FPS USER'S GUIDE

Fiber Processing Software (FPS) for the FSM-100 and LZM-100/110/120/125

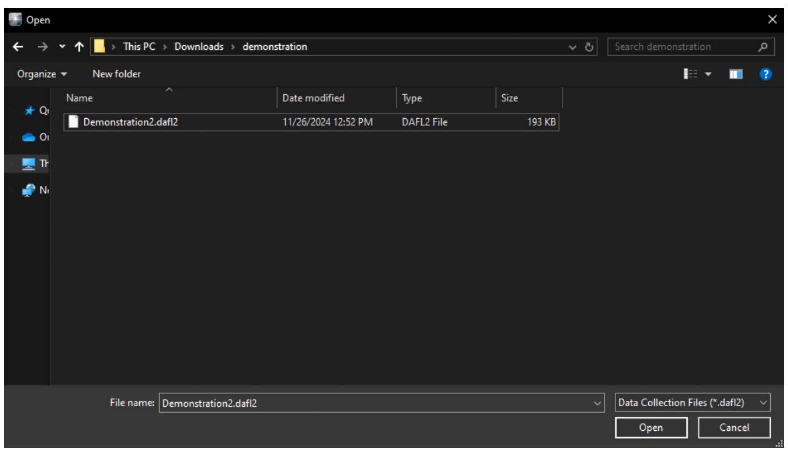


Table of Contents

POWER METER READER

OCB READER

MANUAL CONTROL

SPLICE SCRIPT

COMMAND SENDER

INTRODUCTION

Splicing in a research and development environment often requires tools that are not present in the splicer firmware or are time-consuming to access through the standard splicer menus. To address these needs, AFL developed the **Fiber Processing Software (FPS)** environment. FPS is a unified, PC-based application providing a variety of specialty splicing tools, greatly expanding the capabilities of the FSM-100 and LZM series splicers.

General Features of the Software

- Creating, measuring, and image archiving fiber tapers using FSM100 Fujikura fusion splicers and LZM series CO2 laser glass processor.
- Easily design a fiber taper geometry and define machine parameters to repeat the desired process.
- Capabilities to drive individual motors, initiate and stop the arc or lase, and control the heat power.
- Geometry tools that use embedded algorithms to determine taper diameter and distance between two points of interest.
- Rotation control for overcoming sagging or uneven heating during the taper.
- Real time warm taper image (WTI) monitoring and control.
- Live video monitoring and recording.
- One software application for 8 machine types, FSM-100M, FSM-100P, FSM-100M+, FSM-100P+, LZM-100, LZM-110, LZM-120 and LZM-125.

Installation

System Requirements

- Windows 7 or newer
- 1 GHz processor
- 512 MB RAM
- .NET Framework 4.8 ***FULL*** or newer
- Fujikura Data Connection Software and Drivers

Installation Instructions

1. Ensure .NET 4.8 full version or newer is installed. This can be confirmed by navigating to the “Add or Remove Program” page and looking for “Microsoft .NET Framework X.X.X”.
    a. If the listed version is older than 4.8 or is a client version, execute the “dotNetFx40_Full_x86_x64” application found on the installation CD and follow all instructions. Otherwise, continue to step 2.
2. Ensure Fujikura Data Connection is properly installed. Refer to the manual included with the software for details.
3. Power on the splicer and connect the USB cable to your PC. Ensure it is in a ready state before continuing.
4. Close any other splicer communication programs that may be running, including old versions of FPS
5. If you are using a 64-bit system, navigate to “**FPSx64**” and execute the FPS Click-Once Application. If you are using a 32-bit system, navigate to “**FPSx86**” and execute the FPS Click-Once Application. Click “Install” if prompted.
6. Upon completion of installation, a desktop shortcut will appear, and the home screen will be displayed.
7. Ensure that the status “***CONNECTED***” appears in the bottom right of the parent window. If you see “***DISCONNECTED***”, there may be a communication error.
    a. If disconnected, check the USB connection and ensure the machine is in a ready state. If a connection is not established, ensure the Fujikura DataComm software and drivers have been installed.

HOME SCREEN

FPS manages many applications written specifically for FSM-100 series and LZM series splicers. All applications are launched and managed within the Home Screen, which can run each application concurrently. The modular nature of these applications allows the user to customize the interface based on the task at hand.

For example, if the user wants to monitor live video while designing ball lenses or performing data collections, they can choose to arrange the screen with multiple windows or pull a widow into another screen.

Figure 1 – Home Screen

HOME SCREEN TOOLBAR AND CUSTOMIZATION

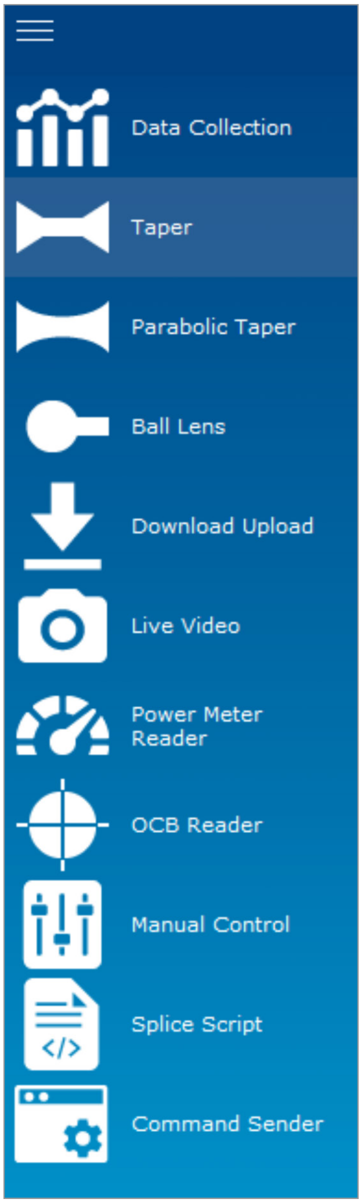


Figure 2 – Home Screen Toolbar
The control panel on the left of the FPS contains buttons to launch all available applications. The order of these choices is also customizable via drag-and-drop.

Clicking the three solid lines in the upper left hand corner will convert the box to symbols only.

LOADING LEGACY FILES

For those switching from older versions of FPS that mainly used unique text files or excel files to store data and parameters will find that these are now considered “Legacy” in that they are not recommended for common use anymore, but the program has been updated to include backwards compatibility, so that both it can load and save in these old formats. To have these legacy files show as they will not in any open/load or saving dialogue windows by default until you switch the selected files by using the bottom right drop-down menu.

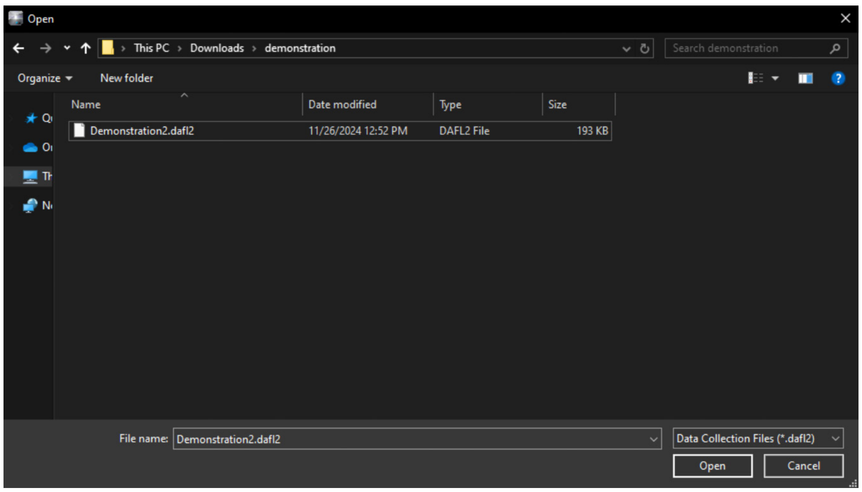


***Figure 3** – Open File Dialogue windows only showing the "modern" file type*

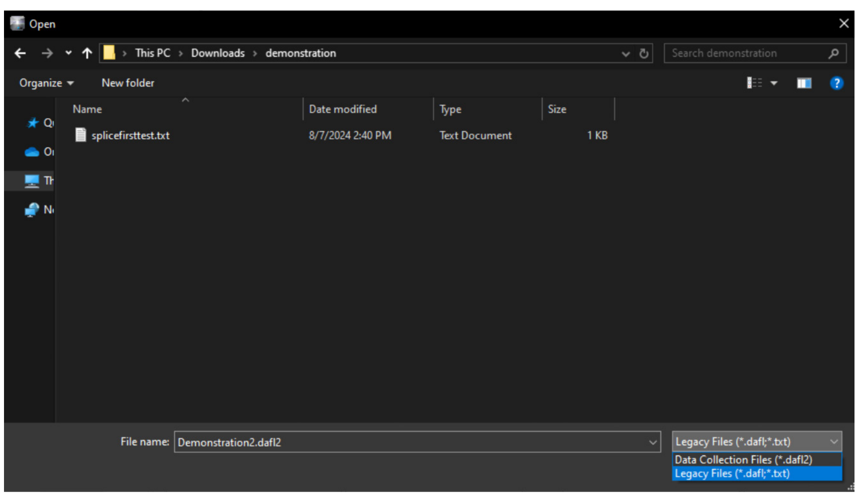


***Figure 4** – The same window displaying the drop-down menu described as well as how the same folder looks after being selected to display the legacy files.*

DATA COLLECTION

The **Data Collection** application is generally used to collect various machine parameters after splicing. It is also used for loss estimation when using a GPIB or USB to tune estimation parameters to more closely match real loss.

Collecting Data

When the application is launched, it will enter the Main screen

The main page contains four buttons and a switch for enabling Power Meter measurement. Their function is detailed below:

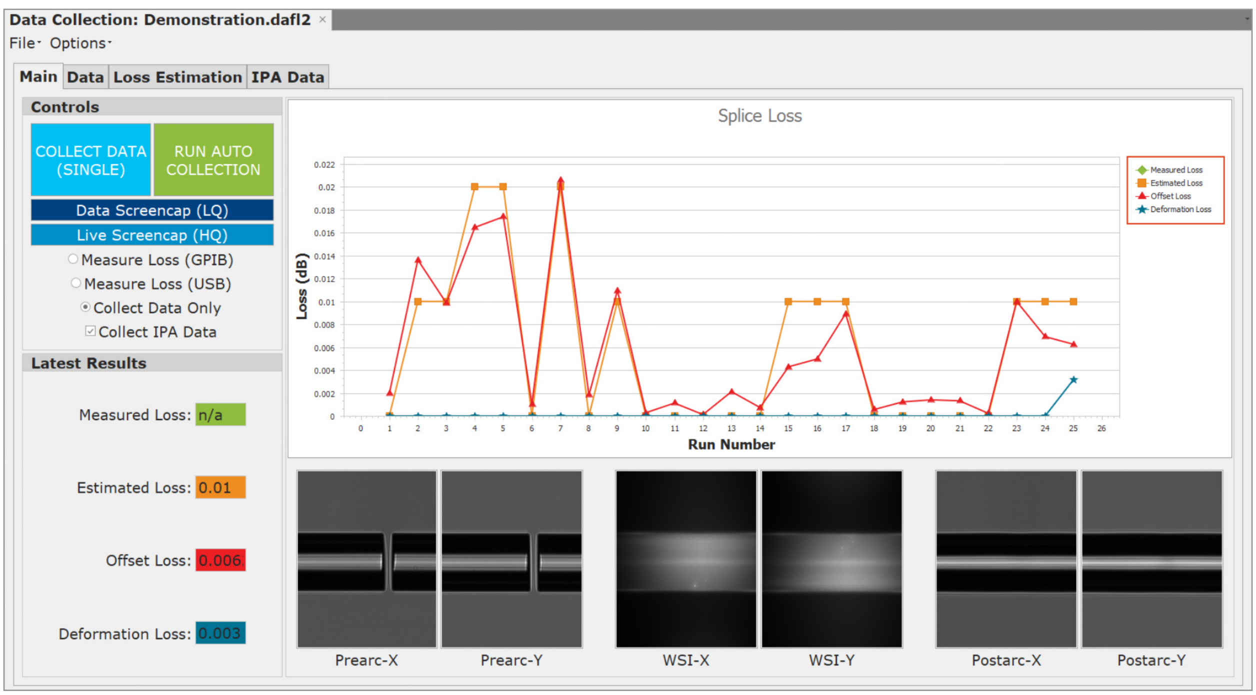


***Figure 5** – Main screen of the data collection app*

The main page contains four buttons and a switch for enabling Power Meter measurement. Their function is detailed below:

COLLECT DATA (SINGLE): Will collect any parameters specified on the **Data** tab, as well as pre-arc, WSI, and post-arc images. To collect splice data, the splicer must be in a Finish state after completing a splice.

NOTE ON SAVE FILES: When pressed for the first time, **Collect Data (Single)** will perform a data collection and prompt you to choose a location to save this data. This file will be ***automatically*** appended every subsequent time with new data when the **Collect Data (Single)** button is pressed or during auto collection. Additionally, this file will determine the folder that all images are saved to. The save location can be changed later by performing a ***Save As...***, or loading a different Data Collection file.

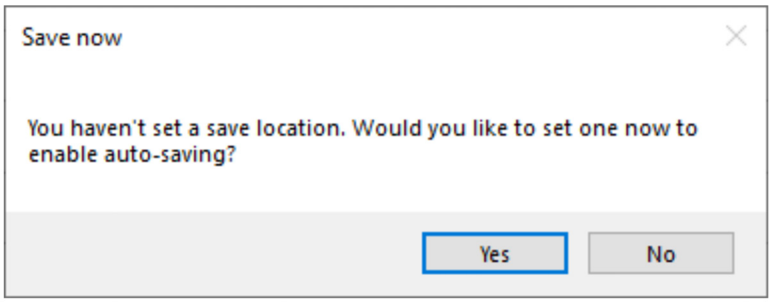


***Figure 6** – Save prompt that launches on first run*

Run Auto Collection: FPS will begin polling the splicer, checking if it is in a finish state. If it is, FPS will automatically perform a Data Collection and append the selected file. Auto collection CANNOT be run without an autosave location.

Data Screencap (LQ): Saves the current splicer image at 240x320 to the same folder as the data file. If no data file has been chosen, you will be prompted to choose a folder for the images.

Live Screencap (HQ): Saves the current splicer image at 480x640 to the same folder as the data file. This image is ONLY of the camera feed, no menus or overlays are captured. If no data file has been chosen, you will be prompted to choose a folder for the images.

Measure Loss (GPIB)/Measure Loss (USB)/Collect Data Only: A GBIP or USB Power meter stream is **REQUIRED** to measure loss. When checking the **Measure Loss (GPIB)** radio button, you will be warned that failure to connect a GPIB will result in a Communication Error, which will crash the splicer and erase your data. If connected correctly, the splicer will read the value from the power meter and report it in a "Measured Loss" column in the data tab, as well as in the loss estimation tab. Selecting **Measure Loss (USB)** will try to grab the value from any currently streaming USB power meter to use as measured loss. This value will be a live reading, not a value that is saved on a splice, so it should be performed while streaming and before moving the splice in any way. Selecting **Collect Data Only** will retrieve estimated loss and other parameters as normal but will not return measured loss or allow for loss estimation.

Collect IPA Data: Retrieves IPA data for a given splice. If this box is checked and there is no IPA data to be retrieved, it will be ignored.

Running data collection upon launch will get default values from the splicer and save them to the chosen file.

Data Collection Tab and Table

FPS will automatically collect all available parameters including the four types of data **Splicer Information (=INF), Splice Parameters (%SPL)**, **Splice Data (=DATH)**, and **Measured Loss**, from the given Splicer Model but also allows for the customization of the table in a variety of ways so that you can show only the data that's needed at the time and allowing for layouts to be saved and loaded between runs.

Note: More information about each of the commands collected and used can be found in the LZM-100 Command Reference Manual.

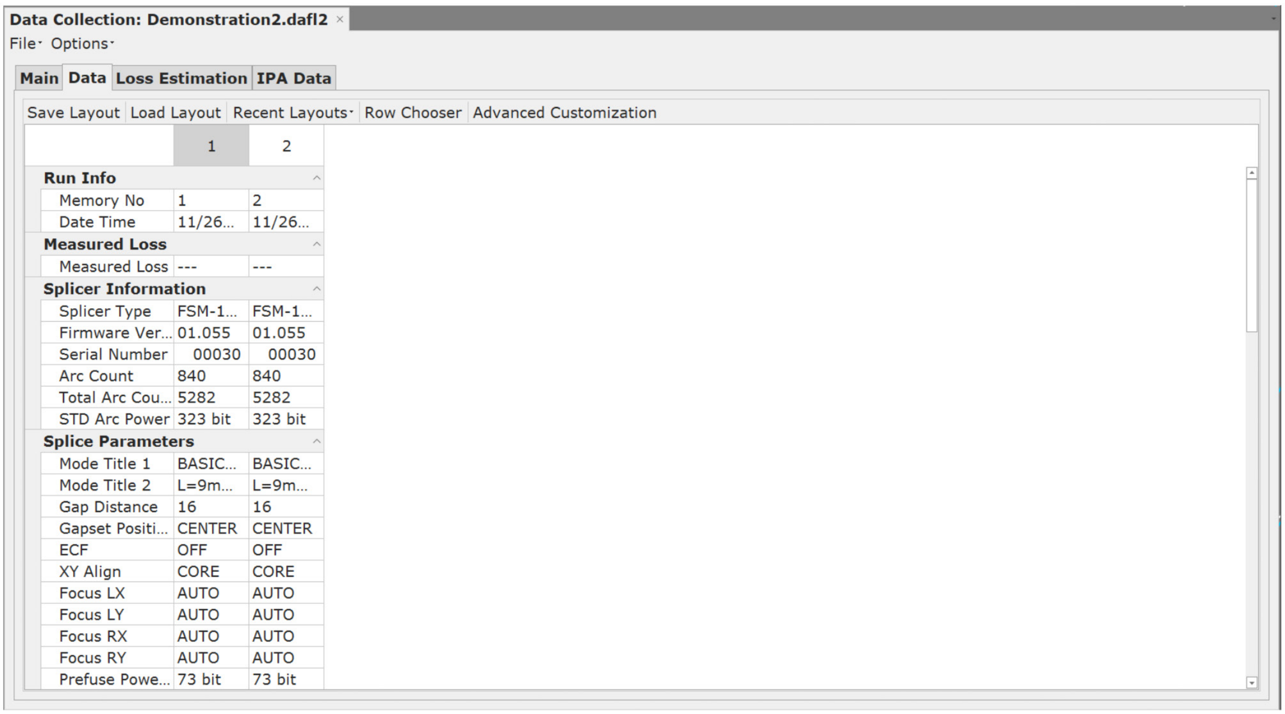


***Figure 7** – The Data table tab*

All rows can be moved around as desired in several ways. The direct way is by clicking and dragging the row header within a group or to the left of another header to move it to a new position. Groups can also be collapsed by using the small arrow on the right.

Notation Rows

Additional Note/Notation row can be added to the table by right clicking on a header which will cause a prompt asking for a name for the column to be given.

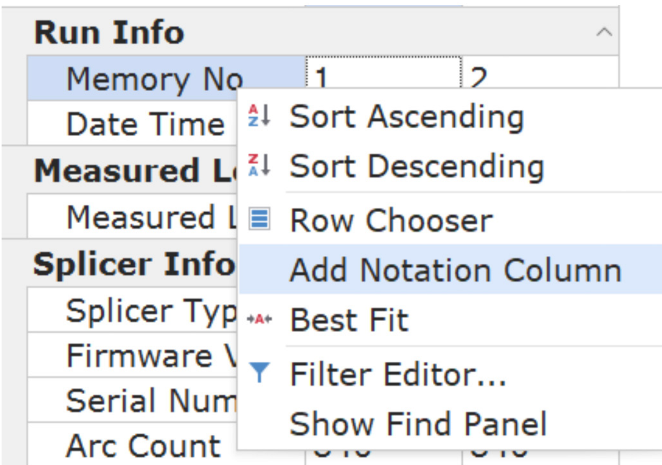


Figure 8 – *Showing the Add Notation Row button*

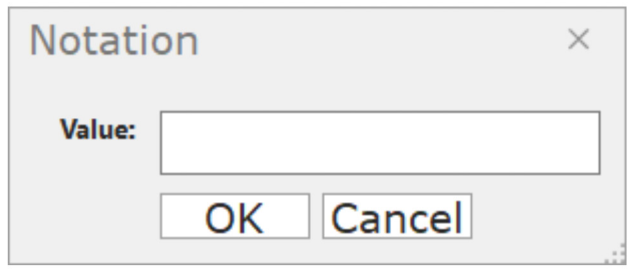


Figure 9 – *The prompt asking for the name of the row*

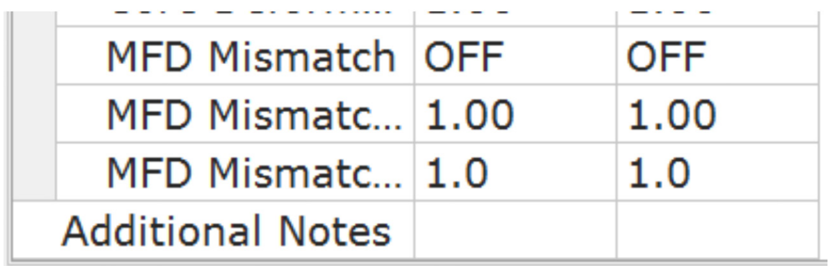


Figure 10 – *The new notation row will always appear at the bottom.*

Note: Notation rows have the option when right click to be deleted. This will PERMANENTLY DELETE any data stored in that row.

Row Chooser

The Row Chooser menu can be opened by pressing Row Chooser button within the layouts row at the top of the table. This menu allows rows to be dragged in and out of it to show or hide the rows as desired. Groups/ Categories can also be dragged in and out of this as well. New Groups can also be created as well.

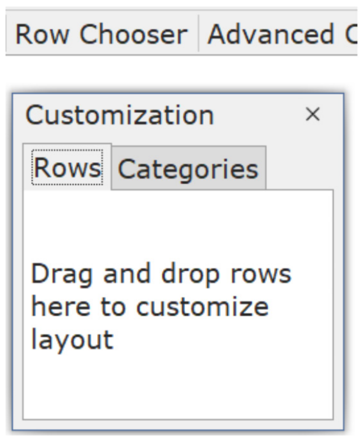


***Figure 11** – Row Chooser button and Menu*

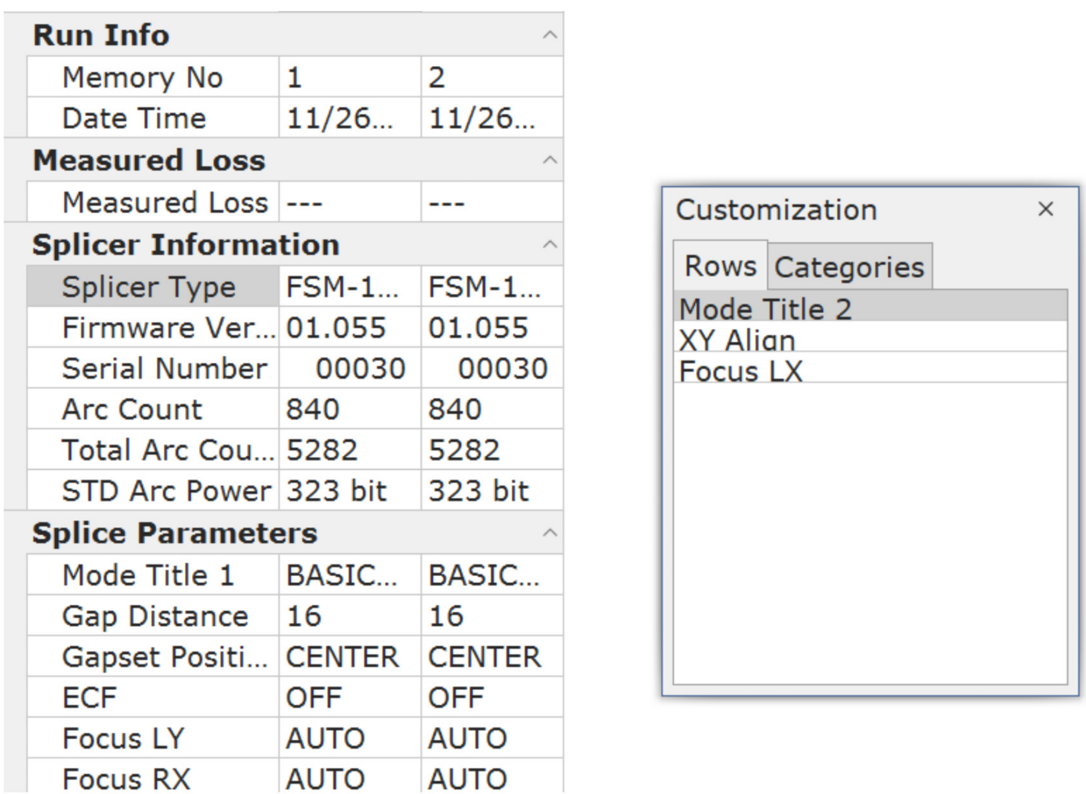


***Figure 12** – Row Chooser with rows dragged in*

Advanced Customization

The Advanced Customization menu can be accessed the same way as the Row Chooser and acts as an alternative way to quickly show and hide rows by allowing you to check and uncheck rows and groups/categories as desired.

