SimuLEDView

Visualization Tool for the SimuLED Software Package

User Manual

Version 4.12

User Support: SimuLED-support@str-soft.com
Software Sales: STR-sales@str-soft.com
Phone: +7 812 320 4390 Fax: +7 812 326 6194
STR Group Ltd. www.str-soft.com
Engels av. 27, P.O. Box 89, 194156, St. Petersburg, Russia

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1 Introduction

SimuLEDView is a visualization module supplied with **SimuLED** software package. It provides visualization of the current spreading and heat transfer computations made by **SpeCLED** and ray tracing computations made by **RATRO**.

2 Getting Started

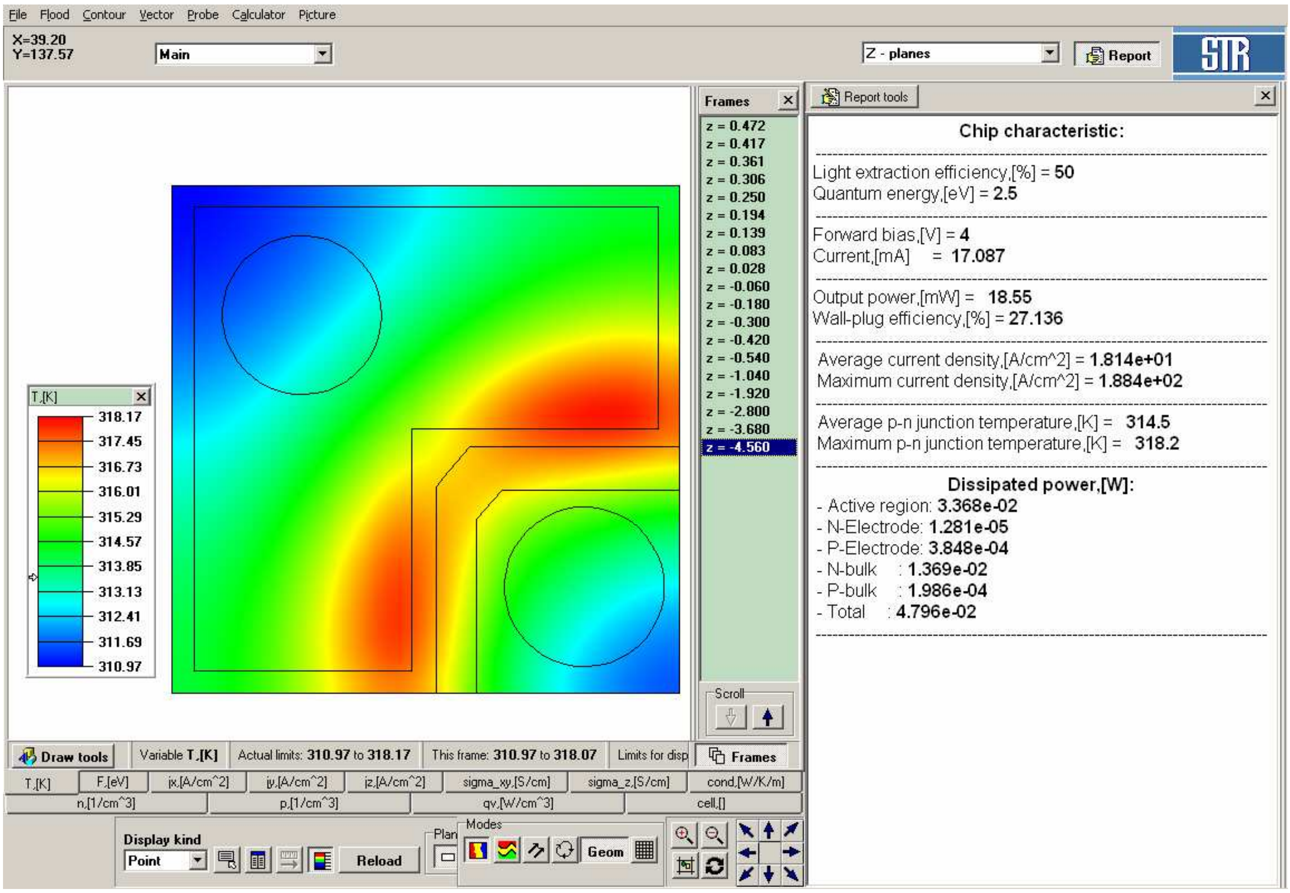


Fig. 1

Results generated by **SpeCLED** program are organized in three main parts:

- A set of integral quantities calculated for the whole chip. This information is presented in the *Report* section available on pressing the ***Report*** button at the right hand side of the window. If several files with the same chip at different biases are loaded, the integral characteristics can also be plotted as functions of bias using the ***Integral*** menu item

- 2D distributions across the active region of heterostructure and a set of planar horizontal die cross-sections. This is presented in the main graphics window of the **SimuLEDView** in the *Main* mode.
- 1D plots of the integral characteristics calculated for the whole chip, such as emission spectrum. This is presented in the main graphics window of the **SimuLEDView** in the *Spectrum* mode. Selection of the graphics window mode is available using a combo box on top of the graphics window at the left hand side.

Results generated by **RATRO** program are organized as follows:

- Integral quantities calculated for the whole chip, namely top and bottom extraction coefficients. This information is presented in the *Report* section.
- 2D distributions across
    - ✓ the top and bottom surfaces of the sphere of a given radius (far-field region) and
    - ✓ all surfaces of the chip (near-field region).
- Radiation patterns computed for the far-field region. They are available using the *Radiation Pattern* item of the *Probe* menu.
- 3D visualization of light intensity distributions for near-field emission.

