WiPTherm

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2.4 M€

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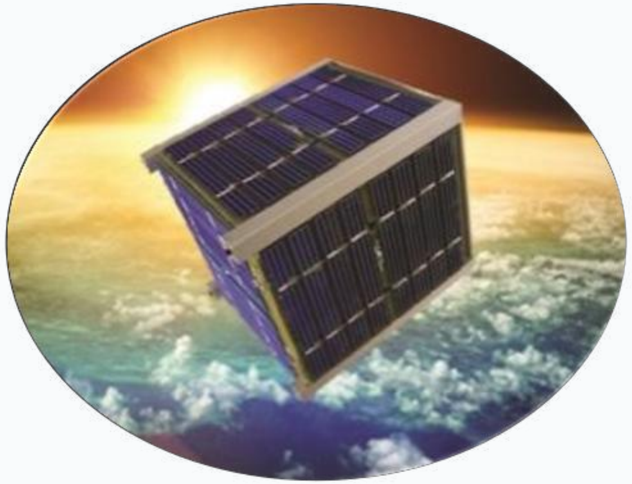
$6.35 billion by 2021, with a CAGR growth of 37.91% in the 2017-2021 period



Energy Power and Storage (EPS) subsystem which has a weight limit of 1 kg per unit-size (1U= 10x10x10 cm)

Energy supplied by Batteries and Photovoltaic

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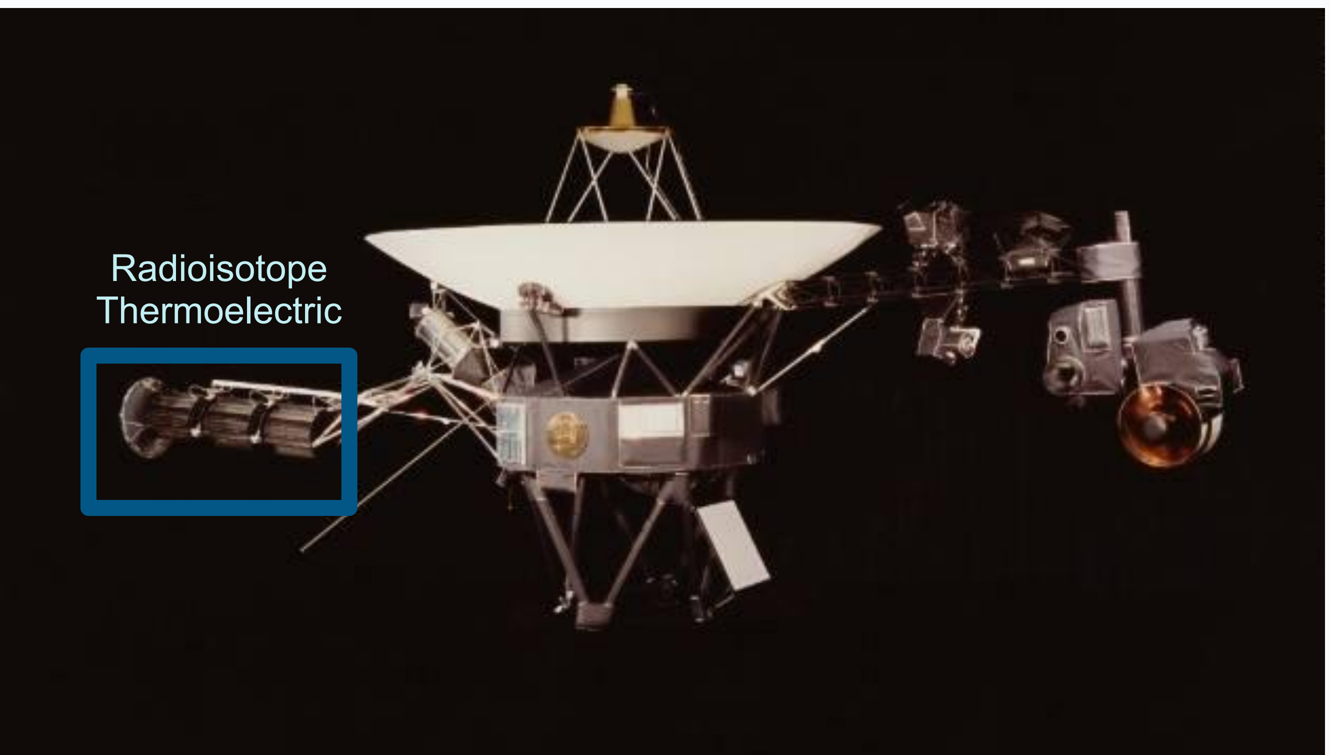
Energy Solutions available on the market:

Photovoltaics (widely used)

Electromagnetic may require
Movement parts

Alternative Energy Solutions for space:



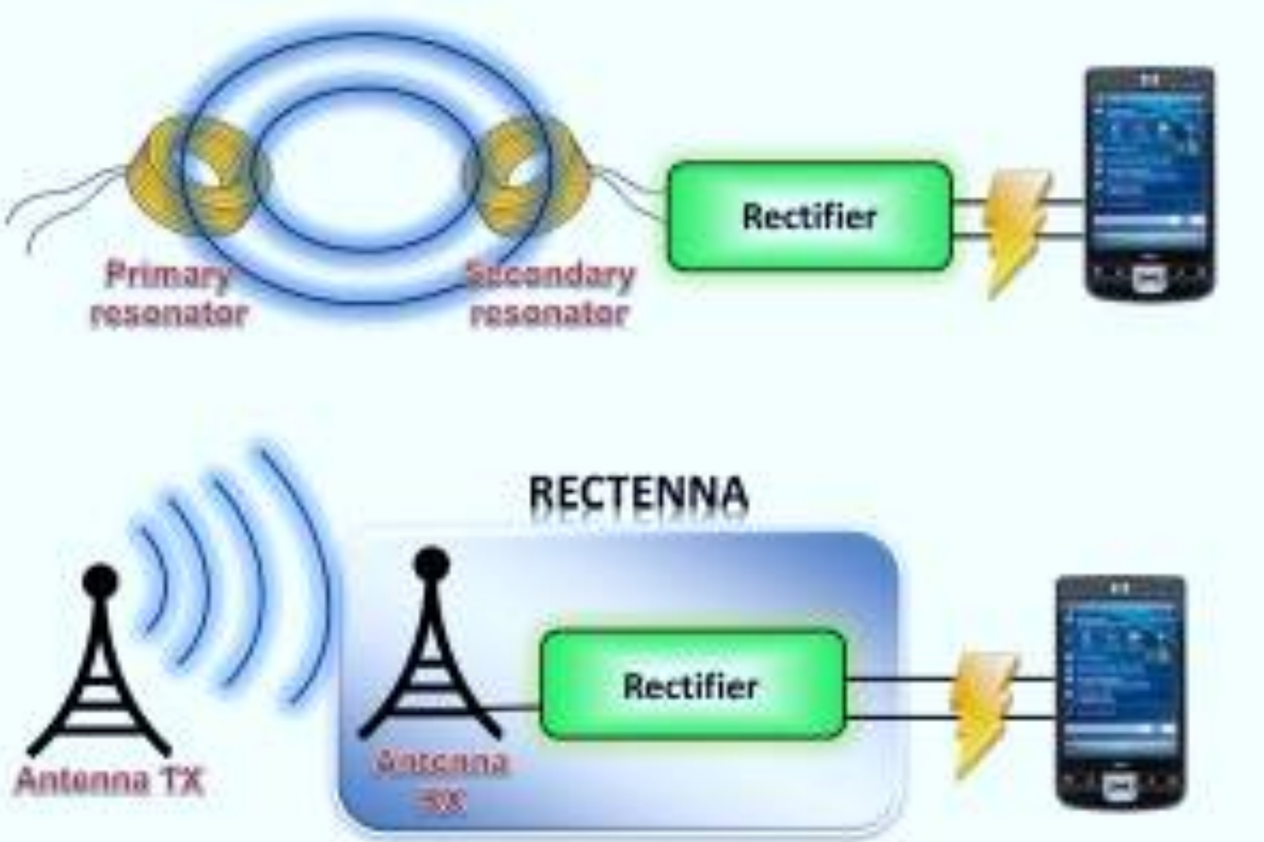
Complex fabrication

Expensive

Nuclear Radiation

Currently solutions may arise on:

Wireless Energy Transfer atually comes from electromagnetic transfer:



Decreases drastically with distance namely for distance higher than the coil size.

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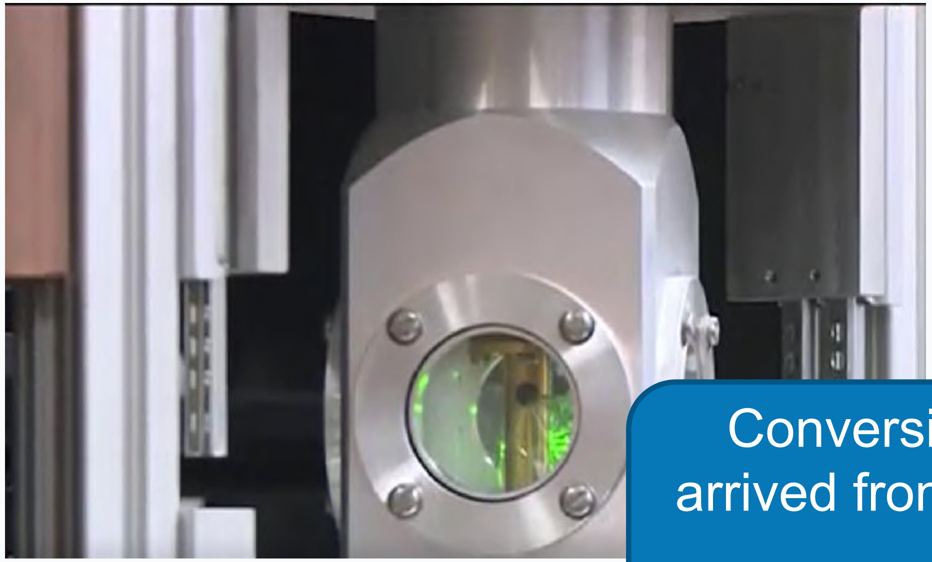
Disruptive solution



Conversion of the energy arrived from laser to electrical energy
(Not Photovoltaic)

