Postdoctoral position (12 months) @ PROMES-CNRS laboratory

Optical design, simulation and optimization of thin film architectures by evolutionary algorithms for solar thermal energy applications

Context and motivations

Solar thermal technologies rely on the collection of the solar radiation to generate heat (by heating a fluid) that can be used for domestic, residential and industrial purposes. If solar irradiance is concentrated using mirrors, this heat can in turn be used to produce electricity via a turbine. These technologies call for optically efficient components with complex and sometimes conflicting optical behaviors. In particular, the solar receiver should be highly absorbing in the solar range (0.28 – 4 µm) to harvest as much solar radiation as possible, but also lowly emissive in the infrared range (1 – 50 µm) to limit radiative thermal losses. This spectral selectivity can be achieved using multilayered coating architectures, associating lowly emissive (e.g. metals) and highly absorptive materials (e.g. dielectric/ metal/dielectric multilayers or metal-ceramic composites), that need to be optically designed and optimized in terms of layer thicknesses and compositions, to guarantee their high optical performance. A judicious preselection of materials is also paramount, as the solar receivers should also be resistant to harsh operating conditions such as high temperatures, high solar irradiation, oxidant and erosive atmospheres and high thermomechanical stress for long durations, while remaining optically efficient.

Moreover, the hybridization of photovoltaic (PV) and concentrated solar thermal (CST) technologies takes advantage of the low cost of PV electrical production and the thermal storage of CST to address the intermittency of the solar resource, producing electricity and heat on demand. A solution for PV/CST hybridization is the “PV mirror” configuration, where PV cells are installed on concentrators to produce electricity, and thermal absorbers are placed at their focus to produce heat (that can be used as such or converted into electricity). This configuration relies on spectrally selective mirror coatings deposited on the PV cells, playing the role of transparent antireflective layer for the cell where the latter is the most efficient (e.g. 0.4 – 1.1 µm for Si) and selective mirror reflecting the remaining solar irradiation towards the CST receiver (e.g. 0.28 – 0.4 µm and 1.1 – 4 µm). The CST receiver selective coating can also be readapted to better absorb the truncated solar spectrum.

PROMES-CNRS laboratory specializes in the development of theoretical and experimental solutions for concentrated solar thermal technologies, on all levels. PROMES has been developing solar selective absorber coatings for more than 10 years (LabEx SOLSTICE www.labex-solstice.fr research topic “Plasma coatings for CSP and Hybrid CSP plants”, ANR projects ASTORIX and NANOPLAST nanoplast-project.cnrs.fr), including: i) their optical design and optimization with an in-house code called COPS (Solar Performance Optimization Code) based on the calculation of Fresnel coefficients from spectral refractive indices and the transfer matrix method, coupled with natural optimization strategies (A. Grosjean, PhD thesis [1]); ii) their plasma synthesis, characterization and aging assessment [2]. More recently, PROMES has also started a study on selective mirrors (SelHySol PhD thesis and project Région Occitanie/Univ. Perpignan, with financial support from LabEx Solstice), using a new and improved version of the COPS software deployed on Python by A. Grosjean and based on a differential evolution optimization algorithm developed at Clermont Auvergne University for photonic structures [3]. A new dedicated 24-core dual processor server is now implemented for even faster calculation.

Description of the expected work

- Contribute to the critical literature review on candidate materials and COPS refractive index database existing at PROMES, to enlarge the selection of potential materials to be investigated by optical modeling for CST applications
- Further investigate and fine tune the parametrization of COPS evolutionary optimization algorithms for specific and complex thin film architectures intended for energy applications (PV mirrors, selective absorbers for solar thermal and concentrated solar thermal, silverless mirrors, low-e coatings, etc.) and compare them with other optimization algorithms
- Investigate the influence of the physical parameters of the problem (nature and order of thin layers, cut-off wavelength(s) for the selective behavior, light incidence angle, performance criteria, etc.)
- Investigate the optimization of coating solutions considering the optical behavior of experimentally synthesized materials at PROMES lab (NANOPLAST and SelHySol projects) in collaboration with a research engineer and a PhD candidate
- Contribute to COPS deployment by updating the project on GitHub, making code improvements, creating a user-friendly GUI, adding new functionalities such as solving 2D/3D Maxwell equations
- Share and communicate the work carried out: write reports and scientific articles, present in project meetings and at national and international conferences

Funding (pending)	The quality of the candidate will be evaluated by LabEx SOLSTICE steering committee before granting the postdoctoral funding. The salary will depend on the level of experience.
Prerequisites	A knowledge of optics, photonics, materials science and/or algorithmics, as well as a basic knowledge of Python or similar programming language, will be strongly appreciated. The knowledge of French would be more practical but is not mandatory.
Location	PROMES-CNRS laboratory, Perpignan or Odeillo (66) (location is negotiable) www.promes.cnrs.fr
Contacts	Please send CV, list of publications and motivation letter to: A. Soum-Glaude (Research Engineer, PROMES) Audrey.Soum-Glaude@promes.cnrs.fr A. Grosjean (Assistant Professor, EPF Montpellier) antoine.grosjean@epf.fr

References

[1] A. Grosjean, Etude, modélisation et optimisation de surfaces fonctionnelles pour les collecteurs solaires thermiques à concentration, PhD thesis, Université de Perpignan, 2018. http://theses.fr/2018PERP0002.

[2] A. Diop, D. Ngoue, A. Mahammou, B. Diallo, B. Plujat, A. Bousquet, T. Sauvage, S. Quoizola, M. Richard-Plouet, J. Hamon, A. Soum-Glaude, É. Tomasella, L. Thomas, Comprehensive study of WSiC:H coatings synthesized by microwave-assisted RF reactive sputtering, Surface and Coatings Technology. 459 (2023) 129408. https://doi.org/10.1016/j.surfcoat.2023.129408.

[3] P. Bennet, Optimisation numérique des structures photoniques, PhD thesis, Université Clermont Auvergne, 2022. https://theses.hal.science/tel-04061844.