



Geodesic Dense Receiver Array TPV Program

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Masimo Semiconductor



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- Overview: Wholly Owned subsidiary of Masimo Corp (MASI) with over 30 years experience providing III/V compound semi R&D services
- Services: Foundry services primarily focused upon discrete components or partial processes
- Capabilities: Epitaxial Growth, Wafer Processing, Device Fabrication (GaAs, InP)
- Personnel: Small but highly qualified science & engineering team with application specific skills
- Production: Batch processing....moving toward higher volume production capacity
- IP: Large library of process “know-how” and a strategic manufacturing oriented patent portfolio

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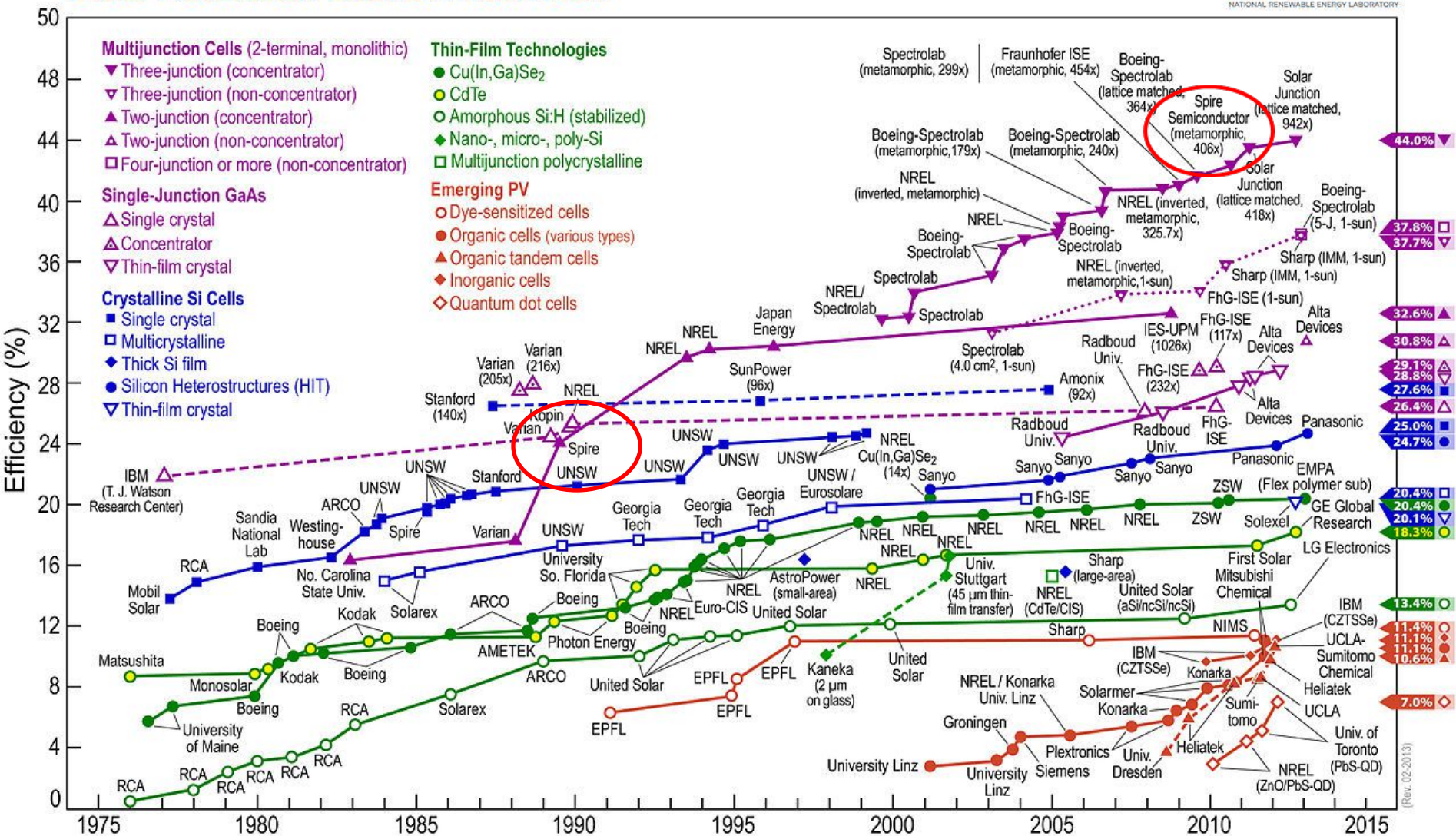
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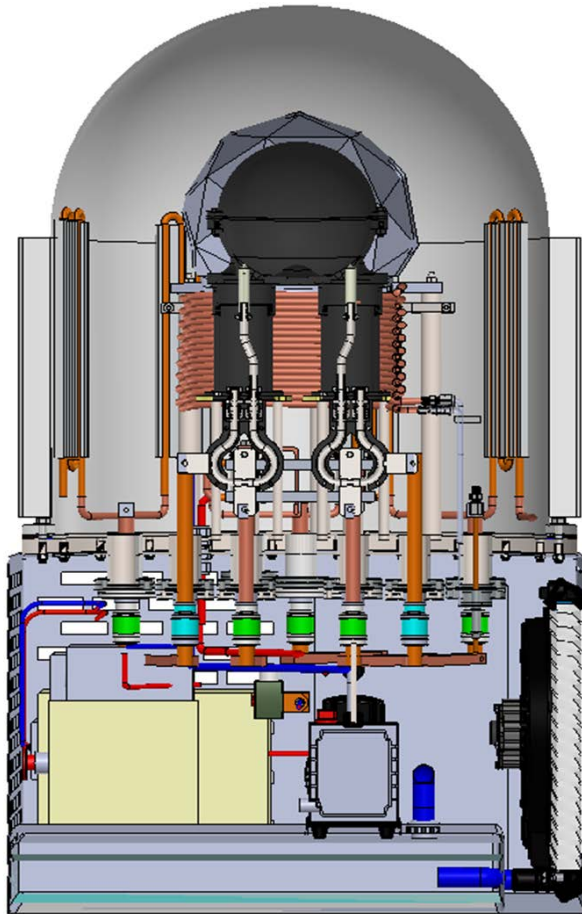


