Advanced Optical Communications

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Lecture No. # 39
Laboratory Experiment - 1

Let us now conduct some experiments on optical fibers. In next couple of sessions, we are going to demonstrate some experiments related to optical fibers, detectors, optical components and various other things. The simplest experiment one can do in the laboratory about optical fibers is launching of light in the optical fibers. So, in this experiment, now we are going to see what is required to create a demonstration experiment in the laboratory for launching of light in the optical fiber.

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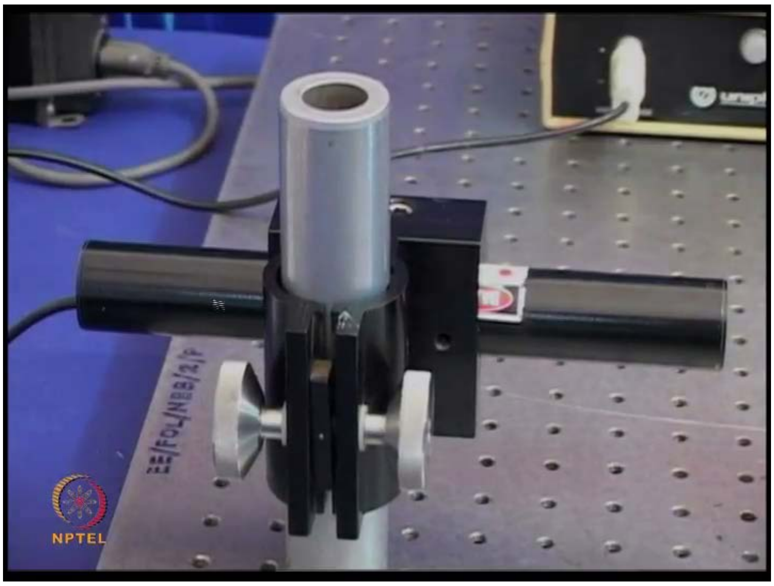

This is what is called the optical bench on which different optical components can be mounted. And this is a source, which is a helium neon laser. This is a power, which is supplied to this laser from here. And this is a tubeless structure; the laser light comes out from this end.

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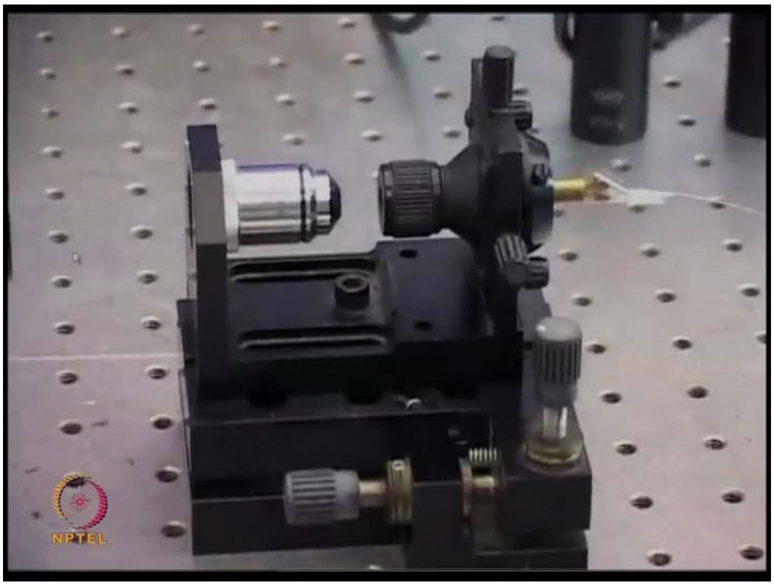

We use Helium Neon laser, because it gives you red color light and for laboratory experiments, this is in the visible range. This is assembly, which is used for aligning the optical fiber with a laser beam.

So, you see there are different knobs here which can be changed. So, that, the position of the optical fiber changes and there is a alignment of the optical fiber. This is a lens through which the light coming from the laser is focused on the tip of the optical fiber. One can have a closer look at the lens.

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In the experimental setup, we have lenses which have different focal lengths; which decide the distance at which the light is going to be focused.

