Fundamentals and Practices of Advanced Aerodynamic Measurement Technology

Operation Manual for Lab #3

2022.11

Response Time Measurement of PSP

1. Experiment Setup

Photomultiplier tube, shock tube, UV-LED light, oscilloscope, PSP sample. The whole system are connected as shown in Figure 1

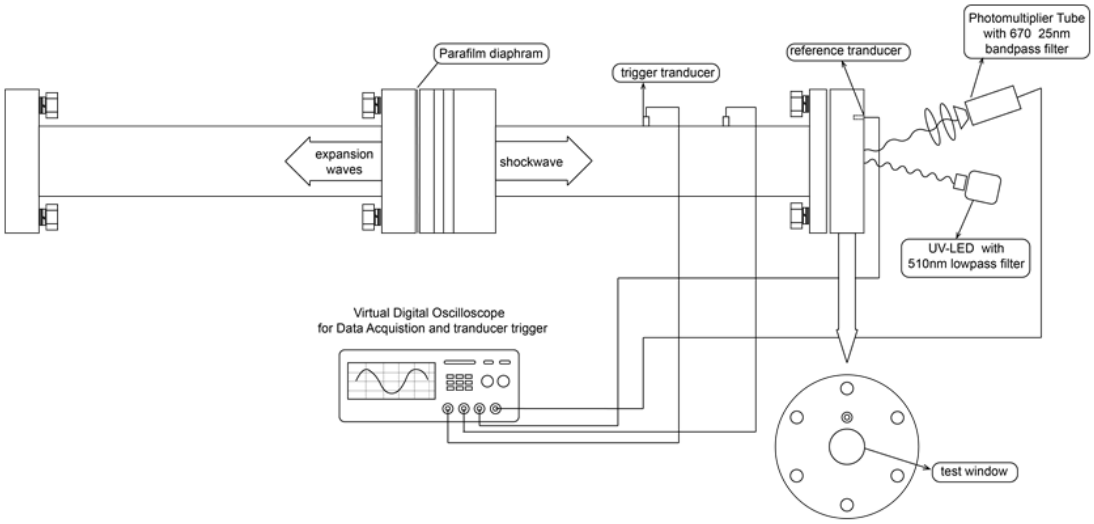

Figure 1 Experiment Setup of Static Pressure Calibration

(1) The UV-LED Light

This LED can produce excitation light with wavelength around 385 nm..

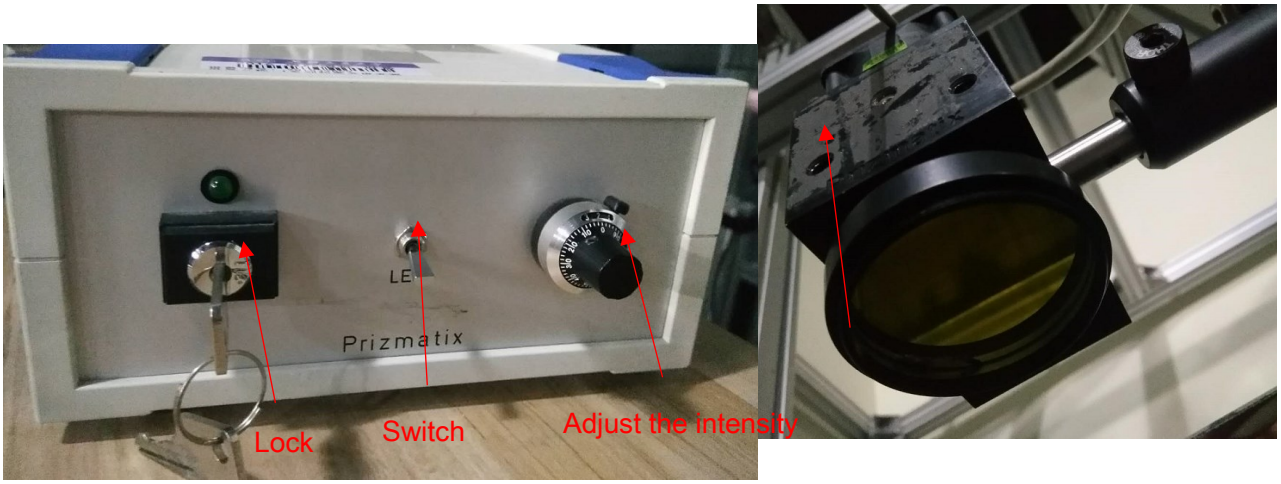

Figure 2 UV-LED light source

(2) Shock Tube

The Shock Tube is an instrument used to produce shock waves so that a step pressure change can be obtained to measure the response time of PSP. We first put a diaphragm between two parts of the tube, then provide high pressure air in one side using an air compressor. When the pressure difference reaches a certain value, the diaphragm breaks, and a moving shock wave is generated.

