Towards Polymer-Free, Femto-Second Laser-Welded Glass/Glass Solar Modules

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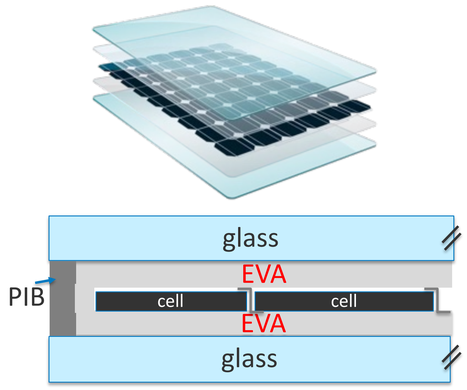
Abstract: This project explores the use of femto-second (fs) lasers to form glass-to-glass welds for hermetically sealed, polymer-free solar modules. Low-iron solar glass coupons were welded together without the use of glass filler using a fs laser with dedicated optics to elongate the focal plane parallel to the incident beam. The resulting welds were then stress tested to failure to reveal the critical stress intensity factor, K_{Ic}. These values were used in a structural mechanics model of a 1 m by 2 m glass/glass module under a simulated static load test. The results show that the fs laser welds are strong enough for a suitably framed module to pass the IEC 61215 static load test with a load of 5400 Pa. Key to this finding is that the module must be framed and braced, and the glass must be ribbed to allow pockets for the cells and welds inside the border of the module. The result is a module design that is completely polymer-free, hermetically sealed, has improved thermal properties, and is easily recycled.[1]

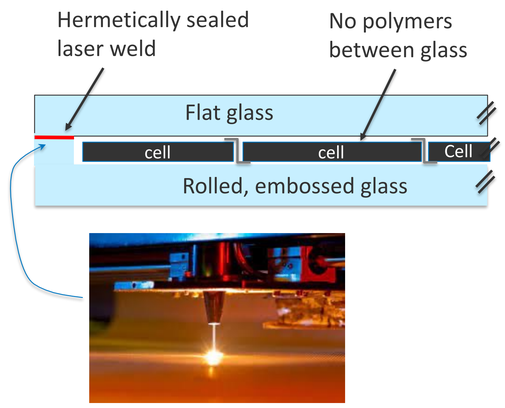
Motivation

Traditional glass/glass module

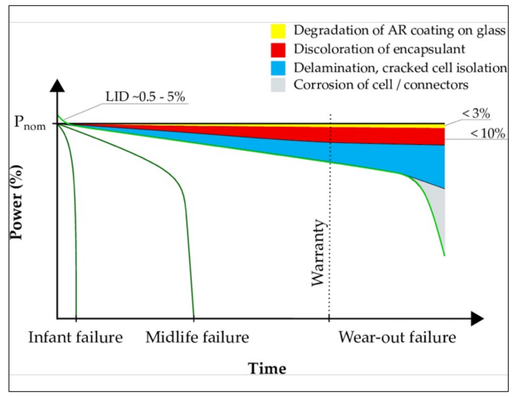


https://www.cleanenergyreviews.info/blog/solar-panel-components-construction

New glass/glass module



Module Degradation Mechanisms



Benefits of the new design:

- No polymer degradation
  - Discoloration
  - Delamination
  - No polymer-related corrosion or PID
- Hermetically sealed module -> no moisture & controlled atm
  - One less barrier for perovskites
- Easily recycled module (glass, metal, semiconductor)
- Potentially less expensive than lamination
  - No polymers and only local heating at the weld
  - Fast sealing times (< 15 mins, current lamination time)
  - Cap Ex ~ laminators
- Potential route to 50-year modules (lower LCOE)
- Better optics with less parasitic absorption -> lower temps

