

Tapestry of Rays – The Simple Questions Series (1)

Mystery of concentric scratches (one night, in the seat of a bus)

One night I was on a bus, sitting in the very front seat, just behind the driver. The driver and I were separated by a clear acrylic panel. Over the acrylic panel, I could see cars passing through the city through the windshield. The glare of many headlights. Small scratches on the acrylic panel shine in the glare.

Looking closely, I noticed that the shimmering scratches on the panel were distributed concentrically, surrounding the headlights seen in distance. Why was that? I thought “This might just be by accident”, and shifted my position slightly. Huh? Even after I shifted my position, the scratches were still distributed concentrically around the headlights. It couldn't be! I shifted my position again, further this time, and looked at a totally different part on the panel. It was still the same - the scratches were distributed concentrically around the far off headlights.

The photos in Figure 1 are such scratches. The photos were not taken in the bus, but in a room, using a CD case instead of the acrylic panel. As the photos show, even when the relative position relationship of the CD case and the flash light changes (Figure 1A and Figure 1B), the scratches are distributed concentrically around the light source.



Figure 1 A



Figure 1 B

Why are the scratches distributed concentrically around the light source when at any position on the panel?

The answer is simple, but it contains many elements of optical image formation.

Let us consider the process after the light exits the light source and enters the eye, passing through the panel. Now, supposing the light source (the headlights of the oncoming car in the case of the bus) is small enough and located far away, it can be presumed that the panel is illuminated by parallel rays. Additionally, eyes can be replaced by a lens. This is shown in Figure 2.

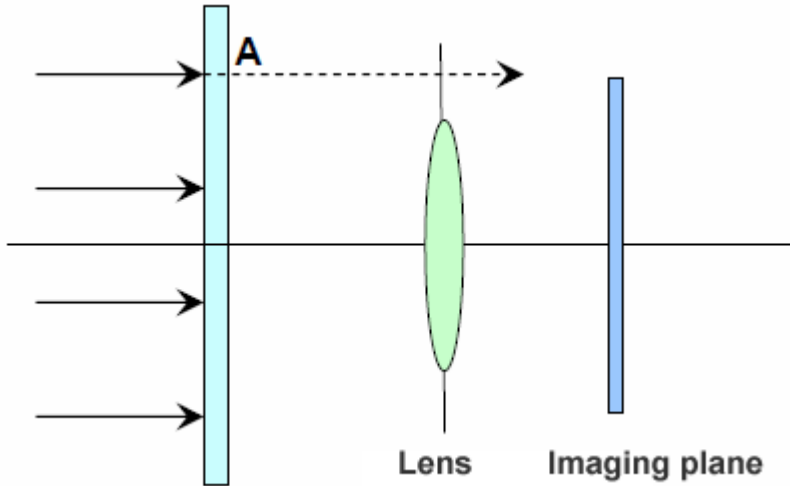


Figure 2

In Figure 2, the parallel rays coming from the left illuminate the panel, and a portion of the light rays that pass through the panel enters the lens. The imaging plane of the lens corresponds to the retina of the eyes. Now, let us consider the peripheral part of panel A. If there are no scratches on the panel, the light rays that pass through A cannot go through the lens as the dotted line in the figure shows, since the light rays travel in a straight line. In other words, the light rays will not enter the eyes. However, if there is a scratch on A, the light rays are diffracted and spread, and therefore a portion of the light rays can pass through the lens (Figure 3). At this point, a human eye can recognize the scratches on A.

