2024 Space Power Workshop
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Thermal runaway in space solar cells

Japan Aerospace Exploration Agency(JAXA)

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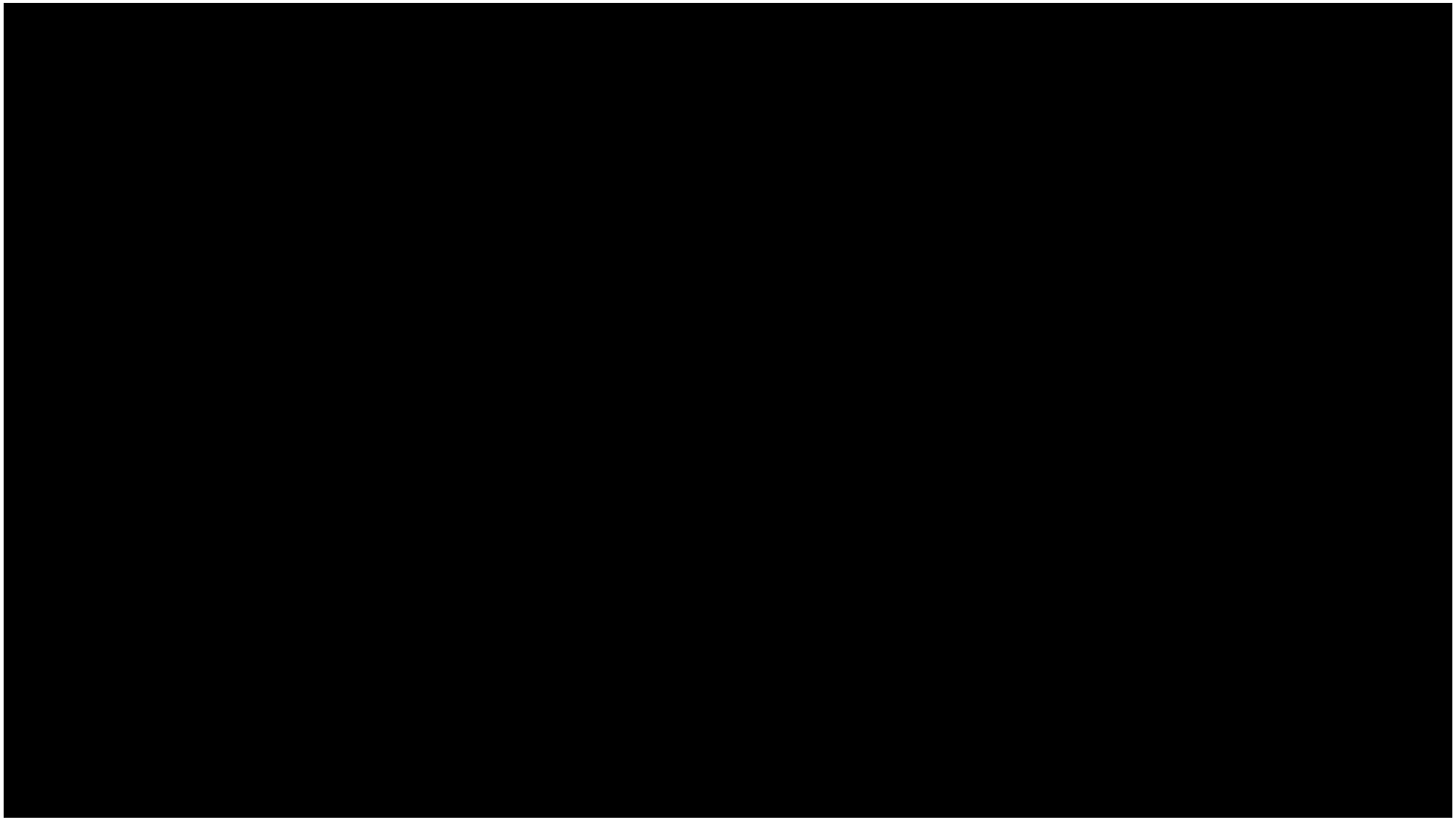
Outline

1. What is thermal runaway in solar cells?
2. Mechanism of thermal runaway in solar cells
3. Evaluation of thermal runaway tolerance
   - 3-1. Creation of artificial shunt spot
   - 3-2. Position of shunt
   - 3-3. Vacuum or atmosphere
   - 3-4. Temperature dependent
4. Conclusion

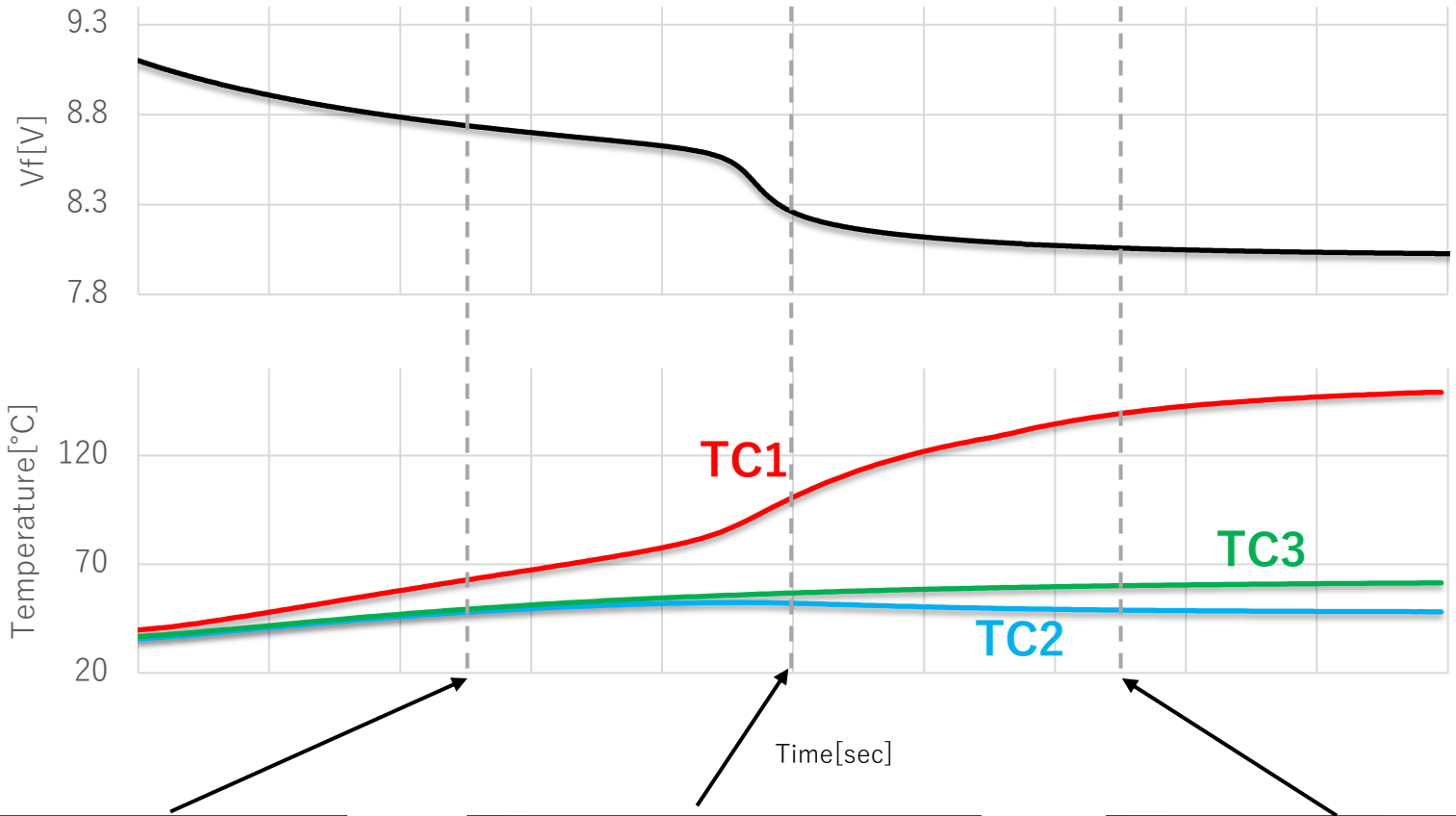
1. What is thermal runaway in solar cells?

