A Quick Tour of LASCAD™

This Quick Tour guides you through the main features of LASCAD. It shows how fast a resonator can be configured by the use of the GUI, and how to experiment with different cavity parameters. It helps you get started, but it does not replace the manual. The manual is found in the directory `Documentation` on the CD-ROM, or in the subdirectory `Documentation` of the application directory after installation. For limitations of the demo version, please open the item "Help/Demo Limitations" in the LASCAD main menu, or refer to the last section of the manual.

After starting LASCAD the window **"Select Working Directory"** pops up, asking you to define a working directory. Click **"OK"**. Then click the item **"File/New Project"** in the LASCAD main menu, or click the left most button in the tool bar, or just press the **ENTER** key. A dialog appears in which you can define the type of simulation and the number of elements. For now leave it unchanged, and click **"OK".**

Two windows will pop up. The upper one shows the gaussian mode shape for a simple 2 mirror resonator, and the lower one shows a field with the parameters of the resonator. The type of analysis, in the present case, "Standing Wave Resonator", is indicated in the caption of the upper window. To get a nice graphical appearance, the mode shape is visualized by 5 lines. The top line is related to scale left of the plot.

The optical elements, initially just 2 mirrors, are represented by vertical lines and the following symbols:

mirrors	filled rectangular triangles
dielectric interfaces	open rectangular triangles
lenses	filled isosceles triangles

Click on one of the vertical lines - but not on the number box - and drag the line to a desired new position. After releasing the mouse button the new mode shape is computed and plotted immediately.

Horizontal extension and position of the mode plot can be changed by the use of controls arranged below the mode plot window.

The "**Shrink and Stretch**" buttons change the horizontal extension of the plot.

The "**Scroll Bar**" moves the mode plot to the left or right side.

The "**Adjust Length**" box at the lower left corner of the mode plot window fits the diagram to the length of the picture box. Uncheck this box to switch off automatic horizontal adjustment. The vertical extension of the plot can be adjusted by checking the "**Adjust Diameter**" box. Unchecking this box prevents automatic adjustment of the plot to the height of the picture box.

To **insert an additional element**, press the **SHIFT** key and click into the mode plot between two vertical lines. The dialog **"Insert Element"** is shown. You can enter parameters for the new element into the boxes that appear. In addition to the parameters describing the element itself, the parameters of the medium at the left hand side of the element can also be defined. The pull down box in the first row allows for selecting different types of elements, such as: lens, mirror and dielectric interface. Choose "lens" and click the **"OK"** button. After clicking **"OK"**, a lens element with a focal length of 21 mm is inserted between the 2 mirrors.

To change the focal length of the inserted lens, click the second box in the row **"Type-Param.:"** of the window **"Parameter Field"**. Enter a new focal length, and click the **"Apply"** button, or press the **Enter** key. The replotted mode shape reflects the effect of the changed focal length. Like the other elements, the inserted lens element can also be dragged to a new position, with the mouse.

The **"Type Parameter"** depends on the type of element you inserted. For a mirror or dielectric interface, it is the radius of curvature. For a lens, it is the focal length.

Instead of using numerical input, a parameter can also be changed by the **slider** located below the mode plot box. When you click on a box in the parameter field, the related parameter, such as the focal length of the lens, is controlled by this slider, and can be changed by moving the slider. The name of the parameter is specified in the box to the left of the slider. The parameter value is in the yellow box to the right of the name. The third box to the right determines a percentage range within which the parameter can be modified. By default it is set to ±50% of the original parameter value, but another value can be entered. While moving the slider, you can see the value of the parameter changing in the yellow box. After releasing the mouse button the mode shape is plotted, corresponding to the changed parameter value. Clicking into the parameter or the percentage box centers the slider at the actual value of the parameter.

Click the tab **"y-plane parameters",** in the window **"Parameter Field",** to show parameters of the y-z-plane of the cavity. For all of them **astigmatism** can be set. For example, a cylindrical lens can be defined by entering a large value into the box for the y-plane focal length. After confirming with the **Enter** key, the background of the corresponding box becomes blue, and the mode plot box splits up. The upper box shows the x-z-plane mode shape, and the lower box shows the y-z-plane mode shape. For an astigmatic parameter, the y-plane value remains unchanged, when the x-plane value is changed. Otherwise the y-plane value follows the x-plane value. To **remove astigmatism** of a parameter, press the **CTRL** key, and click into the related blue box. This resets the y-plane value back to the x-plane value.