Figure 3 Shock tube

The high pressure air is provided by an air compressor. When the pressure in the pump is below 3 MPa, the compressor will start running automatically.

There are two kinds of diaphragm in two boxes, respectively. We take one diaphragm of each type and put them together between the two parts of the tube.

We use an electronic pressure gauge to monitor the pressure in the high pressure side of the tube. Turn on the valve slowly and the diaphragm will fracture when the pressure reaches about 0.6 MPa.

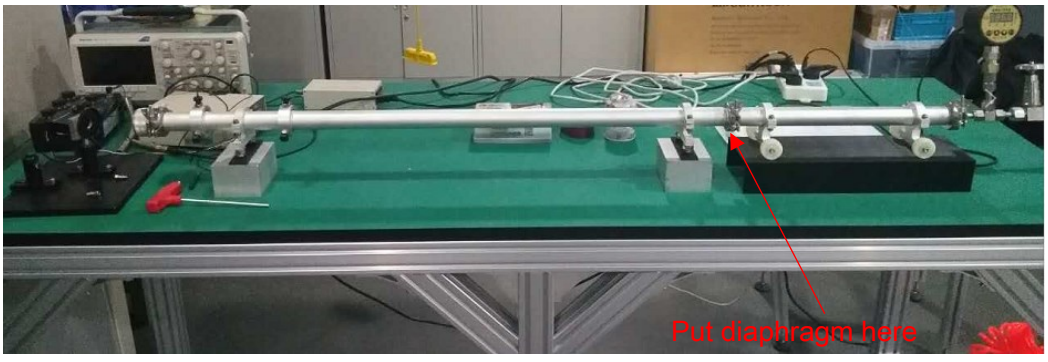

Figure 4 Diaphragm position

Figure 5 Air Compressor

Figure 6 Parts of shock tube

(3) Oscilloscope

We use pressure transducer's signal as the trigger. When the shock wave pass through the transducer the oscilloscope will record the signal transmitted from the PMT. The oscilloscope will be set in advance by TA. Just push down "signal" button before increase the pressure in the high-pressure part of the tube.

(4) The PSP Sample

The PSP sample uses PtTFPP as the pressure-sensitive dye. Its excitation wavelength is around 400nm. Its emission wavelength is around 650nm. We use a 650 +/- 50nm bandpass filter to remove the excitation light. The PSP was sprayed in a glass part which was installed at the end of shock tube.

Figure 7 Oscilloscope

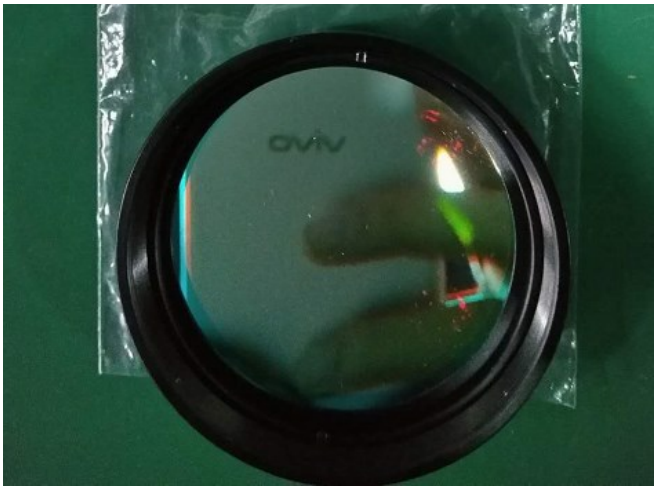

Figure 8 Bandpass filter

(5) Photomultiplier Tube

The photomultiplier tube is extremely sensitive detectors of light intensity. Direct expose of a PMT with power on to bright light may cause damage to it. (Attention: make sure the photomultiplier tube is in a dark environment before turn on. There is a shade cloth in lab.)

