Measurement of Microwave Photon Size

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Abstract

The scientific community has debated the nature of light for centuries. The introduction of wave-particle duality provided valuable insights, but the full 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 plot of power (mW) versus slit width (cm). We have found evidence that horizontal photon size is λ/π and vertical photon size is λ/2π.

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 agreed-upon theory or exact definition of photon size, and the resolution to this issue remains a topic of active discussion [2,3]. Using a simple approach, the size of a photon can be thought of as the minimum-width gap that the particle can pass through. This concept remains untested across a broad range of spectra. We have found a theoretical basis to suggest that the size of a photon should be dependent on λ/π [4,5]. In this experiment, we utilize aluminum plates to create a single slit centered between an emitter and receiver antenna pair. Our aim is to better define the photon size.

Methods

Table 1: Antenna Arm Specifications

Frequency (GHz)	A length (cm)	B length (cm)
1.0	7.1	8.0
1.2	5.9	6.7
1.4	5.1	5.7
1.6	4.5	5.0
1.8	4.0	4.4
2.0	3.6	4.0
2.2	3.2	3.6
2.45	2.9	3.3

Each antenna was constructed with four radial legs (denoted as "B legs") bent at a 45° angle relative to the base of the antenna and one vertical leg (denoted as "A leg") 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 the x (horizontal) direction. A 1 m graduated table was used to ensure the plates were positioned equidistant from a set center line on which the antennas were positioned.

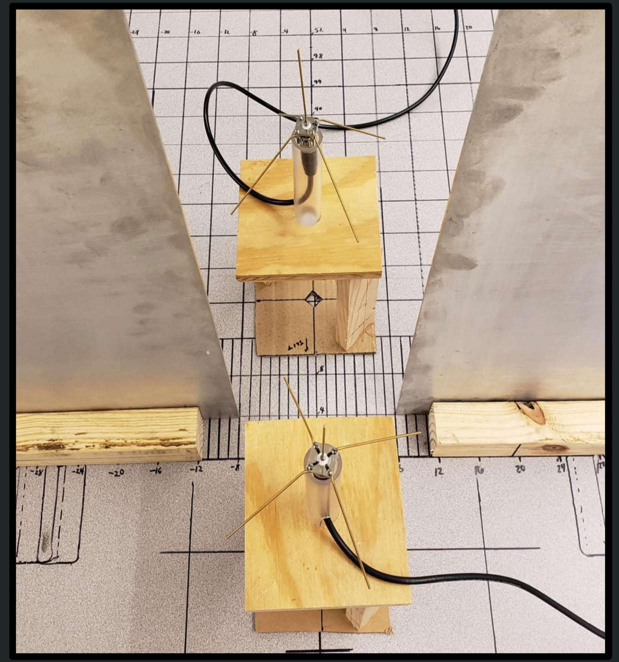
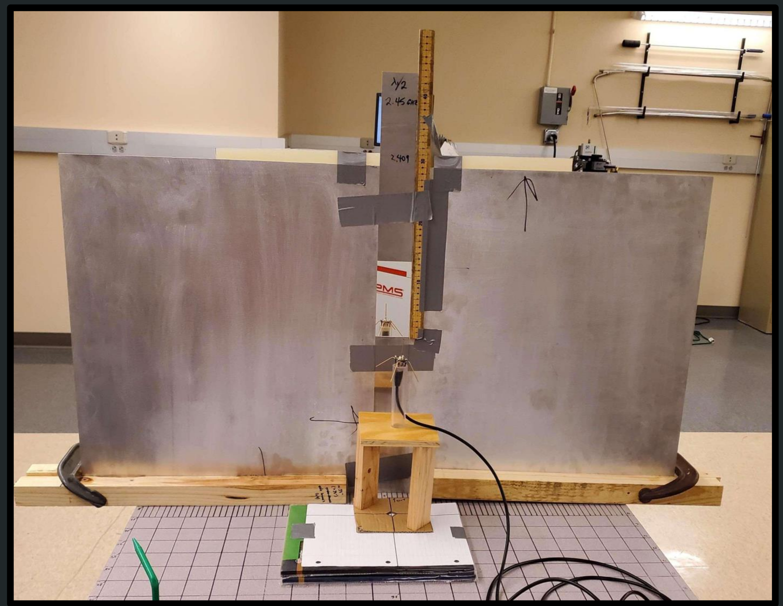


Figure 1: Slit setup for horizontal size measurements on graduated table



We then measured the vertical size of the photons. Pairs of aluminum center plates were created for four frequencies (1.0, 1.6, 2.2, and 2.45 GHz) with widths of λ/π. A plastic guide was used to align the aluminum plates with the center plates, which were then secured during measurements.

