Development of an Argon Light Source as a Calibration and Quality Control Device for Liquid Argon Light Detectors

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Abstract. The majority of future large-scale neutrino and dark matter experiments are based on liquid argon detectors. Since liquid argon is also a very effective scintillator, these experiments also have light detection systems. 127 nm wavelength of the liquid argon scintillation leads to the development of specialized light detectors, mostly based on wavelength shifters, and recently photodetectors sensitive to deeper UV. The effective calibration and quality control of these newly developed detectors is still a persisting problem. In order to respond to this need, we developed an argon light source which is based on plasma generation and light transfer across a MgF_2 window. The light source is designed as a small, portable and easy to operate device to enable the acquisition of performance characteristics of several square meters of light detectors at once. Here we report on the development of the light source and its preliminary performance characteristics.

1. The Argon Light Source

Most future large-scale neutrino and dark matter experiments will rely on liquid argon detectors (see e.g. [1]). For this reason, detectors to measure the scintillation light generated inside liquid argon detectors are needed. The number of photosensors to measure the 127 nm wavelength argon scintillation light is quite limited and usually a wavelength shifter such as tetraphenyl-butadiene (TPB) is employed. The calibration and quality control of these detectors are still an ongoing problem.

In order to meet this need, we made an argon light source that produces light with a wavelength of 127 nm. We transferred the argon light to the outside using MgF_2 window. We made the body of the light source from Polyoxymethylene material. We used titanium wire as the electrode for the light source. The light source body was put under vacuum and the ultimate vacuum was 5×10^{-6} millibars. Then we filled the light source with argon gas. To increase the purity of the argon gas in the housing, we put under vacuum and filled with argon a few times. The light source is then isolated and operated at 2.8 kV. The dependence of the performance characteristics on the gas pressure and high voltage are underway. For the time being, the operational pressure is 1.6 bars.

Figure 1 shows a picture of the vacuum/filling station, the light source and the test tube (described in the next section).

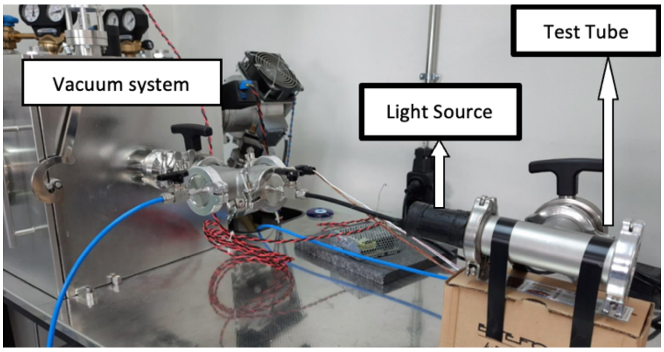

Figure 1. A picture of the vacuum/filling station, the light source and the test tube.

2. Validation of the Light Source

In order to validate the performance of the argon light source, we made a vacuum tight test tube. The exit window of the light source was coupled to a custom flange. Opposite to the light source window was a single silicon photomultiplier (SiPM). Another single-SiPM assembly was made with a SiPM with its window coated with TPB. Figure 2 (left) shows the overlayed signals measured with the clean SiPM looking directly at the light source under vacuum. The data was recorded with Caen v1751 with self-triggering on the light pulses 20 mV above baseline. The main pulse is mostly due to the impurities in the argon, and partly due to the red-infrared emission of argon.

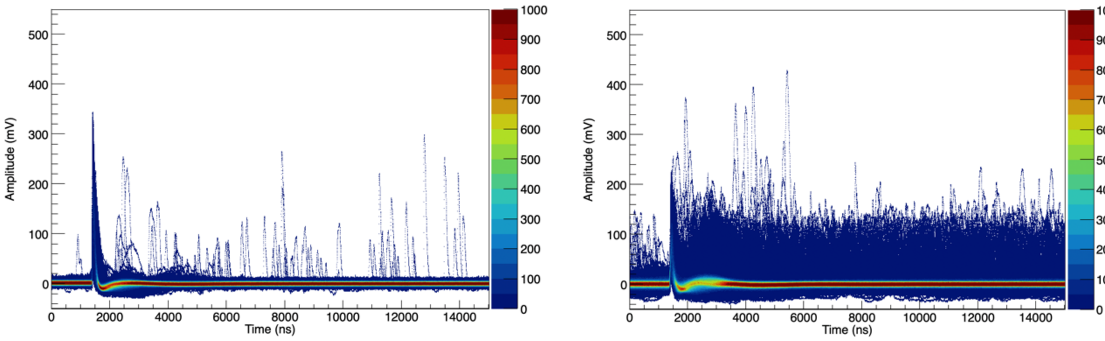

Figure 2. The overlayed signals measured with the clean (left) and TPB coated (right) SiPM looking directly at the light source under vacuum.

