Optical Spectroscopy and Microscopy
Prof. Balaji Jayaprakash
Centre of Neuroscience
Indian Institute of Science – Bangalore

Lecture – 55
Fundamentals of Optical Measurements and Instrumentation

Hello and welcome to the practical demo lab session of this optical spectroscopy and microscopy course. What we will do today in this lecture is that we are going to see how an optical setup is built up in the lab. So the optical setup naturally starts with the light source itself. There is a very wide variety of light sources that you can think of, starting from as simple a light source like a laser pointer.

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So what I am showing you here is a laser pointer that is kind of hacked for its power supply where usually you would have seen this laser pointer in the any seminars or speaker giving you a lecture and stuff like that where he is using his or he or she is using it to point to different aspect of his presentation or her presentation. So what we have done is we have actually removed the battery compartment and made some; attach some wires.

So that we could actually drive it through a lab power supply. So these things I mean the reason for me to show you this is that the light source from such simple devices can also be very, very useful in a lab setting and we use it quite often.

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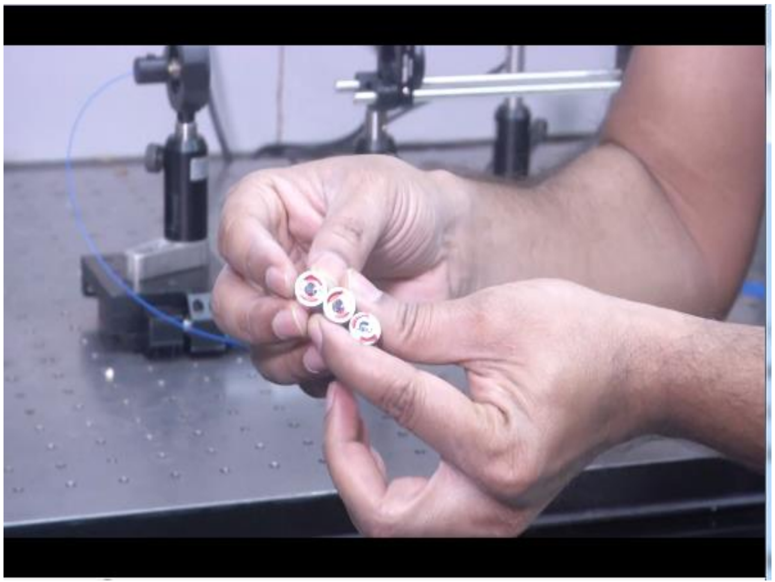

And what if you open up the front element right here and then if you see it what you will see is that this kind of diodes that are coming out from there and I am holding here 3 different units each one of them (()) (02:17) potentially could be; it was at some point in part of the laser pointer, not all of them but at least one of them. So when you have these diodes all you need is really to power them up.

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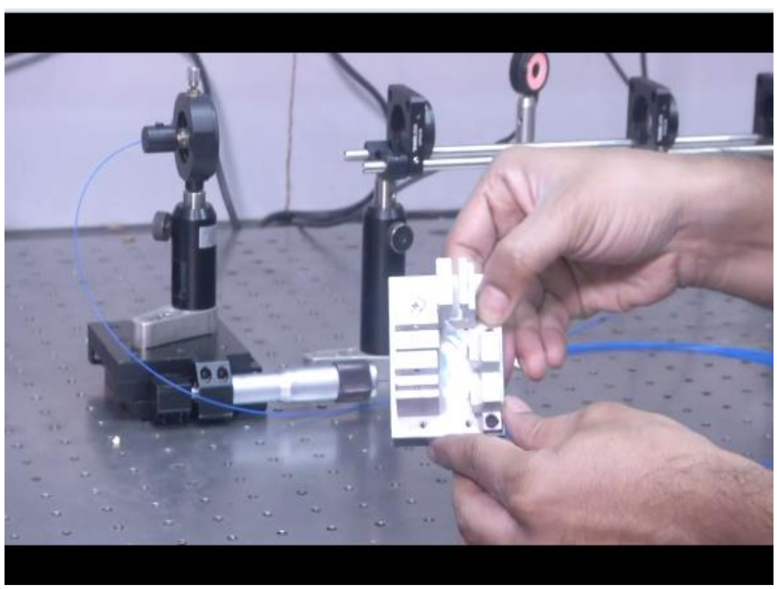

And then what we do is that; this is kind of RGB setup what we say is that three different colors in general or any number of colors that you like but this here commonly we used three different laser colors and one is at 470 other is at 530 and then somewhere 630 is the laser diodes that we are actually looking at. Now the part that you see is that the diode goes in here, alright and now that light beam hits onto this optical element, right.

You see that it is kept at an angle and this optical element is going to reflect this beam it is a dichroic, okay. Now we will see a larger version of this dichroic little later in the course. But you see that the; we have seen this in the theory class where dichroics are the elements where it can transmit or reflect depending on the wavelength of the light that we are using. So this dichroic is chosen such that the diode that we put in that is getting reflected.

However, the light from this diode as well as this diode right this diode comes and hits here and then goes down and this diode passes through; these lights pass through, okay. In effect, what you have is 1 passing through both the electrodes, number 2 hitting at this dichroic getting reflected and passing through this electrode, so reflection pass transmission. This one is pure reflection on-reflection.

With that you can actually generate three different colors. And of course in a lab setting you also want to be able to have a control over how well you; or how fast you can turn on and off and all that along; so along; for that along with this kind of a power supply setup we also have a controller that can actually turn on and turn off. What we; I will show you in a minute is one such controller.

