Development of High-Performance Solar Cells for the Jupiter and Saturn Environments

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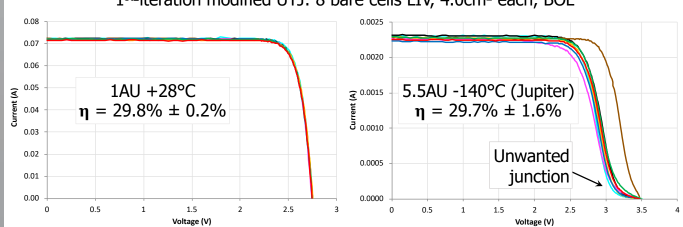
Motivation:

- The planetary science community is interested in targets far from the Sun
- Solar arrays are relatively low-cost, readily available, highly reliable
- However, high-AU environments are challenging for solar arrays e.g.
  Jupiter: high radiation and 3-4% of one sun
  Saturn: milder radiation but only 1% of one sun
- Currently, solar arrays for low irradiance low temperature (LILT) are typically large and massive, e.g. ~600kg for planned Europa Clipper
- **There is a need for cells optimized for Jupiter and/or Saturn**

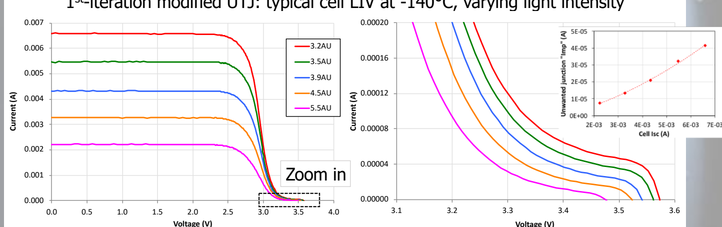
LILT optimization example #1:

- Baseline design: Spectrolab UTJ, cell that is now powering Juno spacecraft
  η = 28% at 1AU 28C (1X = 1367W/m^2), ~30% at 5.5AU -140C (Jupiter);
- 1st design iteration: modified UTJ, changes to epi to increase cell voltage
  LILT only: unwanted reversed junction near Voc in 4th quadrant, limits FF
- Variable irradiance: unwanted junction is photoactive, like a low-Isc cell
- 2nd design iteration: further modified to eliminate problem interface
  This design provides ~17% more power than baseline at Jupiter BOL
- **LILT-only performance issue has been successfully resolved**

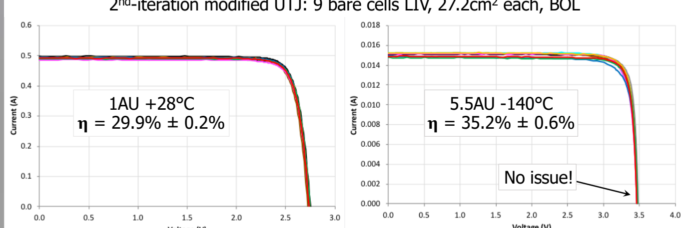
1st-iteration modified UTJ: 8 bare cells LIV, 4.0cm^2 each, BOL



1st-iteration modified UTJ: typical cell LIV at -140°C, varying light intensity



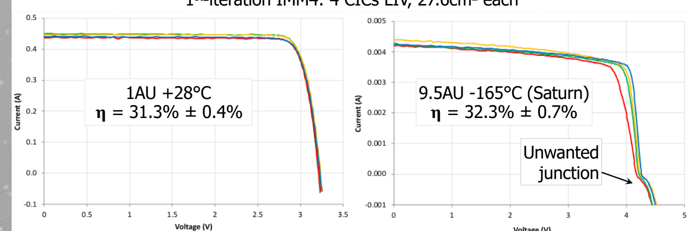
2nd-iteration modified UTJ: 9 bare cells LIV, 27.2cm^2 each, BOL



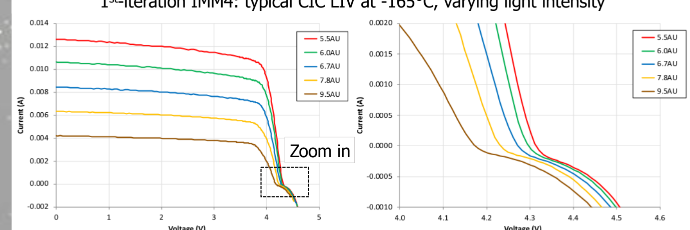
LILT optimization example #2:

- 1st design iteration: SolAero IMM4, advanced cell originally developed for 1AU
  LILT only: unwanted rectifying junction near Voc in 1st quadrant, limits FF
- Variable irradiance: unwanted junction is not photoactive in this case
  Majority-carrier barrier at passivation interface intended for minority carriers
  e.g. BSF, see Hoheisel et al., IEEE JPV 2, 2012; and 42nd IEEE PVSC, 2015
- Also used low-temp IV curve shapes of isotypes to identify unwanted junction
- 2nd design iteration: modifications intended to eliminate problem interface
  This design provides ~7% more power than 1st iteration at Saturn BOL,
  estimated CIC efficiency near-term ~35%, >36% with further modifications
- **LILT-only performance issue has been significantly ameliorated**

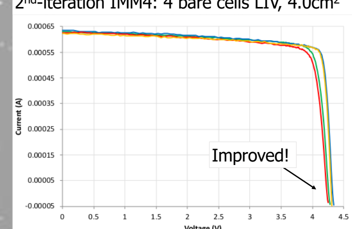
1st-iteration IMM4: 4 CICs LIV, 27.6cm^2 each



1st-iteration IMM4: typical CIC LIV at -165°C, varying light intensity



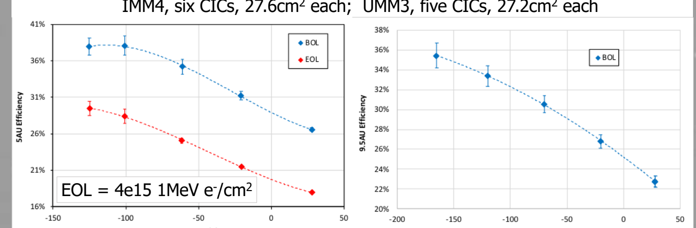
2nd-iteration IMM4: 4 bare cells LIV, 4.0cm^2



High-efficiency cells for Jupiter and Saturn:

- For Jupiter: need superior LILT radiation hardness 3-5e15 1MeV e-/cm^2
  Promising architecture: IMM4 from SolAero
  Efficiency at 5AU -125°C = 37.9% ± 1.2% BOL, 29.5% ± 1% EOL
- For Saturn: immunity from LILT issues as presented in above examples
  Promising architecture: UMM3 from Spectrolab
  Efficiency at 9.5AU -165°C = 35.4% ± 1.2% BOL
- **Applying LILT optimization expected to yield further improvements**

IMM4, six CICs, 27.6cm^2 each; UMM3, five CICs, 27.2cm^2 each



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