Ray Tracing modelling of reflector for vertical bifacial panel

Jakobsen, Michael Linde; Thorsteinsson, Sune; Poulsen, Peter Behrensdorff; Rødder, Peter Melchior; Rødder, Kristin

Publication date:
2016

Document Version
Publisher's PDF, also known as Version of record

Citation (APA):
Jakobsen, M. L., Thorsteinsson, S., Poulsen, P. B., Rødder, P. M., & Rødder, K. (2016). Ray Tracing modelling of reflector for vertical bifacial panel. Poster session presented at 32nd European Photovoltaic Solar Energy Conference and Exhibition, Munich, Germany.

Ray Tracing modelling of reflector for vertical bifacial panel

M. L. Jacobsen[1], S. Thorsteinsson[1], P. B. Poulsen[1*], P. M. Rødder[2], K. Rødder[2]

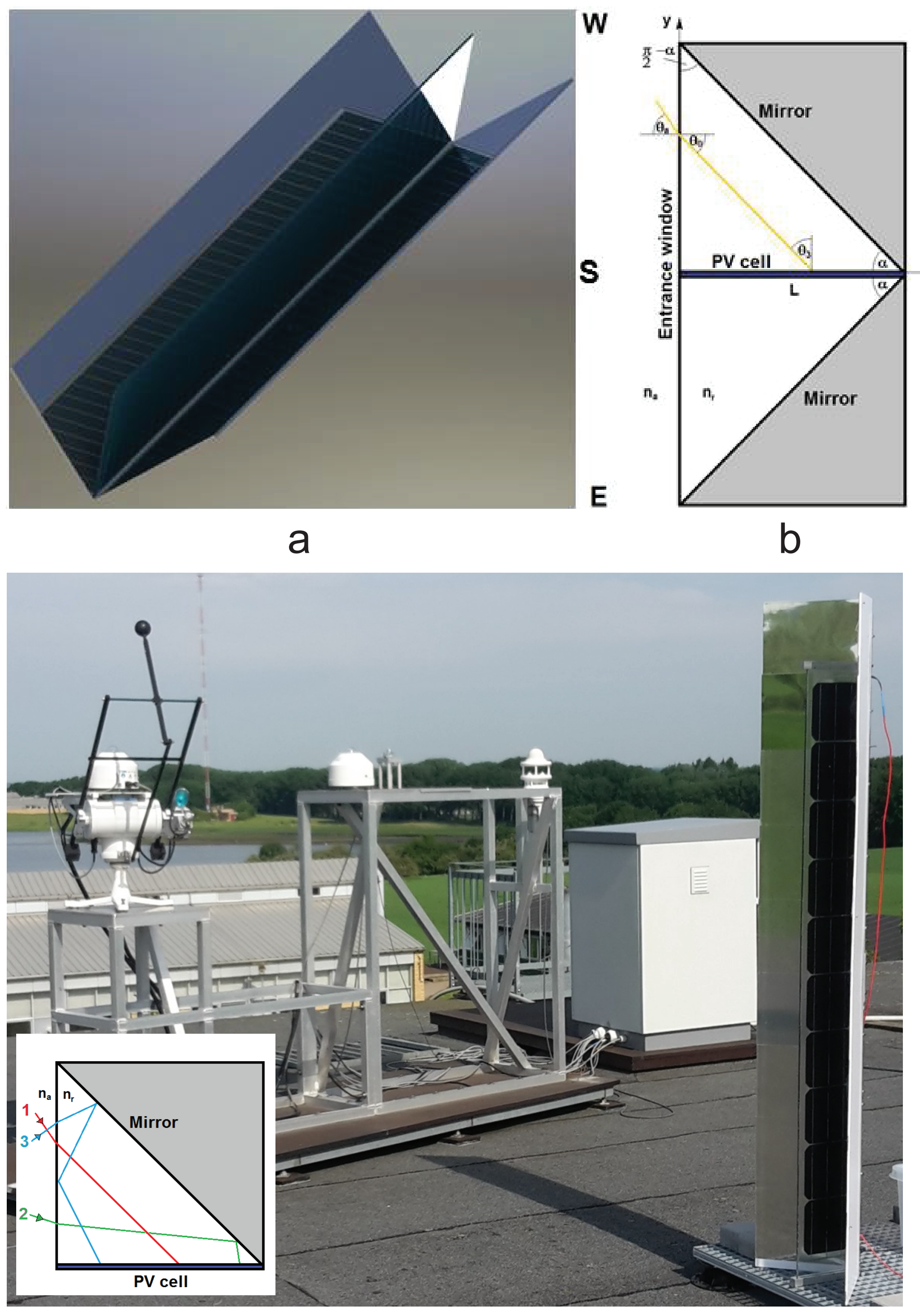
[1] Department of Photonics Engineering, Technical University of Denmark, Frederiksborgvej 399, Building 130, 4000 Roskilde, Denmark
[2] SolarLab, 8260 Viby J., Denmark
[*] Contact: Phone +45 21325110; E-mail: ppou@fotonik.dtu.dk

