MlappPredictBifurcation.m - Help
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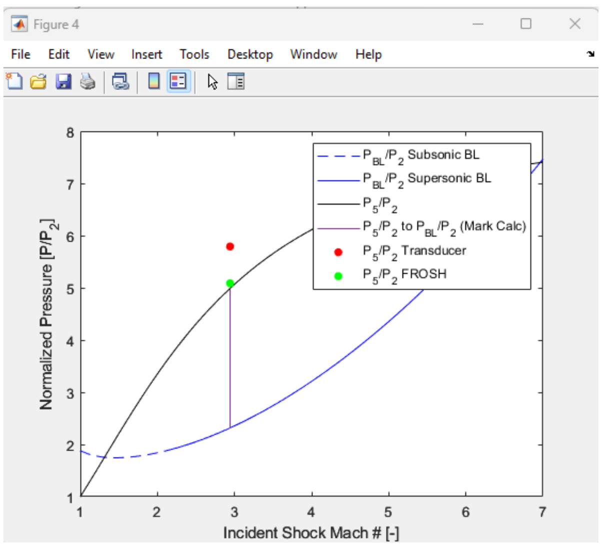
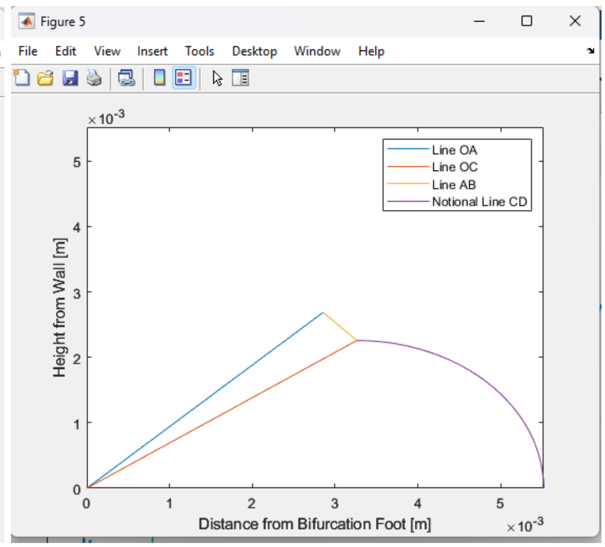
Summary: The purpose of this code is twofold. For a reflected shock in a combustion shock tube:

1) Predict the likelihood of bifurcation based on the mixture and shock properties
2) Estimate the bifurcation geometry at the optical plane based on the above, plus a pressure trace and the schlieren spike in a laser absorption trace measured at the optical plane.

The user is presented with interactive plots allowing him/her to manually identify a number of shock phenomena, which is discussed below.

Outputs: Bifurcation likelihood plot (left) Bifurcation geometry plot (right)





Function Call:

```
function[BifurcationHeight,tA]=MlappPredictBifurcation(ShockFilePath,VacuumFilePath, NumHeaderLines, timeColumn, PressureColumn, PitchColumn, CatchColumn, Mis,Mrs, gamma, MW)
```

Explanation of inputs/outputs *(Copied from the code's frontmatter)*

```
% INPUTS:
%   * VacuumFilePath - full file path and name of csv or excel file with your Vacuum sample data
%       -example: 'C:\Users\mitchell.hageman\Desktop\Data\20240923_001_VacuumData.csv'
%       -assumes that any dark (zero) signal offset correction has already been applied to the recorded voltages.
%   * ShockFilePath - full file path and name of csv or excel file with your sample data
%       -example: 'C:\Users\mitchell.hageman\Desktop\Data\20240923_001_ShockData.csv'
```

```
%       -assumes that any dark (zero) signal offset correction has already 
been applied to the recorded voltages.
%       -Assumes the sample data file and vacuum data file are organized 
identically.
%   * NumHeaderLines - number of header lines in csv file before data begins.
%       -example: My data has two header lines.  Row 1 is data labels, and 
Row 2 is the offset voltage. So my data  begins in row 3.
%   *timeColumn - column of csv where time trace is.  Mine is Column A so 
Timecolumn=1.
%   *PressureColumn - column of csv where detector trace is.  Mine is column 
B so PressureColumn=2.
%   *PitchColumn - column of csv where LAS reference (Pitch) detector trace 
is.  Mine is column C so PitchColumn=3.
%   *CatchColumn - column of csv where LAS signal (Catch) detector trace is.  
Mine is column D so CatchColumn=4.
%   **Note: The following would likely come from a normal shock equation 
solver, such as the FROzen chemistry SHock solver (FROSH)**
%   *Mis [-] - Incident shock Mach number
%   *Mrs [-] - Reflected shock Mach number
%%   *gamma [-] - specific heat ratio of the test gas.  NEED TO CHECK WHETHER 
TO USE STATE 1 or 2 FOR THESE CALCS
%   *MW_Mix [kg/kmol] - Molecular weight of the test gas.
%
% OUTPUTS:
%   *PointData
%       -BifurcationHeight [m]                - Value - See Fig1 & Eq(5) Ref 
1 (BifurcationHeight=l)
%       -Reflected Shock arrival time, tA [s] - Value - Determined from 
Schlieren spike
```