The **SimuLEDView** program works with *.cgs files containing the results of computations. The name of a file created by **SpeCLED** solver is formed from the name of the project (i.e. the name of the corresponding *.dvx file) by adding the Bias value to the end. For example, computations for the geometry defined in Test1.dvx for bias of 3.5 V are stored in file Test1(3.5).cgs. It can contain the following information:

- Distributions across the Active Region.
- Integral chip characteristics.
- Emission spectrum (this is available if the I-V characteristics of the active region are imported into **SpeCLED** from files generated by **SiLENSe**, which contain information on the spectral characteristics of the active region).
- Distributions across metal electrodes.
- Distributions across horizontal die cross-sections (Z-planes).

The name of a file created by **RATRO** solver is formed from the name of the input cgs file generated by **SpeCLED** project by adding “_rtr” suffix to the end. For example, computations for the geometry defined in Test1.dvx for bias of 3.5 V are stored in file Test1(3.5)_rtr.cgs.

The data are loaded into **SimuLEDView** using the ***File*** menu containing the following items:

- ***Open As New*** opens an individual file resetting all visualization options.
- ***Open As Previous*** opens an individual file keeping most visualization options defined by the user.
- ***Load Active Zone Files*** allows the user to load a group of **SpeCLED** files containing active region information (without Electrodes and Z-Planes) corresponding to the same geometry but different value of the *Bias*.

3 Integral Parameters

SimuLEDView provides a set of integral quantities corresponding to the whole chip and overview of chip parameters at which the computations have been made, which include

- For **SpeCLED** computations:
    - ✓ Light extraction efficiency.
    - ✓ Forward bias
    - ✓ Total current
    - ✓ Output power
    - ✓ Wall-plug efficiency
    - ✓ Average and maximum current density
    - ✓ Average and maximum p-n junction temperature
    - ✓ Dissipated power in active region, electrodes and contact layers
- For **RATRO** computations:
    - ✓ List of materials with refraction and absorptions indices
    - ✓ List of surfaces types with assigned surface parameters
    - ✓ List of all chip surface with light extraction through the given surface
    - ✓ Total light extraction efficiency (sum of light extraction over all surfaces)

This information is presented in the *Report* section at the right hand side of the window. The *Report* section opens on pressing the ***Report*** button at the right hand side of the window. The button ***Report Tools*** switch the report to editable mode, allowing the user to format the report or/and add some comments.

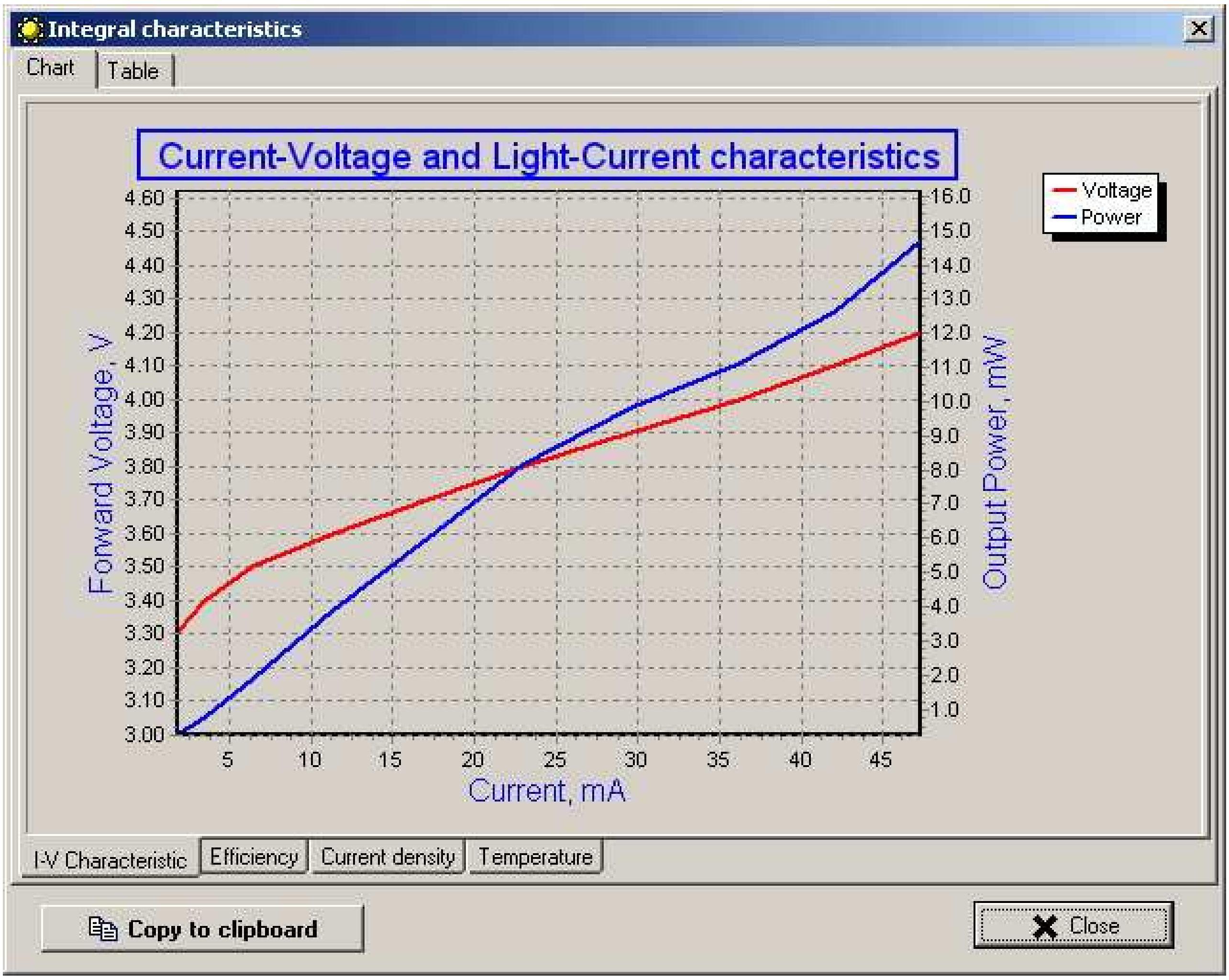


Fig. 2

If several files containing distributions over the active region on the same chip at different biases are loaded (using the ***File -> Load Active Zone Files*** menu item), the integral characteristics are plotted as a function plots of bias. This is available using the ***Integral*** menu item, which opens the ***Integral Characteristics*** dialog window (see Fig. 2) that plots the following dependencies:

