ภาควิชาฟิสิกส์ จุฬาลงกรณ์มหาวิทยาลัย
Department of Physics, Chulalongkorn University

Chula
Chulalongkorn University

Chulalongkorn University-**TSC** collaboration on

Project : High efficiency space solar cell

(Revised on 20th June 2022)

The Collaboration

Chula
Chulalongkorn University

In collaboration with **TSC**, we would like to focus on the development of the *III-V semiconductor-based space solar cell* that can be used in NARIT and TSC space project.

The research and development of this III-V semiconductor-based space solar cell will include:

- Design and fabrication technology #designed and developed by Thai scientists
- Materials and device characterization and optimization
- The space solar cell prototypes #ready for large-scale production
- Space-device certified
- Cross technology incorporation #combine with other materials technologies

The Space solar cell research Team

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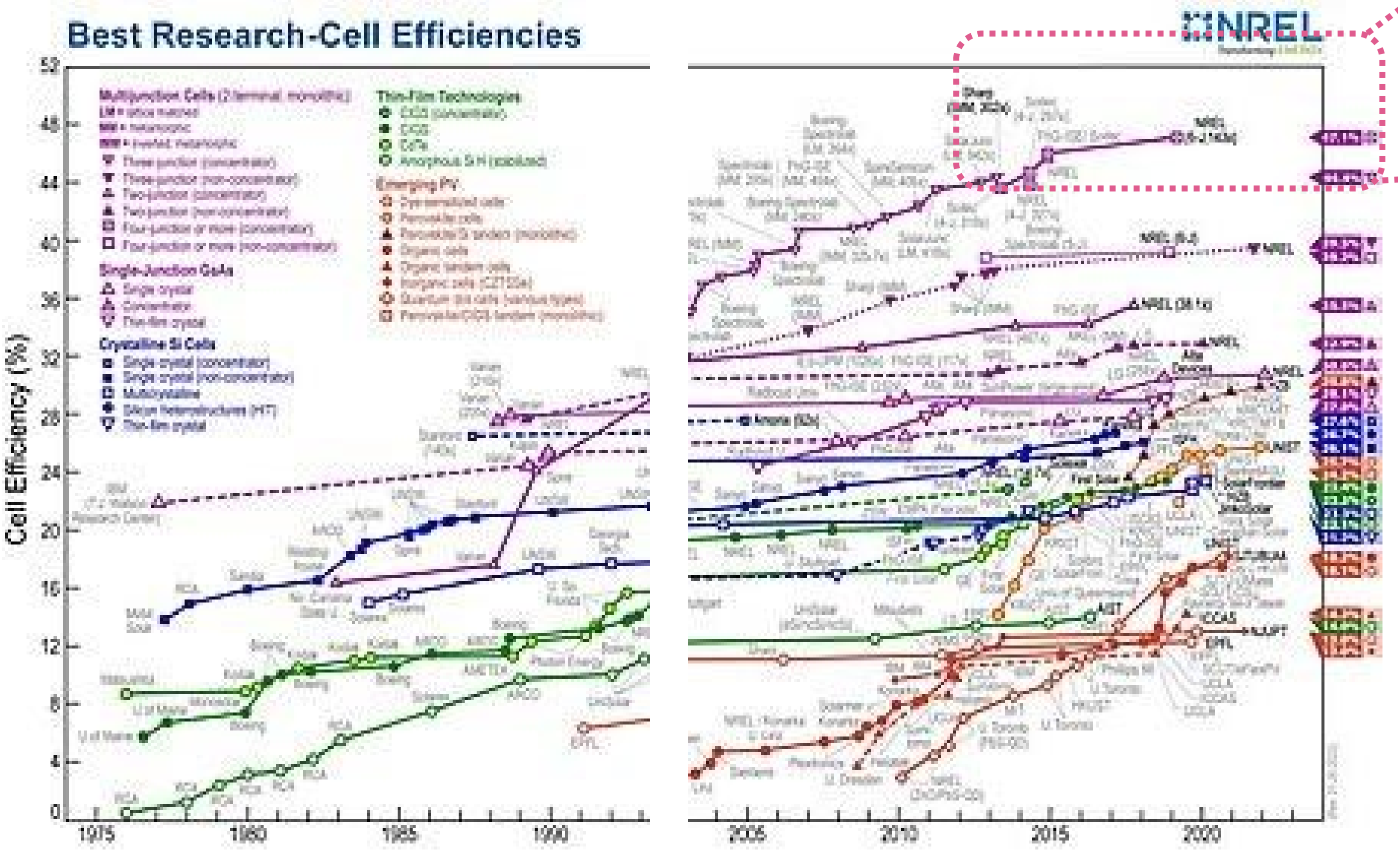
In collaboration with: **Semiconductor Device Research Laboratory (SDRL), Faculty of Engineering, CU**
Metallurgy and Materials Science Research Institute (MMRI), CU

