Measurement of Scintillation in the Q_{weak} Radiator Bars

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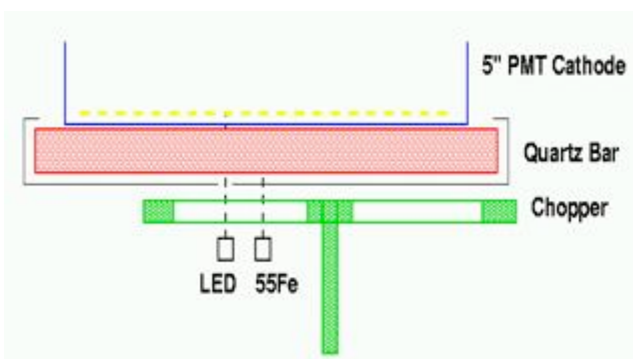
Background information:

The purpose of this experiment is to determine the scintillation rate that is involved with specific quartz bars when a radioactive x-ray source is placed near it. Ultimately, these quartz bars will be used in the Qweak experiment[1]. The key objective of this experiment is to compare the probability of scattering between polarized electrons spinning in opposite directions. In order to do this, a continuous beam of electrons is directed at a hydrogen target. In doing this, the electrons will sometimes be deflected by the electrically charged parts of the hydrogen target, causing the beam of electrons to scatter at different angles. Detectors are used to measure the speed and direction of these pieces of matter as they scatter, and with this information, scientists can study the probability of scattering of electrons. The detectors used in this experiment are essential in determining the exact speed and direction of the scattered electrons. For the Qweak experiment, the objective is to measure the rate of high-energy electrons producing Cherenkov light[2]. Both Cherenkov light, the light caused when a charged particle passes through a medium faster than the speed of light in this medium, and scintillation light, the light caused by the absorption of radiation at any speed, are present in the quartz bars. The Qweak detectors primarily function by measuring Cherenkov light, however because scintillation light will also be produced in the quartz bars, it is essential to determine the rate at which the scintillation light is generated in relation to the rate of Cherenkov light. By knowing the scintillation rate, we can more accurately measure the Cherenkov light in the detectors, which will provide more information in the scattering pattern of polarized electrons.

Experiment procedure:

The setup for this experiment consists of the quartz bar being tested, a spinning chopper, a light source, and a photomultiplier tube which is connected to electronic equipment. A visual of the setup looks like the following:



The equipment connected to the photomultiplier tube converts the analog signals of the light intensity produced into more easily read digital signals. The procedure that will be used to measure the scintillation rate involves measuring with AC current. The chopper's purpose is to cut the

[1] http://www.jlab.org/qweak
[2] For more information on Cherenkov light, go to http://en.wikipedia.org/wiki/Cherenkov_radiation

radioactive waves to be measured by the PMT so that they are concentrated at a known frequency. A frequency can be chosen for the spinning chopper so that a precise measurement of the intensity signal can be detected. This prevents drifting of the signal that would occur without the chopper. A radioactive source placed under a chopper in close proximity will create a low level of scintillation light that can be magnified by the PMT. The LED light provides a way to calibrate the different measurements so they can be easily compared. The chopper rotates at a known frequency, and chops the x-rays so that a spectrum analyzer measures the signal V_S produced at the specific frequency of the chopper. We also measure the signal of the spectrum analyzer at other frequencies and call it V_B for background. If the LED was on, then the signal that is measured is very bright, so we can change the number of samples taken to a smaller number. However, if the LED is off, the duration of measurement must be longer because the signal is not as strong.

Data and Analysis:

We use the equation:

$$R_{scint} = (V_{Soff} - V_{Boff}) \times \left[\frac{R_{on} - R_{off}}{V_{Son} - V_{Boff}} \right]$$

Where R_{scint} is the rate of scintillation, V_{Soff} is the measurement of the signal of the light with the LED off, and V_{Boff} is the measurement of the background with the LED off. Both of these measurements would be with the radioactive ^{55}Fe in. V_{Son} is the measurement of the signal of the light with the LED on and V_{Boff} is the measurement of the background with the LED off. Finally, R_{on} and R_{off} is the rate with the LED on and off, respectively.

I.) First we tested the longer quartz bar at 175 Hz.

Long quartz bar at 175 Hz data:

RUN	**SOURCE**	**LED**	**Vs** Hz	**Vb** Hz	**SAMPLES**	**RATE** Hz
30	OUT	OFF	9.51 ± 0.06	9.57 ± 0.06	74	N/A
31	IN	OFF	10.52 ± 0.03	9.29 ± 0.03	173	924.91
32	IN	ON	135.11 ± 0.97	10.64 ± 097	1	1922

$$R_{scint} = (V_{Soff} - V_{Boff}) \times \left[\frac{R_{on} - R_{off}}{V_{Son} - V_{Boff}} \right]$$

$$= (10.52 - 9.29) \times \left[\frac{1922 - 924.9}{135.11 - 10.64} \right]$$

$$= 1.23 \times \left[\frac{997}{124.5} \right]$$

$= 9.850$ Hz scintillation rate

II.) Next we tested a quartz bar made of a different material that was square at 175 Hz.

Short light guide quartz bar at 175 Hz data:

RUN	**SOURCE**	**LED**	**Vs** Hz	**Vb** Hz	**SAMPLES**	**RATE** Hz
40	IN	OFF	8.26 ± 0.04	6.44 ± 0.04	100	N/A
43	OUT	OFF	6.26 ± 0.02	6.26 ± 0.02	1028	799.55
44	OUT	ON	117.23 ± 0.97	7.80 ± 0.97	2	1642.7

= 14.06 Hz scintillation rate

III.) Using the previous light guide bar, we changed the frequency of the chopper to 30 Hz.

Short light guide quartz bar at 30 Hz data:

RUN	**SOURCE**	**LED**	**Vs** Hz	**Vb** Hz	**SAMPLES**	**RATE** Hz
46	OUT	OFF	4.15 ± 0.02	4.15 ± 0.02	253	N/A
47	IN	OFF	7.46 ± 0.07	4.41 ± 0.07	62	858.26
48	IN	ON	84.42 ± 0.26	5.30 ± 0.26	1	1470.6

= 23.61 Hz scintillation rate

IV.) Again with the same light guide, we tested the signal at 80 Hz.

Short light guide quartz bar at 80 Hz data:

RUN	**SOURCE**	**LED**	**Vs** Hz	**Vb** Hz	**SAMPLES**	**RATE** Hz
49	IN	OFF	8.76 ± 0.02	6.39 ± 0.02	939	858/ sec
50	IN	ON	133.23 ± 0.58	8.06 ± 0.58	3	1857.6/sec
51	OUT	OFF	6.77 ± 0.02	6.742 ± 0.02	151	N/A

= 18.93 Hz scintillation rate

Conclusion:

After finalizing the experiment and calculating the data, we determined that the rate of scintillation is low enough to be disregarded in the experiment measuring Cherenkov light. It is interesting to notice that the scintillation rate changes as the frequency is altered, but the cause is unclear. It appears that as the frequency increases the rate of scintillation decreases. Additionally, it is evident that the long quartz bar is manufactured much differently than the light guide bar as the scintillation rates at the same frequency are inconsistent. Although the cause is unknown, the original purpose of calculating the rate of scintillation was successful. It can be concluded that the rate of the scintillation produced by the longer quartz bar and the light guide quartz bar is negligible in comparison to the Cherenkov light in the detectors.