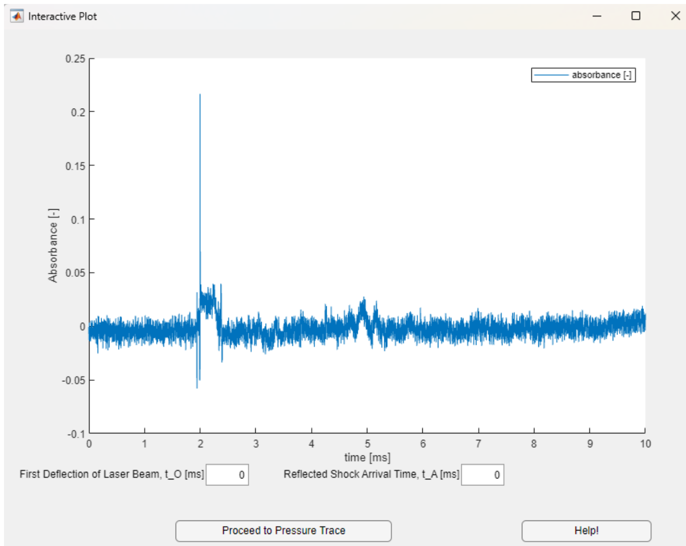
Running the Code:

Let's use the example data files from the repository for this example. Then the code call would be:

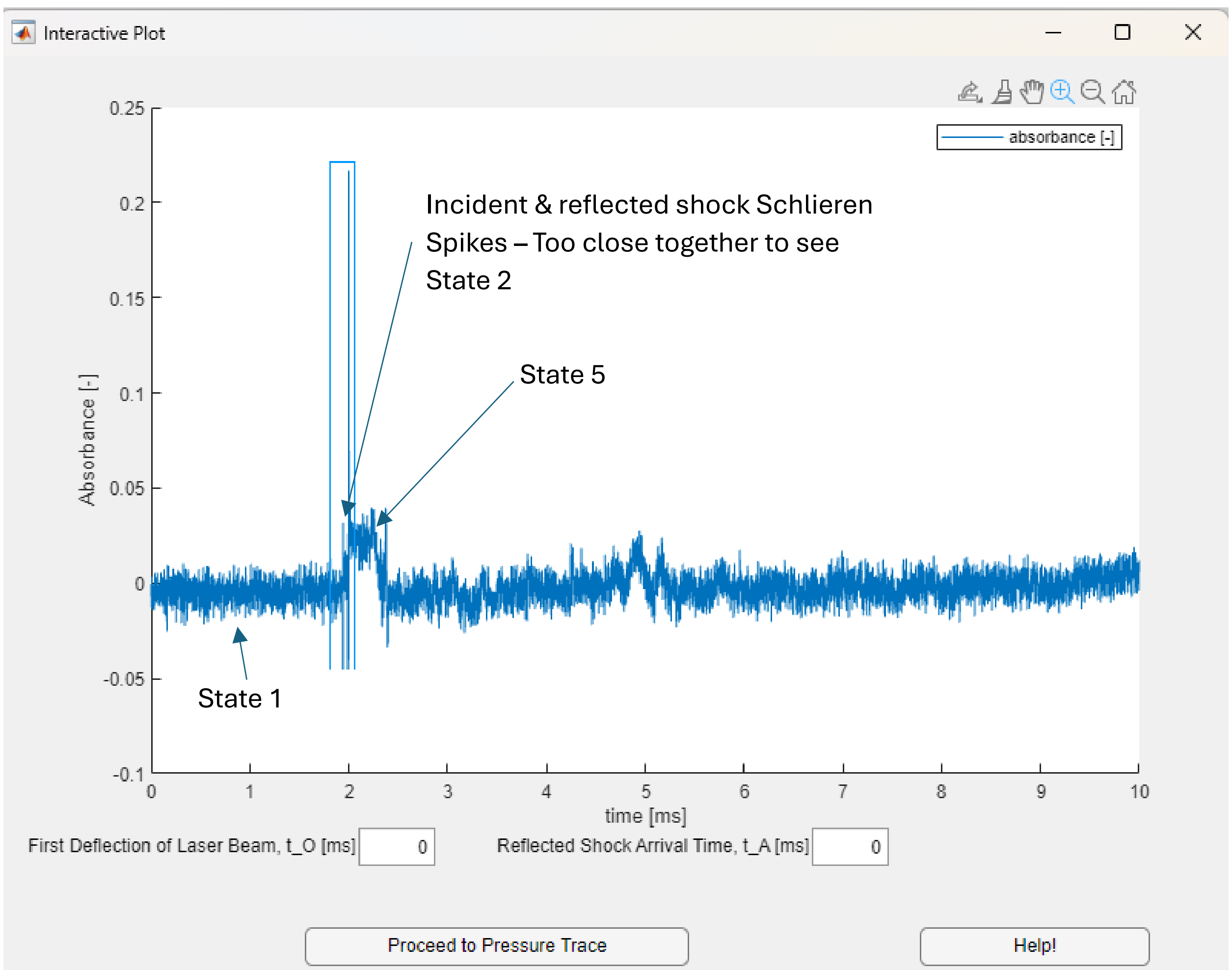
[BifurcationHeight,tA]=MlappPredictBifurcation('C:\Users\mitchell.hageman\Downloads\20220914_002_ShockData.csv', 'C:\Users\mitchell.hageman\Downloads\20220914_002_DarkFullData.csv', 2, 1, 2, 4, 5, 2.9422, 2.1318, 1.3817, 28.8015);