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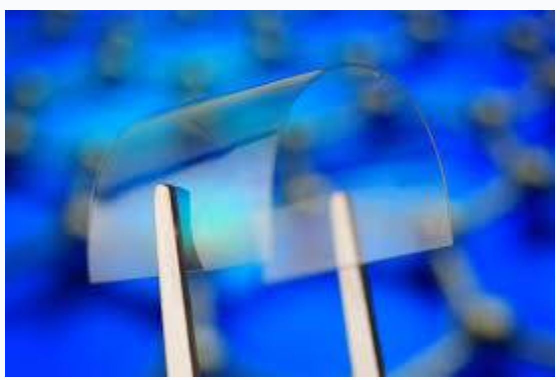
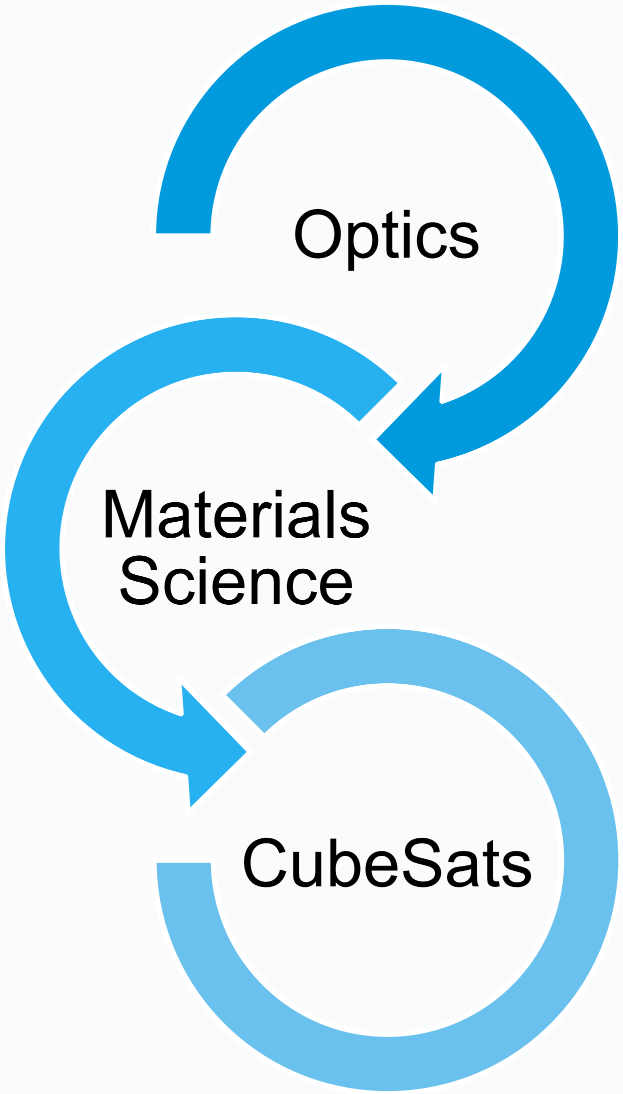
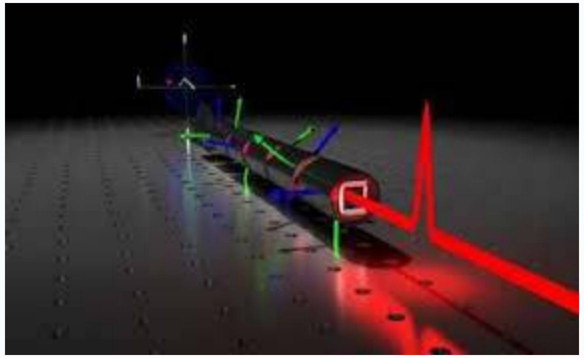
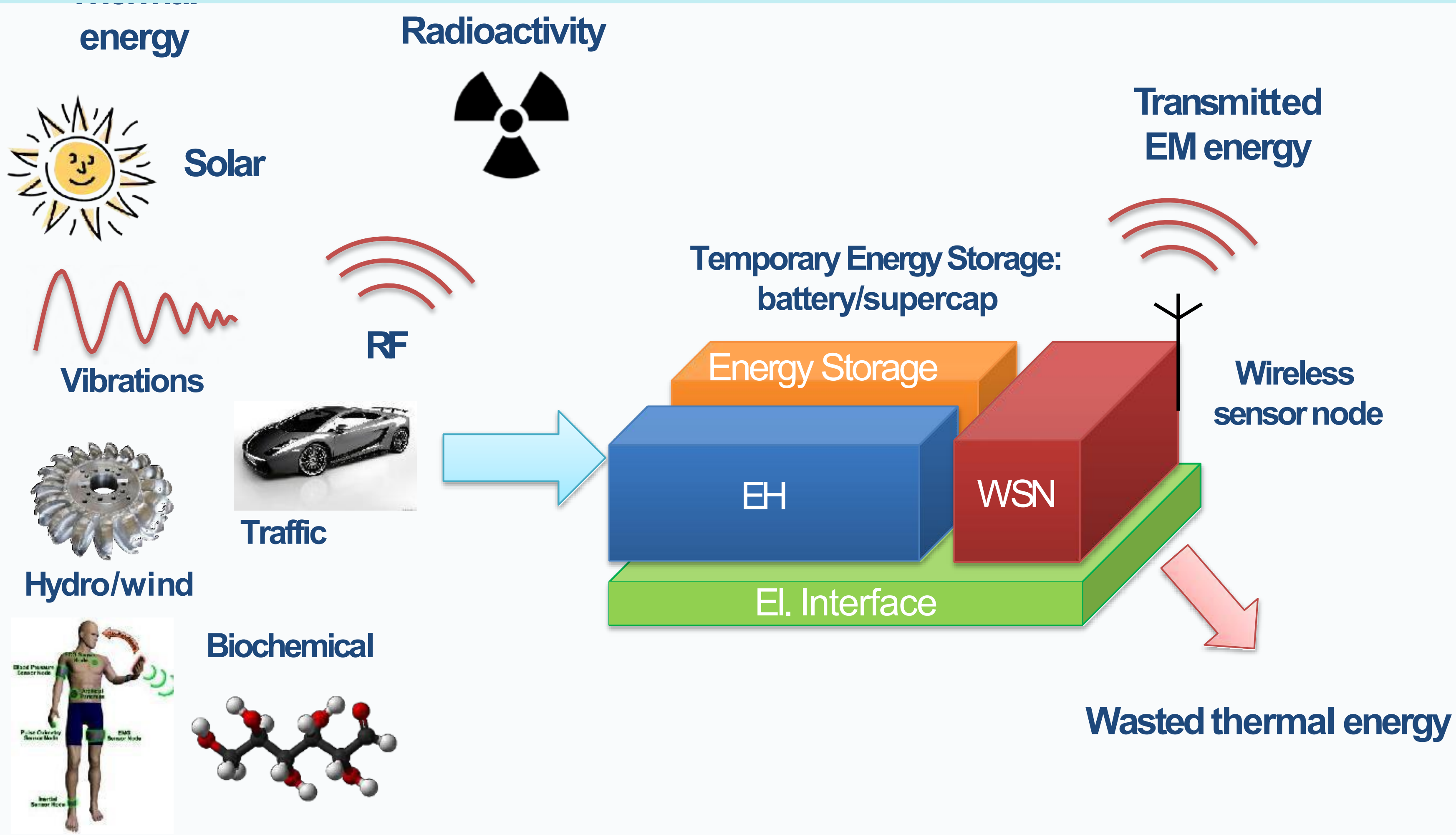
Multidisciplinar Team







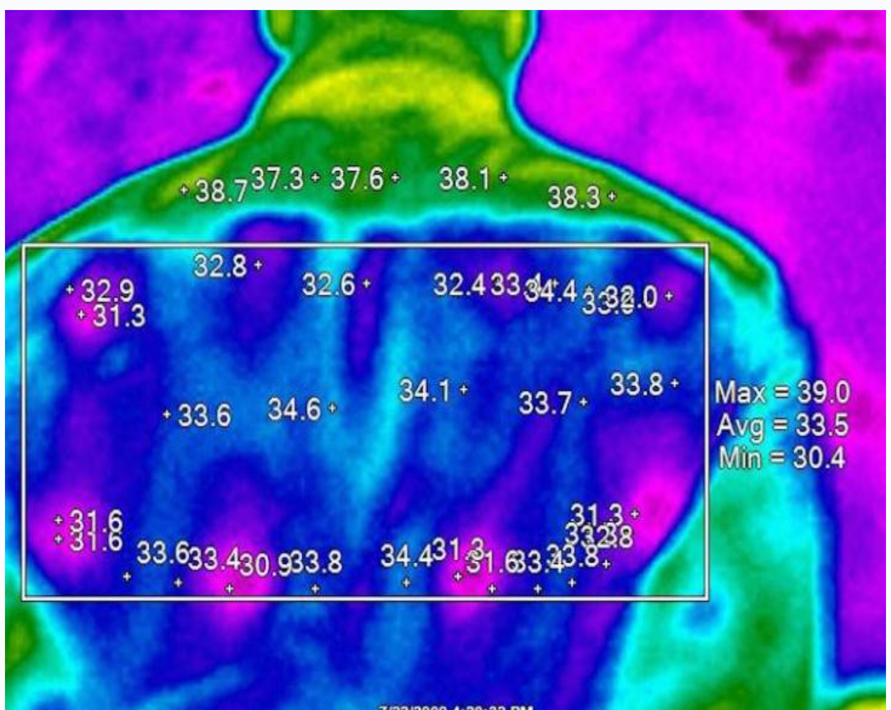
What is an energy harvester ?



What is an energy harvester ?

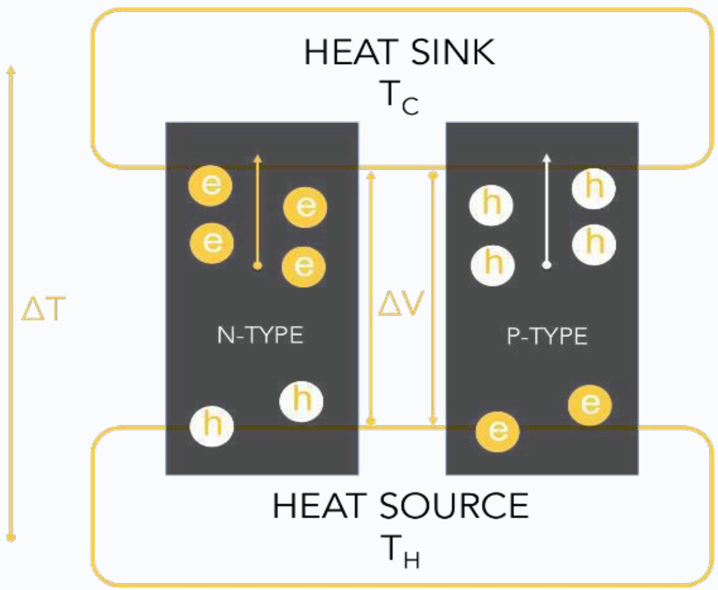
Thermal

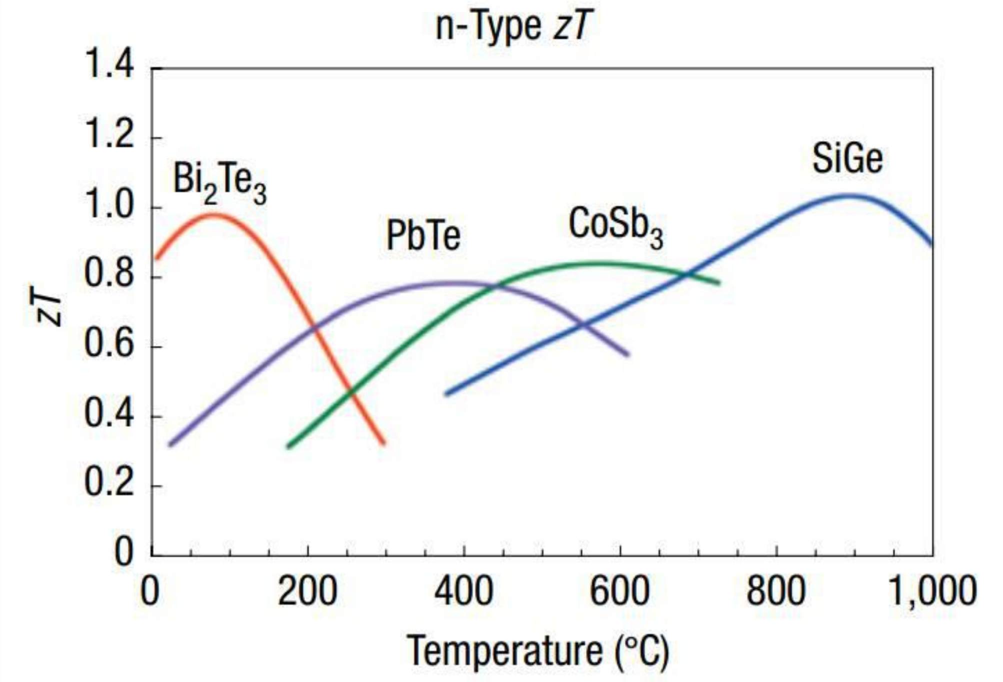
energy



Energy Storage

Seebeck effect





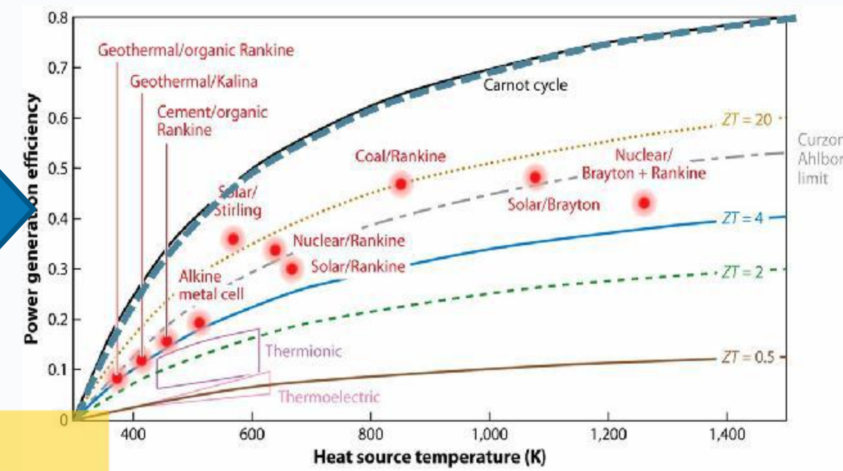
$$S = -\lim_{\Delta t \to 0} \frac{\Delta V}{\Delta T}$$

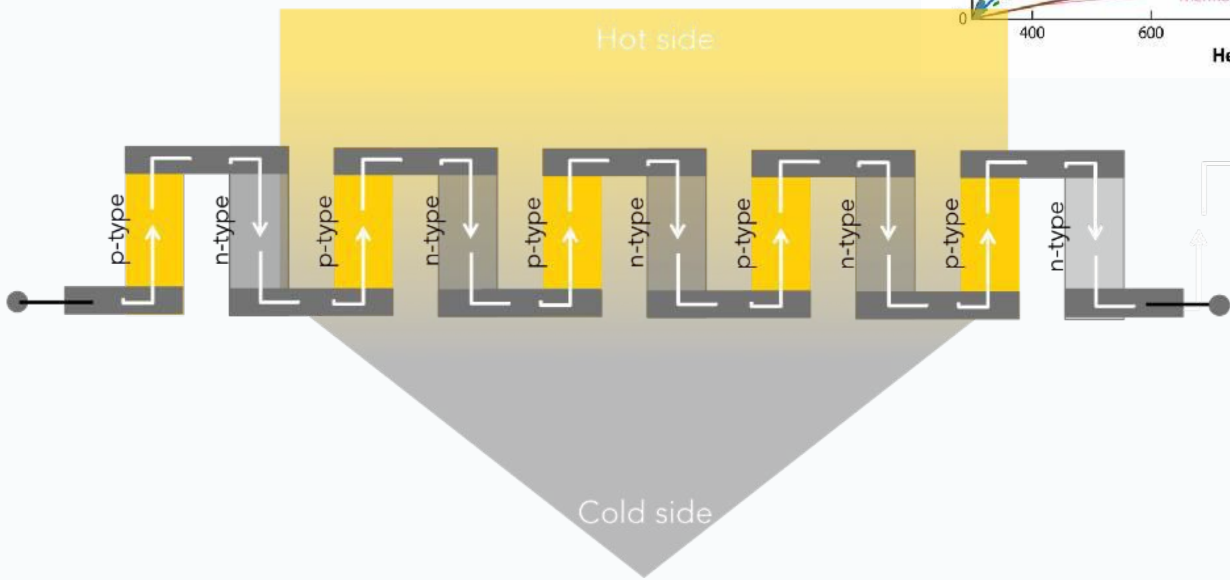
$$ZT = \frac{S^2 \sigma}{k} \mathrm{T}$$