Prototype IMM3J solar cells

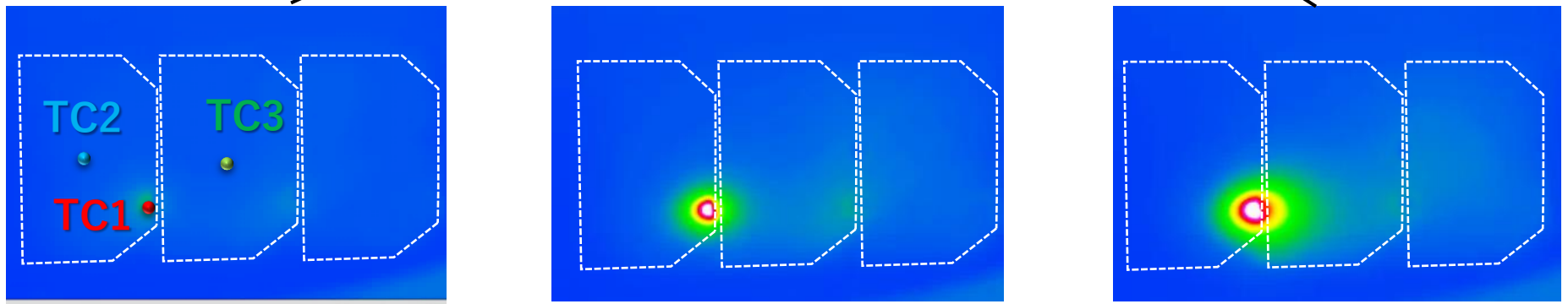
Video



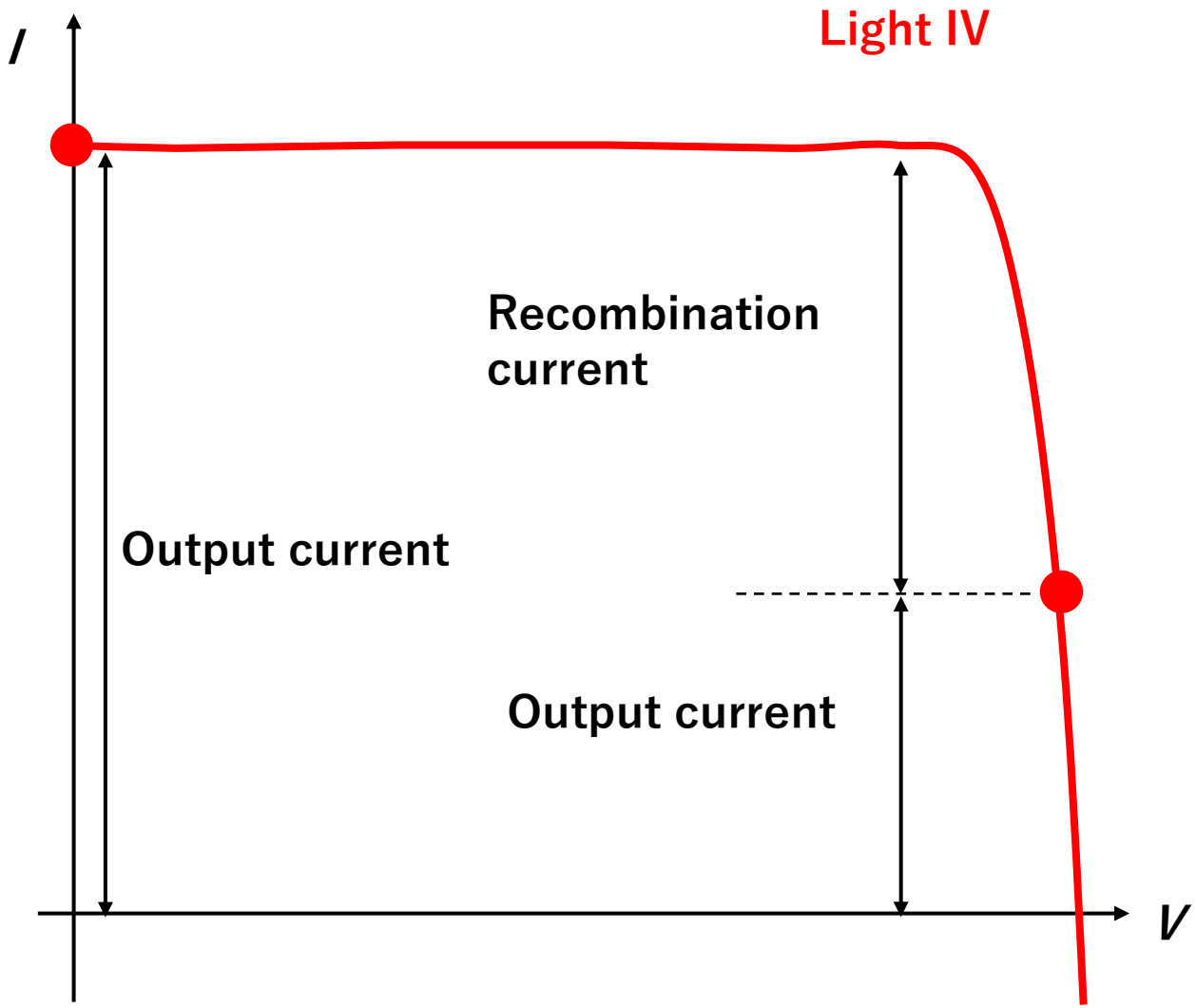
1. What is thermal runaway in solar cells?