To **clear an element,** press the **CTRL** key, and click with the mouse on the corresponding vertical line – not the number box.

To insert elements outside the cavity, start by reducing the horizontal scale of the plot, or shift it to the left or right hand side.

Click the tab **"Spot Size Results"** to show the gaussian spot sizes at the positions of the optical elements. According to common use, the gaussian spot size is the distance from the beam axis where the intensity drops to $1/e^2$.

A Green or red background of the boxes distinguishes spot sizes belonging to the wave front propagating from left to right, or from right to left, respectively. If no gain is present, the shapes of the beams propagating in opposite directions are identical. If, however, a value other than zero is entered into one of boxes "Gain Parameters" in the bottom row of the parameter field window, the curvature of the wave front is modified, depending on the direction of propagation. Therefore, the results for the spot sizes also depend on the propagation direction. A non-vanishing gain parameter prevents the cavity from becoming unstable, a property which is useful when you are playing with different configurations.

To show spot sizes at arbitrary positions, open the window **"Additional Beam Param. ...",** by checking the box **"Show Additional Beam Parameters",** in the mode plot window. Then drag the magenta vertical bar, from the right end, over the mode plot. In addition to the spot size, parameters, like size of virtual beam waist and divergence, are shown at the position of the drag bar.

To show the mode profile at the actual position of the drag bar, check the box **Show Mode Profile,** to open the window **"Mode Profile".**

The UpDown-controls **Mode TEM n0** and **Mode TEM 0m,** found in the lower right corner, allow for showing higher order Hermite–Gaussian modes.

To show the mode shape for a beam quality parameter M² > 1 in the mode plot window, click the Tab **"Miscellaneous",** in window **"Parameter Field",** and enter a new value into the related number box. Alternatively you can click the tab **"Apertures"** to define apertures, and then check the box **"Use x(y)-plane apertures ...",** to determine the maximum M² possible within the defined apertures. Alternatively, beam quality can be computed more accurately with the new **DMA** code, see below.

Besides the mode inside the resonator, you can show the beam leaving the resonator through the right mirror, by checking the button **"Mode + External Beam",** below the mode plot window. Optical elements can also be inserted in the beam propagation path outside the resonator, similar to inserting them inside the resonator. The option button **"External Beam only"** allows showing the external beam only.

To insert a thermally lensing crystal into the resonator, crystal dimensions, material parameters etc. must be defined first. Click the item **"FEA/Parameter Input & Start of FEA Code",** in the LASCAD main menu, to open the window **"Crystal, Pump Beam, ..."**. This window shows six tabs, which can be opened for defining dimensions of the crystal, pumping and cooling configuration, and to control the Finite Element Analysis (FEA), as described in detail in sections 4.2. and 6.10. of the manual.

To start, we use the default settings for an end pumped cylindrical Nd:YAG crystal. To see the pump profile click, the tab **"Pump Light",** and then the button **"Show Pump Light Distribution".**   This opens the graphics window **"Pump Beam Profile",** which shows the absorbed power density. To start the FEA, click the button **"Apply & Run FEA"**. A window pops up showing the progress of computation. With the button **"Skip",** thermal or structural analysis can be stopped after the actual iteration step, in order to proceed to structural analysis, or to finish the computation, respectively. If, at the end of the computation, the message "FEA finished successfully" appears, press **"OK"** to close the dialog.

For graphical visualization of the FEA results, click **"FEA/3D Visualizer",** in the LASCAD main menu, to open the related window. Use the dropdown menu leftmost in the toolbar of this window to select a physical quantity, such as heat load, temperature, etc., to be shown. The other buttons of the toolbar, which are almost self-explaining, are described in the manual. Objects can be rotated, shifted, and zoomed by the use of the three dropdown menu selections, or you can also use a 2-button mouse in combination with the toolbar. The results of FEA are stored in files in the subdirectory FEA of the working directory.

