Tabletop demonstration of Non-Interaction of Photons and Non- Interference of Waves

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ABSTRACT

Recently, Non- Interaction of Waves or the NIW property has been proposed as a generic property of all propagating electromagnetic waves by one of the authors (CR). In other words, optical beams do not interact with each other to modify or distribute their field energy distribution in the absence of interacting materials. In this paper, path taken to re-create CR's original demonstration of the NIW-property as an on-site tabletop experiment is discussed. Since 1975, when the NIW demonstration was first reported, several advances in lasers and optical component design architecture have occurred. With the goal of using low cost components and having agility in setting up on non-conformable platforms for general viewing, a compact arrangement for demonstrating the NIW property was envisioned. In our experimental arrangement, a beam multiplier element was utilized to generate a set of spatially separate parallel beams out of an incident laser beam. The emerging parallel beams from the beam multiplier element were then focused on a one-sided ground glass, the flat side being towards the beam multiplier. This flat side reflects off all the incident focused beams as fanning out independent laser beams, remaining unperturbed even though they are reflecting out of a common superposed spot. It is clear that there is neither "interference between different photons", nor "a photon interferes with itself", even within a region of superposed beams. In contrast, the ground glass surface (same silica molecules but granular or lumpy) was anticipated to generate a set of crisp spatial fringes on its surface as in the original experiment. The fringes are due to granulated individual silica lumps responding simultaneously to the local resultant E-vectors due to all the superposed beams and are scattering energy proportional to the square modulus of the sum of all the simultaneous dipolar amplitude stimulations. The dark fringe locations imply zero resultant amplitude stimulation and hence no scattering. Due to multi-longitudinal mode nature of laser module, the fringes appeared washed out at the backside of the ground glass plate. Experimental refinements followed by our views on whether the fundamental physics behind the generation of superposition fringes by photo detectors different from those due to a ground glass are briefly discussed.

Keywords: The nature of photons, The NIW property, beam multiplier

1. INTRODUCTION

Recently, Non-Interaction of Waves or the NIW property has been proposed as a generic property of all propagating electromagnetic waves by one of the authors (CR). The NIW Property is generally defined **as** propagating optical wave amplitudes (wavefronts) do not interact with each other to modify or distribute their field energy in the absence of interacting materials (medium). This paper attempts to re-create CR's original demonstration of the NIW-property as an on-site tabletop experiment.

From common sense, we can acknowledge the universality of the NIW property all around us. In the linear domain, all waves pass through each other unperturbed. Different harmonic undulations of the same tension field cannot exert any force of interaction on each other. Otherwise these observations would not have been possible. Water waves pass through each other unperturbed. Temporal and spatial scintillations would have detrimentally impacted the visual world due to speckles. The Doppler shift measurements indicating expanding universe from Hubble's deep field observation of galaxies would not have been possible. We can distinctly hear each component of an orchestra team since sound waves of different frequencies co-propagate without perturbing each other. We have been conveniently ignoring the absence of any physical interaction processes between the waves!

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Physics has “known” the NIW-Property; it has been recognized again and again; but failed to recognize it as an integral behavior of nature! (Or as an essential requirement for constructing physical theories). This is because of our methodology of scientific thinking. Mathematically modeling measurable data; rather than trying to visualize the invisible interaction processes. If NIW-property is universal, how do we understand the processes behind the emergence of superposition effects? We observe Superposition Effect as physical transformation experienced by detectors when simultaneously stimulated by multiple beams. It is the processes behind physical interactions that generate measurable physical transformation that have been steadily ignored by modern physics. In order to visualize the existence of this property, we revisit earlier two experiments reported in 1975 and 1976 as illustrated in Figure 1.