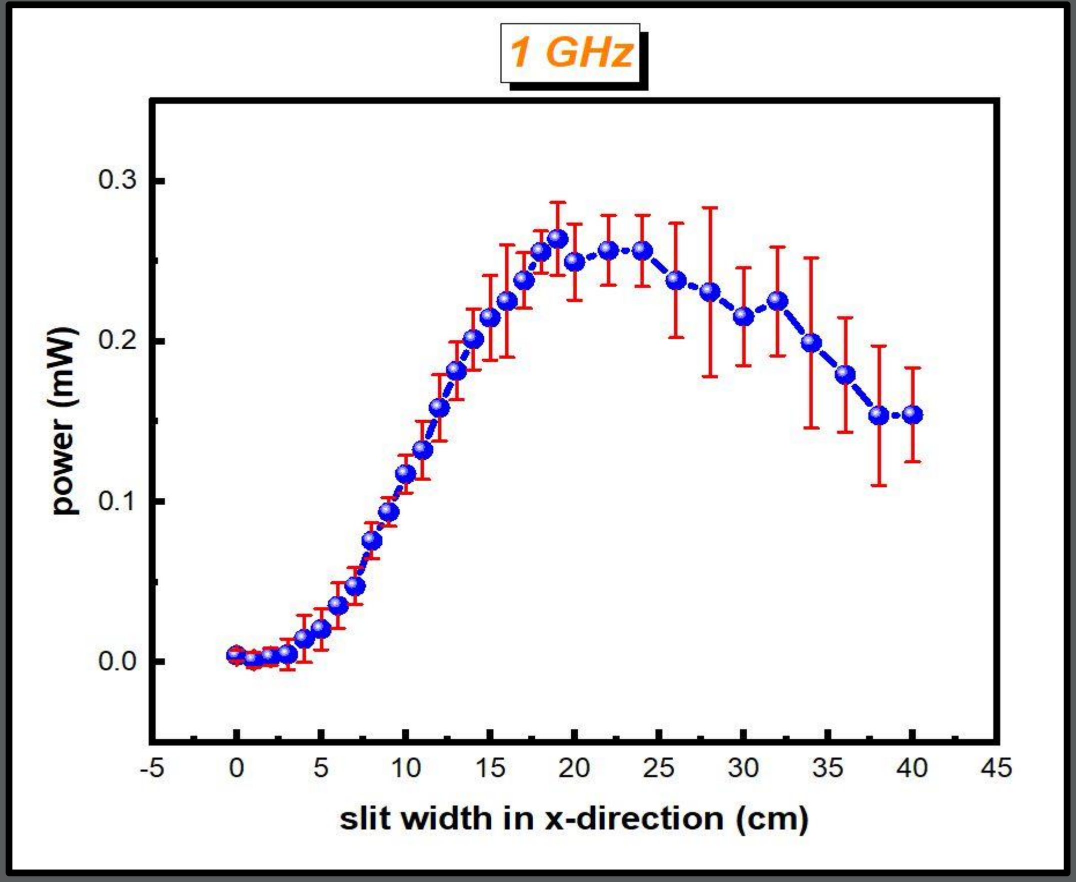
Figure 2: Slit setup for vertical size measurements with fixed center plates