Thermoelectric Devices

$$\eta = \frac{\Delta T}{T_h} \cdot \frac{\sqrt{1+ZT}-1}{\sqrt{1+ZT}+\frac{T_c}{T_h}}$$

Efficiency





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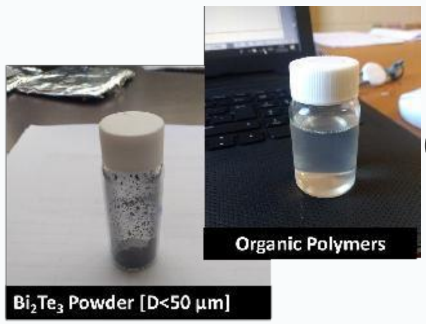
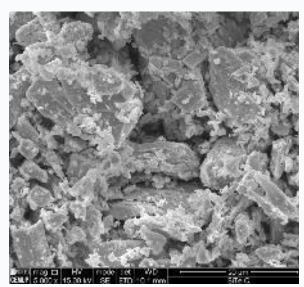
Universidade do Porto

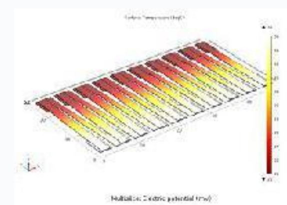


Materials Production

Material Characterization



Design Development



Prototype Fabrication

Prototype Evaluation

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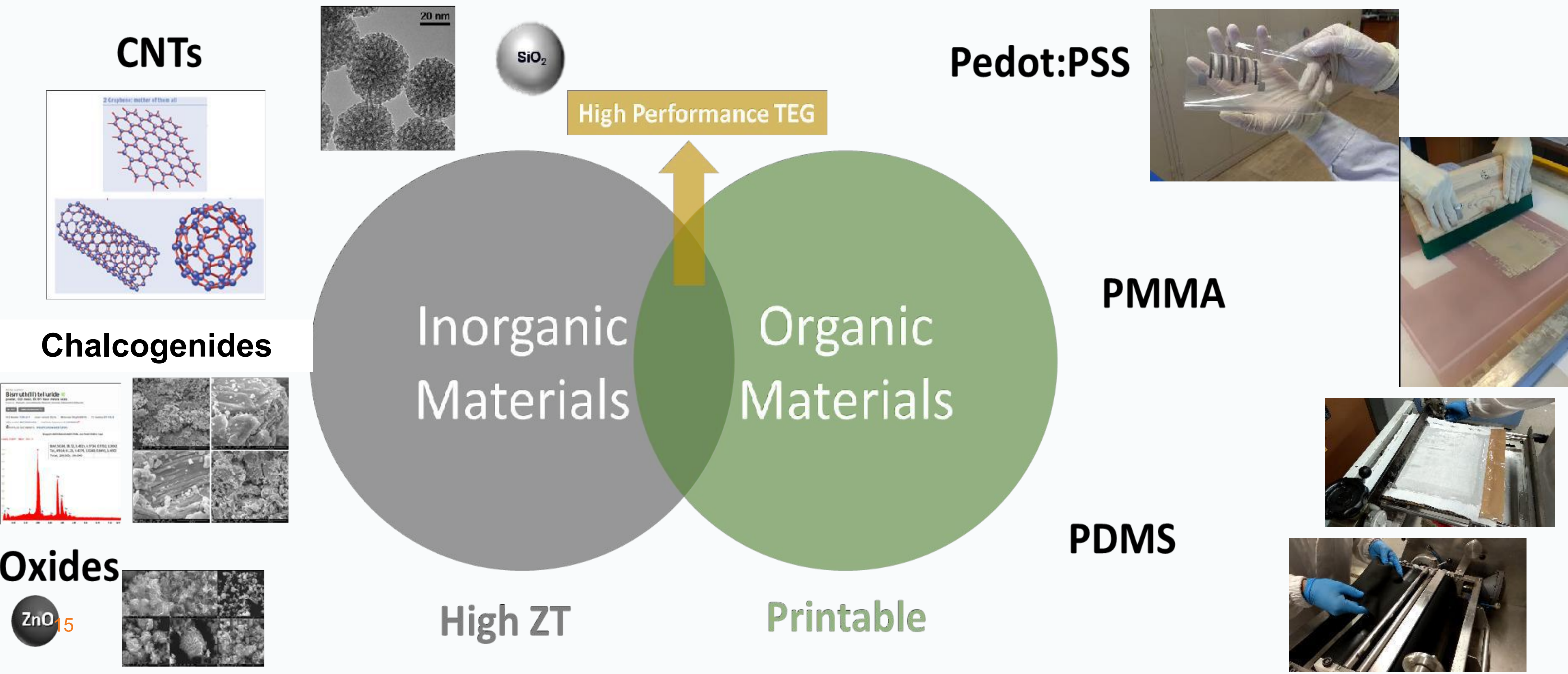

WHICH KIND OF LASER TO ADDRESS WIPTHERM PROBLEMATIC ?

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	Solid-state (bulk crystal) laser	Fiber laser
Thermal dissipation	Good thermal conductivity but poor thermal dissipation due to very low ratio between surface in contact with air and active material volume	Thermal conductivity not so well but excellent thermal dissipation thanks to high ratio between surface in contact with air and active material volume
Laser gain	Low (< 5dB), low tolerance to intracavity losses	High (up to 40 dB), high tolerance to intracavity losses
Spectroscopy	Narrow absorption and emission cross-sections of rare-earth ions in crystal hosts	Large absorption and emission cross-sections of rare-earth ions in silica host : ability of tuning the signal emission wavelength
Beam spatial quality	Easily deteriorated by thermal load or misalignment	Excellent due to guiding mechanisms in the fiber core
Integration	Free-space alignment, more sensitive to environemental perturbations, less compact	Excellent with the possibility of an all-fibered architecture : simple and compact, easily integrated
Pulsed performance	High damage threshold	Detrimental non-linear effects when scaling peak power and low damage threshold in regard of pulse energy: specific fiber designs needed to overcome these issues
CW performance	Power scaling limited by thermal load	Extreme average power scaling thanks to high thermal dissipation (multi-kW class laser sources)

Fiber laser sources are the best candidate for the aimed application

Which fiber designs ?

2 solutions proposed

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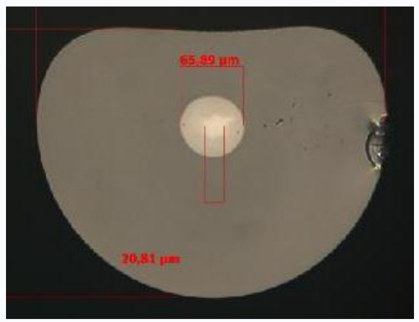


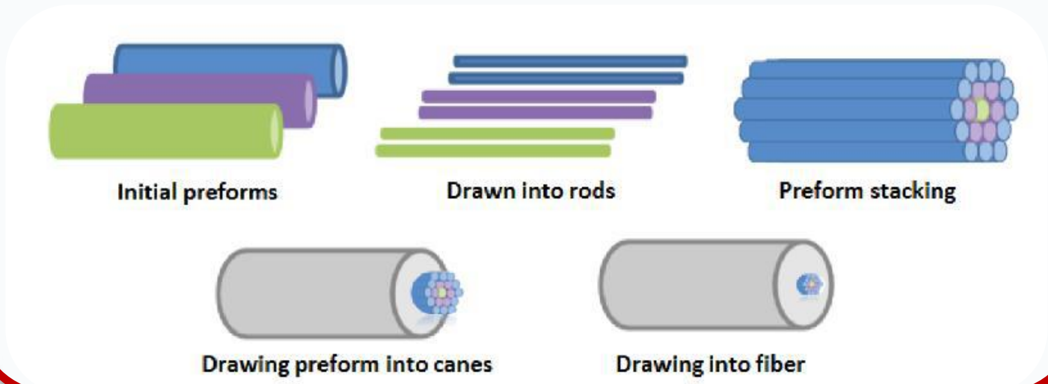
- Index-guiding optical fiber
- Triple-cladding fiber design for ensuring a good spatial beam quality
- Various pump cladding shapes for enhancing the pump absorption
- 20 µm < D_{core} < 60 µm at λ = 1500 nm
- Optimum choice for high average power operation

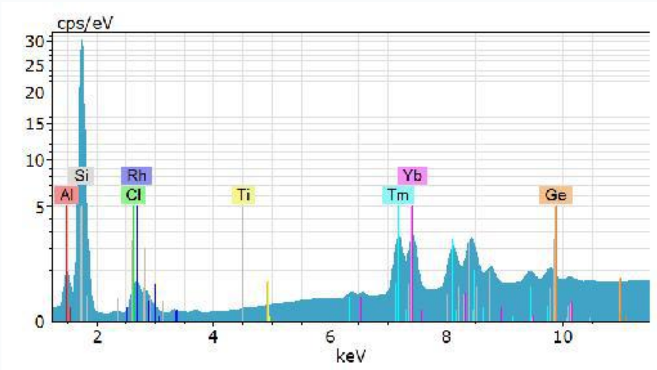
- More complex microstructured fiber design
- Guidance mechanism based on a modal sieve concept with an aperiodic cladding pattern
- 50 µm < D_{core} < 120 µm at λ=1500 nm
- Optimum choice for high peak power/energy operation

→ In both cases the fiber core is doped with rare-earth ions chosen to maximize atmospherical transmission:

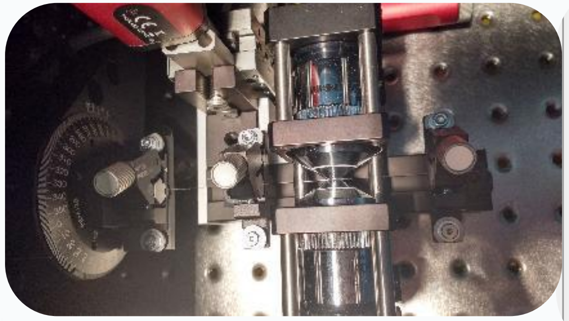
Thulium (emission from 1900 to 2100 nm) or Erbium (emission from 1450 to 1600 nm)

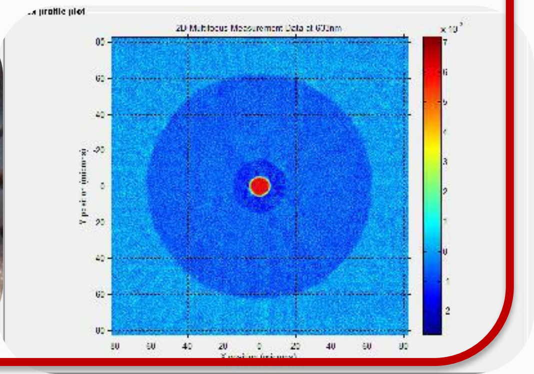
XLIM FACILITIES FOR FIBER MANUFACTURING AND CHARACTERIZATION

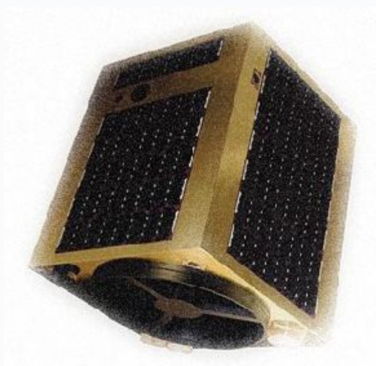




Study of chemical composition and dopant concentration of materials

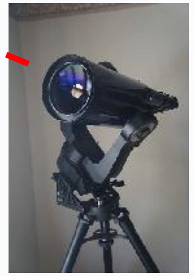


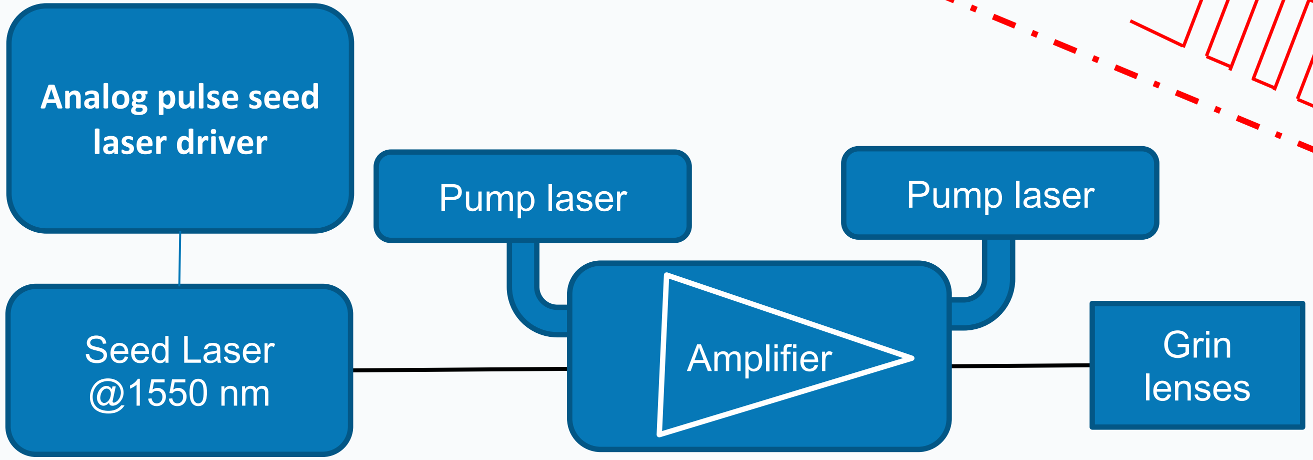




Analog pulse seed laser diode driver

- Pulse width: 5 - 500ns
- Pulse repetition frequency: Single-shot to 500kHz
- Pulse current: 0 - 1.5A
- Bias current: 0 - 100mA
- Separate pulse and CW (bias) drivers
- With integrated TEC controller
- Low power consumption