- Voltage and light emission as a function of total current.
- External and wall-plug efficiency as a function of total current.
- Maximum current density as a function of total current.
- Average and maximum chip temperature as a function of total current.

- Differential resistance as a function of current.
- In addition to graphs, all dependencies are also available in text table format which can be exported to be viewed using an external visualization tool.

4 Planar Distributions

4.1 Variables

2D planar distributions of various variables are presented in the graphics window of **SimuLEDView**. The view of graphics window is governed by a combo box on top of the window at the left hand side. To visualize the planar distributions Main mode should be selected in this combobox.

On bottom of the graphics window a set of tabs is located, allowing the user to specify the variable to be shown. Each variable is shown in its own tab window.

4.1.1 SpeCLED Output Files

The following variables are available in the **SpeCLED** results:

- For active region:
  - **T** (K) – temperature
  - **Jz** (A/cm^2) – vertical component of the current density
  - **JunctionBias** (V) – p-n junction bias
  - **IQE** (%) – local internal quantum efficiency
  - **Emission_Power_Density** (W/cm^2) – light power generated in the active region (The total output power presented in *Report* is given by integration of this distribution over the active region and subsequent multiplying by the external light extraction efficiency).
  - **Wavelength** (nm) – local maximum of the emission spectrum
  - **HeatSourceSurf** (W/cm^2) – heat release in the active region
- For electrodes and pads:
  - **T** (K) – temperature
  - **Potential** (V) – electric potential on the electrode surface
  - **Jx** (A/cm^2), **Jy** (A/cm^2) and **Jz** (A/cm^2) – components of the current density

- **PotDropSurf** (V) – potential drop between the electrode and semiconductor because of the contact resistance
- **HeatSourceVol** (W/cm^3) – volumetric heat release due to Joule heat sources
- **HeatDropSurf** (W/cm^2) – surface heat release due to contact resistance
- **ElectricalCond** (($\Omega \cdot$cm)$^{-1}$) – electric conductivity
- **ThermalCond** (W/(m$\cdot$K)) – thermal conductivity

- Z-Planes:
  - **T** (K) – temperature
  - **Potential** (V) – electric potential on the electrode surface
  - **Jx** (A/cm^2), **Jy** (A/cm^2) and **Jz** (A/cm^2) – components of the current density
  - **HeatSourceVol** (W/cm^3) – volumetric heat release due to Joule heat sources
  - **ElectricalCond_XY** (($\Omega \cdot$cm)$^{-1}$) – lateral electric conductivity
  - **ElectricalCond_Z** (($\Omega \cdot$cm)$^{-1}$) – normal electric conductivity
  - **ThermalCond** (W/(m$\cdot$K)) – thermal conductivity
- Vertical crossection:
  - **T** (K) – temperature
  - **Potential** (V) – electric potential on the electrode surface
  - **Jx** (A/cm^2) and **Jz** (A/cm^2) – components of the current density

4.1.2 RATRO Output Files

The **RATRO** results include:

- For Far-Field Region:
  - **Radiant Intensity** (W/sr)
  - **Radiance** (W/(sr$\cdot$m^2))
  - **Luminous Intensity** (cd)
  - **Luminance** (cd/m^2)
  - **Polarization** – the ratio of extracted TE and TM rays defined as (TE-TM)/(TE+TM)
- For Near-Field Region:
  - **Intensity** (W/cm^2) – output power of the light emission at the active region at each individual chip surface
  - **Model** – type of surface. An integer value from 0 to 6 presenting the index of the local surface type. The surface types with their indices are listed in the Surface Properties section of the report with integral distribution.

- For active region:
  - ✓ **Number of Rays** – number of rays emitted from the given mesh cell. For a uniform emission intensity this quantity is proportional to the cell area.
  - ✓ **Emission Density** (W/cm^2) – local intensity of the light emission. This variable duplicates the Light Emission Intensity in **SpeCLED** output file used as input data for the **RATRO** computations
  - ✓ **Extraction** (W/cm^2) – intensity of the extracted light emitted from the given location of the active region
  - ✓ **Extraction Efficiency** (%) – efficiency of the extraction of light emitted from the given location of the active region calculated as the ratio of **Extraction** to **Emission Density**

4.2 Frames

If the loaded **SpeCLED** file contains several die sections (i.e. electrodes and Z-planes in addition to the active region) or several active region files are loaded, distributions corresponding to each zone are available using *Frames* section at the right hand side of the graphics window. *Frames* section contains the list of available frames which include:

- For electrodes:
  - ✓ n-electrode and p-electrode
- For Z-planes:
  - ✓ z-coordinates of each horizontal section
- For multiple active regions:
  - ✓ Values of bias

When a **RATRO** file is loaded, the *Frames* section includes:

- For the Far-Field Region:
  - ✓ Top and Bottom spheres
- For the Near-Field Regions:
  - ✓ All external chip surfaces

The *Frames* section can be hidden using the button ***Frames*** at the right hand side on bottom of the window.

