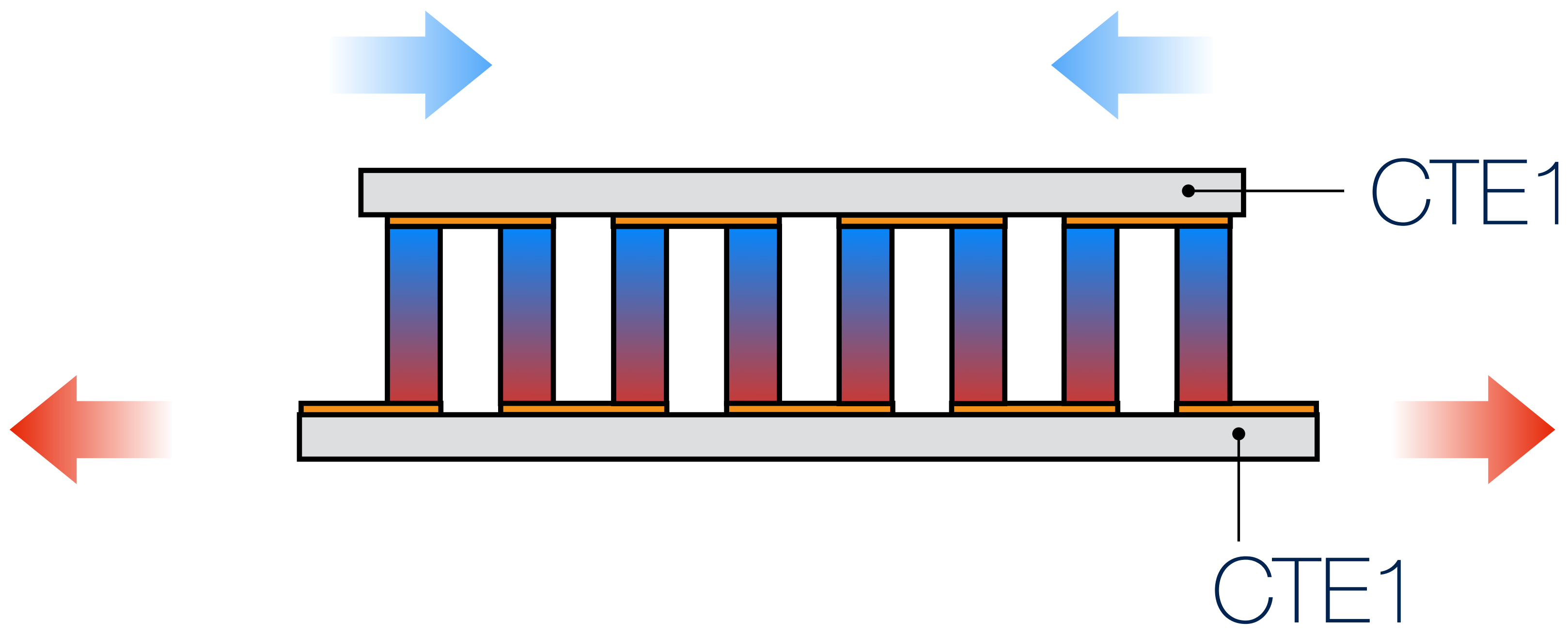
Telcordia GR-468 Standard
Wires Integrity Test



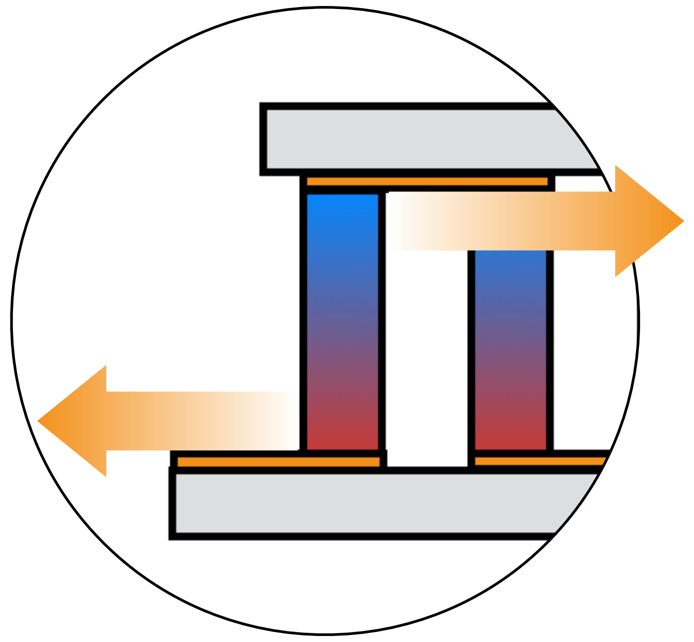
Control Force Level, MIN bending Radius and safe Distance to avoid wires damaging or detachment

Coefficient of Thermal Expansion (CTE) - Basics

During TEC operating
Cold Side shrinks

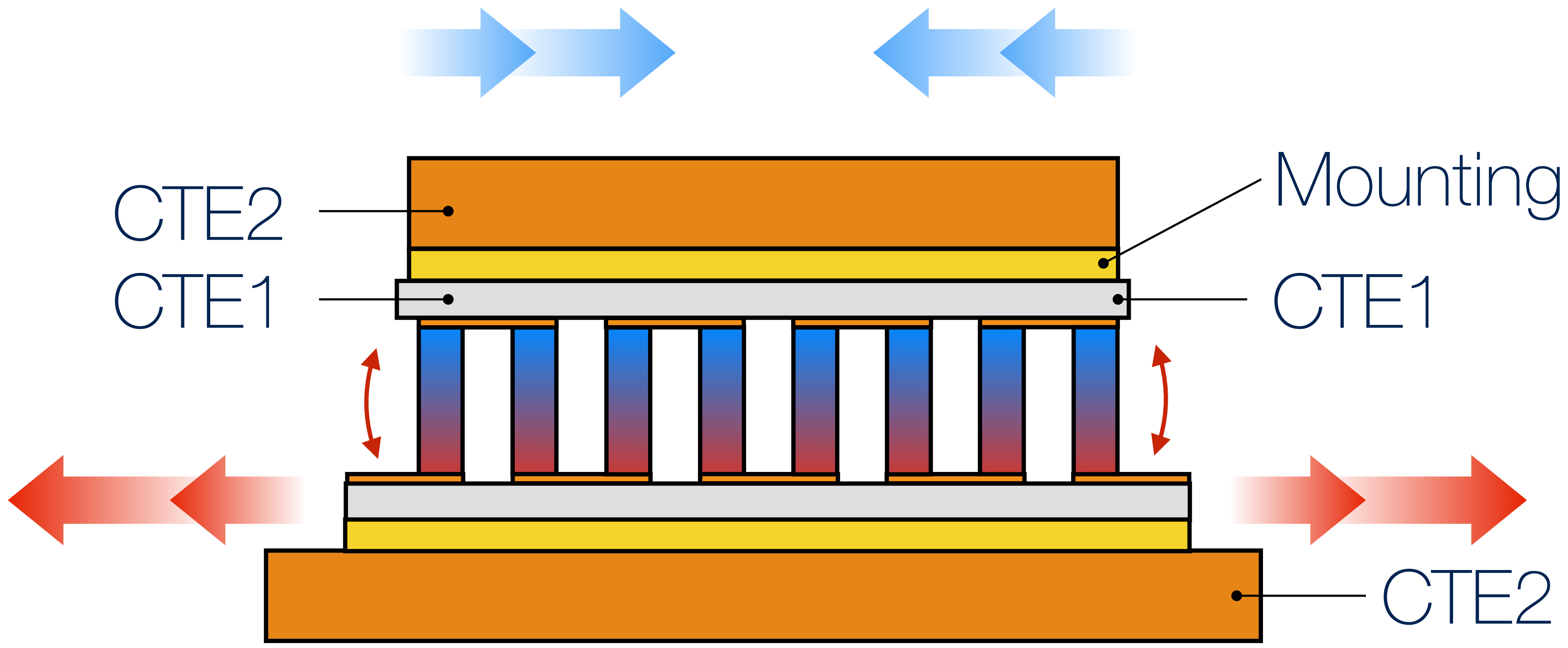


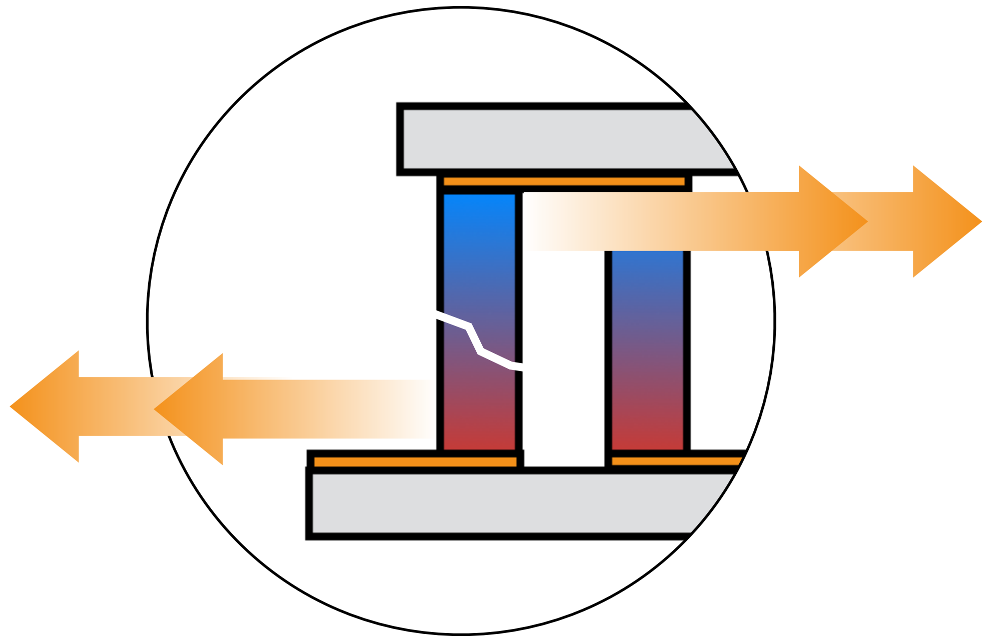
Hot Side expands



Mechanical Strains on Pellets
Safe Level

CTE2 >> CTE1





Multiplied Mechanical Strains on Pellets
Pellet cracks

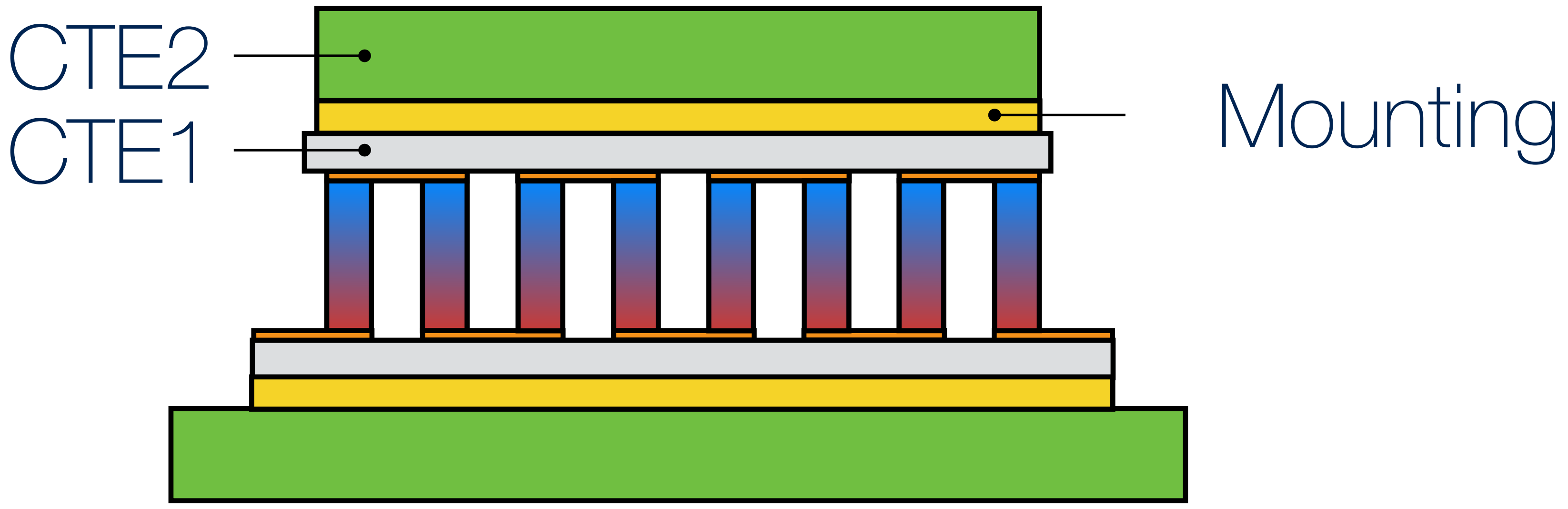
Coefficient of Thermal Expansion (CTE) - Materials