Zoom & Pan:

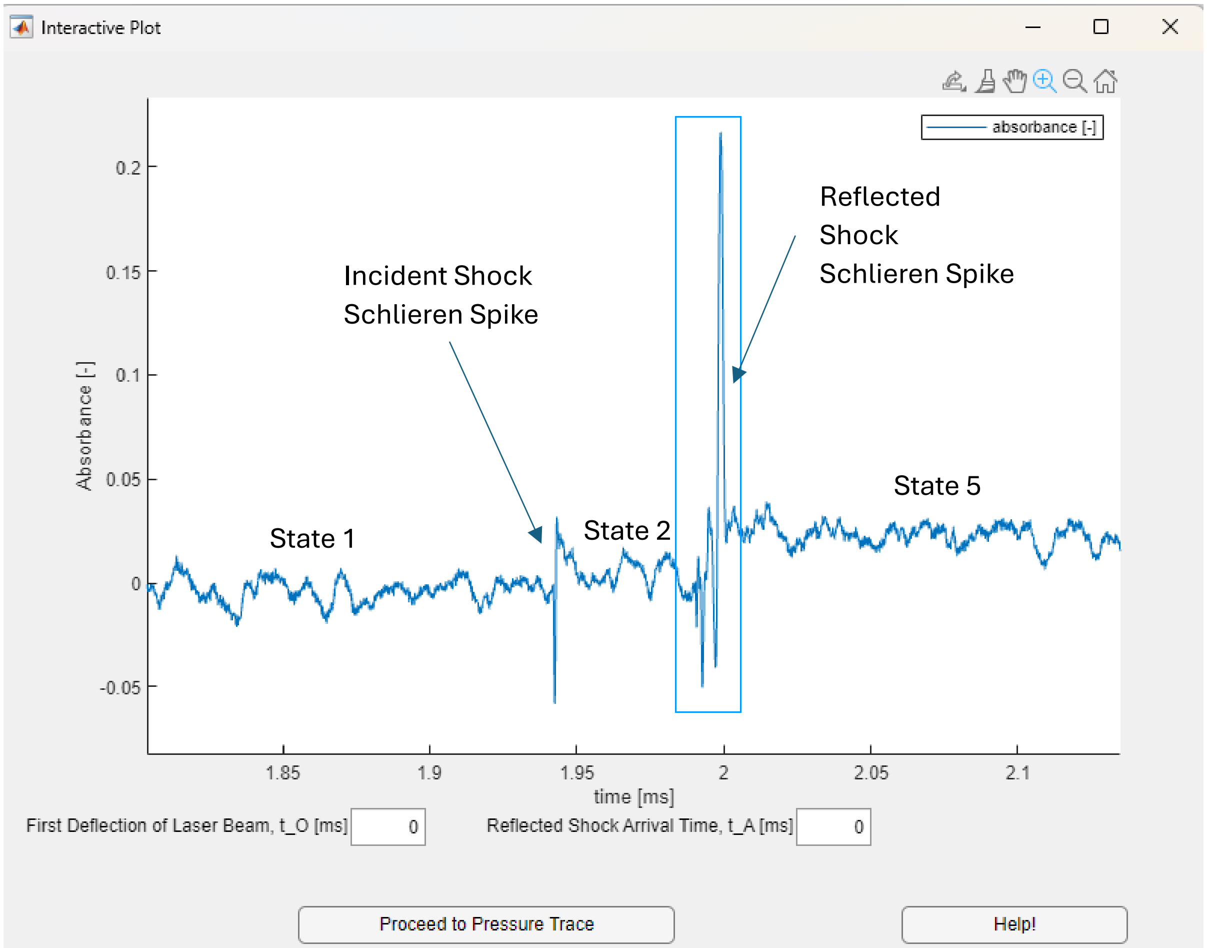
The interactive plot shown below pops up, with the full laser trace record first. Absorbance has already been calculated using dark mode offset correction, and common mode rejection. The schlieren spikes are seen near 2ms, but the incident and reflected shocks are too close together to determine t_0, or t_A. **We need to zoom** in to get a closer look



Below, note the plot toolbar in the upper right corner. In the screenshot below, I have selected the **<u>"Zoom in"</u>** feature, which turns my curser into a crosshairs (+), then I drew a zoom box around the schlieren spikes.