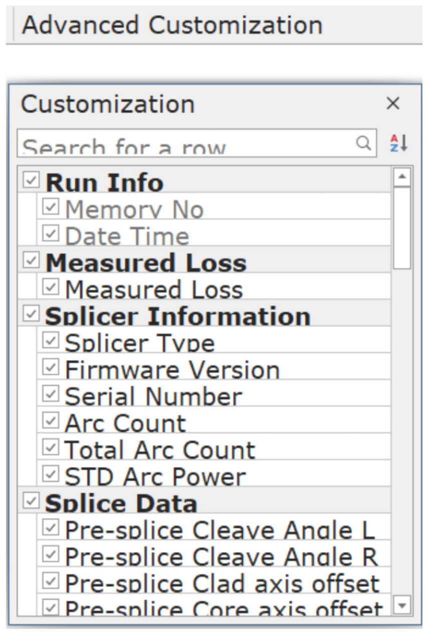


***Figure 13** – Advanced Customization Menu*

Layouts

Any layouts created through the different customization options can be saved and loaded for future use and runs through the Save Layout, Load Layout, and Recent Layouts buttons.

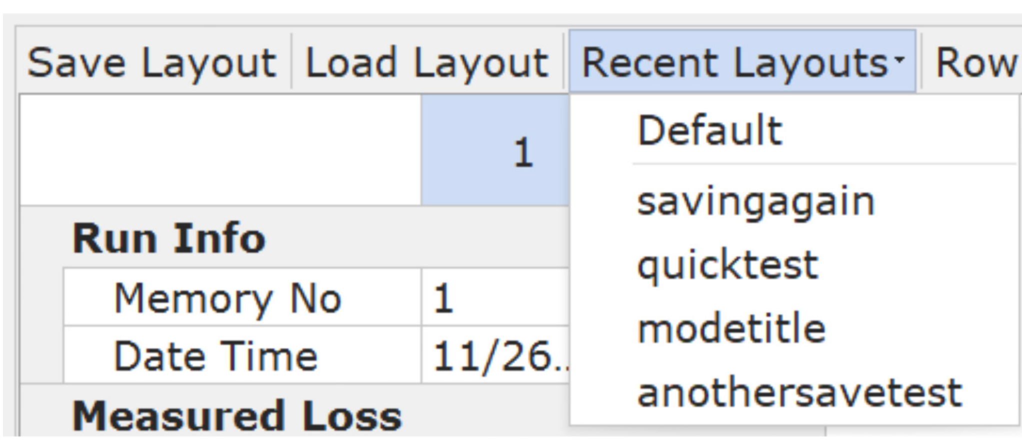


***Figure 14** – Layout buttons*

The Save Layout button will open a save file prompt to save a .lafl file for future use. Doing so will also cause this layout to appear within the Recent Layouts dropdown, this will also occur when loading an already saved layout from the Load Layout or Recent Layouts button itself. The most recent one used will appear at the top of the drop down with up to 5 of the most recent used appearing. Note Default will always appear and reload the default layout setup.

Loss Estimation

The **Loss Estimation** tab is used to tune a set of modifiers so that the splicer's estimated loss closely matches real, measured loss. The **Total Estimated Loss** listed here is **NOT** the value returned from the splicer. When the splicer returns **Estimated Loss**, it is calculated using the same modifiers seen in Figure 15, though each is a hard parameter saved to the mode. The **Total Estimated Loss** reported on this tab reflects what will be reported if those hard parameters are changed to the values set in the **Modifiers** box.

By using the GPIB to return measured loss, the operator can change the modifiers so that the difference between **Measured Loss** and Total Estimated Loss is minimal. If these modifiers are chosen correctly and used as mode parameters, the splicer returned **Estimated Loss** will closely match actual **Measured Loss**.

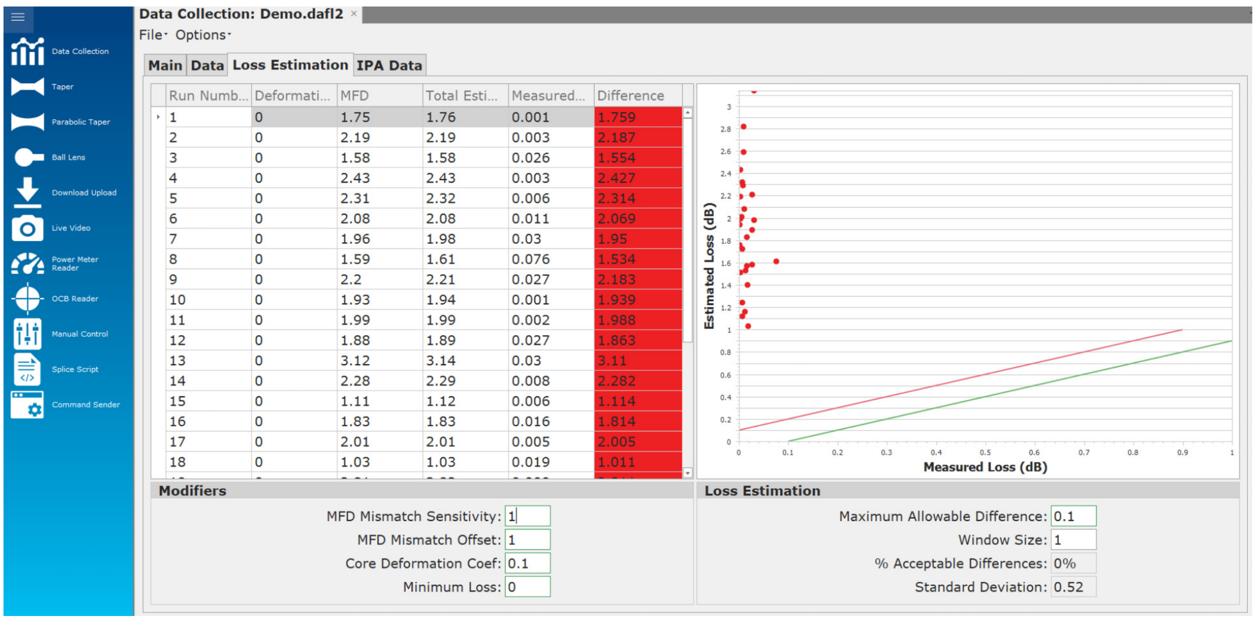


***Figure 15** – Loss estimation before the appropriate **Modifiers** for MFD Mismatch, MFD Mismatch Offset, Core Deformation Coef., and Minimum Loss are set. The red in the Difference column indicates the values fall outside of the "Maximum Allowable Difference." The data points clearly fall outside of the linear region on the "Measured v. Estimated" chart.*

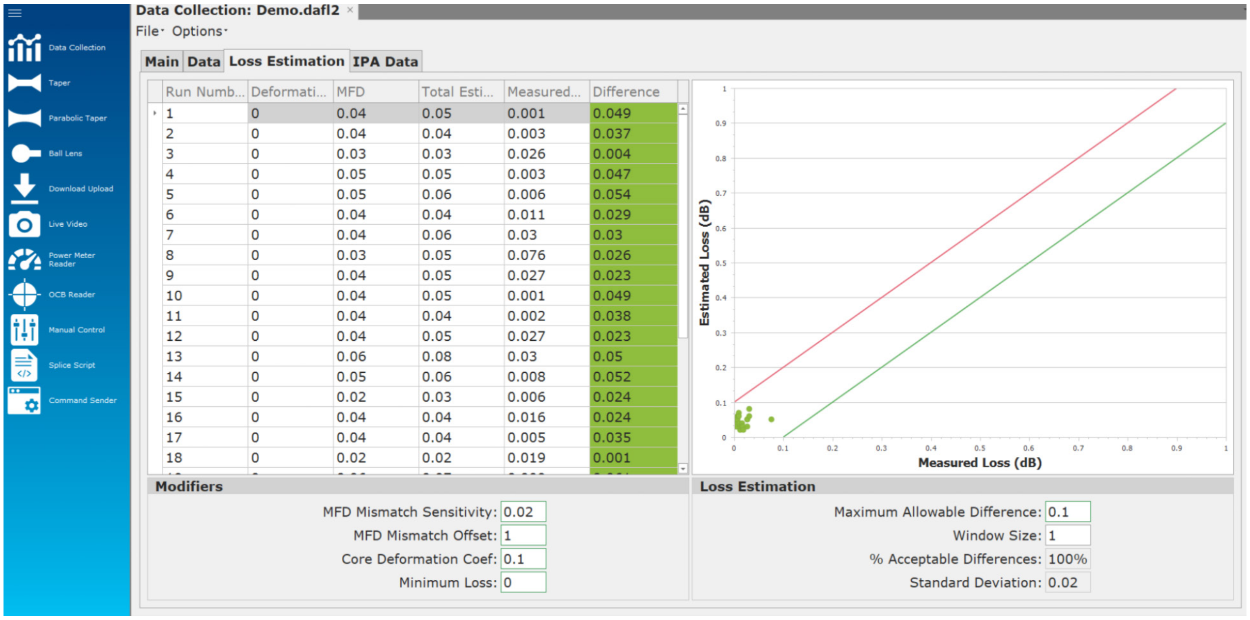


***Figure 16** – Loss estimation with appropriate **Modifiers** values chosen, allowing the machine to accurately estimate insertion loss. The green in the Difference column indicates that the values fall within the "Maximum Allowable Difference." The points also clearly fall inside of the linear region on the "Measured v. Estimated" chart. These **Modifiers** values need to afterwards be entered into the Estimation Parameters within the splice mode in the splicer.*

Modifiers

MFD Mismatch Sensitivity: Coefficient that increases estimated MFD loss.

Calculated MFD Loss = |Index Difference – MFD Mismatch Offset| * MFD Mismatch Sens.

MFD Mismatch Offset: Subtracted from the index difference when determining calculated MFD Loss.

Calculated MFD Loss = |Index Difference – MFD Mismatch Offset| * MFD Mismatch Sens.

Core Deformation Coef: Coefficient that increases estimated deformation loss.

Calculated Deformation Loss = Returned Deformation Loss * Core Deformation Coef

Minimum Loss: Constant added to total estimated loss, regardless of other values. Total estimated loss can never be lower than this value.

Loss Estimation

Maximum Allowable Difference: The maximum difference between **Measured Loss** and **Total Estimated Loss** where it can still be considered a "Good" value. Differences that fall within these bounds will be colored green and counted as acceptable, while differences that fall outside these bounds will be colored red and counted as unacceptable.

Window size: The axis size of the window, in dB

% Acceptable Differences: The percentage of differences that fall within Max Allowable Difference.

Standard Deviation: The standard deviation of all differences.

IPA Data

IPA Data is recorded for splices in which the alignment mode is “PAS” with estimation set to “IPA” for left and right fibers. The IPA Estimation radio button shows post-splice comparisons of the intensity profiles, while the IPA Alignment radio button displays pre-alignment and post-alignment intensity profiles of the splice. Crosstalk is recorded in the Alignment Info box in the bottom right corner:

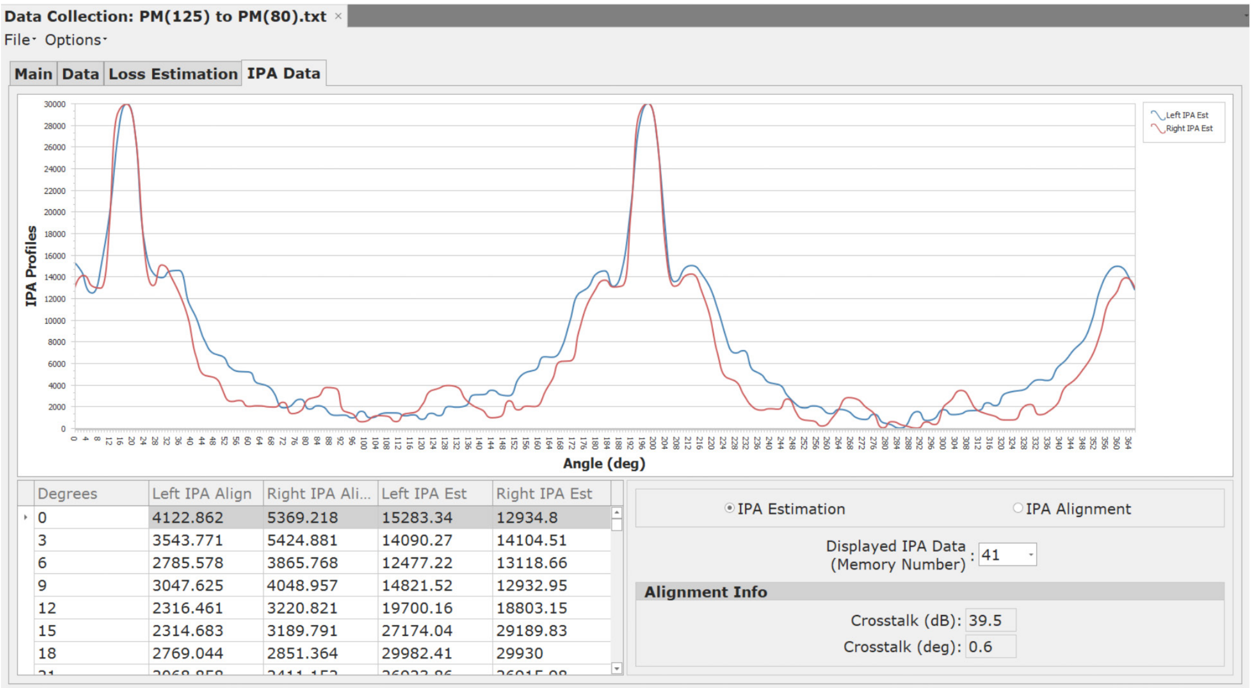


***Figure 17** – IPA Alignment data of a 80 µm PANDA to 125 µm PANDA showing proper alignment via the IPA profile data.*

TAPER

Tapering Theory and Technology

General Taper Theory and Geometry

Tapers are widely used in many different fiber-based components and applications, such as multi-fiber combiners and mode-field-adapters in the fiber laser industry, probes and sensors in biotechnology, and couplers and wavelength multiplexers in telecom. Depending on the application, the fiber used for tapering can be single-mode, a few modes, or multi-mode. The fiber can range in diameter from less than 40 μm to over 2.5 mm. Common terms used to describe a simple taper are illustrated in Figure 18.

The taper ratio, R, is the ratio of the original fiber diameter to the taper waist diameter. In most applications can be from 0.1 to 10, or even wider. For a classic taper, the waist is thinner than the original fiber (R>1). However, some applications require sweeping the fiber through the heating area without changing fiber diameter for thermal core expansion or cladding surface annealing with R = 1. Situations requiring an R < 1 include but are not limited to manufacturing mode field (or NA) expanders, elongated ball-lenses, and end-capping.

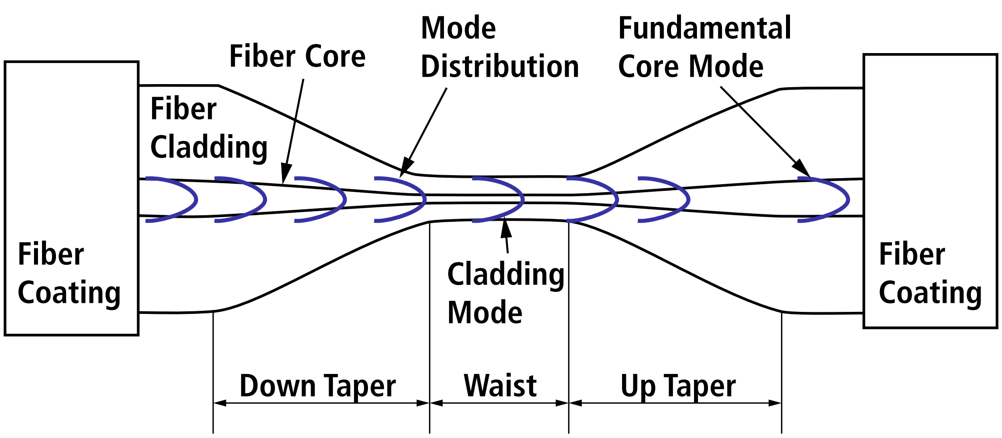


Figure 18 *– Geometry of a fiber optic taper*

Adiabatic Tapering

Adiabatic tapers are those whose shape does not change the fundamental mode in the fiber. The optical energy carried by the fundamental mode is virtually unchanged and the loss due to the taper is very low. This type of taper is important in many applications, especially in high power fiber lasers. The taper illustrated in Figure 18 is adiabatic. Although the core mode of the original fiber is converted to a cladding mode at the waist by the down-taper structure, this mode can be completely converted back to its fundamental core mode by the correct up-taper design. Both down-taper and up-taper need to be very smooth and the maximum taper angle must be kept below a certain threshold at any location along the entire taper. This taper angle threshold is normally referred to as the adiabatic taper angle. For SMF28, the adiabatic taper angle is 0.35 degrees.

However, the adiabatic taper angle varies with different fiber designs. It can usually be determined experimentally for a particular fiber through loss measurements.

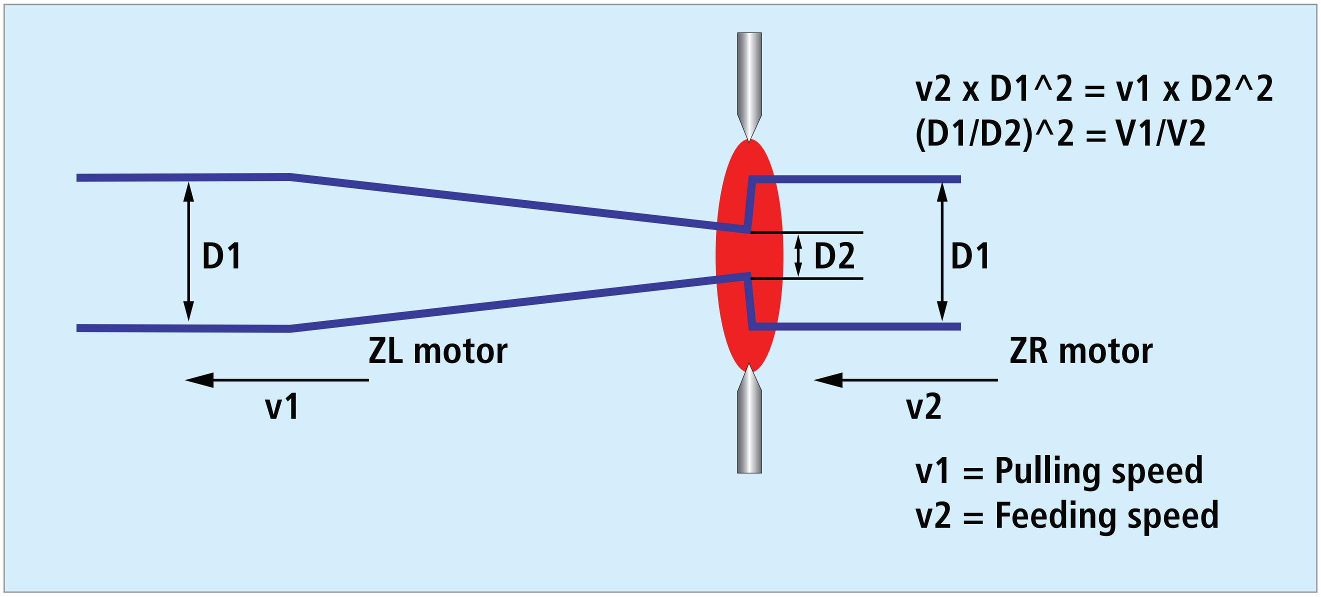


***Figure 19** – Principle for speed control to make a long taper*

For making a long taper, such as an adiabatic taper, the fiber can be pulled from one side of the heat zone and fed from the opposite side. The feeding and pulling directions are the same. But feeding and pulling speed are different, which controls the taper ratio. Due to the material conservation shown in Eq. (1), the glass fed into the heat zone should be equal to the glass pulled out from the heat zone. Based on the definitions shown in Figure 6, we have the following equation to determine the relation between pulling and feeding speeds from the desired taper ratio at any location of tapering process in Eq. (2):

$$\pi D_1^2 V_2 = \pi D_2^2 V_1 \qquad (1)$$
$$(D_1/D_2)^2 = V_1/2_2 \qquad (2)$$

A linear section for either down-taper or up-taper gives the shortest taper length for any desired adiabatic angle. Therefore, it is optimum for adiabatic tapers. Obtaining a linear taper region requires solving a complicated analytic equation with integration. The PC software provides linear and sine taper shapes only. For any additional special taper shape requirements, please contact AFL.

Introduction to the Taper Application

To perform a taper, many parameters and variables must be set by the user. While a detailed description of these parameters is included in later sections, this section is a brief primer on the format and user interface of this application.

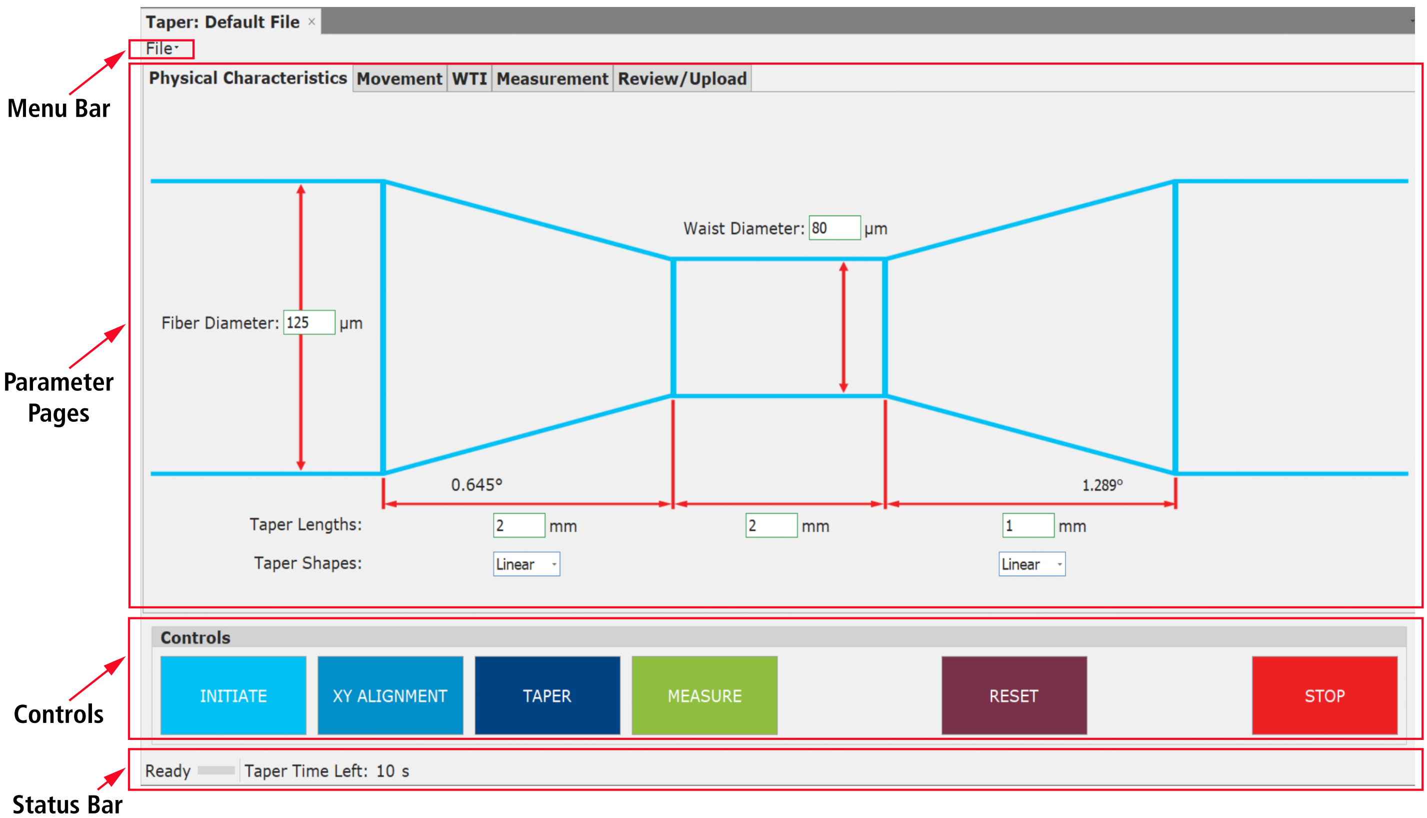


***Figure 20** – Default Taper Form*

Taper Menu Bar

The taper menu bar is used to access taper files. The file system uses encoded text/Taper (.tafl) files and allows users to save a default configuration.

Parameter Pages

Each subset of parameters has its own group and/or tab page, each of which are detailed individually further in this manual. The most important feature shared by all tab pages is ***inline parameter warnings***.

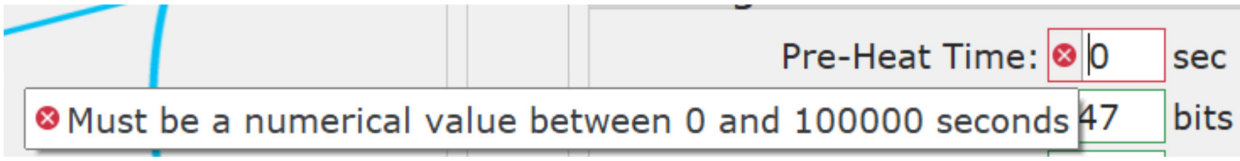


Figure 21 *– Inline Parameter Warning*

If a red **X** mark appears next to a parameter, the current machine is unable to perform a taper using this parameter. Hovering the mouse pointer over the exclamation point will give a detailed description of the warning, as well as how to fix it.

You can still attempt a taper with warnings in place. However, there will very likely be an error thrown while tapering, and you should always correct any warning before proceeding with a taper.