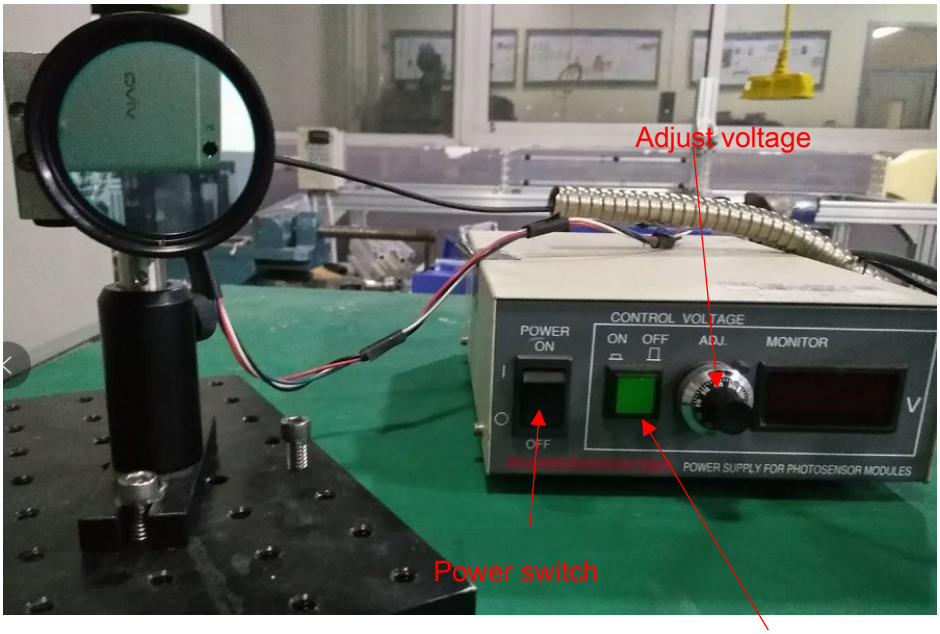

Figure 9 Photomultiplier tube

2. Experimental Principle

This experiment is designed to test the dynamic performance of PSP. The response of PSP signal changes following a step rise in pressure. The PSP signal will change abruptly when the shock wave hits the sample. So the time required for the PSP signal to change from max level to min level can describe the PSP's dynamic response. A typical parameter is the response time which is defined as the time required to reach 1/e of the total difference.

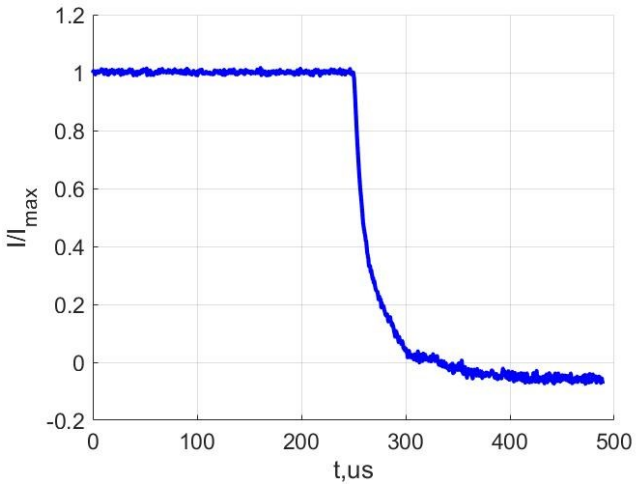

Figure 10 Response curve of PSP

3. Experimental Procedure

(1) Get the PSP sample, install it in the shock tube.
(2) Open the PMT's power switch and Oscilloscope, cover the shade cloth to the PMT, then turn on the voltage switch and the LED light. Adjust LED light and voltage of PMT to get a suitable level of signal. (TA will help you in this step)
(3) Put the diaphragm between two tubes. Connect air compressor to shock tube. Turn on the pressure gauge.
(4) Turn on the valve to allow high pressure air into the tube.
(5) Increase the pressure until the diaphragm breaks. Record and save the response curve on the oscilloscope. Perform the measurement for 3 times.
(6) Turn off all equipment after the experiment is finished.

4. Data Processing

Process the data using software such as matlab or JAVA. Smooth the original data, and normalize the response curve by the max and min levels. Find the response time of PSP.

5. Key issues to be addressed in the report

1. Based on the response curve, determine the averaged response time of the PSP sample. What is the frequency bandwidth of this PSP if a first order response is assumed?
2. Determine the uncertainty of the calibration and give the results in the form of response time τ +/- $\Delta\tau$. Discuss the possible reasons for the uncertainty.