TEC ceramics

Material	CTEx10-6, 1/K	Thermal Conductivity, W/mK	
Aluminium	22.5	237	risky
Bismuth Telluride	12.9	1.5	
Brass	18.0	110	risky
Ceramics Al2O3 - 100%	**7.2**	30	friendly
Ceramics Al2O3 - 96%	7.0	24	friendly
Ceramics AlN	**4.5**	170	friendly
Ceramics BeO	7.0	230	friendly
Cold-roll Steel (CRS)	11.5	50	friendly
Copper	16.7	400	risky
Copper-Molybdenum(15%-85%)	6.9	190	friendly
Copper-Molybdenum(25%-75%)	8.0	175	friendly
Copper-Wolfram(10%-90%)	6.7	180	friendly
Copper-Wolfram(20%-80%)	8.5	200	friendly
Gold	14.0	317	risky
Kovar	5.5	17	friendly
Nickel	13.4	90	risky
Platinum	9.0	72	friendly
Silicon	3.0	150	
Silver	18.9	429	risky
Stainless steel	17.1	14.5	risky

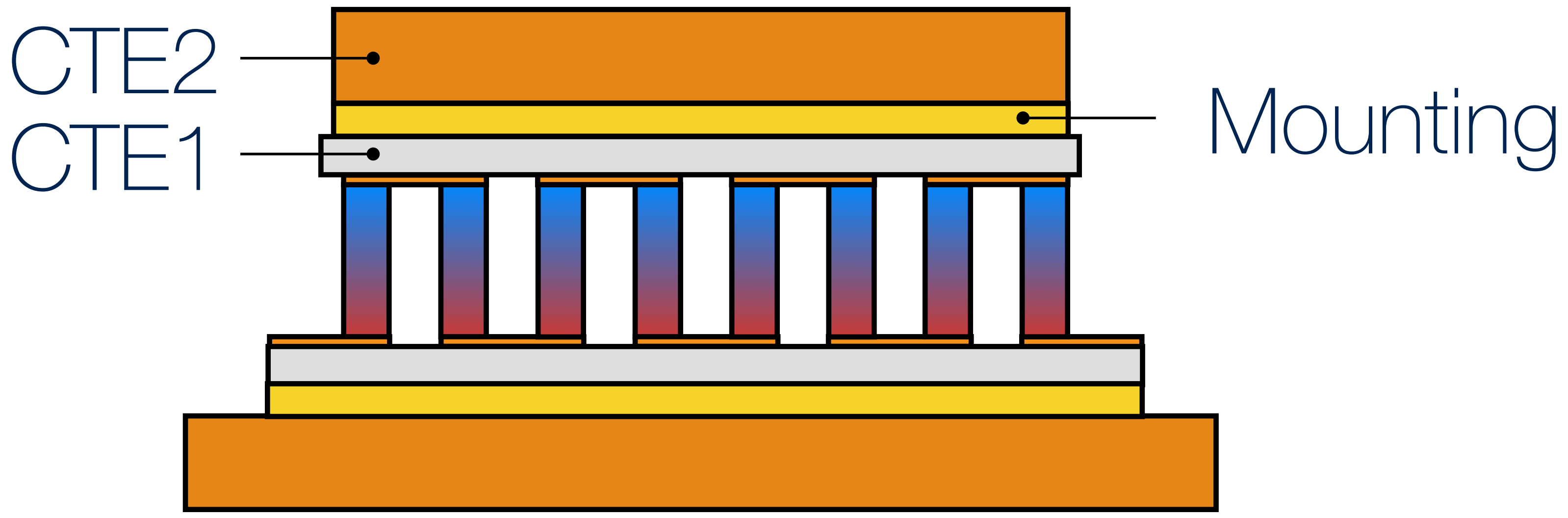
CTE2 ~ CTE1

CTE friendly



CTE2 >> CTE1

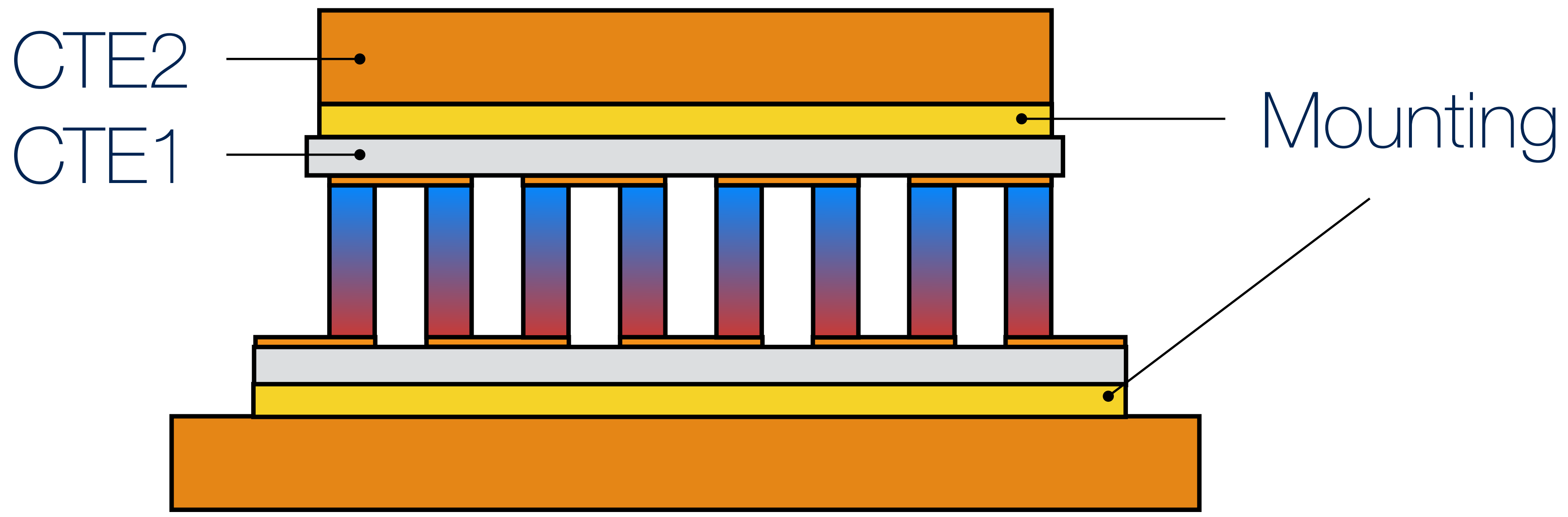
CTE risky



CTE Mismatch Issues - Solution #1 (recommended)

CTE2 >> CTE1

CTE risky



Solution to prevent
TEC damage

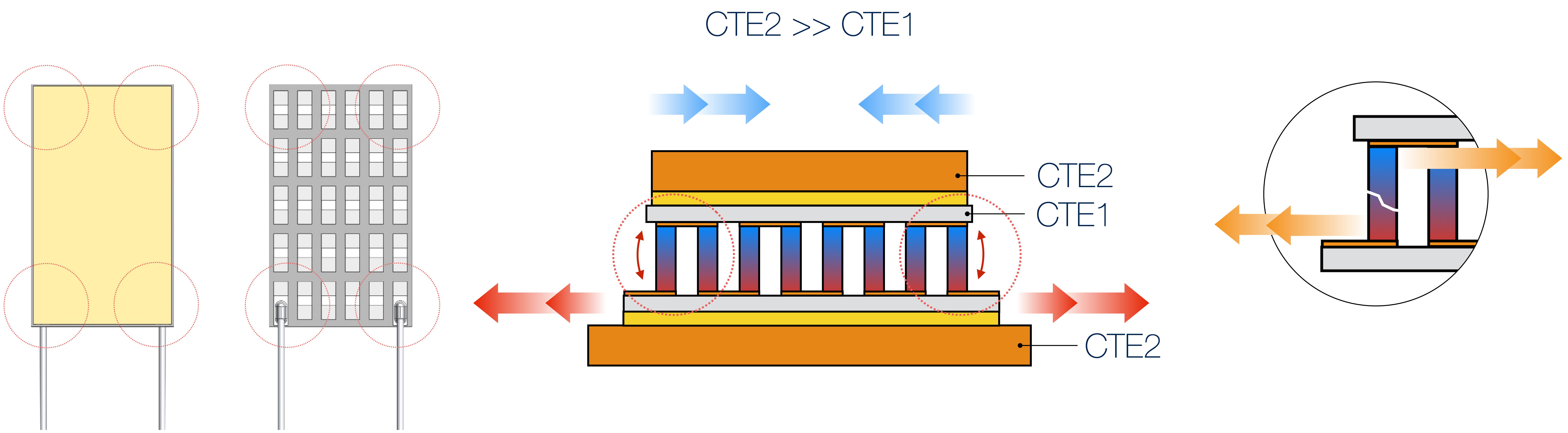
Thick layer of soft Solder
or elastic Glue

Solder 157 100% In	Solder 117 In-Sn	Silicon-based glues

If it's not possible to avoid CTE risky materials, there is a solution to apply mounting with elastic materials - soft solders or silicon-based elastic glues

CTE Mismatch Issues - Solution #2 “Flying Corners” (page1)