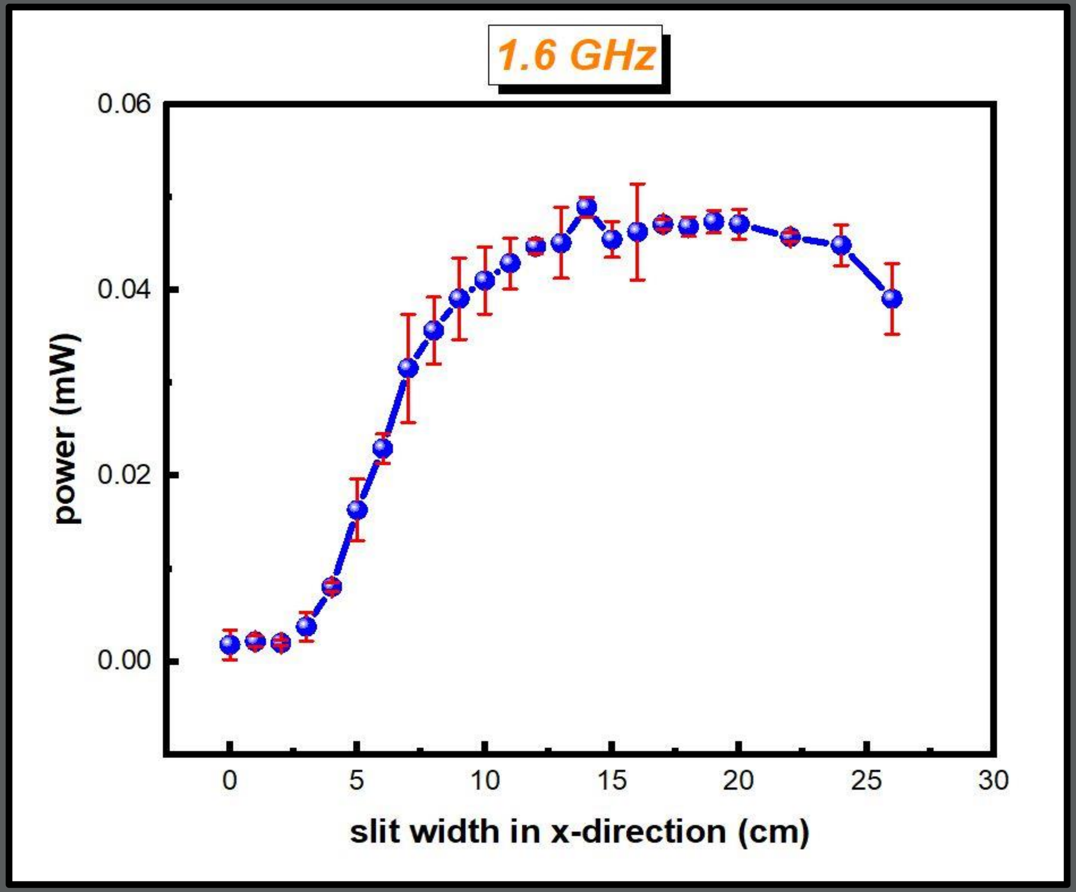
The power output was found using this equation, where P_{dB} is the decibel measurement and P_0 is the base microwave power.