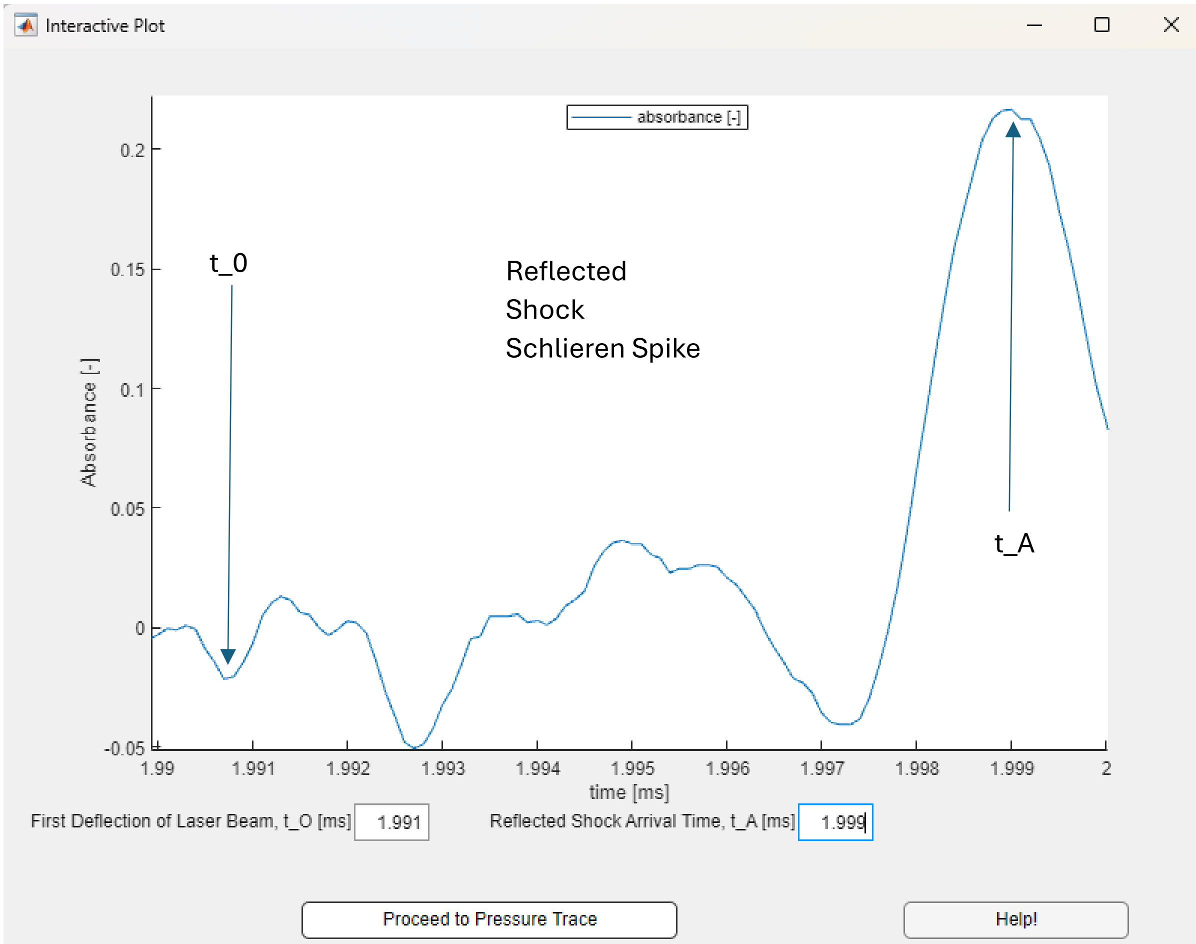


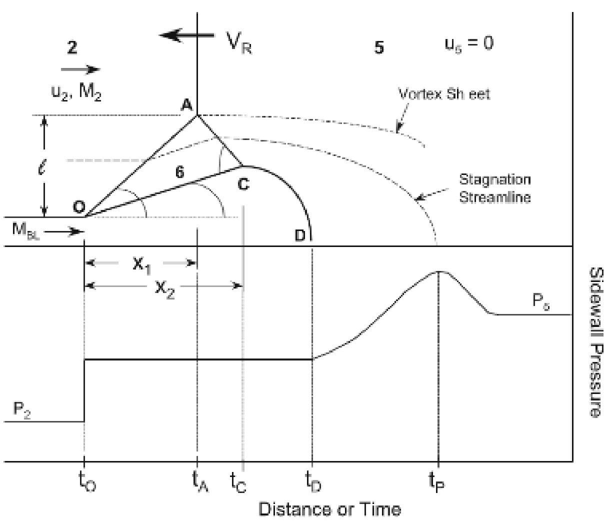
Below, the incident shock schlieren spike is just before 1.95ms, and the reflected shock spike is near 2ms.



Choosing t_0 and t_A:

I zoom in a couple more times until I can clearly read the time of the first laser beam deflection (t_0), and the deflection due to the reflected shock passage (t_A) (See next figure). t_0 should correspond to the bifurcation foot moving past the optical plane, and the peak deflection should be associated with the reflected shock passage. These locations are somewhat subjective. The shape of the laser trace will depend on your laser alignment, and the conditions of your reflected shock. Better laser alignment should result in clearer t_0 and t_A but these