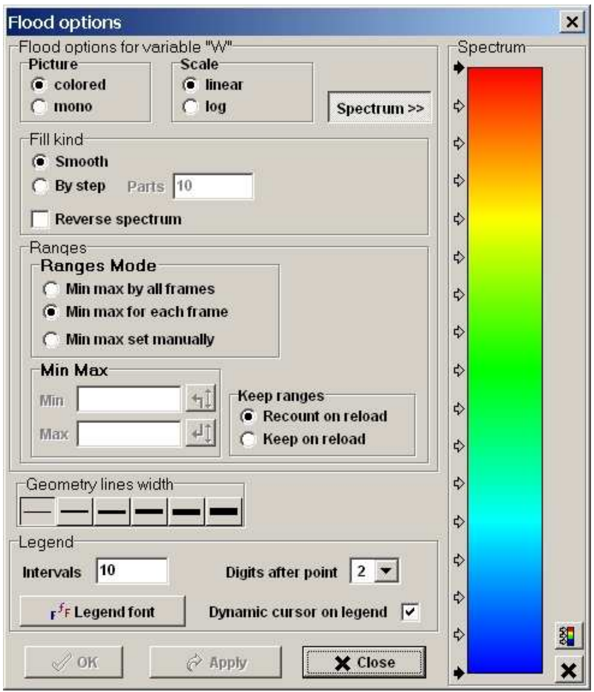


Fig. 3

4.3 Flood

The *Flood* mode is used to visualize the 2D distribution of the current variable (i.e. variable on the selected *Variables* tab). It is activated by the button  in the *Modes* section at the right hand side of the bottom toolbar.

Displaying of the flood legend is governed by the  button at the left hand side of the bottom toolbar.

Customization of the flood mode is available via the *Flood* menu item on top of the window. This opens the ***Flood Options*** dialog window (see Fig. 3).

4.4 Contour

The *Contour* mode can be used to visualize the 2D distribution of the current variable in addition to flooding the image. It is activated by the button  in the *Modes* section at the right hand side of the bottom toolbar.

The set of contours can be customized independently of the Flood options via the *Contour* menu item on top of the window. This opens the ***Contour Options*** dialog window (see Fig. 4).

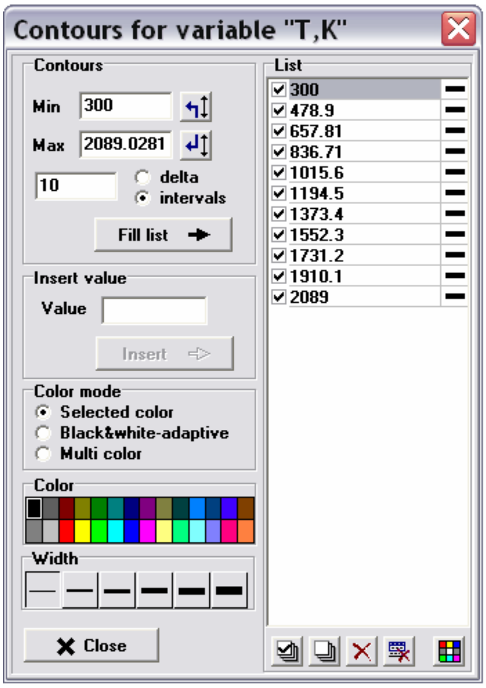


Fig. 4

4.5 *Vector Field of the Electric Current*

The *Vector* mode can be used to visualize the vector field of the current. It is activated by the button  in the *Modes* section at the right hand side of the bottom toolbar. Note that for a better visualization ***Jz*** is directed upwards, so that the direction of electron movement is used as the direction of the current vectors (i.e. its direction is opposite to the conventional current direction).

Customization of the vector mode is available via the *Vector* menu item on top of the window. This opens the ***Vector*** dialog window (see Fig. 5).

Two types of vectors are available in visualization of **SpeCLED** results.

- Horizontal projections of current vectors. This is available in *Z-Planes* or *Electrodes* frames only. The user can specify these vectors by selecting (**jx jy**) item in the *Vector* combo box on top of the *Vector* dialog window.
- Vertical projections of current vectors. This is available in all frames, including the Active Region. The user can specify these vectors by selecting (**Null jz**) item in the *Vector* combo box on top of the *Vector* dialog window.

The vector length can be of a fixed or current value dependent size. Displaying of the reference vector is governed by the button at the left hand side of the bottom toolbar.