Controls

The controls will be visible regardless of which tab is open, and "**STOP**" and "**RESET**" are enabled regardless of whether the splicer is busy. The function of each button is listed below:

- ***INITIATE:*** Move the motors to their starting positions. Since the starting position is dependent on the parameters, this should be pressed after all the parameters are set. Load fiber for taper only after the initiate has been completed.
- ***XY ALIGNMENT:*** When pressed, walks the user through a process that will align X and Y for a taper without first splicing, or capillary. See section 4.10.4 for detailed use instructions.
- ***TAPER:*** Begins tapering with the current settings. If the machine has not been initiated properly, the machine will not taper.
- ***MEASURE:*** Begins a point-by-point measurement of the final taper, based on current settings. If the machine is not in the final position of the given taper, the user will be prompted to move to the taper ending position.
- ***STOP:*** Stops any current process as well as all motors.
- ***RESET:*** Stops any current process and resets all motors.

Machine Restrictions (Taper)

While each 100-series machine can perform tapers, the capability of each machine varies widely. When launched, FPS determines machine type and maximum taper specifications. Those specifications are listed below:

***Table 1** – Theoretical parameter limits by machine type*

Machine Type	Max Taper Length	Max Fiber Diameter	Min Taper Power	Max Taper Power	Max Rotor Speed	Supports Rotation
FSM-100M	10 mm	0.5 mm	180 bit	500 bit	50 deg/s	False
FSM-100P	10 mm	0.5 mm	180 bit	500 bit	50 deg/s	True
FSM-100M+	36 mm	1.2 mm	180 bit	800 bit	50 deg/s	False
FSM-100P+	36 mm	1.2 mm	180 bit	800 bit	50 deg/s	True
LZM-100	150 mm	2.3 mm	1 bit	1000 bit	150 deg/s	Varies by model
LZM-110/110V2/120/125M	10 mm	2.3 mm	1 bit	1000 bit	50 deg/s	False
LZM-110/110V2/120/125P	10 mm	2.3 mm	1 bit	1000 bit	50 deg/s	True
LZM-110/110V2/120/125M+	10 mm	2.3 mm	1 bit	1000 bit	50 deg/s	False
LZM-110/110V2/120/125P+	36 mm	2.3 mm	1 bit	1000 bit	50 deg/s	True
LZM-120/125A+	36 mm	2.3 mm	1 bit	1000 bit	50 deg/s	True

Having a taper fall within these specifications does **NOT** guarantee it is possible. Many different factors, ranging from movement speed to taper ratio, affect whether a taper is possible. Falling outside of those bounds will be reflected with inline warnings, which the user should always seek to correct.

Physical Characteristics (Taper)

The adjustable dimensions used for tapering include fiber diameter, waist diameter, and taper lengths. These values (white text boxes) can be adjusted by manually typing in the desired values.

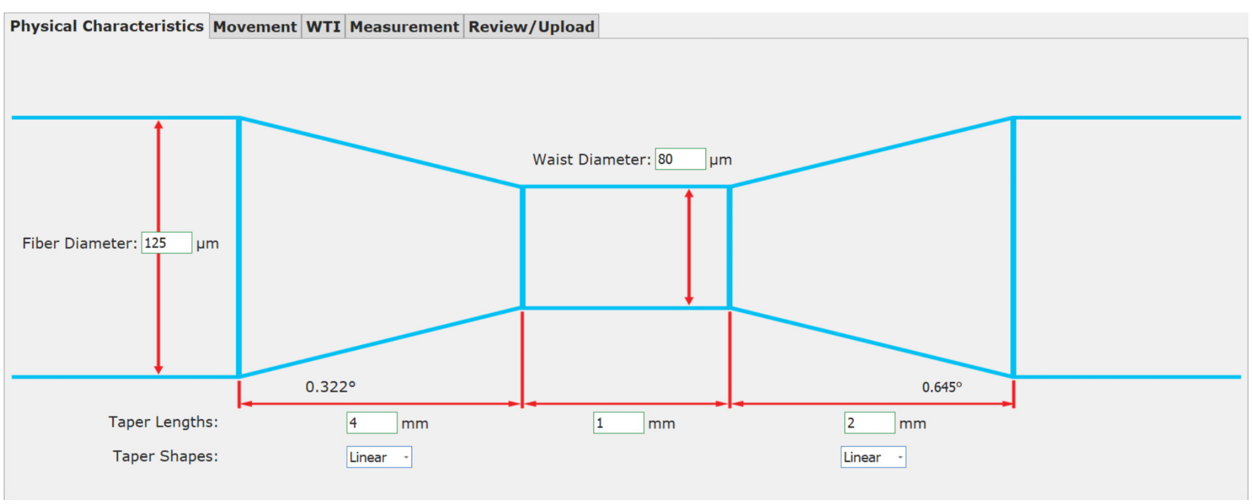


***Figure 22** – Physical Characteristics Tab*

Additional displayed parameters in the fiber dimension section of the software interface include Taper Angle, ZL travel length, and ZR travel length. The values displayed are calculated based on the user defined fiber taper dimensions.

Taper Ratio

The definition of taper ratio in the User's Manual is:

Taper ratio = Fiber diameter / Waist diameter

The maximum one pass taper ratio is 10 for FSM-100 and standard LZM machines. When your designed taper ratio is higher than 10, warnings will be triggered for your waist diam and movement speed that cannot be fixed until the taper ratio is reduced.

Taper Shape

The taper shape is selectable for the down-taper and up-taper individually. Currently there are only two selections, linear or sine curve. For any additional special taper shapes, please contact AFL Splicing Engineering.

Heating (Taper)

There are four user-editable Heating Modifiers in the heating tab, as well calculated heating characteristics. The "Get Calibration Value" is used to auto-populate Absolute Power with the latest STD Calibration from the splicer.

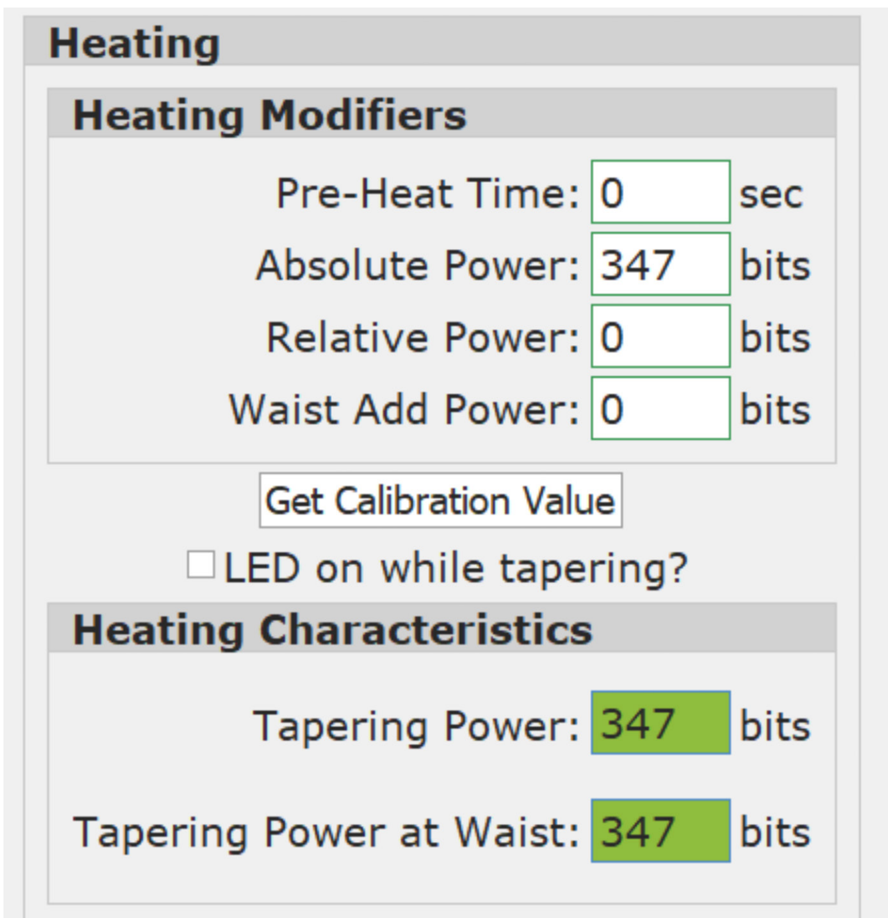


***Figure 23** – Heating Group Parameters*

Heating Modifiers

- ***Pre-Heat Time:*** Time (in seconds) to heat a fiber before movement begins. For a large diameter fiber, preheating before tapering is necessary to soften the glass. For example, a 1 mm diameter fiber normally needs 5 sec preheating, while 2 mm fiber may need 25 sec of preheating. The preheating power is the same as the tapering power, i.e., ***Absolute Power + Relative Power***. The preheating value can also be negative. For this case the heating power will be turn on after the starting of the tapering process. This is useful method for tapering small diameter fiber with some tension applied to the fiber.
- ***Absolute Lazing (Arc) Power:*** The calibrated power value of the machine. This should be set to the same as the [Calibrated Power] by Power Calibration.
- ***Relative Lazing (Arc) Power:*** Adjustment to the absolute lazing power for tapering. This value will be either added or subtracted constantly from the absolute lazing power.
- ***Waist Add Power:*** Additional power to be added or subtracted from the waist. This modifier is gradually applied as the taper nears the waist.
- ***LED on while tapering?*** (LZM only): If checked, FPS will enable the LED during a taper, shutting it off when the taper is either finished or cancelled

Heating Characteristics

- ***Tapering Power:*** The power to be applied and modified throughout the taper. (Absolute Lazing Power ± Relative Lazing Power)
- ***Tapering Power at Waist:*** The power to be applied at the waist, where all of the waist add power will be factored in. (Absolute Lazing Power ± Relative Lazing Power ± Waist Add Power)

Choosing Heating Characteristics

For most tapering processes, a much lower power should be used than is used for splicing. Generally, the tapering power should be 75% of splicing power for the same fiber type. For example, the calibrated power is 330 bit. Then the suggested taper power should be around 330 x 75% ≈ 250 bit. This means that the inputted Relative Power should be 250 – 330 = -80 bit.

For a small waist, the heating power often needs to be further reduced for arc discharge machines (FSM-100) to prevent fiber from deforming, or the heating power needs to be further increased at the small waist for CO2 laser beam heating (LZM) to get enough absorption. So, the Waist Add Power parameter is used for this type of waist power adjustment. It can either be positive or negative values. It will be gradually applied to the fiber at down taper and up-taper region instead of applying abruptly right at the waist. A typical chart of the power profiles during the tapering process is shown below.

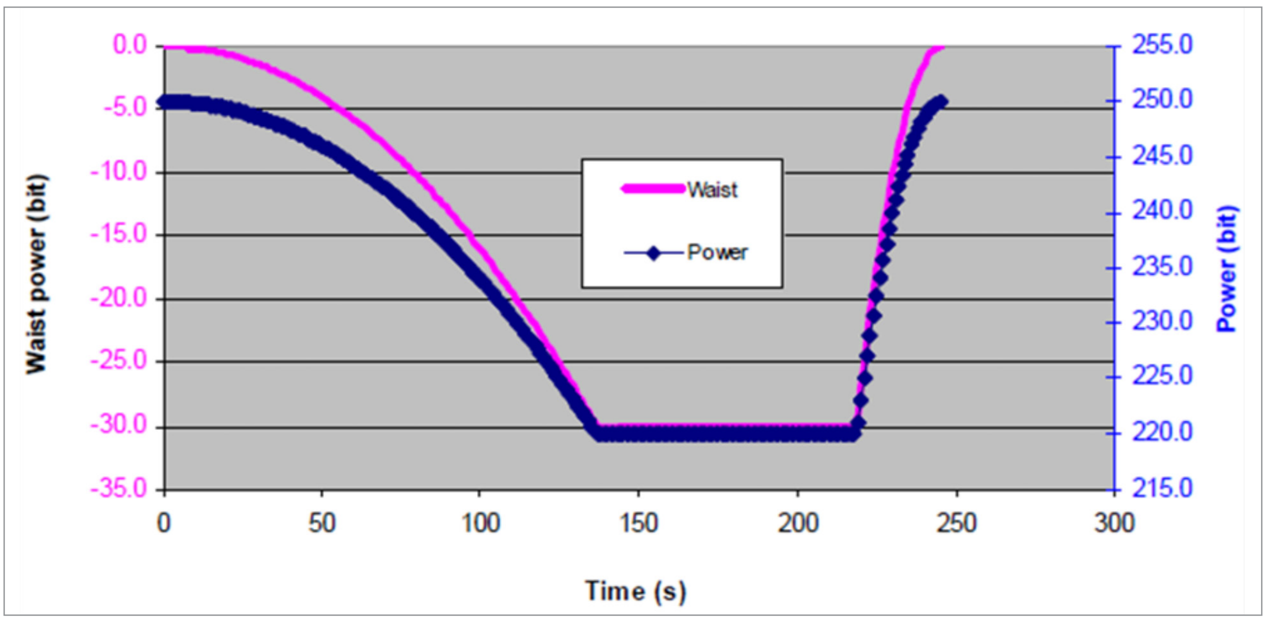


Figure 24 *– Power variation profile for the power setting shown in* ***Figure ##****. The total power (blue curve) gradually drops from 250 bit to 220 bit at the down-taper region and then keeps constant at 220 bit in the waist.*

Rotation (Taper)

The rotation group provides control of rotation during tapering for machines with theta motors.

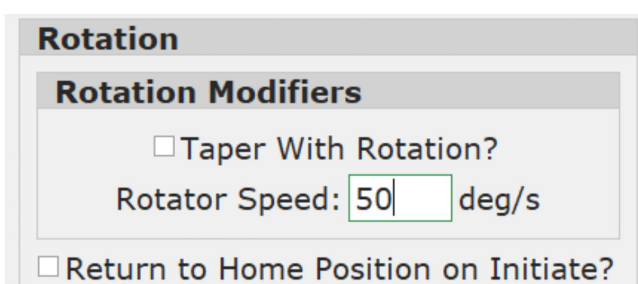


Figure 25 *– Rotation group*

Rotation Modifiers

- ***Taper with Rotation:*** When checked, the fiber will rotate during the tapering process. Rotation during tapering is important to evenly heat non-solid or holey materials. Typically, a higher rotation speed will yield a more even heat. The maximum rotation speed is 50 deg/sec for FSM-100 and 150 deg/sec for LZM-100.
- ***Rotator Speed:*** The speed, in degrees per second, at which the fiber will rotate during tapering. This speed is also used when spin/stop is pressed.

Movement (Taper)

The movement group allows you to set the movement mode, speed, and sweep mode if using an FSM machine.

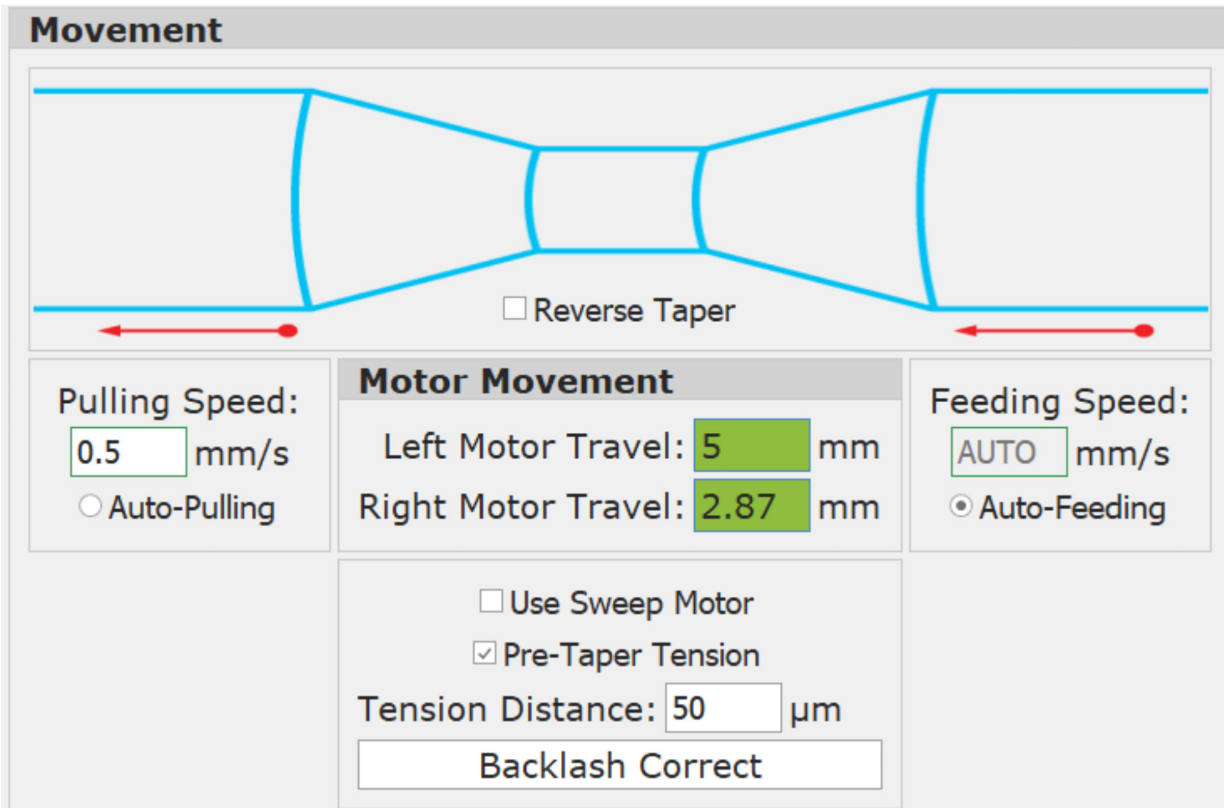


***Figure 26** – Movement group*

If **Auto-Feeding** is selected, as in Figure 26, the user must select a pulling speed, and the feeding speed will be calculated by the software. If Auto-Pulling is selected, the user must select a feeding speed, and the pulling speed will be calculated. The limits of the user-selected speeds vary based on taper ratio and mode; however, if a warning appears, the software will inform you of the acceptable range.

If using an FSM machine, the user will be able to use the sweep motor instead of the left motor, which allows for greater taper lengths but reduced quality. For example, below are two screens of a 7 mm taper on an FSM-100P, with and without the sweep motor. The taper cannot be completed without using the sweep motor

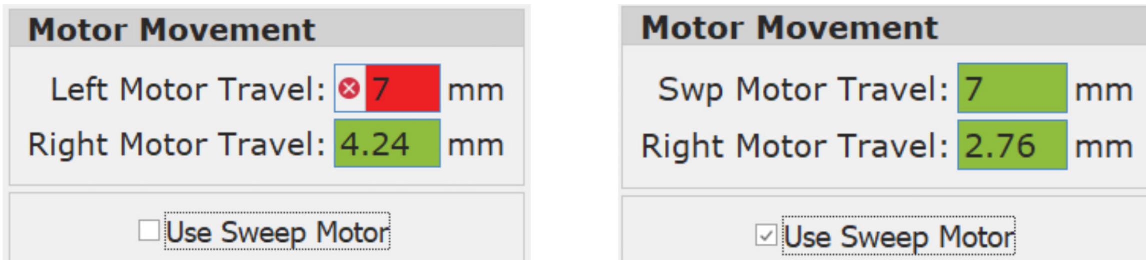


***Figure 27** – Sweep travel on a 7 mm taper*

By checking the Pre-Taper Tension box, the pulling motor will move a fixed distance before beginning the taper.

Warm Taper Image (WTI)

The warm taper image tab is used to view, control, and use the warm taper image for real time control.

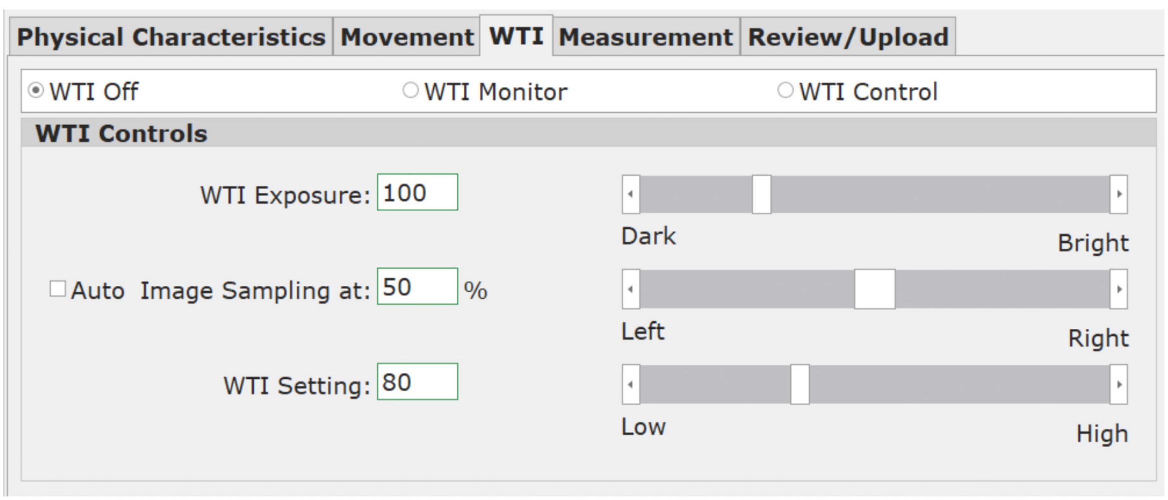


***Figure 28** – WTI tab*

WTI Exposure

The splicer's camera exposure can be set before the taper begins as well as changed throughout the process. Entering a new value in the text box or sliding the scroll bar during a taper will change the exposure in real time, allowing the user to get a clear picture of a taper at any point during the process. For **WTI control**, it is recommended that the exposure not be changed once tapering begins.

Image Sampling

This value indicates from which column of pixels the WTI setting (current brightness) will be determined. If Auto is checked under the Image sampling bar, the brightest location will be automatically determined and used.

WTI Setting

This shows the current average brightness of the column returned by image sampling. When set before running a taper with **WTI Control**, the software will attempt to keep the brightness at that value by adjusting the arc power throughout the taper.

WTI Modes

The warm taper image can be processed three different ways during a taper:

- ***WTI OFF:*** No image data is collected or processed by the taper application. This increases video fidelity and should be used when WTI Control is not needed.
- ***WTI monitor:*** Image data is collected and the WTI setting is displayed, but arc power is not modified as with WTI control. By closely monitoring the setting, this mode can be used to determine the best target setting for WTI control.
- ***WTI control:*** Uses the initial WTI setting (brightness) to control the arc power throughout the taper and maintain a constant brightness. When the **WTI control** is selected, the **Waist Add** does not add power any longer. Instead, it adds extra intensity (plus or minus) to your **WTI setting** value for the waist. For the control to work, you also need to remember to switch to full live X view and full live Y view on the two monitors before tapering. However, not all fiber types and taper shapes are good for the WTI control. For example, some fibers or tapers are too dark to see any warm image during a period of tapering process. It is impossible to do the temperature control without seeing the warm image.

Performing a Taper

After setting all necessary parameters, an operator must follow a series of steps to successfully perform a taper. Tapering with FPS is described in this chapter.

Machine Initiation for Taper Process

Before loading fibers for tapering, the Z-motors should be moved to correct position for the process. Make sure that the splicer is at READY state and then click the **INITIATE** button in the controls panel. If you change or edit the splice mode after the initiation, you must re-initiate again since the motors may be reset to the home position after your splice mode changing or editing.

During the initiation, if you want to stop the operation immediately, you can click the **STOP** button at any time. You can also reset the machine by clicking the **RESET** button. The **STOP** button stops motors at their current position. The **RESET** button will send the motors to their home position.

XY Alignment (Optional)

When tapering a without first splicing, it is critical that the right and left V-grooves are aligned before loading the capillary to be tapered. To do this, after performing an initiate, click the **XY ALIGNMENT** button. The first message will read as follows:

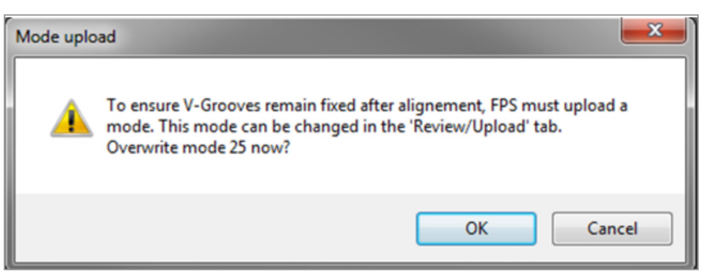


***Figure 29** – Capillary Alignment Mode upload notification*

On clicking OK, the mode ### **ALIGN** will be uploaded to whatever mode is selected in the Review/Upload tab, where ### is the fiber diameter. Once uploaded, the following appears:

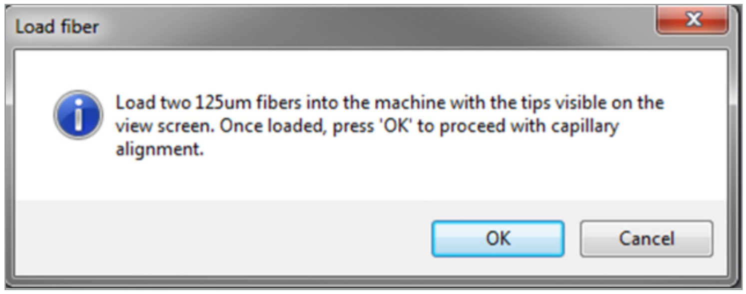


***Figure 30** – Ready for XY Alignment*

DO NOT press okay until the fibers are loaded as pictured in Figure 31, or the initiation must be restarted. Once the fibers are in position, press "OK" on the **Load Fiber** prompt. The machine will then complete the following sequence:

1. Perform a gap set of 120 µm.
2. Perform a cladding XY alignment.
3. Upload a mode ### **FIXED**, where ### is the fiber diameter to the previously specified capillary alignment mode.

Once in the **FIXED** mode, the V-grooves will not move. Proceed with loading the capillary and resume the taper process.