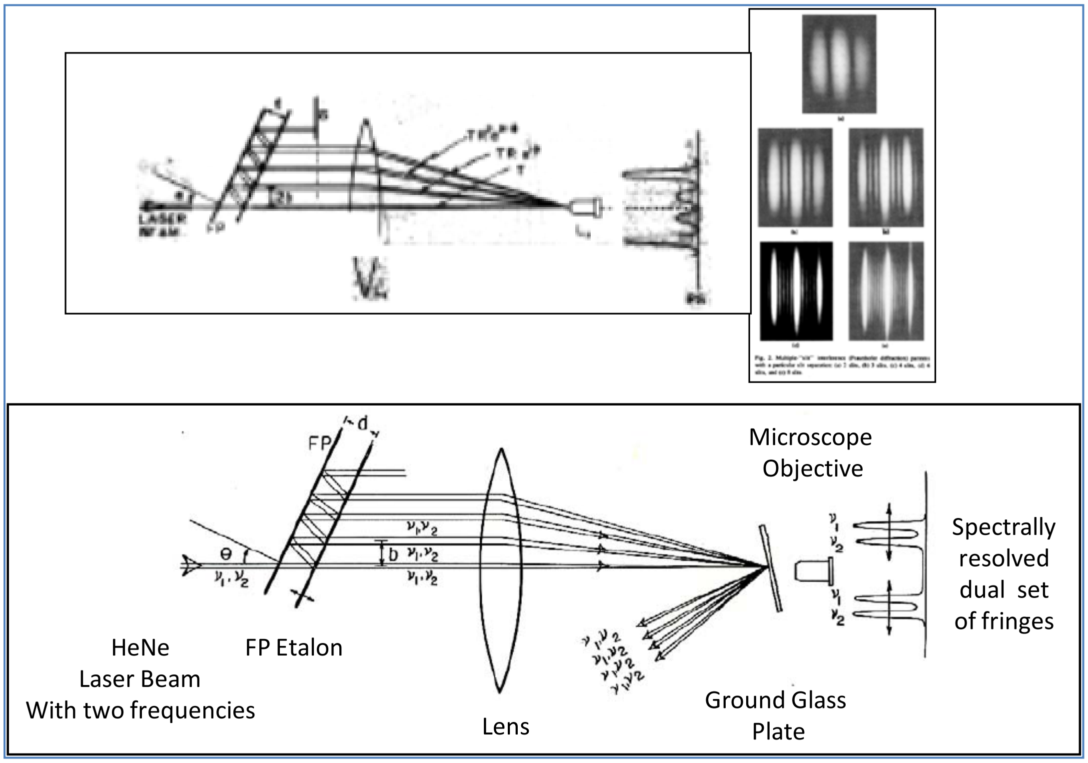

Figure 1. Top illustration: The 1975 experiment with no ground glass plate. [C. Roychoudhuri; Am. J. Phys. 43 (12), 1054 **(1975)** "Demonstration Using a Fabry-Perot. I. Multiple-Slit Interference”]. Figure 2. Bottom illustration: The 1976 experiment with a ground glass plate. [C, Roychoudhuri; Bol. Inst. Tonantzintla 2 (2), 101 **(1976);** "Is Fourier Decomposition Interpretation Applicable to Interference Spectroscopy?"].

In the paper, efforts that were undertaken to demonstrate the NIW property on a compact, handheld, low cost platform using advances accomplished in optical component technologies since 1976 is discussed. One of the goals is to put to rest any doubts that still exist in visualizing this property and to further advance our knowledge in this regard with respect to other photon behavior. Demonstrating the NIW property would help understand the basic nature of photon behavior for those interested in optics discipline. Furthermore, bringing the lab environment to optics students could inspire the students challenge the generally accepted notions of Physics more effectively. In the following sections, mathematical formulation followed by experimental scheme and results obtained are presented.

2. MATHEMATICAL FORMULATION

A beam multiplier is used instead of a Fabry Perot etalon. The output of beam multiplier can be represented by

$$A(\tau)=\sum_{n=0}^{N-1} a_n e^{i2\pi\nu\tau}; \quad \text{For } a_n=1, \quad A(\tau)\approx\frac{\mathrm{Sin}(N\pi\nu\tau)}{\mathrm{Sin}(\pi\nu\tau)}$$

$$A(\tau) \text{ represents grating equation} \tag{1}$$

The recipe for energy scattering or energy absorption is given by the standard square modulus process as shown below

$$A^*A=\sum_{n=0}^{N-1} a_n^2(t-n\tau)+2\sum_{\substack{n,m=0\\ n\neq m}}^{N-1} a_n(t-n\tau)\cdot a_m(t-m\tau)\cdot\cos[2\pi(m-n)\nu\tau] \tag{2}$$

From the above energy exchange equation, it can be seen that at the detector plane, each point receives energy from all the N superposed beams. In the following section, an experimental schematic that would characterize this energy exchange equation is illustrated.