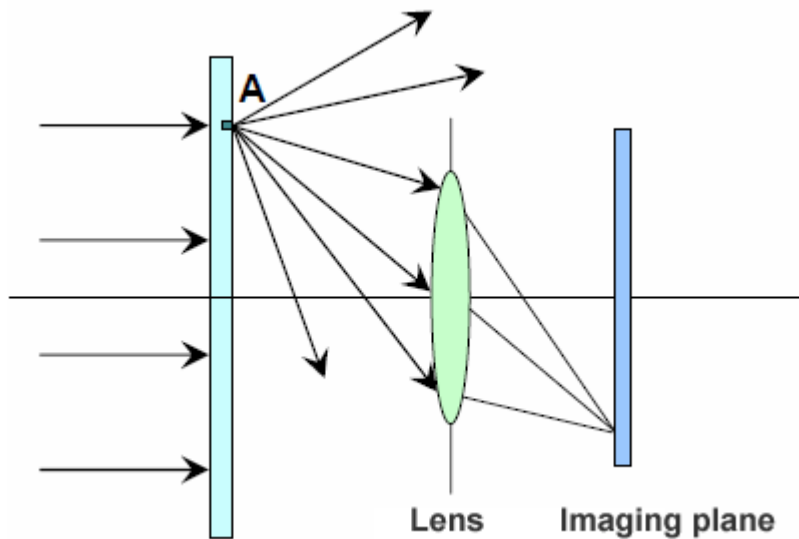


Figure 3

Now, let us suppose that all the scratches are linear (this will not lose the generality). A light ray is diffracted more greatly when the structure of the object is smaller. Therefore, diffraction of a light ray due to a linear scratch is great in the direction of the width of the scratch and small in the direction of the length, as shown in Figure 4.

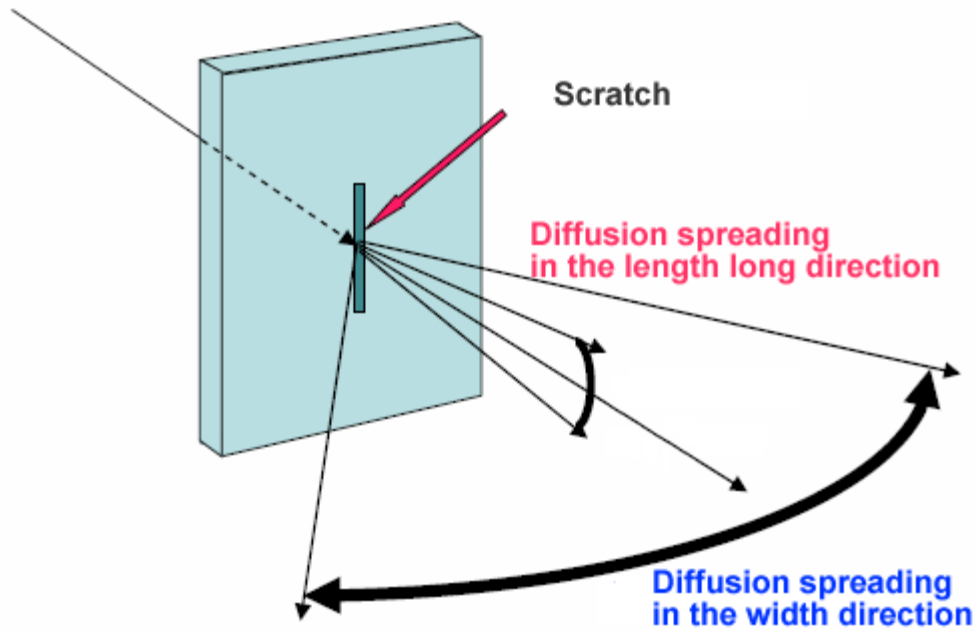


Figure 4

Now, please look at Figure 3 again. Generally, the greater the diffraction of a light ray is, the easier it is for the light to pass through the lens. In other words, the scratches are easier to see. This means that when the width direction of the scratches correspond to the vertical direction of the figure, such scratches are easiest to see, in the case where linear scratches in various directions exist in point A. Namely, the most visible scratches are linear scratches extending in a direction perpendicular to this paper at point A of Figure 3. Although Figure 3 is a cross-section, the same can be said even if it is rotated around the optical axis. Therefore, it can be concluded that the most visible scratches are the ones located concentric to the optical axis.

In other words, it was not that the scratches were distributed concentrically, but that only the scratches located concentrically were visible due to the optical structure. When a scratch is very large, it is more appropriate to express it as refraction in accord with the structure of the scratch, rather than as diffraction. However, the scratch will still appear concentric in this case. Now, the mystery of the bus at night has been solved. But who is the beautiful woman sitting in the seat next to me...?