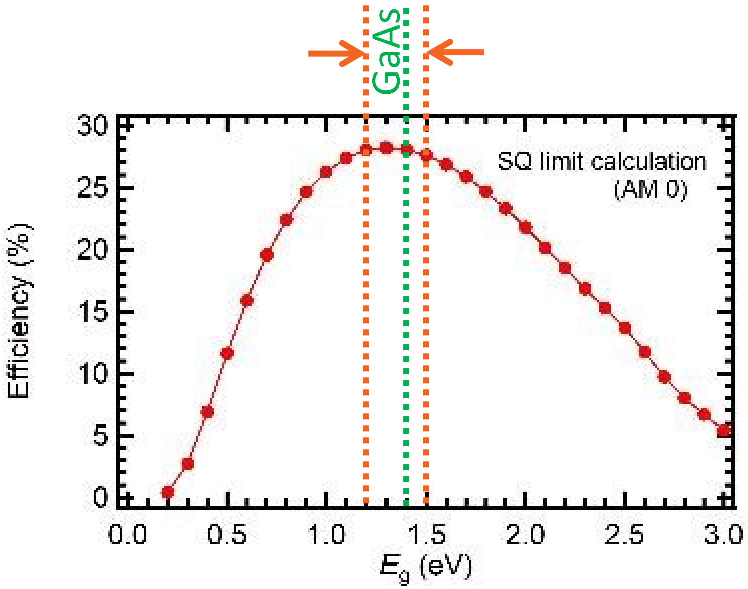
Highest efficiency provided by III-V solar cells

