Optical Spectroscopy and Microscopy
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Lecture – 46
Fundamentals of Optical Measurements and Instrumentation

Hello and welcome to the lecture series in optical spectroscopy and microscopy and so far what we have seen is that how to create; what does an optical hinge point mean and how to move the beam in space in response to a voltage command using the galvanometric apparatus or a mirror. So, now what we are going to do is we are going to put together this motion; an oscillatory motion along with that of what happens when you are taking this beam.

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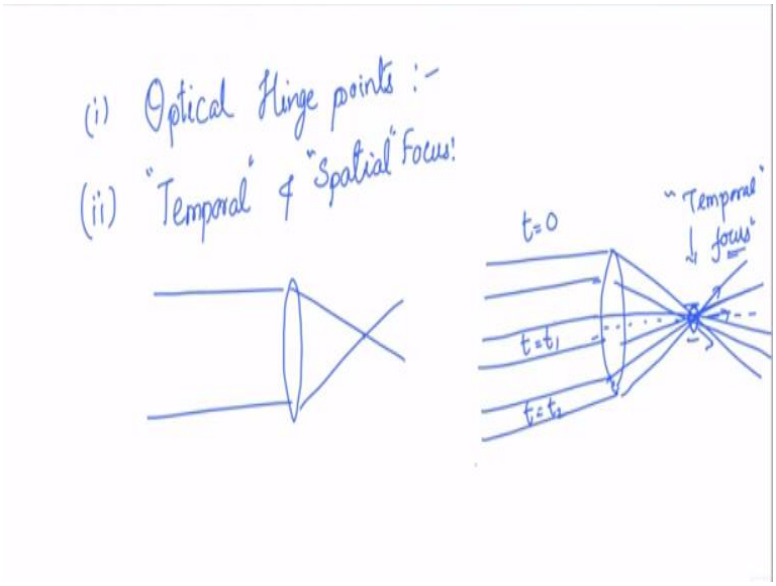

And then move the beam and put it through a lens, if this moving beam is put through a lens so, in that aspect I introduced 2 notions; one is called as we talked about creating optical hinge point and two; I was talking to you about temporal and spatial focus okay, so essentially this temporal and spatial focus are nothing; spatial focus is the normal focus properties of the lens that we actually know of.

That is if you take a lens pass in a parallel beam of light, they will converge at a point in space, so now what I said is I took this and then pretended I mean, and then pretended as if that I am a long exposure detector right, so mean response time is low let us see okay, so then I am exposing the film, I mean imagine that I am going to actually have this lens and then I am going to move the beam alright, as a function of time.

So, let us say this is at t equal to 0 and this is a position at t equal to t1 and that is the position at t equal to some t2. Now, if I did not tell you these are actually different I mean, snapshots of the beam profiles taken at different time points, this could as well be the different parallel; different set of parallel rays all presented before the lens, so then what is going to happen, so now this set of parallel rays are going to converge like that right.

So, let us start from, okay and the one that is going in the centre, it is going to converge to, so alright and so is this guy okay, so now you see at this point it will look as if all these beams are actually merging right, or all present at the same space I mean, if you look at the space they are present in the same space though the direction at which they are actually travelling or different okay, about I mean, about this point, the set of photons that are originated from this beam are travelling upwards.

And about this point these guys are travelling down and these guys are travelling forward, so unless if you look at the direction or unless you look at what happens next or what has happening before you will not be able to tell if they are of different because they are all present in the same space, localized in the same space albeit they, the beams I mean the photons present in this space come at different time points from different these places, right.

The beams coming at a time point t equal to 0 or travelling downwards the beam coming at time point t1 are traveling forward and that time point t2 are traveling upwards now, such kind of a focus we call it as the temporal focus. Now, this is you can think of this as you can actually replace the 1 by u + 1 by v equal to 1 by f formula throughout except here what we are actually talking about is that the light rays that we are actually drawing they are correspond to the boundaries of the beam that are present at different instances in time.