Loading Fiber for Tapering

Splicing before a taper: After the initiation process, the fiber holders may be far away from the center compared to ordinary splicing. If you are going to splice fibers before tapering, you must manually adjust the fiber in the fiber holder to position the fiber end as close to the screen edge as possible. It is best if you can see the cleaved fiber ends on the edge of screen as shown at right in Figure 31. If you do not pay attention to the initial fiber starting position, the fiber and V-groove may be automatically moved forward to a GAP position that is too close to the heating area at the center of the screen. This may either cause a lack of space for motors to travel, or in some cases this may even burn the fiber clamps since one of the V-grooves and fiber clamps may be moved into the heating area. ***IMPORTANT NOTES FOR FIBER LOADING:*** Please pay close attention to the fiber end position after loading fibers for splicing, since the machine does not know your actual strip length. If the clamps are burned, please contact AFL/Fujikura to purchase replacement parts

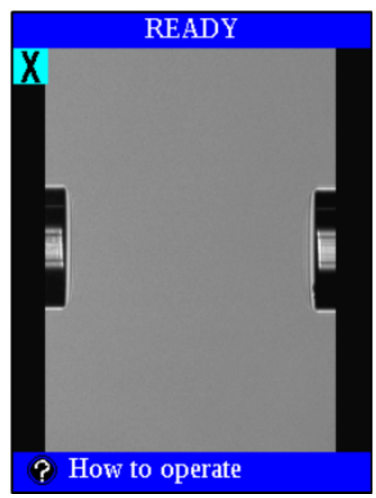


***Figure 31** – Best fiber loading position for splicing before tapering.*

Window stripping before a taper: After performing the initialization, measure the gap and window strip the fiber to fit within it. After fiber has been loaded, add a small amount of tension by moving the left motor slightly, either with the manual controller, using motor drive, or selecting pre-taper tension. This tension is important to keep the fiber straight during tapering, but **SHOULD NOT** be added to spliced fiber, as spliced fiber is already under tension after splicing.

Tapering

Once the machine has been initiated and the fiber has been loaded according to these instructions, press the **TAPER** control to begin the taper process. While it is running, you can observe the movement of the motors with the manual controller, view the live video, and/or monitor the WTI settings and exposure if you wish.

Interrupting the Taper Process

The taper process can be interrupted at any time using either the **STOP** or **RESET** control. Once halted, however, the entire process must be reinitiated before performing another taper. It is not possible to resume an interrupted taper.

Measurement (Taper)

Upon completing the taper, it is recommended that the user press the **MEASURE** button to perform a point-by-point measurement of the final taper and generate an Excel report. If the fiber has been moved since completing the taper, the user will be asked to move to the taper ending position. If this prompt appears and you are certain it is in the correct position, just press “No” and the measurement will continue from the current location.

The measurement tab provides a measurement speed control and data returned upon pressing the **MEASURE** control button.

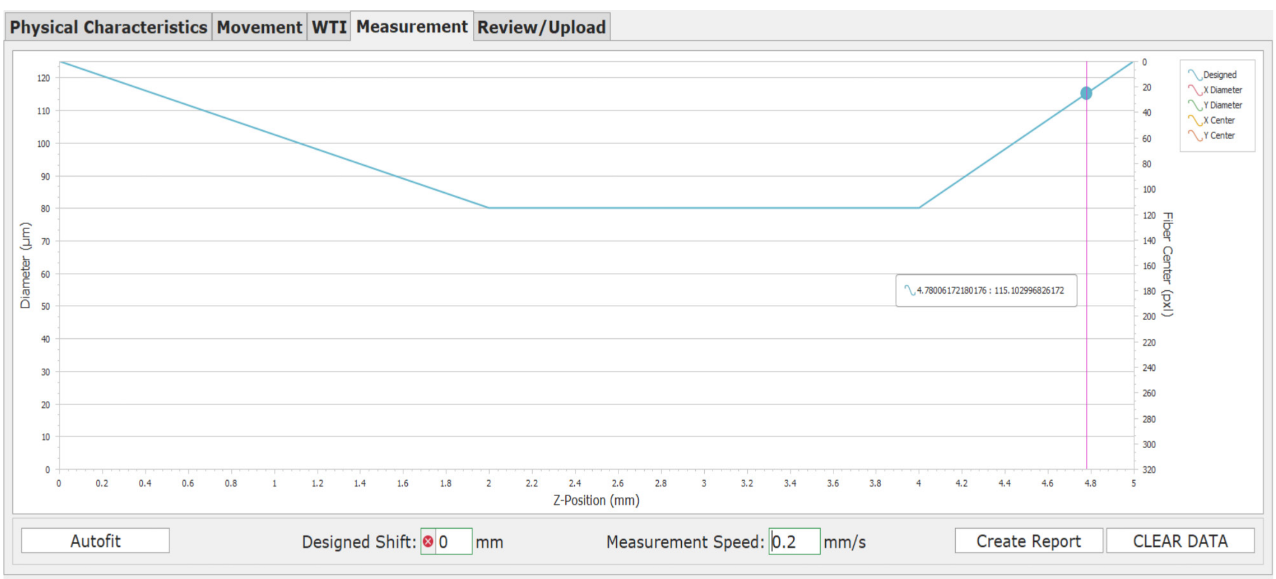
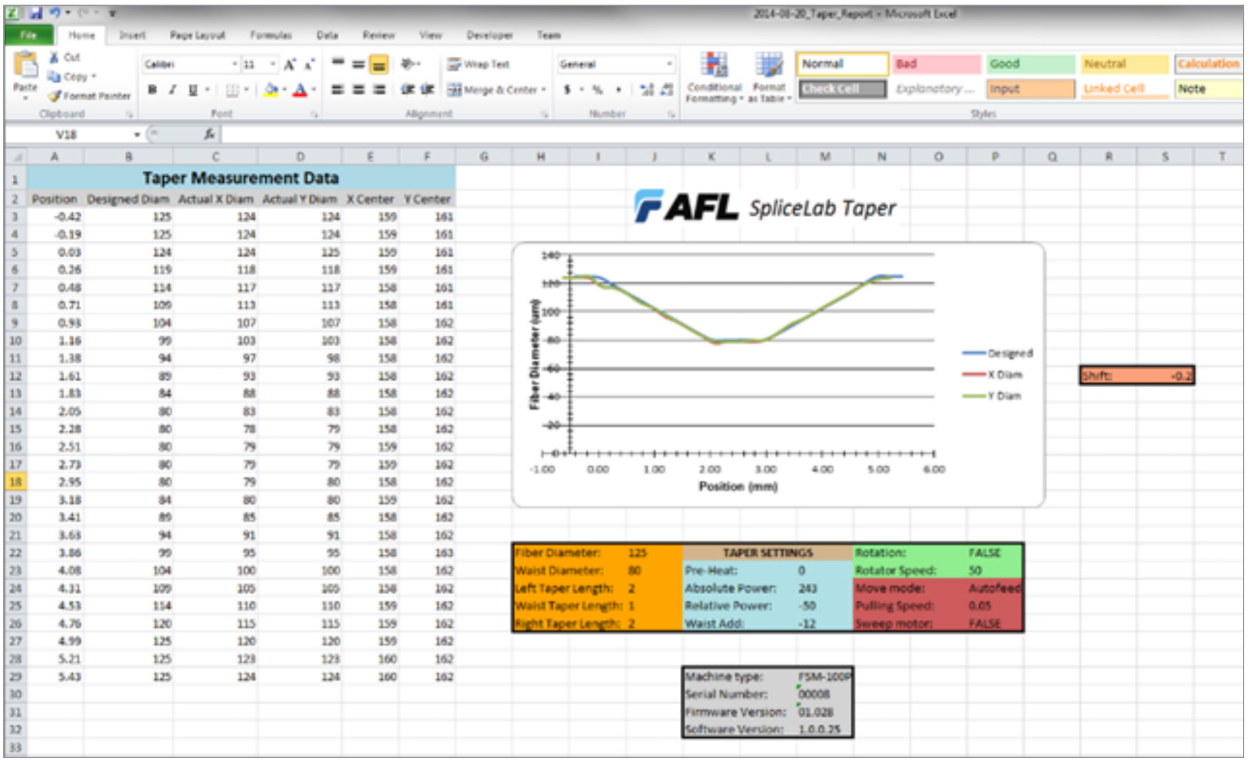


Figure 32 *– Measurement tab*

The blue line on the graph, "Designed," will always reflect changes to physical characteristics and is visible even before initiation. X and Y Diameters are measured point by point. X and Y Center measure the center of the fiber relative to the screen. **Right clicking the graph** will allow you to enable or disable any of the included measurements. After measurement, the **Create Report** button will generate an .xslx file that provides a snapshot of the last taper. You can also click "Autofit" to shift the measured diameters to fit the designed as closely as possible.



Taper Measurement Data					
Position	Designed Diam	Actual X Diam	Actual Y Diam	X Center	Y Center
-0.42	125	124	124	159	161
-0.19	125	124	124	159	161
0.03	124	124	125	159	161
0.26	119	118	118	159	161
0.48	114	117	117	158	161
0.71	109	113	113	158	161
0.93	104	107	107	158	162
1.16	99	103	103	158	162
1.38	94	97	98	158	162
1.61	89	93	93	158	162
1.83	84	88	88	158	162
2.05	80	83	83	158	162
2.28	80	78	79	158	162
2.51	80	79	79	159	162
2.73	80	79	79	159	162
2.95	80	79	80	158	162
3.18	84	80	80	159	162
3.41	89	85	85	158	162
3.63	94	91	91	158	162
3.86	99	95	95	158	163
4.08	104	100	100	158	162
4.31	109	105	105	158	162
4.53	114	110	110	159	162
4.76	120	115	115	159	162
4.99	125	120	120	159	162
5.21	125	123	123	160	162
5.43	125	124	124	160	162

***Figure 33** – Generated Excel Report*

Uploading a Taper

Certain tapers can be uploaded to the splicer as a mode, allowing the splicer to taper without being connected to a PC. To review parameters and upload to the splicer, select the ***Review/Upload*** tab.

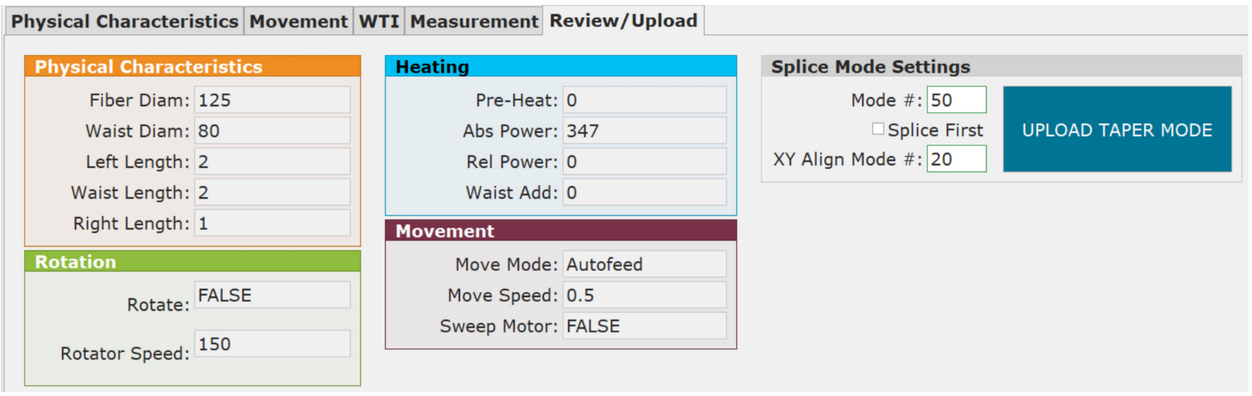


Figure 34 *– Review/Upload*

The values shown reflect the settings in each other tab, allowing you to see all parameters at a glance. To upload, enter a mode and click the **UPLOAD TAPER MODE** button. You will be prompted to overwrite the listed mode. If using **Splice First**, the splice mode box will appear beneath the “Upload” button. The selected splice mode will be copied as the splicing component of the chosen taper mode

Restricted Features

The following features **cannot** be used with an uploaded taper recipe:

- Auto-feeding movement
- Sinusoidal taper shapes
- WTI Monitoring or control

PARABOLIC TAPER

The ***Parabolic Taper*** application allows users edit the parameters of and upload a special parabolic taper to the splicer. A Parabolic Taper File (.pafl) or legacy text file can be saved or loaded to store parameters for later use.

Parabolic Taper Parameters

The Parabolic Taper application builds a special mode based on user-defined parameters that sweeps over the same length of fiber repeatedly until a target width is met.

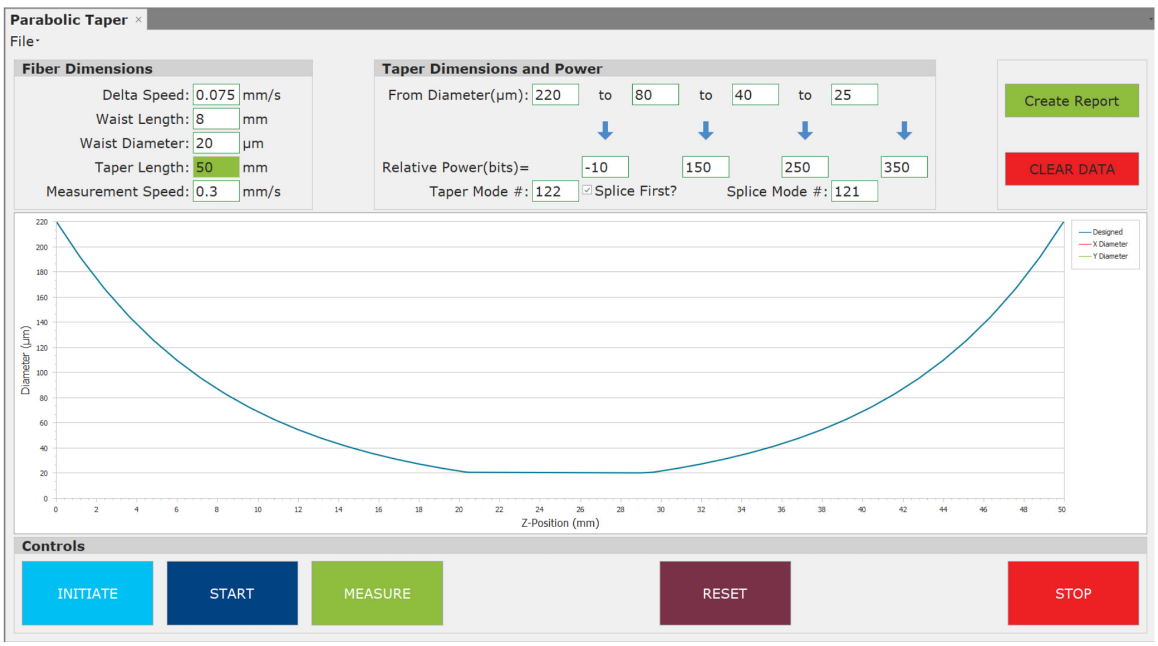


***Figure 35** – 220-20 μm Parabolic Taper with Parameters Highlighted*

The parameters affect the taper profile as follows:

- **Delta Speed:** The difference in motor speed between the ZL and ZR motors when sweeping. A higher delta speed will reduce diameter more quickly each pass, while a lower delta speed is more accurate.
- **Waist Length:** The length at the base of the taper to equal the waist diameter.
- **Waist Diameter:** Diameter at the base of the taper, this is the lowest targeted diameter when sweeping. When the machine measures this diameter, it will stop sweeping.
- **From Diameter to Relative Power:** The syntax of these lines follows the following logic: In Figure 35, the line begins From Diameter 220 to 80 with an arrow pointing to -10 in the ***Relative Power*** row. This means that, as long as the measured diameter of the fiber at the waist is between 220 and 80, relative power will be -10. The pattern continues to mean that between 80 μm and 40 μm, relative power will be 150; between 40 μm and 25 μm, relative power will be 250, and below 25 μm the relative power will be 350. The power is relative to the calibrated power of the splice mode.

Splicer Modes

On pressing initiate, parabolic taper will upload a mode to the splicer. That mode, as well as any splice information not related to the taper, is selected using three mode parameters:

- **Splice First:** If checked, the splice mode parameter will be displayed, and that mode will be written to the splice portion of the final parabolic taper mode. If unchecked, the uploaded taper mode will not include a splice. The user will also be prompted to perform an XY alignment before proceeding.
- **Taper Mode #:** The mode that will be overwritten with the new parabolic taper mode.
- **Splice Mode #:** The mode that will be copied into the parabolic taper mode. Serves as the splice recipe before the special function.

BALL LENS

Making a Ball Lens

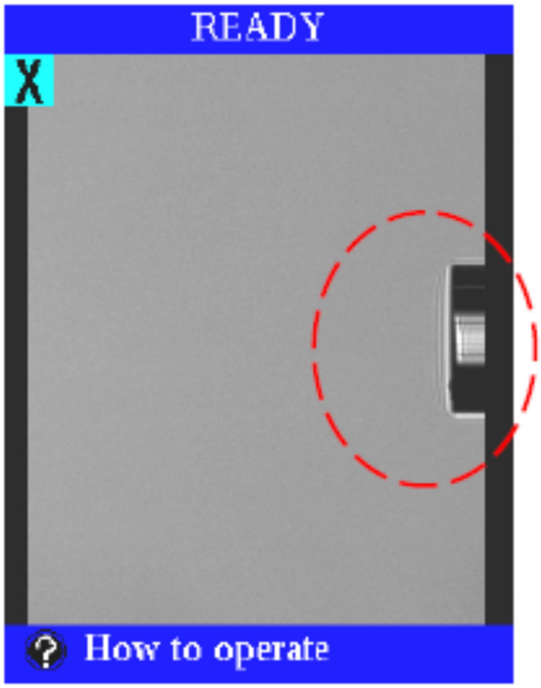
With the automated ball-lensing process, you normally need to complete the following steps: (1) parameter input, (2) machine initiation, (3) starting ball-lens process, and (4) ball-lens geometry measurement.

For making a desired ball lens, you need to determine and input the ball length geometry, heating power, rotation speed, feeding speed, the mode number selection in the splicer that will be utilized for making the ball lens, the mode number which contains the splicing parameters (if a splice will be performed prior to making the ball lens), etc.

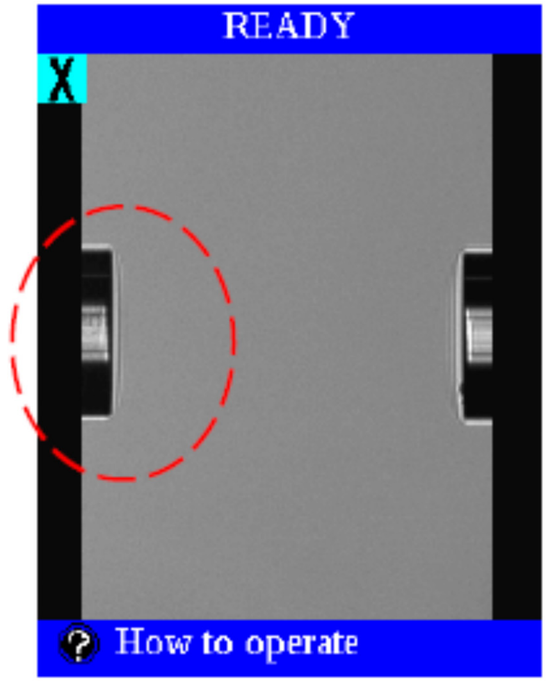
Figure 36 *– Controls for automated ball-lensing process*

At the moment when the Initiate button is clicked, all your input and selected parameters will be sent to the selected mode of the splicer. The splicing parameters previously contained in the mode will be overwritten. The ZR and ZL motors as well as the Va and Vb motors will move to the initial positions based on your input parameters and be properly positioned to be ready to accept fiber loading. If any of the Pause functions are ON, you will be required to turn them all OFF.

Important notes for fiber loading: please keep in mind that for making a ball lens, the blue v-grooves may be far away from the center position compared to ordinary splicing. You need to manually adjust the fiber strip and cleave length in the fiber holder to keep the fiber ends as close to the screen edge as possible. It is best if you can see the cleaved fiber end on the edge of screen as shown below in Figure 37. If you do not pay attention to the initial fiber starting position, the fiber and V-groove may be automatically moved forward to a GAP position that is too close to the heating area at the center of the screen. This may either cause a lack of space for the motor travel, or in some cases it may even burn the fiber clamps since one of the V-grooves and fiber clamps may be moved into the heating area. Please pay close attention to this note, since the machine does not know your actual strip length. If the clamps are burned, please contact AFL/Fujikura to purchase replacement parts.



***(a)** Single fiber ball lensing*



***(b)** Dual fiber ball lensing*

***Figure 37** – Best fiber loading position for ball lensing. The red dashed-line circles indicate the critical location for ball-lens processing.*

After loading the fiber, you can either click the Start button on the PC screen or press the SET button on the splicer to start the ball-lens processing. Since all the ball-lensing parameters are already transferred to the splicer, you can repeat the same ball-lensing process on the production line with the splicer without connection of a PC.

Important note for ball-lensing with rotation and splicing: During this process, since the right fiber holder moves backward right after splicing in order to reach the proper breaking point of the left fiber, the right fiber will be bowed between the right-side rotator and right-side fiber holder. As soon as the rotator starts rotation for the ball lensing step, the bowed fiber will be snapped and broken by the rotator. Therefore, it is important that the right fiber should be pulled slightly to the right after the splicing to keep it straight (and unbowed) inside the rotator.

When the ball-lensing process is completed, by clicking the Measure button you can obtain the ball lens measured diameter, shape displayed on the screen, and images saved to the folder where the ball-lens program is located.

During any process described above, if you would like to stop the process immediately, the **STOP** button can be clicked. This button will stop all the motors at the current position as well as turning off the heating power in the splicer. It also stops the Excel program process. If the process is stopped, it cannot be resumed. If you would like to start another ball-lens process, you need to either click the Initiate button on PC screen or press the RESET button on the splicer.

In the following sections, the application and functions of all parameters and settings will be described in detail.

Ball Lens Geometry

In the following example, a ball lens of 400 µm diameter is going to be made with a coreless fiber with 125 µm cladding diameter. In this example, the coreless fiber is spliced to 125 µm diameter SMF28 fiber. The distance between the splice point and the ball center is set to be 250 µm. This process therefore results in a pure silica ball lens on the end of a single-mode fiber.

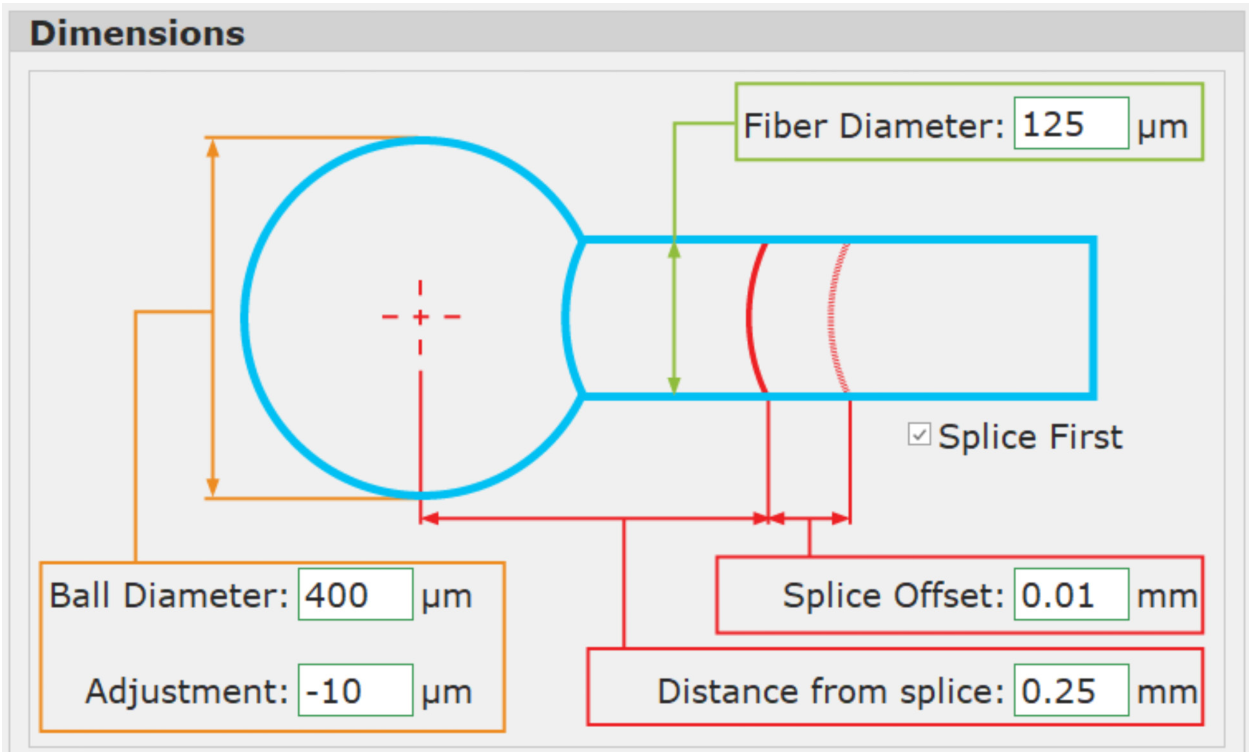


Figure 38 *– A 400 µm ball lens is to be made with splice 125 µm diameter fibers. The splice point is set to be made 250 µm from the ball center.*

The 125 µm diameter is typically a fiber diameter specification value, however the actual fiber diameter may vary from that specification by a few microns. This difference will cause a ball lens diameter deviation. After performing a few tests, you can easily identify a diameter adjustment value, either positive or negative, to help you to reach the desired ball lens diameter. In a similar way, a fine adjustment of the distance between the ball-center to the splice point can by input by using the ***Offset*** value.

If the ball lens is to be made with a single fiber, the ***Splice First*** check-box should be unchecked. And the ***Distance*** and ***Offset*** values will automatically become blank.

