Fiber – Optic Communication Systems and Techniques

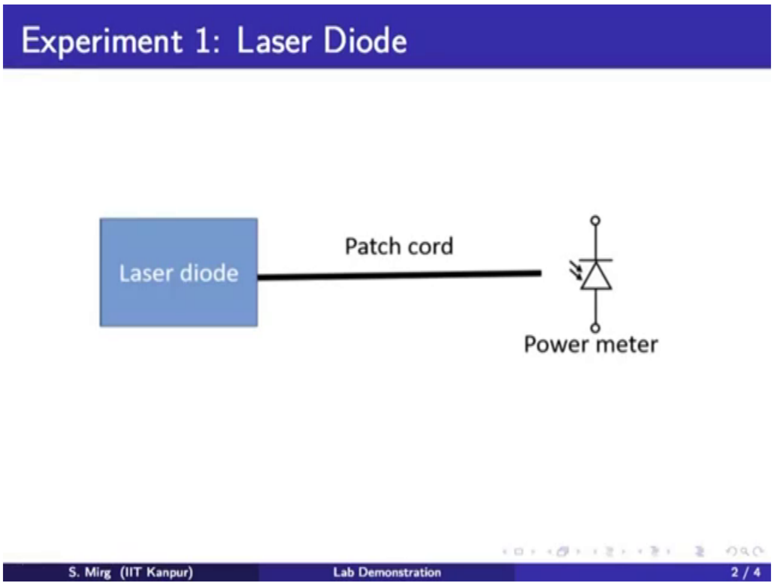
Prof. Pradeep Kumar K
Department of Electrical Engineering
Indian Institute of Technology, Kanpur

Lecture – 61

Lab Demonstration (Laser diode characteristics, Loss measurement, Optical Intensity Modulation)

Hello all! I am Shubham Mirg. I am the TA for the MOOC Fiber - Optic Communication System and Techniques. Today, we will be having a lab demonstration in the Fiber and Quantum optics lab. In the course, we have studied the theoretical aspects of fiber optic communication systems and techniques. Now, we will see how those theoretical studies that we have been doing transform into a real world applications and we will look for various components and we will demonstrate how simple modulation works as well.

(Refer Slide Time: 00:48)

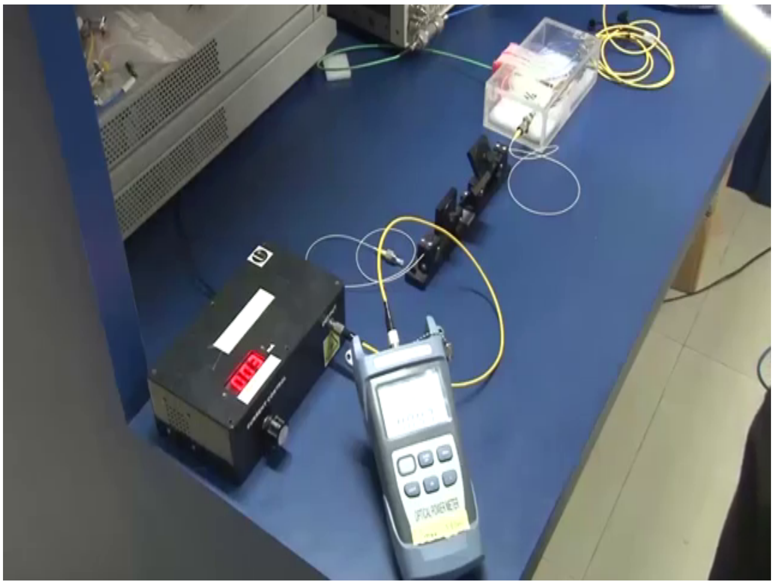


Experiment 1: Laser Diode

S. Mirg (IIT Kanpur) Lab Demonstration 2 / 4

So, we will start with the first experiment. As you can see on your screen, the experiment contains a Laser diode followed by a Patch cord and followed by a Power meter. I will explain each of the components. So, the first we have a Laser diode.