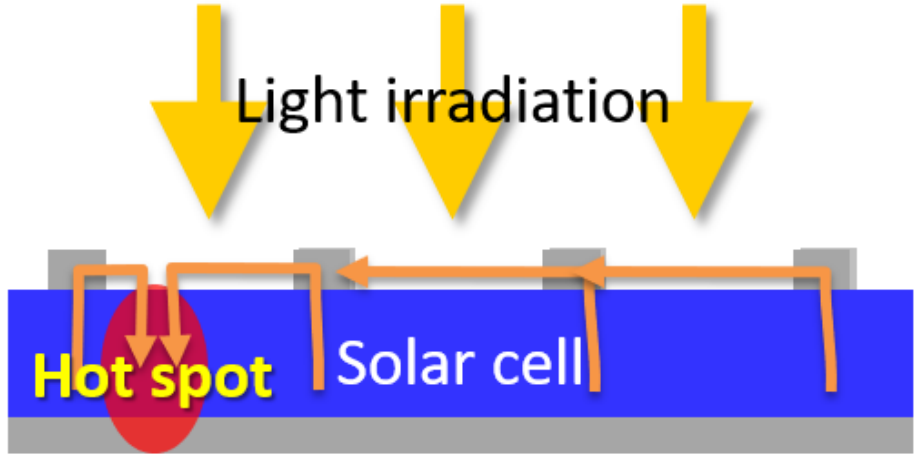


Thermography

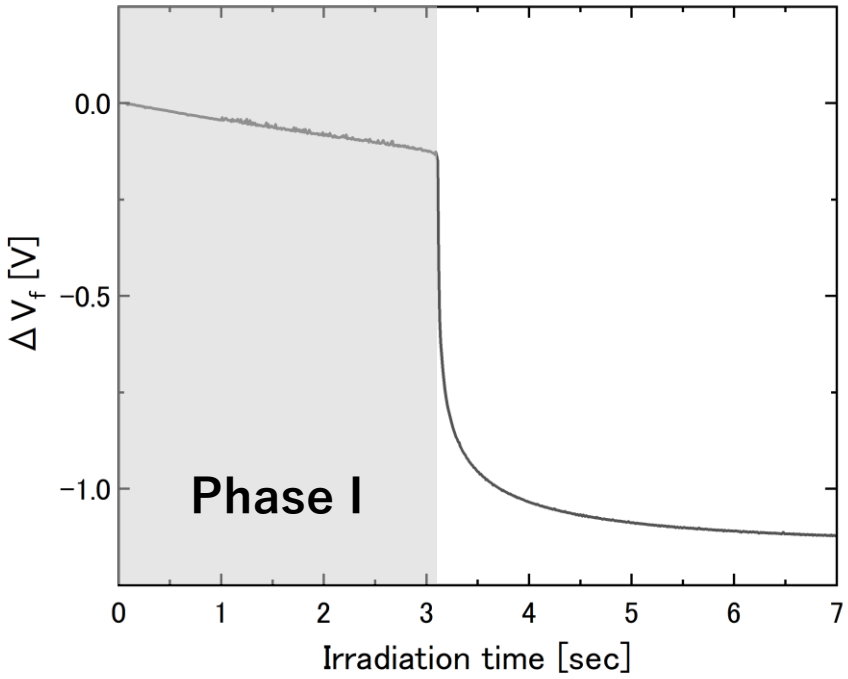


1. What is thermal runaway in solar cells?



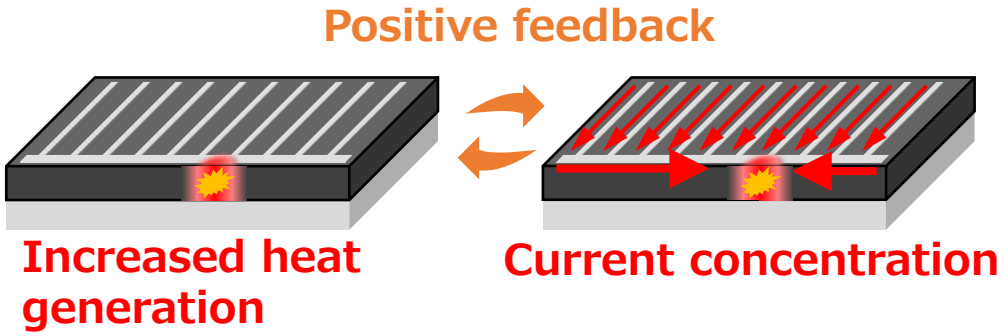


2. Mechanism of thermal runaway in solar cells

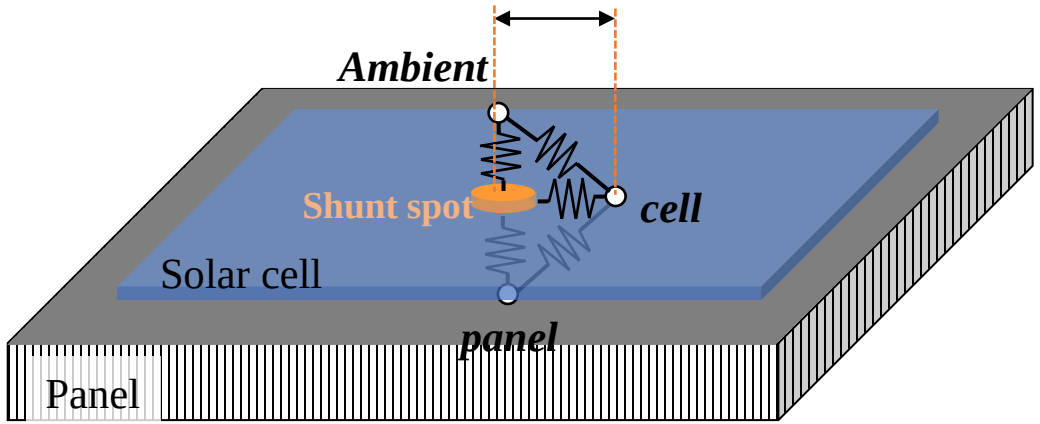


$$\Delta T_{spot}(t) = R_T Q_{cell}(t)\left[1 - exp\left(\frac{t}{R_T C_T}\right)\right]$$

R_T: Combined thermal resistance
Q_{cell}: Heat generated by the inflow current into spot
C_T: Thermal capacity

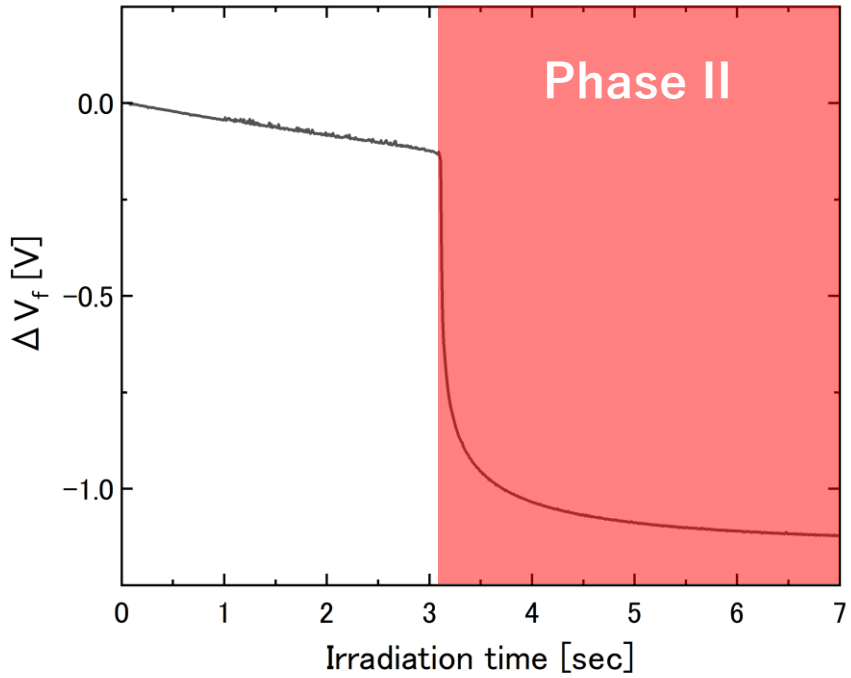


$$\Delta T_{spot} = T_{spot} - T_{cell}$$

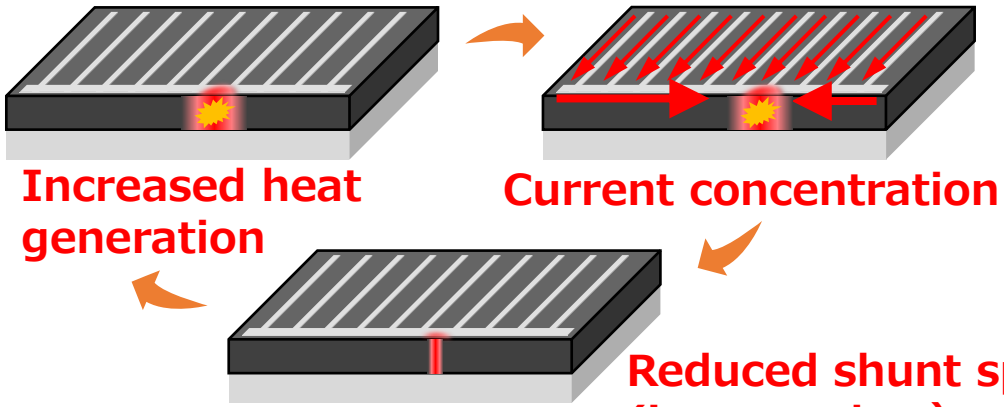


T. Nakamura et al., Jpn. J. Appl. Phys. **57**, 08RD03 (2018).
T. Nakamura et al., Jpn. J. Appl. Phys. **62**, SK1049 (2023).

