RUTGERS

Aresty Research Center for Undergraduates

Investigation of Stokes-Helmholtz Reciprocity for An Isotropic, Non-Active,Non-Magnetic System

Gradeigh D. Clark[1], Siamak Abaslou[1], and Dr. Wei Jiang, Ph.D[1]

[1] School of Engineering, Rutgers University, New Brunswick, NJ 08901,

ABSTRACT

In electromagnetism and optics, the Stokes-Helmholtz law of reciprocity states that light traveling thru an optical system composed of non-active and non-magnetic components (such as lenses, mirrors, and prisms) would experience the same amount of attenuation traveling from the source to the receiver as it would if the system was reversed; i.e. that if light traveled from the receiver to the source. The statement of the law is a curious result considering that optical systems containing multiple components of variable characteristics admit different cones of energy--and yet it is a result we have come to accept on a daily basis: "If I can see you then you can see me." We set out to examine whether the law holds for a simple optical arrangement of two fibers and two lenses each with different specifications (focal length, diameter, etc.) than its pair; light will be passed through both ends of the system and measured at the respective output.

BACKGROUND

Reciprocity is a fundamental law in optics. However, it is a very curious result to witness that the strength of light received between two fibers that accept cones of energy of different sizes and travel through lenses of different focal length in reverse direction are basically the same. The result is non-intuitive and the question is whether or not this is true for a simple arrangement and to accurately explain why. If this result could be invalidated for certain arrangements then it would be possible to construct a diode or a rectifier for light without employing the use of a Faraday rotator (a construction that uses magnetic fields to affect a phase change in the light as it travels through the rotator) to change the polarization of the light.

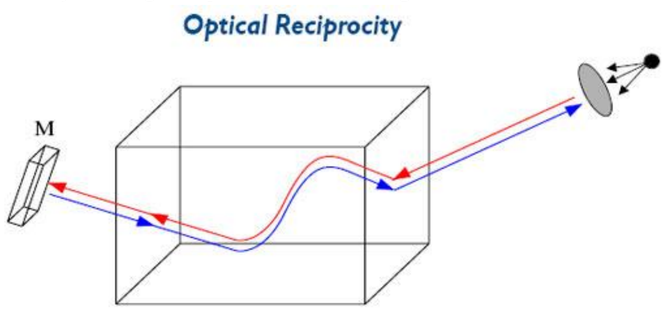

Figure 1. Illustration of reciprocity.
www.optometrics.com

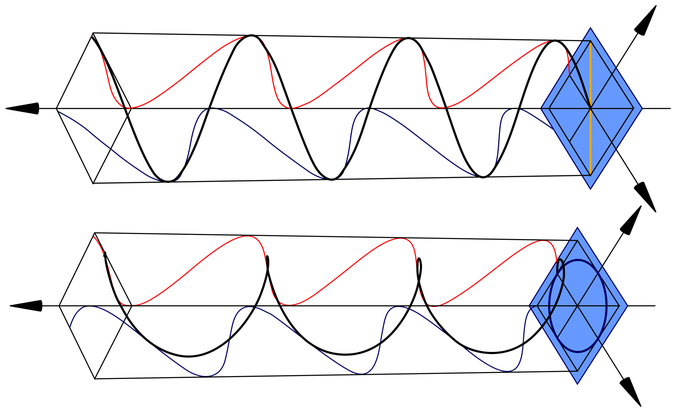

Figure 2. Example of polarized light.

MATERIALS AND METHODS

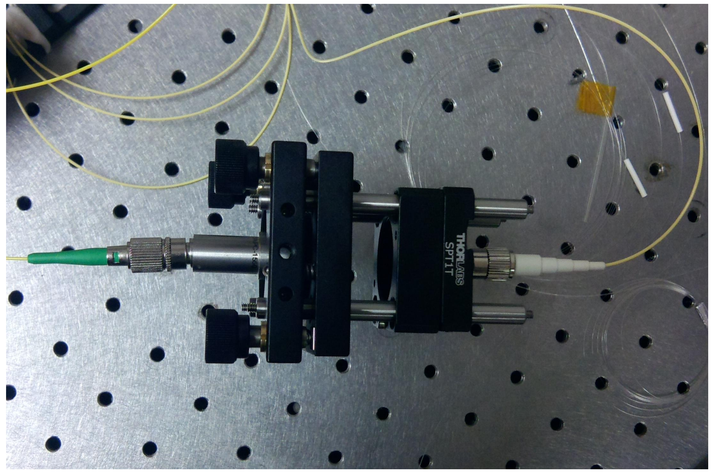

Figure 4. The experiment setup.