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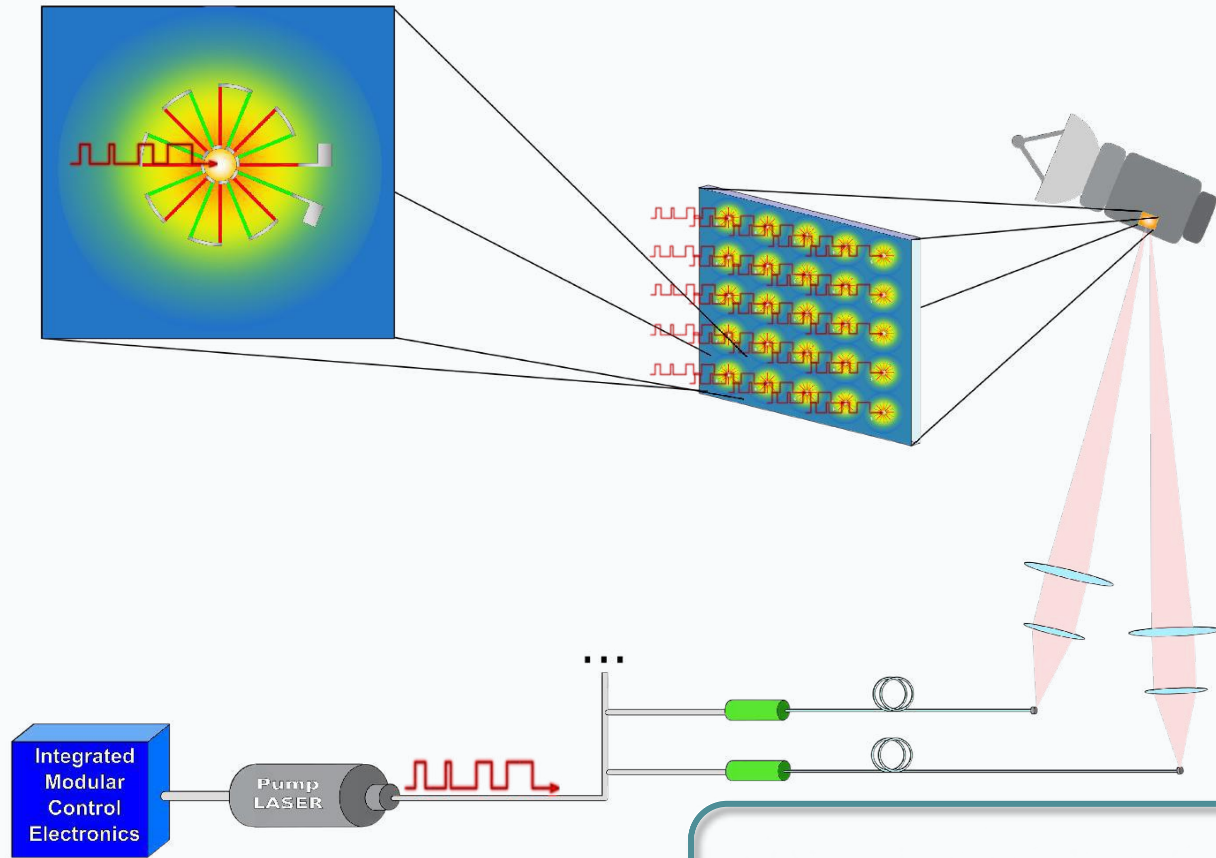
Innovative Wireless Energy

Transfer system

Flexible arrays of photo-thermoelectric plasmonic devices



Clean, safe and long distance energy delivery

Long distance wireless power transmission

Usage of a pulsed laser to maximize the efficiency of power conversion

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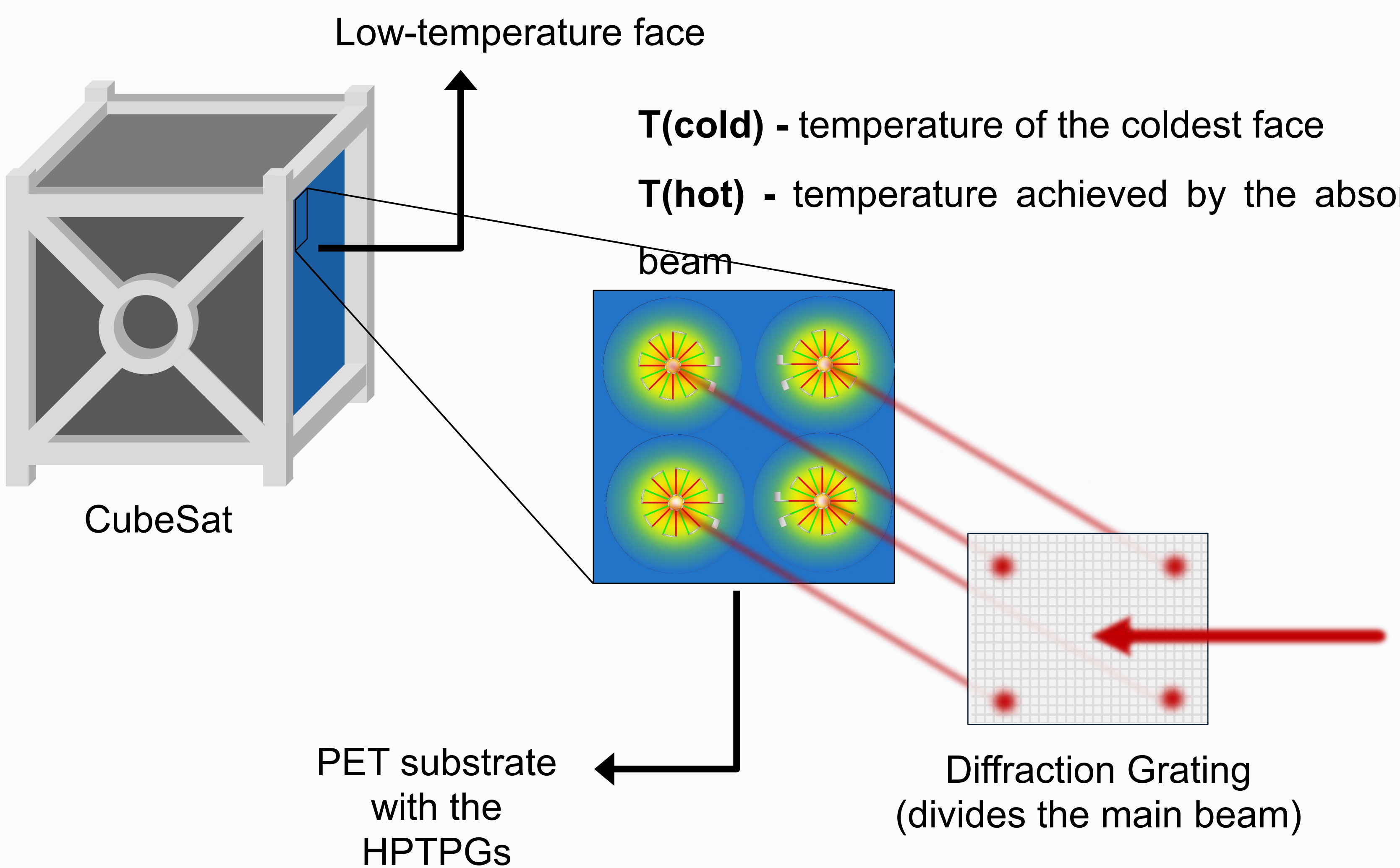
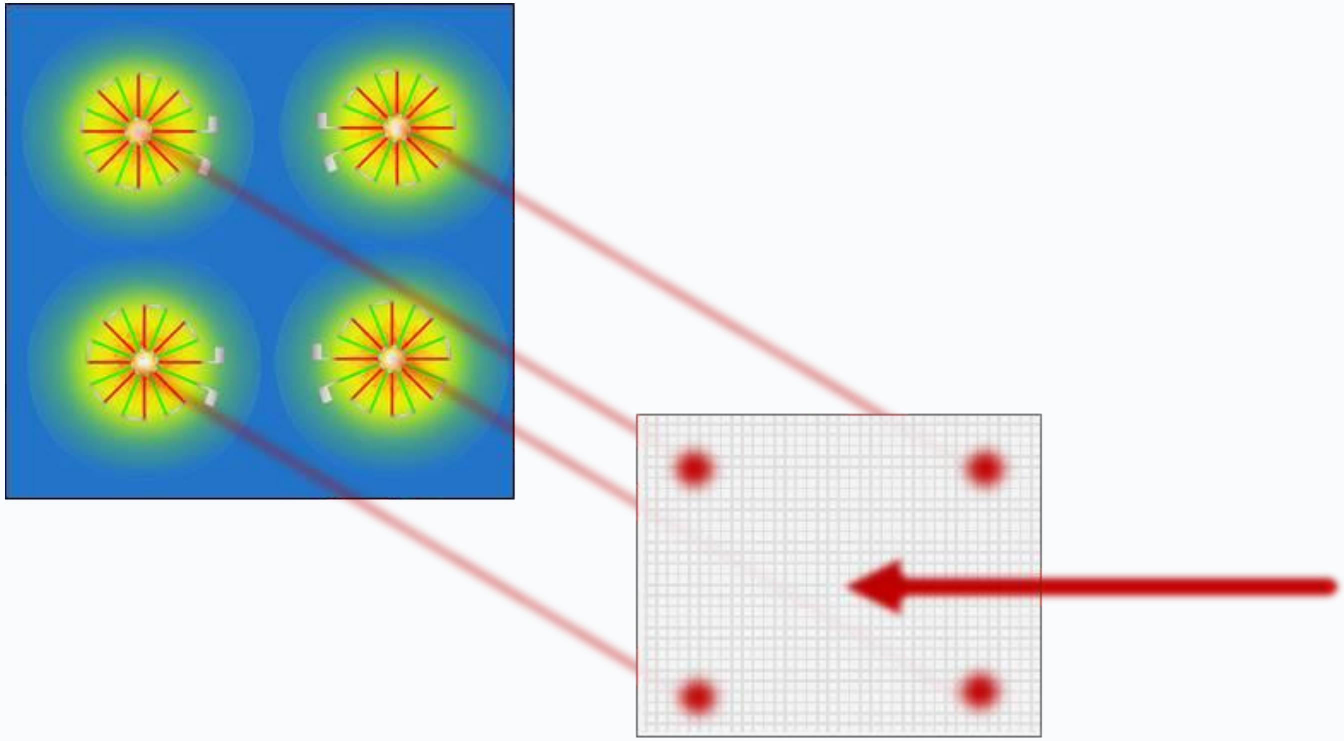
T(cold) - temperature of the coldest face

T(hot) - temperature achieved by the absorber due to incident laser beam



Concept of wireless transfer:



Diffraction Grating
(divides the main beam)