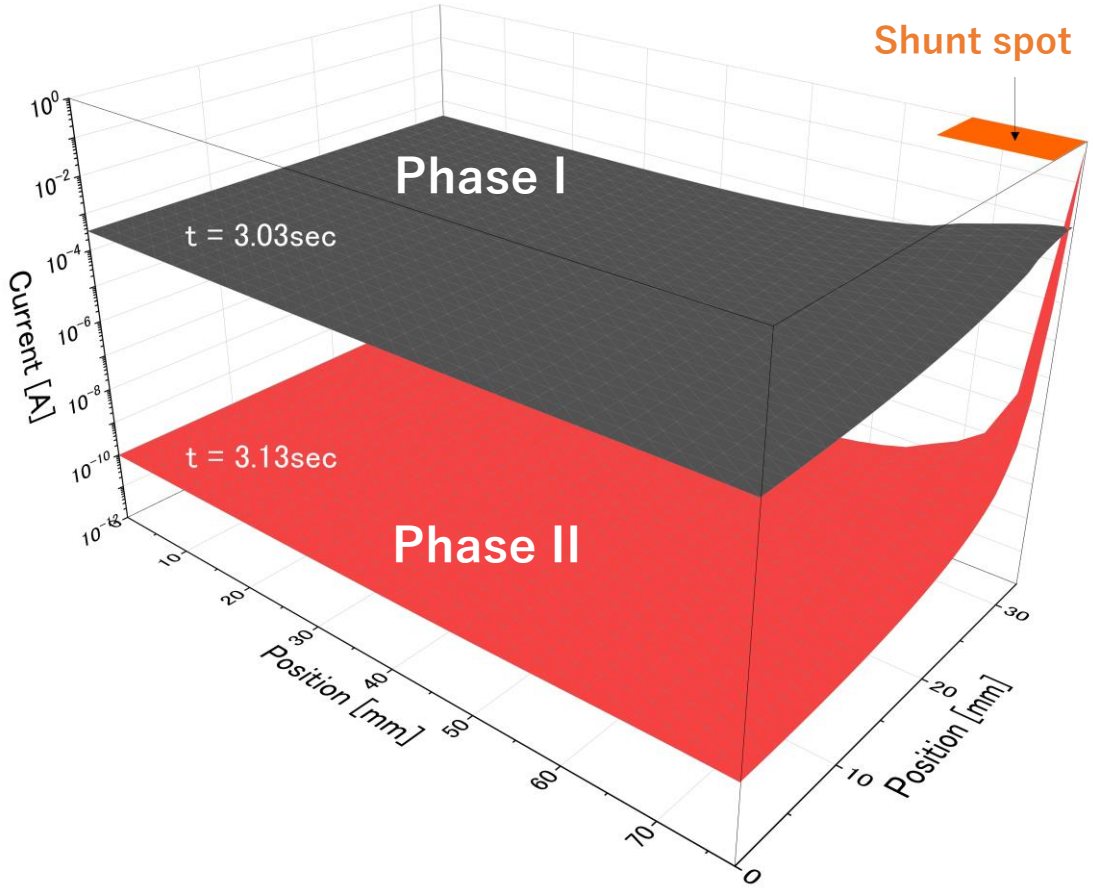
2. Mechanism of thermal runaway in solar cells



Positive feedback



$$\Delta T_{spot}(t) = R_{T\_TR} Q_{cell\_TR} \left[1 - \exp\left(-\frac{t - t_{TR}}{R_{t\_TR} C_{t\_TR}} \right) \right]$$



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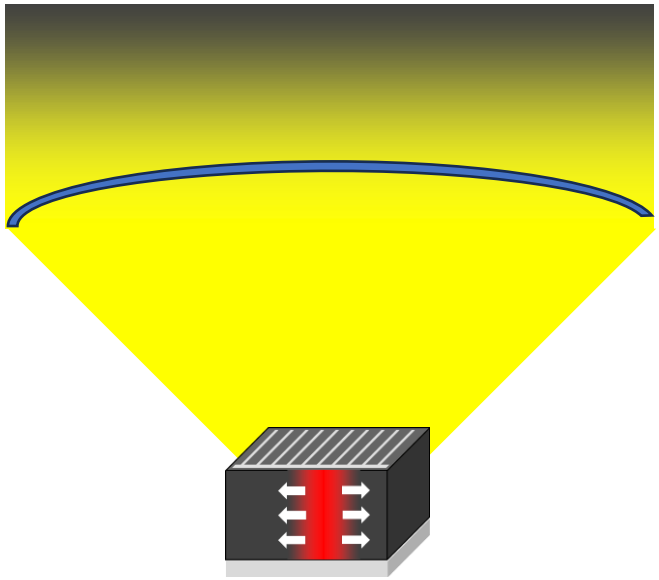
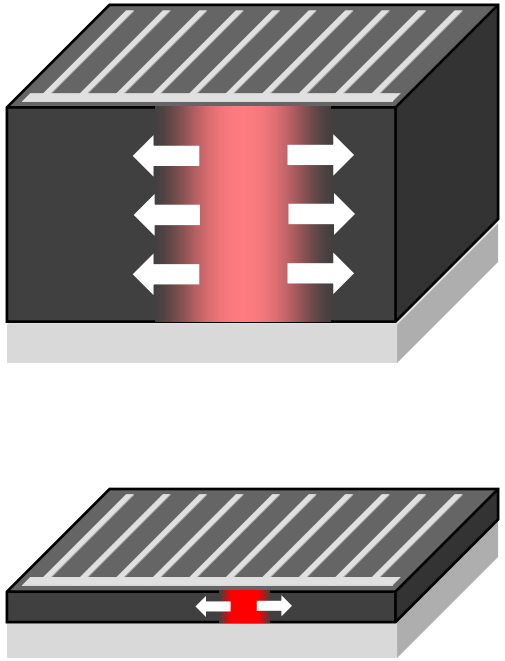
3. Tolerance of thermal runaway

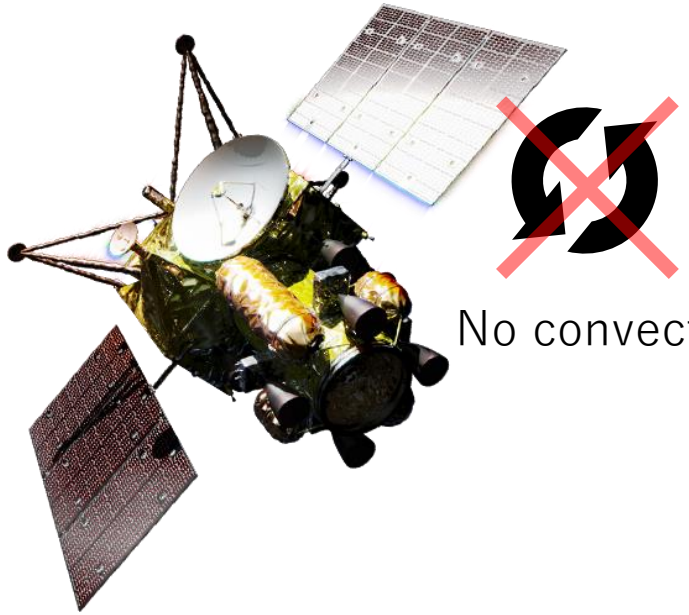
Solar concentrating systems (High intensity environment)[1-5]



Thin film structure[6-8]



