assignment9

Zhuan

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The incident beam and the scattered beam are showed in following diagram. Because of the spherical symmetry, we only need to consider a cross section of the water drop.

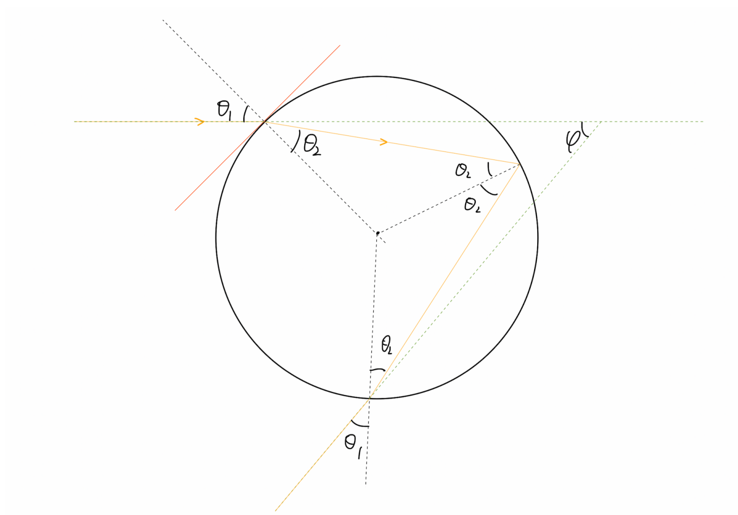

Figure 1: The incident beam and the scattered beam for just one reflection in the water drop.

It is obvious that the angle between the incident ray and scattered ray $\varphi = 4\theta_2 - 2\theta_1$. For the more general case, if the ray reflected n times in the rain drop, we have:

$$\pi - \varphi = (\theta_1 - \theta_2) + n(\pi - 2\theta_2) + (\theta_1 - \theta_2) \tag{1}$$

Here, the ray will deflect the angle of $\theta_1 - \theta_2$ when it enter of exit the water drop, and $\pi - 2\theta_2$ when it reflect back to the water drop. And the total angle of deflection is $\pi - \varphi$.

When $n = 1$, we will get the normal rainbow, and when $n = 2$, we will get a double rainbow.

If we assume that the ray is uniformly distribute in the horizontal direction, we can calculate the distribution density of light with different frequencies. The result is showed in follow.

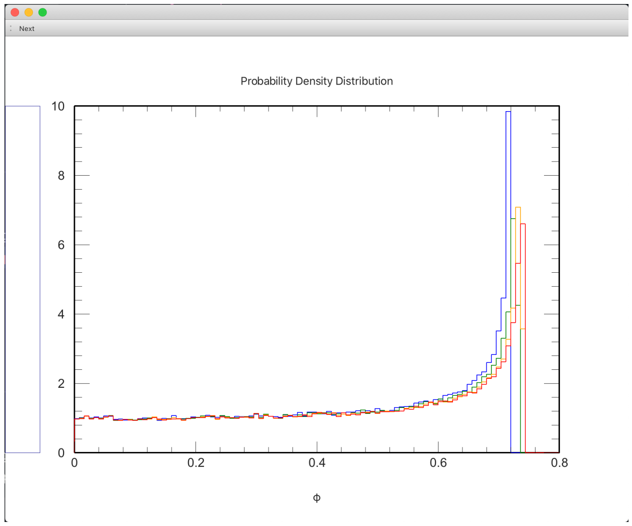

Figure 2: The distribution of light with different frequencies after one reflection in the water drop.

There is a peak around 0.7rad $\sim 40^\circ$. And when the angle is smaller than 0.6rad, the number of the photon with different colors in the same angle are all most the same, which will give us the white light. Therefore we can only get the colorful rainbow in a narrow interval of angle. If we focus on this interval, and consider the direction of the ray, we can plot the image of the rainbow.

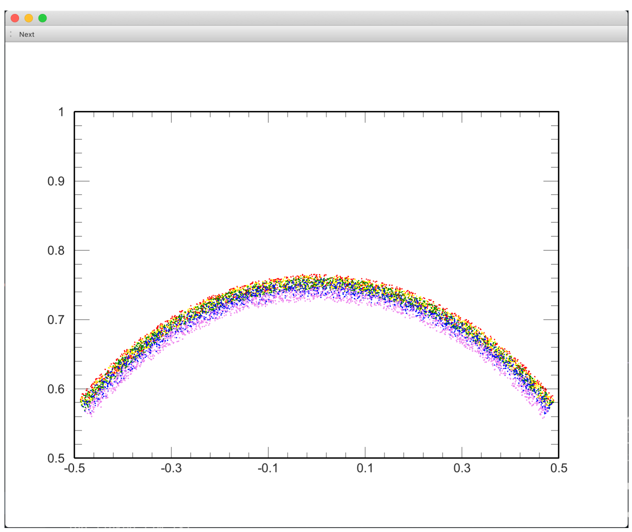

Figure 3: The image of simulated rainbow. Each dot in the diagram represent a photon.

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For the parallel computing part, I considered a little more complex situation, the ray can be reflected in the water drop for multiple times. For each reflection, half of the photon will

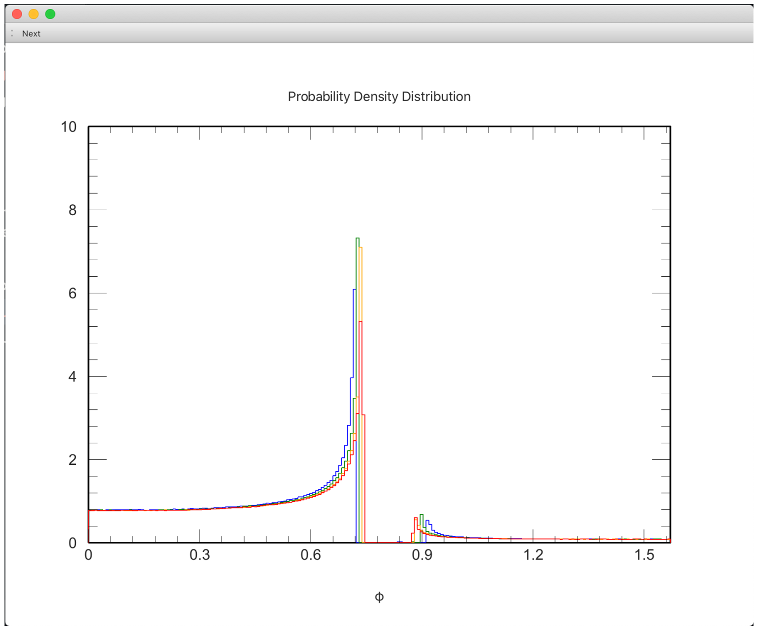

Figure 4: The distribution of light with different frequencies after multiple reflections in the water drop

transmit into the air. I simulate 4×6 million photons in four threads, and the result are showed in follow: Now we get the double rainbow, while the second one is much dimmer than the normal one. The order of color in two rainbows are opposite to each other. And the second rainbow reach the peak around 0.9rad $\sim 51°$. There is a dark region between the two rainbow, which is called the Alexander's band. With all this properties consist with the rainbow in real world, we think the simulation is quite accurate.