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Performance Improvements in Microsystems Enabled Photovoltaics with Wider Acceptance Angles

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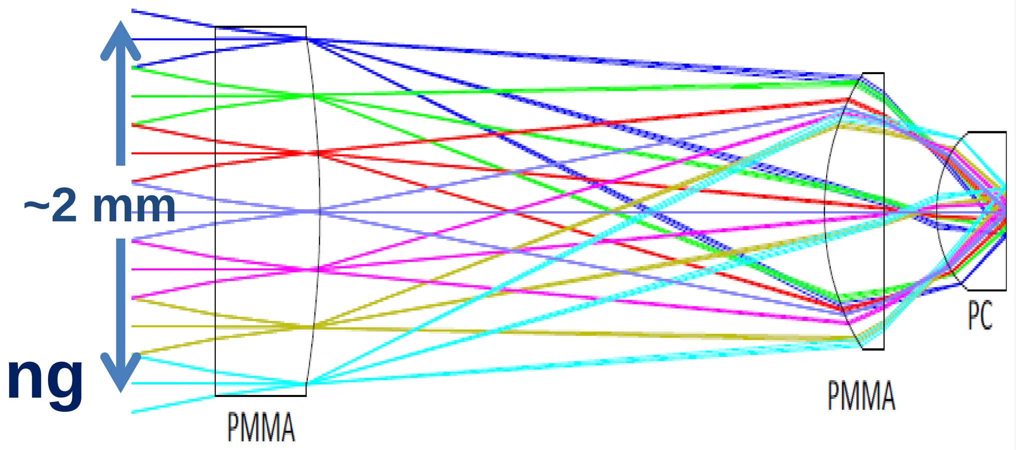
MEPV uses micro-scale pixelated ~100s µm wide cells

Advantages

- Improved cell performance
- Better thermal management
- Thin module form factors
- Improved robustness to partial shading
- Wider acceptance angles



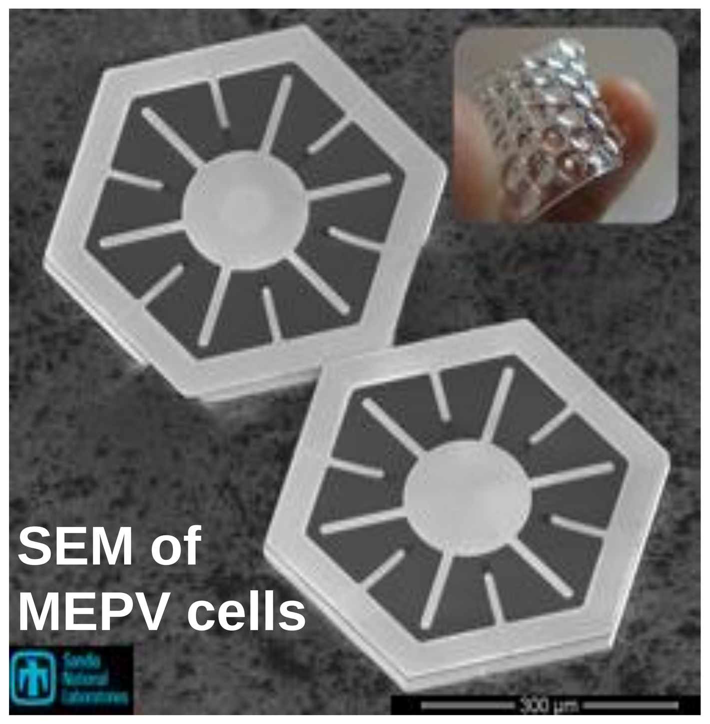
Example optical concentrator design

Challenge

- Current optics concentrates direct radiation
- Most diffuse radiation is lost

Approach

- Investigate radiation within small fields of view (<±10°)
- Calculate potential performance improvement with wider acceptance angles



Effect of Atmospheric Variables on Solar Spectra

NREL SMARTS 2.9.2 Model used assuming cloudless conditions.

Major input variables

- Aerosol Optical Depth (AOD)
- Precipitable Water (PW)
- Elevation
- Air mass (AM)