Motivation

Bifacial solar cell modules can provide a price advantage in production relative to normal solar cell modules if the effective light collecting area can become twice the area of a normal single-sided solar cell module of the same size. This can only be achieved by designing an adequate reflector. Particularly, a design which is optimized for local winter conditions has our highest priority.

We use ray-tracing models to optimize the interaction between the vertical bifacial solar cell module and vertical reflector designs and compare its performance with a almost reaches our ultimate goal of 2. single-sided PV-cell of same size. In case the bifacial PV cell could be unfolded the light collecting area and the power gain would be twice the reference.

In this work, we investigate the impact of the reflector volume, being filled with a refractive medium, and shows that the relative power gain



a b

c d

Fig.1 (a). The bifacial solar cell and its two reflectors are illustrated in a 3D plot. The corresponding horizontal profile is illustrated in (b). In (c) the three ray models, which are included in the model, are illustrated. The three colors mark the same contributions in Fig.3. In (d) the experimental solar device is illustrated.

The model

The vertical reflector consists of two mirrors mounted at ±45 deg. relative to the x-axis. The bifacial PV cell coincides with the x-axis, and all three components meet at x = L. As illustrated in Fig. 1a and Fig. 1b, the PV cell and the reflectors are surrounded by air with a refractive index of (n_a). The cavity between the mirrors contains either air or a transparent medium with a refractive index of n_r. The path of the incoming light is modelled by three ray paths, as it can be seen in Fig. 1c. Direct incidence of light onto the PV cell is modelled by the red line. Light reflected once at the mirror and then incident onto the PV cell is modelled by the green line. Light reflected once at the mirror, and again at the entrance window/interface – if a medium is present - is modelled by the blue line.

These results include Fresnel losses at dielectric interfaces, material absorption due to propagation in the dielectric medium and reflection at the mirrors. However, the sun model does not include diffuse light and we assume that the sun intensity is constant as long it is above the horizon.

The results

In Fig. 2 and Fig. 3 the individual ray contributions are plotted as a function of azimuth angle of the incoming light when air ($n_r = n_a$) or acrylic (n_r = 1.49) is present in the retroreflector, respectively. The blue line contributes with zero power when air is present in the cavity.

For the reflection coefficient for the mirrors is set to 95%. The absorption coefficient for acrylic are set to 0.3 m^{-1}.

The table to the right lists the relative power gains modelled at four locations of different latitudes, and modelled for a day in the summer (23/6) and a day in the winter (21/12). The first numbers in the tables are for air between the mirrors, while the second numbers are for acrylic in between the mirrors.

Software from Zemax is used for the ray trace modelling.