The configuration of the experiment is that there are two fibers (one APC and the other PC) facing one another end to end. One fiber acts as a receiver for the light and the other fiber acts as a source for the light. In between the two fibers are two lenses; one is a set focal length and the other one is half of that set length. The other materials are there to align the fibers in three dimensions.

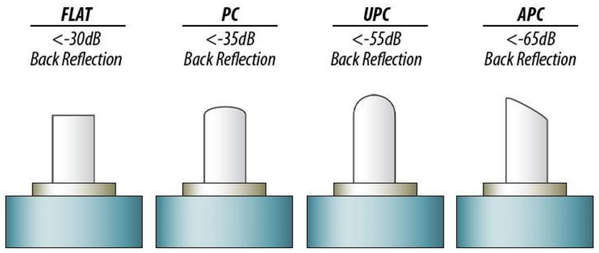

Figure 5. Different fiber types.
www.fiber-optic-cables-plus.com

RESULTS

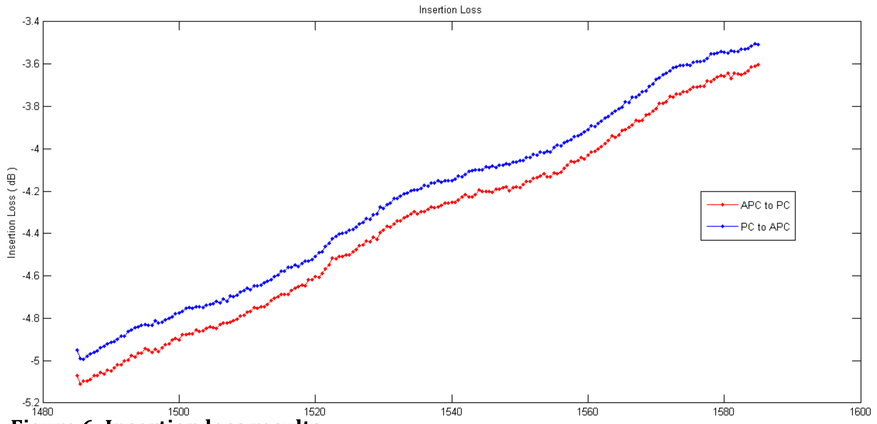

Figure 6. Insertion loss results.
There is a 0.5dB shift between the two.

CONCLUSIONS

When the light passes through the lens closest to the fiber, it exits parallel to the optical axis, as shown below. When the light passes through the second lens, it is focused to a point on the second fiber itself to be measured, also seen below.

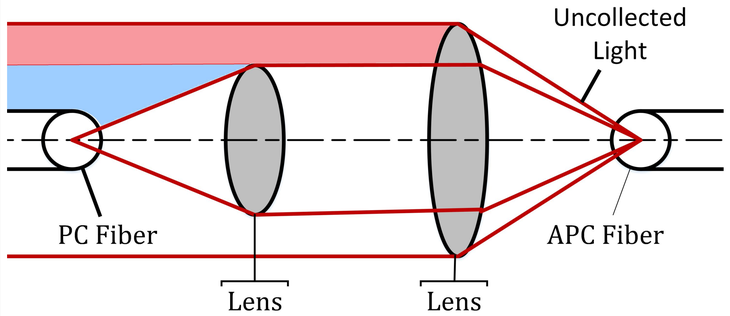

Figure 7. The optical setup.

When light passes from right to left, it appears that more of the focused light is lost to the surroundings since the leftmost lens that it sees is not large enough to couple the light to the leftmost fiber.
But when it passes from left to right, all of the focused light of the first fiber is collected and focused onto the second fiber

But the measured insertion loss is the same, as evidenced by the figure under Results. The area of lost focused light is represented by the red shaded area at the top; this amount is also lost at the bottom.

The reasoning for why the insertion loss was the same became evident as we considered that the fibers emit equal amounts of light, so there are certain angles at which the leftmost fiber cannot couple light into the first lens anymore, so this light is also lost. The angles at which light would be lost is any light that enters the blue or red shaded region in the figure. This amount of uncoupled lost light from left to right is approximately equivalent to the amount of lost focused light from right to left; this is why the loss is reciprocal in both directions.

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