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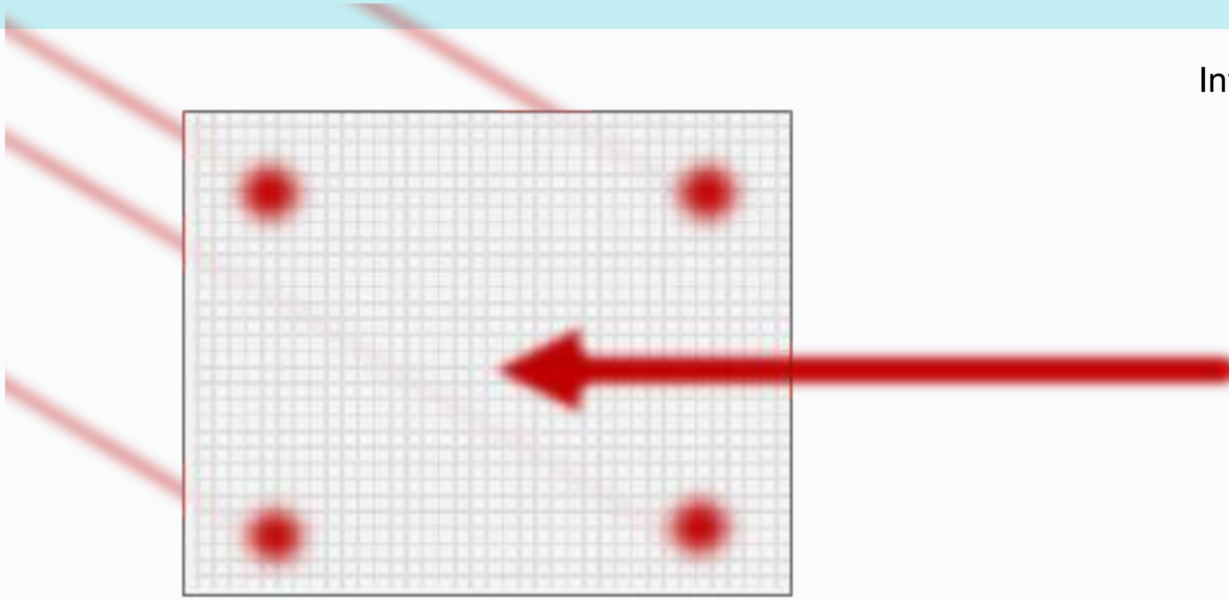
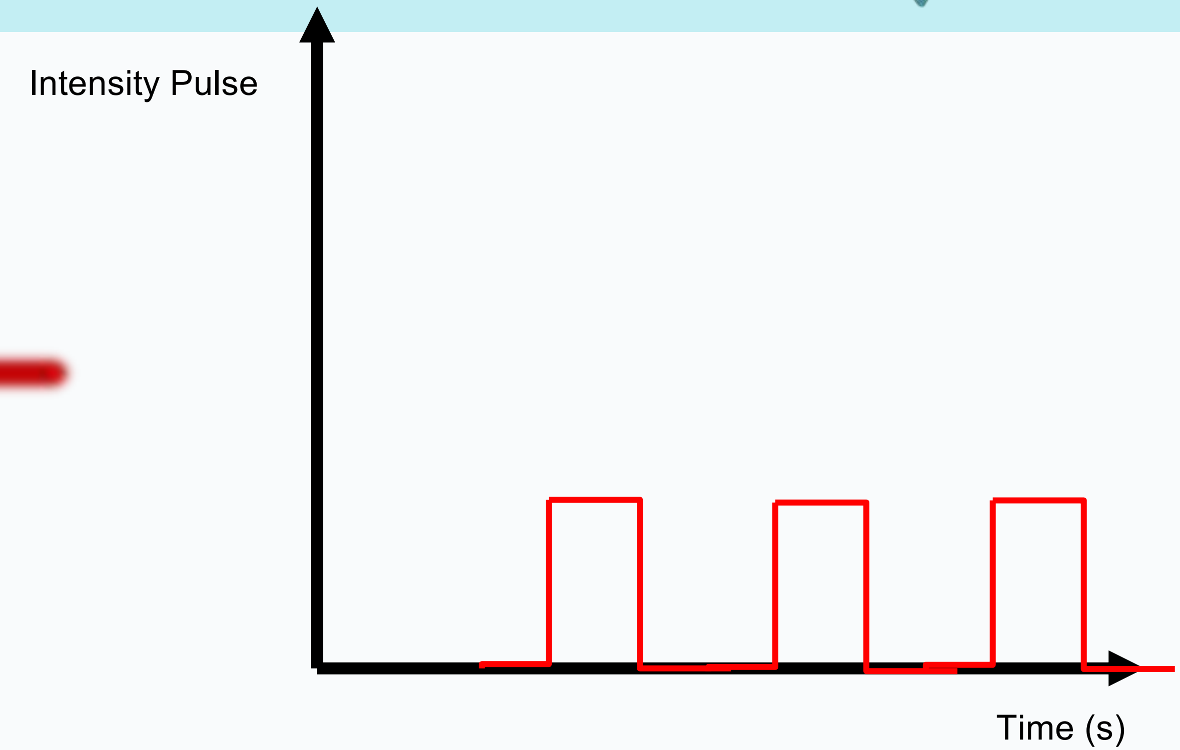
Laser profile:

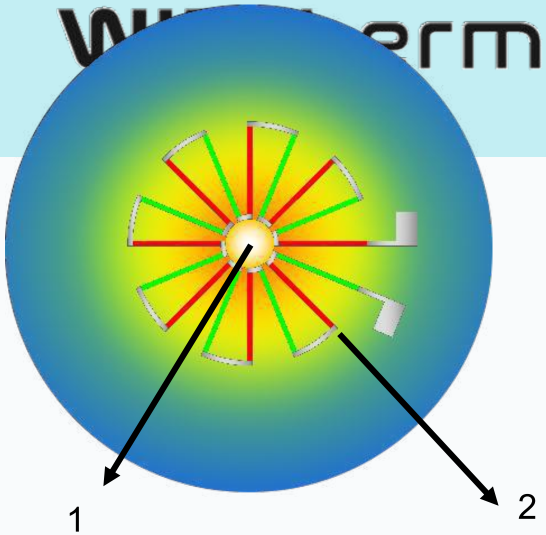


Diffraction Grating
(divides the main beam)



Laser fiber Er or Tu wavelenght: 1550-2000 nm
Power 638 W/m2

This wavelenght have lower atmosfere absorption and in fact Nasa already show wireless communcation using similar wavelenghts.
https://www.kiss.caltech.edu/final_reports/OptComm_final_report.pdf

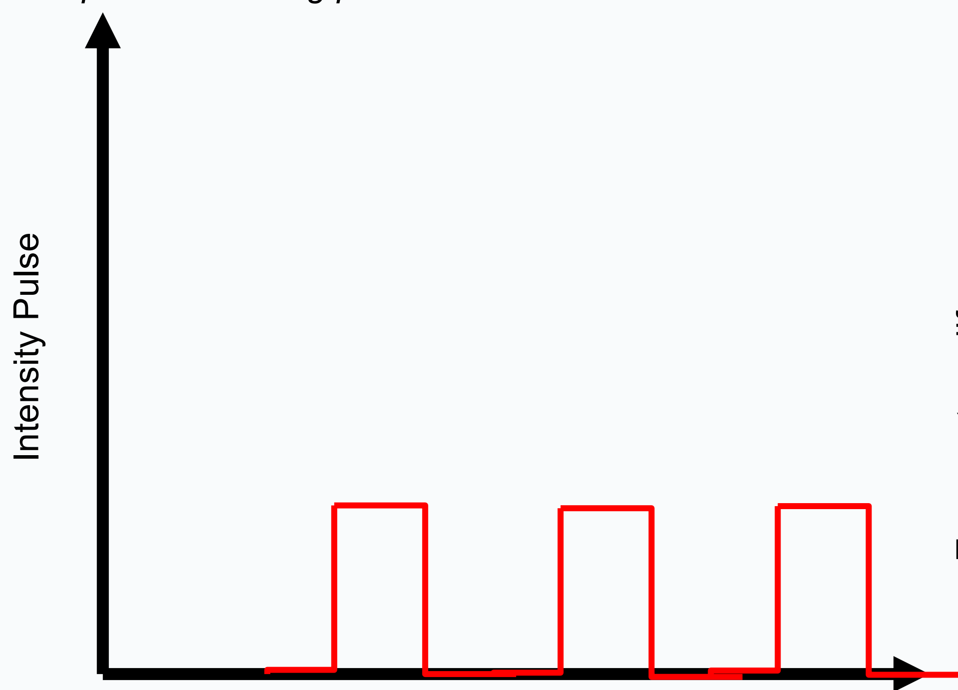


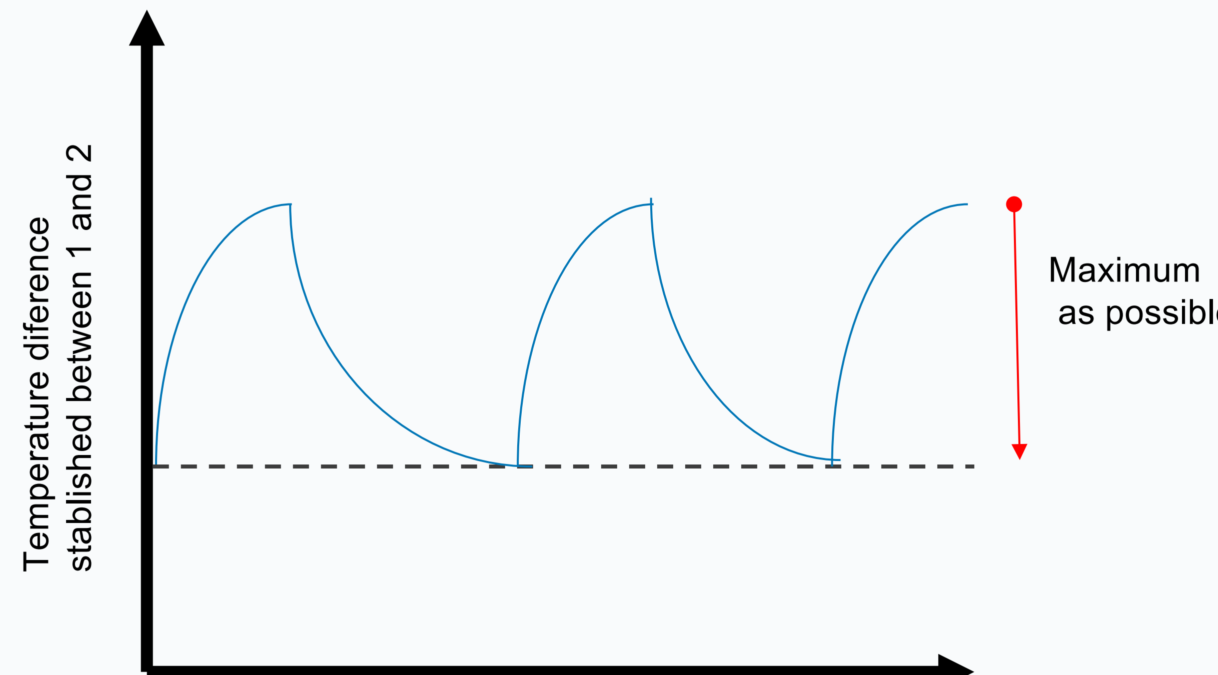
Painel with thermoeletric generators:

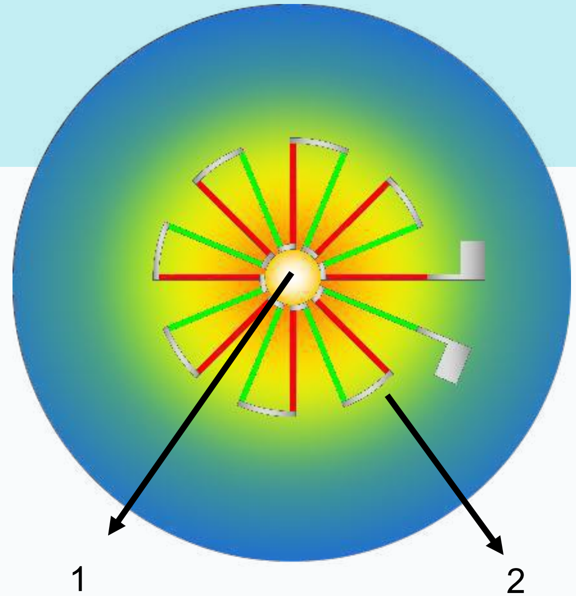
Substrate: Plastic (PET or Kapton), Glass, (Option of printing directly on the cuebsat surface (Al_2O_3)
Materials inks: Bi-Sb-Te, Carbon Nanotubes/graphene, Gold nanoparticles, $Fe_2V_{0.8}W_{0.2}Al$,
Binder polymers: PVA, PTFE, PVDF, PEDOT PSS

Thickness of all system: (500 *μm* at maximum 1 *mm*)
Area Size: (lateral dimensions of the cubesat)
Power expected converter: Between 5-10% of the energy that arrives to the satellite