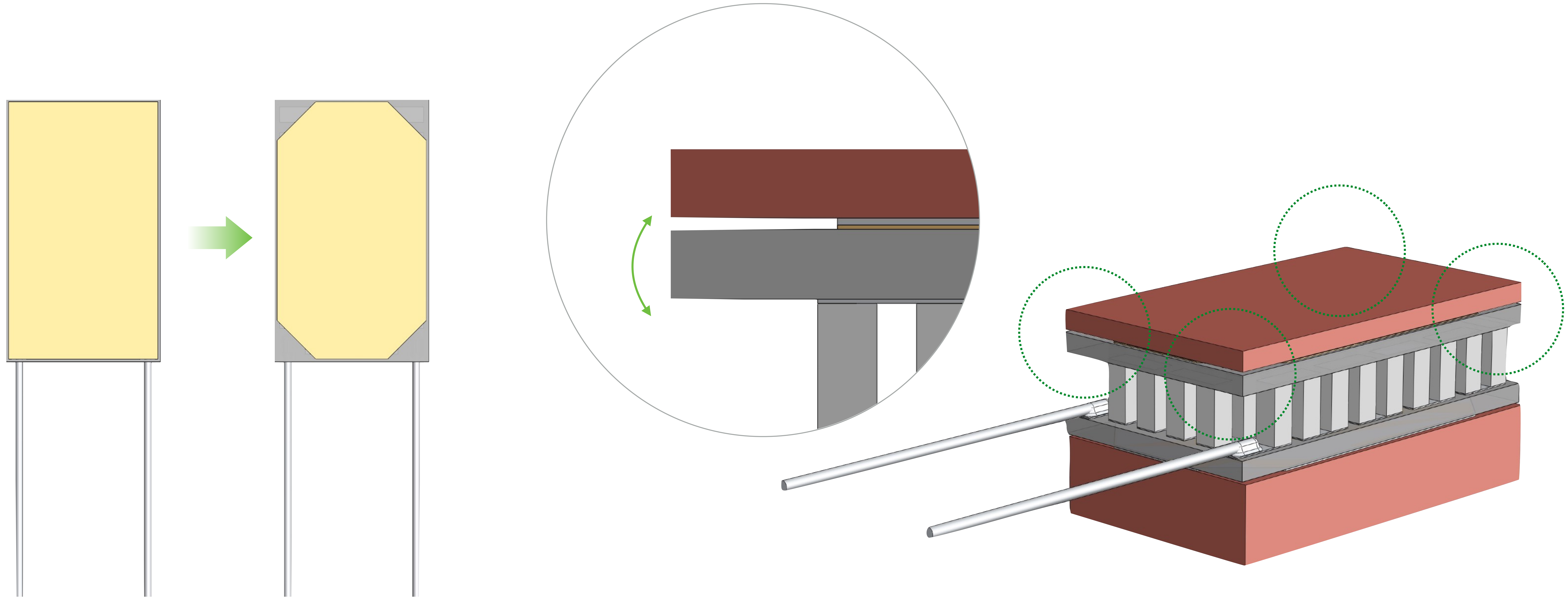
The most critical areas affected by thermomechanical strains due to CTE mismatch are located in corners inside TEC



During thermomechanical stress caused by CTE mismatch in most cases pellets are damaged in TEC corner areas, where strain force affect reaches the maximum

CTE Mismatch Issues - Solution #2 “Flying Corners” (page2)

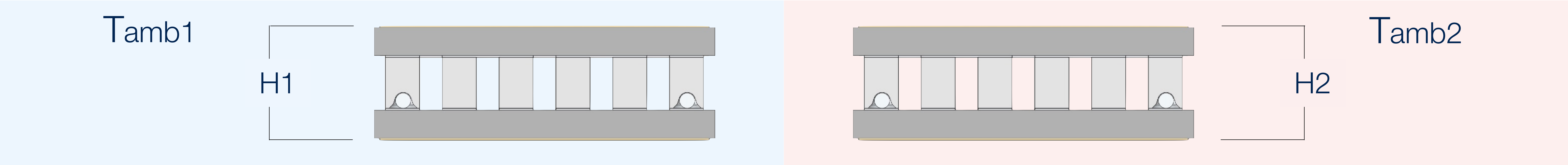
“Flying corners” solution keeps TEC corner areas without Direct Contact to objects. TEC gets certain elasticity in corner areas, reducing strain affect on internal pellets.



Up to ~15% contact area can be used for “flying-corners” w/o TEC performance reduction.
The solution is recommended for soldering mounting with CTE risky materials only.

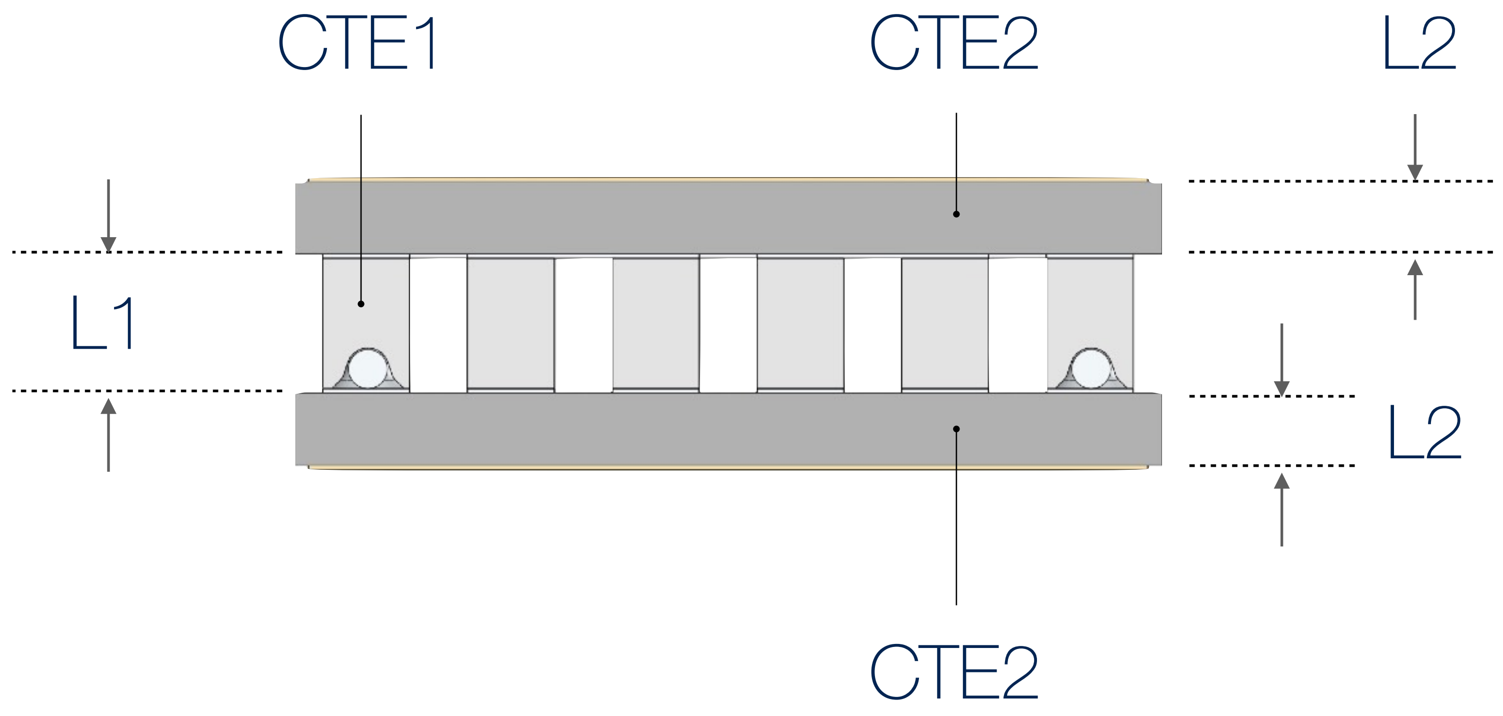
Optical Axis alignments - TEC Height changes depending on Ambient Temperature

$$dT_{amb} = T_{amb2} - T_{amb1}$$



$$dH = H2 - H1$$

$$dH = (N \times L1 \times CTE1 + M \times L2 \times CTE2) * dT_{amb}$$



N - number of TEC stages

M - number of Ceramics plates

L1 - BiTe pellets Height

L2 - Ceramics thickness

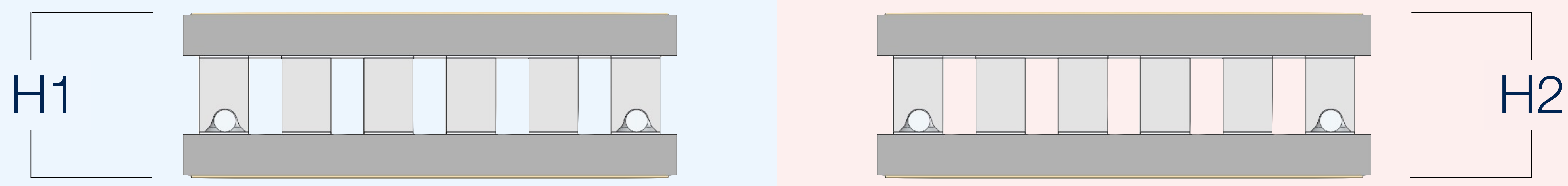
CTE1 - BiTe Coefficient of Thermal Expansion

CTE2 - Ceramics Coefficient of Thermal Expansion

Optical Axis alignments - TEC Height changes, Example

$dT_{amb} = T_{amb2} - T_{amb1} = 60^{o}C$

$T_{amb1} = 25^{o}C$



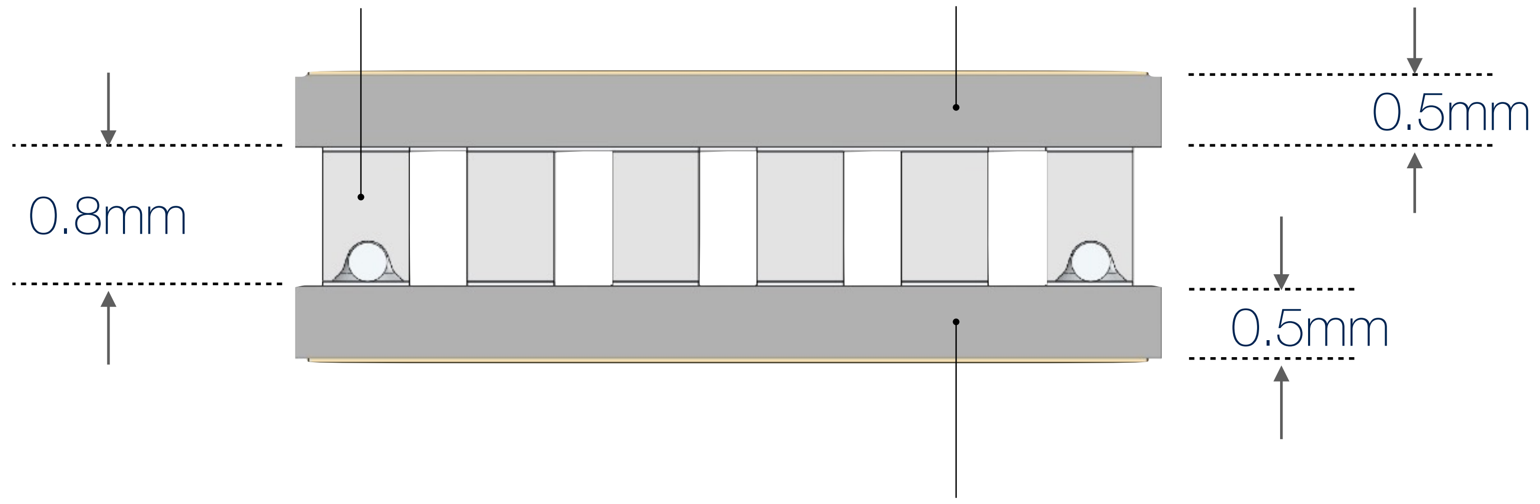
$T_{amb2} = 85^{o}C$

$dH = H2 - H1$

$$dH = (1 \times 0.8 \times 12.9 \times 10^{-6} + 2 \times 0.5 \times 7.2 \times 10^{-6}) \times 60 = 0.00105mm = 1.05um$$