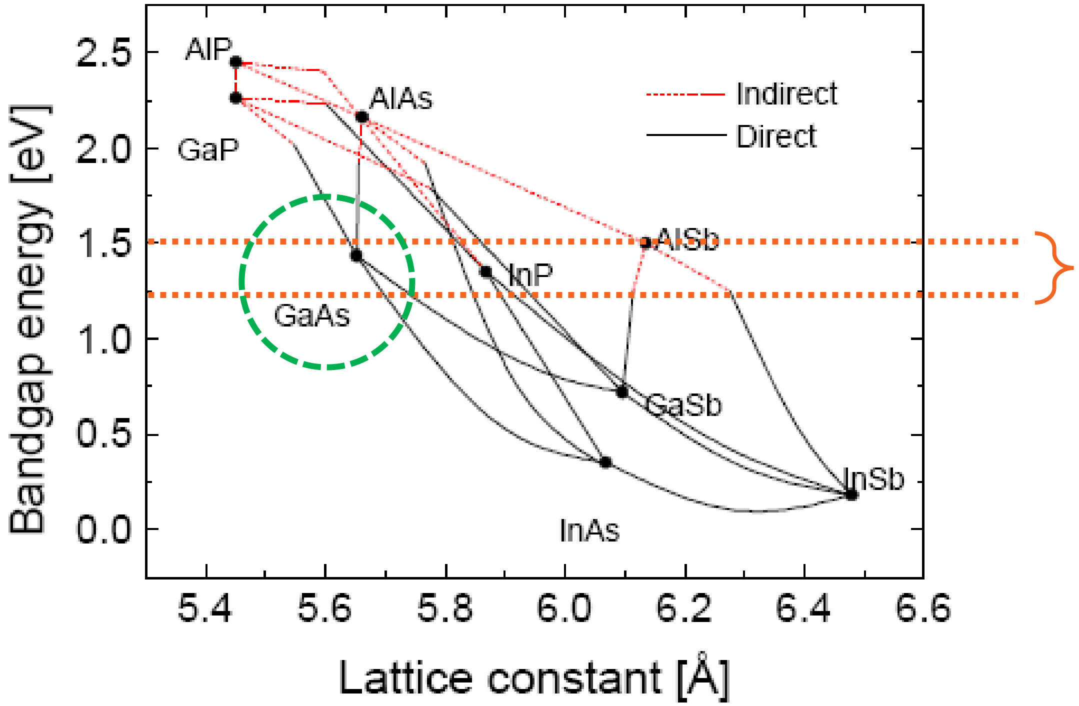


- 6-junction solar cell measured under 143x concentrated AM1.5 solar spectrum
- Although, it provides highest efficiency, the production cost is extremely large!!

Candidate III-V materials

For AM0 –space solar spectrum





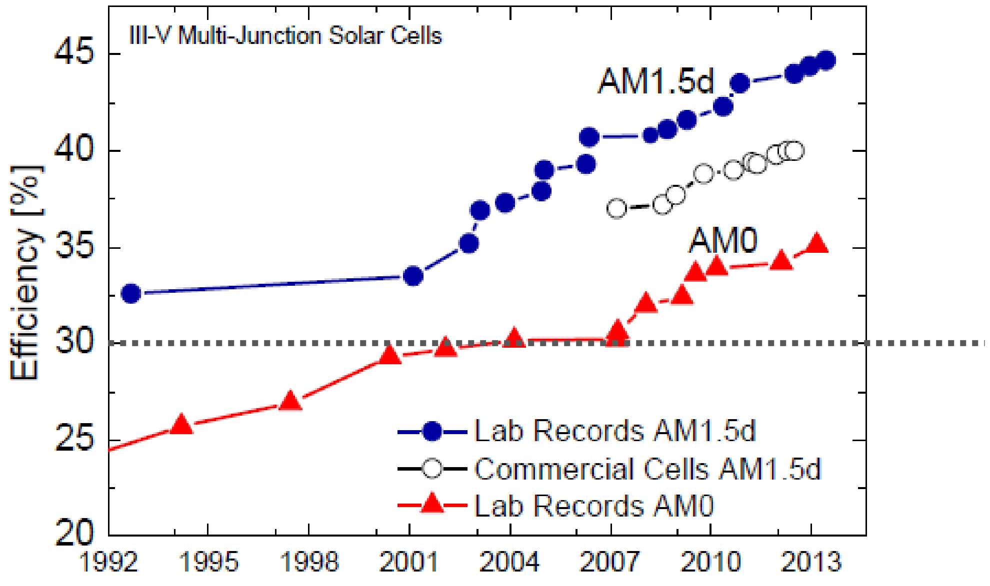
Effective range for high-efficiency solar cell

2-inch GaAs substrate

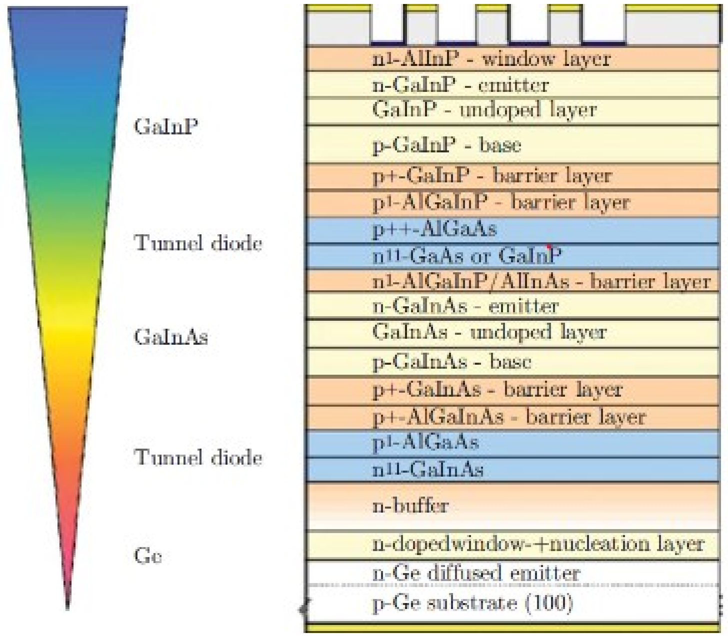
- GaAs is one of interesting candidates
  - Band gap = 1.42 eV
  - Commercially available for substrate