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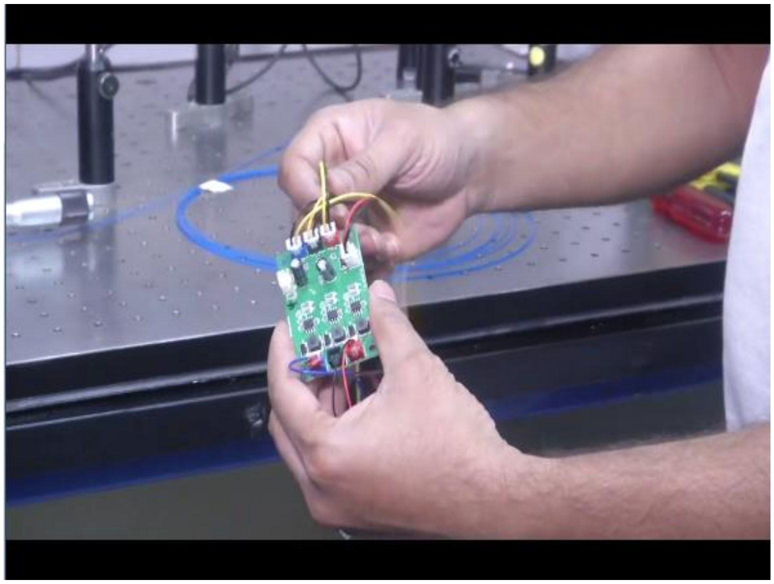

So here what we are actually going to; what we are seeing is that three different cables attached to this power board which is basically the support controller for the diodes. So what you can actually do is you can send them in TTL pulse. Basically, these are pulses that go between 0 to 5 volts and when it is anywhere between closer to the 5 volts that is a range that is defined is not exact fine but it is in an around 5, you can actually look it up.

And if you are able to give that voltage then it is considered on or switched on and then close to 0 in around 0 it is off and there is a gray region that we will be able to generate nice TTL pulse to turn off and on. Now such a board is actually controlled using and in our set up here Arduino, alright.

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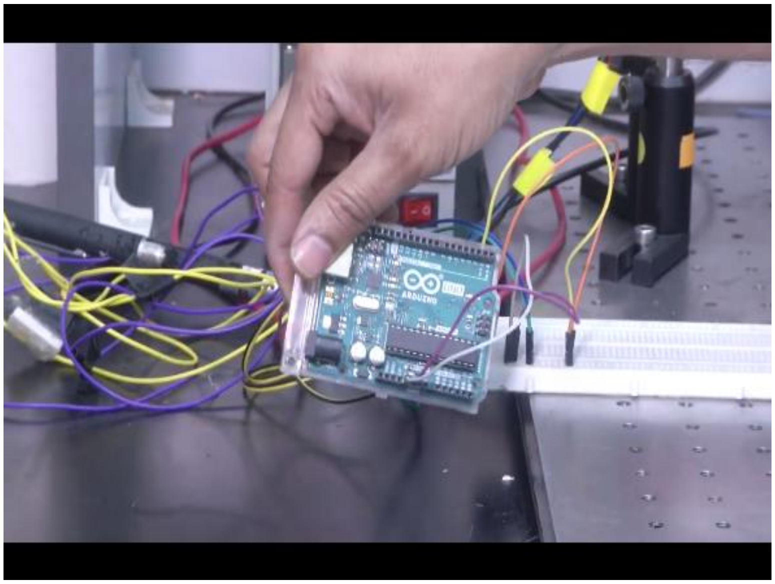

And this Arduino device then actually takes in the power and reads it is already programmed so you can choose what kind of program that you want to have this light.

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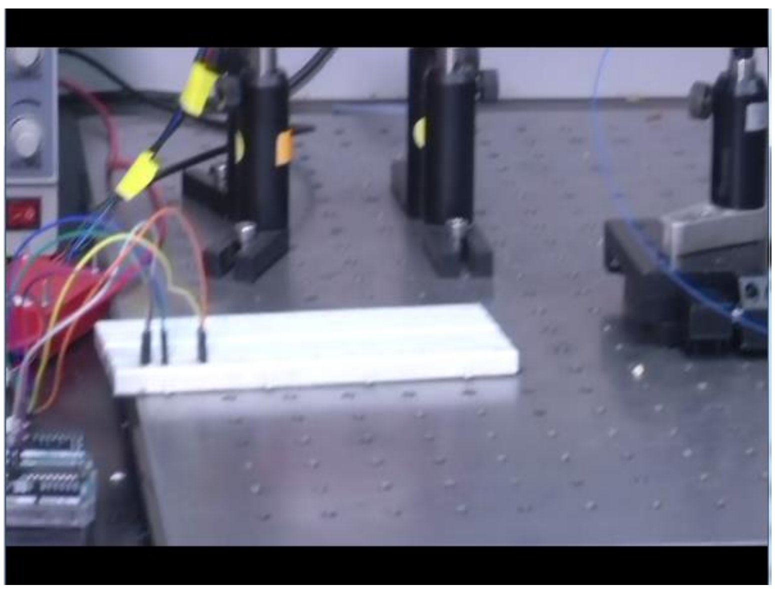

So right now for this demonstration what I have done is that we have set it up such that this we have a breakout board just to make sure that we get a minimal light out of this laser system. So for today's setup what we have done is we have taken a breakout board and so this is just to make sure there is no turning off and on all that, very simple turn on and off, okay. So we have done that.

So before going into this there are a few things that I need to really make you aware one is that since we are working in an optical lab typically we will be working with laser light. And there are things that we need to ensure that does not harm you right. There are many things that one can keep listing out, so it is; since that is not the purpose of this course but I do need to make you aware that we need to adopt some safety precautions and we do, do that.

I am going to just mention a few points, alright and pass by and you have to keep that in mind when you are doing it in your lab by yourself and the assumption is that wherever you do that lab that people would be able to guide you through these safety procedures, okay. Principle points that you want to keep in mind is that laser light of all the places, one place it, do not want to get into is; into your eye, it can actually be very, very damaging.