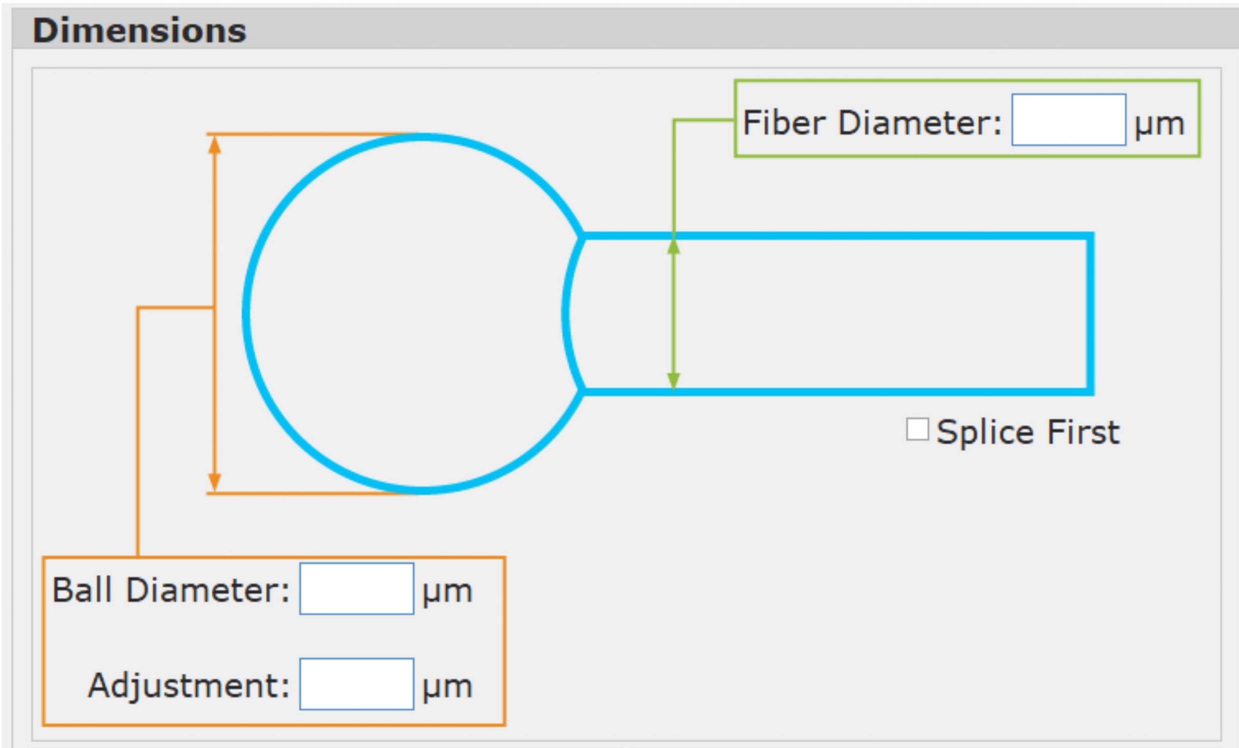


***Figure 39** – A 400 μm ball lens with "Splice First" unchecked.*

Feeding Speed

For making a proper ball lens, you need to input a Feeding Speed for the process. The acceptable range of the speed is from 0.01 mm/sec to 1 mm/sec. If a value outside the range is input, the value will show on the screen in a red font color, instead of blue. The lower the speed, the higher quality of the ball-lens that can be made. But the slower speed requires longer processing time. Optimize the speed to balance the ball quality and the production time to meet the needs of your application.

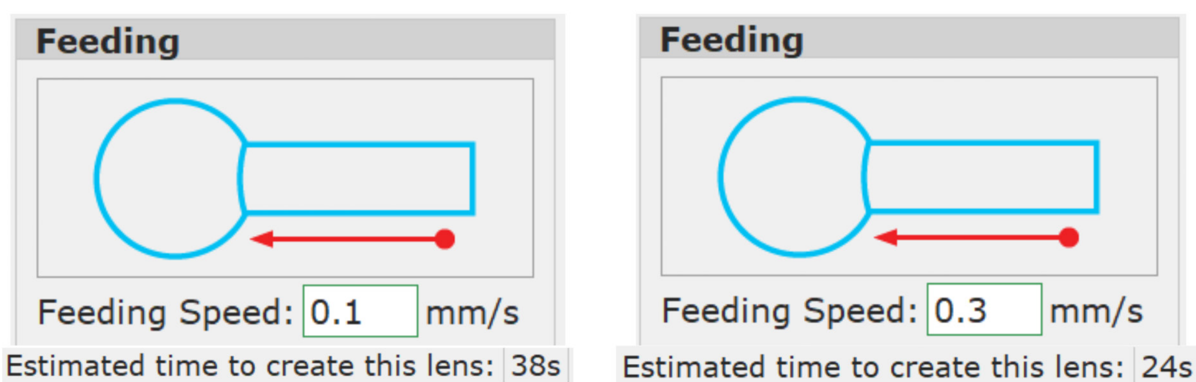


***Figure 40** – Different feeding speeds will cause different process times and different ball quality.*

Mode Numbers for Ball-lensing

Once the splice parameters are correct and you press **INITIATE**, the software will upload the new mode to whichever slot has been placed in the ***Ball Lensing Mode*** text box. You can use any mode number for your ball-lensing procedure. However, it may be a good idea to select an empty mode, since all the parameters contained by this mode number will be permanently overwritten when the INITIATE button is clicked. If you are creating a ball lens with a single fiber, you only need to choose the ***Ball Lensing Mode***.

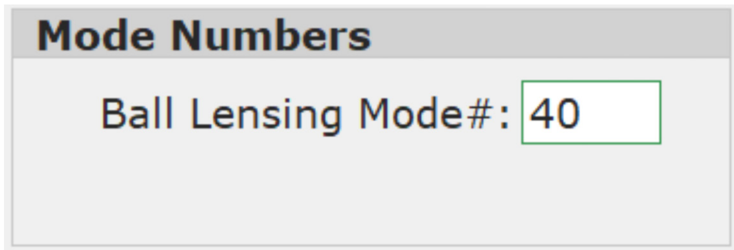


Figure 41 *– Ball lens without splice to be uploaded to mode 40.*
This will overwrite any parameters currently in mode 40.

Mode Numbers for Ball-lensing and Splicing

A ball lens can be made with either a single fiber (without splicing) or using two fibers after splicing. A checkbox ***Splice First*** in the physical characteristics tab is used for this selection. When this checkbox is checked, you need to provide a mode number which contains the appropriate splicing parameters for the fiber combination you are going to splice (in addition to selecting a mode number for the ball lens operation). It is a good idea to make a splice trial with the splice mode first to make sure the splicing parameters are valid and work well for your fiber combination. Please also notice that the fiber to be kept with the ball-lens attached is always on right side. For ball lens operations without splicing, you must load the single fiber in the proper position on the right side of the splicer. For splicing first followed by creating the ball lens, the fiber that will provide the material to form the ball lens is loaded in the left side of the splicer, and the fiber to which the ball lens will be attached is loaded on the right side of the splicer.

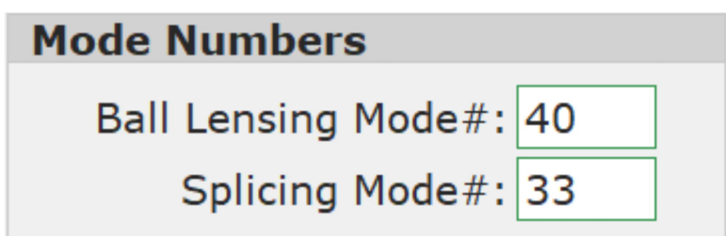


Figure 42 *– Ball lens with splice to be uploaded to mode 40. In the example above, mode 40 will be used to make the ball lens. The parameters in mode 33 will be copied to mode 40 for the splicing operation that is performed prior to ball lens making.*

For splicing parameters in the splicing mode, please make sure to use the Special Arc Calibration for FSM-100 splicers. Please also keep in mind that the electrode gap and electrode height for splicing in this mode will also be used for ball-lensing. So, please choose a larger electrode gap value and zero electrode height value, when possible, since the large electrode gap will provide enough heat power for ball lensing. For example, for splicing 125 µm SMF28, a 1 mm electrode gap is normally used. But for achieving a 400 µm ball, a 2.2 mm electrode gap should be used. So, in the mode which providing the splicing parameters for ball lensing (mode 33 in the Figure above), 2.2 mm electrode gap should be used for splicing. For the LZM-100, those electrode-related parameters will make no difference since there are no electrodes in the CO_2 laser splicer. Moreover, the Standard Power calibration is good for LZM-100.

Power Calibration and Power Setting for Ball-lensing

To determine the proper heating power to use for ball-lens generation, a power calibration should be made in advance. For either a single fiber ball-lensing operation (without splicing) or a dual fiber ball-lensing operation (with splice), you should always use the fiber which you want to keep as the pigtail to run a special arc calibration at electrode gap 2.2 mm and 0 electrode height for the FSM-100. For the LZM-100, use the standard lase calibration.

The power used for ball-lensing is normally 30% higher than that for splicing. The best power level to be used is fiber type dependent and therefore the power parameters need to be optimized. As shown in the following figure, 3 parameters can be adjusted for heating power. The ***Absolute Power*** should be set to be the same value as the ***Power Calibration*** value, which can be read from the splicer. The ***Relative Power*** is the additional power required for ball-lensing. It can be a positive or negative value. The ***Break Add*** power is used only for the additional power to break the fiber when fibers are spliced before ball-lensing. (***NOTE:*** In this case, just after splicing, the spliced fibers are moved in unison to the right a distance calculated by the ball lens software, and an additional arc or lase is used at the ***Break Add*** power to heat the left fiber at a distance away from the splice point. This is done while the fibers are pulled outwards, so the left fiber will therefore be broken apart at a distance from the splice point. This operation results in the correct amount of remaining left fiber type to generate the correct size ball lens, at the correct distance from the splice point.)

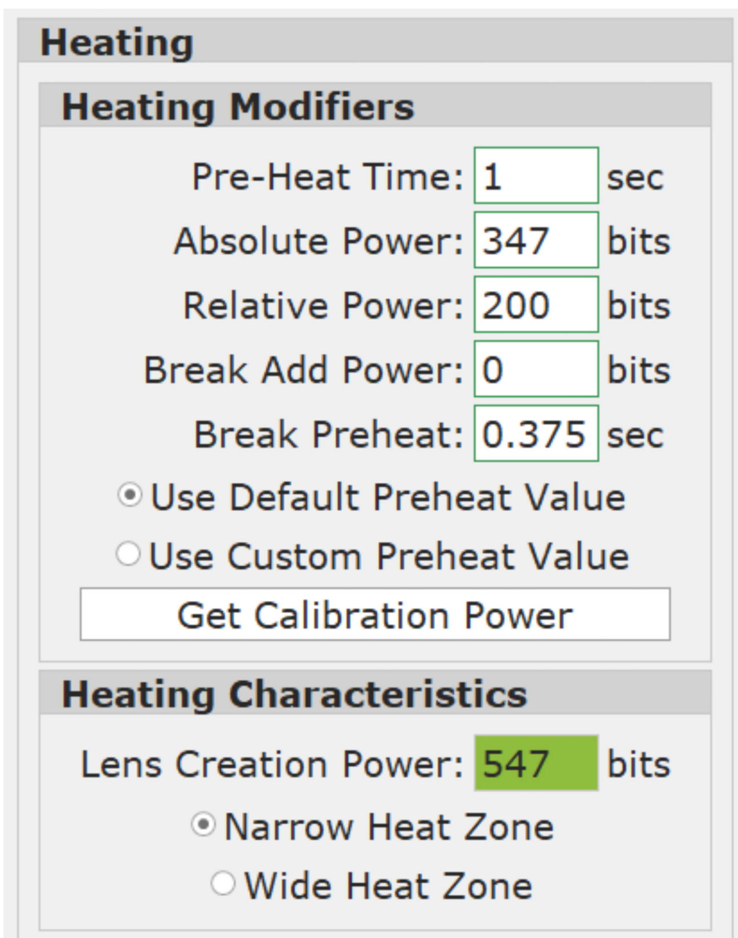


Figure 43 *– Heating Group*

Additional Power Parameters for Laser Splicers Only

For LZM-100 and LZM-110 series machines, the ***Break Preheat*** box and ***Lens Type*** radio buttons will be visible. Break Preheat can be customized if additional time is required to heat large fibers before a break. If set to default, the preheat time will be formula-ically determined. The ***heat zone type***, either Narrow or Wide, allows you to select your expected heating profile based on whatever lenses you are using.

Rotation Parameters

The rotator control settings are only functional for splicers which have one or two rotators installed, such as the FSM-100P, FSM-100P+, and LZM-100 with at least a rotator option on the right side of the machine. If no rotator is found on your machine, rotator controls will be disabled. If you are sure there is rotator with your splicer, please close FPS and reopen it again to let software re-communicate with your splicer.

For creating a ball lens with a large ball diameter to fiber diameter ratio, rotating the fiber during the ball-lensing can effectively reduce the effect of gravity and keep the offset between the ball center and fiber center negligible or very small. Generally, a higher rotation speed will yield a lower value of the offset. The maximum rotation speed is 50 deg/sec for the FSM-100 and 150 deg/sec for LZM-100. The offset of ball lens center relative to fiber axis center is not only related to rotation speed. It is also strongly related to the feeding speed. A feeding speed that is too fast will cause a heating of the neck of the ball lens. This will result in a very large offset between the ball and fiber centers.

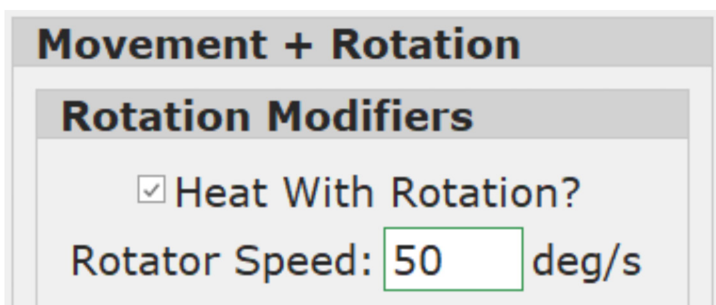


Figure 44 *– Rotation modifiers*

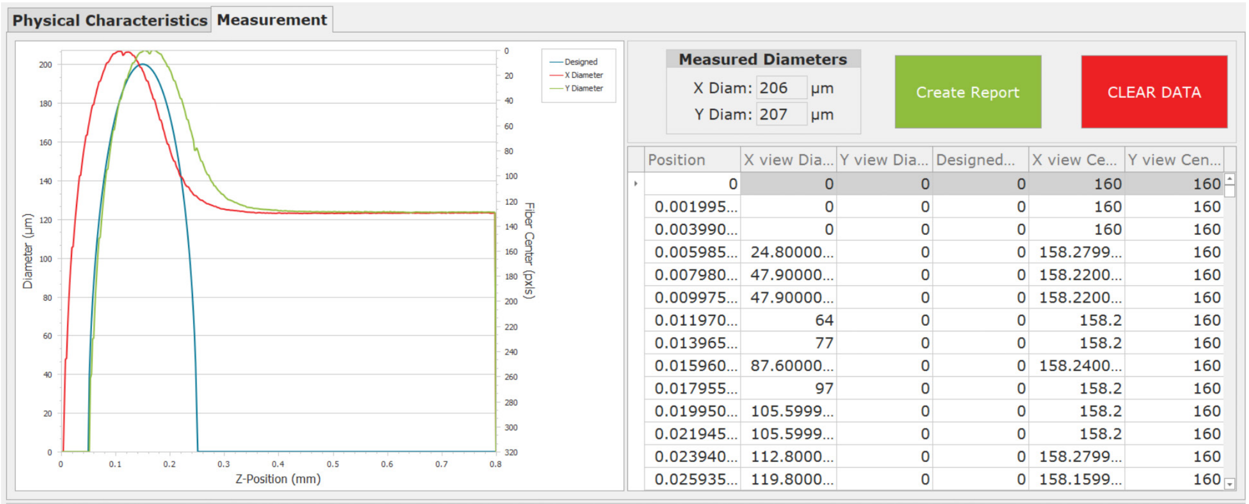
To spin the fiber during ball-lensing, the ***Heat With Rotation*** check-box needs to be checked. After ball-lensing, the rotator will go back to the home position automatically when the wind protection cover is opened.

Other Parameters and Buttons

Real Time Control (FSM Only): By checking this checkbox, the ball diameter will be measured at the end of the ball-lensing process. If the ball lens is smaller than the target, an increment of ball-lensing process will be repeated up to 10 times and the ball lens will be re-measured until the target is reached. By reducing the Ball diameter adjustment value, you can ensure that the initial ball lens diameter at the end of the ball-lensing process is always slightly smaller than the target diameter. Then the Real Time Control can be used to automatically increment and approach the target size. This process will require a slightly longer total process time, but you can obtain better geometry accuracy and repeatability.

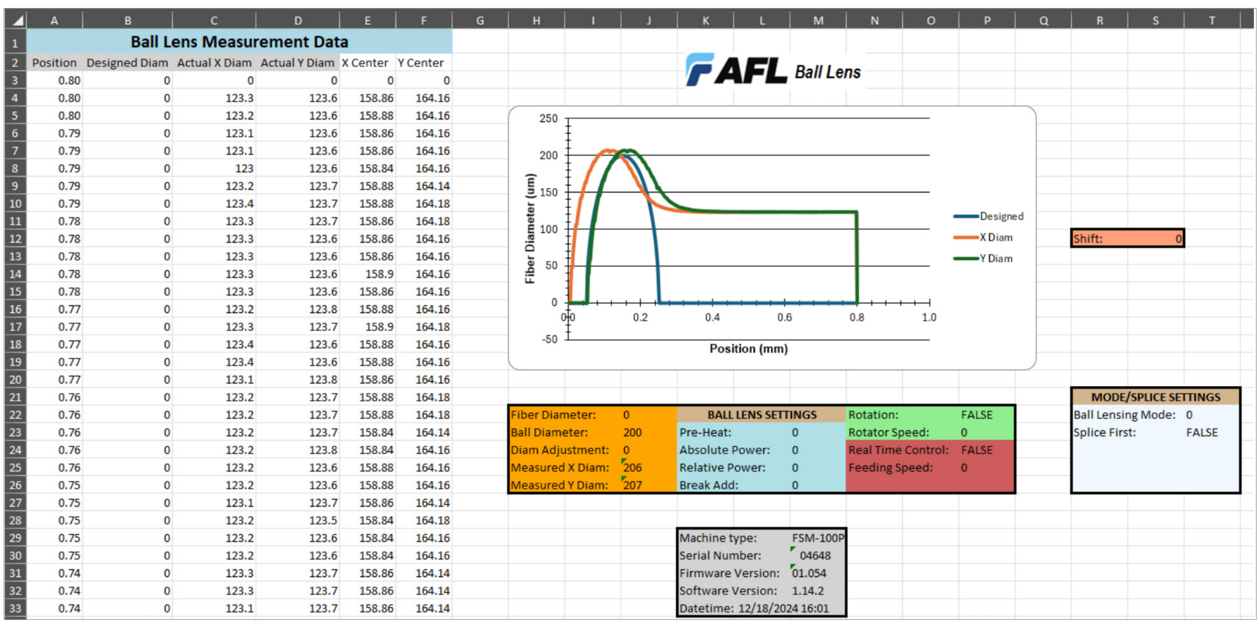
Pre-heat: This value can be positive or 0. If it is positive, it will provide extra fiber heating time (selected in seconds or fractions of seconds) before the ZR motor feeds the fiber forward for ball-lensing. This pre-heating may be necessary for fibers with very large diameter (> 1.0 mm). If it is zero, the preheating is disabled.

Create Excel Report: Once measurement is complete, clicking the Create Excel Report button at the top right of the Measurement tab will generate a .xlsx report similar to the taper report.



Position	X view Dia...	Y view Dia...	Designed...	X view Ce...	Y view Cen...
0	0	0	0	160	160
0.001995...	0	0	0	160	160
0.003990...	0	0	0	160	160
0.005985...	24.80000...	0	0	158.2799...	160
0.007980...	47.90000...	0	0	158.2200...	160
0.009975...	47.90000...	0	0	158.2200...	160
0.011970...	64	0	0	158.2	160
0.013965...	77	0	0	158.2	160
0.015960...	87.60000...	0	0	158.2400...	160
0.017955...	97	0	0	158.2	160
0.019950...	105.5999...	0	0	158.2	160
0.021945...	105.5999...	0	0	158.2	160
0.023940...	112.8000...	0	0	158.2799...	160
0.025935...	119.8000...	0	0	158.1599...	160

***Figure 45** – Measurement tab with "Create Excel Report" located at top right.*



Ball Lens Measurement Data

Position	Designed Diam	Actual X Diam	Actual Y Diam	X Center	Y Center
0.80	0	0	0	0	0
0.80	0	123.3	123.6	158.86	164.16
0.80	0	123.2	123.6	158.88	164.16
0.79	0	123.1	123.6	158.86	164.16
0.79	0	123.1	123.6	158.86	164.16
0.79	0	123	123.6	158.84	164.16
0.79	0	123.2	123.7	158.88	164.14
0.79	0	123.4	123.7	158.88	164.18
0.78	0	123.3	123.7	158.86	164.18
0.78	0	123.3	123.6	158.86	164.16
0.78	0	123.3	123.6	158.86	164.16
0.78	0	123.3	123.6	158.9	164.16
0.78	0	123.3	123.6	158.86	164.16
0.77	0	123.2	123.8	158.88	164.16
0.77	0	123.3	123.7	158.9	164.18
0.77	0	123.4	123.6	158.88	164.16
0.77	0	123.4	123.6	158.88	164.16
0.77	0	123.1	123.8	158.86	164.16
0.76	0	123.2	123.7	158.88	164.18
0.76	0	123.2	123.7	158.88	164.18
0.76	0	123.2	123.7	158.84	164.14
0.76	0	123.2	123.8	158.84	164.16
0.76	0	123.2	123.6	158.88	164.16
0.75	0	123.2	123.6	158.88	164.16
0.75	0	123.1	123.7	158.86	164.14
0.75	0	123.2	123.5	158.84	164.18
0.75	0	123.2	123.6	158.84	164.16
0.75	0	123.2	123.6	158.84	164.16
0.74	0	123.3	123.7	158.86	164.14
0.74	0	123.3	123.7	158.86	164.14
0.74	0	123.1	123.7	158.86	164.14

***Figure 46** – Ball Lens Excel Report*

Auto Mode Example: Coreless Ball Lens Splice to 80 µm Fiber

This application example illustrates setup and use of the ball lens auto mode. In this example, an 80 µm single-mode fiber is spliced to a 125 µm coreless fiber. A 350 µm ball lens is generated with the coreless fiber. In this case, the splice point should is just to the right edge of the ball lens. For the initial splicing of the 125 µm coreless fiber to the 80 µm single-mode fiber, the standard 80 µm fiber splicing mode can be used, which can found in the splicer database and loaded into mode 41. In the case of performing this operation with the FSM-100, a few splice recipe parameter modifications should be made: Change the electrode gap from 1 mm to 2.2 mm, turn auto stuffing OFF, increase the pre-fuse power by 30 bits, and change the left fiber diameter 80 to 125 microns for the coreless fiber. (Parameter adjustments for the LZM-100 80 µm program are similar, but with no need to set electrode gap.) Perform a few splices to check the splice result, and tweak the splicing parameters further if required.

For the ball lensing parameters (as shown in the figure below) it is necessary to set the starting fiber diameter to 125 µm since the coreless 125 µm fiber will be used to generate the ball lens. Also, considering that the splice point of the 80 µm to 125 µm fiber will have a tapered diameter transition, it is necessary to set a slightly larger value for the distance from the ball center to the splice point.