3. EXPERIMENTAL ARRANGEMENT

Figure 2 illustrates the experimental schematic with specifications shown in Table 1. The setup consists of a collimated laser beam, a beam multiplier, a focusing lens, a ground glass plate and a microscopic objective. The beam multiplier generates a set of spatially separate parallel optical beams out of an incident laser beam. Using a converging lens, these

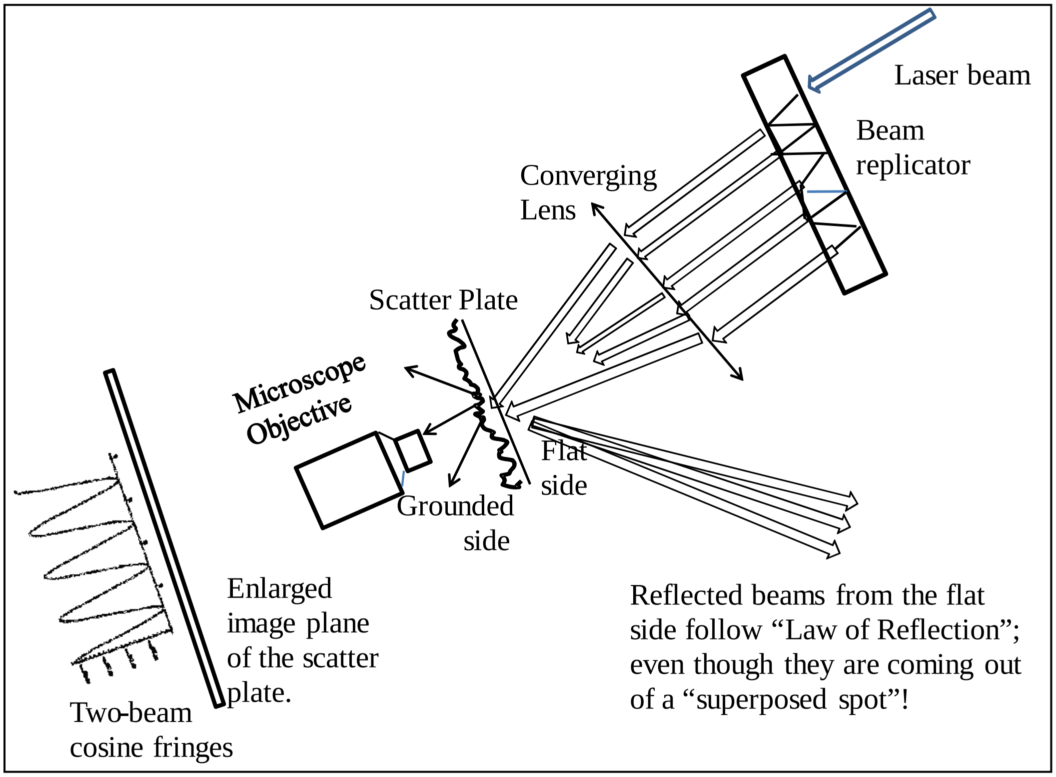

Figure 2. The experimental schematic with one significant difference from CR's original experiment. The use a beam multiplier element generated similar kind of parallel beams as that of a Fabry-Perot etalon.

multiple laser beams are then focused on to a ground glass plate with one of its surfaces being flat and polished; The flat side being pointed towards laser source. Earlier, we had planned to use a Fabry-Perot etalon but later we were able to obtain a beam multiplier element that generates parallel beams for this purpose. This element significantly enabled to assemble a low cost, simple, and hand held setup for demonstration of NIW property. The beam multiplier costs around \$300, an order of magnitude low when compared with a Fabry Perot unit used in original CR's experiments that was ~\$30,000. Table 1 shows the specifications of key components.

Table 1. The specifications of the solid state laser and optical elements used in our experiment.

Component	Parameter	Value	Units
Semiconductor Laser	Wavelength	635	nm
	Output Power	4	mW
	Beam Size	4	mm
	Beam Divergence	<1.8	mrad
Beam Multiplier	Design Wavelength	633	nm
	Dimensions	5x5x25.4	mm
Convex Lens	Focal Length	50	mm
	Diameter	1	Inch
Groundglass Plate	Grit	220	
	Diameter	1	Inch

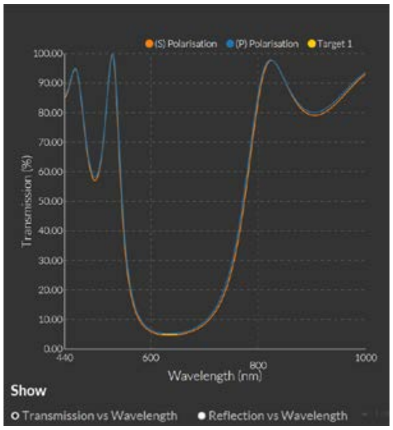

Figure 3 shows the experimental arrangement.