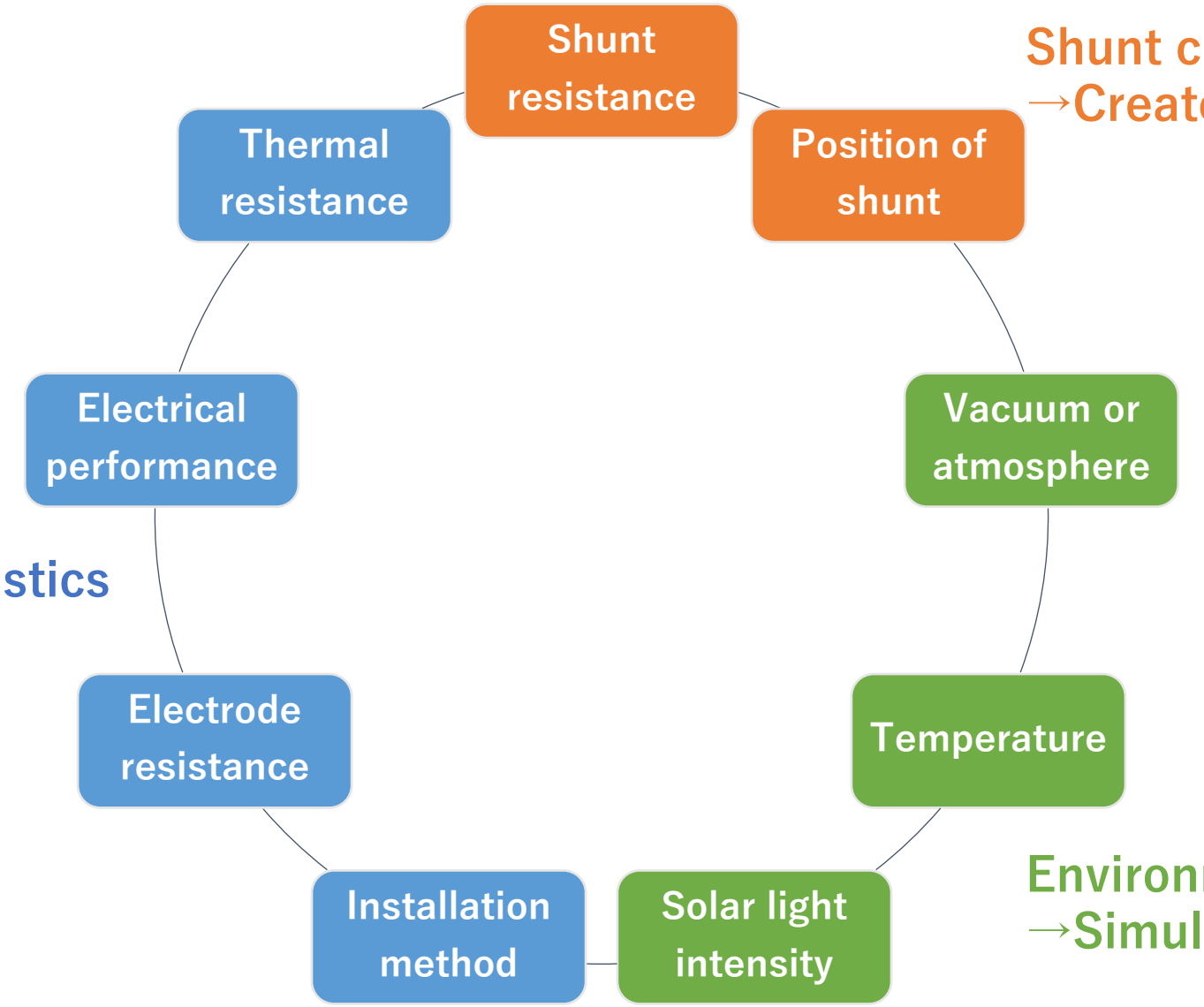
Space application[7-8]



[1] K. Araki et al., AIP Conf. Proc. 1407, 2011 p.303.
[2] C. G. Zimmermann, Appl. Phys. Lett. **102**, 233506 (2013).
[3] C. G. Zimmermann, Proc. IEEE 40th PVSC, 2014, p.3612.
[4] M. Steiner et al., IEEE J. Photovolt. **4**, 2, 749 (2014).
[5] H. Lv et al., Int. J. Low-Carbon Technol. **13**, 4, 432 (2018).
[6] M. D. Perez et al., Mater. Sci. Semicon. Proc. **41**, 529 (2016).
[7] T. Nakamura et al., Jpn. J. Appl. Phys. **57**, 08RD03 (2018).
[8] T. Nakamura, Ph. D. Thesis.

Quantitative evaluation of thermal runaway tolerance in thin-film solar cells is important for space applications

3. Tolerance of thermal runaway

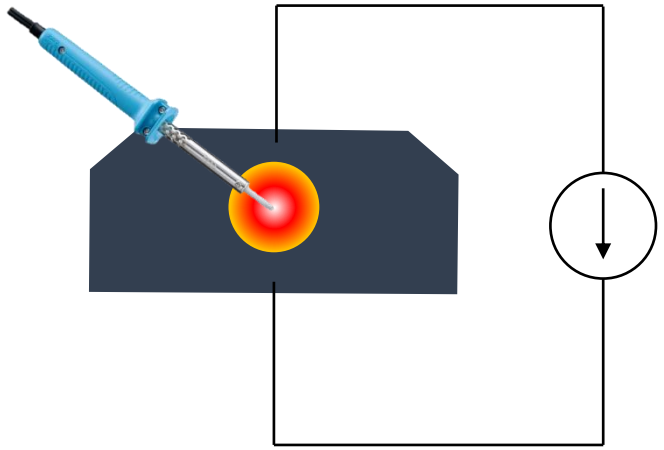


Shunt characteristics
→Create artificial shunt spot

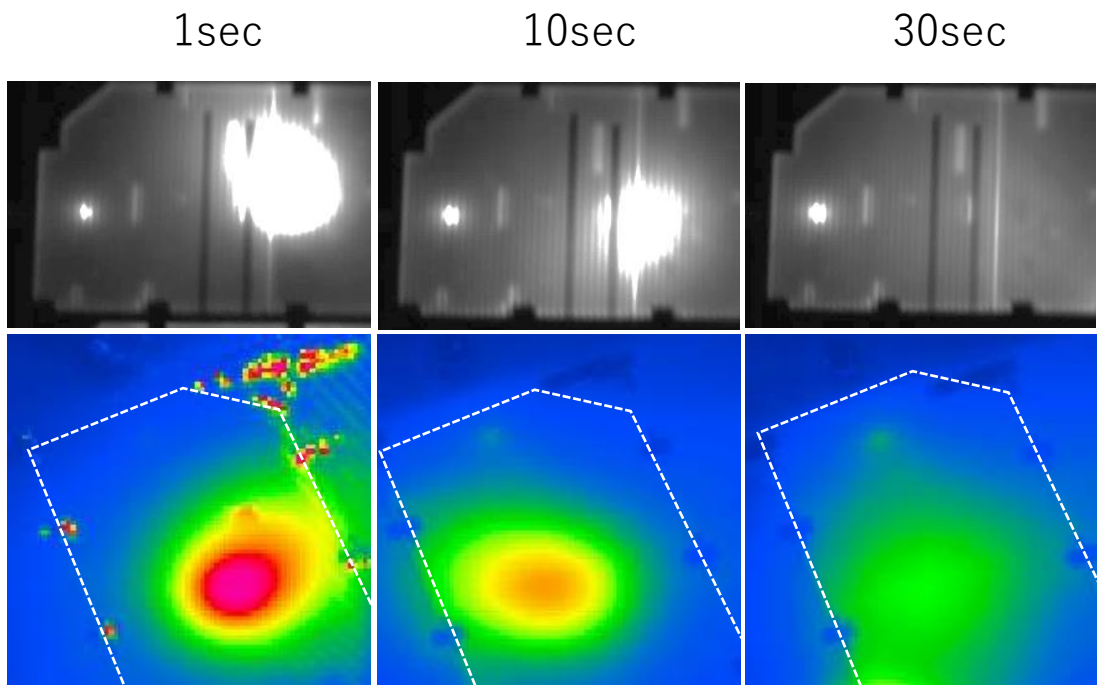
Cell/panel characteristics
→Use coupon panel