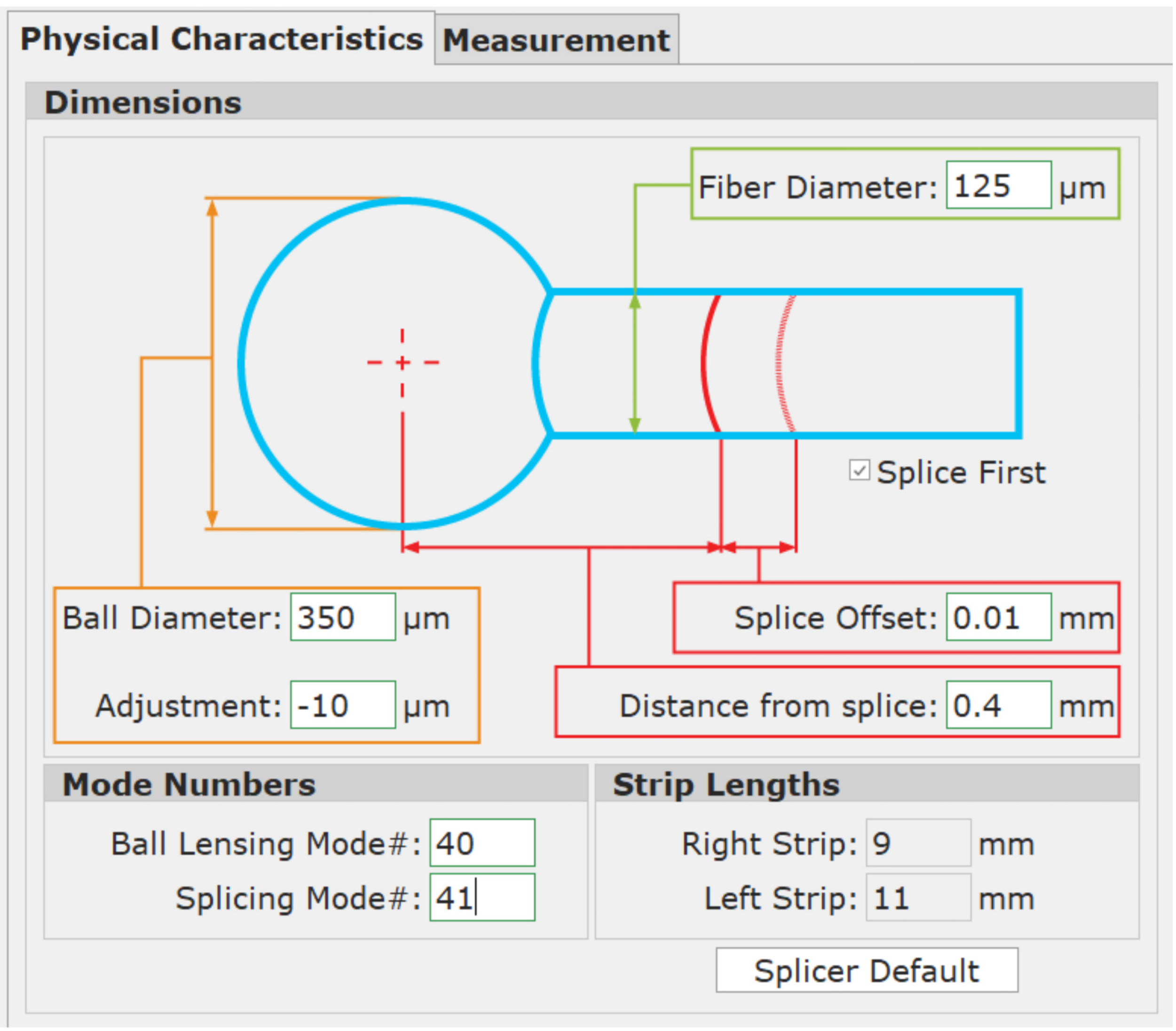
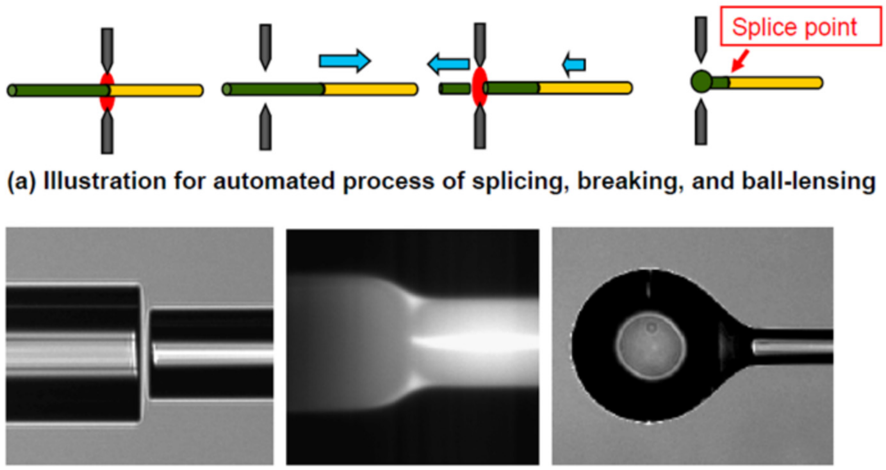


***Figure 47** – Controls parameters for a 350 µm ball lens with 125 µm coreless fiber spliced to 80 µm single-mode fiber using FSM-100P*



(a) Illustration for automated process of splicing, breaking, and ball-lensing

(b) Before splicing (c) During splicing (d) Final ball-lens

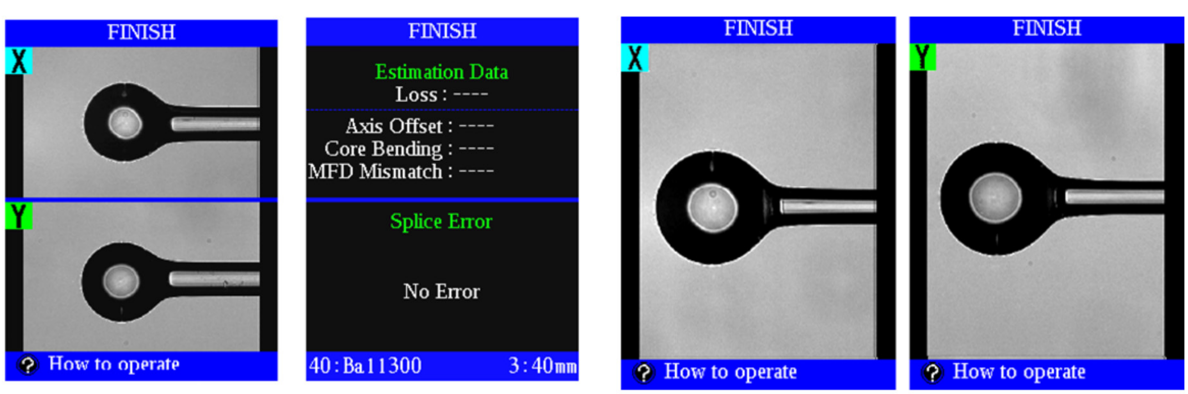
Figure 48 *– Process and results are shown for a 350 µm ball lens with 125 µm coreless fiber spliced to 80 µm single-mode fiber using the FSM-100P splicer. Total process time is 96 seconds with a measured ball diameter of 348.6 µm.*

Ball-Lens Measurement

After making a ball-lens, it is very important to make an accurate measurement of diameter and shape. The ball lens images should be easily analyzed and archived. This Ball-Lens software provides all of these functionalities.

Measurement Procedure

After the ball-lensing process, the splicer will display the images based on your Splicer Settings. As examples, you may see displayed on the screens split images of X and Y view with splice or fiber information, the warm image taken during splicing, the fiber-ends images taken before splicing, the live full images of X and Y view, etc. Some of those images are shown in the charts below. By pressing the ***X/Y*** button repeatedly on the splicer, you should be able to see the full images of X and Y view each on a different display. The ball lens measurement is better performed when these images are shown on the splicer display monitors for valid image analysis (see details in Sec 5.2). In the case you cannot find these images by pressing the ***X/Y*** button, modify the ***Display at Finish*** selections in the ***Splicer Utility Settings*** sub-menu.



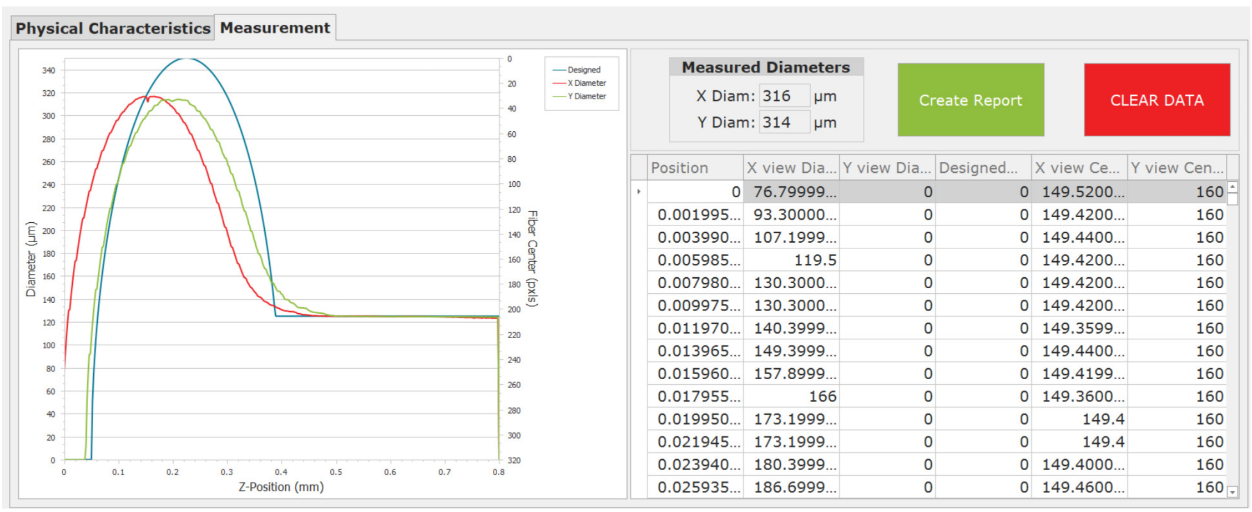
(a) Split X and Y view images with splice info on the right

(b) Full live XY images, better for measurement

Figure 49 *– Examples of images shown after ball-lensing process*

Important Note: Before clicking the ***Measure*** button on PC screen, please make sure that the splicer is in ***Finish*** mode, i.e., “FINISH” is shown on top of screen. Since the processing time on the PC screen is an estimated value, sometimes the process on the PC may be shown as completed but the actual process in the splicer is not, especially when the ***Real Time Control*** process is running. If you click the Measure button too early while the actual ball lens process has not been completed, you may see an error message indicating loss of communication on your PC. When this happens, you may need to unplug the USB cable connecting to the splicer and re-plug it to re-establish the USB communication.

After the ***Measure*** button is clicked on the PC, the right fiber holder will move forward to position the ball lens on the screen (within the field of view of the FSM-100 splicer cameras) to enable a better measurement. If the ball position is not the desired position, you can always click the manual control buttons to move the right fiber a little left or right.

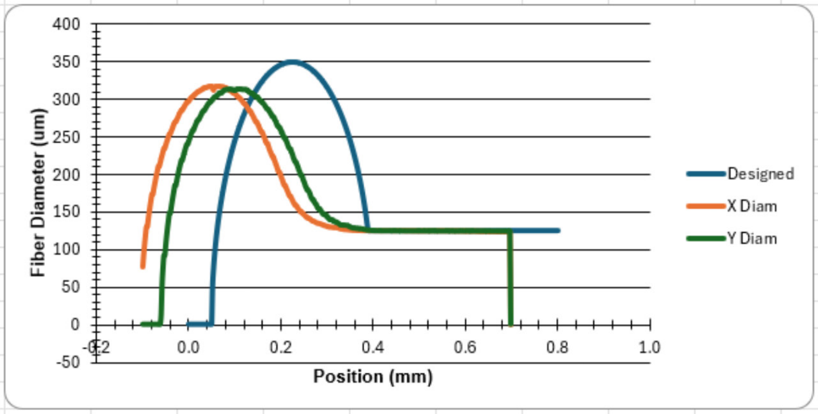


Position	X view Dia...	Y view Dia...	Designed...	X view Ce...	Y view Cen...
0	76.79999...	0	0	149.5200...	160
0.001995...	93.30000...	0	0	149.4200...	160
0.003990...	107.1999...	0	0	149.4400...	160
0.005985...	119.5	0	0	149.4200...	160
0.007980...	130.3000...	0	0	149.4200...	160
0.009975...	130.3000...	0	0	149.4200...	160
0.011970...	140.3999...	0	0	149.3599...	160
0.013965...	149.3999...	0	0	149.4400...	160
0.015960...	157.8999...	0	0	149.4199...	160
0.017955...	166	0	0	149.3600...	160
0.019950...	173.1999...	0	0	149.4	160
0.021945...	173.1999...	0	0	149.4	160
0.023940...	180.3999...	0	0	149.4000...	160
0.025935...	186.6999...	0	0	149.4600...	160

Figure 50 *– Measurement of a 316 µm ball lens*

The measurement data is better viewed in the Excel report, which includes all parameters and has a shift function. An example of the excel report with measured results fit to designed results is shown below:

AFL Ball Lens



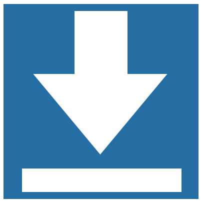
Shift:	-0.1

		BALL LENS SETTINGS			
Fiber Diameter:	125	Pre-Heat:	0	Rotation:	TRUE
Ball Diameter:	350	Absolute Power:	297	Rotator Speed:	50
Diam Adjustment:	-20	Relative Power:	50	Real Time Control:	FALSE
Measured X Diam:	316	Break Add:	20	Feeding Speed:	0.03
Measured Y Diam:	314				

MODE/SPLICE SETTINGS	
Ball Lensing Mode:	133
Splice First:	TRUE
Splicing Mode:	134
Splice Distance:	0.35
Splice Offset:	0.01

Machine type:	FSM-100P
Serial Number:	04648
Firmware Version:	01.054
Software Version:	2.0.1
Datetime:	01/09/2025 13:59

***Figure 51** – Excel report with the shift changed to -0.1 to better fit the data*



DOWNLOAD UPLOAD

The ***Upload/Download*** application allows users to change, store, and transfer splice and/or utility parameters using PC control. Mode files (.mafl) and Utility files (.uafl) or Legacy excel files and be saved or loaded for future use.

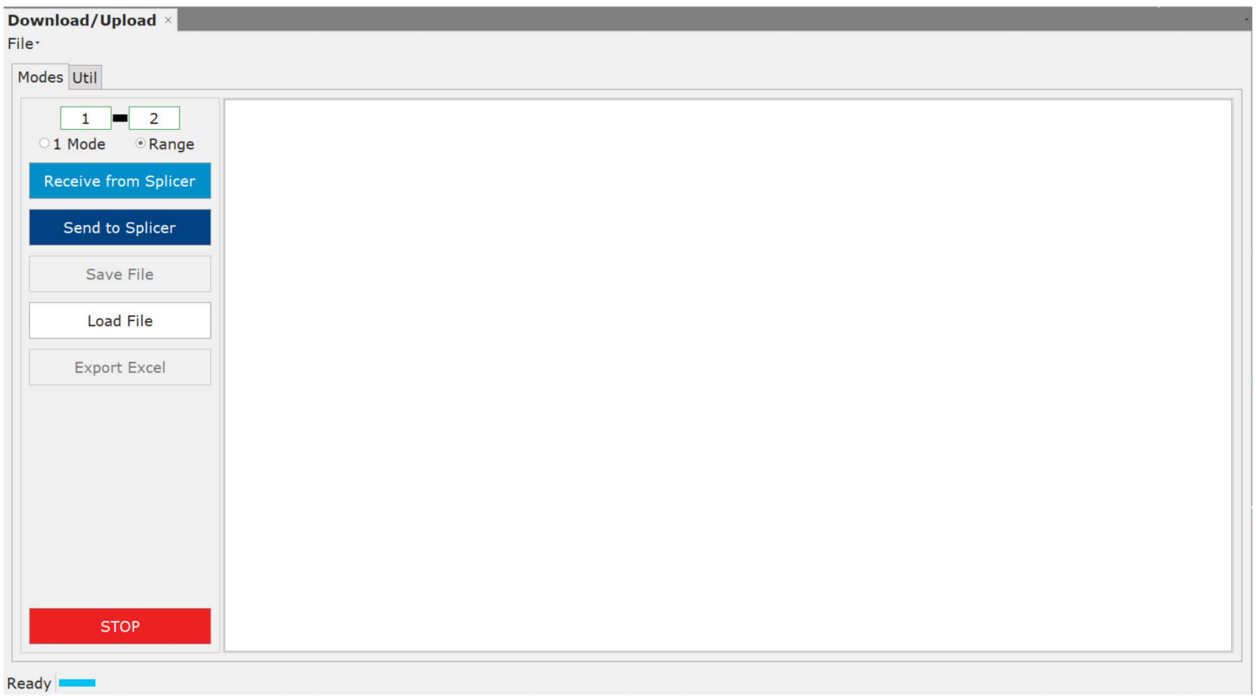


***Figure 52** – The empty mode screen*

Receiving/Sending Modes

Upload/Download can receive modes from a connected splicer through either the 1 Mode or Range Mode. **Note:** when using range mode, the left number must be lower than the right number.

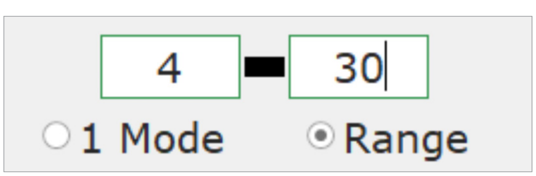
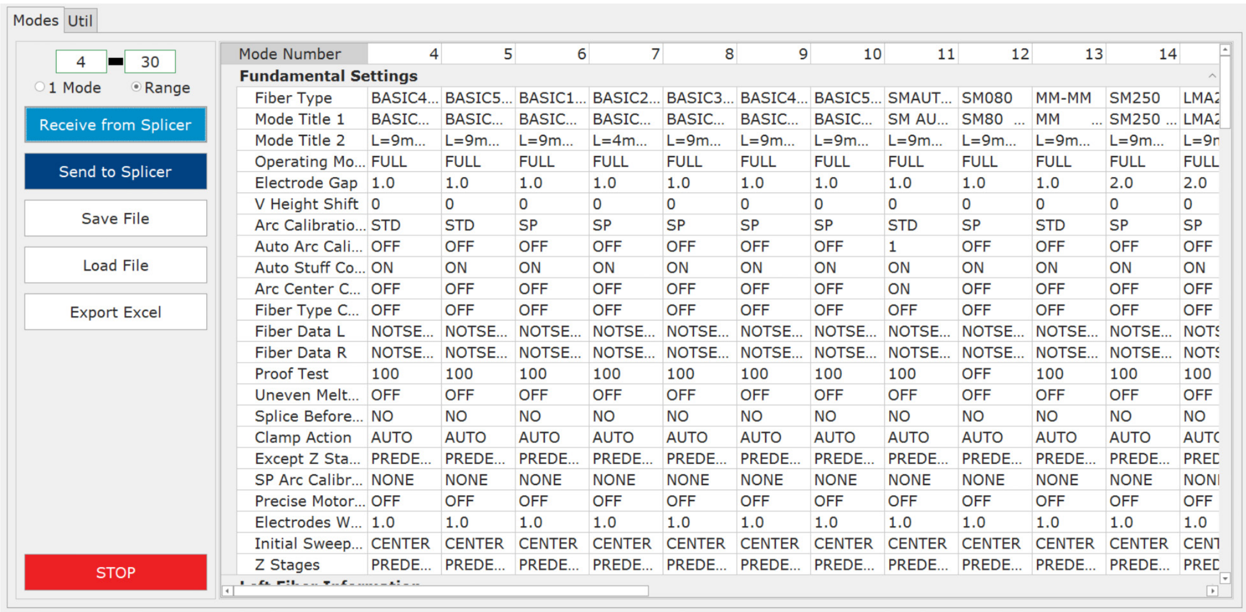


***Figure 53** – Example of using the range mode to receive modes 4-30 from the splicer*

***Figure 54** – Using 1 Mode to receive mode 10 from the splicer*

While downloading the column(s) will be filled one by one and the progress if downloading a range of modes can be seen at the bottom next to the progress bar until it has completed, and this process can be stopped with the **STOP** button if needed.



Mode Number	4	5	6	7	8	9	10	11	12	13	14	
Fiber Type	BASIC4...	BASIC5...	BASIC1...	BASIC2...	BASIC3...	BASIC4...	BASIC5...	SMAUT...	SM080	MM-MM	SM250	LMA2
Mode Title 1	BASIC...	BASIC...	BASIC...	BASIC...	BASIC...	BASIC...	BASIC...	SM AU...	SM80 ...	MM ...	SM250 ...	LMA2
Mode Title 2	L=9m...	L=9m...	L=9m...	L=4m...	L=9m...	L=9m...	L=9m...	L=9m...	L=9m...	L=9m...	L=9m...	L=9r
Operating Mo...	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL	FULL
Electrode Gap	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	2.0
V Height Shift	0	0	0	0	0	0	0	0	0	0	0	0
Arc Calibratio...	STD	STD	SP	SP	SP	SP	SP	STD	SP	STD	SP	SP
Auto Arc Cali...	OFF	OFF	OFF	OFF	OFF	OFF	OFF	1	OFF	OFF	OFF	OFF
Auto Stuff Co...	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON	ON
Arc Center C...	OFF	OFF	OFF	OFF	OFF	OFF	OFF	ON	OFF	OFF	OFF	OFF
Fiber Type C...	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Fiber Data L	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTS
Fiber Data R	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTSE...	NOTS
Proof Test	100	100	100	100	100	100	100	100	OFF	100	100	100
Uneven Melt...	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Splice Before...	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Clamp Action	AUTO	AUTO	AUTO	AUTO	AUTO	AUTO	AUTO	AUTO	AUTO	AUTO	AUTO	AUTC
Except Z Sta...	PREDE...	PREDE...	PREDE...	PREDE...	PREDE...	PREDE...	PREDE...	PREDE...	PREDE...	PREDE...	PREDE...	PRED
SP Arc Calibr...	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONE	NONI
Precise Motor...	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF	OFF
Electrodes W...	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Initial Sweep...	CENTER	CENTER	CENTER	CENTER	CENTER	CENTER	CENTER	CENTER	CENTER	CENTER	CENTER	CENT
Z Stages	PREDE...	PREDE...	PREDE...	PREDE...	PREDE...	PREDE...	PREDE...	PREDE...	PREDE...	PREDE...	PREDE...	PRED

Figure 55 *– The modes table filled after downloading modes 4-30*

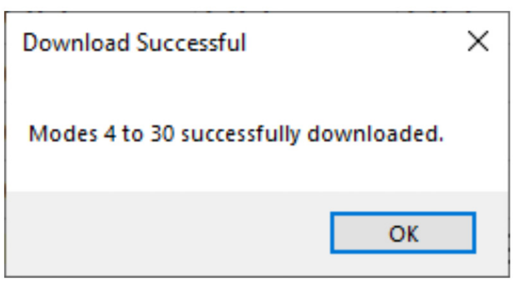


Figure 56 *– Dialogue box showing modes 4 to 30 downloaded to the table successfully*

Modes can be sent from a loaded Mode File or Excel file by using the Send to Splicer button with the selected range or single-mode depending on which is selected. Once it has been pressed a dialog form will open giving the option of giving a target mode or mode range to replace with the selected. This range must be within 1 to 300 the max end of the range will automatically update according to the min end and will match the selected range's size.

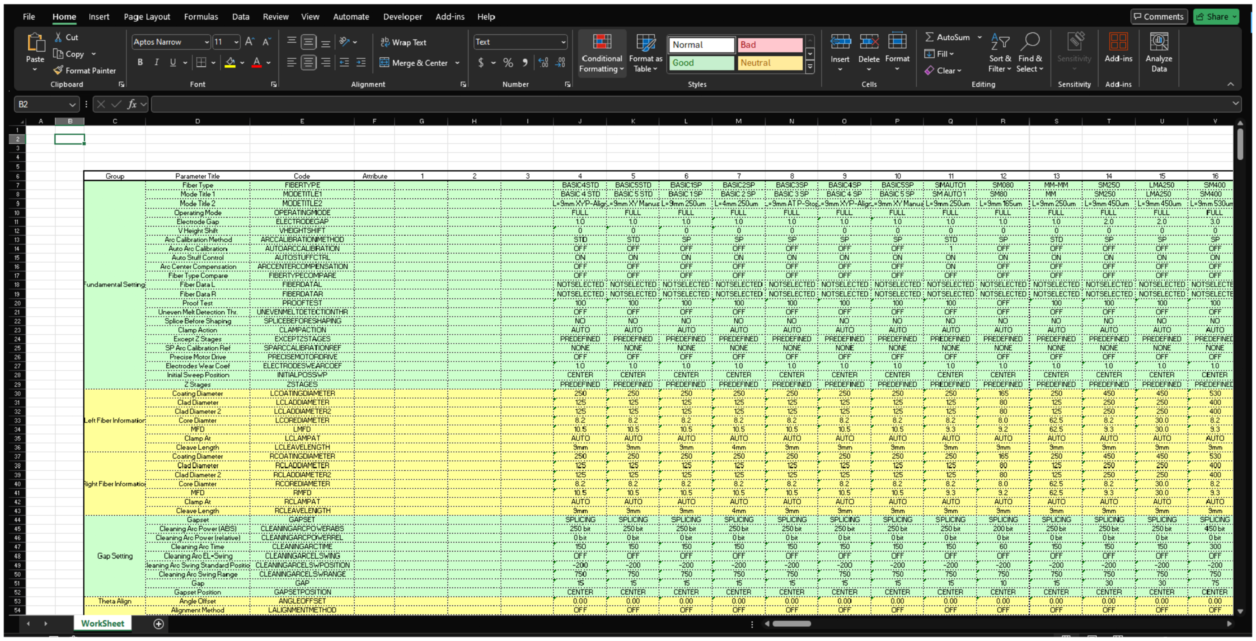


***Figure 57** – Excel format/export example*

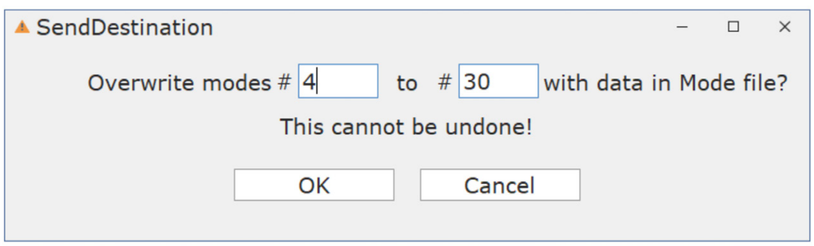


***Figure 58** – Dialogue box showing the same range as the selected before uploading to the machine*

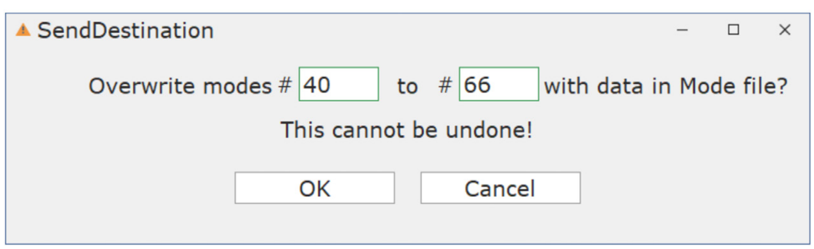


***Figure 59** – Dialogue box showing the range changed but keeping the same length*

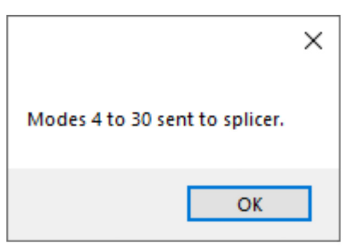


Figure 60

Utility Parameters

Utility Parameters can also be downloaded, uploaded, saved, loaded, and exported like the normal modes. Nearly functionally identical to the modes tab but with only containing a single column. It should also be noted that the Utility files will save as a .uafl extension file.