Even though it is a pretty simple low-power the house; house of a low power lasers it can be pretty damaging. So the goal here is to set up the procedure set up the system such that there are feel safe mechanisms so that even if you do a failure I mean if there is a problem right it does not go into your eye that is the goal here. So what do we do? Number 1, of course you wear a safety goggles. So you have not turned it turned any laser so I cannot demonstrate the thing, the goggle are something like this.

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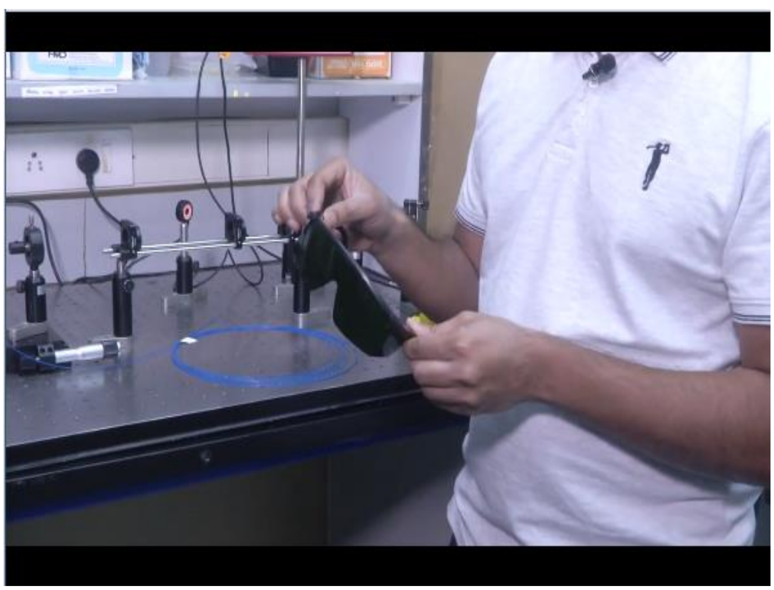

So we are in; you see that they are they have a particular color, okay. This in particular one we have gotten in the lab this are pretty wide band which; that is why it is pretty dark and so but slight things of with a slight pinch of dark green. So it is pretty wide band. However, that; the reason being that we kind of work with very different wavelengths in the lab starting from the visible light all the way to infrared pulses and so forth.

So you would want to be wearing the goggles when you are actually working with the laser light. However, I have two points to make here right in general. So there are two kinds of users that I want to distinguish with, one person who is actually routinely working in the lab and setting up things and so on so forth other who comes in and uses, okay there are two kinds of users. Definitely, definitely for the people who are just coming in and using you have to be wearing these goggles all the time, nope no doubt at all.

Because you do not know where the laser beam is, you do know how the system is set up. So it is a very, very important we wear this goggles there. And for the people who are actually aligning there is a small catch here because if you actually wear this; the idea of this is to actually reduce the interacting with the beam. So when you attenuate the beam then so if you wear this and then I am going to look through this then the amount of light that I get to see right that gets attenuated drastically.

So which means you need to keep in mind two things. Number one is that you are aware of the fact that the beam that you are looking at the beam that your eye is looking at though it looks low intense that is only because you are writing the goggles, okay. The moment when you are; the instance of where you are wearing and taking it off you have to be absolutely clear it or when it drops off or whenever it is you need to be absolutely clear that you have to understand that the reduction in intensity that you see is only because that you are wearing the goggles.

Second, many instance in time where you are actually hurting; hunting for the last photon which means you are working with very, very low intensity lights. Typically, they are that is; that low; those low intensity lights we do not have a problem; we are actually trying to align so then you are you can work without the goggles. However, when you are aligning the main beam so it is good to keep in mind that the reduction intensity is because of the goggles that you are wearing along with it you also have to understand.

It is only reducing the intensity it is not making it; get to 0 which means the best practice is to adapt your habits the alignment habits and the optical work habits such that you have a very low probability of sending getting the beam into the eyes, that is; you have to have a tremendous importance that tends to be stressed on that are given to that because you do not want to get a false security of, okay I am wearing the goggles so it all be safe that is not true at all, okay.

In many ways I would stress on the clean work habits more than just wearing the goggles and thinking that it will be safe. In this setup; so now as I explained we have a visible laser, so what we are going to show is that the way we have talked about in the course how we can use the mirrors, okay to set up the laser light to go through predefined line in space, we called in the course the predefined line as a line as an optical axis, okay.

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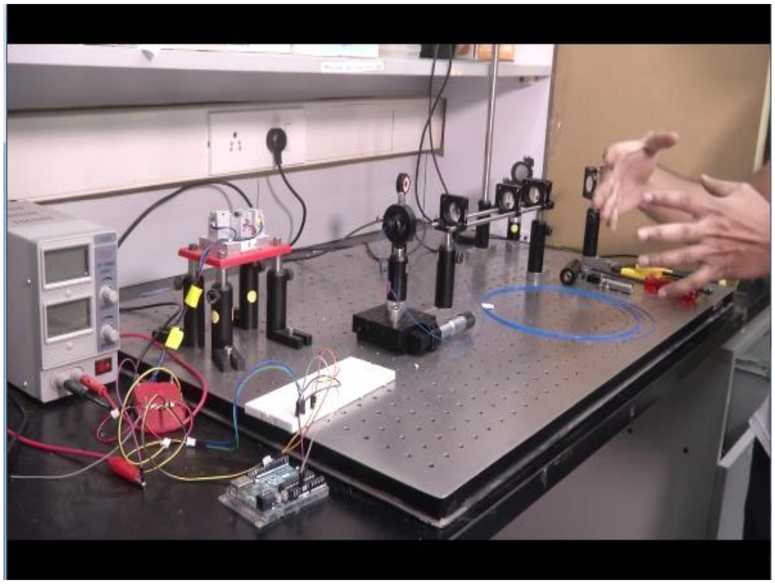

So now the idea here is that the setup we have is going to we are going to use this setup to send the beam right to through an optical axis, okay.