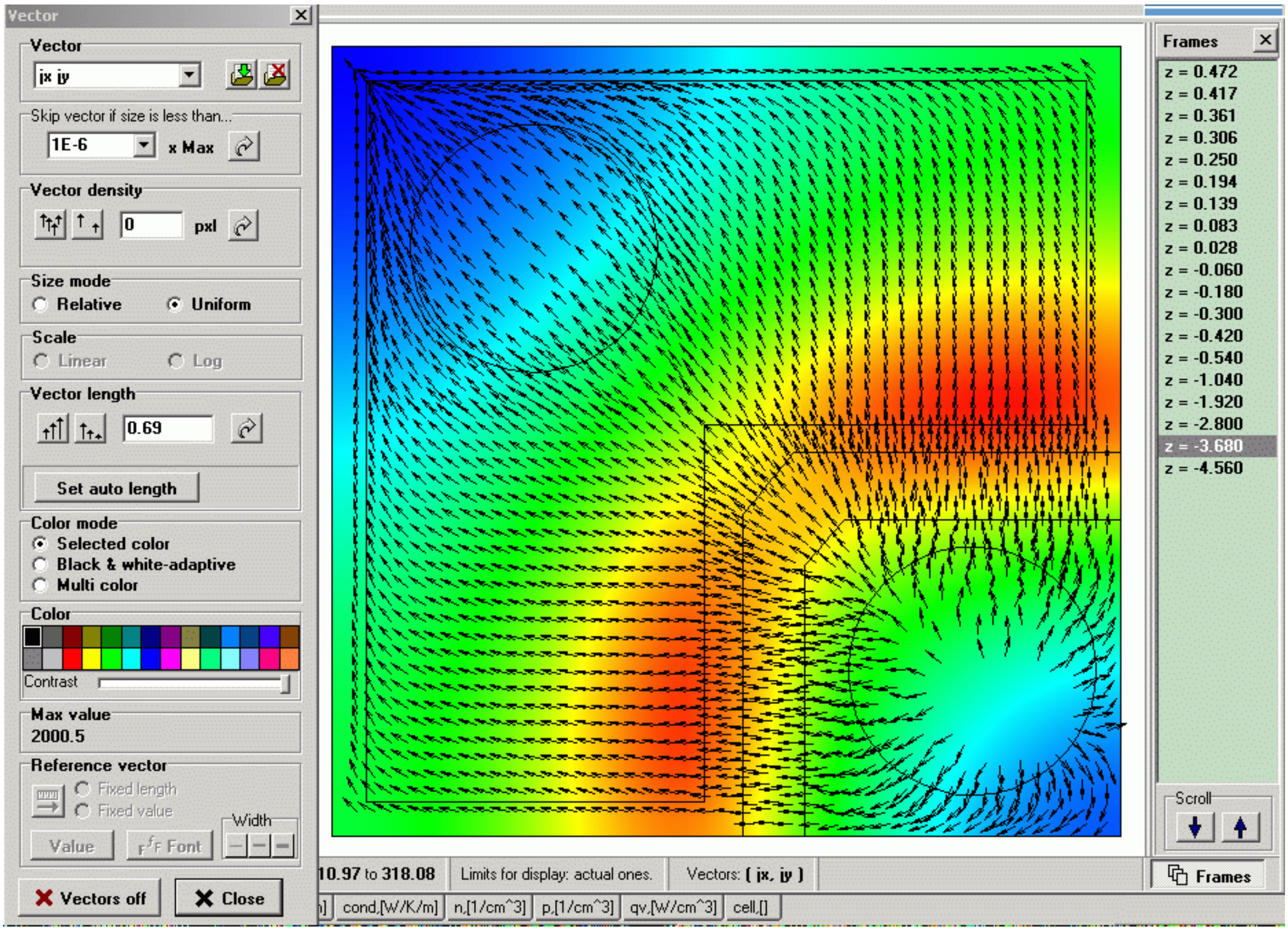


Fig. 5

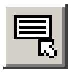
4.6 Die Domains and Computational Grid

Visualization of the boundaries of chip elements is governed by the **Geom** button at the right hand side of the bottom toolbar.

Visualization of the computational grid is governed by the button at the right hand side of the bottom toolbar.

4.7 Probe

The following probe modes are available:

- Mouse Probe of the Current Variable is available on pressing the  button (*Indicator for Current Variable*) at the left hand side of the bottom toolbar. In this mode the value of the active variable is shown on white background in a small rectangle under the cursor.

- Mouse Probe of All Variables is available on pressing the  button (*Indicator for All Variables*) at the left hand side of the bottom toolbar. In this mode the values of all variables are shown in Watch dialog window (see Fig. 6). The values are automatically updated on displacement of the mouse cursor.

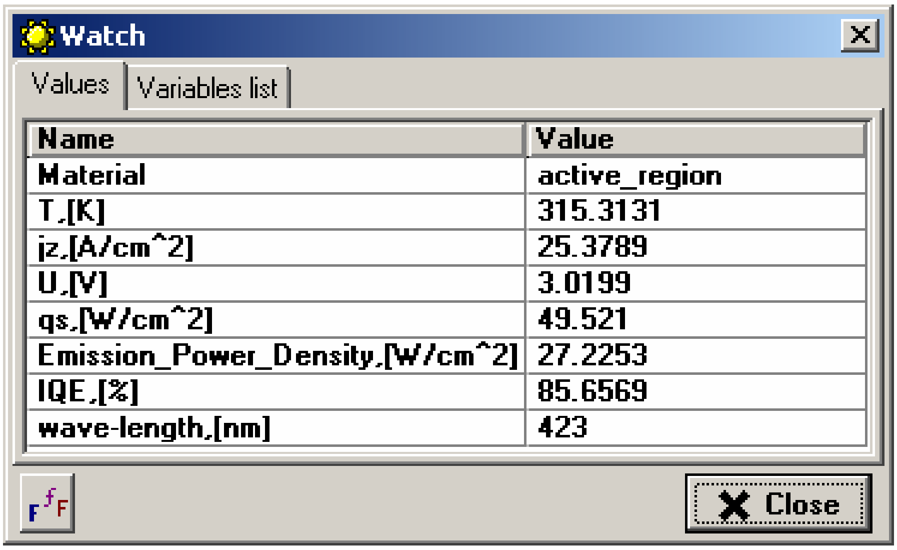


Fig. 6

- ***Point Probe*** mode allows the user to view the values of all variables at a set of discrete probe points. It is available via the *Probe -> Point Probe* menu item on top of the window. This opens the *Point Probe* dialog window (see Fig. 7) which provides visualization of all variables at each probe point, specification of new probe points and displacement of the existing ones. To specify a new probe point the user should click the left mouse button keeping the *Shift* key pressed.