$$P_{dB} = 10\log(P/P_0)$$

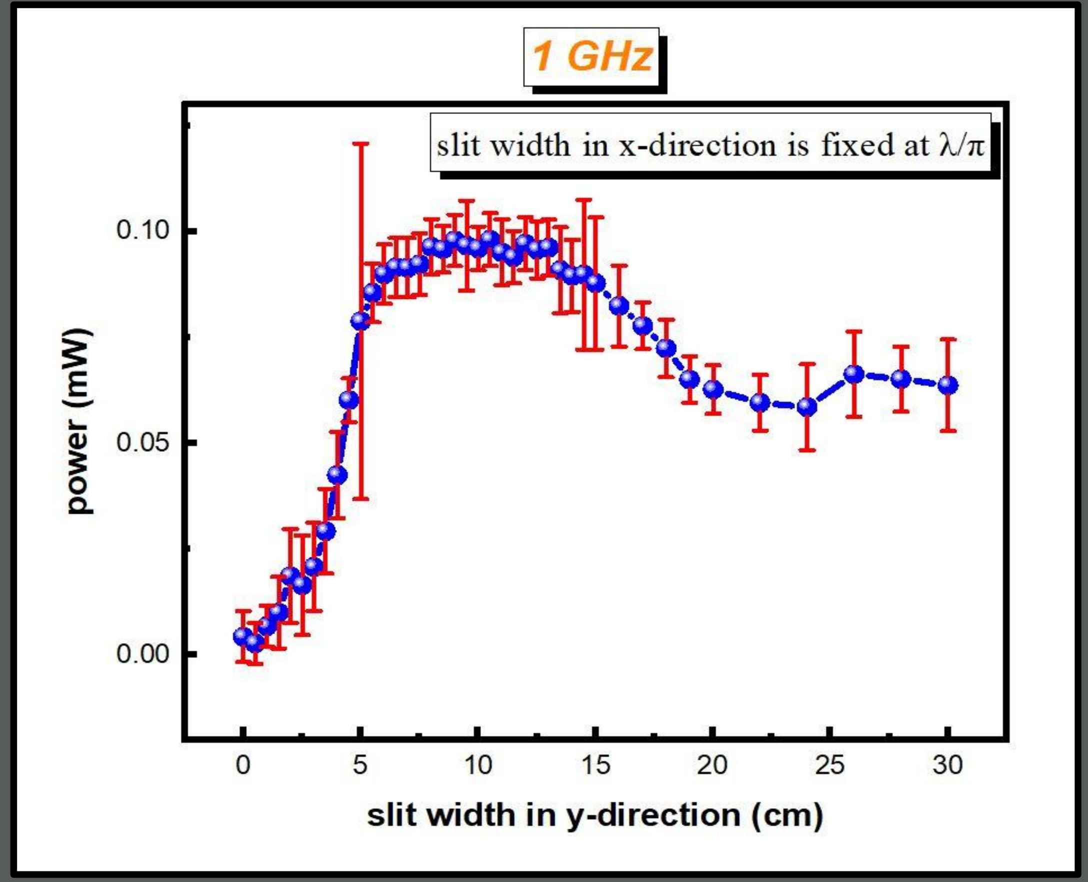
Results

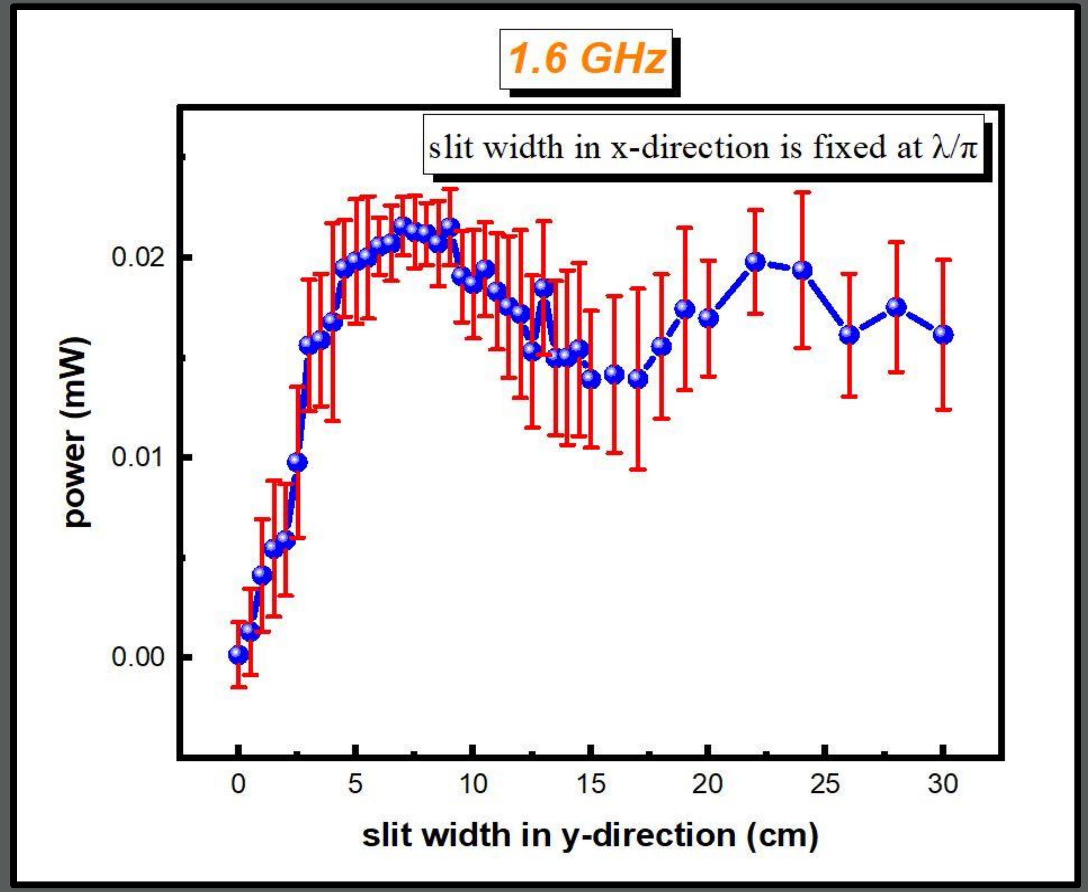
Horizontal Size

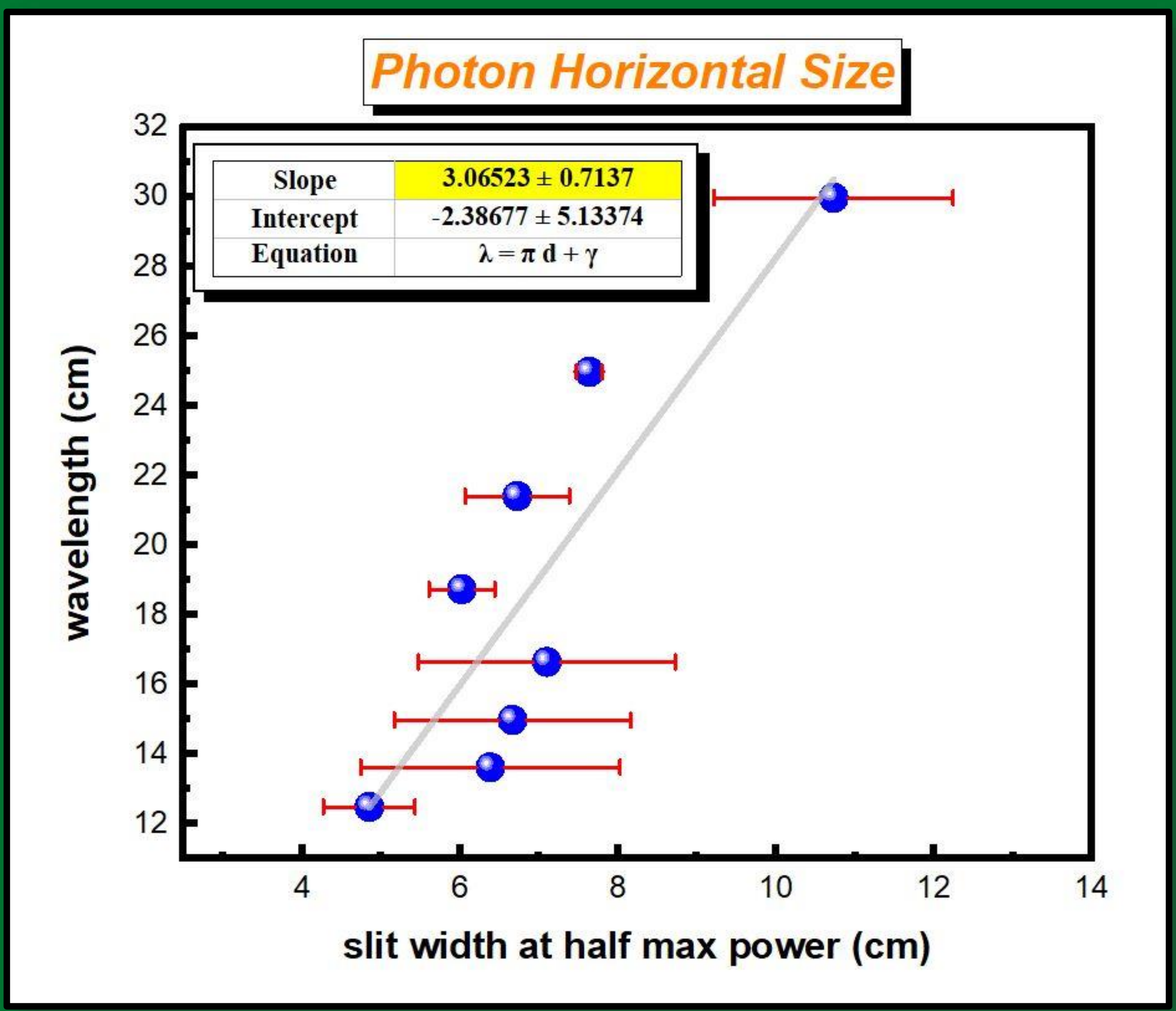


