IMB PMT

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1 PMT Hamamatsu R1408

Photomultipliers (PMTs) are extremely sensitive detectors of light in the ultraviolet, visible, and near-infrared ranges of the electromagnetic spectrum. PMT used in IMB experiment is "Hamamatsu R1408". In this section, the broken PMT from IMB is opened and we take off the base circuit finding where it is broken.

1.1 Structure

First of all, we open the PMT showed as figure1 and took off the base circuit as figure2.

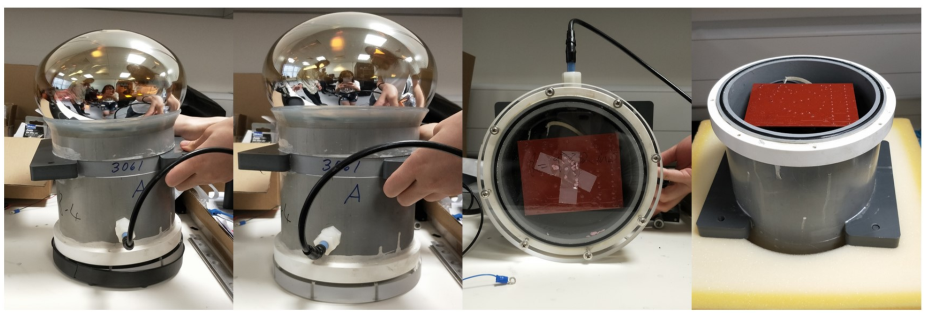

fig.1. Process of opening PMT Hamamatsu R1408

fig.2. Base circuit of PMT Hamamatsu R1408

1.2 Base circuit

The structure of base circuit can be obviously figured out (figure3) which is similar to the schematic of base circuit structure.

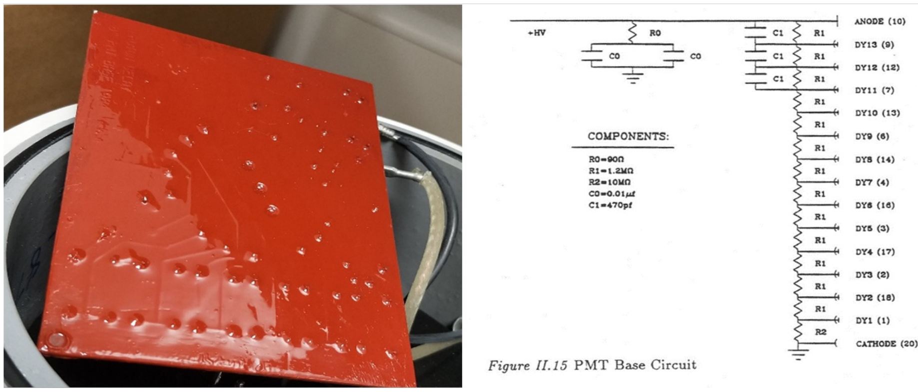

fig.3. PMT base circuit[2].

In the base circuit, every resistors are in series. Thus, the resistance between signal and ground should be around 25.6MΩ. However, the experiment value is around 5MΩ which is much smaller than theoretic calculation. However, the resistance is not infinite, which prove the PMT works and the main problem might happened in the base circuit or cable. Since the structure of circuit can be figured as figure3, every resistors can be measured.

Table1

Resistor Number	Resistance (MΩ)
1	1.3
2	1.4
3	1.2
4	1.3
5	1.2
6	1.2
7	1.3
8	1.3
9	1.2
10	1.85
11	1.2
12	1.3
13	1.3

From table1, the resistor R10 is unstable and abnormal. But that is not the main reason why the PMT is broken.

1.3 Cable

The cable of PMT is consisted by four parts, which is divided into signal and ground. In addition, we tried to add a connector as figure then it can connect to the test setup to measure the response of PMT. The type of connector is RADIALL coaxial connectors R317.005.000 (figure4).

