$$EF_{tot} = \frac{\int_1^{365}\int_0^{24} A_{avg,enh}\ \mathrm{d}t_{LT}\ \mathrm{d}t_{day}}{\int_1^{365}\int_0^{24} A_{avg,Bare}\ \mathrm{d}t_{LT}\ \mathrm{d}t_{day}}. \tag{8}$$

This means that even the total enhancement factor EF_{tot} is slightly increased for the Penrose tiling. Even though the enhancement factor for the square lattice reaches a value of 16.6 around noon during summer, the total enhancement factor of the Penrose tiling is slightly larger due to the more constant values during the course of the day as well as over the year.

4. Conclusion

We have calculated the absorbance spectra for different polar and azimuthal angles for thin-film silicon solar cells. Absorption enhancement compared to the bare silicon-on-insulator substrate was reached by introducing a layer of gold disks placed on top of the Si layer in a 2D quasiperiodic as well as a 2D periodic fashion. The calculated absorbance spectra are based on a Fano model with fitting parameters obtained from fits to the normal incidence S-matrix simulations. We have shown that the structure with the Penrose tiling is much more isotropic than that with the square lattice and also excites much more waveguide modes for absorbance spectra dependent on the azimuthal angle as well as the angle of incidence. This leads to a more constant enhancement factor throughout the day as well as over the year. The variation during summertime ranges between 15.8 and 16.2 for the quasiperiodic lattice, even in the morning and evening hours, whereas the value changes between 15.4 and 16.6 for the periodic lattice. In the quasicrystalline case, this range is valid between the beginning of March and the mid of October, at least for local times between 10:30 a.m. and 2:30 p.m. In contrast, the enhancement factor varies for the square lattice during the same period of time between 15.5 and 16.6. Additionally, the total enhancement factor is slightly larger for the quasiperiodic lattice. Therefore, the performance of the solar cell with a quasicrystalline arrangement is expected to be more stable than that with a periodic arrangement. In particular, during morning and evening hours the Penrose lattice provides higher enhancement. This is desirable as energy consumption is highest at that time. Also, a more evenly distributed solar power feed is beneficial for the stability of the electric grid. The purpose of this paper was to predict the absorption enhancement of a quasiperiodic compared to a periodic solar cell. However, the design of the solar cell can still be optimized and the predictions should be verified by experiments, what has to be done for future research. A higher density of the plasmonic disks, i.e., a smaller period, shifts all waveguide modes to higher energies. In a thicker Si layer more waveguide modes are expected for both structural arrangements.

Acknowledgments

The authors thank S. Hein for help with graphical visualizations. This work was financially supported by Deutsche Forschungsgemeinschaft (Open Access Publishing, SPP1391, and FOR557), by Baden-Württemberg Stiftung, and by BMBF (13N9155 and 13N10146).