World record on space solar cell

- For space solar cell (operated under AM0), we now mainly focus on 3-junction cell



- Efficiency of 3-junction solar cell under AM0 (Space solar cell)



} InGaP top junction

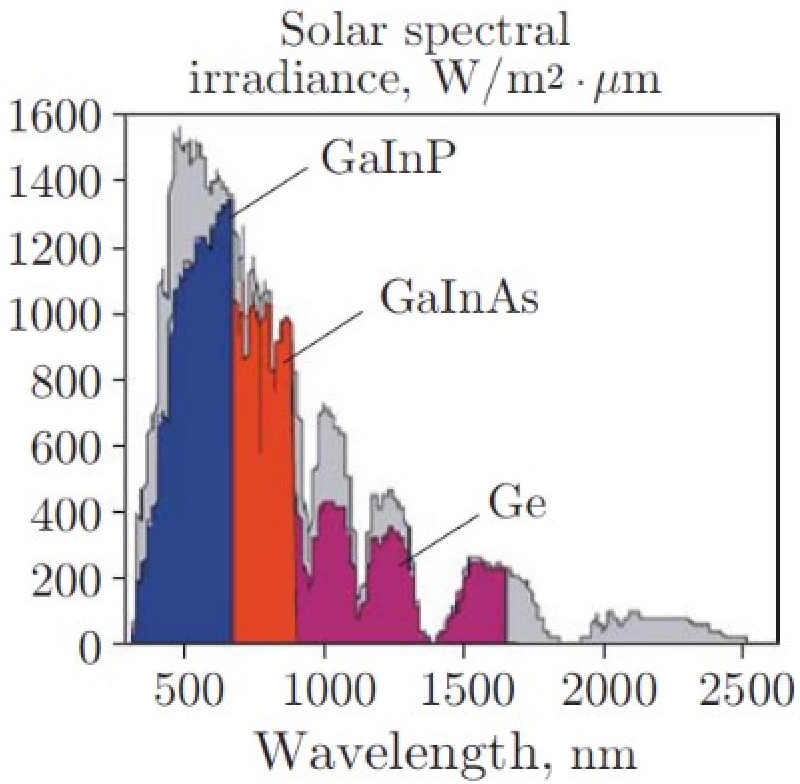
} $In_{0.01}Ga_{0.99}As$ middle junction

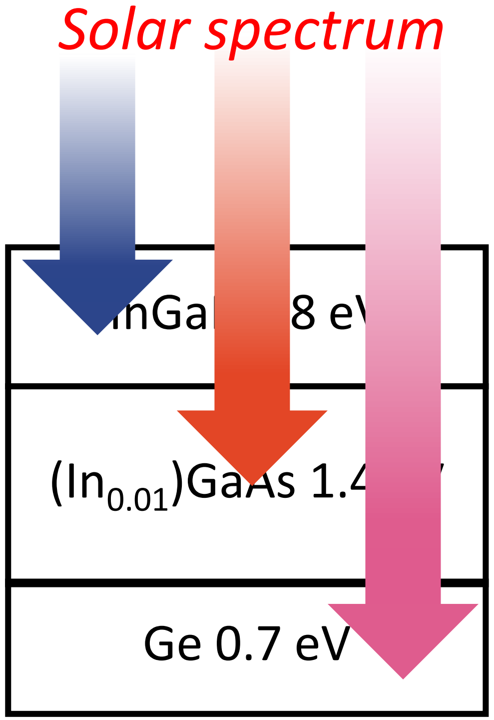
} Ge bottom junction

A. W. Bett, et al, Proc. of the 28th Europ. Photovoltaic Solar Energy Conference and Exhibition, Paris, France, 30 Sept.- 4 Oct., 2013, pp. 1–6.