Environmental condition
→Simulate environment

3-1. Creation of artificial shunt spot

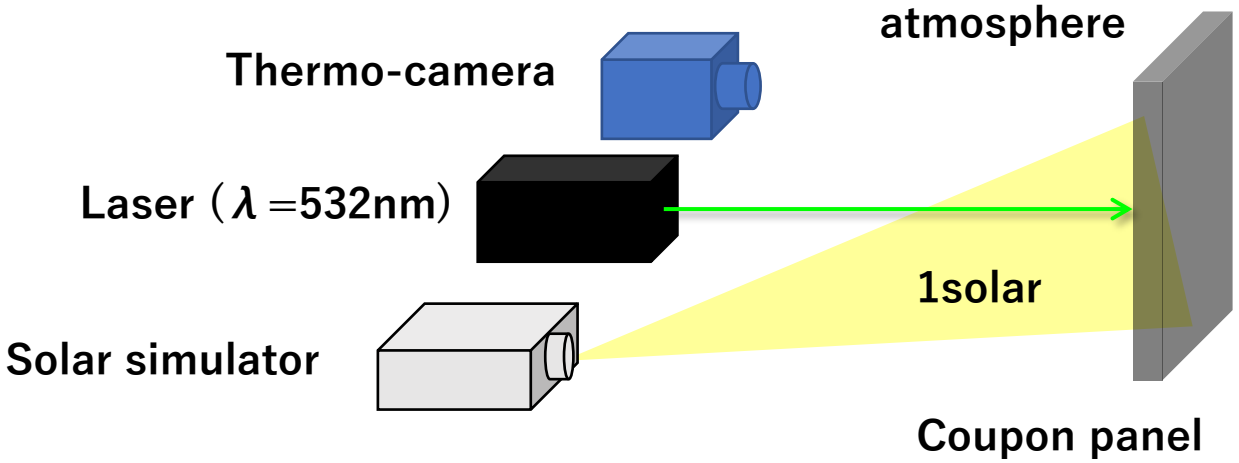


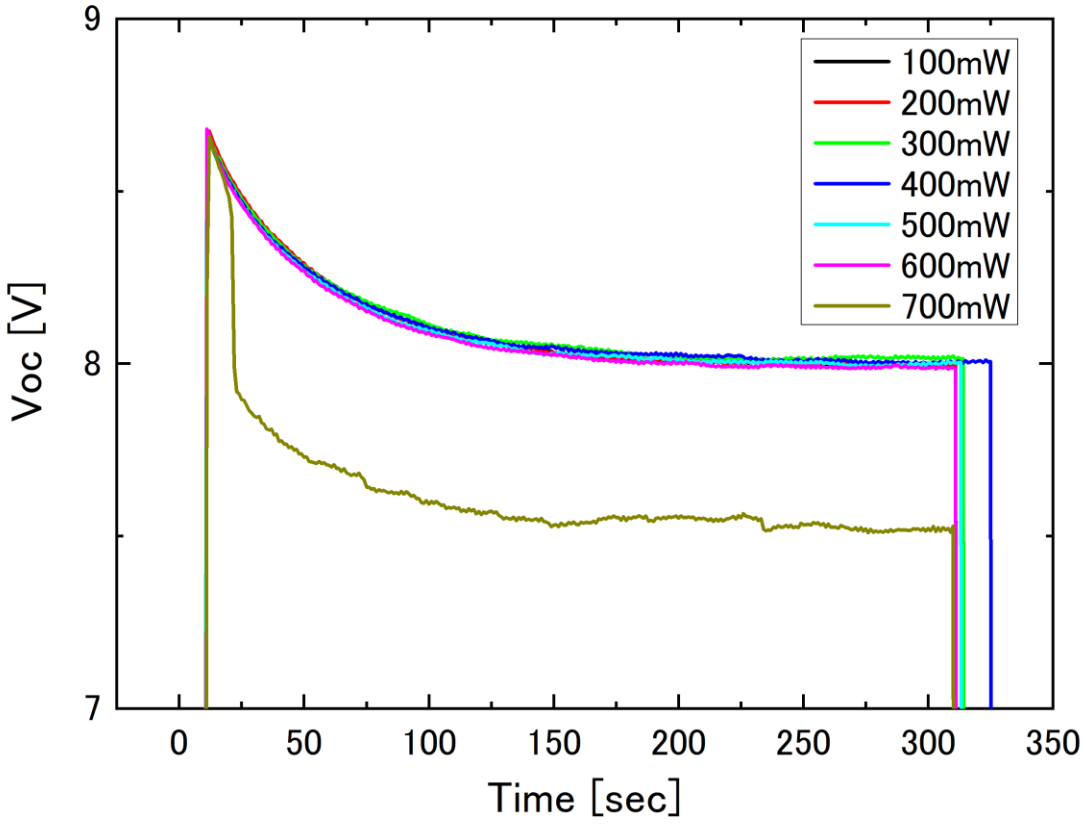
* 0 sec = Remove soldering iron and start current injection



Since high temperature region has low forward voltage, the current concentrated at the hot spot