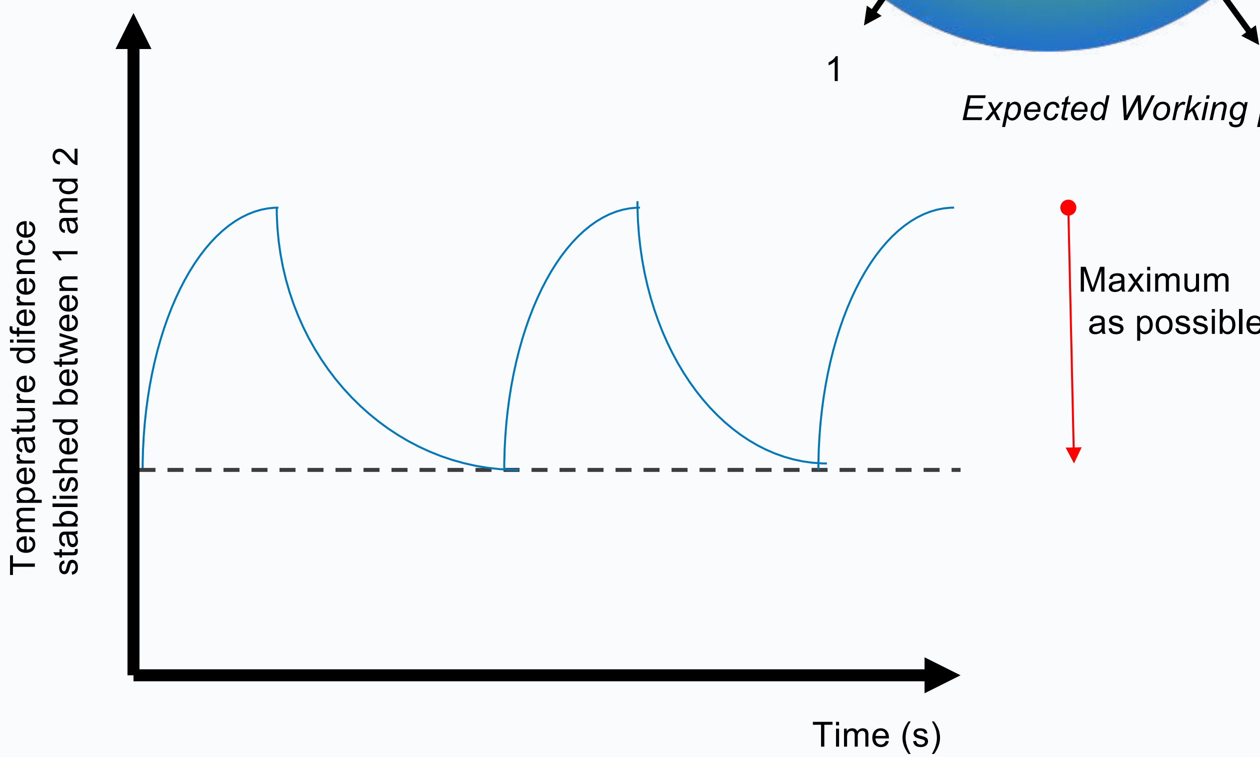
Expected Working perfil:

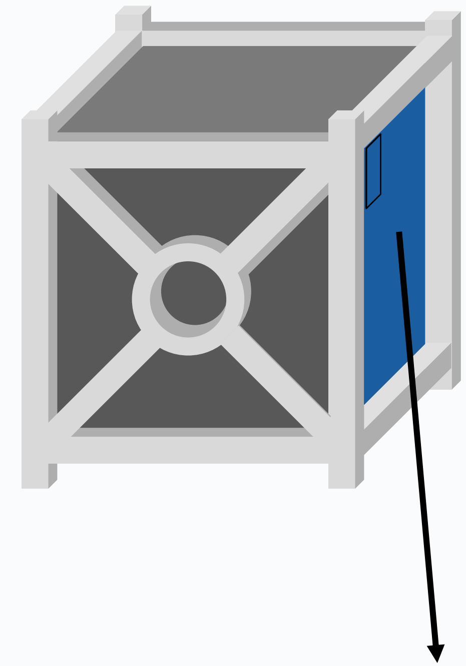






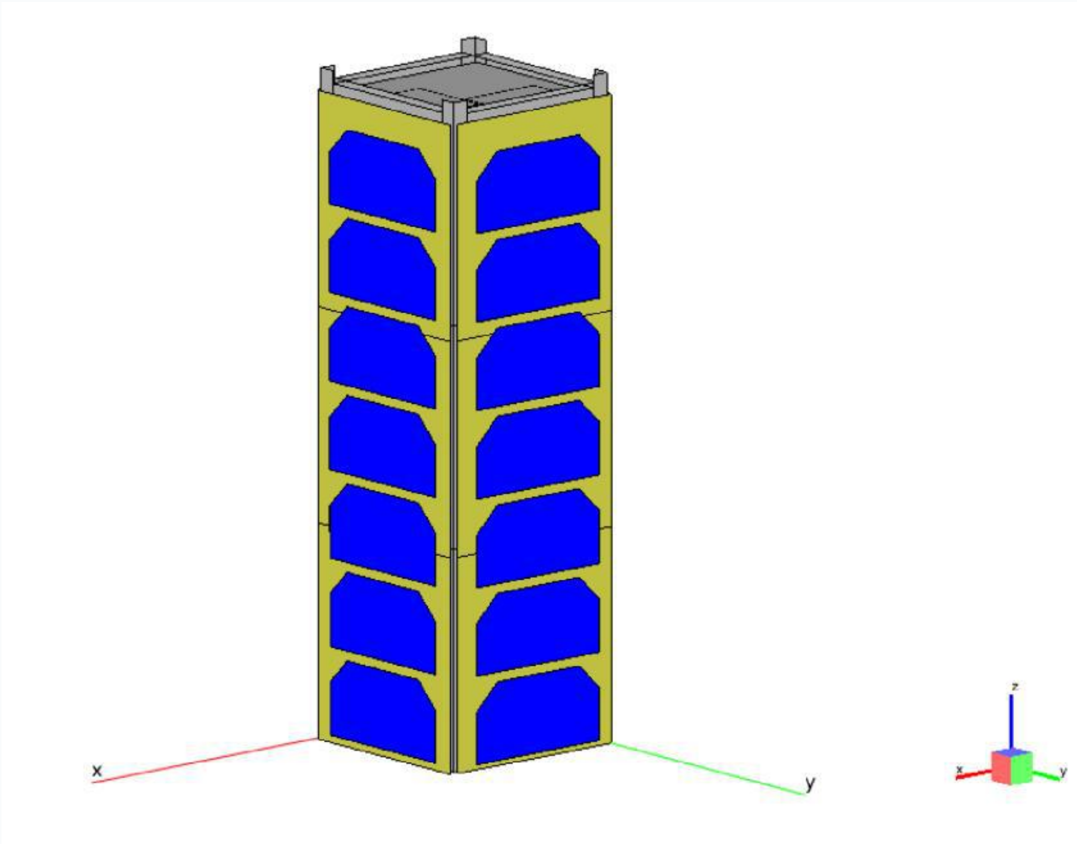
Expected Working profile:

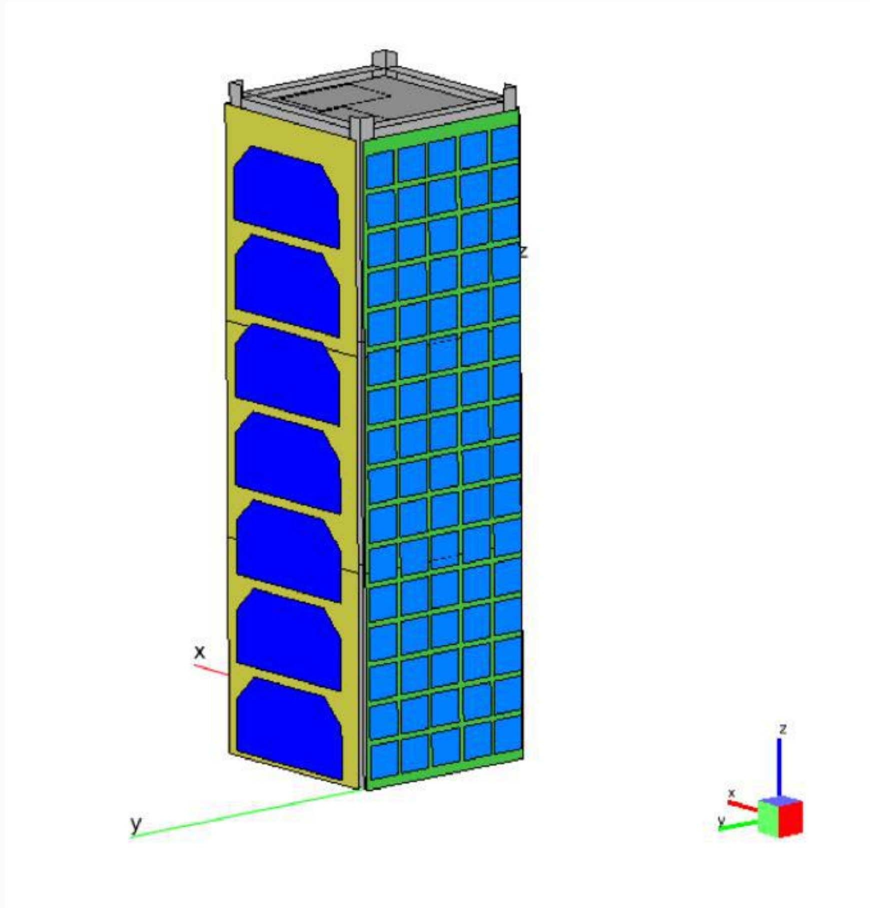




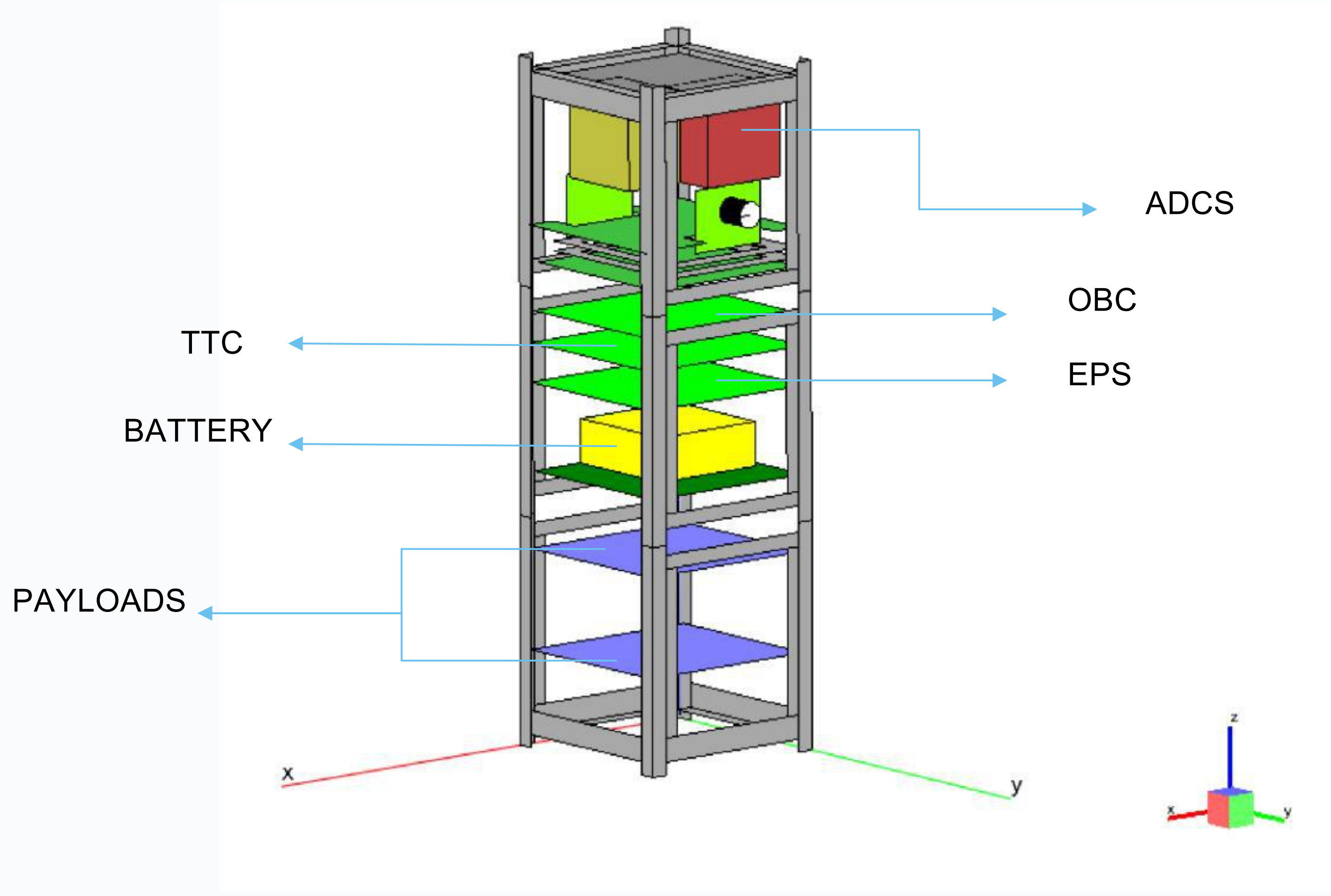
Under operation (laser working) , the average temperature of this face should not surpass the highest temperature threshold possible for the CubeSat.