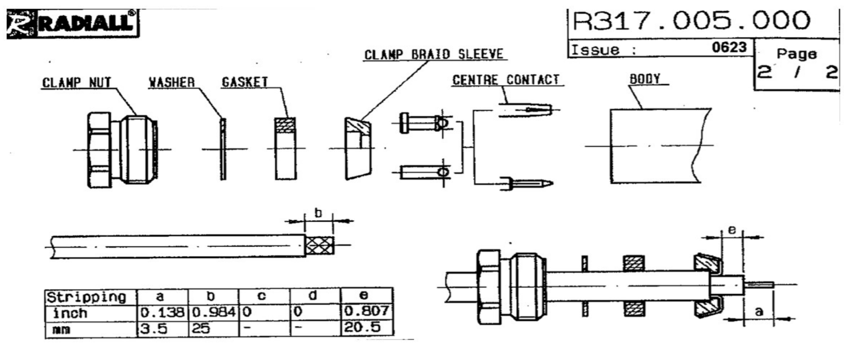

fig.4. Schematic of RADIALL coaxial connectors R317.005.000[1].

1.4 Splitter

The test setup used to measure the response of PMTs at low light levels. The pulse is picked off the high voltage line shown in the left side of figure5. The parameter of components is 10kΩ, 0.01μF, 10Ω and 1.5kΩ in our setup. Firstly, we used a board and solder all the components on the board but power supply always trip and spark appeared on board. Thus, the board cannot support high voltage and we soldered every component directly finally.

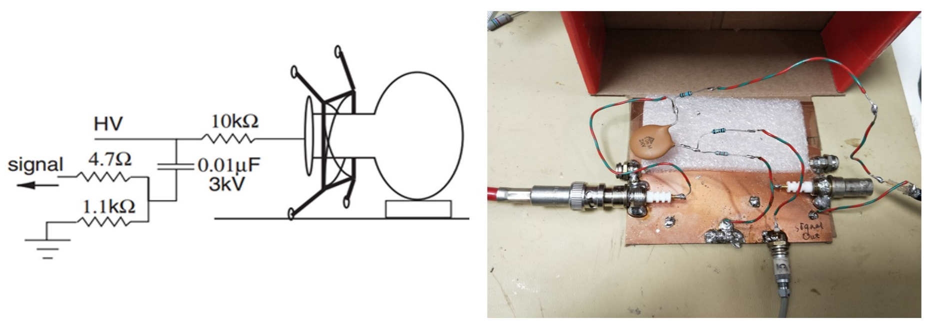

fig.5. Schematic of test setup[3] and the splitter made based on that.

2 Fixing of the PMT

The power supply always trips at 200V. In this section, we found the trouble and fixed it.

2.1 Remaking of Base circuit

Because the base circuit is complex, a new base circuit is made according to figure, which is shown as figure6.

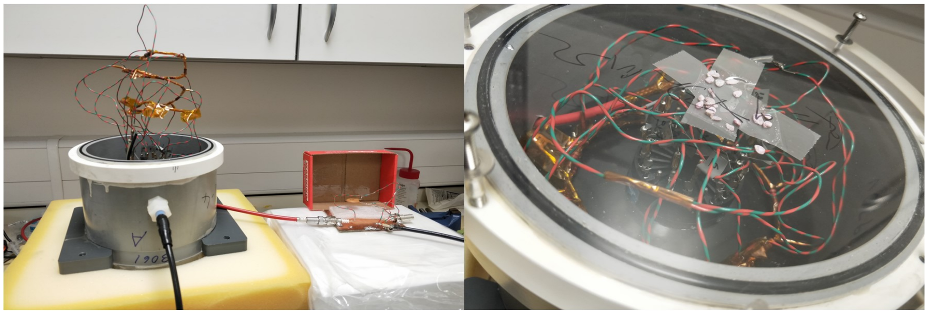

fig.6. New base circuit base on fig.3.

As a result, both the previous base circuit and the new one will trip and they will be fine if it connect to the splitter directly, which shows the cable might be broken.

2.2 Cable

It looks cable can support only around 200 300V, the reason of which might be degradation of insulator. Thus, the cable is changed into a new one as figure7. And this time the charge can get 2kV successfully.

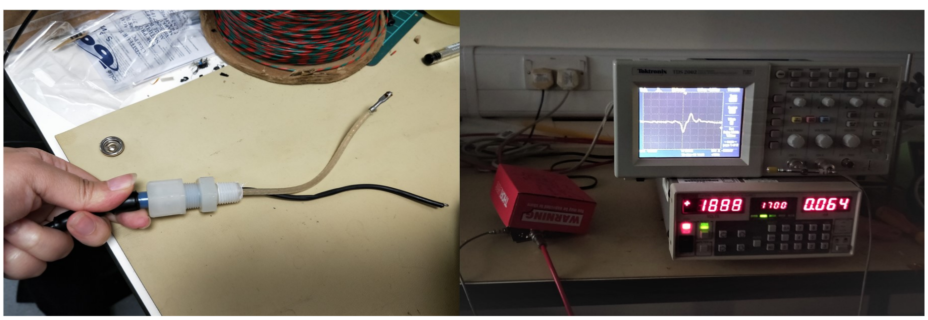

fig.7. Previous broken cable and new cable changed in the setup with waveform.