BiTe CTE1 = 12.9×10^{-6} 1/K

Al_2O_3 CTE2 = 7.2×10^{-6} 1/K



Al2O3 CTE = 7.2×10^{-6} 1/K

N=1- number of TEC stages

M=2- number of Ceramics plates

L1=0.8mm - BiTe pellets Height

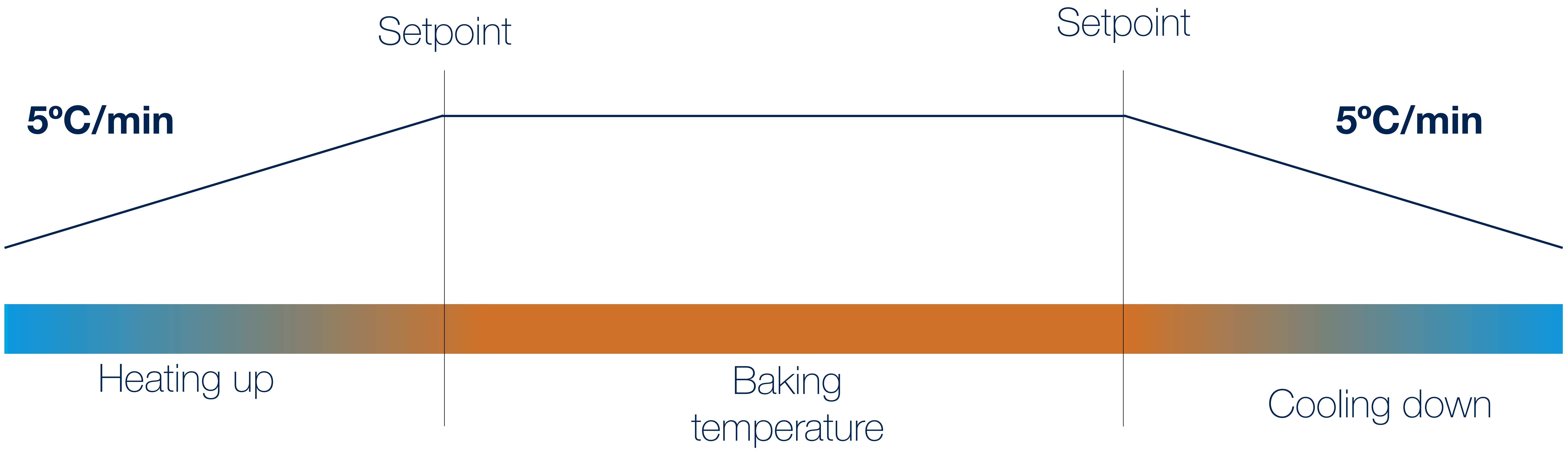
L2=0.5mm- Ceramics thickness

CTE1 - BiTe Coefficient of Thermal Expansion

CTE2 - Al_2O_3 Coefficient of Thermal Expansion

TE Coolers Baking process in case of Epoxy Gluing

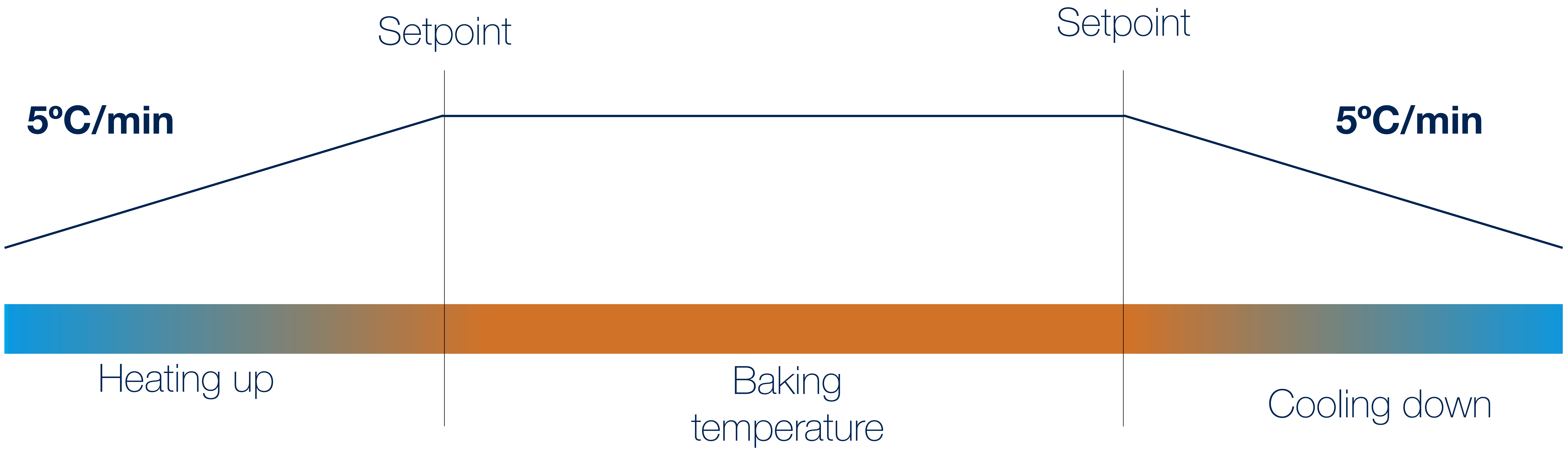
1. Silver Epoxy and similar solutions are very common for TECs mounting.
2. Epoxy mounting method usually requires curing at high temperature.
3. Typical curing process can be made at +125ºC…+150ºC for several hours



Important: Curing process to be with temperature ramping at heating up and cooling down stages to avoid thermal shock. The recommended rate is 5ºC per minute during heating up and cooling down.

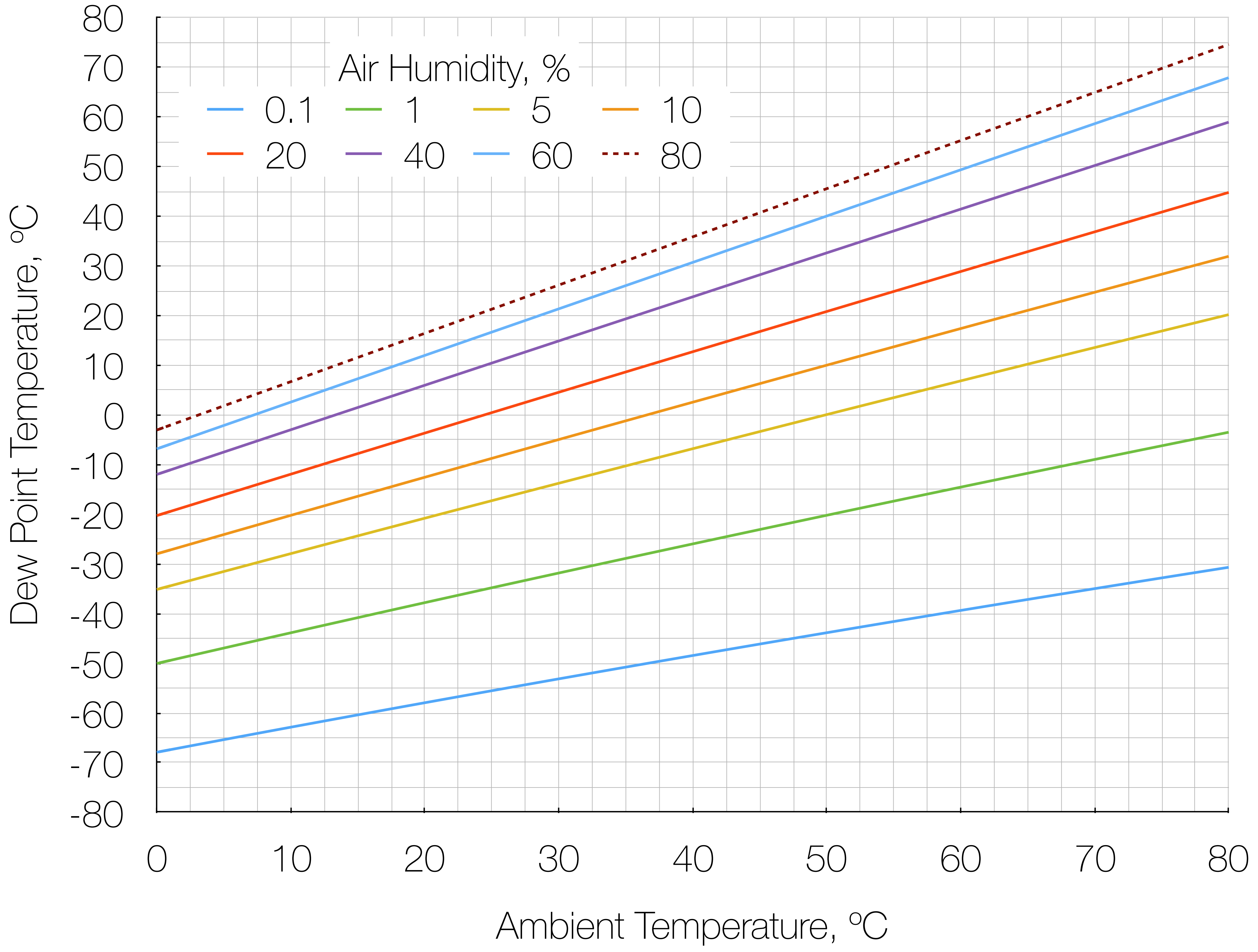
TE Coolers in UHV applications

1. All TEC Microsystems TECs are Flux-Free and suitable for vacuum and UHV applications.
2. TE Coolers require baking (annealing) before final assembly in vacuum application.
3. Typical baking process is made at +125ºC…+150ºC for several hours



Important: Baking (annealing) process must be applied with temperature ramping to avoid thermal shock. The recommended temperature change rate is max 5ºC per minute during heating up and cooling down.

Ambience Humidity and Dew Point Risks



Dew Point Td at relative humidity RH and the actual temperature T of Air is estimated as:

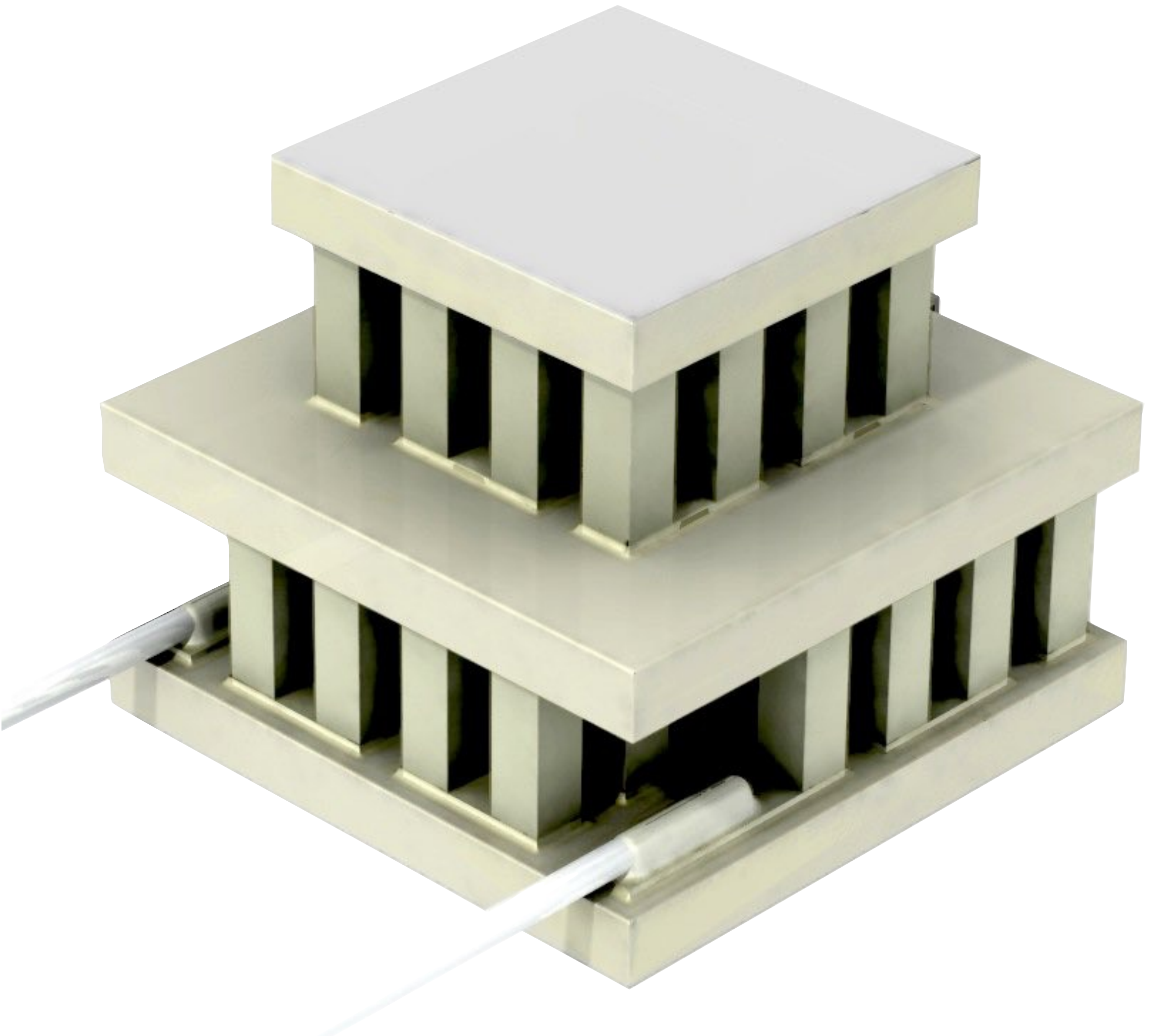
$$Td = \frac{237.7 \times Y(T,RH)}{17.27 - Y(T,RH)}$$