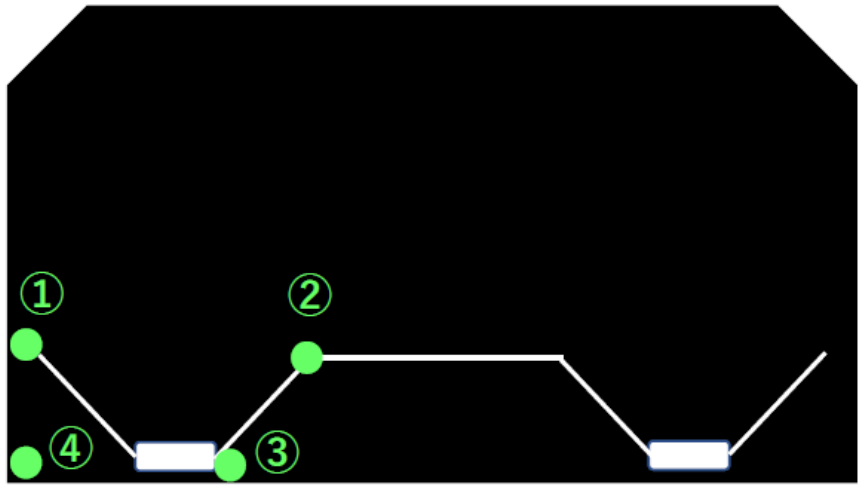
3-1. Creation of artificial shunt spot



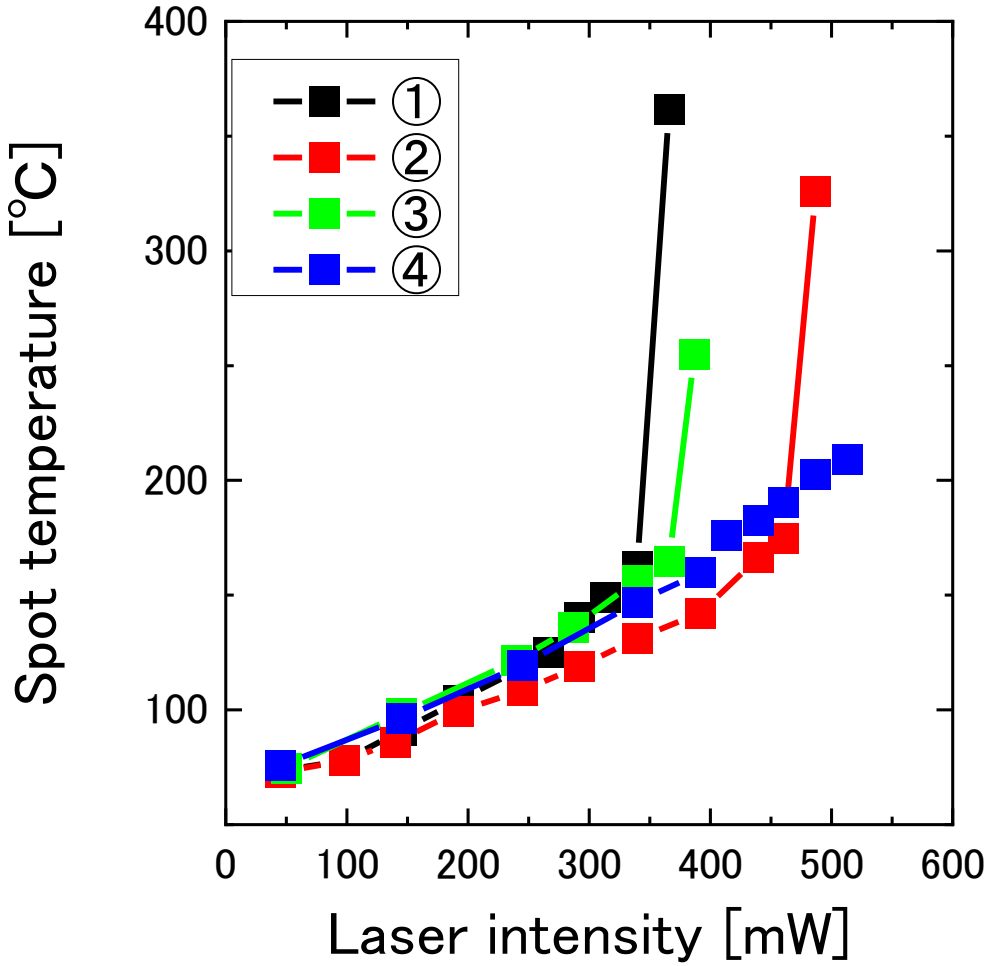


We succeeded in inducing thermal runaway using an artificial shunt spot

3-2. Position of shunt

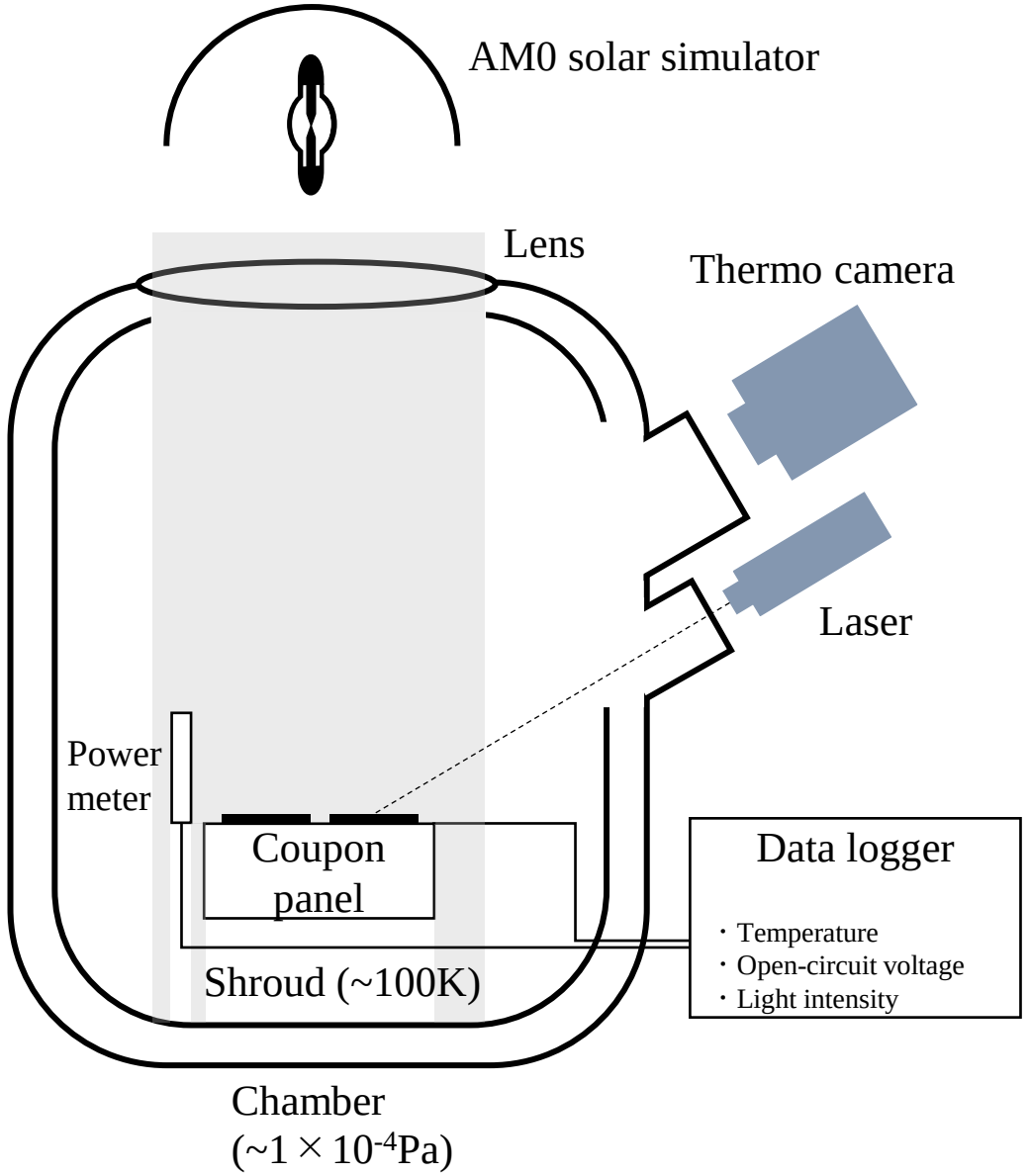


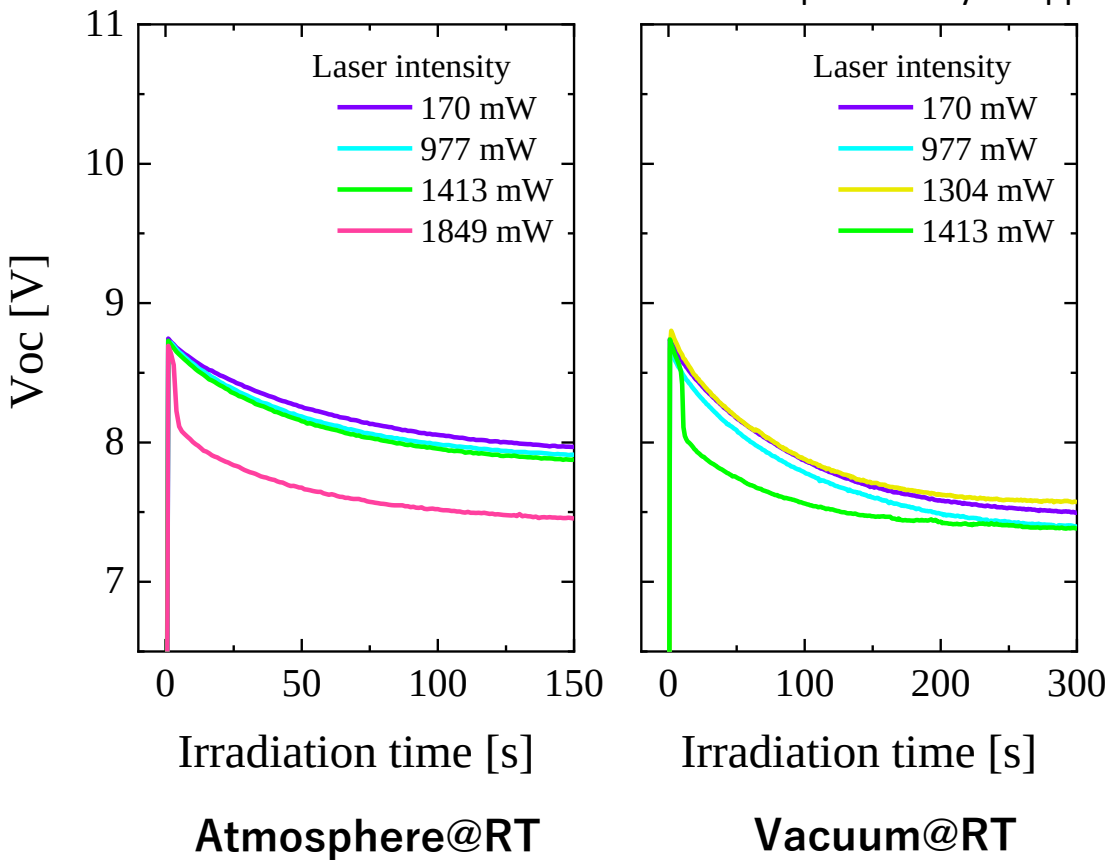
	Electrical resistance	Thermal resistance
①	Low	High
②	Low	Low
③	Low	High
④	High	High