is subject to human error, and experience is your best friend. Make your best judgement. See Figures 1 & 2 in Ref 2 (2006 Petersen) below for more guidance. Enter t_0 and t_A in the text boxes provided, then press "Proceed to Pressure Trace".





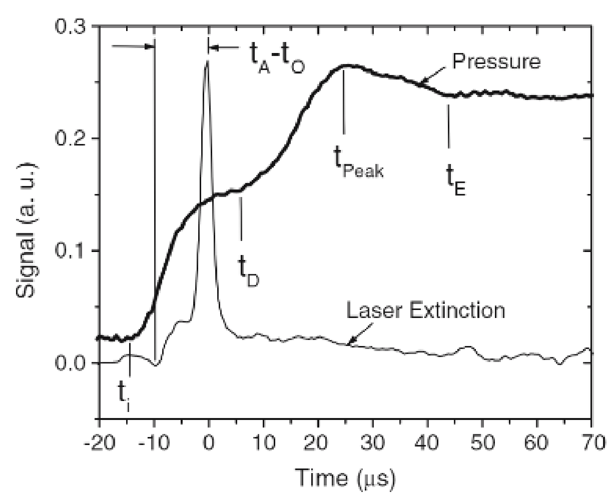


Fig. 1 Model of reflected-shock bifurcation and corresponding sidewall pressure trace. For this ideal depiction, the pressure transducer has zero width and responds instantaneously

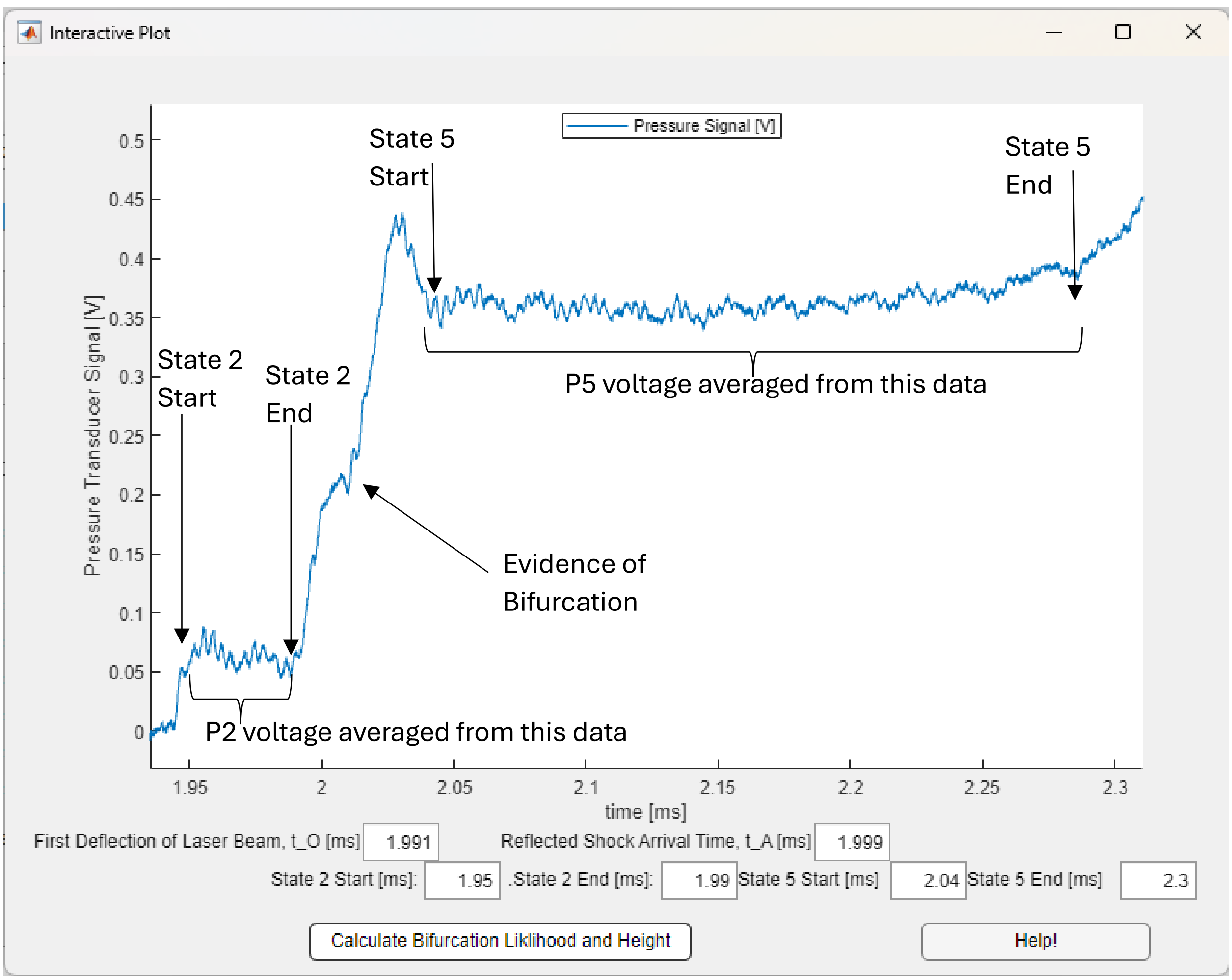
Fig. 2 Transmitted laser intensity (inverse) showing schlieren spike due to the passage of the normal portion of the reflected shock. A comparison with the sidewall pressure is also provided for reference (see Fig. 1). Mixture 4; $T_5 = 1{,}630$ K; $P_5 = 55$ atm