Figure 2 (right) shows the overlayed signals measured with the TPB coated SiPM looking directly at the light source under vacuum. Compared to the clean SiPM overlayed signals, the height of the triggering pulse is decreased and the readout window is populated with many additional pulses indicating towards a nearly continuous emission of 127 nm light, which was not visible with the clean SiPM.

Figure 3 (left) shows the number of pulses with peak amplitudes above 30 mV in the 15 μs window per triggered event. The triggered events with the clean SiPM mostly contain single pulses with peaks above 30 mV; there is a significant fraction of events with peaks above 20 mV (the trigger threshold) and less than 30 mV; and the number of two or more peaks is significantly reduced. For the case of TPB coated SiPM, the number of pulses in the readout window with peaks larger than 30 mV is much higher. As the only difference is the introduction of the TPB on the SiPM window, which simply increases the sensitivity to 127 nm light, the operation of the light source is validated.

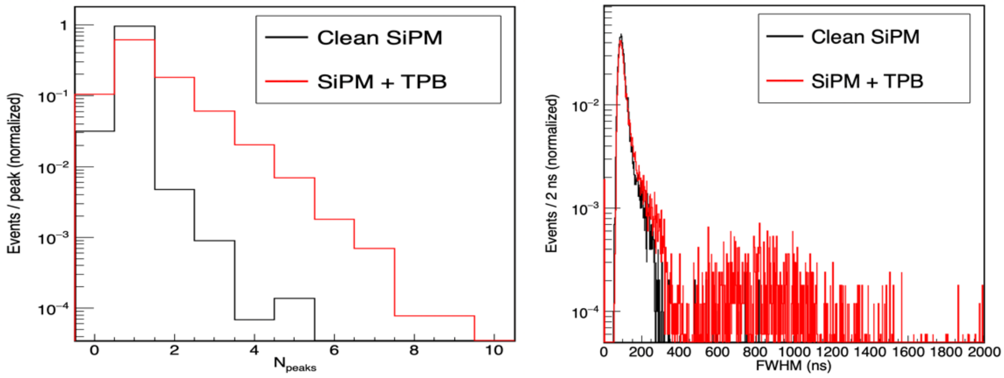

Figure 3. The number of pulses with peak amplitudes above 30 mV (left) and the FWHM of all the pulses (right) in the 15 µs readout window.

Figure 3 (right) shows the full width at half maximum (FWHM) of all the pulses in the 15 ms readout window for the clean and TPB coated SiPM. The majority of the pulses have less than 500 ns width. On the other hand, the TPB coated SiPM pulses have an accumulation around 800 ns. Figure 4 (left) shows an example of the pulse with less than 500 ns FWHM, and Fig. 4 (right) shows an example with larger than 500 ns FWHM for the TPB coated SiPM. The wider pulses are attributed to the 127 nm light. The 127 nm light seems to be originating in bursts within which the individual pulses are a few ns apart. The time structure of the light is under further investigation.

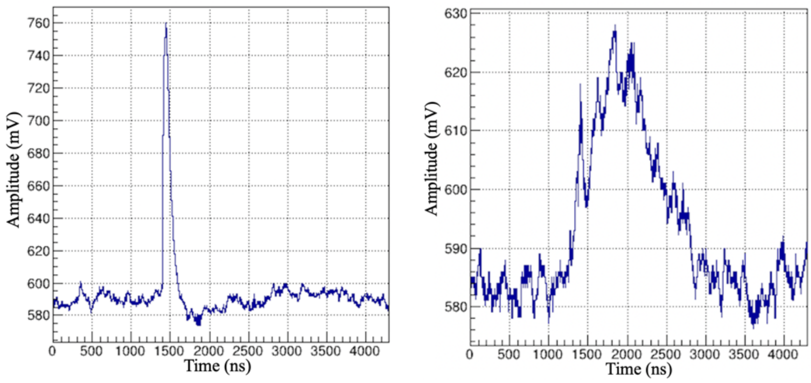

Figure 4. Examples of pulses with less than 500 ns FWHM (left) and with larger than 500 ns FWHM (right) for the TPB coated SiPM.

3. Conclusions

An argon light source to be utilized as a practical calibration and quality control device for liquid argon light detectors is developed. The characterization of the light source is underway. The preliminary measurements indicate a successful generation and detection of the 127 nm VUV light. Various operational parameters such as the pressure and high voltage are under study. Plans include improvements on vacuum sealing and purity, and a careful study of the duration of stable performance with single filling.

4. Acknowledgements

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References

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