Thermal runaway is easy to occur where the electrical resistance is low and thermal resistance is high

3-3. Vacuum or atmosphere





Thermal runaway occurs more easily in a vacuum environment

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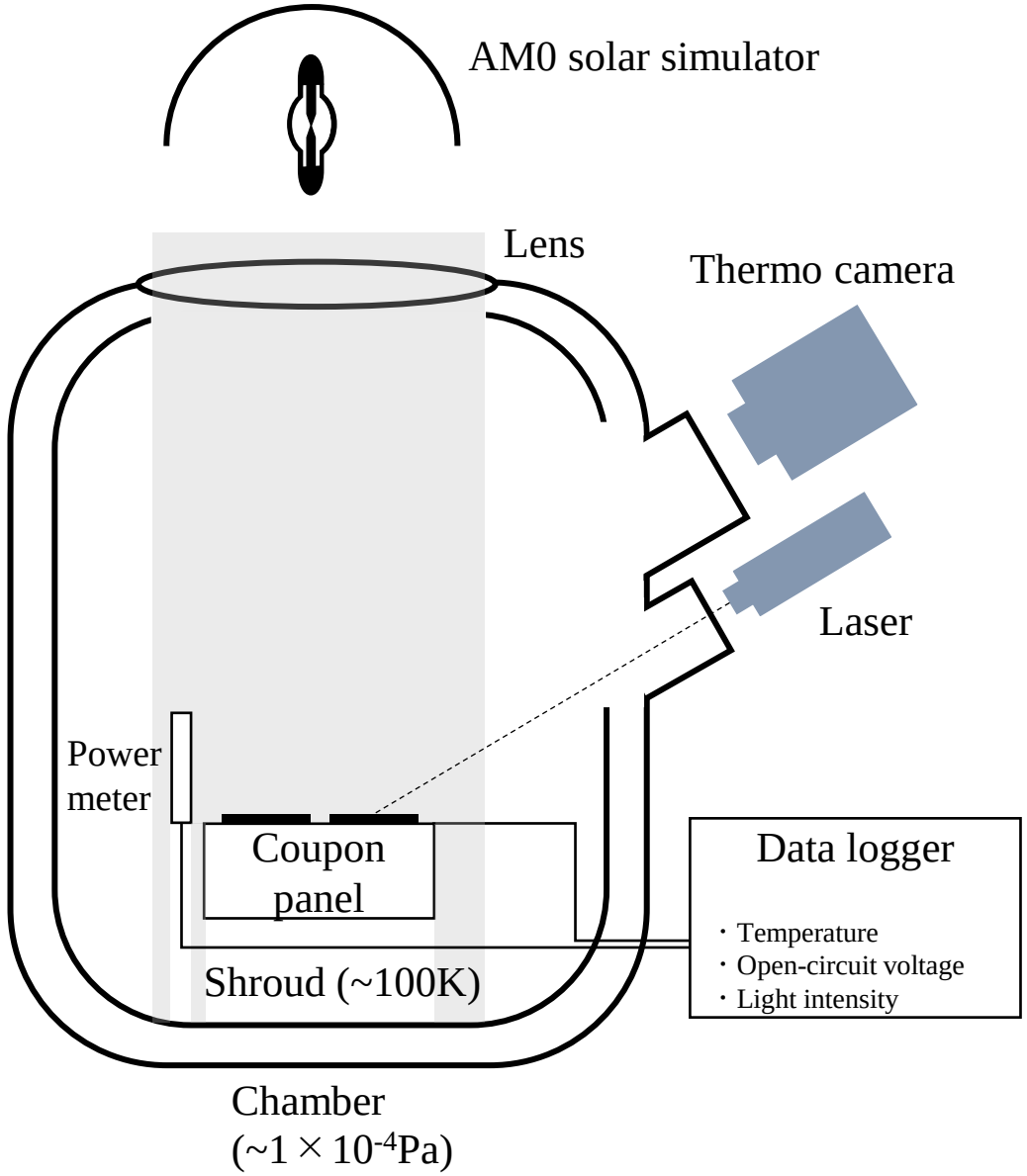
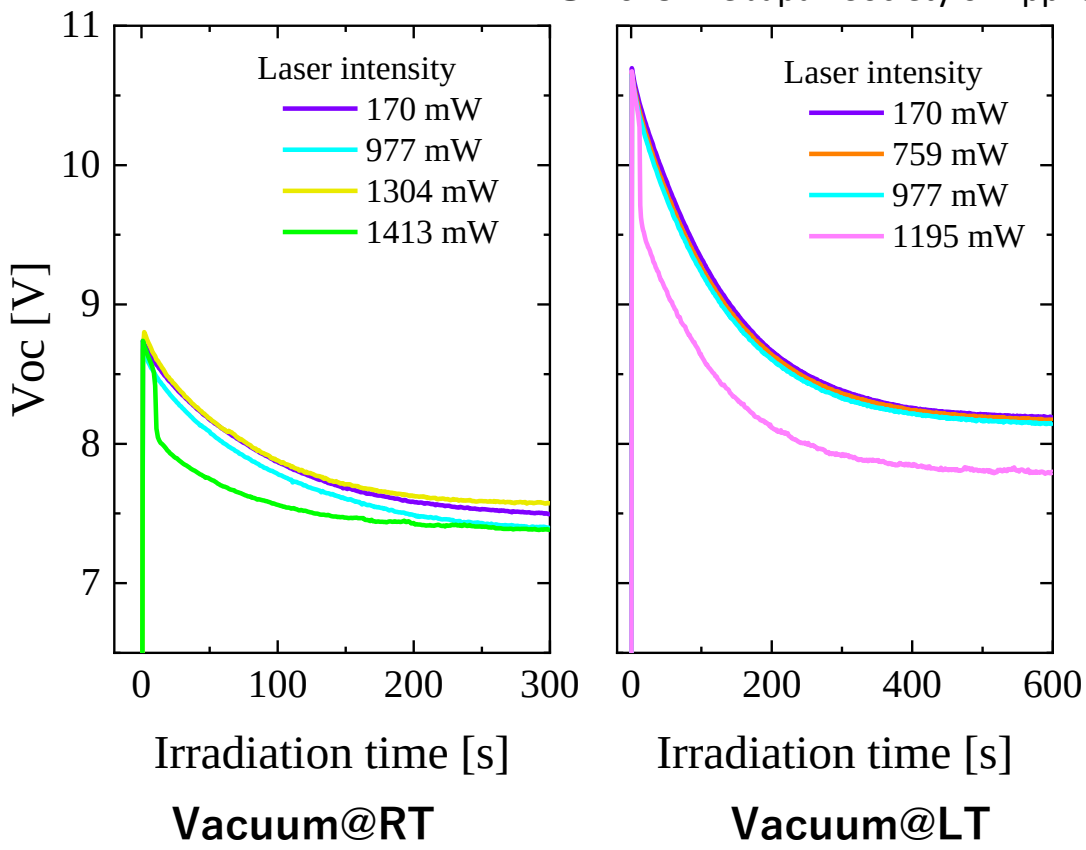
3-4. Temperature dependent





Thermal runaway easily occurs in a low-temperature environment because temperature difference between the shunt spot and non-shunt region increases when light is irradiated at the low-temperature

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4. Conclusion

To prevent thermal runaway of solar cells in orbit…

1. Prepare coupon panel
2. Create artificial shunt spot and investigate weak points of thermal runaway
3. Solar light and laser irradiation test under a simulated actual operating environment
4. Exclude solar cells containing shunt spots where thermal runaway can occur or improve the thermal runaway tolerance