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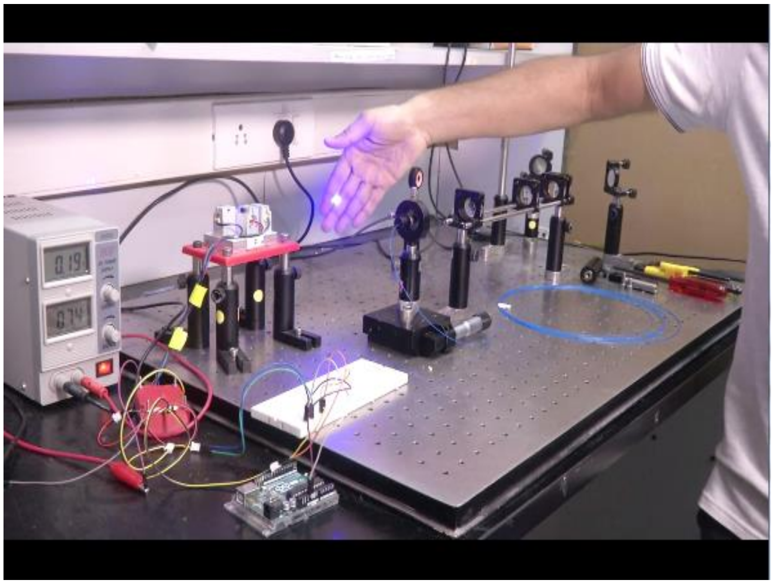

So now what I am going to do is that I am going to turn on the power source for the light as soon as it turn on you can start to see the light beam coming through and from this light assembly. So right now we are only; we have only turned on the blue laser, okay.

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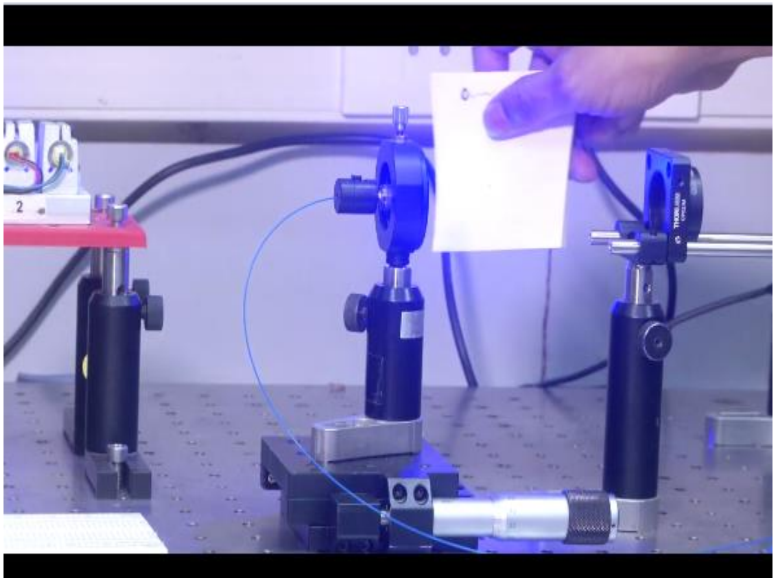

And you can nicely see this blue laser beam that is emerging out from that light source coming in all the way and then getting into getting in; on this mirror; hitting on this mirror and; which then sends it to another mirror before it goes to set up things. But the idea here is that I want to actually be able to couple it to an optical fiber, okay.

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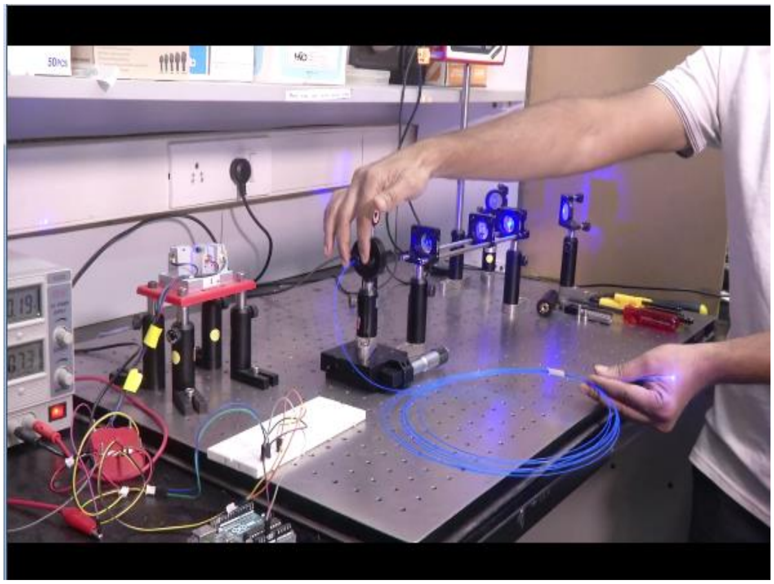

So already I can show you this is just a long optical fiber and of course what you are seeing here; one end of the optical fiber is being held into the fiber optic coupler and on the other end we can actually see the light, alright. So coming out emerging from the fiber and better off with small paper to transfer and you can actually see that coming out. So now clearly for this laser light to come out so and keeping it in inside so, so from the safety point one thing that I was telling is a good habit is always important just not the protect; not just the protecting device.