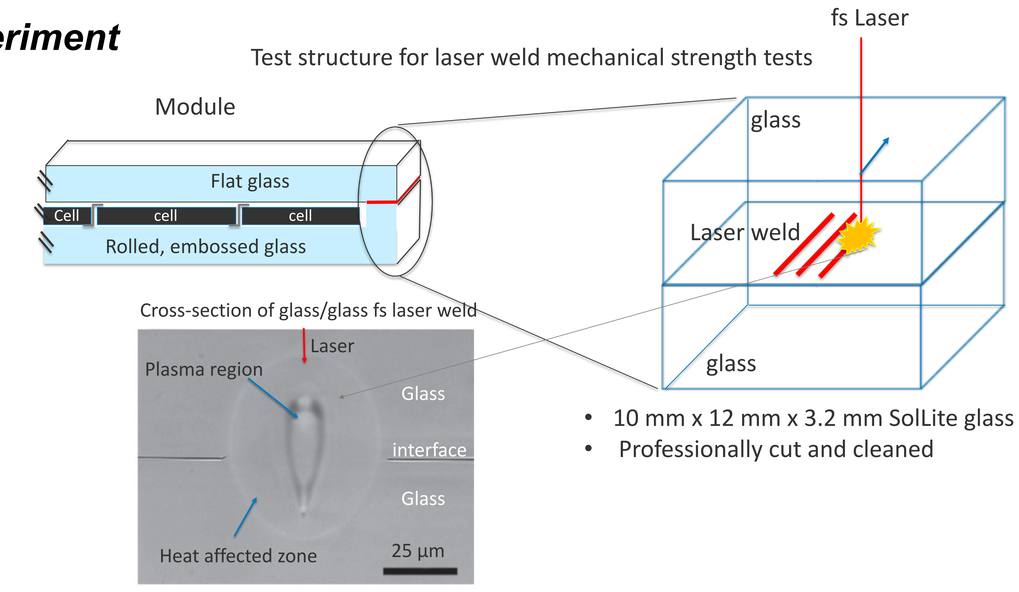
Challenges to new design:

- Strick dimensional tolerance for rolled glass
- Metal/glass feed through (known, but not tested for PV)
- Mechanical strength of glass/glass weld

This work →

Experiment

Test structure for laser weld mechanical strength tests



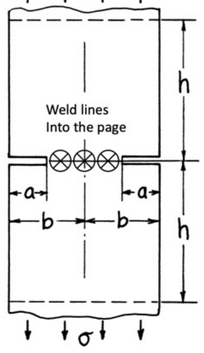
Cross-section of glass/glass fs laser weld

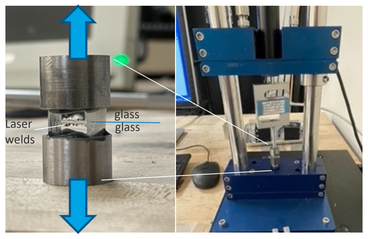
- 10 mm x 12 mm x 3.2 mm SolLite glass
- Professionally cut and cleaned

- Weld is a function of (laser power, pulse length, repetition rate)
- Already used in medical devices and laser head manufacturing

Handbook of Laser Welding Technologies, edited by S. Katayama, Elsevier Science & Technology, 2013.

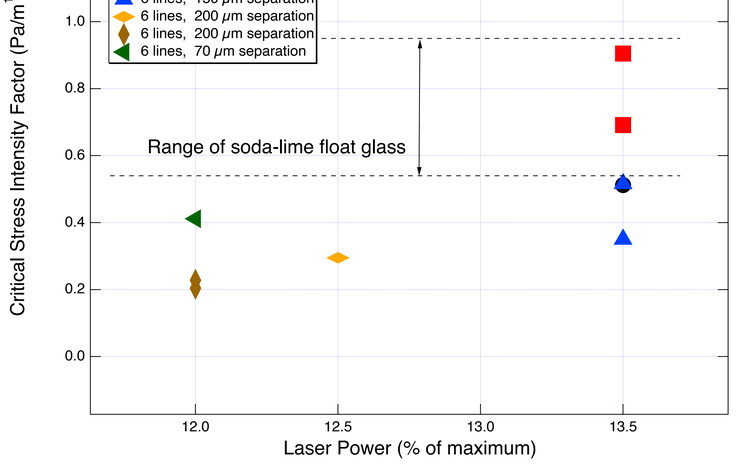
Pull glass until weld fails (measure max force)