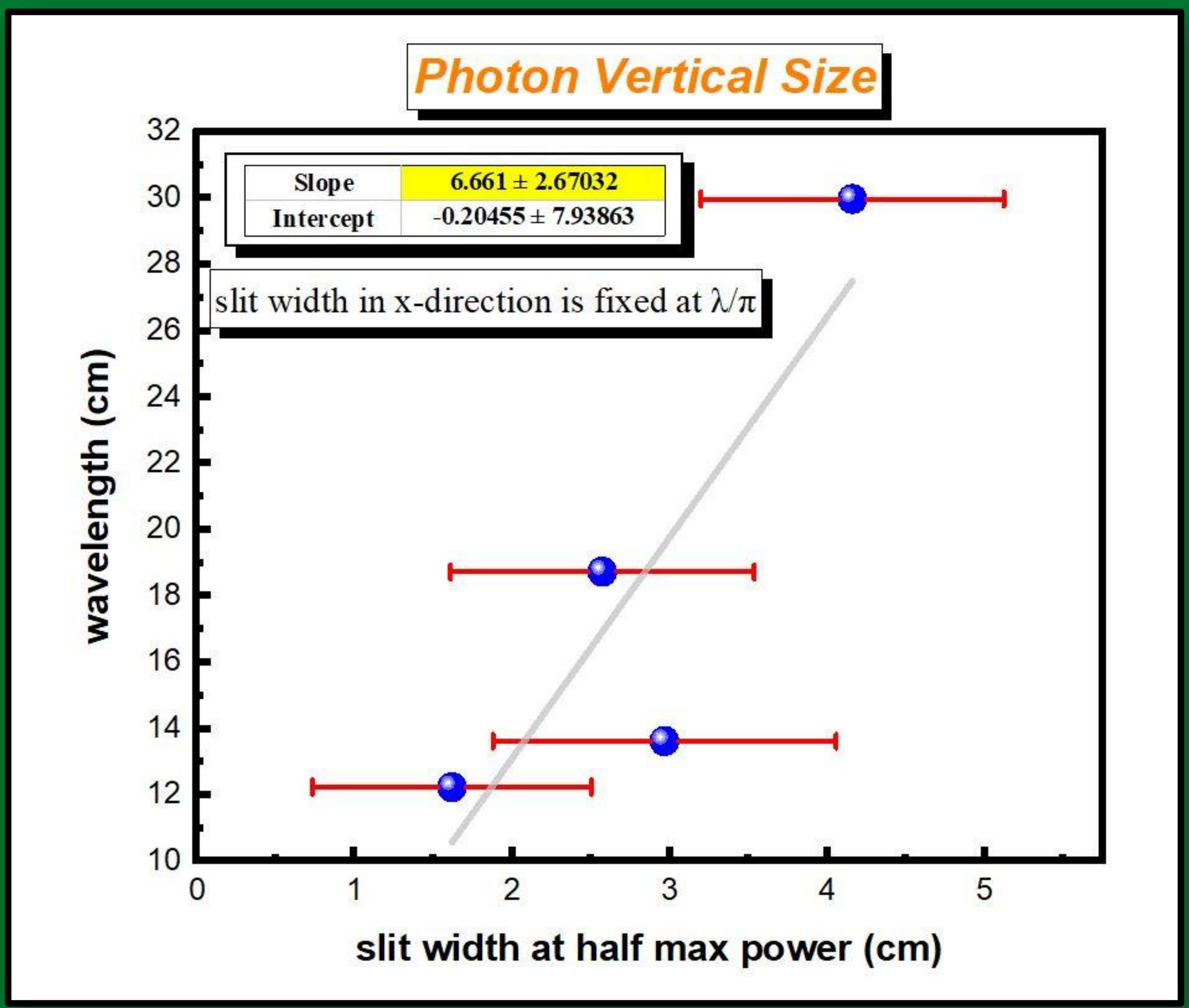


Vertical Size









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 λ/π and the vertical size is λ/2π. 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.

Horizontal size: λ/π
Vertical size: λ/2π

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