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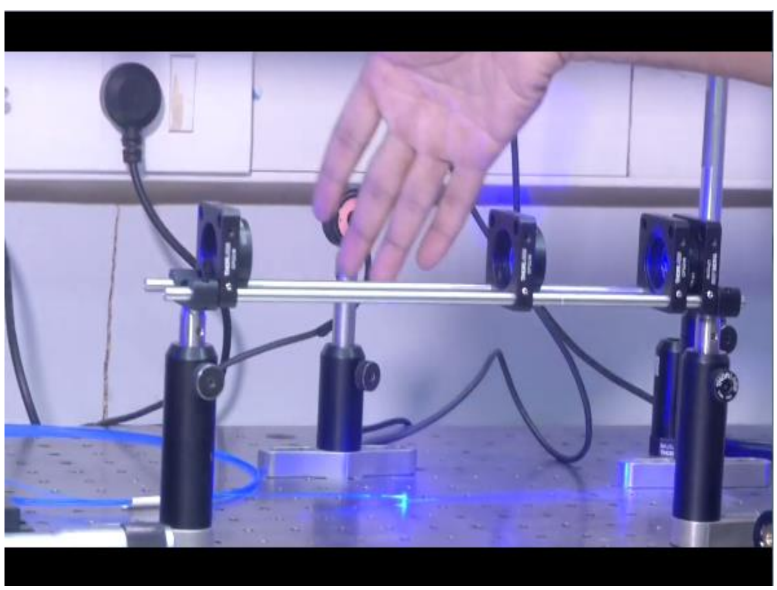

One of the habits is that to maintain a height of the laser beam right, so this is traveling in free space. So to maintain the height of this laser beam well below your eye level, right, so that is one of; so right now as you can see it is at my waist level. So typically that is the level that 3 to 4; 3

to 3 and half feet from the ground if you, you would like to keep that laser beam. Second thing is that we will show you how do we align it.

At that time, we will talk about a little bit more of the safety thing but then let us come here to very simple point where you know where the entry and the exit points of the laser beams is. So you want to make sure around that there are no, no chance of people coming in. Like for example if you see here there are spots of some scattered light here and here and here, right. So the reason why we have these boards here.

And the way, we have oriented this is just to make sure that for example this light is coming from reflection of these two so that it will go only from here. So once you align it you want to make sure that nothing is coming out from here and all of them are; all of them whether exiting out from your setup is blocked that is what I mean by saying, you know the entry and exit point so you block the exit points other than that I mean intended exit points, okay good.

So that is so much for the good habits and I am pretty sure the lab that you working will have a set of safety measures and you will be able to follow that and they will instruct you to follow that. So now here given this what we what the aim is to send the beam through an optical axis. So now what how do we define an optical axis? Remember, so the goal of this is to be; a goal of this experiment is we be able to couple the beam into this fiber.

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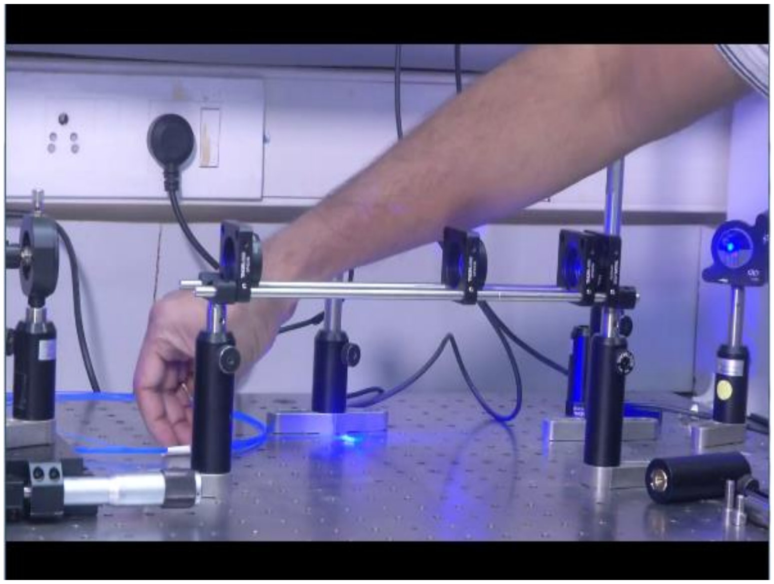

Now if you look at the beam if we look at the optical fiber this optical fiber is about it is one of the wider varieties it is a; the core of the optical fiber is about 400 micrometers. So if you look at the size of this it is about less than a millimeter is about 400 micrometers. We do not normally use it for any experiments here unless we want to have a very wide area illumination. Here I; we have put together this just for the demonstration purposes.

So now a 400 micrometer laser beam need to be in; I mean a 400 micrometer optical fiber needs to be kept at a position where the laser beam if you actually look at it from; just my hand you know easily it is about few millimeters or so, okay. So now how do we reduce the size of this laser beam to 400 micrometers and at the same time be able to get into the fiber, that is called fiber coupling.

So one is that you can actually match the point right, you have the think of this my; this being my the direction of the incoming light ray. And if my fiber face is this so what you are actually trying to do is you are trying to match this but it cannot be just matching to the point it also has to be to the angle and right it can be just; if it is like this you cannot hope the light will go through it have match the angle.

And on top of it you realize that if you have to actually make it to a small 400 micrometer beam you cannot have a 400 micrometer beam propagating in space you have to actually focus it down. So when you focus it down you have to match the front face of the fiber also to the focal point of the lens system.

Now why I am calling it as a lens system and not a lens, typically when you want to focus again we have seen this in the course; smaller the width of the beam that you want to get the larger you have to start with, okay. It is; if you want to get the smaller and smaller you want to get larger and larger. So if you want to do that naturally then what happens is that, this light beam need to be expanded so that expansion again we have seen is done through a telescope system.

We have two lenses and if you have two lenses kept at a distance of f1 + f2 then you know the incoming beam will undergo either a magnification or demagnification depending on the ratio of the f1 and f2. So once you have that in this case we actually try to amplify a magnifying tiny bit just to; I mean in this case actually there is a slightly different reason.

The light coming out from here the laser diode tend to be slightly diverging it is not collimator at all it is not; I mean if you take the center ray that is passing through the beam and the boundary ray they are not necessarily travelling in parallel to each other. If they start to travel with an angle to each other so then they start to diverge, so the size starts to increase. So to correct for that divergence it is always a good practice to put a lens system, two lens system here such that the light coming out from here the out of the two lenses are collimator.