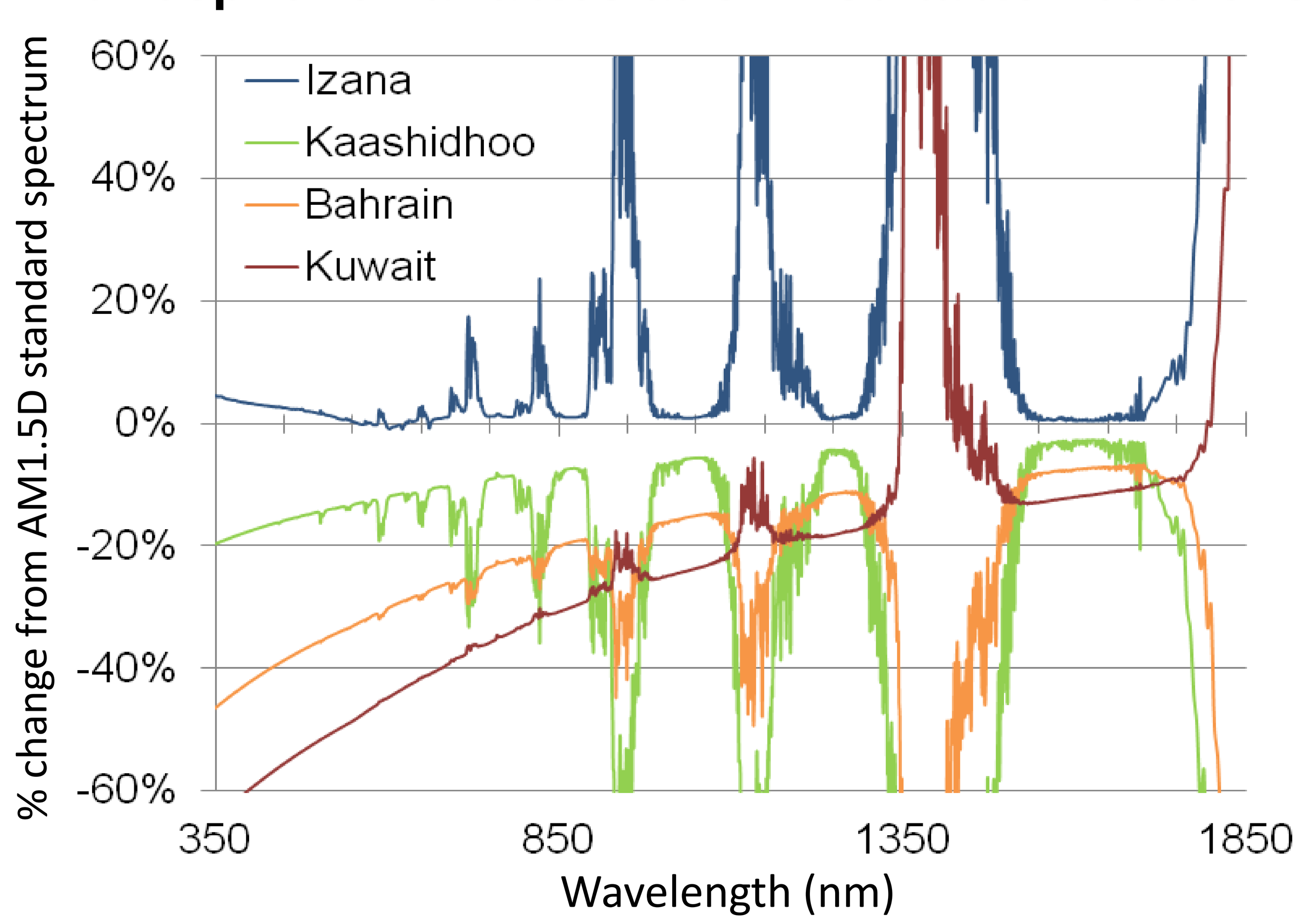
Location	Elevation (m)	Annual Average AOD	Annual Average PW (cm)	Annual Average Daily DNI (kWh/m^2-day)
Izana, Spain	2391	0.057	0.43	6.80
Sevilleta, USA	1477	0.076	0.98	6.72
Kaashidhoo, Maldives	0	0.192	4.29	5.79
Bahrain	25	0.388	1.93	6.50
Kuwait	42	0.588	1.27	6.33

Atmospheric Variables at CPV Suitable Locations

It is observed that there is considerable variation in all of the important parameters at the CPV suitable locations.

From a comparison of the spectra at a few locations to the standard ASTM-G173 AM1.5D spectra we see that:

- PW mainly affects the spectra in specific absorption windows.
- AOD affects the entire spectra, esp. the shorter wavelengths.



Percentage change in solar radiation from the base case of ASTM-G173 AM1.5D to the typical spectra at various locations