A long PV History

Best Research-Cell Efficiencies



Geodesic Dense Receiver Array (gDRA)



Brilliant Light Power gDRA Prototype

Total Input Power 136.4kW

Tungsten Emitter 3000K

Emitter Radius 3.25 in

Optical Intensity - Dome 184 W/cm²

Optical Intensity - Cell 128.5 W/cm²

TPV Cell (InAlGaAs-InP) 1jct

Operating Temp (Cell) <60C

Total Output Power 15.5kW

Efficiency (gDRA) 11.4%

V_{op} 750V

I_{op} 207A

Coolant Flow ~43 GPM

Coolant Temp Incr. 7.5C

Pressure Drop <1PSI

Brilliant Light Power gDRA Proto - v2

TPV Cell (InAlGaAs-InP) 2jct

Total Output Power 28.5kW

Efficiency (gDRA_J2) 20.9%

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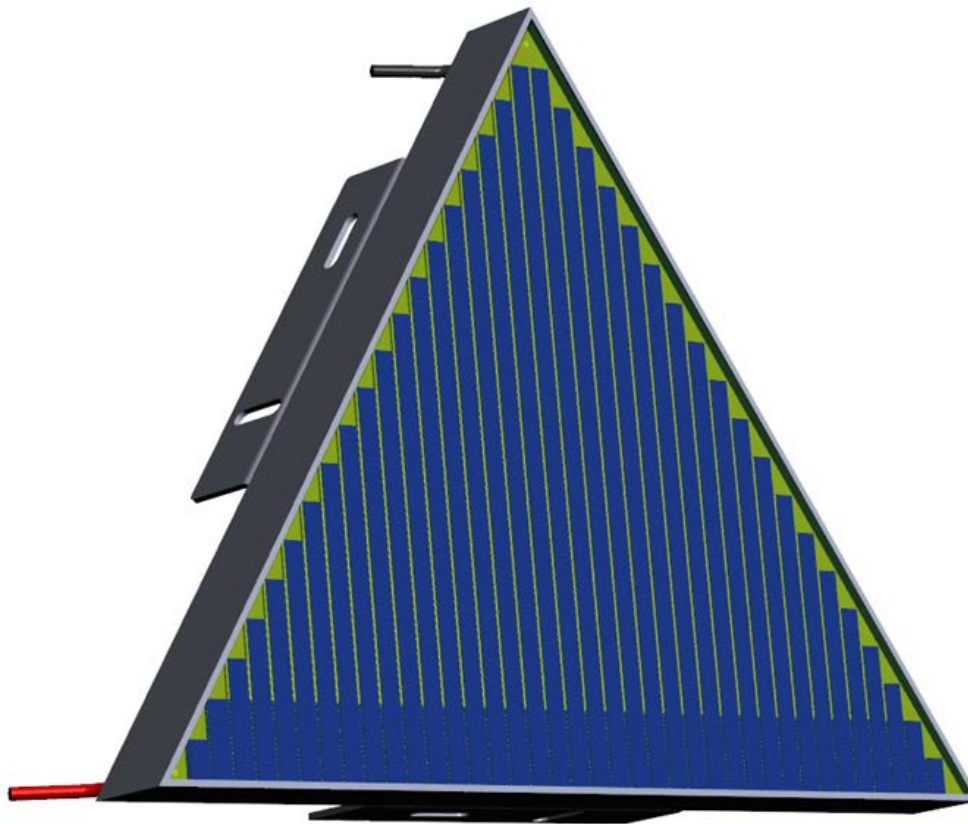
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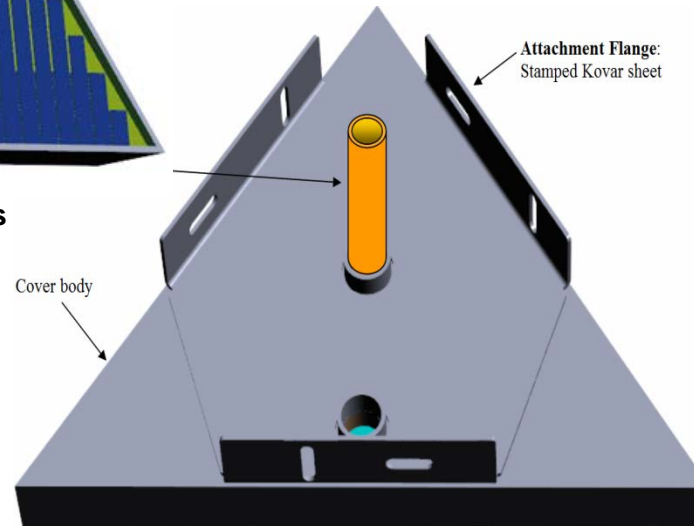
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gDRA - Individual "TRU" (Triangle Receiver Unit)