Current generated in each junction

- Photon absorption and current generation in each junction





Efficiency **30 %** under AM0

- By average, it can be considered as each junction can be generated **10%** efficiency

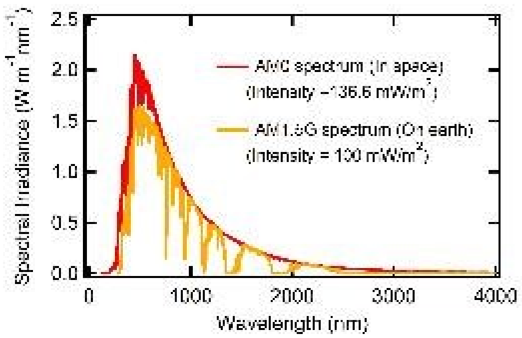
  - Target of 10% efficiency for GaAs single junction cell is satisfactory

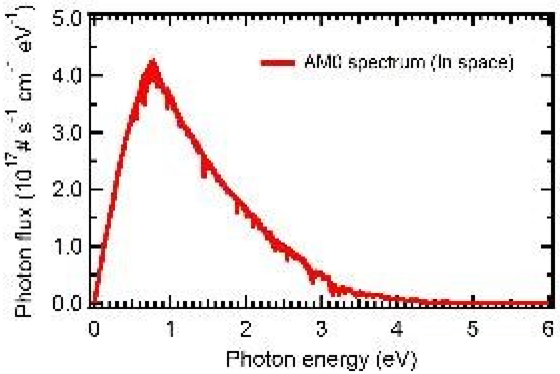
Calculation of current & efficiency

Chulalongkorn University

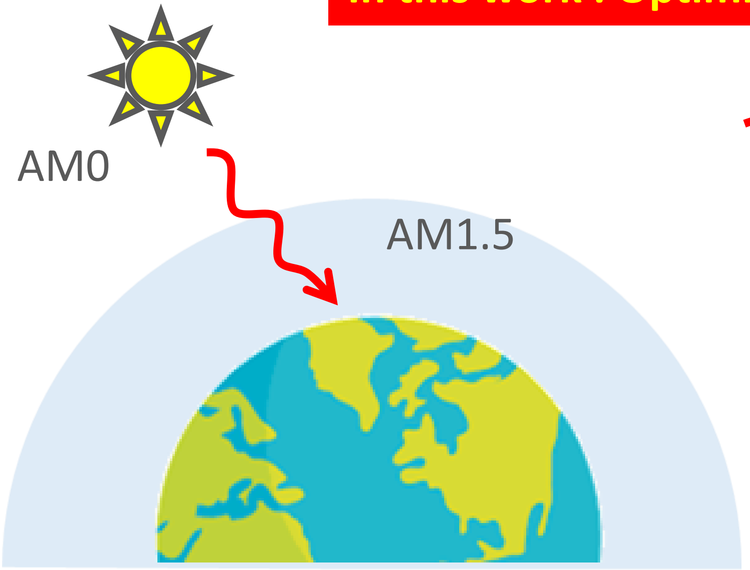
(1) Photocurrent

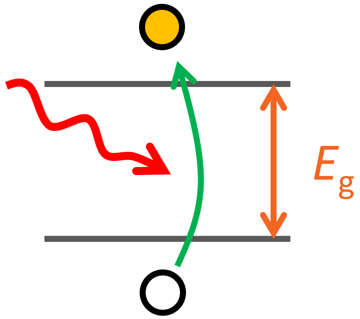