Source: Measurement of reflected-shock bifurcation over a wide range of gas composition and pressure" E. L. Petersen · R. K. Hanson, Shock Waves (2006) 15:333–340DOI 10.1007/s00193-006-0032-3

<u>Choosing State 2 & 5 bounds to double-check P2/P5 calculation:</u>

Initially, the pressure trace will be zoomed in to whatever x-axis scale you used for the laser trace. Use the zoom function to find State 2 Start, State 2 End, State 5 Start and State 5 End. These will be used to determine a P2/P5 from the average pressure transducer signals, in a manner independent from the calculations provided by Refs 1, 2, and 3. This is used to double-check the Ref 1,2, and 3 Mach# and γ based calculations. Although the Y-axis is given in volts, we just want the ratio P2/P5, so the units don't matter.

<u>Below, I have already zoomed in and out several times to find the State 2 Start, State 2 End, State 5 Start, and State 5 end.</u> Most pressure traces will start near zero, which is State 1. That's the initial pressure of the reactants before the shock reaches the pressure transducer. The incident shock creates the first jump. The "State 2 Start" is the first point after that jump. After the incident shock passes the transducer, it reflects off the endwall, and the reflected shock passes back over the transducer causing the second jump. The "State 2 End" is the last point before the pressure jumps again. The second jump may be more or less vertical. It may or may not have evidence of bifurcation, and it may or may not overshoot the state 5 steady pressure. I choose "State 5 Start" to be the first point near the steady state level after any overshoot.



