Measurement of Microwave Photon Size

Zachary Alton and Carly Brown
Advisor: Dr. Yew San Hor

Abstract

The scientific community has debated the nature of light for centuries. The introduction of wave-particle duality provided valuable insights, but this dual nature is still not completely understood. No conclusive measurement of photon size exists. We propose a method for measuring the apparent size of microwave photons using a single slit setup. Vertically polarized microwaves were emitted and received using pairs of quarter wavelength monopole antennas. We began by taking microwave power measurements at a maximum slit width dependent on wavelength and continued taking measurements at set decrements until the slit was closed. We recorded the slit widths corresponding to 50% of the maximum power using a pair of power meters versus slit width (y). We have found evidence that horizontal photon size is \( \lambda/\pi \) and vertical photon size is \( \lambda/2\pi \).

Motive

Photons are quantum objects and behave as both waves and particles simultaneously [1]. The particle nature of photons suggests they can propagate through a gap of any size. However, optical phenomena such as diffraction demonstrate this is untrue; photons have a size. Currently, there is no accepted theory or semi-empirical to photon size, and this resolution to the issue remains a topic of active discussion [2,3]. Using a simple approach, the use of a photon can be thought of as the minimum width gap that the particle can pass through. This concept remains contested across a broad range of optics. We have found a theoretical basis to suggest the size of a photon should be dependent on \( \lambda/\pi \). In this experiment, we used aluminum plates to create a single slit centered between an emitter and receiver antenna. Our aim is to better define the photon size.

Methods

Table 1: Antenna Arm Specifications

<table>
<thead>
<tr>
<th>Frequency (MHz)</th>
<th>A length (cm)</th>
<th>( \lambda ) length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.2</td>
<td>0.6</td>
<td>0.45</td>
</tr>
<tr>
<td>1.6</td>
<td>0.65</td>
<td>0.40</td>
</tr>
<tr>
<td>1.8</td>
<td>0.75</td>
<td>0.35</td>
</tr>
<tr>
<td>2.2</td>
<td>0.8</td>
<td>0.30</td>
</tr>
<tr>
<td>2.45</td>
<td>0.85</td>
<td>0.24</td>
</tr>
</tbody>
</table>

Each antenna was constructed with four radial legs (diameter 3.2 mm) bent at a 90° angle relative to the base of the antenna and one vertical leg (diameter 3.2 mm) positioned orthogonal to the base.

We first collected measurements for horizontal photon size. To do this, the aluminum plates were clamped in place upright. These plates were then pushed together along a straight line to vary slit width in a horizontal direction. A 4-in graduated table was used to ensure the plates were positioned equidistant from a set center line on which the antennas were positioned.

Figure 1: Slit setup for horizontal size measurements on graduated table

We then measured the vertical size of the photons. Pairs of aluminum center plates were created for four frequencies (1.2, 1.6, 2.2, and 2.45 MHz) with widths of \( \lambda/\pi \). A plastic sheet was used to shield the aluminum plates with the center plate, which were then secured during measurements.

Figure 2: Slit setup for vertical size measurements with fixed center plates

The power output was found using this equation, where \( P_{in} \) is the incident measured and \( P_o \) is the base microwave power.

\[
P_{dB} = 10\log(P_{in}/P_o)
\]

Results

Horizontal Size

Vertical Size

Discussion

- We are only analyzing the 50% power feature because low power regimes (e.g. 1% power) are difficult to differentiate from background noise.
- The initial power increase is due to photon self-interaction with the diffraction from the slit.
- The clear power decreases and linear trends support a finite photon size.

Conclusion

For photons in the microwave range, our results demonstrate that the horizontal size is \( \lambda/\pi \) and the vertical size is \( \lambda/2\pi \). The difference in horizontal and vertical size shows that photons in our system are non-symmetric; this provides justification for future research into the shape of photons. This data can be further reinforced by repeating the experiment with a focus on 10% and 1% of max power. Moreover, this is clearly not a purely classical result. Classically, the photon particle would be able to pass through an open slit of any size which would result in a steep drop-off to zero power at the origin. These findings may have applications in our future research into pilot wave theory via microwave interferometry and single photon detection.

Acknowledgements

We thank our research advisor Dr. Yew San Hor, who was instrumental in the success of this project. We extend our deep appreciation to Physics graduate student Max Holland for supervising the project and providing essential review. We thank Alex Herber for creating the data figures. We would like to extend our gratitude to Jason Summers, an Academic Specialist with expertise in electronics, as well as traditional Indigenous and Moldovan, who both provided essential support as mentors. Their efforts and continued assistance made this project possible. We thank the Experimental Learning office for the opportunity to participate in the S&T program and for their provided support.

References