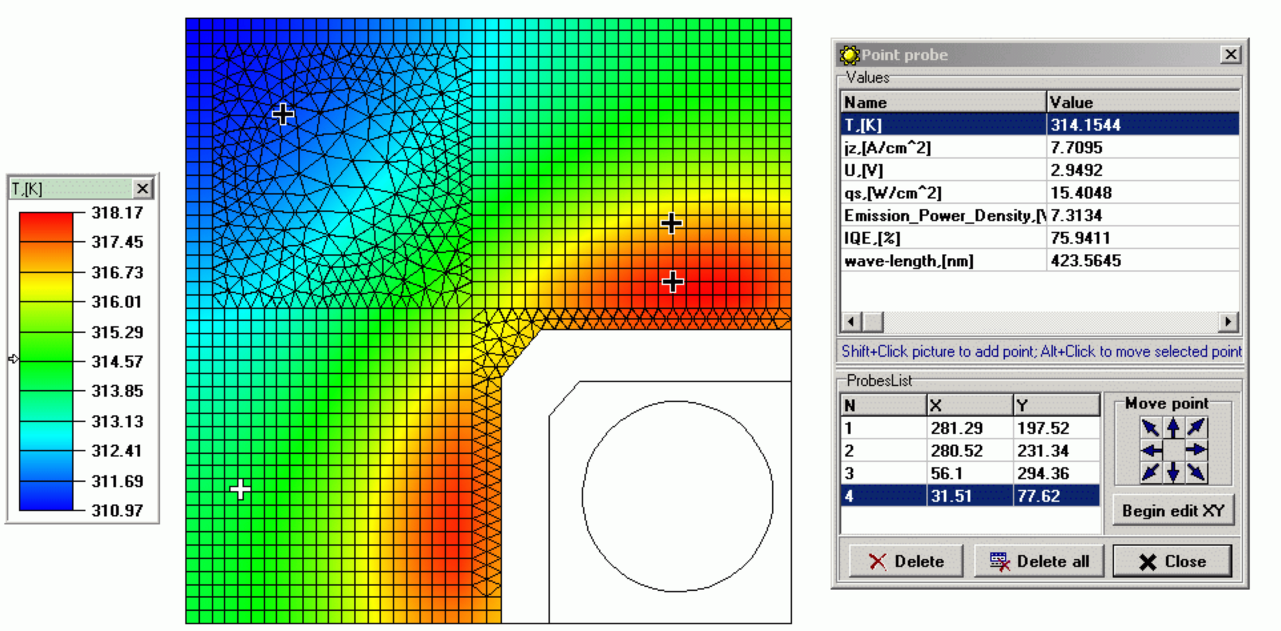


Fig. 7

- ***Line*** Probe mode provides visualization of 1D distributions along the user defined cross-sections. It is available via the Probe -> Line Probe menu item on top of the window. This opens the *Line Probe* dialog window (see Fig. 8) which provides 1D plots of the distributions of all variables along the specified line, specification of new lines, and displacement of the endpoints of the existing ones.

To specify a new probe line the user should twice click the left mouse button keeping the Shift key pressed, assigning the first and the last endpoints.

To move the first point of an existing line the user should specify its new position by clicking the left mouse button keeping the *Alt* key pressed. To move the second point of an existing line the user should first swap the endpoints by pressing the Swap Ends button end then to specify its new position by clicking the left mouse button keeping the *Alt* key pressed

In addition to 1D plot the probe data are presented as a table that can be saved in a text file.

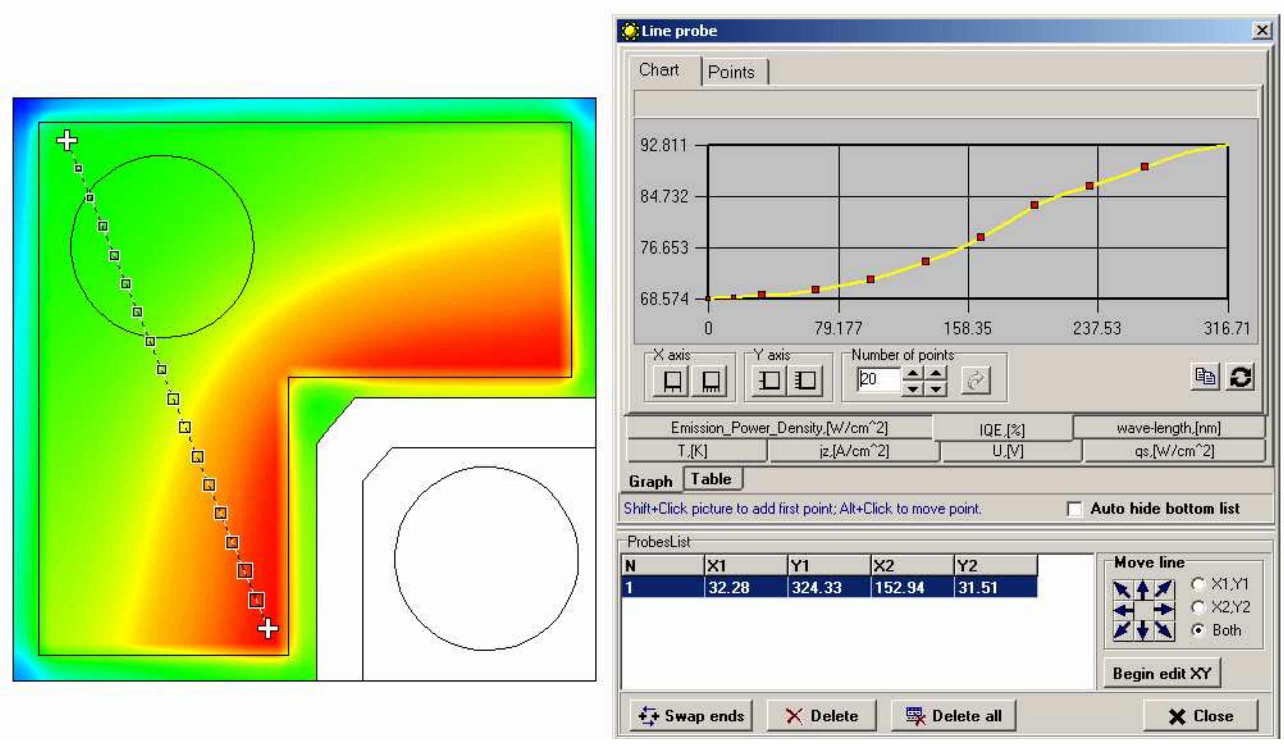


Fig. 8

- ***Frame Probe*** mode provides visualization of 1D distributions along the vertical die cross-section in Z-Planes mode. Visualization of frame probes is available via the Probe -> Frame Probe menu item on top of the window. This opens the Frame Probe dialog window (see Fig. 9) which provides a bar diagram of all variables along the vertical cross-section, specification of new cross-sections which are defined by their x and y coordinates, and displacement of the existing ones. The bars on the diagram correspond to the discrete Z-planes.