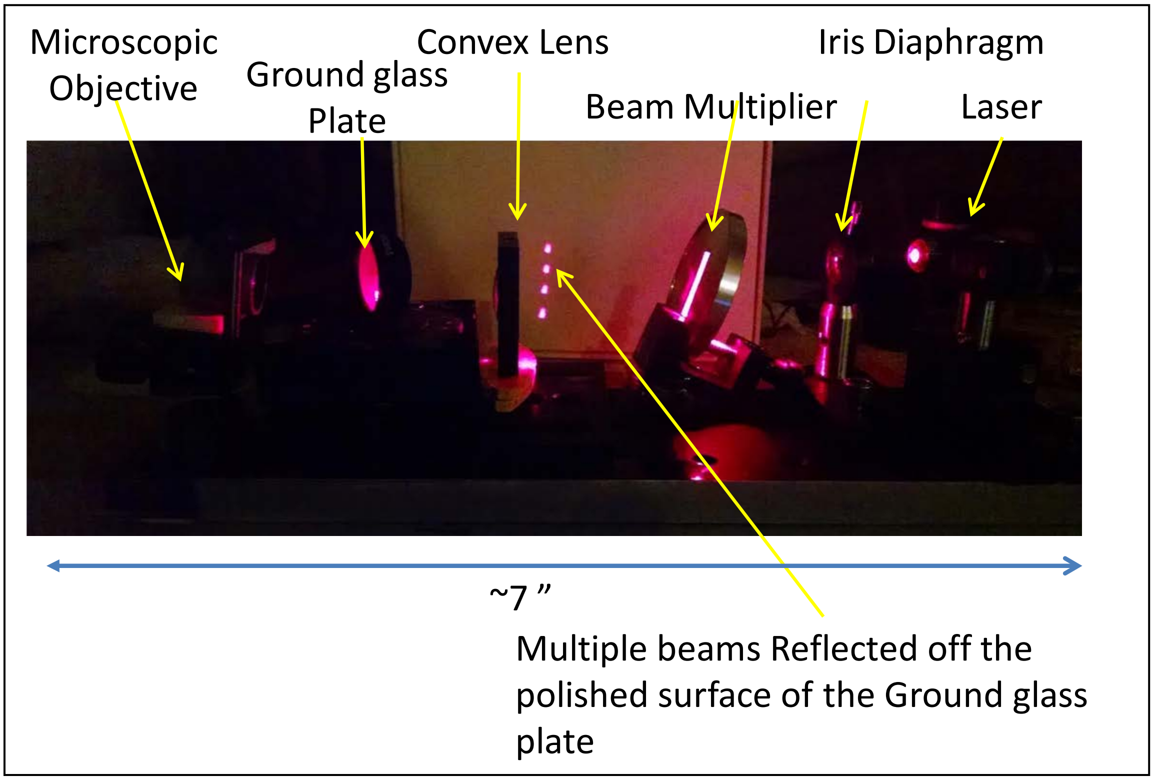

Figure 3. The experimental setup to demonstrate the NIW property.

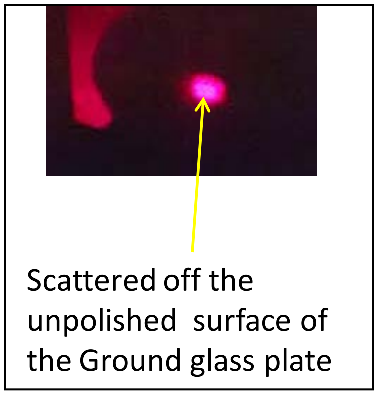

Figure 4. The scattered optical spot seen at the back of ground glass plate.

From specifications listed in Table 1, the components used are readily available except for the beam multiplier. The beam multiplier has become recently available from Light Machinery firm. These components were arranged on less than a 10” x 4” plate.