Photon flux Φ_{ph}





In this work : Optimization under AM0



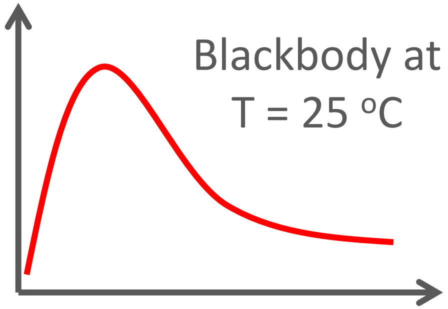


Photons $E > E_g$ can be absorbed

$$J_{sc} = qQ_s = \int_{E_g}^{\infty} \Phi_{ph} dE$$

(2) Dark current

$$J_{dark} = \underbrace{qQ_C}_{J_0}\left(e^{\frac{qV}{kT}} - 1\right)$$



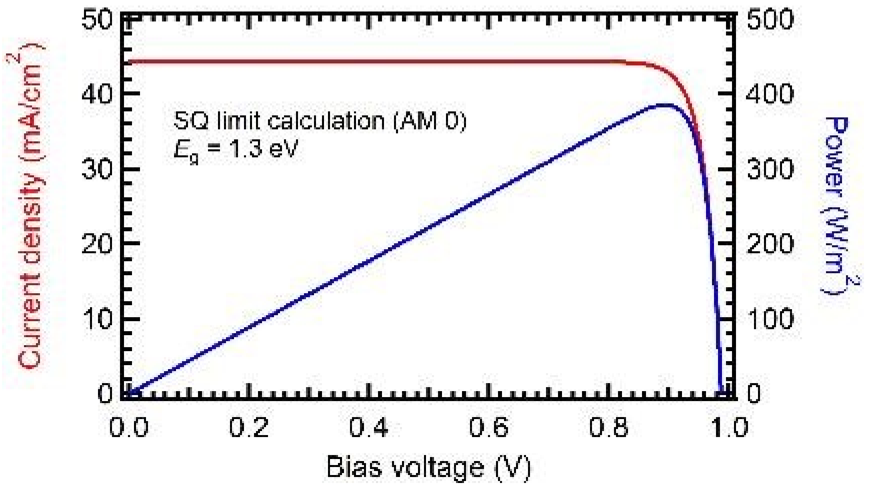
Blackbody at T = 25 °C

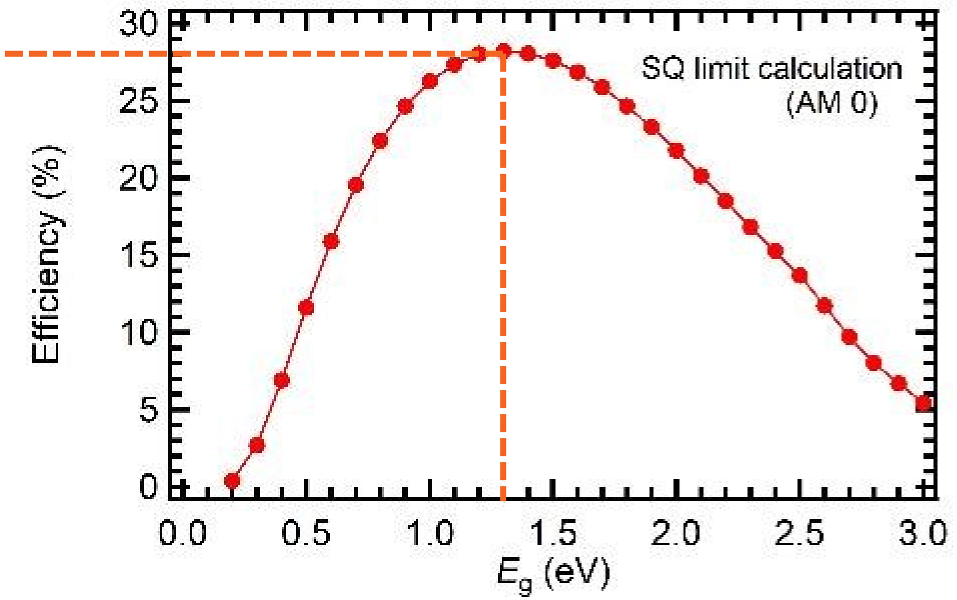
$$J_0 = qQ_C = q\left[\frac{2\pi q^3}{h^3 c^2}\int_{E_g}^{\infty}\frac{E^2}{e^{\frac{E}{0.026}} - 1} dE\right]$$