To specify a new probe cross-section the user should click the left mouse button keeping the *Shift* key pressed.

In addition to 1D plot the probe data are presented as a table that can be saved in a text file.

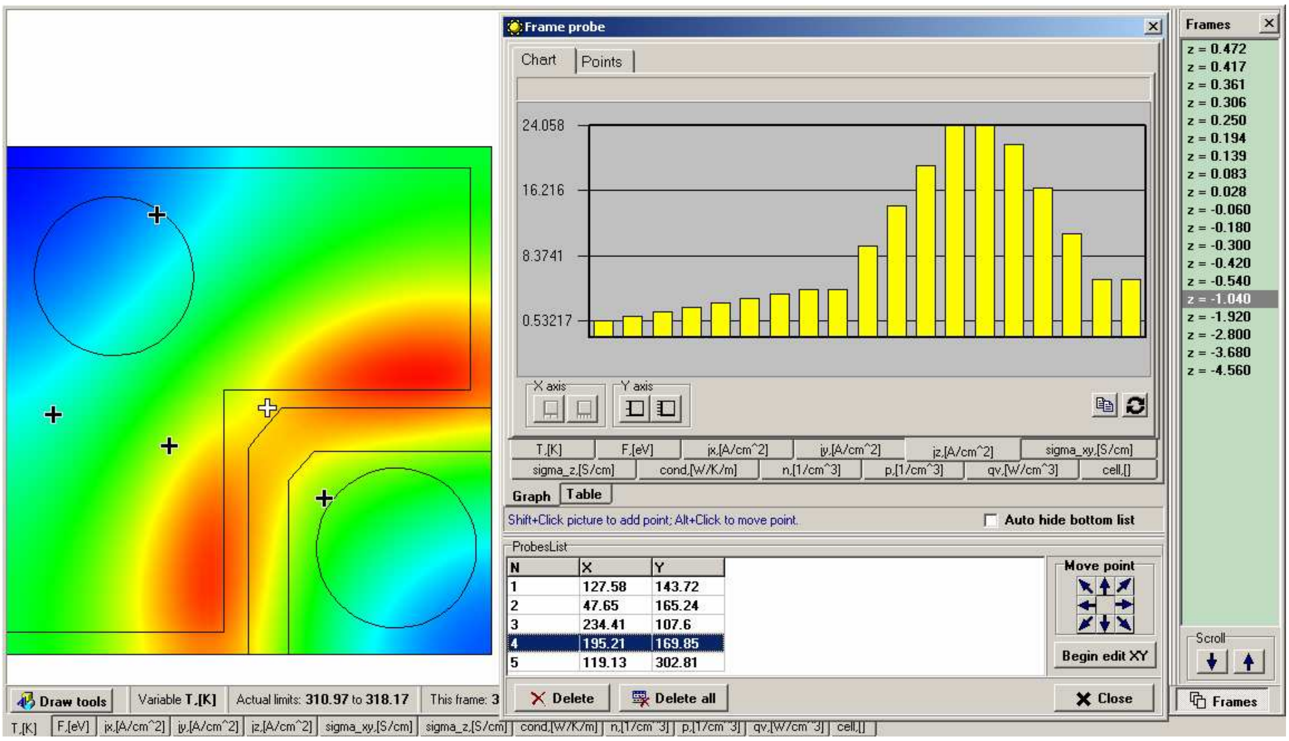


Fig. 9

4.8 Calculator

The *Calculator* option allows the user to compute and display new variables. It is available via the *Calculator* menu item on top of the window that opens the *Calculator* window. To specify a new variable the user should press the *New* button and enter the name of the new variable and its definition as a function of the existing variables. The names of the existing variables are defined by the names typed on the *Variable* tabs omitting the ending dimensionality. For example, the temperature in Kelvin is shown in tab “T,[K]” . The Celsius temperature can be introduced as “TC=T-273.16”.

Note that the variable name can not coincide with a name of already existing variable.

The new variable is automatically added to the *Variable* tabs. The calculator window contains the list of all user-defined variables so the expressions of the existing user-defined variables can be edited.

4.9 Image Options

The *Picture* menu allows the user to customize the image and to save it to a file. It contains the following items:

- *Contrast* allows the user to change the saturation of the flooding colors and contrasts (from Black to Light Gray) of *Grid* lines (see Fig. 10).
- *Save in .bmp file* allows the user can save the image in a file.