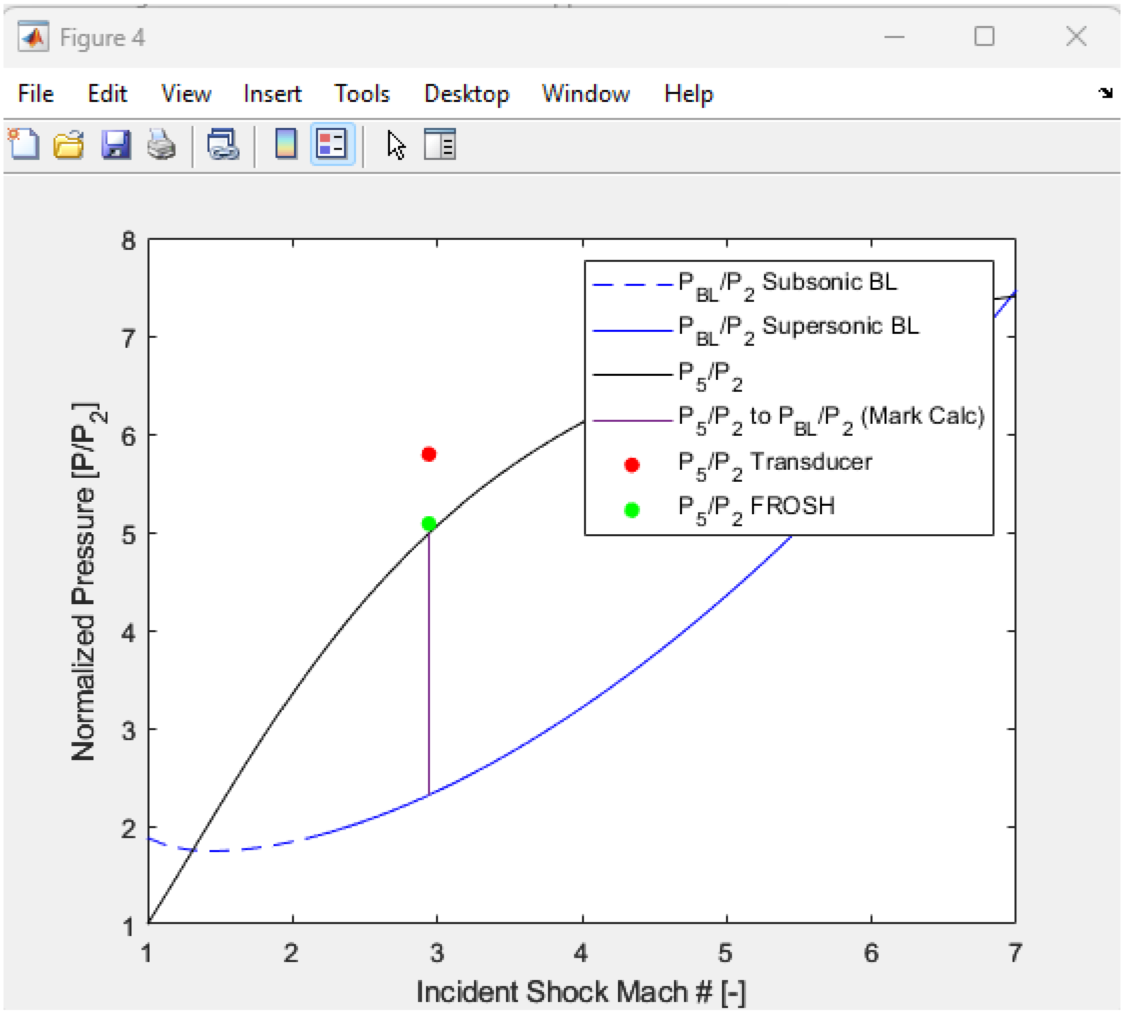
“State 5 End” may be a pressure rise due to ignition, or a pressure drop due to the arrival of the rarefaction wave. Ignition may be a rapid jump, an asymptotic rise (as shown below), or a small hump, depending on the reactant mixture, temperature, pressure, and level of dilution. In that case, “State 5 End” is wherever the user believes ignition has begun. This is subjective, and test-dependent so you have to know what you expect for your experiment, then use your best judgement. Without ignition, the pressure remains relatively constant until the rarefaction wave reaches the transducer and causes the pressure to drop. In that case, “State 5 End” is chosen to be the last point before the rarefaction wave hits. Again, this is subjective and requires your best judgement.

The figure shows the entries agree approximately with the pressure trace. Press “Calculate Bifurcation Likelihood and Height” when finished filling in the text boxes.