Once you have the collimated beam and that is wider then you put in another lens which actually focuses it down to the point; at the point where you have your fiber. So clearly to match this in space you will need X, Y and Z, right all three different degrees of freedom. So the X and Y that is the movement of this face of the plate the fiber plate. I will show you the individual components of this fiber plate and how these things are put together in a minute but just bear with me.

There is a fiber plate that actually moves when you actually use this, okay use this screws to tighten it or loosen it and similarly what we have done is we have put in this assembly onto a small platform here, right. Now this platform is capable of movement and it is held in place by a nice spring lock system. Again you can actually see this can be done very precisely because there are micrometer readings that you can actually read and then go back to that same place so that every time you can be at the same place.

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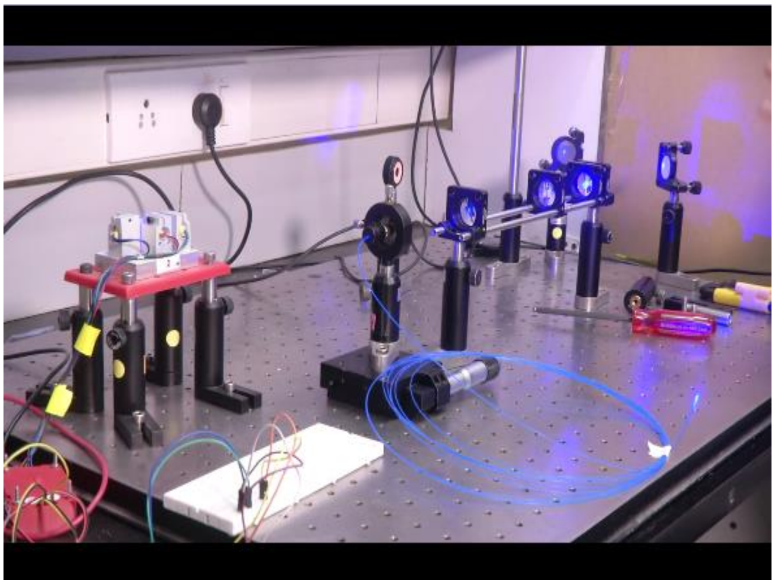

Now, so that is kind of the setup that we have and in the beauty of why we need this is that you want to optimize, you want to actually get the maximum power output from this device. So now how does one go about doing that. So it is very simple. Now the very, very crude way you can think of is to actually look at the power output the brightness of the beam shooting out to the; at a wall or a screen I mean typically we use a visiting card it is very good to; how was couple of visiting cards.

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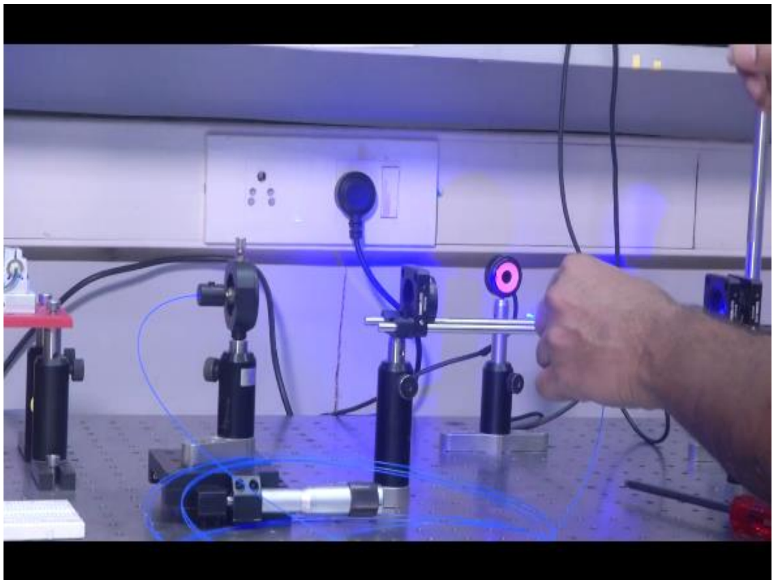

But you can actually see that and then increase the brightness, but that is only very qualitative. So what you can; what we have done; what we usually do is that we have a power meter it is actually a photodiode actually and that is this, right. Now this photodiode what it does is it is a capable of measuring the amount of light that is incident on it. So now what we; what we meant to do is; I am going to hold this fiber, okay of course I am going to hold this fiber such that I am not obstructing the light my hand is not obstructing the light. And then, now you can actually read out the power that is coming out from here.

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So as a very simple demonstration what I am going to do is that actually what; it is a good practice to actually hold it in place. So what we are going to do is I am going to stick this into this so that it is a held tight and we do not have to move it. I am going to bring this photodiode close to this, all right. So I wanted to place this fiber or and the photodiode such that I am not holding it I am holding it; I mean this held at a fixed position.

The idea here is that I want to keep the; keep; I want to send the beam light beam into this fiber in a best possible way I mean has; it has sufficient way as possible. So what does this do? This is a photodiode, right. And in the photodiode, photodiode is going to measure the light and the output of that it is connected to here to here. You can actually read, now here I have to actually adjust the wavelength to be 450, okay.

Now you are getting about 25 milliwatts out from this fiber. So the light coming in is also roughly about 24-25 milliwatts. So now the question is that how does this help. So now what we are going to look at is this number is going to tell us how efficiently I have aligned. So now carefully watch as I know each of this axis, alright. Now this is the first axis, so this when I move the fiber plate is going to move up and down like this, alright.

So you can actually see that as I go down it is actually going down so and; so let us say if you have started with some position like this what you want to do is that you want to actually move up, move up, move up you are keep going in the same direction until you keep increasing the power and now it starts falling down. So, so you go back and then leave it at the place where it is maximum and you need to do it for each of this axis.

So I am going to do that for the other access too which, which is not giving us much more but a little bit more. So now that would have optimized for your X and Y right. Now there is an optimization along the Z-axis too, so that is done through your; the; moving the platform, okay. We will see these individual platforms in a bit.