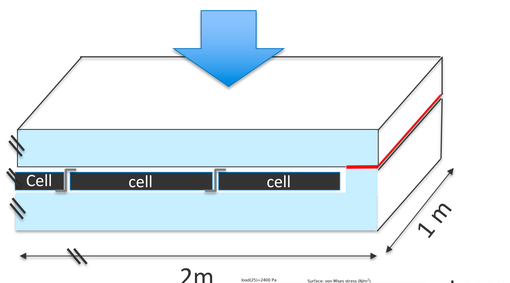
Dynamic Mechanical Analyzer

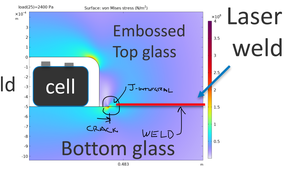
Experimental data



Modeling

5400 Pa uniform pressure
(IEC Static Load Test)

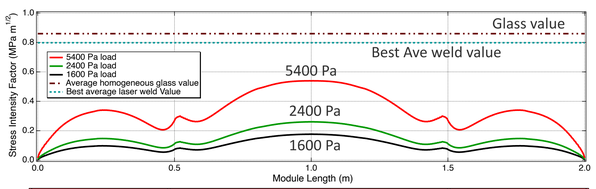


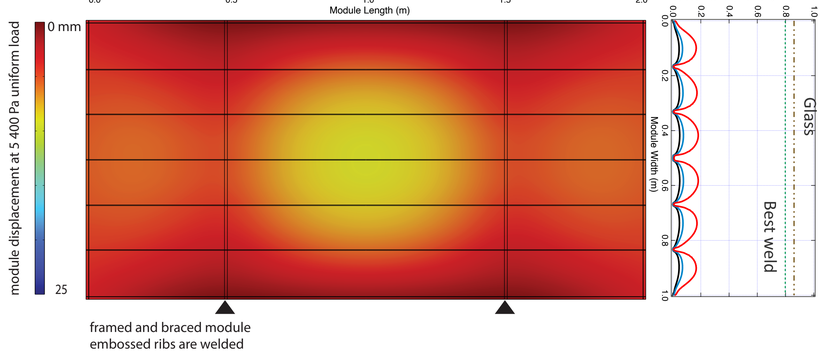


COMSOL model of weld

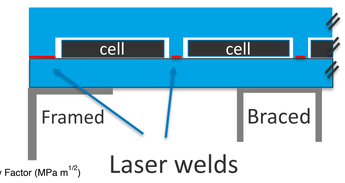
Laser weld

COMSOL module model for static loading





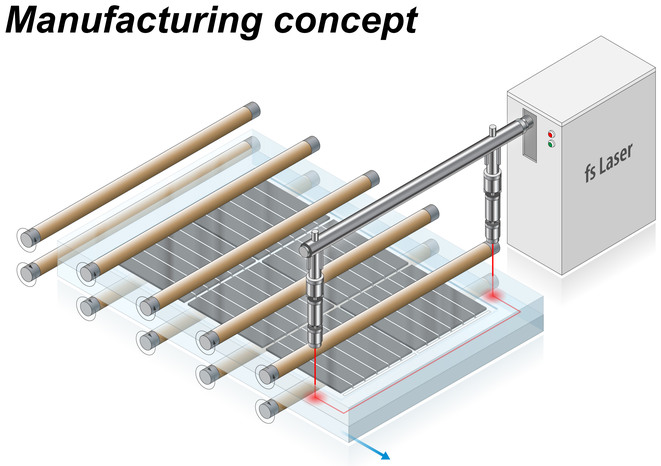
framed and braced module
embossed ribs are welded



Conclusion

Glass/glass fs laser welds are tough enough to withstand the IEC solar panel static load test

Manufacturing concept



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