Connecting the cable to the splitter, the signal is shown by oscilloscope as figure. The pulse wide 25ns and height 30mV. However, there is a big reflection because the previous cable is 93Ω while the new cable is 50Ω. Every parts should have equal resistance to decay the reflection, but the previous base circuit is 93Ω which is different from the cables and cause the reflection.

3 Modification of the PMT

Although cable is changed into a new one and it works, the signal has a big reflection. In this section, we tried to modify the circuit to get a better waveform and fix the new base.

3.1 Resistors

Instead of replacing the previous 90Ω resistor, we added a 110Ω resistor and the whole resistance will be 49.5Ω as figure8 shown.

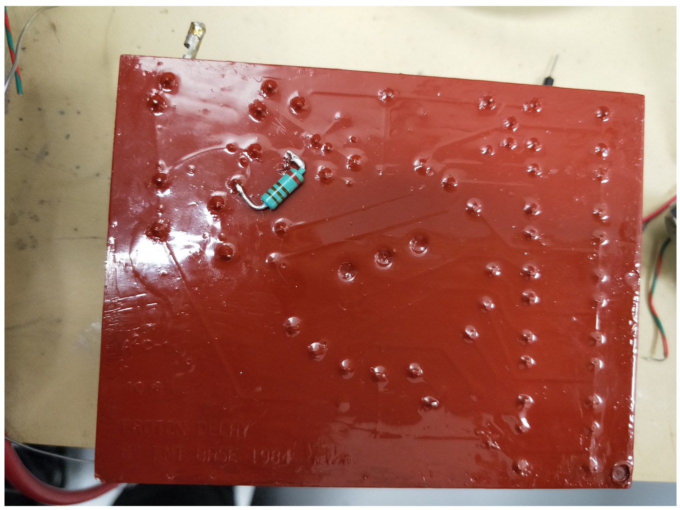

fig.8. 110Ω resistor multiple to control the whole resistance of base cricuit.

The pulse is 25ns width and 20mV height which is smaller than the previous 90Ω base circuit and noise become very large (figure9). Moreover, we found two types of noise.

- One is high frequency noise which has similar time scale with the signal.
- Another is low frequency noise which looks like a signal pulse but the width and height is much larger than PMT pulse. And the time scale of low frequency noise is around 150μs. It might caused by the power supply, because the height of peak will get small if the setup move far away from the power supply.

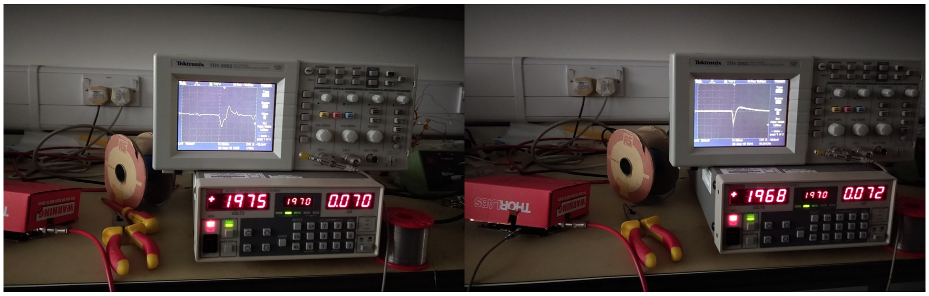

fig.9. Waveform of PMT pulse and two different frequency noise.

3.2 High Voltage

Power supply is changed into ORTEC 659 5kV Bias Supply and Wenzel elektronik HII30-4 RL665 H.V. Power Supply to test the affect of power supply. However, the signal from the setup which supported by Wenzel electronik HII30-4 RL665 H.V. Power Supply looks not the pulse but the noise, because it appears in very low voltage. To measure the value of voltage output from ORTEC 659 5kV Bias Supply, another low voltage connector is used to make the exact output high voltage. Voltage from 100V to 600V is used to fit the linear function between high voltage and low voltage as figure10 show.