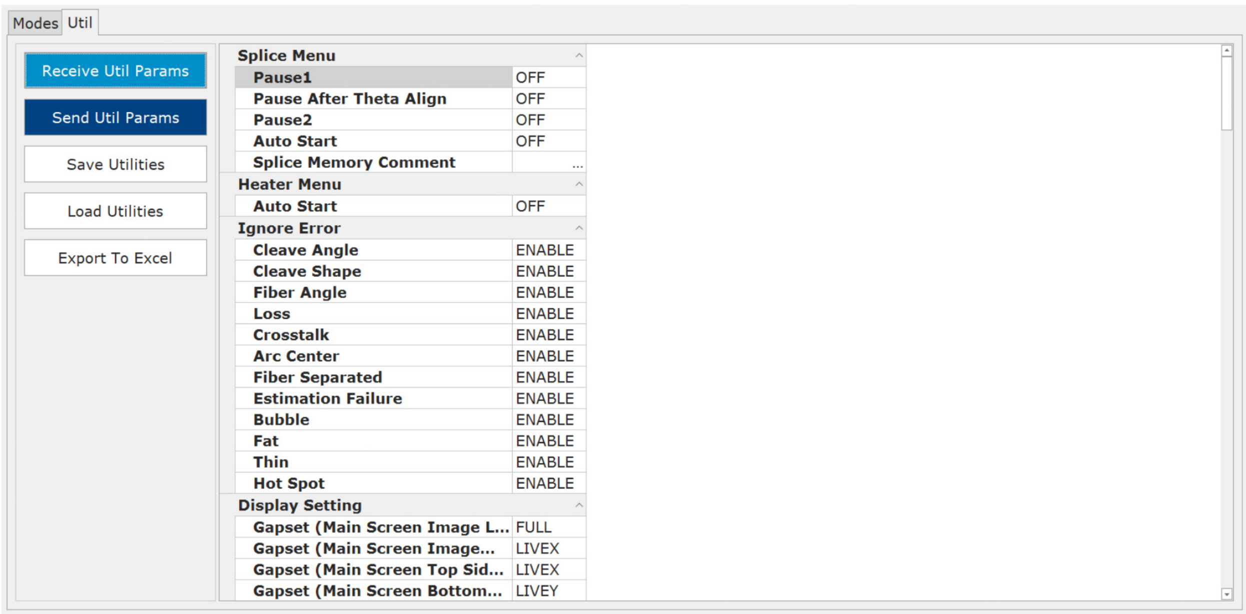


Figure 61

LIVE VIDEO

The Live Video module displays a live feed from the splicer. By default, it will not begin playing the video until the START button has been pressed. On the sides are buttons that are equivalent to the ones physically on the splicer's panels. There are also additional buttons to save a screencap of the video as well as saving the image. A Rotation checkbox also is present to ensure that the video feed matches the correct orientation of the splicer's setup.

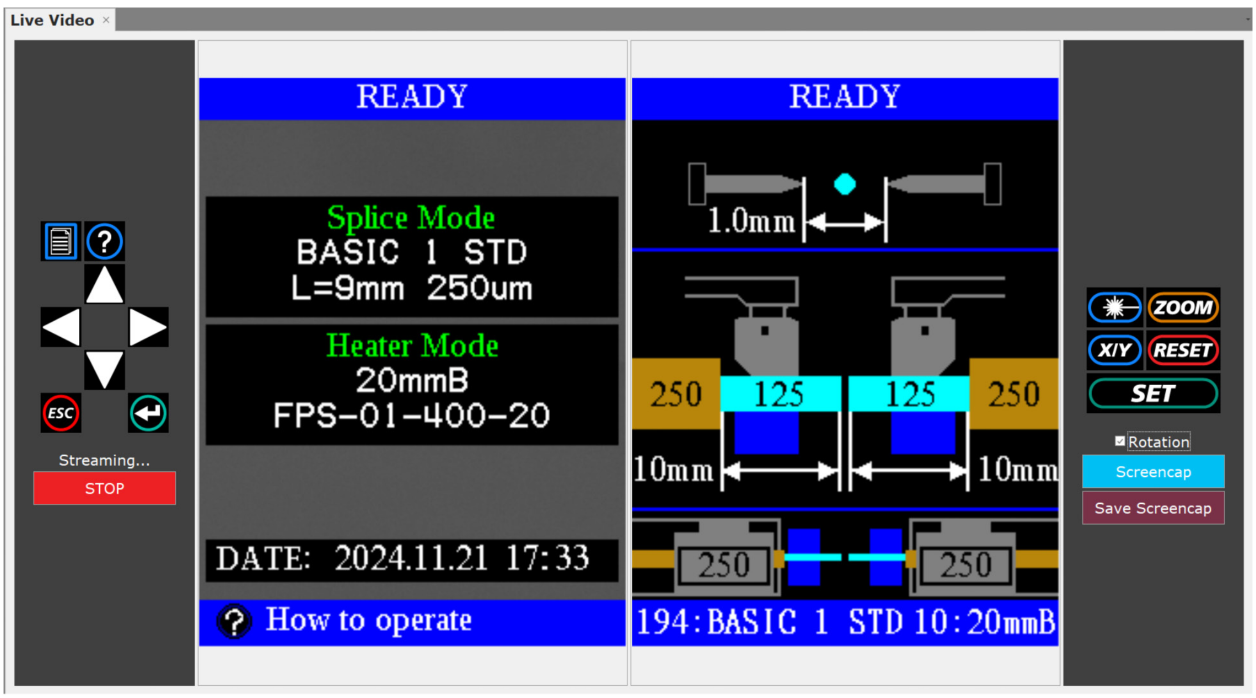


Figure 62

POWER METER READER

The **Power Meter Reader** allows reading of select USB Power Meters, as well as the capability to perform active alignments by providing feedback to the connected splicer or to the PC with parabolic alignments.

Streaming Readings

By default, FPS only supports the AFL OPM5, though other power meters are available for purchase or development. Once connected to your computer with the proper drivers, simply clicking the **START STREAM** button will establish a connection and show loss in dB in FPS.

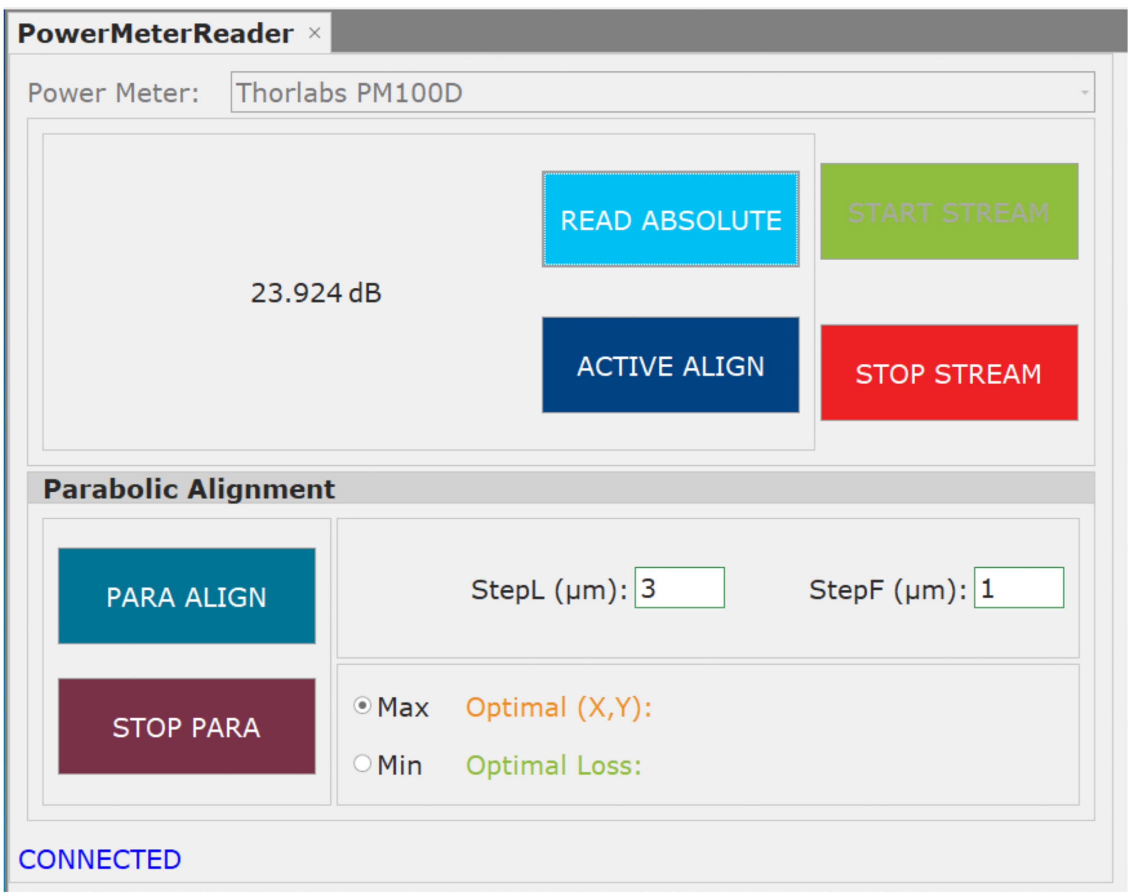


***Figure 63** – Streaming from a Thorlabs PM100D*

This is the reading the splicer will use when performing an active alignment, discussed in the next section.

Active Alignment (Connection Through Splicer)

To set up active alignment for a splice, follow the guide below:

1. Enter the Machine Settings menu of your splicer.
2. Navigate to the Power Meter Alignment Tab, and select the External Instrument variable
3. Scroll down to and select USB

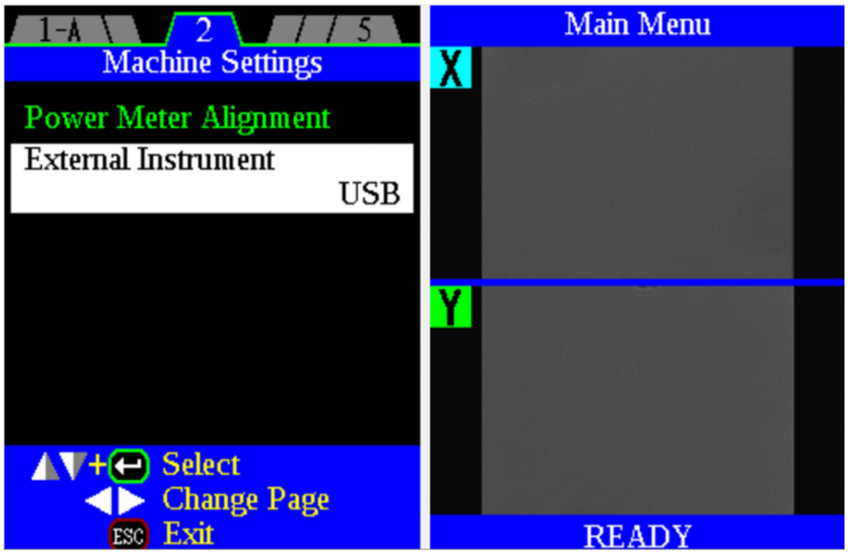


***Figure 64** – Selecting USB as the Power Meter*

4. For the splice in question, navigate to the XY Alignment splice parameters.
5. Set Alignment Method to P-Meter and Alignment Mode to Min if your PM returns a positive reading, Max if it returns a negative reading.

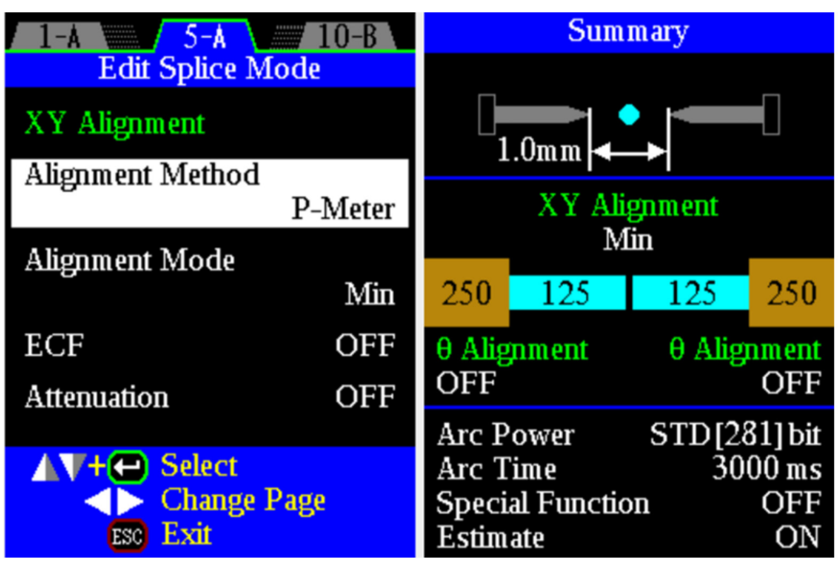


***Figure 65** – Setting the Splice Mode for Power Meter Feedback*

6. In FPS, click the ACTIVE ALIGN button on the Power Meter Reader application.
7. Leaving Power Meter Reader in this mode, run the splice.

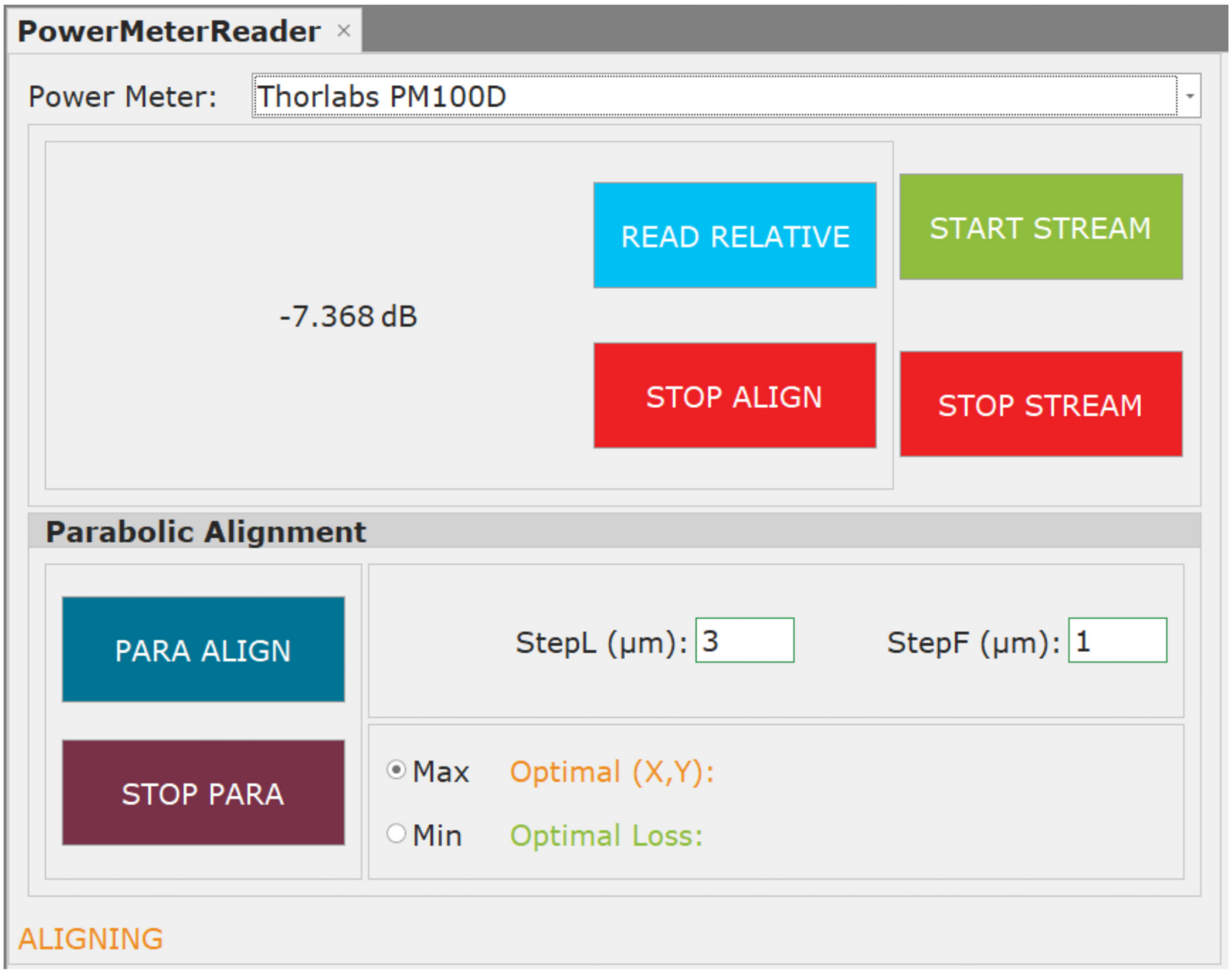


Figure 66 *– Running an Active Align Mode in FPS*

Parabolic Alignment (Connection through PC)

Parabolic alignment is generally faster than splicer alignment and does not require any special setup on the splicer. It works by scanning the loss values over a large area and building a parabola related to their XY position, then completing a finer scan of the XY positions around the minima of the rough parabola. The following parameters can be customized as needed:

- **Max/Min:** Power meters may sign their losses differently depending on the manufacturer. **Max** alignment should be selected if your PM reports a negative value (i.e. moving an initial loss of -10dBm to -1dBm), and **Min** should be selected if your PM reports a positive value (i.e. moving an initial loss of 10dB to 1dB).
- **StepL (µm):** This is the distance moved on each iteration during the **Rough Alignment** phase. The larger this value is, the larger and less accurate the rough search area will be.
- **StepF (µm):** This is the distance moved on each iteration during the **Fine Alignment** phase. It should be smaller than the **StepL** value to refine the initial results.

To set up parabolic alignment for a splice, follow the guide below:

1. Complete a **GAPSET** of the fibers to be aligned. This can be done several ways but is most commonly done automatically as part of a splice before entering **PAUSE1**.
2. Click **PARA ALIGN** within the module. You can monitor progress within the toolstrip at the bottom of the module:
3. On completion, **Optimal (X,Y)** and **Optimal Loss** will be annotated. Optimal (X,Y) is the cladding offset at the optimal loss position.

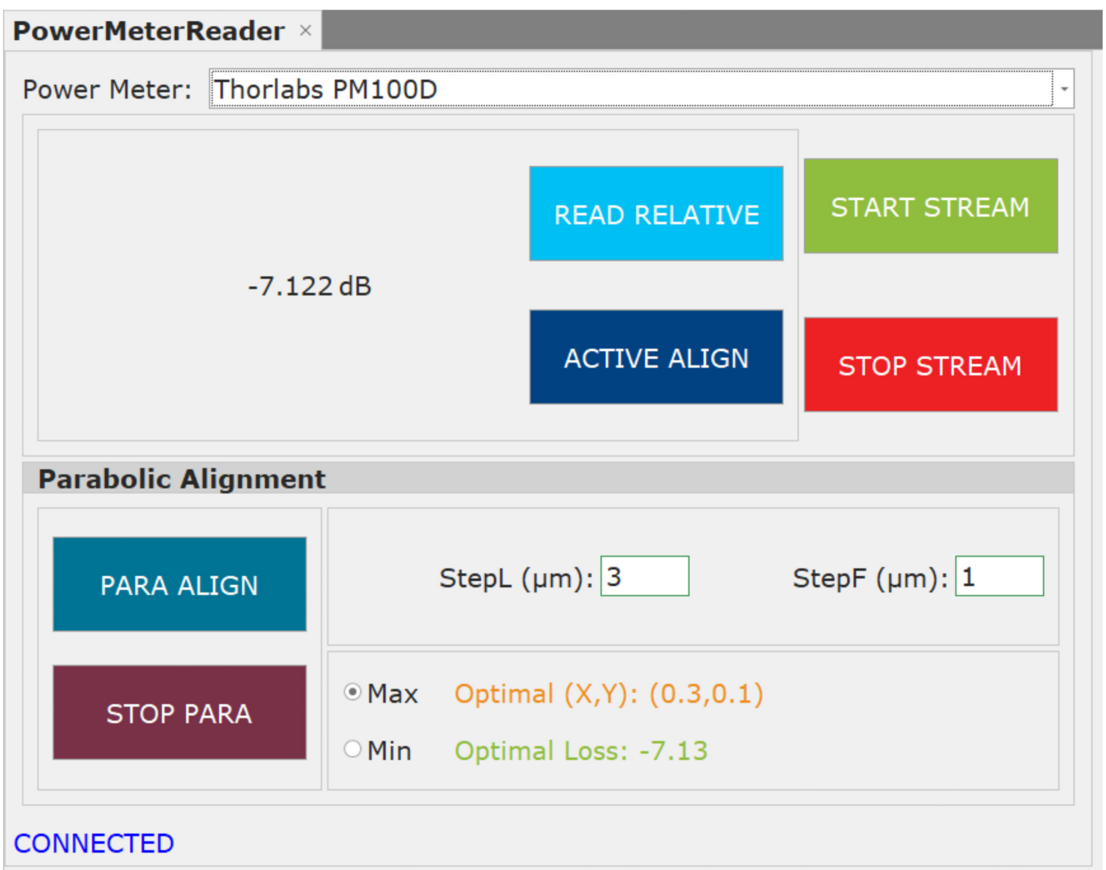


***Figure 67** – Completion of Parabolic Alignment*

OCB READER

The **OCB Reader** is an application that interfaces with the Optical Control Board on the LZM-110/120. It can read and log laser position, temperature, and power. On models with optical motors, it is also capable of controlling their position and path configurations. It can be used for beam alignment, monitoring laser stability, monitoring laser status, and updating firmware.

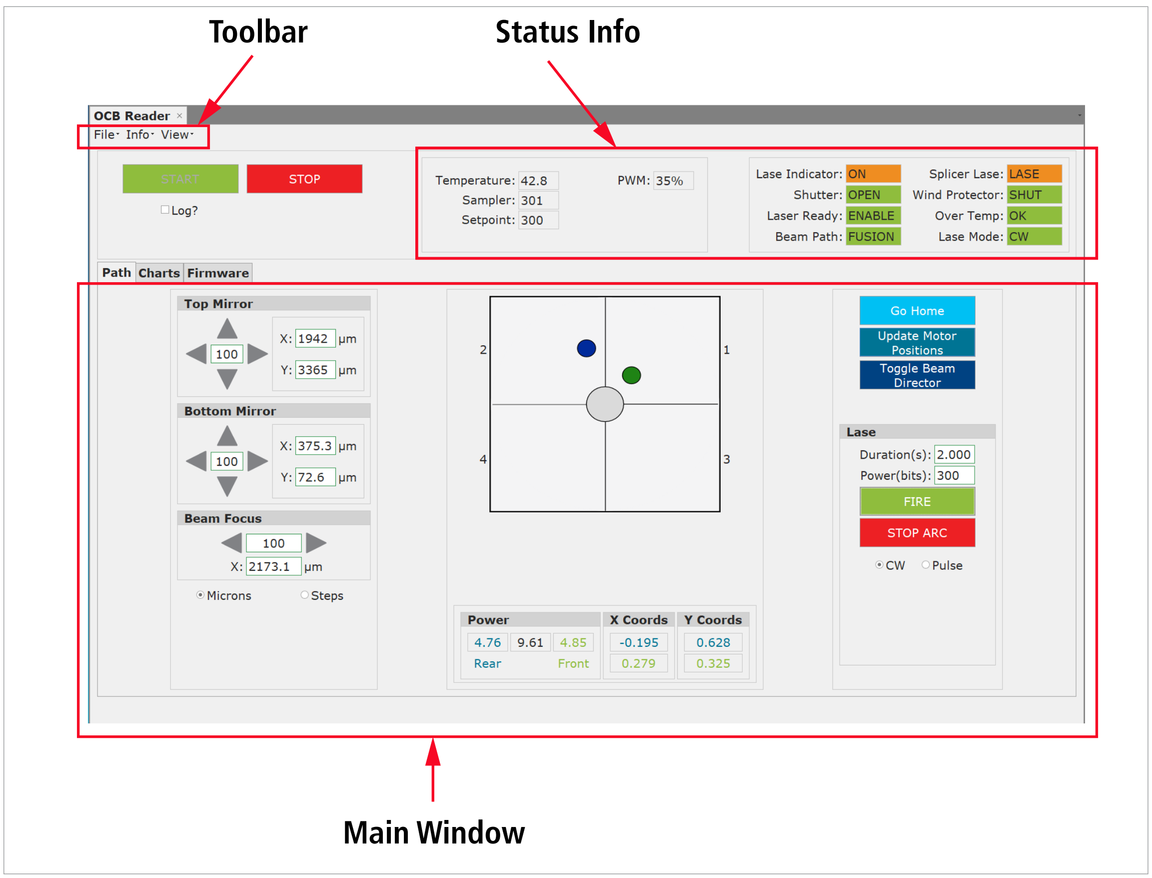


Figure 68 – Main screen of the OCB Reader

Overview

Start begins streaming data packets from the OCB and **Stop** cuts off communication. The ***Status Info*** above the tabbed box is always visible, including:

- Laser **temperature** in degrees Celsius
- Laser **sampler** value
- Current laser **setpoint** (lase value from the splicer)
- **PWM** percentage (duty cycle)
- **Lase indicator:** The laser is on.
- **Splicer Lase:** The splicer is setting the laser value.
- **Shutter:** Shutter is open or closed.
- **Wind protector:** Indicates the wind protector status. Splicer cannot lase when open.
- **Laser Ready:** Indicates good communication with the laser with no faults
- **Over Temp:** Indicates the laser is too hot, and must cool down before lasing again.
- **Beam path (A+ only):** Indicates whether the splicer is on the fusion path or ablation path.
- **Lase mode (A+ only):** Indicates the laser mode, either CW or pulse.