Possible maximum efficiency

Intensity of AM0 solar spectrum = 1366 W/m²

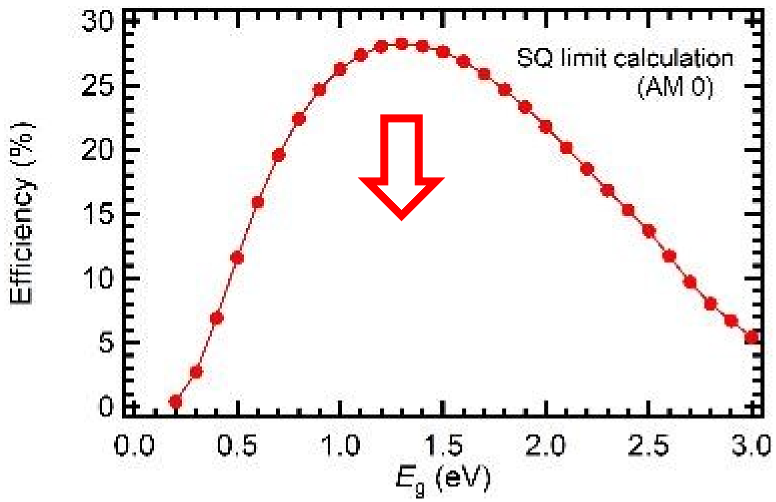
$$\eta = \frac{P_{max}}{1366\, Wm^{-2}} \times 100$$





Maximum efficiency under AM0 for single junction = **28%** at $\boldsymbol{E_g}$ **= 1.3 eV**

Solar cell with additional physics phenomena



- This SQ maximum limit *only* consider

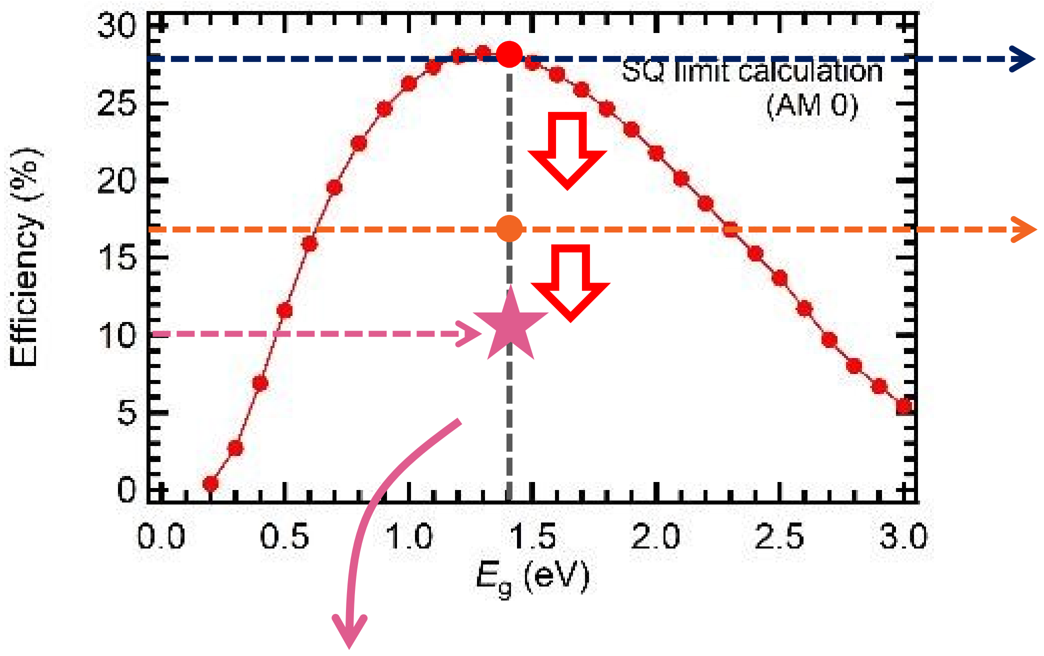
  100% absorbed photon ⇨ Output current

- There are other ***unavoidable*** physics phenomena in solar cell
  - Radiative recombination
  - Carrier transport (Mobility, drift velocity, etc.)
  - Impacts of the particles and radiation in space

  } Decrease efficiency

There is an opportunity for research and development to improve the efficiency of available space solar cell! #incorporated design

Summarize on efficiency of n-p GaAs space solar cell



Ideal SQ maximum limit (GaAs bulk 1.42 eV)

28%

The simplest n-p GaAs single junction
(With additional physics phenomena)