$$LV = 0.117HV + 1.226$$

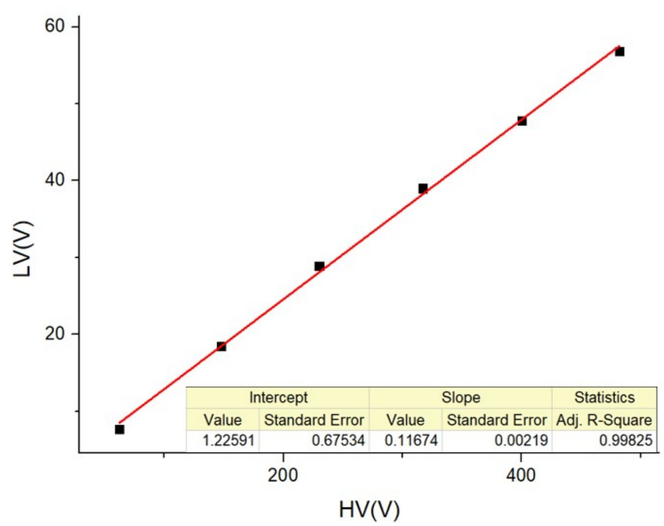

fig.10. Linear fitting of high voltage and low voltage.

Thus, standard high voltage should be 1970V where the value of low voltage is 231.2V. The pulse in that situation is 25.0mV height and 25ns width (figure11) and there is a reflection peak height 15.0mV. The distance between the signal peak and reflection peak is 150.0ns. Moreover, there are still two types of noise. The low frequency noise is only 25.0mV height and 100μs width, the time scale of which is much smaller than before. But the pulse is near noise which cause the baseline of the waveform unstable.

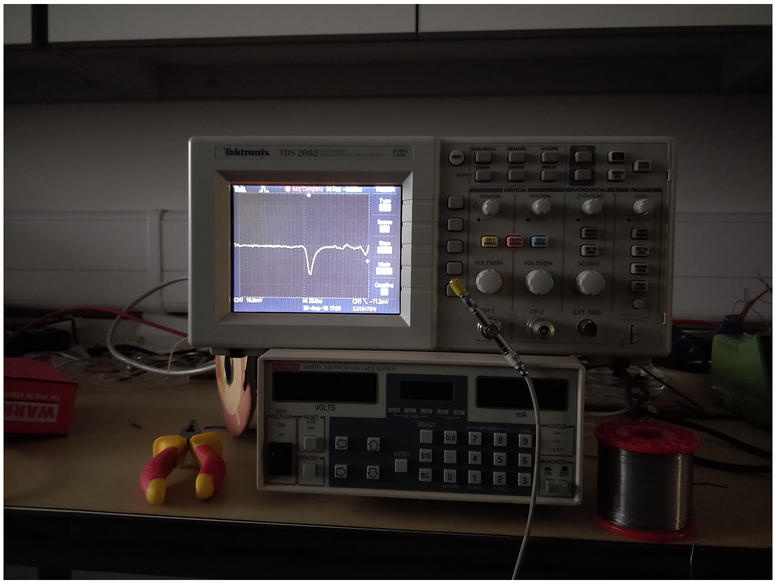

fig.11. Waveform of PMT pulse.

3.3 New Base Circuit

If we replace the new base circuit into the PMT, no signal come out. To find out the reason, we check each resistor and the voltage between each two nearest connectors as table2. However, every components are fine and probably the disconnection between the pins and connectors cause signal vanished.

Table2

Resistor Number	Resistance(MΩ)	Voltage(V) (+100V AC added)
1	1.297	4.0
2	1.289	4.0
3	1.281	4.0
4	1.274	4.0
5	1.300	4.0
6	1.287	4.0
7	1.295	4.0
8	1.296	4.0
9	1.291	4.0
10	1.321	4.1
11	1.267	3.9
12	1.260	3.9
13	1.298	4.0
14(R2)	12.08	24.3

4 Conclusion

The broken PMT ”Hamamatsu R1408” from IMB experiment opened, where we take off the base circuit and remake a new one base on figure3. In addition, A splitter built to measure the response of PMTs at low light levels. As a result, the degradation of the cable cause the PMT broken and a new cable replace to fix it. Moreover, a pulse can be discovered with two different types of noise.

References

[1] IMB PMT Base

[2] Instructions of Radiall R317005000EN-855041

[3] S. J. Brice, etc., Photomultiplier Tubes in the MiniBooNE Experiment, Nuclear Instruments and Methods in Physics Research Section A, 97-109.