$$Y(T,RH) = \frac{17.27 \times T}{237.7+T} + \ln\left(\frac{RH}{100}\right)$$

Important: Water condensation creates significant risks for TEC normal operating. To prevent water condensation filling gas must be dry and have Dew Point lower than required cooling temperature.

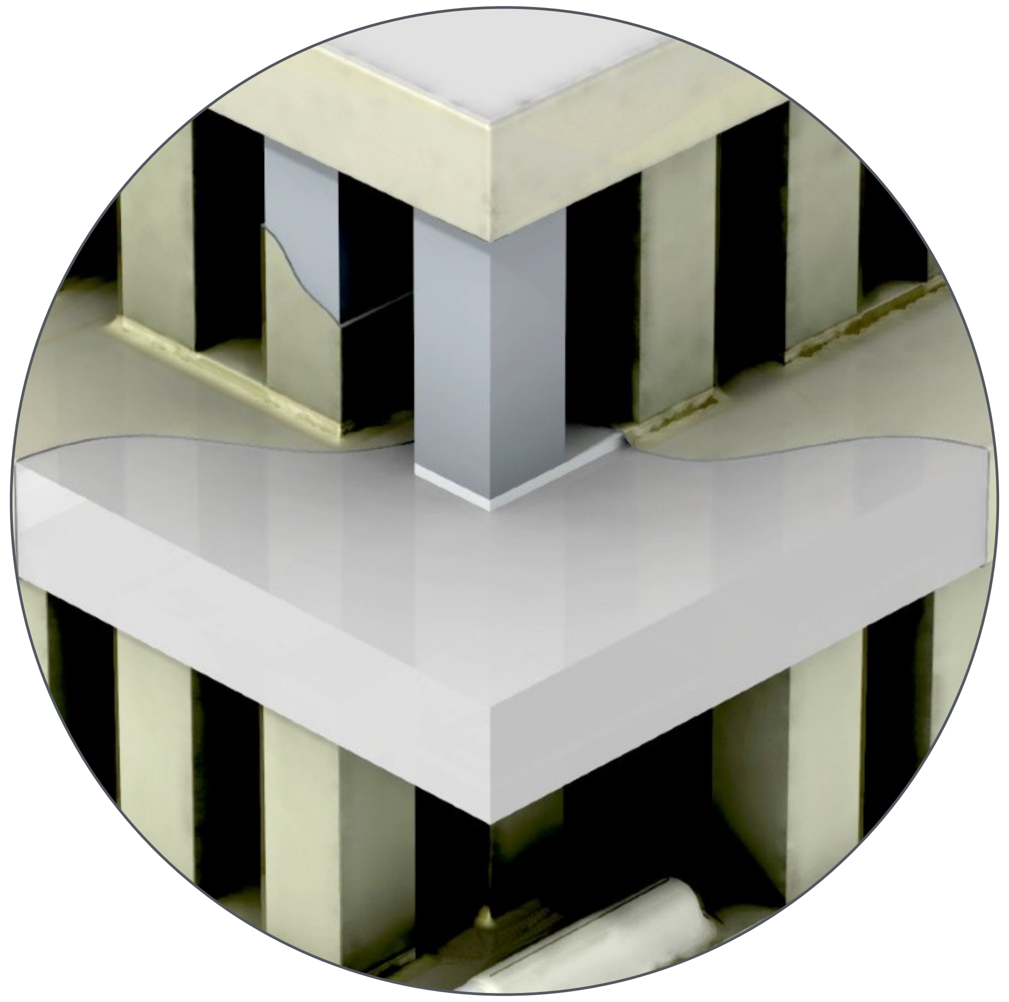
TEC Advanced 3M™ Protective Coating against wet Ambience

TEC Protective Coating



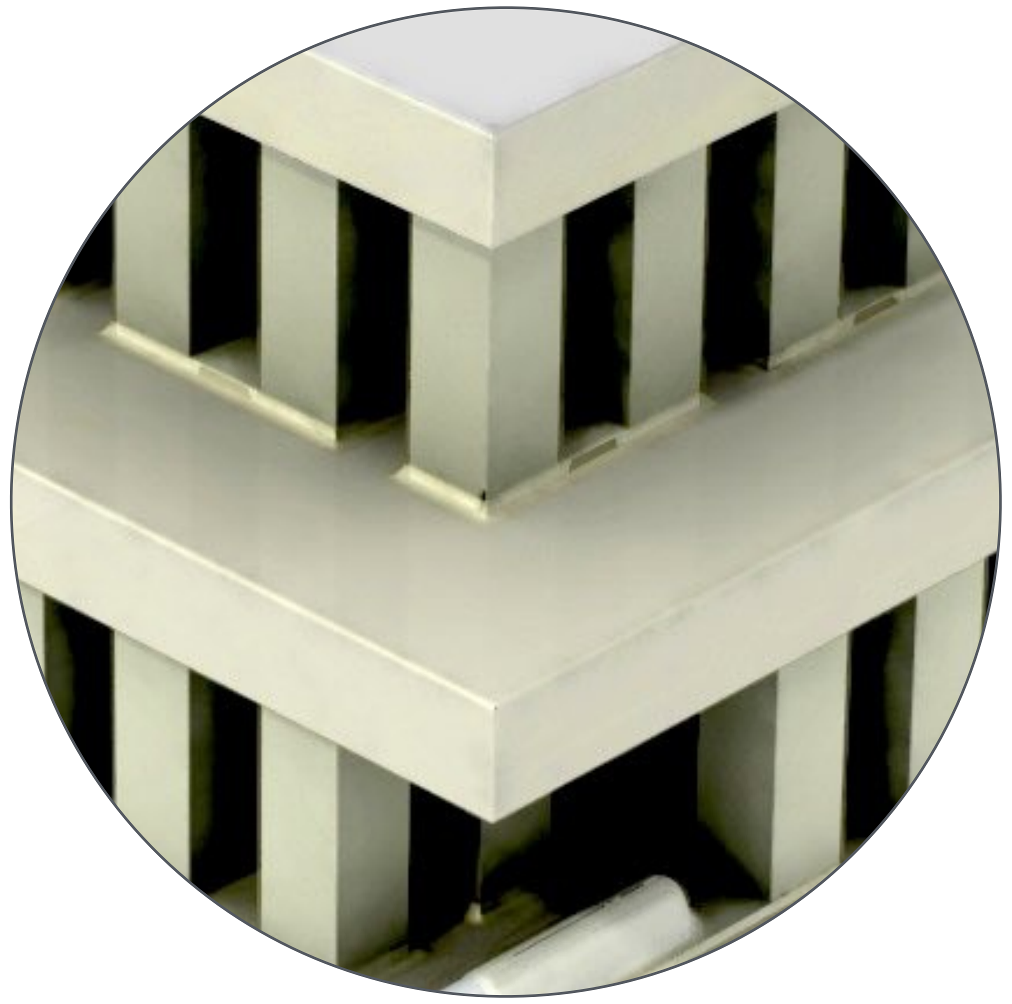
Withstand up to 200ºC during mounting (short time)