Multiple beams reflected off the polished ground glass plate after being focused tightly down to a spot can be clearly observed in Figure 3. Figure 4 illustrates the optical spot scattered off the unpolished side of the ground glass plate. This scattered spot appeared as a uniformly illuminated shimmering spot. To our disappointment, we could not see crisp fringes. After analyzing our experiment and associated specifications, we realized that the laser used in the original experiments was of single longitudinal mode. When this experiment was planned, we overlooked the requirement of single longitudinal mode characteristics for the laser. We assume the output optical spot represented the superposition of multiple fringes being generated by the multi-longitudinal mode laser. The next key step is to replace the multimode laser with a single mode laser.

4. RESULTS AND ANALYSIS

The flat side reflects off all the incident laser beams according to the laws of reflection; the fan of independent laser beams remain unperturbed even though they are reflecting off and emerging out of a common superposed spot. Neither "interference between different photons", nor "a photon interferes with itself", even within a region of superposed beams can be seen. In contrast, the ground glass surface (same silica molecules but granular or lumpy) scatters intensity and presumably generates a set of spatial fringes on its surface when observed through a microscopic objective as indicated in previous experiments. In our case, each mode is forming its own set of spatial fringes. Different frequencies are forming their sets of fringes but spatially displaced and the combined effect is fringe washed out intensity.

We ask ourselves “are the fundamental physics behind the generation of superposition fringes by photo detectors different from those due to a ground glass”? It is already known from scattering physics that, granulated individual silica lumps will respond simultaneously to the local resultant E-vectors due to all the superposed beams and the scattering energy is proportional to the square modulus of the sum of all the simultaneous dipolar amplitude stimulations. The dark fringe locations imply zero resultant amplitude stimulation and hence no scattering. As such, the ground glass can respond to the square modulus of the resultant amplitude but not the polished glass.

Flat front surface sends out the laser modes with convergent beams as a divergent set as if reflection from a flat surface does not allow them to experience each other! Silica lumps in a ground glass are classical super position effect detector (generator) and in contrast silver halides (photographic plates and Photoelectric detectors in inherently quantum mechanical in nature. In our case, the “Locality” condition is valid since the “detector” must be within the physical volume of the superposed beams to register fringes! Ground glass behavior displaying superposition clearly implies that it is not inherently quantum mechanical phenomena**.**

Wave Phenomena is a collective phenomena; Poynting Vector is orthogonal to the wavefront curve and cannot be defined by a point. The polished side responds to collectively to the “collective wavefront”. Note that Snell’s law and laws of reflection apply for polished surfaces. Superposition effect is not inherently a quantum mechanical phenomena at all (Silica lumps are behaving classically which is different from quantum photodetectors where electrons are bound quantum mechanically). The superposition phenomena is local. The energy response is proportional to the square modulus of the resultant amplitude and the square modulus creates the superposition effect(NIW). The resultant intensity creates the superposition effect and there must be interaction with materials to see fringes that execute square modulus process; Polished glass cannot respond to local intensity but ground glass can.

In order to further refine this experiment, the immediate plan is to conduct the experiment with a single longitudinal mode laser and add a detector array for instantly capturing and analyzing the output beam behind the ground glass plate. Next, the setup will be upgraded to study the behavior of polarized light in the framework of the NIW property. This experiment lends itself for exploring with 3D printed mounts to make it lightweight and easy assembly for tabletop demonstration especially in classrooms to understand the nature of photons.

5. SUMMARY AND CONCLUSIONS

In this paper, the first attempt to recreate CR's two experiments carried out in 1975 and 1976 illustrating the NIW property using advances made in lasers and optical elements since then is discussed. A novel beam multiplier element instead of an expensive Fabry-Perot etalon was used to generate parallel beams. The parallel beams from the flat side reflected off all the incident laser beams according to the laws of reflection. The fan of independent laser beams remains unperturbed even though they are reflecting off and emerging out of a common superposed spot. Neither "interference between different photons", nor "a photon interferes with itself", even within a region of superposed beams can be seen. However, crisp fringes on the back side of the ground glass plate are yet to be demonstrated. Since the laser used in our experiments was a very compact solid state laser instead of a HeNe laser used in the original experiments, the uniform shimmering spot is presumed to be the result of washed out finges due to multiple fringe patterns resulting from multiple longitudinal modes. Plans are underway to further refine the experiment with a single mode laser and a detector array.

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