External faces WipTherm model





Internal components
Wiptherm model



Mars Scenario for WipTherm

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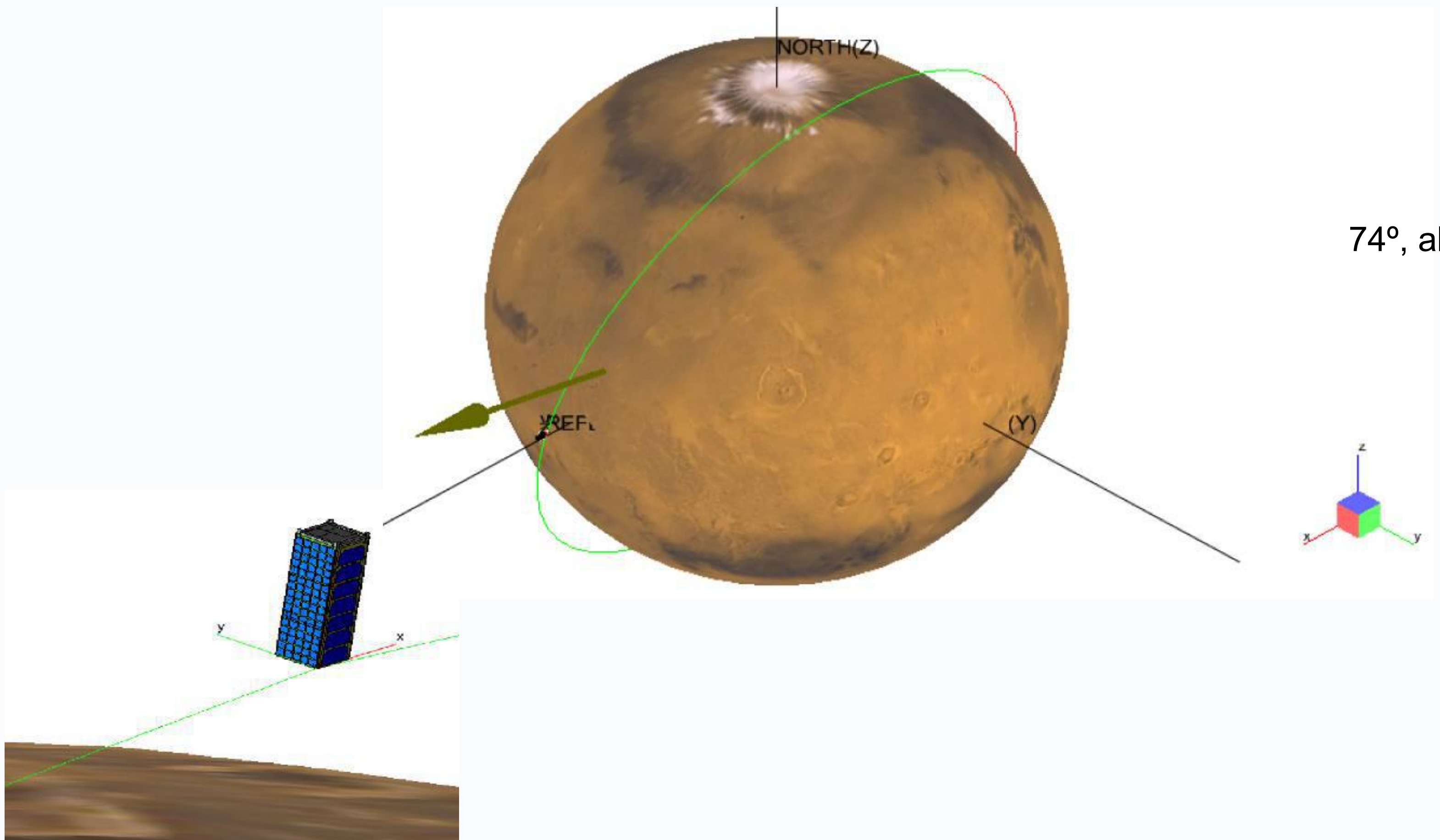
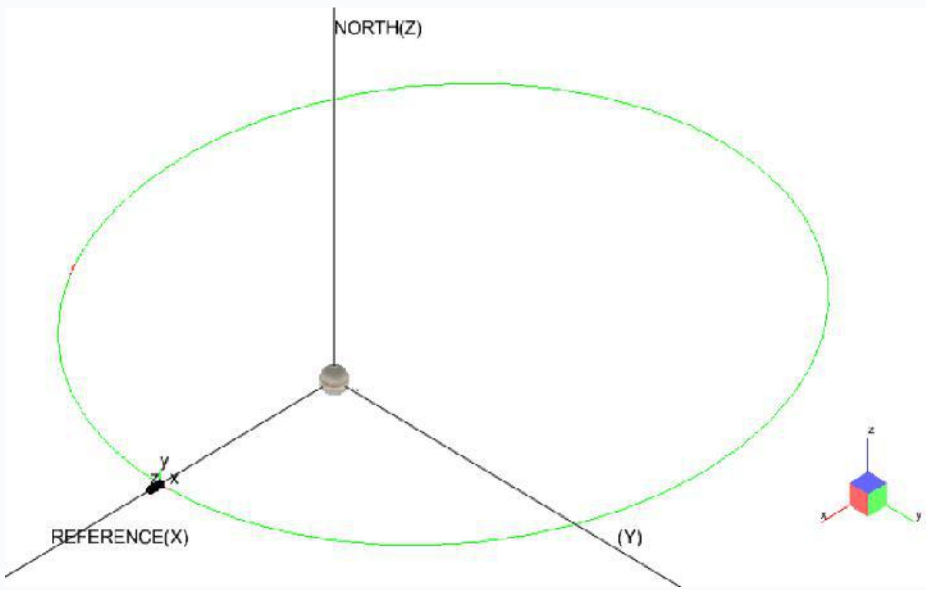
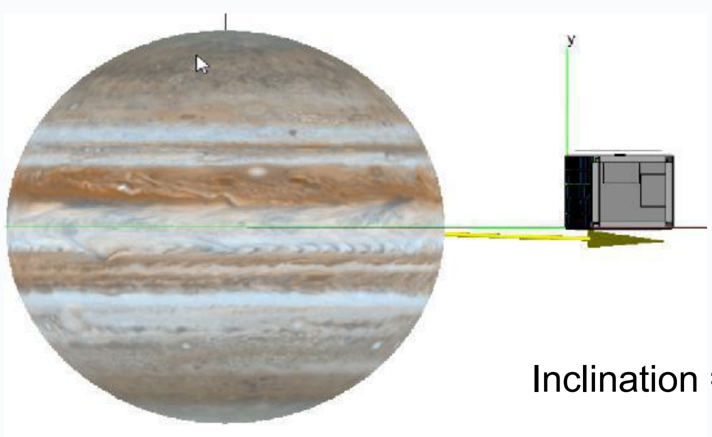


74º, altitude = 400 km (circular orbit)

Jupiter Scenario for WipTherm





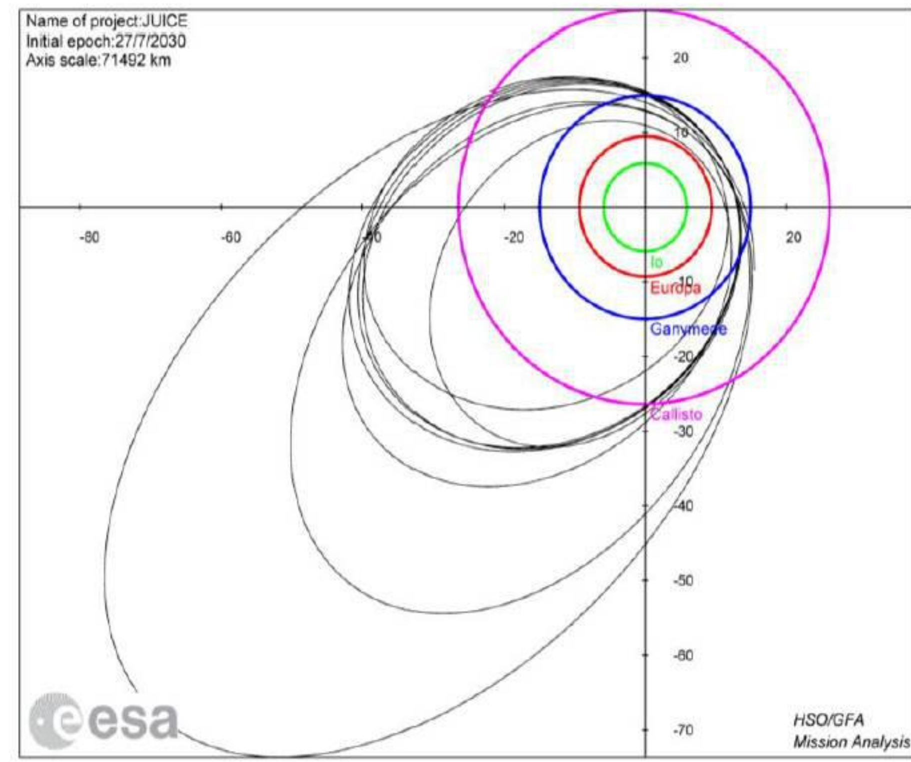
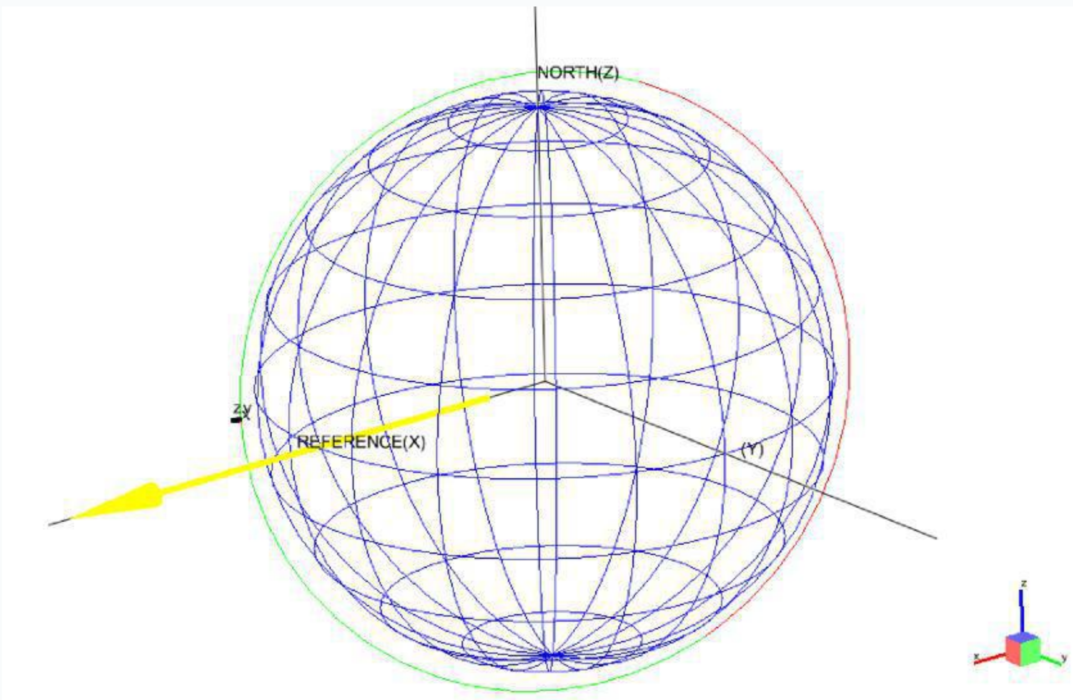


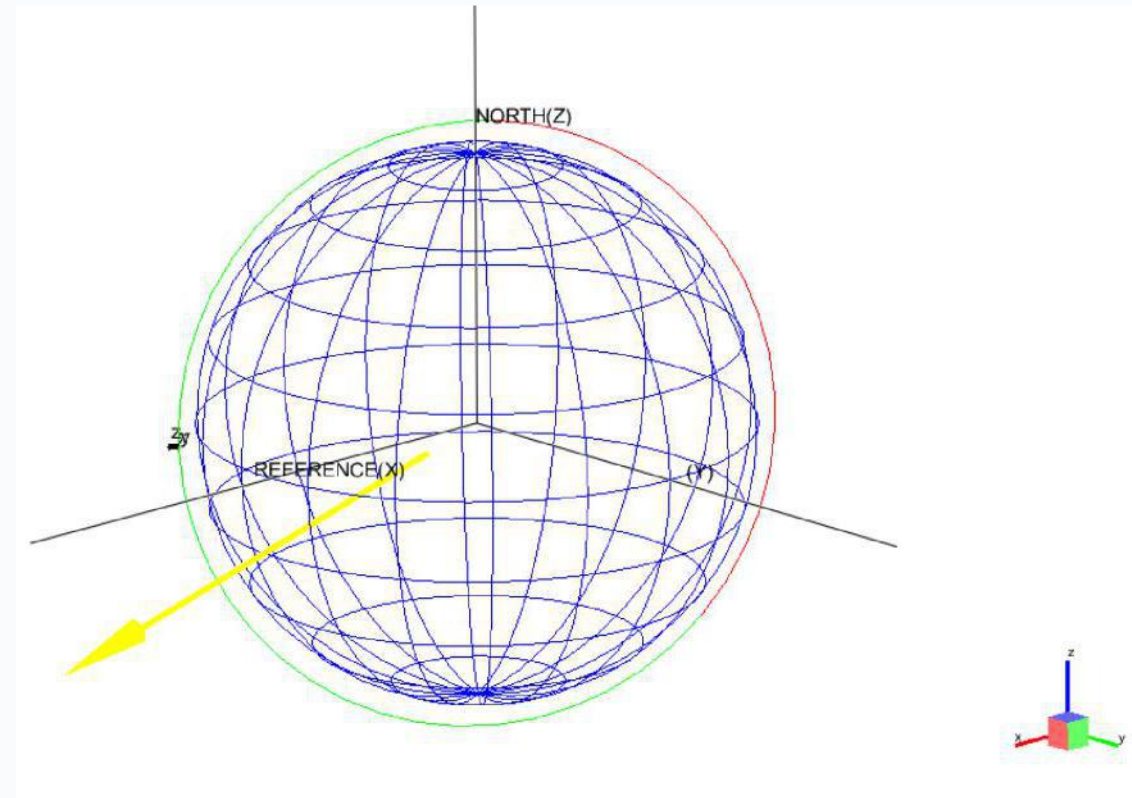
Figure 5-4. Trajectory from G2 to the Callisto flyby preceding the transfer to Europa (C7 for the 140a).