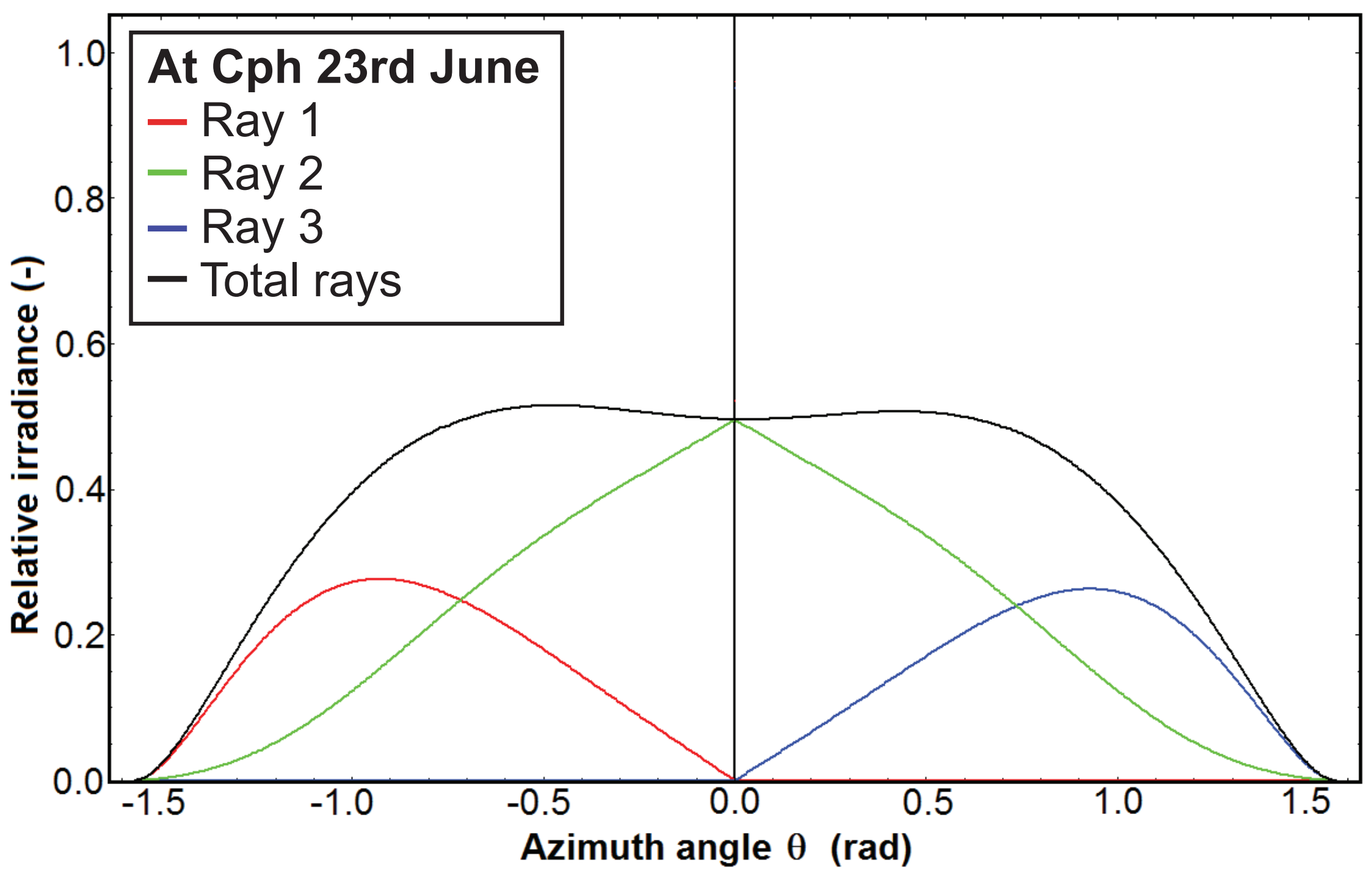


Fig. 3. The simulated relative irradiance the bifacial PV-cell and reflector when filled with acrylic (nr = 1.49), obtained on a summer day in Copenhagen

