CALIFORNIA STATE SCIENCE FAIR
2006 PROJECT SUMMARY

Name(s)

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Project Number

S1505

Project Title

The Unbearable Beingness of Light: A Study of the Mysterious Nature of Light

Abstract

Objectives/Goals

In the 17th century, physicists such as Newton and Hooke debated whether light was a particle or a wave. Decisive experiments around the turn of the 18th century resolved these debates conclusively in favor of the classical wave theory. But in the early part of the twentieth century, experiments that studied the photoelectric effect required light to also have particulate properties. Theoretical explanations to resolve these disparate pieces of evidence gave birth to the modern quantum theory of light, where particles may act, in some sense, as both waves and particles simultaneously. This project presents a number of experiments that demonstrate, first, why the wave theory was accepted in classical physics; second, why light must sometimes be considered a particle; and third, how the interference associated with the classical wave theory occurs even when there is only a single "particulate" photon in the apparatus at any one time. The only known explanation for these behaviors is quantum mechanics.

Methods/Materials

To demonstrate that light exhibits the wavelike property of interference, I perform updated versions of classical experiments (Young's Slit and Poisson's Spot). Then using a single photon detector, I show that light exhibits particulate properties. Finally, I repeat some classical experiments at very low light levels using the photon detector to measure the interference patterns.

Results

As expected, I was able to repeat the classical experiments and show the interference patterns indicative of the wavelike properties of light. However, with my single photon detector, I was able to show that photons are detected as individual particles. Repeating the classical experiments, I demonstrated that, even at photon counting rates so small that only one photon is in the apparatus at any one time, the "wave" interference patterns are still observed. In a sense, the photons seem to be interfering with themselves.

Conclusions/Discussion

I observed that light exhibits both wavelike and particulate properties. However, neither of these properties can be those of our common sense perceptions of them. The only known explanation of this is the theory of quantum mechanics, which predicts the behavior of light very well, but doesn't allow us to feel comfortable saying we "understand" light.

Summary Statement

My project experimentally studies the properties of light and demonstrates its quantum nature.

Help Received

Dr. Jaroslav Va'vra assisted me in acquiring the necessary materials. My dad acted as my mentor on the project, helping my understand some of the science and helping me conduct experiments where multiple people were necessary. My mom helped me proofread my writeup.