Inclination = 0º. Radius of perapsis = 15 RJ; Radius of apoapsis = 35RJ (RJ: radius of Jupiter).

LEO Scenario for WipTherm



COLD CASE



HOT CASE

WipTherm Potential Use

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- A medium power Deep space mission could use i.e. **150W** punctually for charging their CubeSats.
- With Wiptherm technology, at least 10% of laser energy is expected to be converted in the CubeSat, so 15W could be available.
- To compare with solar energy
- the area of solar panels with an optimistic efficiency of 30% to have 15W at Earth, Mars, and Jupiter is calculated:
  - Earth: 1400 W/m2 x 0.3 x A = 15W → A=0.0357 m^2
  - Mars: 700 W/m2 x 0.3 x A = 15W → A=0.0714 m^2
  - Jupiter: 70 W/m2 x 0.3 x A = 15W → A=0.714 m^2

WipTherm Potential Use

- Reversely, to compare with solar energy in a 10cmx30cm (0.03m^2) body-mounted solar panel, 15W/(0.1mx0.3mx0.3)=1667W/m^2 are needed for the solar panel to provide the same power to the CubeSat than WipTherm.
- This is 1.2 times the sun flux at the distance of Earth.

WipTherm Potential Use

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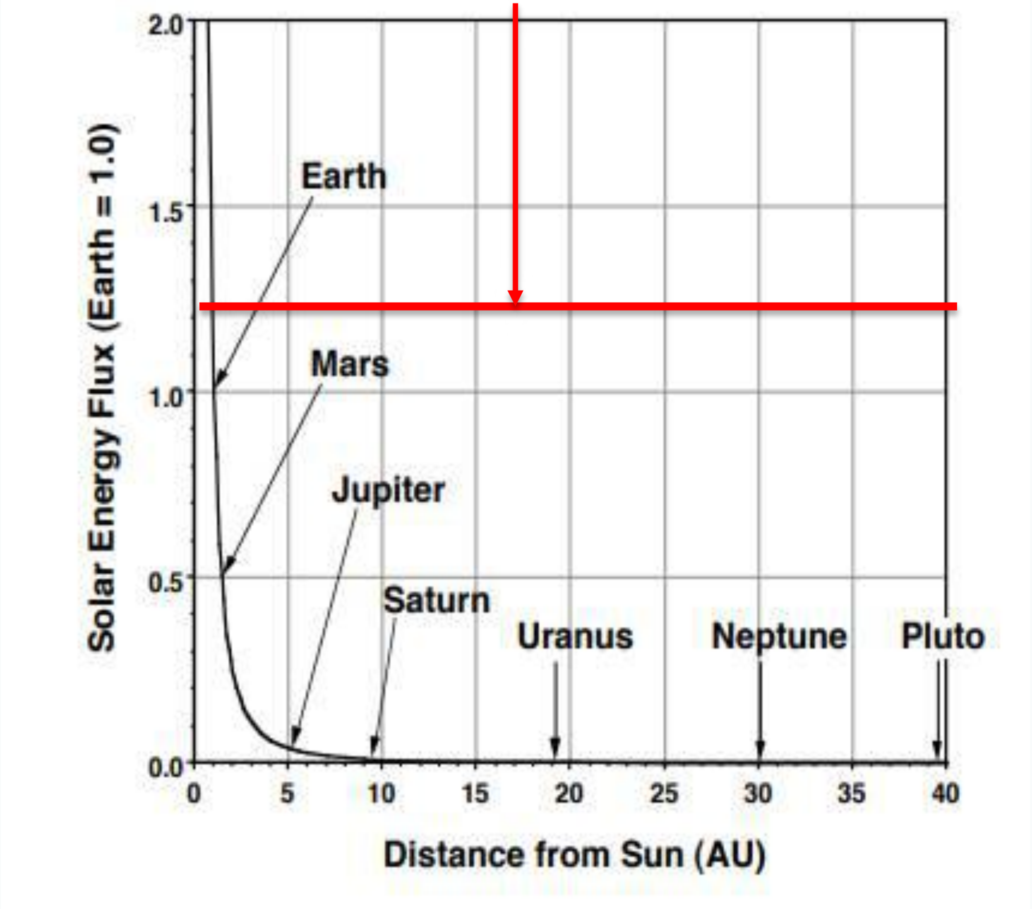
- In Jupiter:
- Solar panel → 70 W/m2 x 0.1x0.3 m2 x 0.3 = 0.63 W in the CubeSat
- Wiptherm → typical Jupiter mission JUICE 900W → it could use 150W with a efficiency of 10% to charge Cubesats → 15W in the CubeSat

15 Watts with 0.1x0.3 m2 → 1667 W/m2 → 1.2 Solar Energy Flux with respect 1 UA



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Questions?

Backup Slides

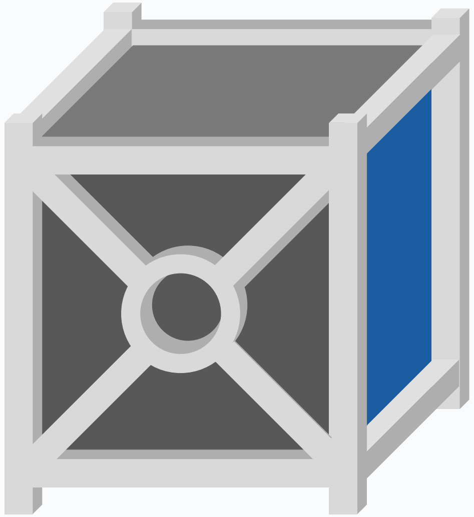
Universidade Vigo

The University of Vigo (UVIGO) is a public University located in Galicia (Northwest of Spain).

UVIGO has placed a considerable emphasis on R&D activities by way of numerous internal funded projects, as well as through its various services and research centres. This support has enormously increased the scientific output and the capacity to obtain external resources.

- The Team of UVIGO has been working in last years on design, development, integration and operation of 3 Cubesats:
    - 2012: Xatcobeo: first Spanish Cubesat.
    - 2013: HUMSAT-D, first satellite of the HUMSAT constellation developed within the Basic
    - Space Technology Initiative of the Office of Outer Space Affairs of United Nations.
    - 2016: Serpens, in cooperation with the Brazilian Space Agency.

- Coordination of the activities to assure that the HPTB subsystem will be compatible in terms of integration, functionalities and operation with Cubesat based missions.
- Definition of the requirements, interfaces and tests of the Hybrid Photo-Thermo electric Plasmonic Converter to be assured its integration in an operational CubeSat satellite.



Université de Limoges

The University of Limoges, founded in 1968, is a multidisciplinary higher education establishment adhering to the core values of openness and excellence.

XLIM is a Joint Research Unit of the University of Limoges and the CNRS (Centre national de la recherche scientifique) located on several geographical sites in Limoges, Brive and Poitiers.

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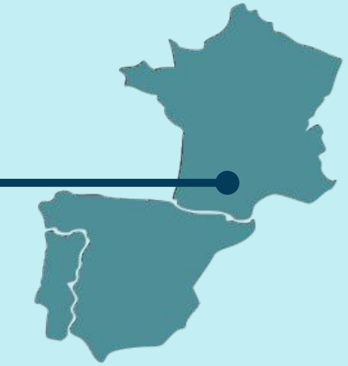
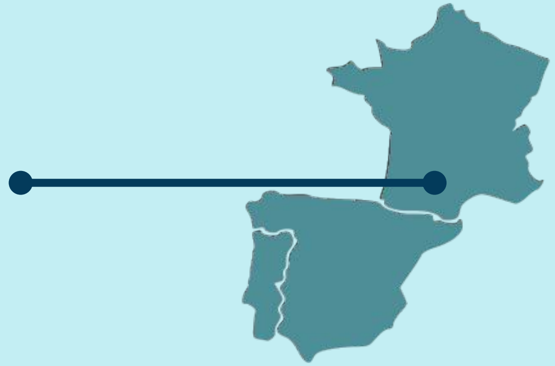


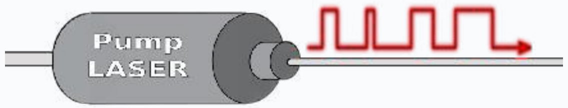
- The Institute is structured around 3 scientific poles:
    1. Electronics.
    2. Photonics.
    3. Mathematics, Computer Science, Computer Imaging.

- The Photonics Department, gathering about 26 researchers and engineers and as many PhD students, has a long-standing experience in designing and fabricating specialty fibres for various applications such as UV-VIS supercontinuum generation or high-power Yb- doped fibre lasers.

Université de Limoges



- Design, fabrication and characterization of application-specific optical active fibers for the power scaling of high power lasers.



CeNTI

Centre for Nanotechnology and Smart Materials

CeNTI is a distinct European Research and development Centre, equipped with cutting-edge technology, and conducting world-class research and development.

CeNTI's services are comprehensive and integrated: from R&D to scaling-up production.

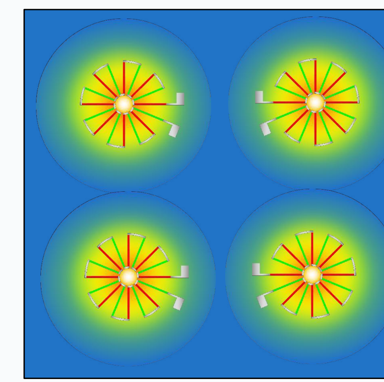
CeNTI

Centre for Nanotechnology and Smart Materials

- CeNTI provides, in a business to business approach, applied R&D, engineering and scaling-up production of innovative functional and smart materials and devices.

- CeNTI has strict protocols to protect client confidentiality and intellectual property. Their services take a multi-disciplinary approach and include the participation of experienced technologists and researchers (physicists, chemists, electronics/chemical/materials engineers).

- Development of the electronic controls of the Thermoelectric Devices.
- Development of the thermoelectric devices using Flatbed Screen Printing and Rotary-Screen Printing in Roll-to-Roll technologies.
- Performance evaluation and characterization of the printed devices.



INESCTEC

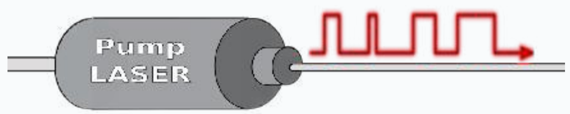
INESC Technology and Science – INESC TEC is an Associate Laboratory with 30 years of experience in R&D and technology transfer, is a private non-profit research institution having as associates the University of Porto, INESC and the Polytechnic Institute of Porto.

- With around 800 researchers (350 PhD), working in the interface between the academic world and the industrial and service companies, as well as the public administration, the activity at INESC TEC runs under the paradigm of the knowledge to value production chain.

- The Team of INESC TEC has been working in last years on lasers for gas detection, atmospheric links, lasers for medical applications and for remote sensing. This group has also developed technology for optical amplification using rare earth doped fibers.

INESCTEC

- Development of high power fiber lasers using fibers developed by XLim for thermoelectric applications.
- Design of all the development and definition of the hardware and firmware of the system.
- Test of the laser prototype at laboratory scale.
- Test of the Hybrid Photo-Thermoelectric Plasmonic Converter after CubeSat integration Laboratory System Functionality Performance Evaluation of the full system under controlled environment.



U.PORTO

FACULDADE DE CIÊNCIAS
UNIVERSIDADE DO PORTO

IFIMUP
Instituto de Física de
Materiais Avançados,
Nanotecnologia e Fotónica
Universidade do Porto

Founded in 1911, the University of Porto is a reference university of education and scientific research in Portugal. The research developed under **WiPTherm** will be performed at **Institute of Physics of Materials of the University of Porto (IFIMUP)** which is one of the 65 R&D laboratories of Porto University with more than 30 years of experience on advanced material science and nanotechnology.

- FCUP MISSION is, using physics insight, to enhance scientific knowledge in the fields of functional materials, photonics, nanoscience and nanotechnology, performing research, advanced training and services to the scientific community and industry.

- FCUP VISION states as an interdisciplinary and multidisciplinary institute of Excellence with high international impact on research and innovation, maintaining active exchange programs with research centres, universities, industry and other worldwide facilities.

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- Management of the project.
- Preparation of optimized thermoelectric inks and collector inks to be used in the development of the Hybrid Photo-Thermoelectric Plasmonic Generator.
- First Principles Calculation of the Materials and Comsol Simulation to improve the efficiency.
- Characterization and performance evaluation of the final generators.
- Development of the YouTube channel and other relevant scientific disseminations.