Ultra-thin 3-5um Layer



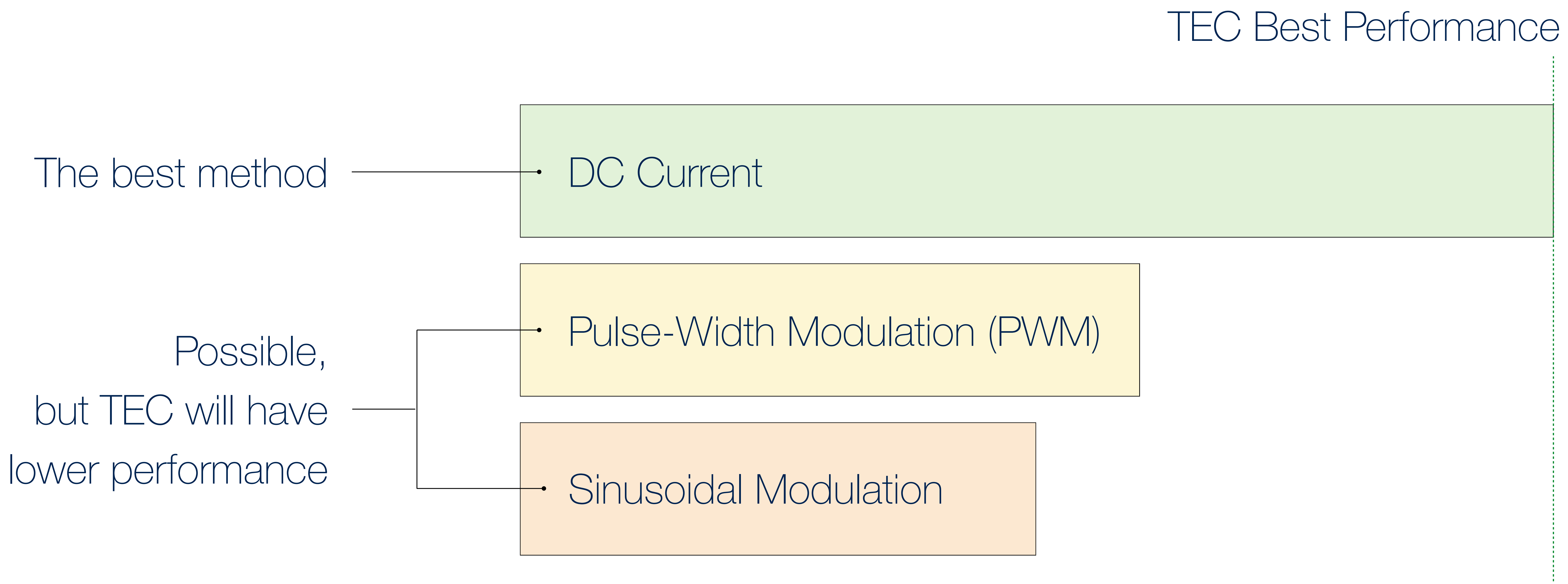
Doesn’t affect TEC Performance

Covers all TEC inner surfaces



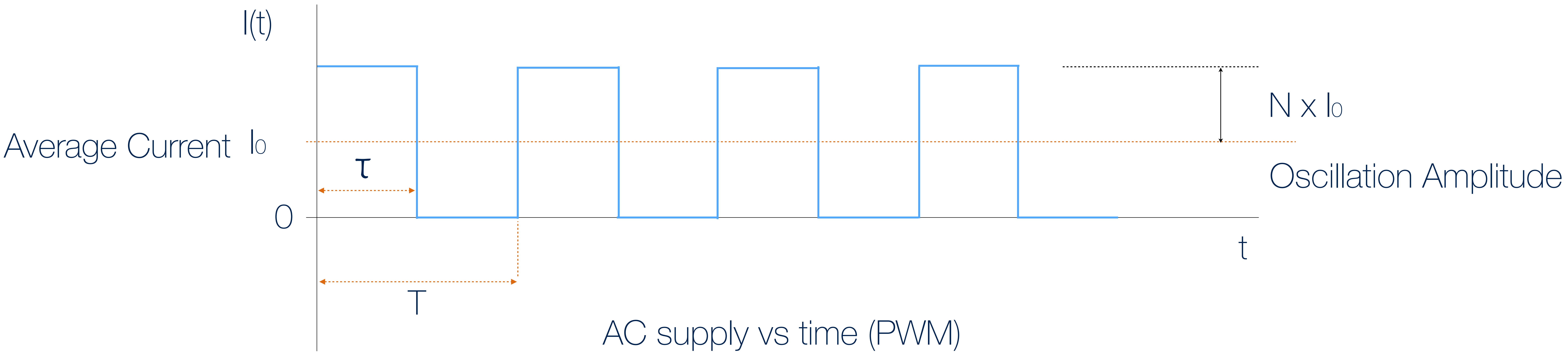
Protects TEC even being submerged in water

TE Coolers Power Supply



TEC is DC regulated device. The best TEC performance is achieved with DC power supply.
It’s possible to use Sinusoidal modulation or PWM, but it will decrease TEC performance and efficiency.

TEC Power Supply - Pulse-Width Modulation (PWM)



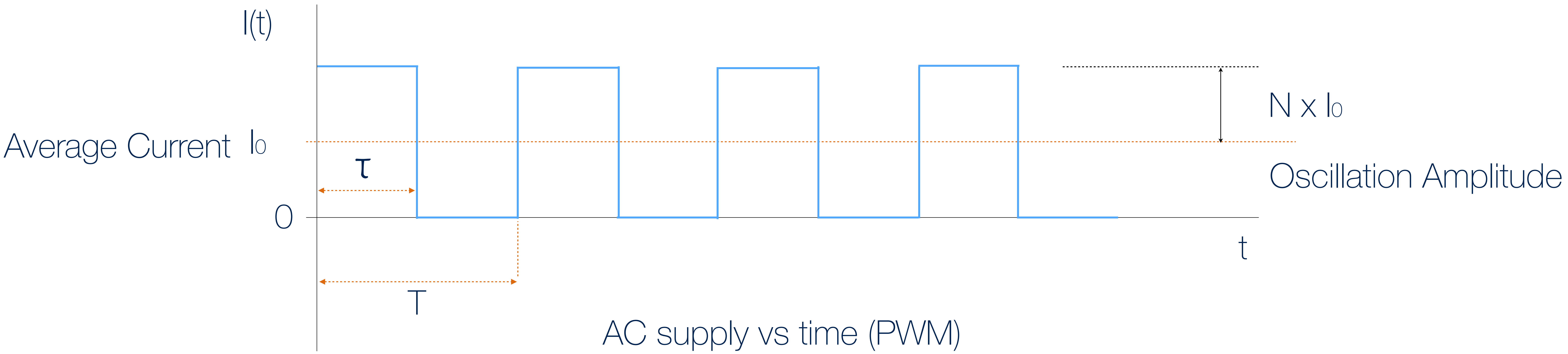
AC supply vs time (PWM)

$$\text{Duty Cycle } Q = \frac{\tau}{T}$$

$$\frac{dT_{max}(PWM)}{dT_{max}(DC)} = \frac{(1 + N \times (2Q-1))^2}{1 + 2N \times (2Q-1) + N^2}$$

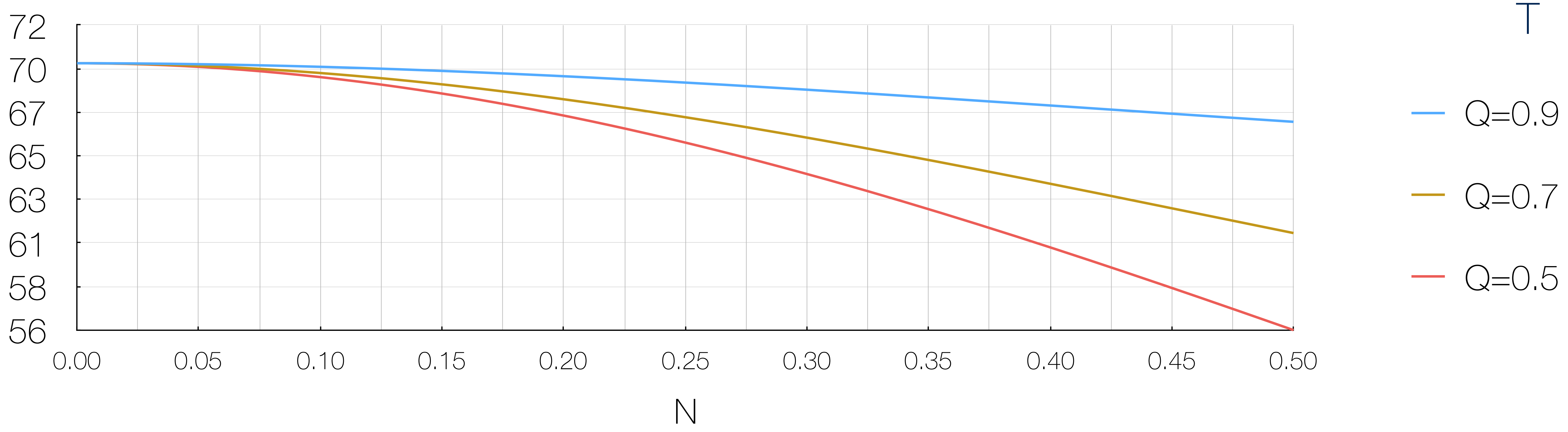
TEC is a DC current device. PWM reduces TE module efficiency. The reduction of dTmax can be estimated by the formulas specified.

Example - dTmax reduction at Pulse-Width Modulation (PWM)



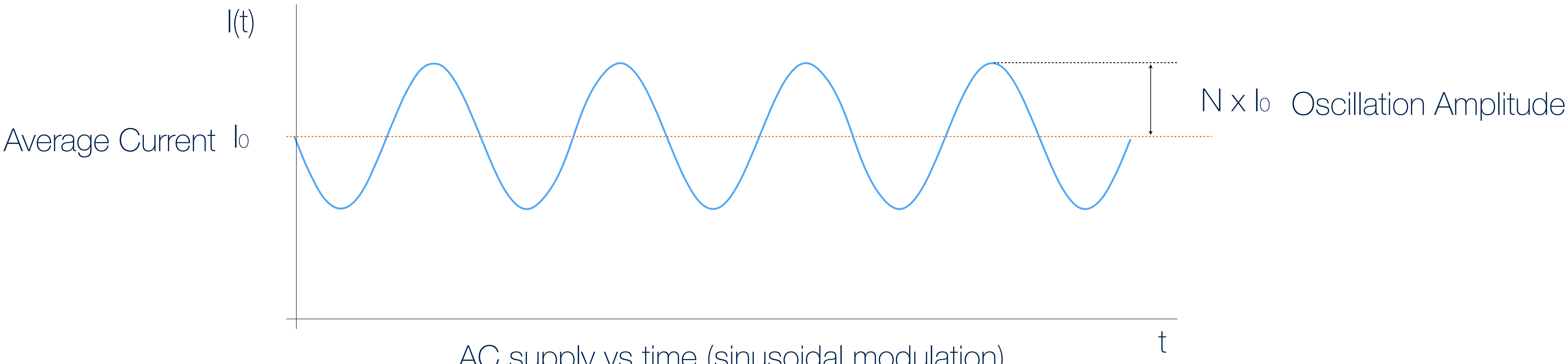
AC supply vs time (PWM)

$$Q = \frac{\tau}{T}$$



Single-stage TEC dT_{max} reduction at PWM

TEC Power Supply - Sinusoidal Modulation

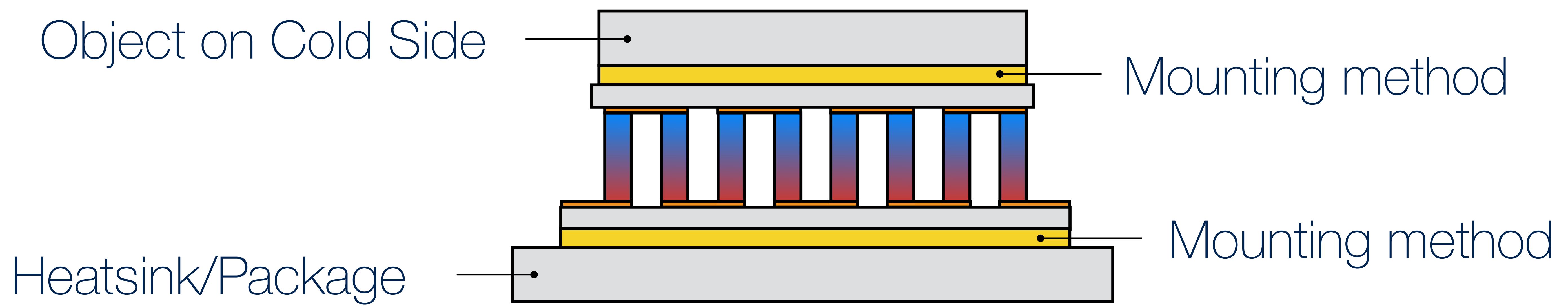


AC supply vs time (sinusoidal modulation)

$$\frac{dT_{max}(DC)}{dT_{max}(AC)} = \frac{1}{1 + \frac{N^2}{2}}$$

TEC is a DC current device. AC current of any nature reduces TE module efficiency. The reduction of dTmax can be estimated by the formula specified.