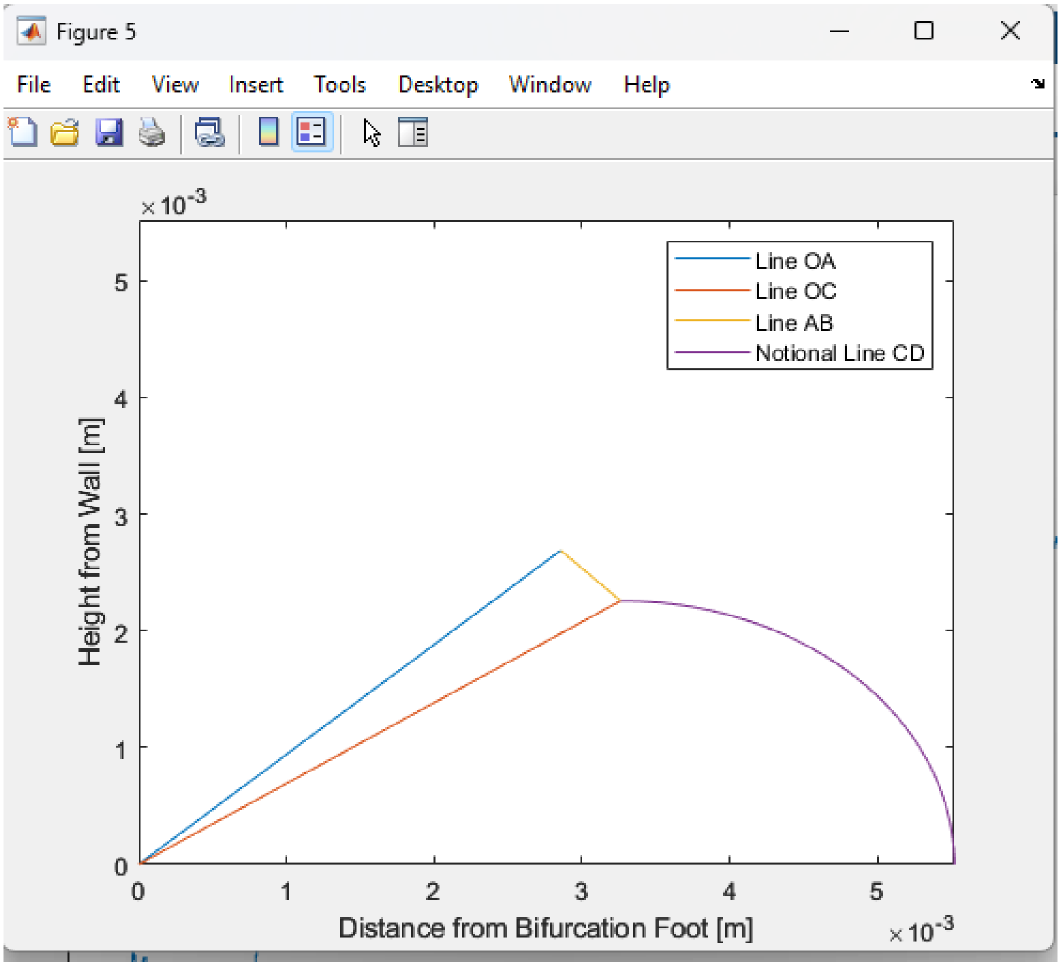
Output Plots:

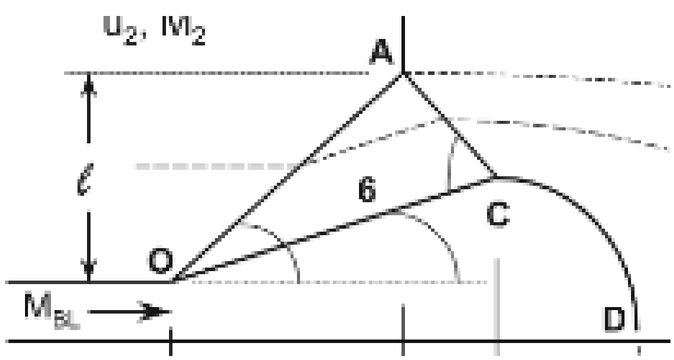
Output 1: Bifurcation Likelihood The Bifurcation likelihood is plotted first (See next figure). The black and blue lines show the full range of P_{BL}/P_2 (Blue) and P_5/P_2 (Black) possible for this mixture and incident shocks from Mach# =1 to Mach# =7. The dashed blue line represents the Ma range where the boundary layer would be approximately to be subsonic, and the solid blue line represents Mach# where the BL would be approximately supersonic. The vertical purple line corresponds to the Mach# for this specific test. It simply connects the test-specific P_{BL}/P_2 and test-specific P_5/P_2 to make it easy to see where the test conditions fall in terms of overall likelihood.

Where the purple line intersects the black line is your test-specific P_5/P_2 calculated using equations from Mark 1958 (Ref 1). It’s based on the mixture’s ratio of specific heats (γ), and the incident shock Mach#. However, you also calculated P5/P2 when you selected the State 2 and 5 bounds on the pressure transducer trace. That is the red dot. Additionally, if you have the Frozen Chemistry Shock Solver (FROSH) it’s possible to calculate P2 and P5. This is also based on the specific heats (γ), and the incident shock Mach#, but calculated with a slightly different, iterative process. If you use FROSH, you can add the FROSH-calculated P_5/P_2 to the workspace before running MlappPredictBifurcation, and name it “P5overP2FROSH,” and that will add the green dot. This is simply a double-check on the Mark 1958 math. P5/P2 is now determined via three independent methods, and we get a sense of how well they agree. Here the agreement is within 20%.



Output 1: Bifurcation Geometry The Bifurcation Geometry is plotted second. Note that the axes are in meters, but the bifurcation height should be in mm or cm. The “x10^{-3}“ on these axes mean that the numbers can be read as mm. So, here the bifurcation height is approximately 2mm. The diagram is drawn similar to Figure 1 in Petersen 2006 (Ref 2). The purple line is a circular section whose radius equals the bifurcation height. It has no mathematical precedence. It’s a notional drawing of the backside of the bifurcation foot, and is labeled as such.





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