And this is the tip of the optical fiber. This is a slot in which the optical fiber is placed. So, that it can be inserted into the assembly. So, you can see here, there is a small slot here in which the optical fiber is placed and the assembly is inserted in this mounting device, and it is tightened. So, that the assembly does not move. So, you have now the fixed location of the optical fiber. Another device which you will need for conducting the experiment is the optical detector.

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And this is the optical detector; you see this is the inner region here that is the actual optical detection device. When light falls on this, you get a photocurrent and the photocurrent is collected, and passes through this cable which is then amplified.

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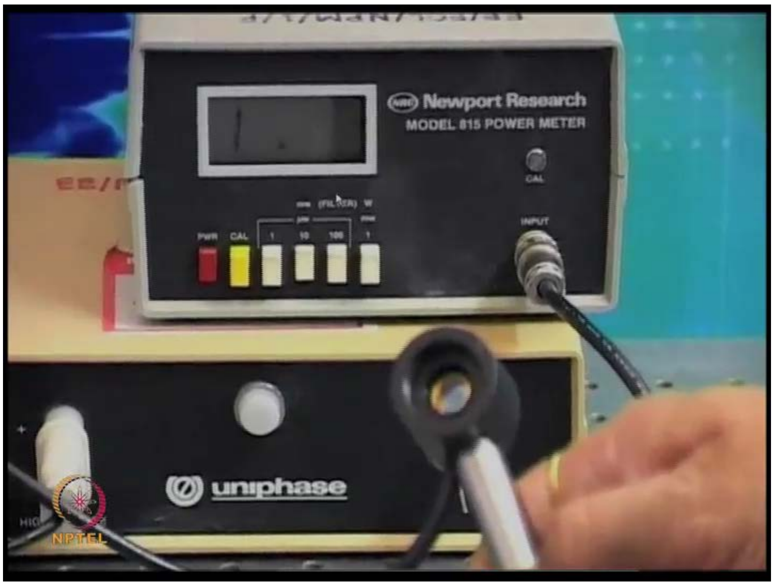

This is a device at which the photocurrent is amplified. And this is a display, on which you get the display of the current which is proportional to the intensity of light falling on the photo detector. So, this is the other end of the optical fiber, where light is coming out. This fiber is placed in front of the photo detector. This is the power source for the

Helium-Neon laser and one can see when we turn it on, you see the laser light coming out of this. Since after focusing, one can see it on a piece of paper. So, now, the laser is off, there is no light here. When the power is turned on, that is the laser beam which is reflected from the paper.

Then the light beam is focused by this lens on the tip of the optical fiber. You can see here, this is a tip of the optical fiber at which the light is focused and it is guided to this optical fiber, and reaches to the detector. You see, this is the output of the optical fiber; light is coming from optical fiber. Optical fiber is here, you cannot see it, but the tip of the optical fiber is seen very clearly; the light is coming out of this. So, now, you see, there is no light falling on the tip of the optical fiber. You see, the detector reading is about point three four. So, that is the reading corresponds to the ambient light which is falling on the detector.

You see, this is the fiber which is going like that and coming here, and is mounted in front of the photo detector. So, regular experimental setup would consist of a Helium Neon laser, a lens, a fiber mounting assembly, a detector and an amplifier for amplifying the photocurrent. Now the laser is on and you see the reading is now eighteen point six. It is a small fluctuation which we will always see, because there is always ambient light which is having a small variation or also there is a noise. And because of that you will see a small fluctuation in the detector output.

Let us now see, if we take this fiber and bend it. Look at the reading here, as we bend the fiber, you can see that the reading drops; that means, now the light reaching to the detector is reduced and that is what we normally see what is called the bending loss in the optical fiber. Whenever, a fiber is bent, there is a radiation loss and because of that the light leaks out from that bend. So, the other end of the fiber the light reduces. You can see again, the fiber is bent. We can see, now the intensity is again reduced at the other end of the optical fiber. Fiber is straight again and you see the reading is back.

And, that is what, we always emphasize while dealing with the fiber. That fiber should not be excessively bent. Otherwise, there will be loss from the bends. We are seeing here again the bending loss. So, see the fiber is coming here, when the fiber is straight it is dark, but as soon as the fiber is bent it starts glowing. And this glow is because the light leaks out when the fiber is bent. So, what we saw earlier with the help of the power meter, the same thing now we can see in dark. Now, when the fiber is bent, you see it starts glowing. So, there is radiation coming because of this bent.