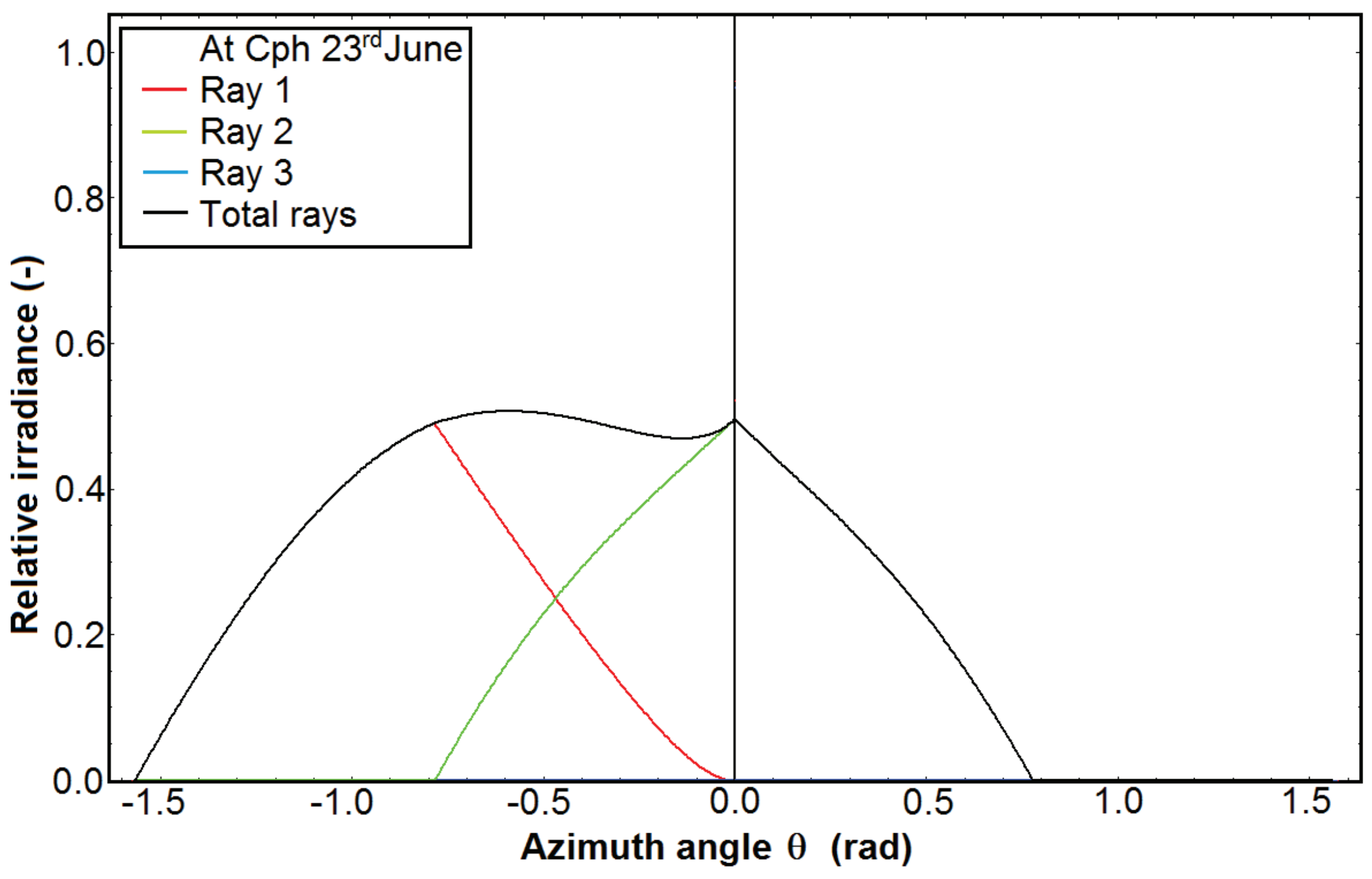


Fig. 2. The simulated relative irradiance for one half of the bifacial PV-cell and reflector. (nr = na), obtained on a summer day in Copenhagen

Latitude	Power Gain December air/acrylic	Power Gain June air/acrylic
Trondheim (64°)	1.61 / 1.91	1.36 / 1.92
Copenhagen (56°)	1.45 / 1.91	1.35 / 1.92
Münich (48°)	1.39 / 1.91	1.33 / 1.92
Rome (42°)	1.38 / 1.92	1.35 / 1.92

Conclusion

An optical raytracing model has been introduced to the bifacial PV-cell mounted inside a reflector. We demonstrate that relative to a single-sided PV cell of the same size we can obtain a relative power gain of at least 1.9 at any latitude with the bifacial PV design.

Outlook

The model will be developed further in the near future, to include diffuse light, realistic sun data (see Fig.1d) and different reflector configurations.

This research is funded by the Danish Energy Agency within the EUDP programme with the project journal number 64014-0508 “SENSORPOWER – Bifacial PV Energy Reflector Tower”.