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The development of thin film solar cells is highly accelerated by using rigorous optimization approach. A large set of parameters is involved in the solar cell operation: active layer thickness, composition, bandgap, doping, contacts, etc. The study of the solar cell performances with respect to these linked parameters is necessary to better understand the underlying physics and to optimize the final device. We propose in this paper presentation (*) a new open-source solar cell optimizer: SLALOM for SolAr Cell multivariate Optimizer. SLALOM implements, for the first time for solar cells, a rigorous multivariate approach while the standard optimization work used to use the one-by-one parameter procedure. SLALOM is implemented to be easily extended to any simulator, the core code itself does not depend on any particular engine. It can be adapted for any solar cell structure, runs locally or remotely on a calculation server, using the SSH protocol and includes a graphical user interface to real-time monitor the optimization. Two study cases, InGaN and CZTS solar cells, are presented to show the SLALOM ability to become a useful tool for the development of novel solar cells.

(*) Article independently submitted to EPI Photovoltaics

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**SLALOM: principle, implementation and application to InGaN and CZTS solar cells**

**CLASSICAL OPTIMIZATION METHOD: THE PARAMETRIC ANALYSIS**

- **Solar cell Parameters** ($P_{o}, P_{d}, \ldots, P_{n}$, $P_{v}$)
- Equation: $P_{o} = (P_{n} - P_{d}) / (1 + R_{s} P_{d})$
- **Simulation**
- **Efficiency**
- **Procedure**

**SLALOM: RIGOROUS OPTIMIZATION METHOD**

- **InGaN cell multivariate Optimizer**
- Uses state-of-the-art mathematical optimization algorithms to find the parameter set that yields the optimal solar cell efficiency
- Takes the interdependence between the parameters into account
- Minimizes the computing time, compared to the classical method
- **Procedure**
- Defining a set of parameters pertaining to the solar cell operation (e.g., composition, doping concentrations, layers thickness...)
- Using a semiconductor simulation engine that allows the numerical evaluation of the solar cell efficiency from its parameters (cf figure)
- Using a mathematical algorithm designed to find the parameter vector that maximizes the efficiency using a numerical iterative procedure

**SLALOM: IMPLEMENTATION**

- **Linux Remote Server**
  - **Server**
  - **Client**
- **Linux Optimization**
  - **Server**
  - **Client**

**APPLICATION TO INGAN AND CZTS SOLAR CELLS**

InGaN and CZTS solar cells optimized using Slalom®

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**OPTIMIZATION OF INGAN BASED SOLAR CELLS**

Optimization of the InGAN solar cell determined by SLALOM using the L-BFGS-B and SlupS methods: both methods converge to the same optimal parameters in about two hours for L-BFGS-B and one hour for SlupS in a Red Hat Linux server with two 2-core Xeon processors and 32 GB of RAM. The InGAN simulation files for Slalom® are included in the SLALOM distribution.

The optimal parameter set gives an efficiency of around 18%, a short-circuit current of 20.3 mA/cm$^2$, an open-circuit voltage of 0.85 V and a fill factor of 78%, obtained for the following set of values: $e$-Payer thickness of 0.05 μm, n-Slayer thickness of 1 μm, n-Payer doping of 10$^{15}$ cm$^{-3}$, an n-layer doping of 10$^{17}$ cm$^{-3}$ and an InN composition of 56%.

Current-voltage characteristic of the InGAN solar cell at the optimum:

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**OPTIMIZATION OF CZTS BASED SOLAR CELLS**

Copper Zinc Tin Selenide CuZnSnSe$_{4}$ (CZTS): abundance of elements and high photocurrent performances.

The CZTS simulation files for Slalom® are included in the SLALOM distribution.

The set of parameters chosen to be optimized is the CZTS absorber doping and thickness. The other data used in the simulation, such as the CZTS bandgap, mobilities and absorption coefficient and the CZS layer parameters, are fixed to their experimentally known values.

Optimal efficiency found by SLALOM: 20.5 % for a CZTS thickness of 1.3 μm and a doping concentration of 1.4×10$^{17}$ cm$^{-3}$.

Efficiency is higher than the InGAN solar cell efficiency, showing the potential of this alternative material for photovoltaics.

The optimization duration was about three hours, more than ten times faster than rough parametric analysis.

Current-voltage characteristics for the optimal efficiency: