Circular Dichroism and Mossbauer and Spectroscopy for Chemists

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Lecture – 19
The Physical Background of Chiral Response - III

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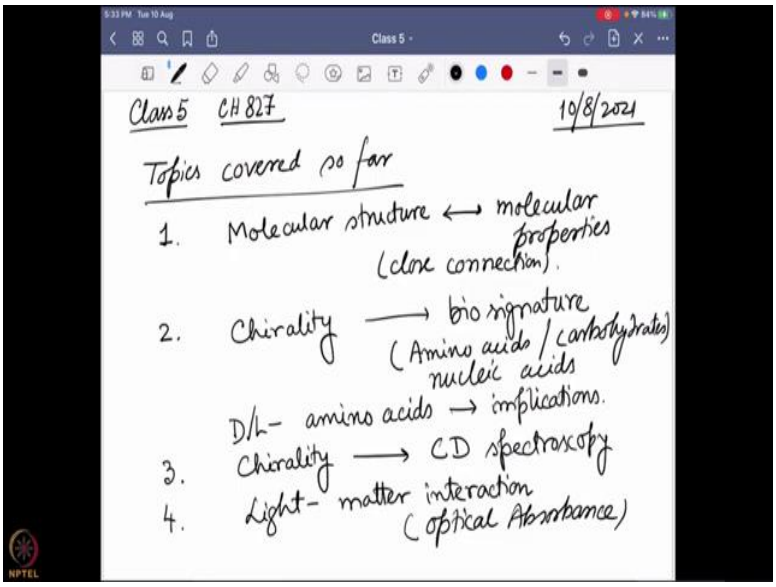

So far, the things we have covered let me just point it out. At the following that molecular structure and molecular properties are very much connected. So, they actually depend on each other. So, there is a close connection between them. And one of such molecular properties that we can follow to understand what is the structure of the molecule? What is the orientation of the molecule?

Is chirality and we are mostly interested in chirality because this chirality can be used as the bio signature this sign of life. Because most of the important factors that actually considered as the building block for cellular life, such as amino acids and proteins, carbohydrates and nucleic acids, they are all known to form chiral molecules, especially when they form their polymeric structure.

And over there we have specially looked into the D and L-amino acids. And we have also looked into the functionality for the effects I would say it implications of D and L-amino acids on life. So, over there one of our goal is to how to follow chirality? And another way we can easily follow chirality is by following something called CD spectroscopy. But before we go to CD spectroscopy, the last class we have learned, what is a light matter interaction?

And what is happening in the molecule level during a simple optical absorbance? So, up to this part we have studied and today we would like to go into a little bit more details. What happens in a chiral molecule? Especially, the phenomena we have all know, optical rotation. Why does it happen?

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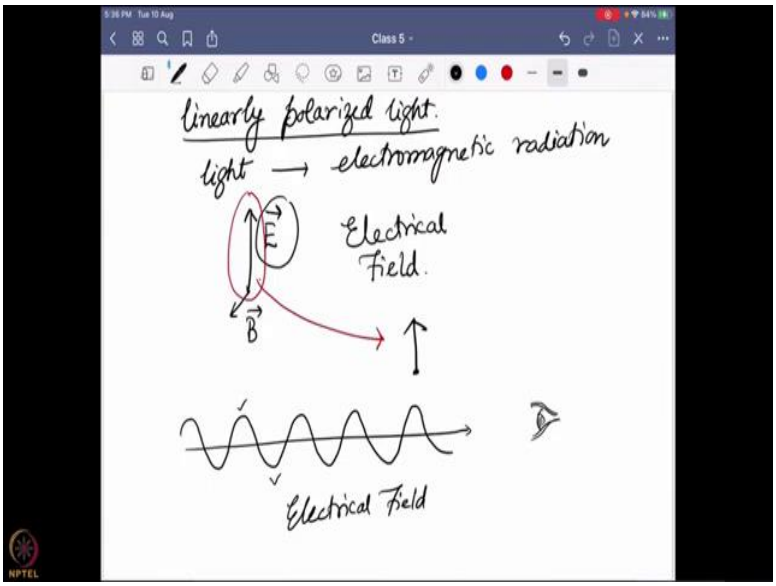

So, let us go into the details. So, what we have known so far that if we really want to observe an optical absorbance for a chiral molecule? One thing we actually need is called linear polarized light linearly polarized light. Now, the question is, why do we need a linear polarized light? So, before going there we have to go back a little bit and talk about the light as an electromagnetic radiation itself. So, when we talk about light, we say okay it is an electromagnetic radiation.

And in the last class we know that it actually has an electric field and it also has a magnetic field, sitting perpendicular to each other. Now, when you look into that especially, the electrical field we are more interested in because that is the most strong feature of this electromagnetic radiation. It does contain both magnetic and electrical field but electrical field is much more intense.

So, when we draw this particular line over here, what do we mean by that line? So, if I want to bring it over here and draw this line again, what do I mean that this is the direction of this electrical field and it is not a static field? It is actually having more of a wave nature. So, if I look into this particular electrical field from the side, what it will show me? Is this an electrical field? So that is what we are going to see from the side.

So that is the direction of the electrical field which is actually going to wave nature. So, it has maxima and a minima

and it is going through a particular line. Now, what happens if we look this particular electrical field from the front? So, what happens? If we put our eyes over there and try to look into it, what is actually coming to my mind? So, how that will look like. So, let us take a look into a bit more details on that.

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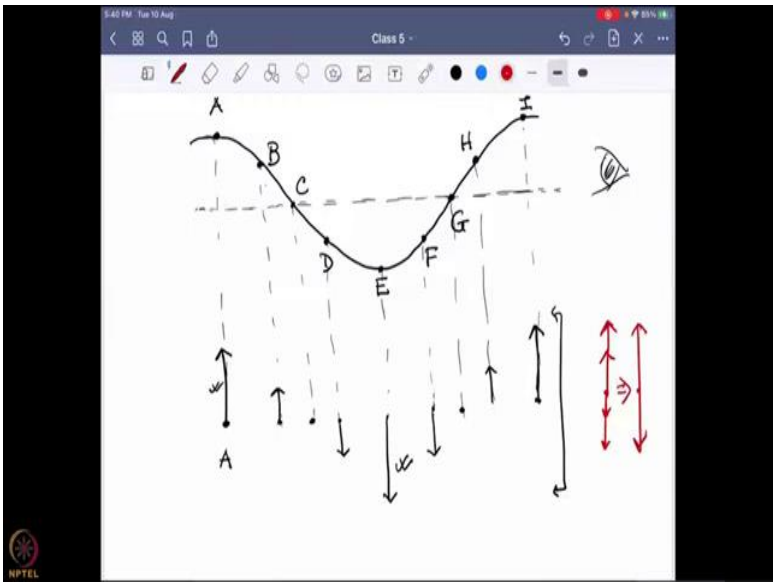

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So, now say of this particular wave. I am just drawing one portion of it. So, over here this is the maxima say this is point A. So, at this point A if I start again looking from this side, what I will see is actually a line like that. And this point over there signifies this middle line. So that is what I am going to see at point A. Now, shall I come to point B.? So, what I am going to see? So, when we are looking at point B what we are actually going to see? That this p could be much more smaller because the intensity is going down.

Now, say we move forward go to point C at this point. What you are going to see? Is nothing, because there is no electrical field present because right now, it is changing the direction. Now, say I come to point D. So, over there, what I am going to see now? It is moving towards the opposite direction. Similarly, if I want to point E which is the maxima of this, I will be able to see that. And this intensity at this intensity is going to be the same because of this web nature.

Then, if we move point F, it is again going to shrink down a bit, maybe point G it is going to be 0 again. And then say it will start moving forward. You are going to point it again. I am sorry I am going to point I that is going to show in the maxima. So, all together what I am going to see? Is that this is going to start from very high amplitude. Then it slowly goes to 0 then goes to the opposite direction again, slows down comes to 0 again and moving forward.

So, all together what I can say? If I combine all these things together because now, when I am looking from the front, I am not going to see them in different points. What I am going to see? They are actually going to fit on top of each other. And what I am going to see? Is the following that this particular thing is actually going like this it is more of like it is a blinking thing which is going to go?

So that is why we try to write that in this particular way, a double headed arrow which actually shows that it is actually blinking and is blinking means that it is actually following this particular of nature. And this is how the electrical field is actually oriented.

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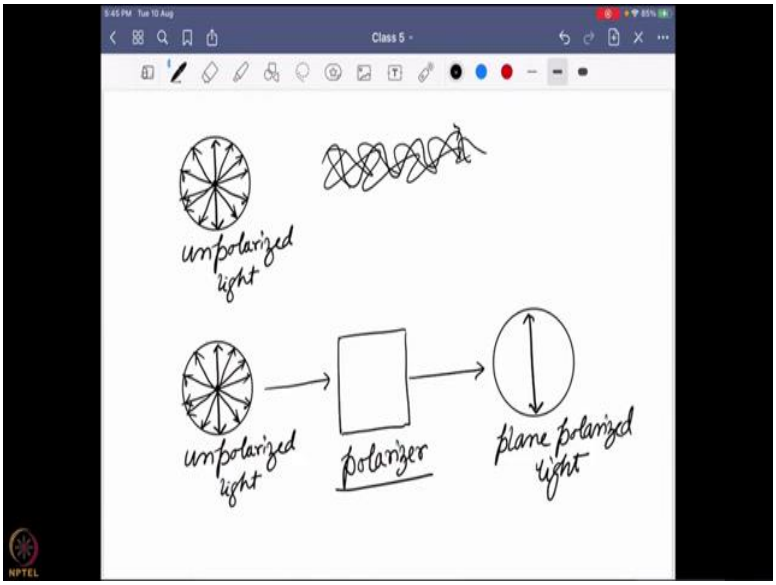

Now, if I go further and write down this line like this and say I am covering that with a circular motion. So, this circle actually showing that a particular area of the light that is actually we are actually seeing. So over there So, over here what we are going to see? That this particular line is actually showing that if I see the electrical field of front I am going to see this is actually blinking along to this particular axis this electric field, how it is coming out.

Now, when a light actually comes up, it is not like it is going to show electrical field, one particular direction. It is possible to have this electrical field in any possible direction. All possible direction you can think about and this is something known as unpolarized light. So, you can think about what I am actually saying that this electrical field I was talking about. If I see from the side, it is not only happening in this particular direction and it is happening in this direction, in this direction.

So, all possible direction I am not drawing anymore, otherwise it will be very easy. So, it is possible that the electric field, the wave is coming in all possible direction. And that is how the unpolarized light looks like. And that is how we actually present them because that is the electrical field and electrical field is the strongest feature of the asymmetric radiation. So that is why we are representing that. So that is how an unpolarized light look like.

Now, if I take this same unpolarized light, it is written over here. And now, say that I am passing it through a particular crystal and coming into that, what is that particular crystal? That this crystal has a particular property that it can absorb all the possible electrical fields in all direction, except one. And what will happen when it passes through it is the

following that once it passes through that it actually shows electrical field in only one direction.

So, this is unpolarized light passing through a particular crystal and at the end I am seeing the electrical field only showing up in one particular direction. So, this will be called as plane polarized light. And this particular crystal is known as polarizer. So, what is the role of this particular polarizer? I am not going into the detailed physics of it but you can think about. It is like a comb that we use to brush over hair.

So, this is such a way oriented that when it sees that your hair is coming from all particular direction but when you combs through that it has to follow the the trend of the comb, how it actually wants to orient your hair. Similarly, the unpolarized light coming from all direction but this polarizer have some grating or have some space that the light can move so only through that particular direction.

And by that it actually ensures that the light is passing through only one particular. And this is very easily controlled because polarizer has molecular planes to control. So, this is how the plane polarized light is actually coming up. So, again it is the electrical field, it is coming through only one particular direction.

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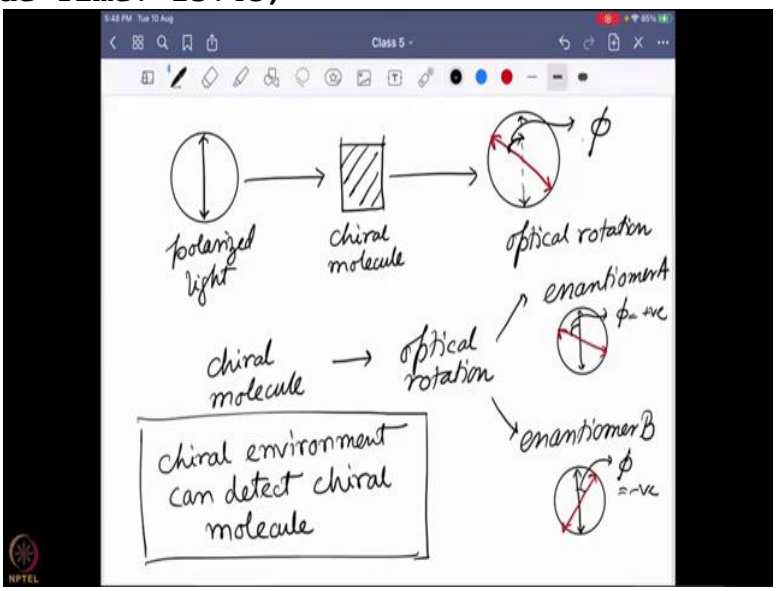

Now, what happens? Is the following if you take this plane, polarized light and now, passes it through a chiral sample so, it is a chiral molecule in a sample. Very similar that you do optical spectroscopy but instead of any particular unpolarized light now you are using a polarized light. And what we are expecting to see? Is the following that this light actually passes through but when we actually detecting it.

What we detect? Is the following that the light should be along this plane but we actually started with but if it is chiral what it is going to do, it is going to move the plane? It is going to rotate it. And this particular phenomenon is known as optical rotation. So, where the plane polarized light was and where it is now, there is a difference between them. And this difference can be given by an angle so, it is phi(ψ). So that is it is known as the optical rotation.

Now the question is, we all know so far, all these acts but the question is, why it is happening? And that we are going to look into details. So, so far, we have discussed that this chiral molecule can show this optical rotation and if you have 2 different enantiomers. So, say this is enantiomer A and there is another 1 enantiomer B. They are going to show similar rotation but exactly opposite direction. So, it is not exactly circular.

So, over there previously the pinpoint light was like this but once it is rotated one is this way that will be exactly the other way if all the other factors remain same that means the concentration and temperature, everything remains same. This angle is going to be similar magnitude but opposite in direction. So, say one of them I am showing it as positive, one of them showing it as negative. So that is what we also know that.

The question is that why it is happening? Why a chiral molecule can induce optical rotation? The answer lies in the simple fact that we have already learned only a chiral environment can detect chiral molecule. So that means this plane polarized light have to have something guided in nature which is actually detected by this chiral molecule. Now, what is present in this plane polarization light? That can be chiral.

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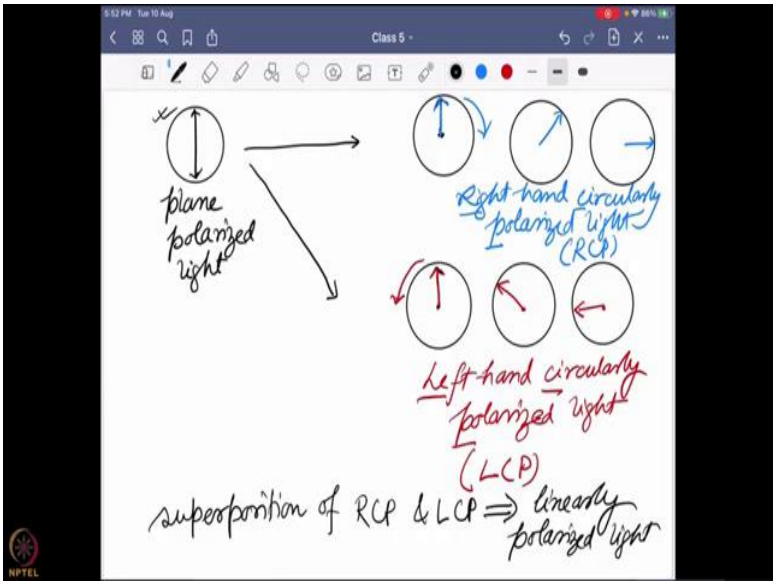

So, let us take a look so, what has been found? That when we are talking about a plane, polarized light that can be seen as a superposition of two different circularly polarized light? What do you mean by circularly polarized light? So, so far, I was talking in such a way that the electrical field direction is actually only blinking in this particular position over here at a particular plane.

But in reality, what is found that? It is actually not a simple plane, polarized light but it can be given as a circularly polarized light. So, what do I mean by circularly polarized light? Circularly polarized light means that there is electrical field like this but instead of staying in the same plane, they can actually rotate. And when they rotate, they can rotate in two different directions either in the right hand side or in the left hand side.

So, what do I mean is the following? So, once we have it so we will try a few more so, this particular line over here is actually going to rotate like this in the right hand direction. On the other hand this one is going to rotate on the left hand direction. So, these are the two different circularly polarized light present which actually generates this plane polarizer. And over here you can see this light is rotating on the left hand side. So, this is called the left hand circularly polarized light.

Sometimes the hand is taken out. So, it is known as LCP and this one on the other hand is known as the right hand circularly polarized light is known as RCP. And this superposition of RCP and LCP actually going to provide you a linearly polarized light. How that actually works? So, let us actually draw this at different level and see, how it is actually going to work? So, what we are actually saying at this moment? That the plane polarized light we are seeing.

It is nothing but actually a superposition or combination of two different lights which are actually rotated in nature, actually rotating, not just blinking in a particular plane. And one of them rotate on the right hand side and one of them rotate in the left hand side.

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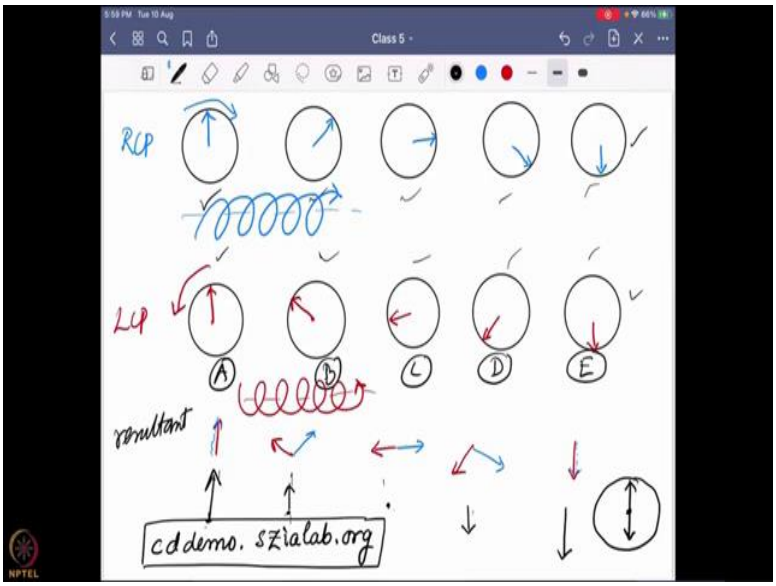

So, how they actually, going to give me a system plane polarized light. So, what I am going to do over here? Going to draw different versions of right hand side circularly polarized light and left hand side circularly polarized light. At the bottom, I am going to draw, what is the resultant will look like? So, say I am drawing right hand side circularly polarized light in blue and left hand one in red. So, this blue one is moving like this and the left hand one is also moving and they started from the same phase.

So, they are exactly opposite to each other and after this half rotation they arrive the same place but rotating through the opposite direction. So, there it is writing on the left hand side over there this is writing on the right hand side. So, this is the RCP and this is the LCP. Now, what I want to do? To see what is the resultant will look like? So, I am going to take the resultant in this five point A B C D E and see how it looks like.

So, the first point, the blue and the red one will be exactly on top of each other. So, this is the red one, this is the blue one will be exactly on top of each other. So, the resultant will be like this in the same direction. Now, the next one, what will happen? This is on this direction, this is on this direction. Now, previously there are the same direction, so, the resultant will be the maximum but now it is a very simple vector (23:24) addition you can think about, what will happen?

The resultant will be somewhere in middle but will be lower in the intensity compared to the previous one because now they are in opposite different directions. Whereas in point C they are exactly opposite to each other so, the resultant will be 0. They will be cancelling each other. And then it goes to the next position where both of them are downward motion. So, the resultant will be also coming on the target side.

And in the last one they are exactly in the same direction. So, this is how it is going to be looks like? So, take a look into that whether they are rotating in different direction does not matter but the resultant looks like stays in the same plane all the time. And it is nothing but we have got it together it is the same blinking motion the plane polarized light. So that is why we are saying that the left hand and right hand circularly polarized light there superposition is giving me a plane polarized light.

Now, some of you probably hearing this for the first time and might take some time to digest it. So, there is a very nice website where we actually can go through there. And this is the website cddemo.szialab.org, where you can find a video of all these things showing up. And I am going to show you a few examples, how to do that? The first one we are going to look into, how it looks like? When 2 circularly polarized light is moving and their resultant is a plane polarized over here.

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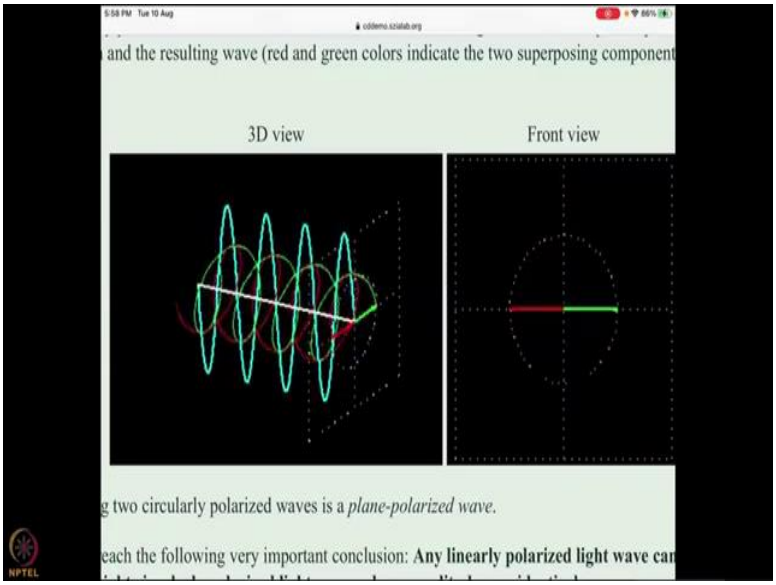

(Video Starts: 25:32) So, let us take a look into it. So, over here you can see there are look into the first on the right hand side figure the simple one. So, the green one is actually rotating left hand side motion the red one is rotating on the right hand side motion and the blue line is the resultant. You can see in the same phase they are moving on the opposite direction.

And the resultant is nothing but a plane polarized light and on the left hand side they are actually showing how a circularly polarized light actually looks like. So, it is actually moving forward while it is taking a circular motion. So, it looks like more of like a spring, a helical structure. So, the green one is moving on the left hand side, red one is moving on the right hand side and as a result and what we are getting this plane polarized light?

If I look from the side, it will look like it is creating this wave, the blue colour wave staying in the same plane. So that is why we can say that when we actually superimpose 2 different circularly polarized lights, it is actually going to create this plane polarized light. (Video Ends: 26:48) So, later you guys can take a look into it and find out a better idea on this particular part.

So, any questions up to this part, why we can explain a plane polarized light? By superposition of two circular polystyrene because that is, how it is actually behave? Okay So, now and over there I am going to draw that how it actually looks like if I look from the side. So, from the side, the right hand circularly polarized light will look like this moving on the right hand rotation.

So, it is kind of rotating right hand side and you are moving forward at the same time. So, it is going to provide a helical structure and over there for the LCP it is exactly going to be the opposite one. So, it is also moving forward while making a left hand turn all the time. So that is how this RCP and LCP actually look? But when you look actually from the front side, it is going to show me this kind of simple rotations.

And this is what it looks like from the side view? And this one are actually the front views. okay So that is how this right hand circularly polarized light is actually behaves (28:11). Now, you can see over here this right hand and left hand circularly polarized light are actually exactly opposite in nature and not only that they are actually chiral because you cannot really super impose this RCP over the LCP.