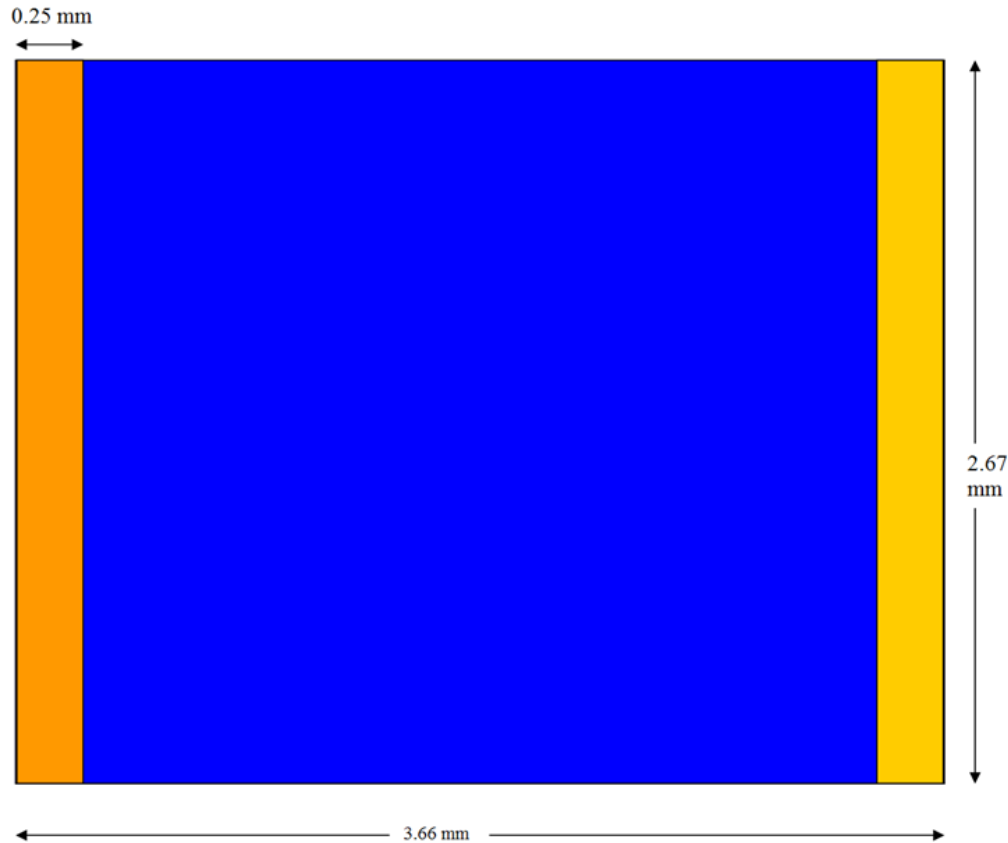


Cells on TRU, Protected by Cover Glass

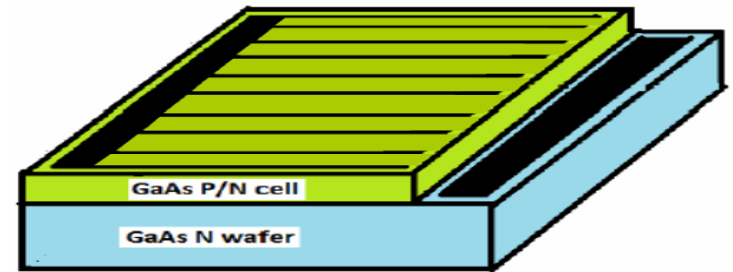


Brilliant Light Power gDRA	"TRU"
Tiles per gDRA	54
Cells per Tile	209
Tile Area	23.1cm ²
Tile Height	5.82cm
Tile Width	7.94cm
Cell Area Coverage	88.5%
Power Output	288 W
Vop	125 V
Iop	2.3 A
Thermal Performance (Vert)	0.05K/W/cm ²
Coolant Port Size	1/4" ID

gDRA – Individual TPV Cells



Cell size that works for both $V_{oc} = 0.74V$ and $V_{oc} = 1.35V$
 Bottom contact on one side, bus bar on the other side



Brilliant Light Power gDRA	"Cells"
Cells per Tile	209
TPV Cell (InAlGaAs-InP)	1jct
Cell Area	0.098cm ²
Cell Height	0.366cm
Cell Width	0.267cm
BusBars	250um
Efficiency (330K)	11.4%
Power Output	1.435W
Voc	0.7V
Vop	0.595V
Isc	2.5A
Iop	2.3A

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TPV Cell - Roadmap

Calculated Efficiency of Cell Technologies

Cell Material		GaAs 1J on GaAs	InAlGaAs 1J on InP	InAlGaAs 2J on InP
Cell Temperature	C	25	25	25
BB Temperature	C	3000	3000	3000
Avg Emissivity		0.39	0.39	0.39
Total Power	W/cm ²	179	179	179
Emission Peak	nm	965	965	965
Cell Length	cm	0.564	0.564	0.564
Cell Width	cm	0.389	0.389	0.389
Cell Area	cm ²	0.219	0.219	0.219
Cell Bandgap	eV	1.42	1.00	1.06/0.75
Cell Cutoff Wavelength	nm	872	1242	1170/1650
Optical Power on Cell	W	39.3	39.3	39.3
Cell Isc	A	3.0	8.8	7.9
Cell Voc	A	1.14	0.75	1.35
Cell FF	%	86%	70%	80%
Cell Output Power	W	2.9	4.6	8.5
Cell Output Power	W/cm ²	13.4	21.1	38.7
Total Efficiency	%	7.5%	11.8%	21.6%