One can see one more thing, and that is, if you press the optical fiber then it starts glowing. When I increase the pressure here on the optical fiber, it starts glowing. Why that happens? Because when you have a pressure on optical fiber higher order modes are excited, but these modes cannot propagate inside the optical fiber, because they are below the cut off. So, these modes essentially radiate out. So, slowly those modes radiate, but when we are having a pressure on the optical fiber, there is going to be excitation of these modes and that will result in to leakage of optical power.

Now, one of the things which one would like to know about optical fiber is called its numerical aperture. Now, a numerical aperture is essentially the sine of theta maximum or the cone, at which the light propagates inside the optical fiber. So, you see, if I hold the tip of the optical fiber away from, let us say some screen, then, this is the spot which is created by the light coming out of the optical fiber. One can measure the diameter of the spot; one can measure the height of the tip of the optical fiber from the screen and from there, one can calculate the angle of the merging cone of light.

So, one can use to get an approximate estimate of what would be the numerical aperture for this optical fiber; one can measure the diameter of this; one can measure the height of this and from there, one can calculate this angle which gives the numerical aperture. And as we know, the numerical aperture tells the launching efficiency of optical fiber; that means, if the fiber is put in front of light source. The rays within certain angle only can be accepted by optical fiber.

We know that, when the light propagates inside the optical fiber, it propagates in the form of modes. Here we are going to show you few more patterns which you see in the emerging light. You see, here, there are very clear; this four quadrants which you see here. So, that means, we are having a variation here which is a two cycle variations. So, the index which you see for this is nu equal to two. And, in the radial direction, you are having only one loop which is this.

So, this would correspond to a mode which is the Azimuthal index two and the Radial index one. So, that is the intensity pattern which you see. If you take a very multimode fiber, then there are large numbers of modes which propagate and when the light comes out of the optical fiber, the different modes have interference and that interference pattern appears in the form of what is called speckle. So, that is the typical tip of the optical fiber, we will see when large number of modes are propagating in the optical fiber and we can project the light coming out of the optical fiber on some screen.

This is the pattern, which is called the speckle pattern. And, this is created because of the interference of different modes propagating inside the optical fiber. So, you can see this is a very granular structure. You can see, there are dark spots and there are bright spots, and these are just the interference patterns which are almost random in nature. So, wherever, we are having coherent light; we see the speckle patterns, because the coherent light propagating by different parts have different phases and when the interference takes place a random pattern is created what is called a speckle pattern.

In this experiment, we will see the coupling and decoupling of light to a step index channel waveguide. This is a step index waveguide which is connected to a prism. First prism is a coupling prism; the second prism is used to decouple the light in waveguide. The assembly is used to change the coupling angle to the waveguide. You will see that, the end of the waveguide there is a bright spot. Here you can see, that the light is coupled the coupled light can be bent to almost ninety degrees.

This is a laser source, six thirty three nanometer laser diode. Light coming out of it is focused by a convex lens to the prism. Here, you can clearly see the guiding of light along the channel waveguide. This is a coupling prism; light is coupled to the waveguide and is guided to the other end. So, as we change the angle of incidence, you can see the change in mode along the waveguide. As you can see, a decoupled light on the screen; as you change the incident angle, you can see, there is a change in the lines on the screen.

The (( )) end mode changes with change in the incident angle. You can see change from two line pattern to a single line pattern. As we can see, two lines on the screen; as you change the angle of the waveguide, pattern on the screen changes. One of the important operations which we do on optical fiber is what is called Fiber splicing. Fiber splicing is exactly equivalent of soldering in electrical wires. So, as we all know, that, the fibers come in different sizes, different spools and they have to be connected, and this permanent joint which is there between the fibers is what is called fiber splice.