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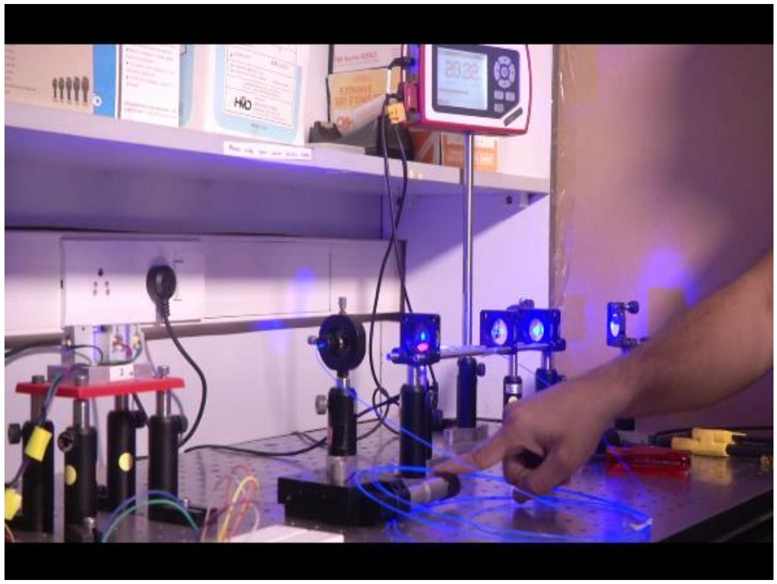

So; if as I rotate here this what you will see is that the platform is moving while the platform is moving; now this is little less sensitive compared to the other ones. You have to move quite a lot to actually get, get to that; that is because we are already in the optimal range, okay. So we come back and it is precisely for this ability that we can actually go and come back. We use this kind of amounts that allows you to precisely come back is called kinematic mounts.

So, so now that is a way of optimizing the light through the fiber, okay. Now to get to this point where we can actually keep a fiber plate and then move this in and around and to maximize your power output we need few other things, okay we are going to look at that one by one now. So to get; in order to get to this setup, I said we need a few things.

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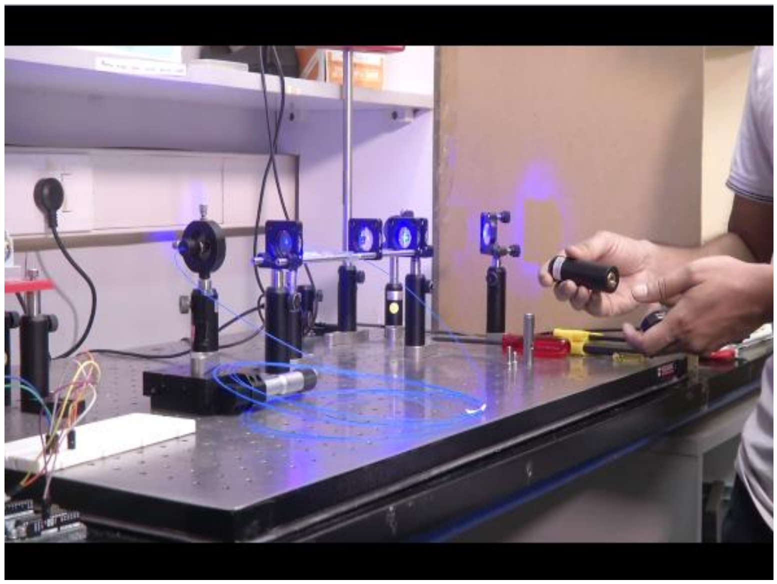

Now what I am going to talk to you about is that how we actually put together these individual components, all right. So the beauty of this; any optical setup is it is almost it is optomechanical components, okay. So you could generalize any of these set up into post, post holder assembly or cage assembly or a rail assembly. So what I am going to do; today show to you are two kinds. One is the post, post holder assembly and then also talk to you about the rail assembly, okay. And this purely mechanical things and we will see how these things are very, very handy and useful.

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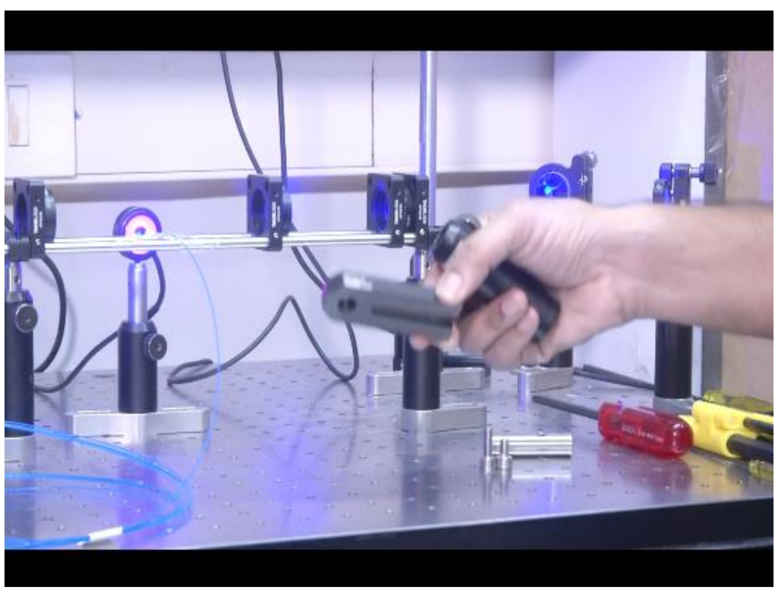

So now let us look at this, right. So we need some we need to hold the lens, okay or a mirror or a photodiode or our fiber. So then what we do? So all of them have one; few general things, you will have a base clamp okay there are variety of designs for the base clamp. The idea here is that this goes on to and breadboard optical breadboard where you see that; regular pattern of holes here. So you could actually the tie in any of this base clamps using this here.