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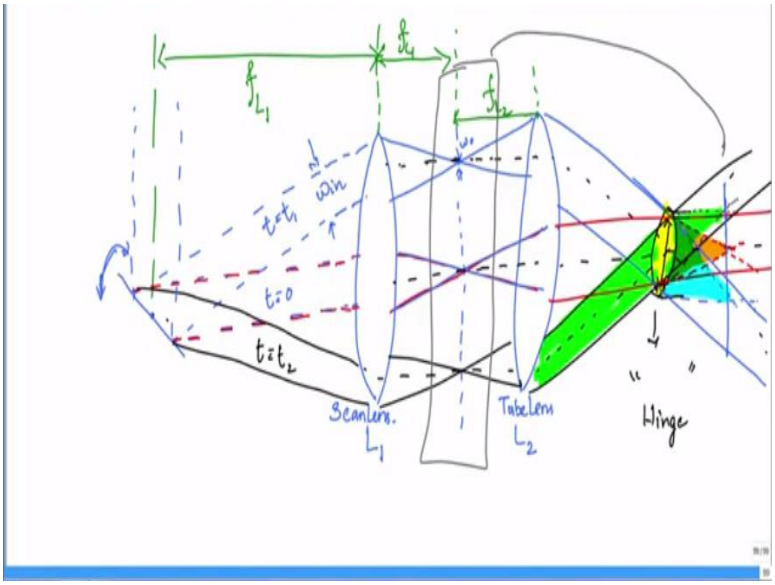

So, now you can actually see how we can actually create a hinge point about the objective lens, so now let us see, you have a mirror that is actually and let us say, the incoming beam is a collimated beam, so now this is a galvanometric mirror so, it is actually going to the axis about which it is going to rotate is coming out of this board and into this board that is about that you are actually rotating, oscillating.

So, which means at some instance, the light is travelling like this and at some other instant, I am going to just take 2 that is travelling in the direction, now if we actually place a lens here, then what you see is that this beam; the beam located at the central axis along the travelling along the central axis is going to create a focus something like that while that part of the beam, so let us say t equal to some t1.

And this is t equal to 0, central position okay, so now you can actually see you have a focus spot, alright that is traversing or spanning equal distances in equal intervals of time okay, for it to move along this axis, it takes equal amount of time that is not true when you are actually having an angular motion, right so because this about this place, you have the beam travelling I mean, the beam spending more time compared to that of the angular I mean, the edges.

So, here that problem is averted, if they do then you are going to create an artificial contrast because since you are; I mean if you are assuming that it is equally sampled, then you are going to create an artificial contrast, if you do not assume then it is important for I mean, it is a hard for us to know that how much is this time I mean, because it is much easier if you could actually avoid that and they have a linear sampling of this entire plane.

So that is what this is; this allows you to do but then but we actually said is that we want to have a beam that is as wide as that the lens and still be able to move it now, how do I actually do this? So, now what we can actually do is this is our lens L1, which is typically called as a scan lens and I am going to place another lens, this is actually I am going to send it into a microscope body and this let us call it as lens L2 or it is also called as a tube lens.

Now, here multiple things start to happen; number 1 is that because these are 2 lenses, it is a 2 lens system and they have a fixed focal length right, so now for you to have a linear motion in the focal plane of the scan lens and this distance need to be fixed okay, this needs to be the okay, I am going to use a different colour, forgot to use it, so this need to be the focal length of the scan lens.

So, we have L; focal length of the lens L1 and I mean, draw it to scale but on the other side that happens to be the focal length good, so now since it is tube lenses, another lens, another biconvex lens now, if you keep if you match this focal length depending on the ratio of this fL1 to fL2, now you are going to expand this beam okay, now you need to choose your scan lens accordingly such that you expand the beam.

And expand it such that now you are going to create the angular motion again here, right because you then imagine this for this lens, there is a linear motion which is equivalent to a parallel beam of light impinging on it which you have a parallel beam of light, they are going to actually form a focus. So, now when the form of focus and the beam width is going to be different, so I am going to kind of exaggerate that a bit here.

So, it is going to be and at the same time spatially, if you look at it, they have been focused so they are going to be collimated now here and alright, so now at time t equal to; the path that I have traced here right, so okay I am going to kind of so let us say, the red and blue, this colour represents the t equal to 0 beam path, okay. So, now that will be the initial time, so now t equal to t1 is the blue path.