To use the results of the FEA with the ABCD matrix code, the temperature distribution, multiplied by the temperature dependence of the refractive index, is fitted parabolically at right angles to the optical axis, using the finite element mesh subdivisions. Similarly, a fit of the deformed end facets of the crystal must be carried through. Click **"FEA/2D Data Profiles and Parabolic Fit",** in the main menu, to open the dialog **"2D Data Profiles and Parabolic Fit"**. The window shows diagrams displaying the temperature distribution at different cross sections perpendicular to crystal axis. To show other items, please refer to section 6.13 of the manual.

Click **"Refresh & Fit"** to compute the parabolic fit. A graphical representation of the fit is then shown, and simultaneously, a yellow information window pops up. According to the instructions given in this window, press the **ALT** key, and click in the mode plot into the field where you want to insert the crystal. A yellow-ocher colored symbol for the thermally lensing crystal is then inserted. The length of the field is adjusted to the length of the crystal as defined in the tab **"Models"** of the window **"Crystal, Pump Beam, ..."**. The elements at both ends of the field are transformed

into the end facets of the crystal. Like the other elements, the crystal can also be dragged with the mouse to an other position. To **clear the thermal lens,** press the **CTRL** key and click into the crystal.

To compute laser power output two tools are available. You can click the menu item **"Laser Power CW",** to open the window **"Laser Power Output"**. It is providing several options to compute slope efficiency, lasing threshold etc.. But this window also can be used for approximate computation of pulsed operation using rectangular pulses. A more realistic computation of pulsed operation is possible with the new tool **DMA** for dynamic analysis of multimode and Q-switch operation which can be opened by clicking the menu item "**Dynamic Multimode Analysis**".

For cases where parabolic approximation and ABCD matrix code are not sufficient, the **FEA results can alternatively be used as input for a physical optics code,** based on the beam propagation method (BPM). This code provides full 3D simulation of the interaction of a propagating wave front with the hot, thermally deformed crystal, without using parabolic approximation. The mode structure of the resonator is computed by the use of a Fox and Li type iteration procedure, which propagates the wave front in small steps iteratively between the end mirrors of the resonator. To use this code, click the item **"BPM/Run BPM"** in the LASCAD main menu. This opens the window **"Beam Propagation Method",** where you can define several parameters to control the execution of the BPM code, as described in section 8 of the manual. For the present purpose use the default values, and click the button **"Run BPM",** to start the BPM code. A window pops up asking you if input files needed by the BPM Code shall be overwritten or not. After clicking "yes" or "no" the window **"BPM"** is opened, which has its own menu and several child windows, as explained in section 8 of the manual. If a thermally lensing crystal is present in the cavity, the FEA results are first interpolated with respect to the BPM grid. After interpolation is finished, a Fox and Li type iteration starts, which is recorded in the child window **"Graphic 1"**. After the first iteration, a 2D Array Visualizer window is opened,[*] showing a plot of the intensity profile at the right end mirror. The profile is redrawn after every round trip of the wave front. In addition, the window **"Convergence of Beam Radius with Cavity Iteration"** is shown, which is a child of the LASCAD main program. It shows the spot size at the right mirror as it develops with increasing number of cavity iterations. All files created by the BPM code are stored in the subdirectory BPM of the working directory.

To show intensity and phase distribution after the BPM is finished, click the item **"BPM/Show Beam Profile",** in the LASCAD main menu, as described in section 8.3 of the manual.

To keep this introduction short, not all features of LASCAD are described in this Quick Tour. Please refer to the manual or to the tutorials, which can be found in the directory Tutorials on the CD-ROM. Examples are provided in the directory Examples on the CD-ROM. The directories Tutorials and Examples are also copied to the LASCAD application directory during installation.

Additional information can be found in the PowerPoint file introduction and overview.pdf on the CD-ROM.

And now, please enjoy working with LASCAD!

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[*] If you have problems running the Array Visualizer, showing the intensity distribution, please refer to readme.txt in the subdirectory Documentation of the LASCAD application directory.