prepared by S. Wojtczuk, Masimo Semiconductor, Hudson, NH, 2 June 2016

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Development Timeline - Prototype

Major Tasks	Weeks	3	4	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	33	37	41	45
1.0 System Input Analysis & POC DRA Design																											
1.1 Optimize gDRA Design for revised 3000C Blackbody Spectrum		○	●																								
1.2 Integrate gDRA with System Interconnects, determin optimal "Halogen" approach		○	●																								
1.3 Provide POC DRA Drawings & Complete Manufacturing Process			○	●																							
2.0 Design, Develop & Manufacture CPV cells																											
2.1 Model & Design Single-Jct GaAs/GaAs based CPV cell			○	●																							
2.2 Model & Design Single-Jct InGaAs/InP based CPV cell			○	●																							
2.3 Design & Procure CPV cell production mask sets			○	●																							
2.4 Epitaxial Growth of CPV wafers			○	●																							
2.5 Fabrication of CPV cells from CPV wafers					○	○	○	●																			
2.6 Testing of CPV cells (1-sun & Concentration AM1.5D measurements)						○	○	●																			
3.0 Manufacture & Integrate Prototype gDRA																											
3.1 Review Prototype gDRA, Create SW Model (w/CFD, Raytrace) - Generate Optimized Mfg Process (D1)				○	○	○	○	○	●																		
3.2 Procure Materials & Design Set-up Tooling / Integration requirements								○	○	○	○	●															
3.3 Develop Baseline Components (Housing, MCC-LCP, ARC/Coverglass, ALN)								○	○	○	○	○	○	●													
3.4 Integration (MCC, AIN-DBC, Housing, Elec. Interconnect, ARC/Coverglass)												○	○	○	○	○	○	○	○	○	○	○	○	○	○	○	○
3.5 Interconnection & manufacture & Test first article J1 Triangle-Receiverlet Unit "TRU" (D2)															○	○	○	○	○	○	○	○	○	○	○	○	○
3.6 Manufacture gDRA Frame & Integrate additional 8 "TRU's" (D3)															○	○	○	○	○	○	○	○	○	○	○	○	○
3.7 Manufacture completed gDRA & Integrate total 60 "TRU's" (D4)																			○	○	○	○	○	○	○	○	○
4.0 Iterate & Optimize POC DRA																											
4.1 Develop & Manufacture Revised Dual - Jct CPV cells																											
4.2 Integration (MCC, AIN-DBC, Housing, Elec. Interconnect, ARC/Coverglass)															○	○	○	○	○	○	○	○	○	○	○	○	○
4.3 Manufacture additional 54 "Tile"Units																									○	○	○
4.4 Manufacture gDRA Frame & Integrate "Tiles"																									○	○	○
4.5 Assemble Second Revision Prototype gDRA_J2																									○	○	○
4.6 Testing of Complete Prototype gDRA_J2 & Report																									○	○	○

- Week 1: July 27, 2016.... Masimo Semi currently under TPV Cell contract and drawings
- Week 10: Oct 19, 2016.....Masimo Semi currently under gDRA prototype development contract
- Week 14: Nov 4, 2016.....1-Junction Cells on GaAs & InP complete
- Week 16: Nov 18, 2016....gDRA Prototype 3-D model complete
- Week 24: Jan 13, 2017....gDRA Prototype (1-J) Single TRU complete
- Week 28: Feb 17, 2017.... 2-Junction Cells on GaAs or InP complete (requires contract)
- Week 40: May 7, 2017....gDRA Prototype (2-Junction Cells) complete (requires contract)

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Thank You



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