And clearly, what you can see is that the light beam travelling at an angle becomes focused because it is a parallel beam of light, incoming beam is a parallel beam of light with some omega in and that gets into some small focus here okay, omega 0, however you also see that

temporally, I mean it is in impinging with an angle, now if you rotate this mirror, now at some other later instant okay, so the initial instant t equal to 0, it was actually going through the lens just like normal lens.

And then you are going to focus and then here the net result what you have is an expanded beam of light or something like that. Similarly, you can also go ahead and draw out a picture for t equal to t2, if you like all the way coming from going in something like that let us try doing that with a black line so okay, so now what is going to happen here is that focal plane is still the same, it is going to be like this.

And now this tracing is no; because it is a focus beam, so it is going to become parallel and of course, where you can actually see that remember, I have given you a guide lines of looking at temporal focusing what you said; what I said is that you think of representing the central portion of the beam with a line and then see in t equal to t2. So, what happens to them; so now if you look at that, then you will see that the central portion of the beam would be represented like this.

Naturally, they are parallel to each other, travelling parallel to each other, so naturally after the lens they are going to converge, so this convergence is because of the temporal focus okay. Now, you see you have created a space; a wide space at which the beam width is not changing, okay as a function of time, the beam width is the cross section of this (()) (16:04) essentially, little bit more than the size of the beam.

But practically but you can think of this as the width of the beam itself because that is where the 2 red lines are meeting right, so at any instant in time, the width of the beam remains exactly the same though the direction at which they are actually travelling is different. Now, this is the definition of hinge point and all we have to do is to actually place our objective lens, right about here.

So, what you have done is that you have actually created an optical hinge or the movement of the beam, the incoming beams are coming at different angles; incident at different angles on to this objective lens and the size of the beam is exactly the same and they do not get chopped off, as a result what you end up getting is after this lens, a complementary portion of or an image of this portion okay, now this portion is kind of formed here as you can see.

Because the incoming beams of parallel so and it is coming at an angle with respect to time, so what is going to happen is it is going to focus like that and I mean it will mess up this region, so what I am going to do is; I am not going to draw that but what I am going to do is; I am going to move this region out, oh it is not working, that is not working, so essentially if I were to represent this lens, you can actually think of how do I do this.

Now, let us draw with the dotted lines, I am going to just draw with the same colour, so when the response for the black light would be like that and for the red would be like that and for the blue, so now if you look at this plane right that is our focal plane, this is complementary to the plane that is existing between the scan lens and the tube lens and just a way here the beams were actually travelling or scanning the space in a linear fashion.

They are actually scanning in the linear fashion which is exactly what you want, if you want to actually represent a sample equally sample these regions and then at the same time, you have created a possibility of making the smallest possible spot, right because the beam that is coming in and impinging on this lens right, is the so, I am going to highlight this lens here, so that we see this nicely, okay.

And the similar way, so I am going to talk about the focused beams here, so that is one and blue is like that and green is like that, so you can actually see that the focus is formed very tightly and for creating this focus, if you actually trace back the beam; the extent of the beams they are actually the widest possible right, nothing stops them from being the widest possible, they are not chopping at any instant in time.

So that is making it really messy, so I will just leave it with one of the; highlighting one of the beam, so you can actually see that is true with being the green at t equal to t2, the red at t equal to t0 or the blue at t equal to t1, so thus what you have been able to do is to be able to generate linear movement of the tightly focused laser beam and if you could; if you able to measure the photons, detect the photons from each of these points, we have defined these points.

And if you can actually measure the contrast from these points, then we would be able to nicely obtain a representation of this sample without having to move the sample, we are

actually moving the light beam using a galvanometer and without having to move any heavy apparatus all that we are doing, the only thing that is moving here is the galvanometric mirror.

And we will see in the lab and how these mirrors are and how they move you will; when you see that you will see that they are very thin, they can be made thin and small, so as a result you can actually move them really, really fast and when you move them really fast, it allows you to be able to create these representations really fast and I hope that you are able to follow this laser scanning basics.

And that is; with that what we will do is; we will actually move on to be able to measure this contrast, when I mean trace back the light and measure this contrast and when that using detectors, okay and we will see more on this in the future classes, thank you.