Shedding light on changing properties of photons

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FROM THE LAB

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THE RESEARCH

Finding out whether the momentum of light photons increases or decreases when it enters another medium like water or glass

LIGHT HAS many special properties, most of which are well understood. However, one unresolved issue, for over 100 years now, is how some of its properties change when it comes in contact with a different medium, like air, glass or water. Its momentum is known to change, even though the energy remains the same. There is difference of opinion on whether the momentum of light photons increases or decreases in such a case.

Hermann Minkowski, Albert Einstein's teacher, had proposed that the momentum of light photons increases while passing through another medium. However, German physicist Max Abraham measured a decrease in the momentum. Scientists have not been able to conclusively establish one over the other. Both suggestions could also be true under different conditions.

If there is a loss of momentum, for example, this loss needs to be absorbed by the medium. That is what the Law of Conservation of Momentum says. If a ball is thrown at a hanging cloth, the ball loses its momentum after hitting it and a depression is created in the cloth. Similarly, the light photons should create a depression on the surface of water when it strikes it. The nature of the dent in the surface will reveal whether the light photon has lost or gained momentum. The effect of momentum change is small and difficult to measure.

In the 1970s, some US researchers pointed a high-power light beam at water to examine the depression. Their experiments proved Minkowski's theory, that light photons gained momentum while crossing another medium. But some scientists were not convinced, as it was not very clear whether the depression observed was due to momentum change or heating by the beam.

During our own experiments, instead of using one medium, we used two. We put a drop of water on glass surface and directed a beam of light on it. Both are transparent mediums and most light crosses through it. But a small amount gets reflected by the water drop and forms a spectrum on a screen opposite it. A small amount of light gets reflected from the glass surface as well and another spectrum is created. The two reflections form an interference pattern, which is dependent on the shape and size of the water droplet. We also introduced some other changes, like bringing in a magnetic field, to see how the interference pattern changes. By doing this we noticed how a change in the water drop, changes the interference pattern.

The next step was to direct another beam of light at the water drop that was placed on the glass surface. This caused a change in interference pattern. Having studied these patterns earlier, we were able to tell what kind of depression in the water drop had led to these changes, and whether it was related to a loss or gain in momentum of photons.

Our observations showed that the light photons actually gained momentum while interacting with the water-glass interface. This might not be true in all circumstances, in all mediums. But at the same time, unlike the US research, in which the laser beam was pointed perpendicular to the water surface, our results were not dependent on the angle from which light is directed at water surface. The result holds true at all angles and shows that in the kind of medium and settings we used, Minkowski was right.

Our results might be useful in making reconfigurable fluid lenses and to trap tiny objects on fluids by using light forces.

For your research to be considered for this column, please write to Senior Editor Amitabh Sinha at amitabh.sinha@expressindia.com

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