But the point is that the base clamps go in such that they can take in the screw fell down so; accidentally. Now this is a good example where how do we actually go about doing things safely because we know the laser light is at this level, right. And of course I cannot see it because I am totally wearing the goggles and now I need to pick up the screw first thing I do is that I rotate my; rotate away from the optical bench, sit down not bend down sit down pick this, get up and come back to the position, alright.

And a second thing is it is always good to work near the table particularly when you are dealing with an optical component. It is a screw that falls down then no problem but then if you have an optical component like a glass or a dichroic as we will be handling later and if it falls down it can break. So you want to make sure that they are close to the table, right and we fix the base clamp, okay when to the post holder so that allows you to be able to place this anywhere on the table then we have posts, okay. This post that go in and then you can clamp on to this, okay good.

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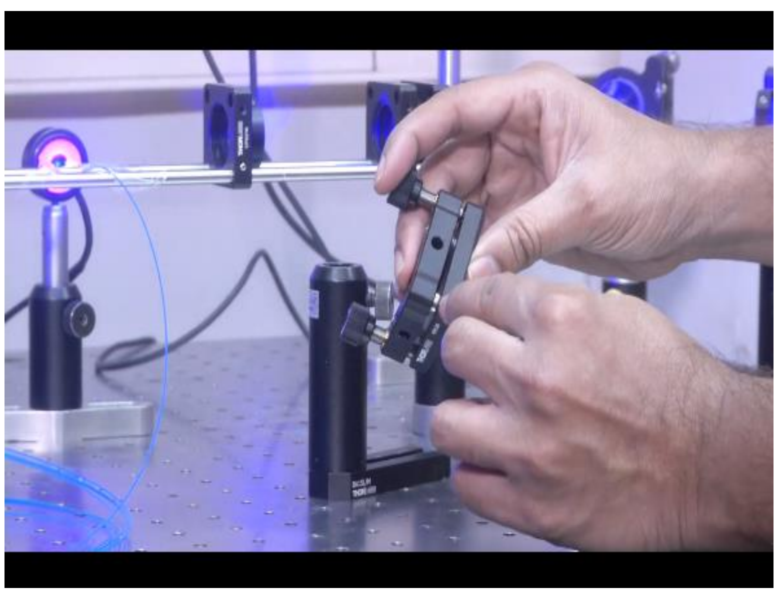

On top of this you will have several options one of them is kinematic mount, okay. So; and there are also fixed mounts but we are going to talk about the kinematic mounts here. So what happens is that the mirror goes in here and you will see you could use this through-hole, through countersink hole here to hold post downstairs like that, the whole setup goes onto the (()) (32:09). Now why we doing in this?

Now if you closely watch this kinematic mount has two parts two face, right. One is this here and the front. Now it is mounted with a ball right here and spring attached to place one and place two. The idea here is that you are actually holding; preventing these two plates to come together using a ball the plate will come together because they are attached with the spring so this is; the spring is pulling these two together and this spring is pulling this two together.

Now this allows you a very nice way of kinematically adjusting the mirror position because I can actually rotate this screw when I rotate it you will see that this plate moves with relative to this plate, okay. You can watch it closely, so alright. So same way you have it on the other axis too, okay. Good. So now this in turn allows you to operate on these two planes. When I rotate this you can actually move the mirror on about this axis, when I adjust this the one on the bottom then I get to move the mirror on this axis.

Now these are the two planes that we want to actually operate on right so that is you can think of this as if you are mounting it like this it is a vertical plane and the other one is the horizontal plane. We have two planes. One is a vertical plane and other is a horizontal plane.

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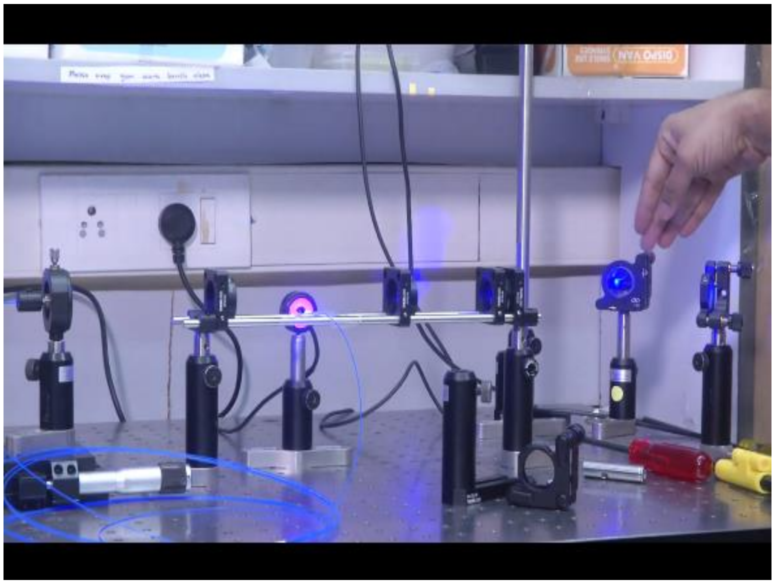

So now you see these nodes right are the variants of these modes being used all over, right; right here we have a mirror that is mounted on this kinematic mount and again on this other mount too. Using this; so we need two of this, right. We have seen this in the theory class that if you were in the theory that if you have to align a laser beam right that is a laser beam that is coming out like this and make sure that it follows a straight line, right.

Now what is that straight line in this setup; we will; the definition of the straight line is crucial and the definition of the straight line is provided by set of optical elements present here along with the fiber end, okay. So now; while we are talking about these parts we will see that; little bit more. But then having defined that straight line, now you need these two mirrors to be able to send the beam into this line, okay.

So now that; for that you need one adjusting the intercept and the other adjusting the slope, okay. This; the notion of the slope and intercept we have seen in the theory. When we come in the next lecture, we would see in practice what happens to this; the path; light path when we adjust these two.