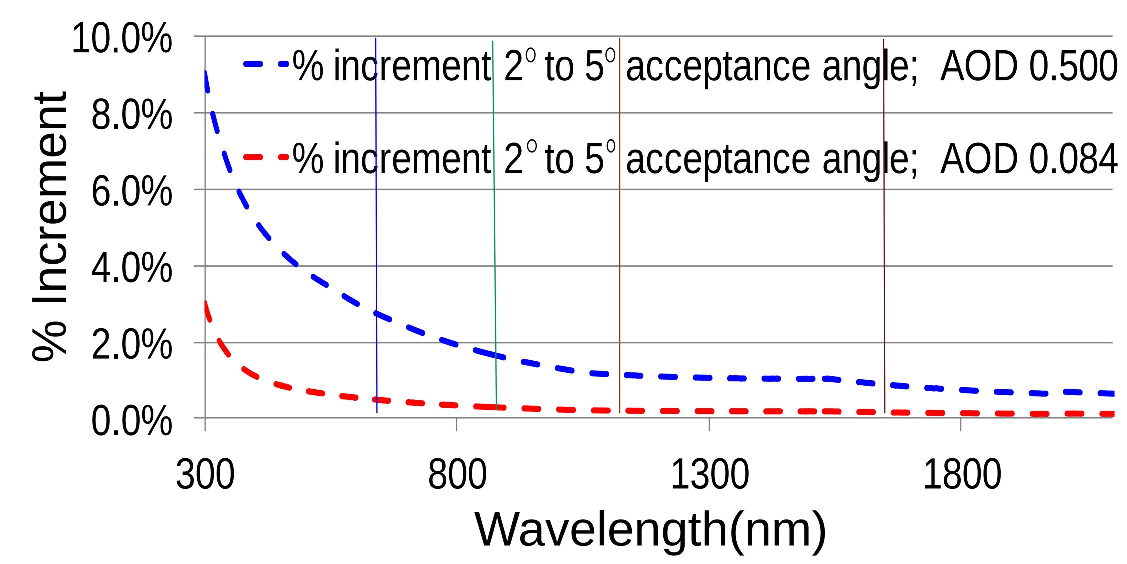
Effect of Acceptance Angles on Solar Spectra

Integrated Incident Power per unit area in 300nm to 1700nm

PW	AM	2°, AOD 0.084, Elevation 0m: Intensity (W/m^2)	5°, AOD 0.084, Elevation 0m: % Increase	2°, AOD 0.500, Elevation 0m: Intensity (W/m^2)	5°, AOD 0.500, Elevation 0m: % Increase	2°, AOD 0.084, Elevation 1500m: Intensity (W/m^2)	5°, AOD 0.084, Elevation 1500m: % Increase	2°, AOD 0.500, Elevation 1500m: Intensity (W/m^2)	5°, AOD 0.500, Elevation 1500m: % Increase
0.470	1.0	966	0.24	739	1.22	982	0.24	750	1.22
	2.0	813	0.44	495	2.15	836	0.44	506	2.16
	3.0	701	0.62	349	2.89	726	0.62	358	2.92
1.416	1.0	931	0.25	708	1.24	947	0.24	720	1.24
	2.0	774	0.46	466	2.20	796	0.42	477	2.21
	3.0	659	0.64	323	2.97	684	0.64	332	2.99
4.250	1.0	884	0.25	669	1.27	901	0.25	681	1.27
	2.0	723	0.47	429	2.26	746	0.47	440	2.27
	3.0	607	0.66	291	3.05	632	0.66	300	3.08

Impact of *increasing the acceptance angle* is more pronounced at:

- *higher AOD* as there is more diffuse light due to the increased scattering caused by the larger aerosol content.
- *higher AM* as the fraction of diffuse radiation is larger due to the increased scattering during the longer path.
- *shorter wavelengths* – indicating that there is a significant increase in scattering with decreasing wavelength within the narrow cone angles around the solar disk.



% Increment in irradiance from 2° to 5° acceptance angle at AM2.0, PW 1.4164

Annual Energy Production

- Solar Spectra used to compute efficiencies for a 4-cell multi-junction cell.
- Efficiency results are utilized to calculate the annual average energy produced at different latitudes under the various atmospheric conditions.

PW	Latitude	2°, AOD 0.084, Elevation 0m: Energy (kWh/m^2)	5°, AOD 0.084, Elevation 0m: % Inc.	2°, AOD 0.500, Elevation 0m: Energy (kWh/m^2)	5°, AOD 0.500, Elevation 0m: % Inc.	2°, AOD 0.084, Elevation 1500m: Energy (kWh/m^2)	5°, AOD 0.084, Elevation 1500m: % Inc.	2°, AOD 0.500, Elevation 1500m: Energy (kWh/m^2)	5°, AOD 0.500, Elevation 1500m: % Inc.
0.470	5° N/S	2057	0.39	1331	1.85	2104	0.39	1356	1.85
	50° N/S	1720	0.49	1009	2.19	1767	0.49	1029	2.21
1.416	5° N/S	1966	0.40	1264	1.88	2014	0.40	1289	1.88
	50° N/S	1635	0.50	951	2.23	1682	0.49	972	2.24
4.250	5° N/S	1848	0.41	1178	1.92	1896	0.40	1203	1.92
	50° N/S	1526	0.51	879	2.28	1573	0.50	900	2.29

Conclusion: Performance improvement of ~0.4-2.3% is possible by increasing acceptance angle from 2° to 5°.

Acknowledgement

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