Mounting Methods related to miniature TE Coolers



Soldering

- Mechanical durability
- Thermal Conductivity
- No outgassing
- Requires technological skills and equipment
- Optimal for vacuum apps

Gluing

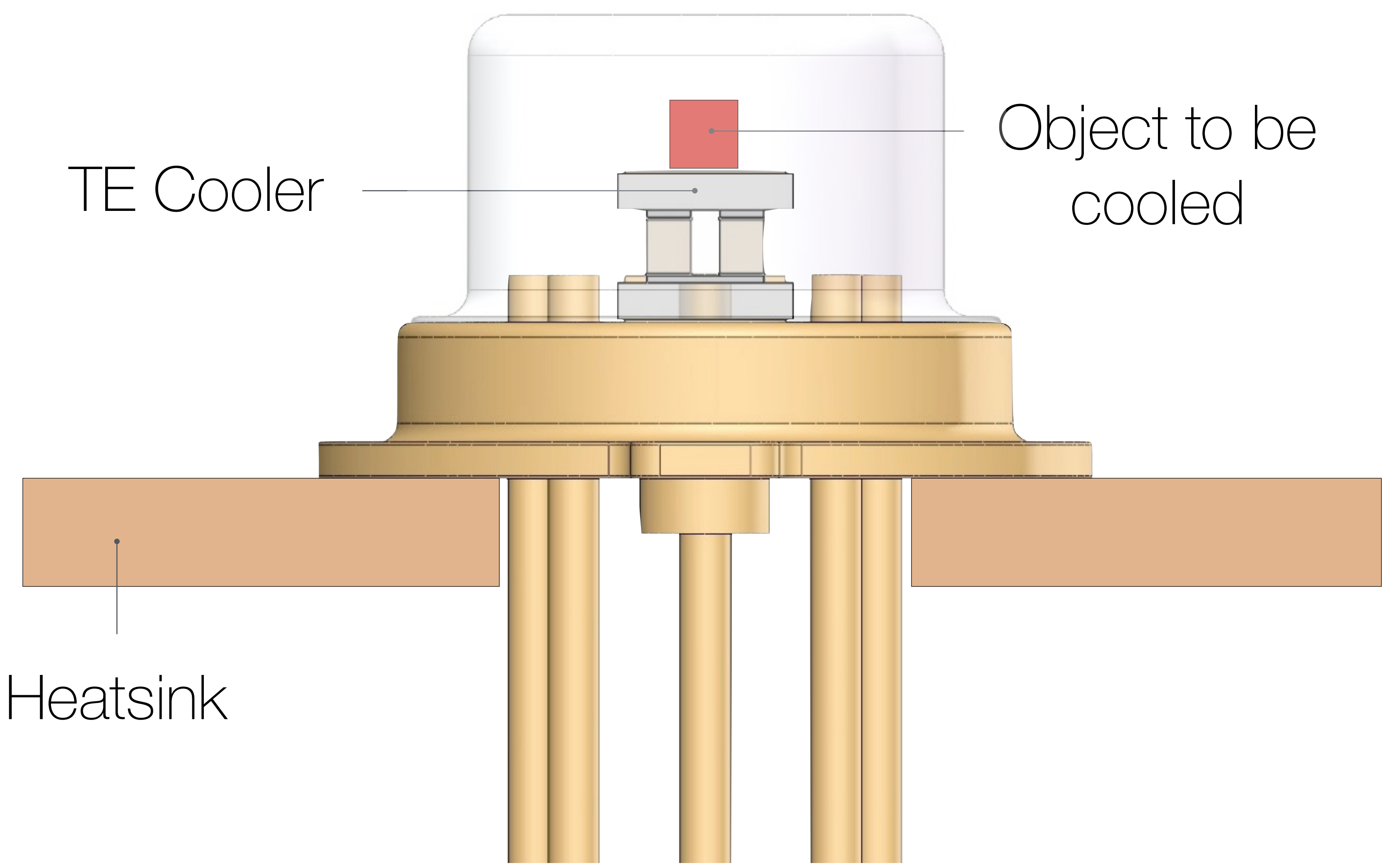
- Easy to implement
- Requires annealing process
- May have thermal conductivity issues
- Requires an appropriate glue for application

Mechanical mounting

- Used usually for large TE Coolers mounting
- Requires thermal grease for best results
- Not suitable for very small TE Coolers

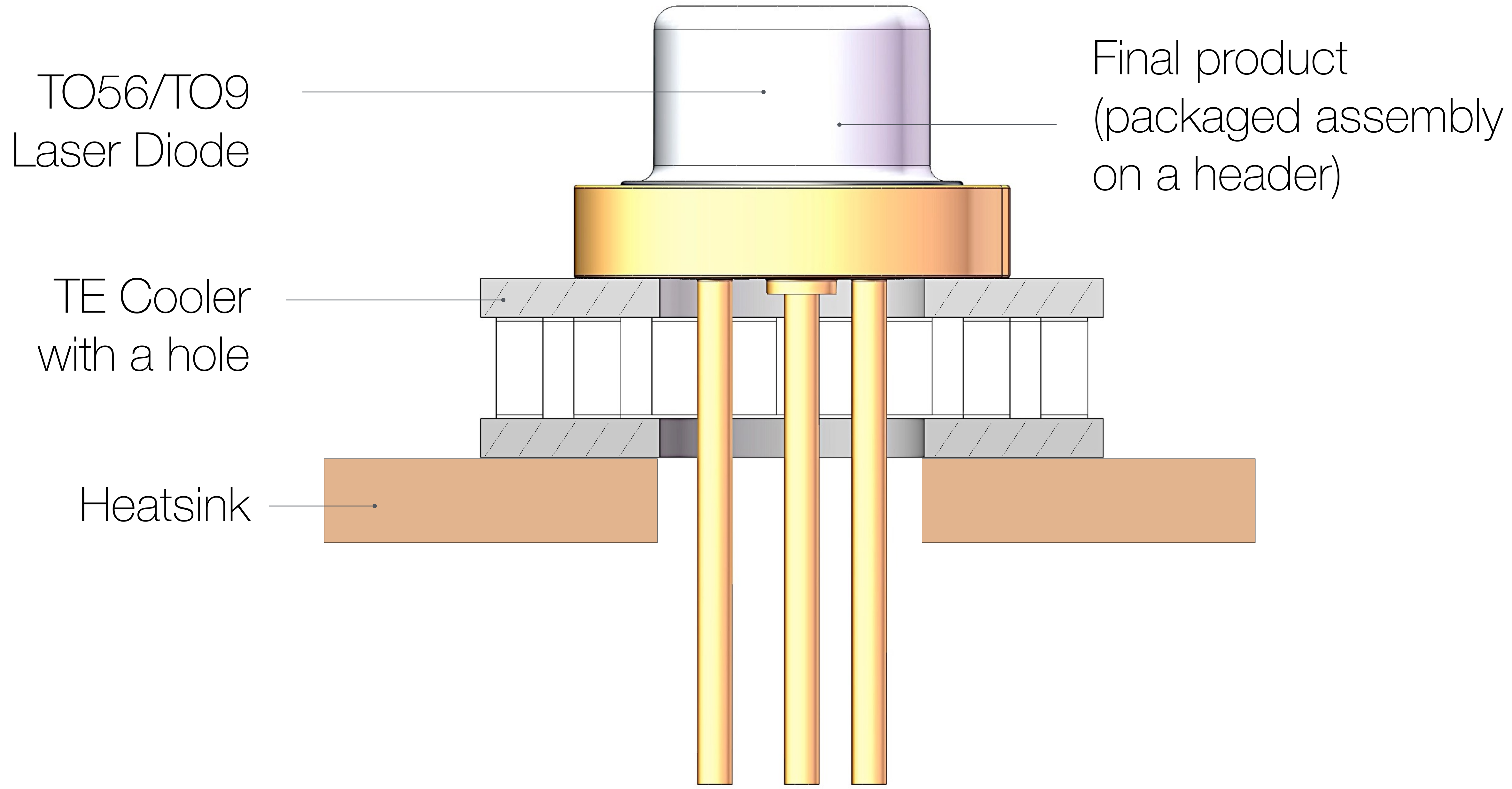
“External” and “Internal" Cooling Methods with TECs