So, this is machine which is the splicing machine, which is used for joining two optical fibers. One can open this machine and see what the machine really contains. So, this machine is a fully automatic machine. You see, this is the place where the splicing takes place. These are two electrodes. And, these are the groups in which the fibers are placed. One can open this. And, the fibers are placed from two sides - one from this side and one from this side. They are aligned properly. Then after the alignment, the arc is passed by the electrodes. So, the fusion takes place between the two fibers.

Before, the splicing, the fiber phase has to be prepared. And, this is a machine which essentially cuts the fiber and creates the phase tip of the optical fiber flat. So, that when it is spliced, there is no excessive loss. Firstly, you see, this is a fiber here, which has a polymer coating; this is the actual bare fiber which is thin one inside that. This cleaved fiber is then placed inside the groove; this is the groove. And, by this clamp the fiber will be held steady before the splicing takes place. This is the other fiber which you want to join with this fiber.

Now, here, the display of the splicing machine which shows the alignment of the two fiber in two different plains: the horizontal plain and vertical plain. And, since, this is a automatic machine, you will see that, the fibers will be automatically aligned; when the button is pressed and also the phases are clean. So, that when the splicing takes place there is a good alignment of the fibers and less loss. When machine is initializing now. The machine has various settings. See, the fiber is aligning now.

The splicing has taken place, it is not a very good splicing. You see, there is a lot of gap between the two tips of the fibers. Let us do it again, because the splice was not very good. Again, you are seeing these two fibers which are getting aligned. You see, there is some problem here; there is a break in the fiber. So, it has to be redone. The splicing is done now. You can remove the fiber which is spliced. And you can see here, this is a joined fiber. This thicker one, which you see is the plastic coating; which is there on fiber.

So, you see now, for this machine there are various settings to this menu. See, you can change the conditions that, different function you can change and also there are some maintenance. And are instructions, you can use different types of fibers. These are different settings which you will see. So, you can set the arc temperature; you can set arc timing duration gap of the arc can be set. So, that was the experiment on the splicing of optical fibers.

In this lecture, we will see different types of connectors, fibers and adapters. This is a commonly used connector which is of the type as C. Here, we can see, there is a safety cap to protect the ferrule. Here, you can see, the surface of the ferrule is angled, this is SCAPC. This connector is also of the type SC, but here the surface of the ferrule is plain. This type of the connector is SCPC. This is another type of connector which is called the FCPC. PC stands for physical contact and APC stands for angled physical contact.

This is another type of connector called SMA. Here, you can see the difference in the thickness of the ferrule. This is a simple patch with SME connectors on both sides. This is another type of connector called ST connector. Specialty is that, the connector has a bonnet type of connection. This is an ST to ST patch chord. Now, this is a common adapter. You can see there is an alignment slot; this is used to connect two FC type of connectors. You can see the alignment key fixed in the slot and then it can be tightened.

Similarly, at the other end, we will have to align the slot with the alignment key. This is another type of adapter. So, here, one side is for SC and other side is for FC. This can be used to connect a patch chord with FC type of connector, to that of a SC type of connector. You can see, here also, the alignment key fits in the slot to ensure proper coupling of light. This is the adapter for ST to ST. You can see standard BMC type of goose on it. Here also, the alignment key has to be in line with the slot; this connector has BNC type fitting.

This is a spool of fiber, that is, bare fiber. You can see the glass fiber; this is also fiber with the connector fitted to the end. Fiber can be connected to the system using the connector. This is another type of plastic fiber with a SME connector; this is a plastic fiber. Light couples to the fiber at one end and it comes out at the other end. We can clearly see that, by blocking one end, the output of the fiber is switched. Here, light is coupled at one end of the fiber and it travels to the fiber to the other end.

This is a preform used to draw fibers. Here, you can see the core and cladding part distinctly. There is a difference in the intensity of light at the core and cladding. This preform is down to form fibers. These are some of the commercially available optical fibers. A number of optical fibers are combined in a cable. You can see the fiber at the center with protective coating outside. A number of optical fibers are enclosing a same cable. This is a bared fiber; this fiber is stripped at one end and you can see the difference in the thickness; you can see that this part is the core.

To remove the cladding of a fiber, we use stripper; this is a stripper. We insert the fiber at its end and just pull it. So, we can see that, the cladding is also removed. It has fallen on the paper. You can see, the difference between the core and the cladding distinctly here.