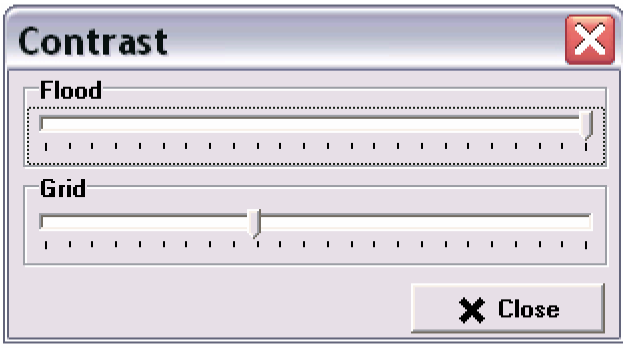


Fig. 10

5 Radiation Pattern

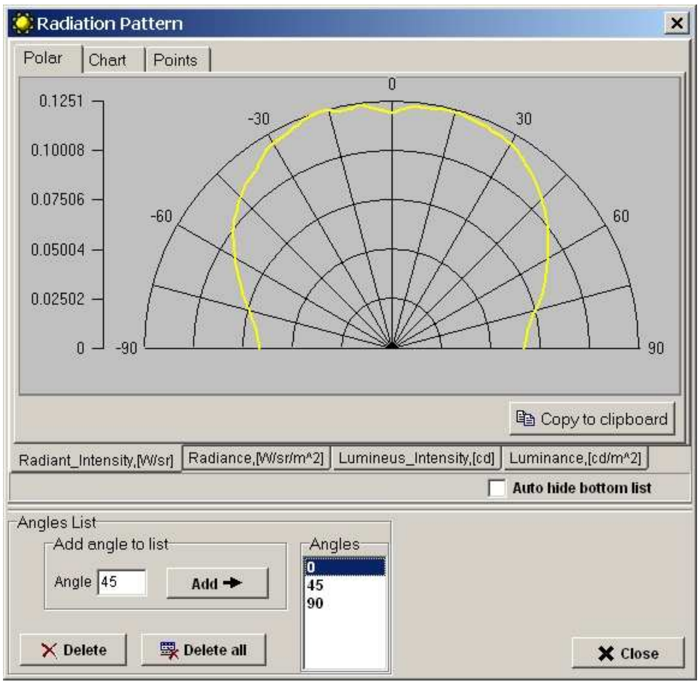


Fig. 11

For **RATRO** output files, visualization of the radiation pattern is available via the *Probe -> Radiation Pattern* menu item on top of the window. This opens the *Radiation Pattern* dialog window (see Fig. 11) which provides 1D plot for a selected orientation. The plots can be plotted either in polar (Polar tab) or Cartesian (Chart tab) coordinates. Horizontal (Angle = 0) and vertical (Angle = 90°) directions are assigned by default. The user can also specify an arbitrary angle of the plot.

The radiation patterns are generated using the far-field distribution calculated for the given sphere radius. So the *Probe -> Radiation Pattern* menu item is only available when *Far-Field Region* mode is selected. The radiation patterns are available for the following quantities:

- Radiant Intensity (W/sr)
- Radiance (W/(sr·m^2))
- Luminous Intensity (cd)
- Luminance (cd/m^2)

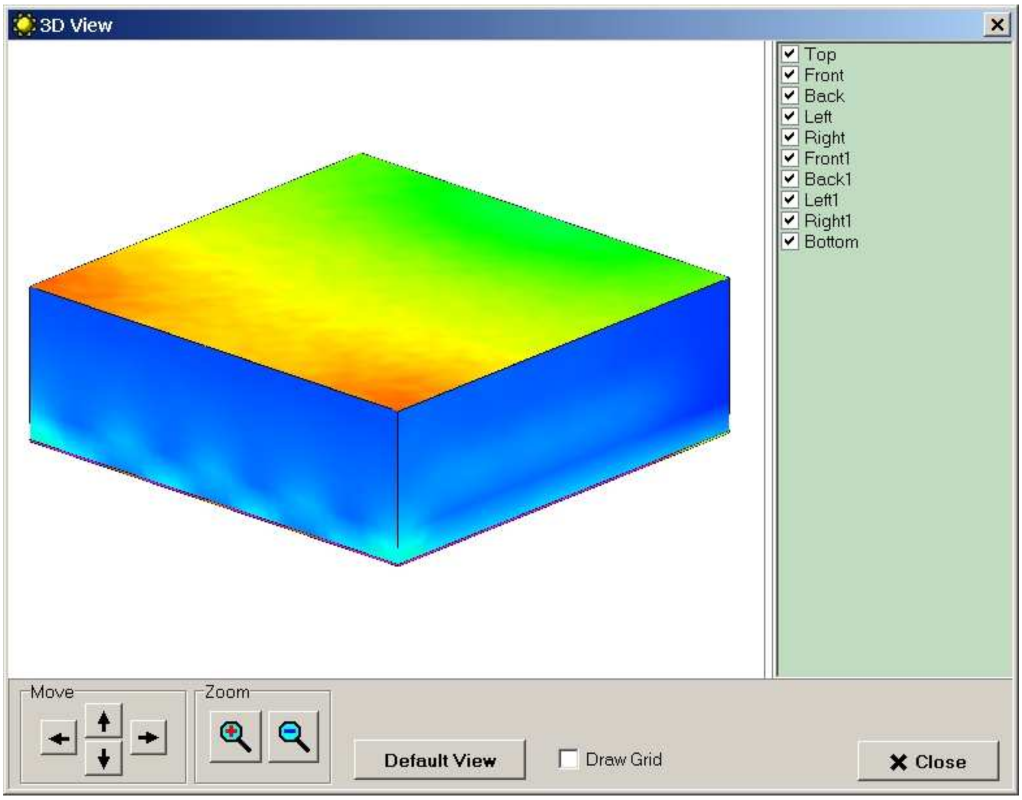


Fig. 12

6 RATRO 3D View

For **RATRO** output files, a 3D visualization of the light extraction from the LED chip is available. The **3D View** window (see Fig. 12) is activated by pressing the 3D LED button located on the tool bar at the bottom of the window. It provides intuitive visualization of light extraction though all chip surfaces. The image can be rotated by the left mouse button, moved by the right mouse button, and zoomed by the middle mouse button or by mouse wheel.