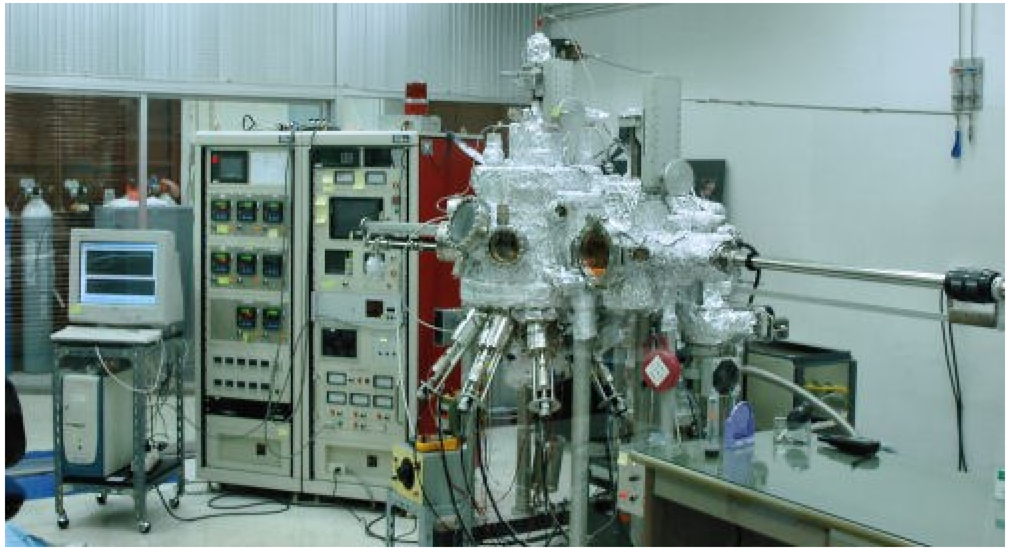
~ 17-18%

Optimize each major junction of the device to reach the highest possible efficiency!!

In real solar cell : other degradation due to cell quality

- Non-radiative recombination via defects
- Surface trapped recombination
- Not perfectly carrier extraction (Schottky contact)
- Shunt and series resistance

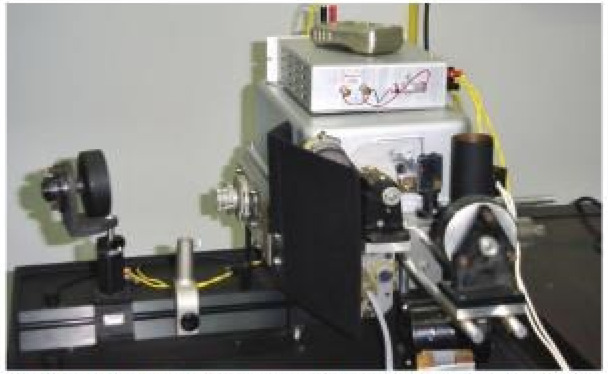
Research Facility & readiness @CU



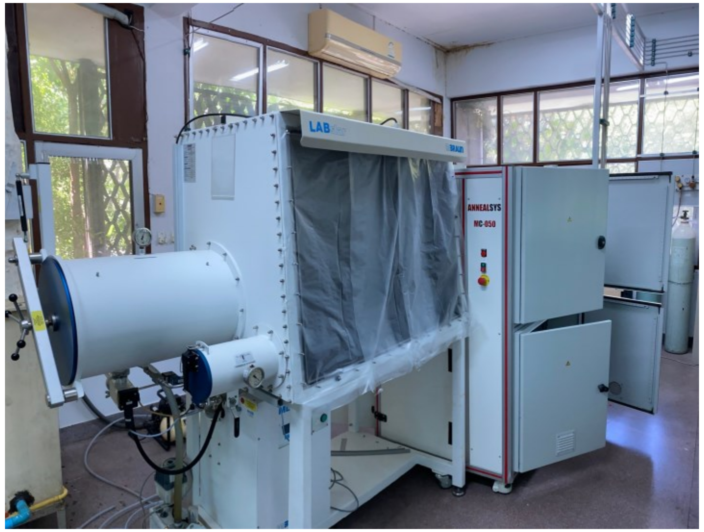
Solar Simulator

The standard solar simulator used for testing the efficiency of the thin film solar cells.

Quantum Efficiency Measurement Setup



A homemade quantum efficiency setup is used to measure the efficiency (at each photon energy) of the solar cells we fabricated with respect to the standard cell.



“Thank you and hope that we can go to space together”