The **Tab Window** has multiple tabs:

1. The **Path** tab displays the readings from the LZM-110/120/125 thermopiles. Power is displayed in watts, and the coordinates are in millimeters relative to the center point. If the laser is very close to the center, the indicator becomes double the size and the movement scale for the indicator is doubled. On A-series machines, this also includes motor movement and laser controls.
2. The **Charts** tab displays charts with selectable series. By right clicking, users can display temperature, sampler values, setpoints, coordinates and power over time. The scale of data displayed is adjusted by changing the Window Size textbox on the right of the window.
3. The **Firmware update** tab has two buttons:
    a. **Update Firmware** begins the OCB update process. After backing up calibration values, users will be prompted to select a firmware file. These are .afl files provided by AFL. Once selected, the board will take about 1 minute to perform an update. Once complete, users can reconnect by hitting the start button to launch the new firmware.
    b. **Reset Control Board** performs a hard reset of the board, cycling power to the microcontrollers. If the board is unresponsive, using this reset will usually resolve the problem.

Saving Data in OCB Reader

1. Clicking **Save Data...** on the Charts tab will export all the data *currently* displayed on the chart tab to a CSV the user selects.
2. Checking the **Log?** Box below the start button before or during operation will log all *incoming* packets to a file automatically generated at C:\FPS\OCBLogs. This file will not include data currently on the chart.

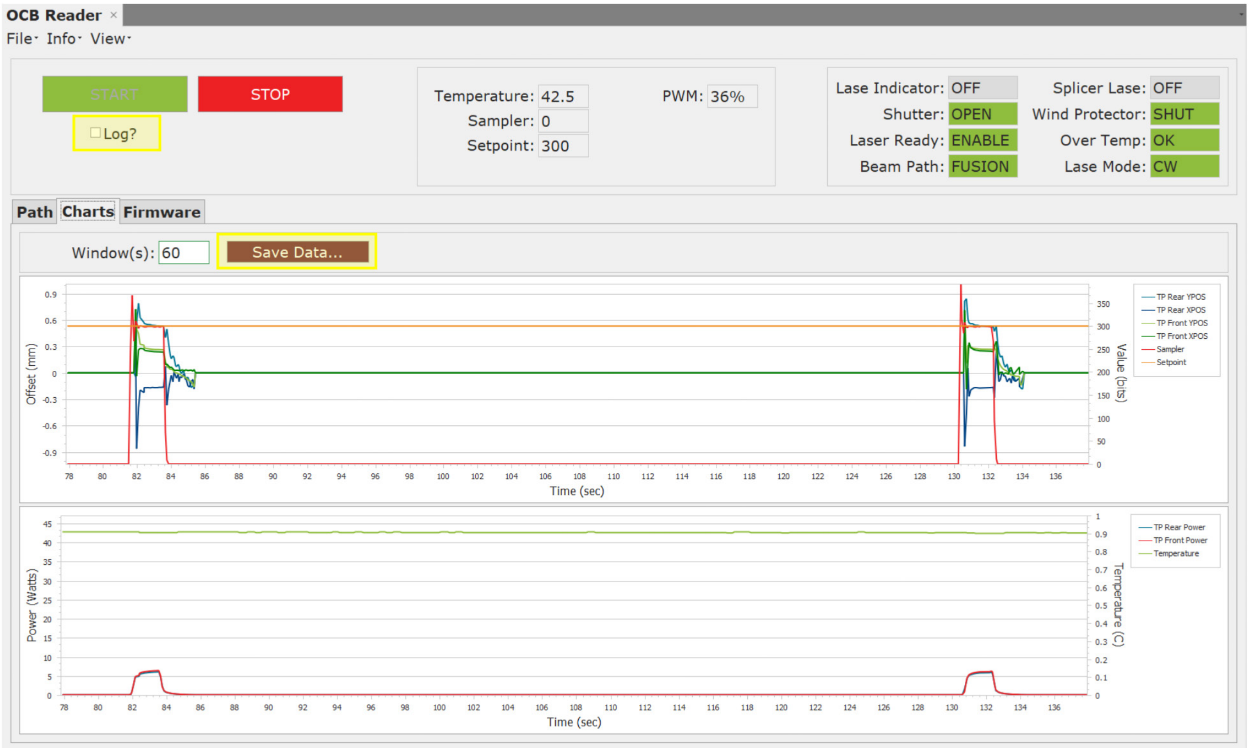


***Figure 69** – Methods of logging OCB data*

Motors/Path Control

When connected to a machine with optical motors, Motor/laser info will be visible on the Path tab. It is broken down into the following sections:

1. **Motor view:** The mirror positions can be viewed or manipulated individually using these controls. By default, all values are shown in microns. The switch at the base of this section allows the user to change all values to steps. To change the amount a motor moves when clicking an arrow, enter the desired distance in the step text box located in the middle of the four arrows as shown in Figure 68. Users may also directly move the motor to a desired position by changing the value of a position text box located to the right of the arrow buttons like shown in Figure 68.
2. **Path Controls**
    a. *Go Home:* Moves the motors to their sensors, and then to the home positions of the current path.
    b. *Toggle Beam Director:* Switches the beam director. Does not change motor positions.
    c. *Update Motor Positions:* Refreshes motor positions listed in the Motor View section.
3. **Lase Controls:** Fire for several seconds at a specified power in either CW or Pulse mode. This will not change the path, allowing user to fire, for example, in CW mode on the ablation path.

MANUAL CONTROL

The **Manual Controller** module allows the user to manipulate the Z, Theta, and X/Y motors of the splicer as long as the machine is not in a busy state. The layout is expanded upon below:

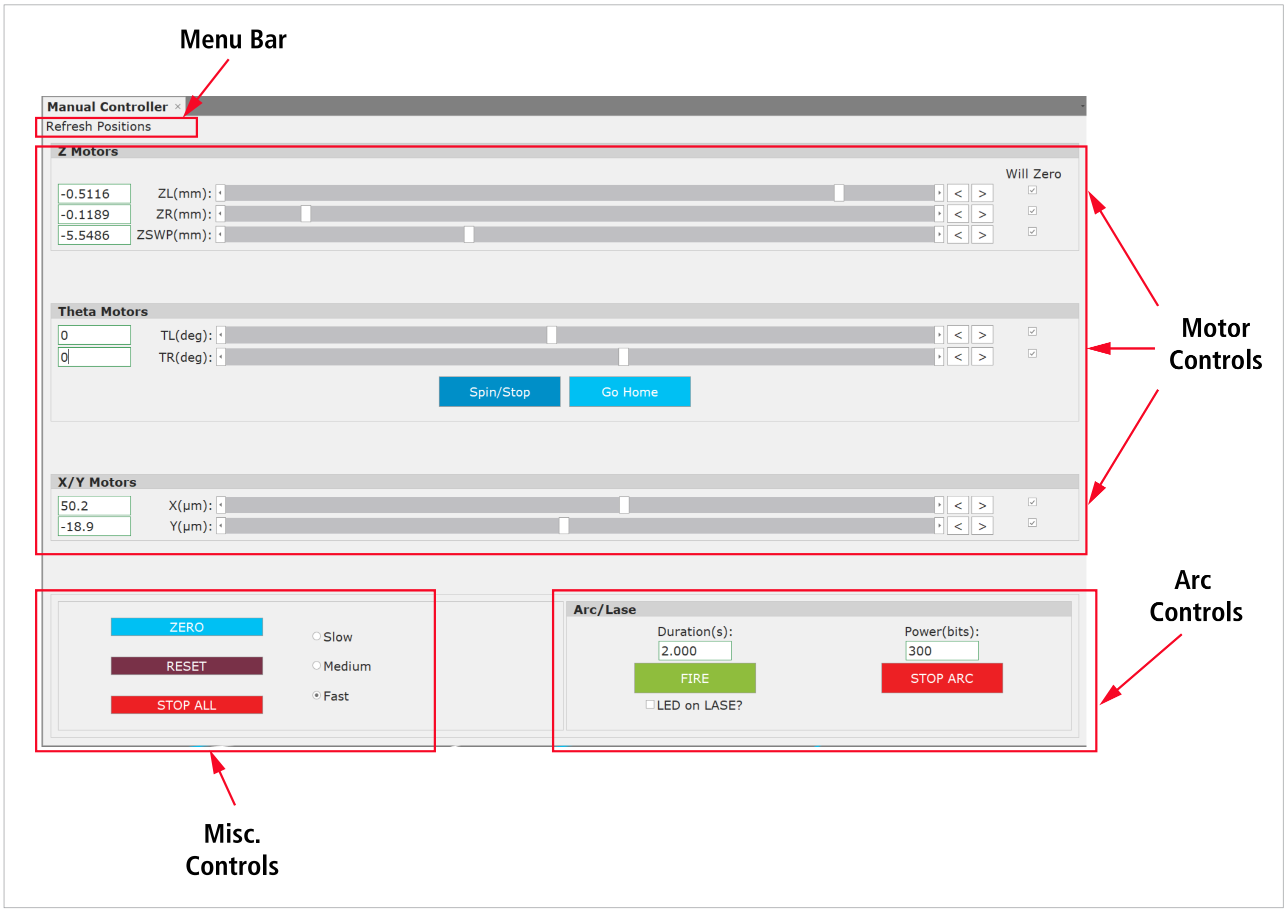


Figure 70 – Manual Controller with motors at various positions

Manual Controller Menu Bar

The Menu Bar contains one option:

- **Refresh Positions** gets the current motor positions from the splicer and updates each position on the manual controller.

Motor Controls

Each control can be moved three different ways:

- The **text box** reflects position, in mm, relative to the zero/reset position. Users can manually enter positions into these boxes and press "Enter" to move the listed motor to that position.
- The **scroll bar** will move the motor to the selected position when it is dragged and released. It reflects position relative to the zero and movement limits of the splicer.
- The **left/right arrows** can be clicked and held for movement, with their speed determined by the radio buttons "Slow/Medium/Fast". Releasing the button stops motor movement.

Arc/Laze Controls

There are two buttons in the "Arc/Laze" box:

- **FIRE** begins arcing/lazing at the selected duration and power.
- **STOP ARC** cancels any currently executing arc/laze.
- **LED ON LASE** when checked, will leave LZM LEDs on when firing the laser for better viewing of the fiber.

Misc. Controls

There are three buttons, and a radio selector listed here:

- **ZERO** sets the relative position of all motors checked "Will Zero" to zero. This is useful if working from a known position that you need to return to easily.
- **RESET** resets the splicer
- **STOP ALL** stops all motors

The radio selector changes how quickly motors move, increasing speed or precision as needed.

SPLICE SCRIPT

Splice Script is a visual programming tool being designed for AFL's 100 and 110 series splicers to make the creation of modular, reusable splice recipes simpler. In addition to the creation of individual recipes, these can be strung together in sequence to make complex recipes flow simply. A tapered ball becomes Taper->Sweep to middle->Break->Ball lens, where each piece of the sequence is separately developed timeline. It allows users to translate plain language pseudo-code into increasingly complex commands.

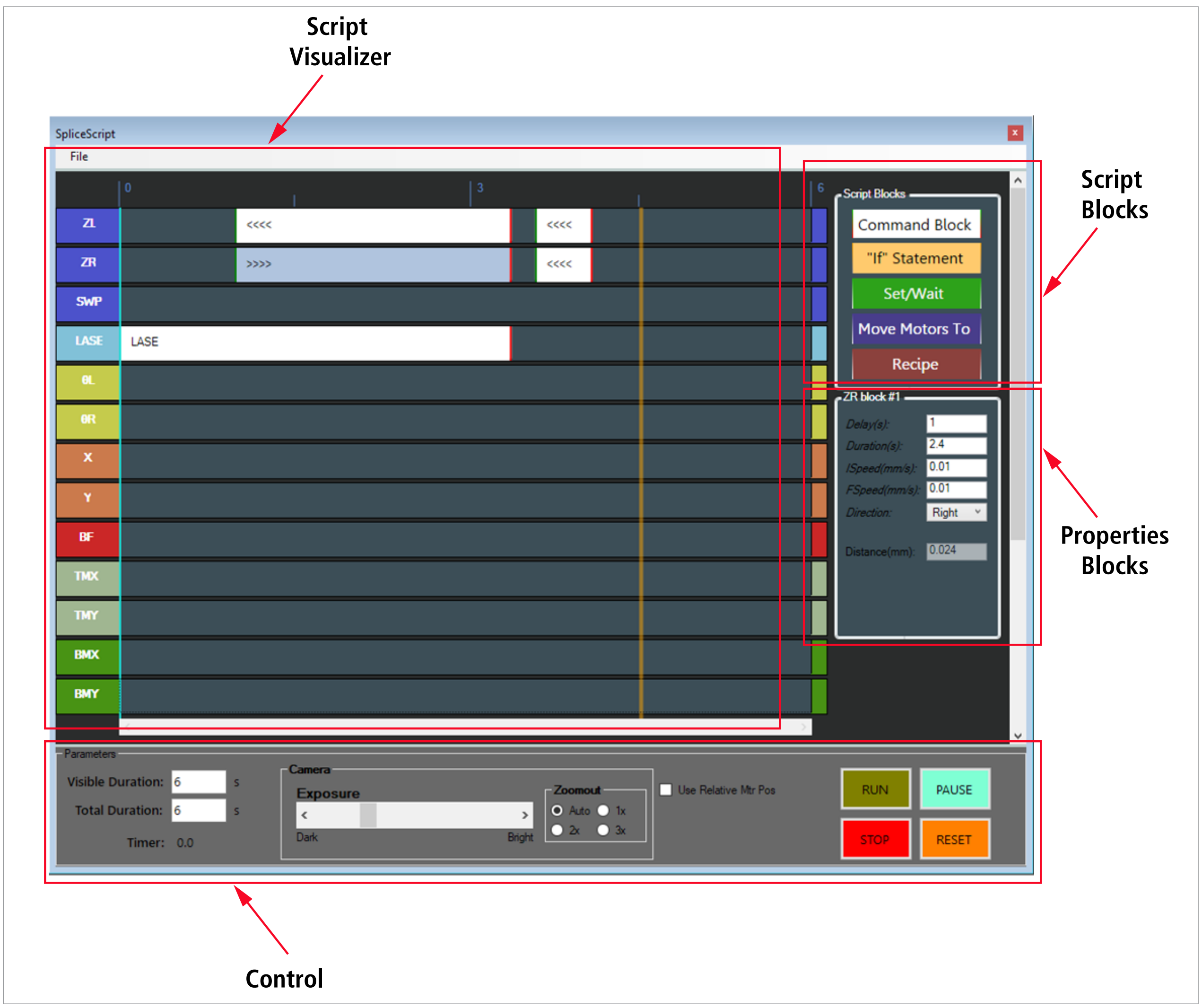


***Figure 71** – An LPG created in Splice Script*

Below, we'll look at the sectors of the Splice Script interface and how they work together to create and run scripts.

Script Visualizer

The timeline pictured in this section is a visual representation of what the script is going to execute. Each rectangular gray box next to a motor or laser (ZL, ZR, Lase, etc.) can be manipulated to perform instructions by dragging and dropping the script blocks in them. In Figure 71, for example, Lase will begin executing the white **Command Block** as soon as it is started, with ZL and ZR starting to move apart about a second later. ZL and ZR than pause when the laser turns off and continue moving left. This process is repeated if a condition is met in the yellow line, an **"If" statement** whose color correlates with the box in the script blocks column.

Manipulating these blocks in the timeline is fairly intuitive. To add a white **Command Block** to the ZL Motor, simply drag and drop the white "Command Block" in the script block section to the desired location. To edit the blocks properties, click on it. The selected block will turn blue, and the current properties will populate in the section right of the timeline:

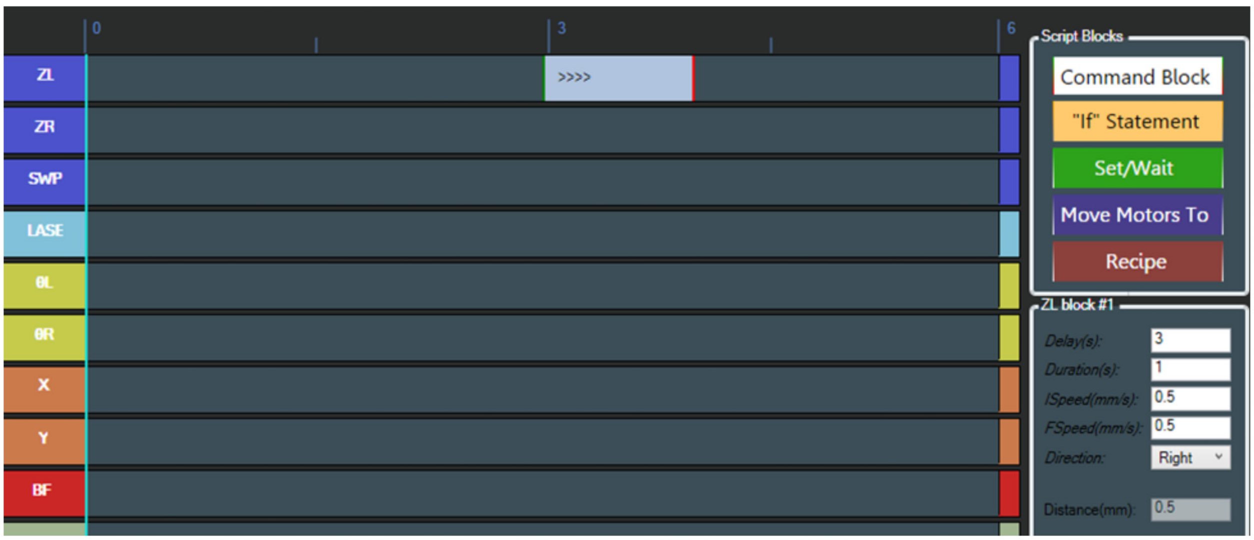


***Figure 72** – Adding a ZL Command Block. In the block, you can see >>>>, .5mm, 1s, .5mm/s. This means when the timer reaches the block, ZL will move right .5mm over the course of 1 second. These properties are editable in the properties block.*

To delete a block or line, select it and press the delete key.

Adding the other script blocks functions similarly, though they are universal and will be represented as a line, since they are affecting the entire script. More details of script block properties can be found in section Script Blocks.

When executing, the teal line visible on the leftmost side of the timeline in Figure 72 will move in time with the actions.

You can also **hide** individual timelines by right clicking on the associated colored block and selecting **"Hide "X" Timeline"**.

Script Blocks

The script blocks each do something different when dragged and dropped onto the timeline. Each can be clicked and edited. Below is a list of the script blocks, their function and their properties:

- **Command Blocks** are the basic movement and lasing blocks associated with individual motors. The properties vary by motor, but can be generalized as:
  - **Delay(s):** the time from the previous command block or the start of the timeline.
  - **Duration(s):** how long the motor/heat source will be active for. This can also be adjusted by dragging the green and red lines on the visualizer.
  - **ISpeed/IRPower:** The initial speed or the initial relative power of this block.
  - **FSpeed/FRPower:** The final speed or the final relative power of this block. If different than ISpeed, machine will automatically accelerate from ISpeed to FSpeed if possible. If ISpeed and FSpeed are the same, machine will move at a constant speed/power.
  - **Direction:** Movement direction of the motor
- **"If" Statement:** Allows the user to embed conditionals in the script. It can be read as a statement. In the figure to the right, the script will Check the listed condition at 5.288s. If Fiber Min Diam is less than 400, then start time will go to 0.5 s. See Figure 73.
- **Set/Wait:** Calls a listed mode at whatever time is selected, and then waits for it to complete. It also allows you to select pauses in the mode.
- **Move Motors To:** When clicked, shows positions and check boxes next to them. When checked, that motor will move to that position when this line is hit. See Figure 74.

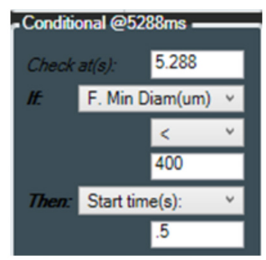


Figure 73

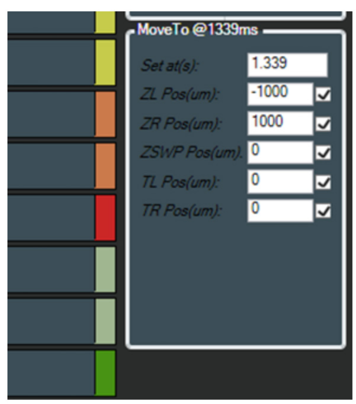


***Figure 74** – A selected "Move Motors To" block. When hit, this will move all motors to the corresponding absolute positions. If the checkbox "Use Relative Motor Positions" is checked, the positions will be relative to wherever they were when the script began.*

- **Recipe:** When dropping a recipe, you will be prompted to select a file to load into that block. You must select a previously saved recipe. When this line is hit, that recipe will appear on the screen as if it just started executing. When finished, it will resume wherever it was in the parent recipe.

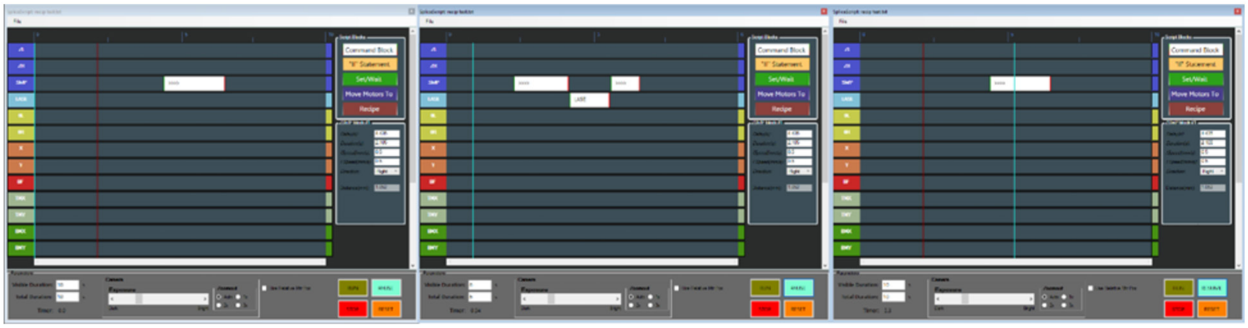


***Figure 75** – Before, during, and after an embedded recipe execution.*

Controls

The controls for Splice Script are visible in a box beneath the interface. They include:

- **Total Duration Box:** The total length, in seconds, of the script.
- **Visible Duration Box:** Adjusting this will change the scale of the script visualizer to contain only as much of the timeline as listed. If this is set to be smaller than the visible duration box, a scroll bar will appear at the base of the visualizer to allow navigation of the total duration.
- **Exposure bar:** Dragging this bar will make the camera exposure darker or brighter as indicated to the left and right extremes of the bar.
- **Use Relative Motor Positions checkbox:** When checked any operations that use motor position (“Move Motors To” lines, certain conditionals) will be relative to the starting motor positions on clicking “Run”. When unchecked, Splice Script will use the absolute positions received from the splicer.
- **Run:** Begins a script.
- **Pause:** Pauses a script. Clicking this again will resume operation from the last point.
- **Stop:** Stops a script and all motors.
- **Reset:** Stops a script and all motors, then performs a motor reset.

COMMAND SENDER

The **Command Sender** module allows the user to send individual USB Commands directly to the splicer. This is for advanced users and can be used to test any command included in the **FSM100/LZM100 Command Reference Manual** included with the splicer. Once the text is entered in the “Enter Command” box, either press Enter or click “Send Command” to communicate with the splicer.

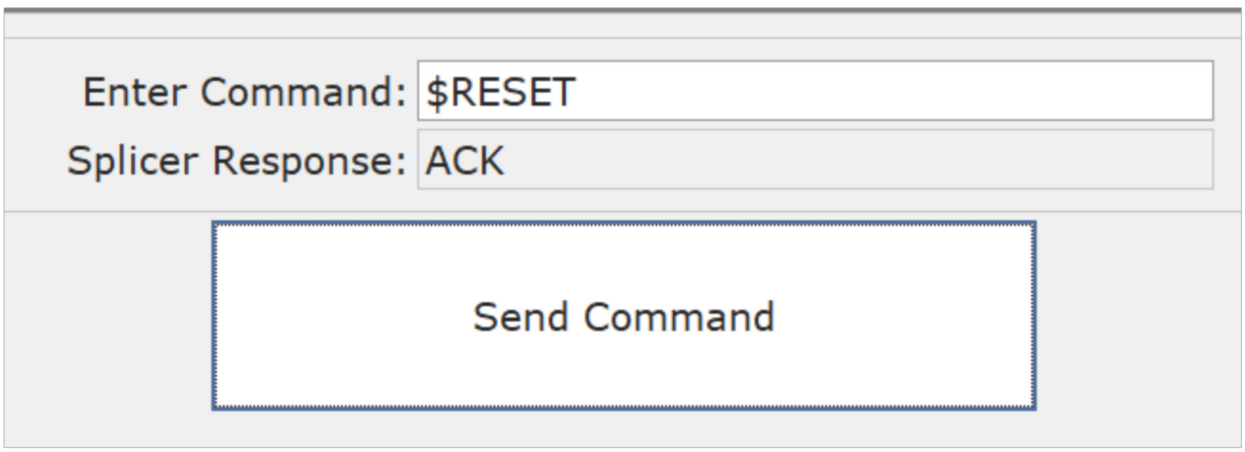


Figure 76– *A "Reset" command is sent to the splicer and acknowledged.*