“Internal” Cooling



TEC directly controls the temperature of the object to be cooled

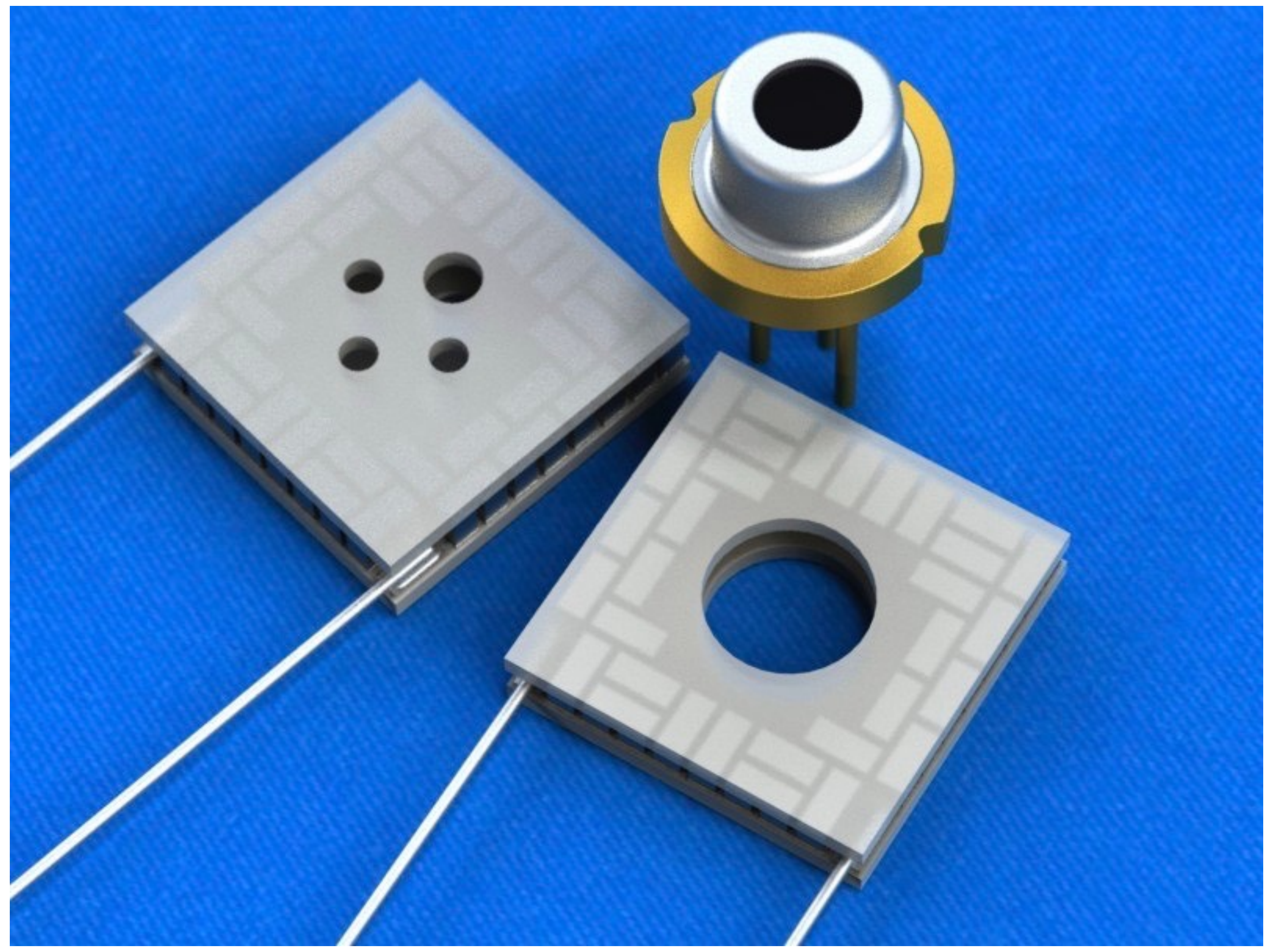
“External” Cooling



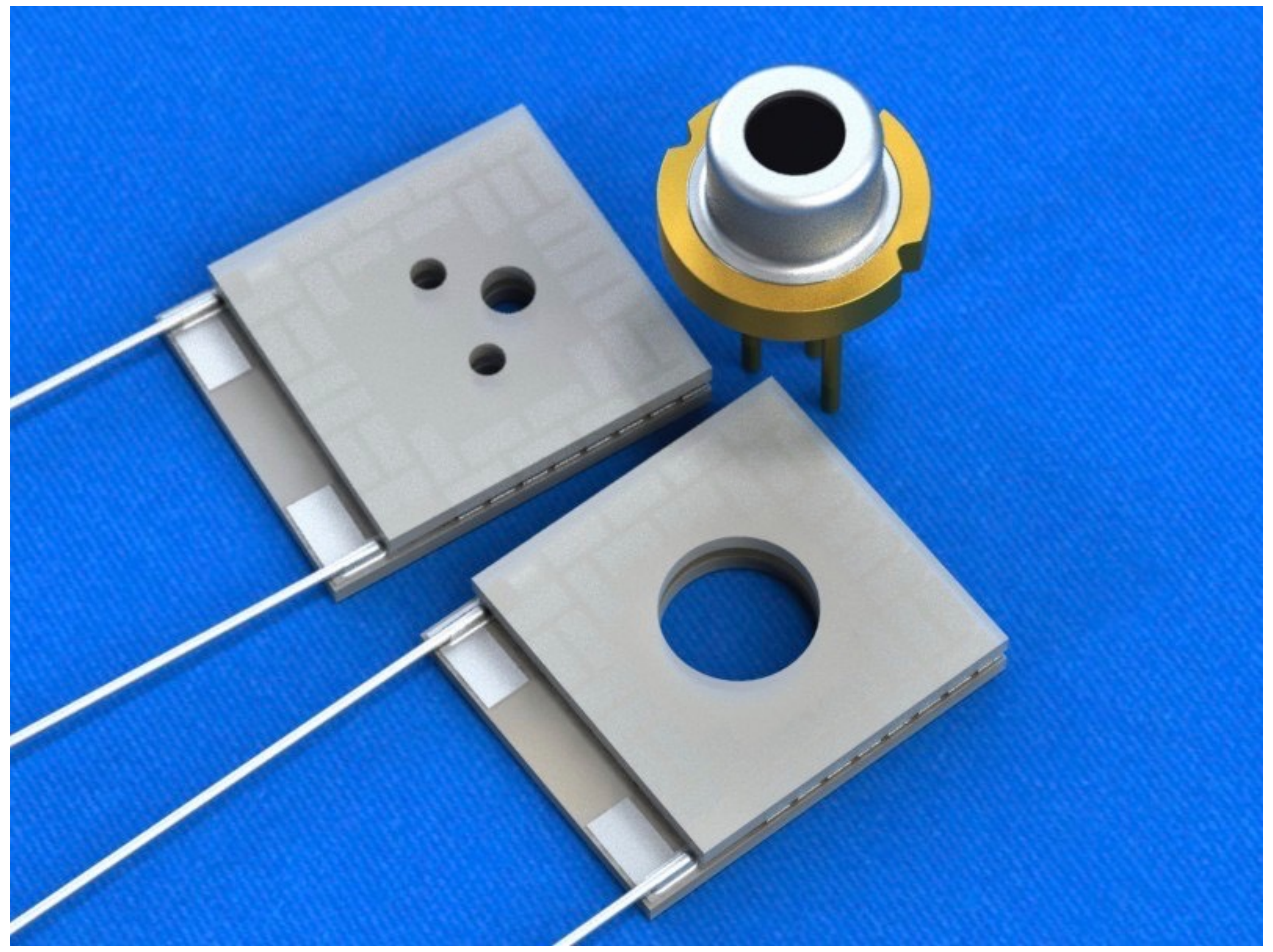
TEC controls the temperature of an assembly with the object to be cooled

“External” cooling method can be applied, if there is no space (or possibility) to integrate TEC in assembly

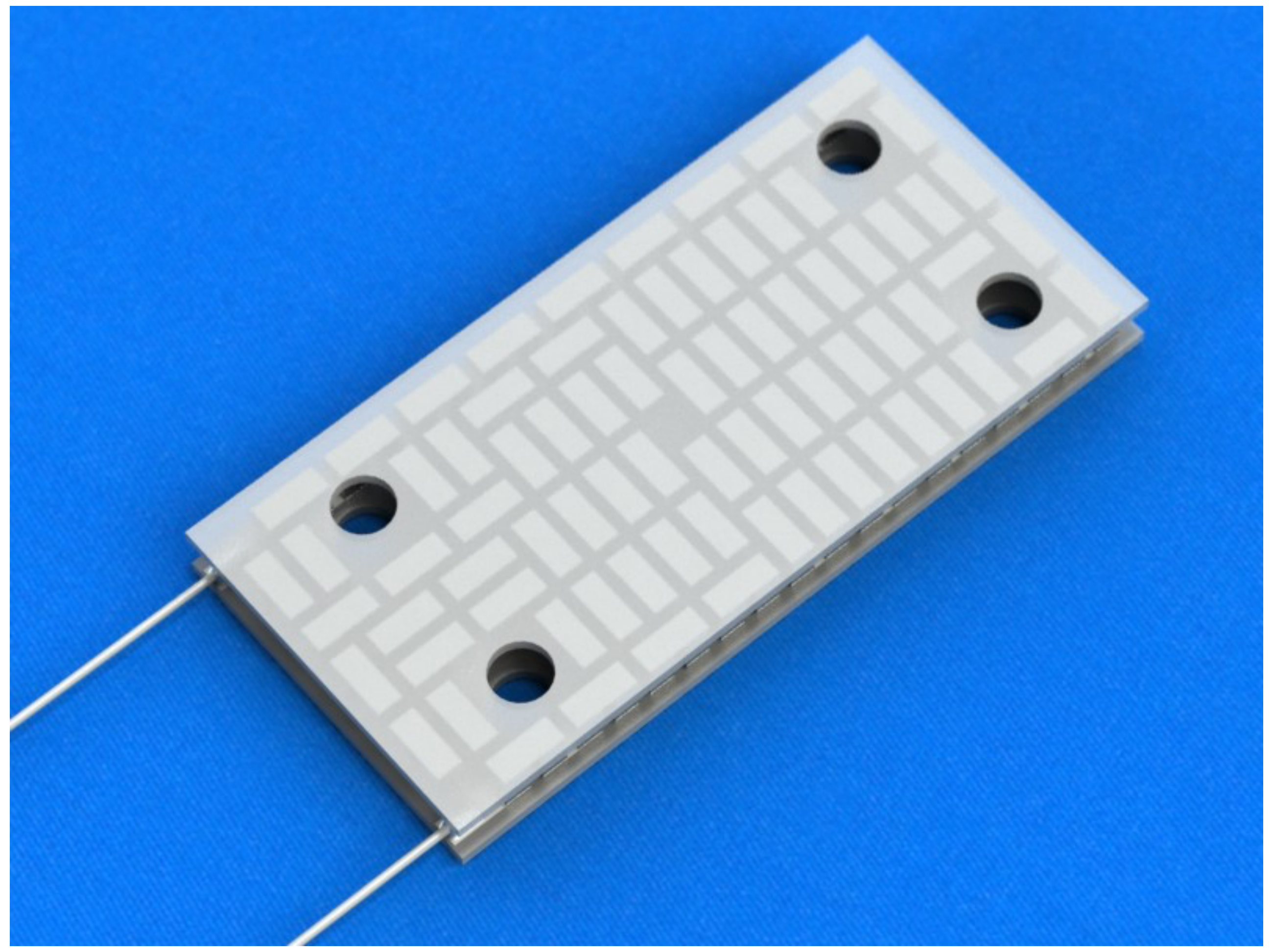
Thermoelectric Coolers with Holes for “External” Cooling



Single- and Multi-Hole layouts for standard TO-56 and TO-9 LD types



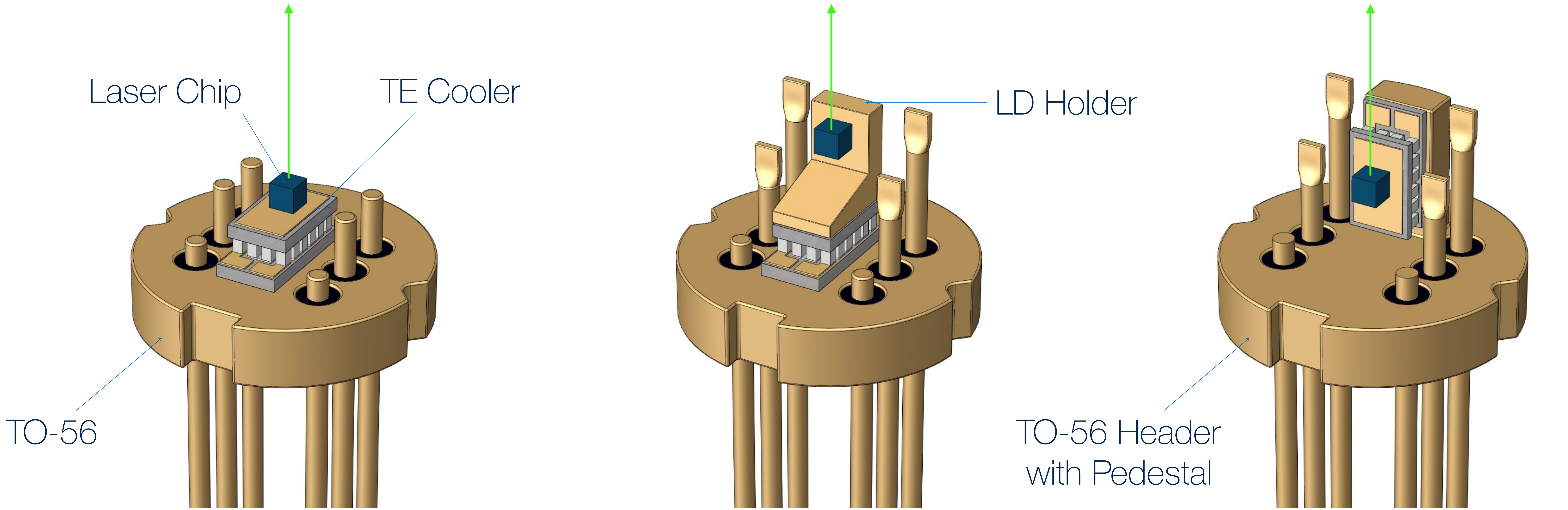
Low-height, High-Power TE Cooling solutions



Development of customized TEC types

TEC Microsystems provides a wide range of TE Coolers with holes for external cooling.

Miniature TEC Integrating on TO-56 and similar Headers



“Horizontal TEC integration” for top-emitting LD

“Horizontal TEC integration” with holder on cold side for edge-emitting LD

“Vertical TEC integration” on Header optimized for edge-emitting LD

5mm

TEC Microsystems provides ultra-small TECs and value-added services for integration in cooled LD TO-can applications

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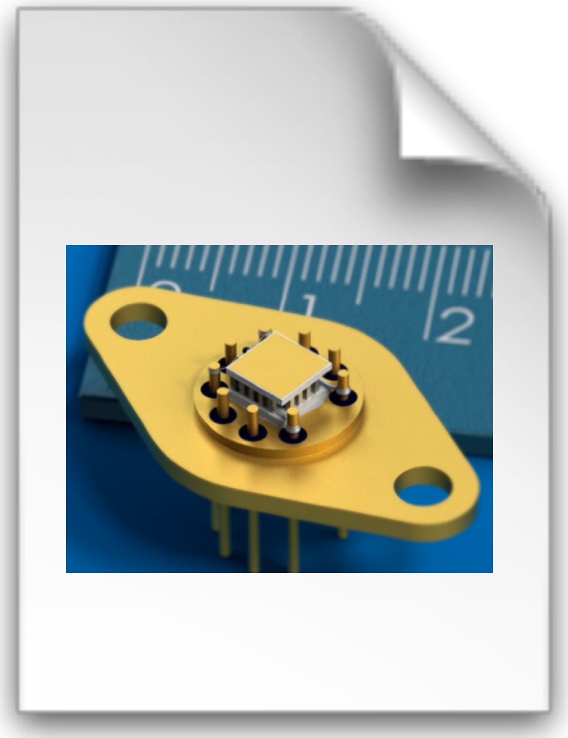

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