(Refer Slide Time: 01:02)



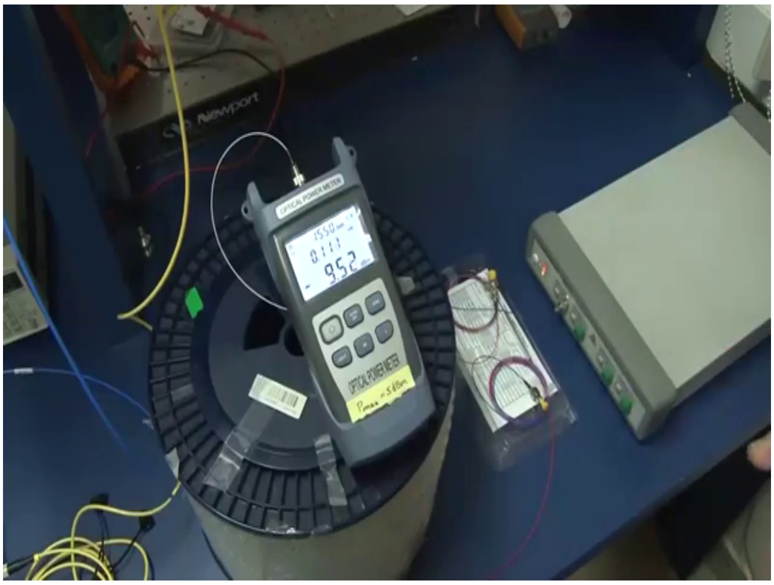
As you can see it is a black box here, it is a DFB laser.

So, unlike the conventional lasers which have two mirrors. In this scenario, we have greetings which act as mirrors and they a very wavelength selective. So, we can actually obtain a very narrow band a wavelength and this actually lasers at around 15, 50 nanometer which is the standard wavelength around which fiber optic communication happens because the loss at that particular wavelength around that band of wavelength is minimum which is around 0.2 dB per kilometer and the patch cord it is the yellow; yellow cord. It is a single mode fiber; it is 50 centimeter in length. As you can see its pretty study and then, we have a power meter which has an inbuilt photodiode.

So, the purpose of this experiment is to show you how we slowly as we slowly increase the laser current, we see that there is a dramatic increase in power after a certain threshold. So, that is how a normal diode would also operate. So, as we has, I will show you. So, this is lazing at 15 50 nanometer. That is very important to note and as we slowly on almost a lamplight increase to the current; we will see that we will see that the power is increasing. But it is not dramatically increasing. This no needs are increase in the power as you can see its minus 30 dBm minus 29 dBm minus 23 dBm minus 27 and we have a term 36 Milli Amplifier current. So, as you further increase to yeah. So, this is this is around where we see that you know with directly jump from minus 57 to minus 12 and as we further increase.

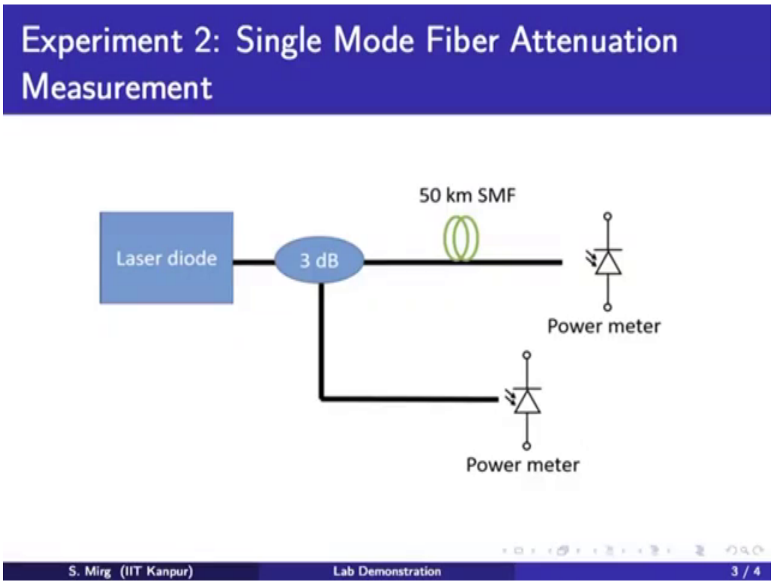
So, this is this is where the threshold starting to happen; energy further increase we can actually achieve around 0 dBm and you can go even higher we to keep in the safe unit, we will just go around 0 dBm. So, this was the first experiment. So, the purpose of this experiment was to show you how as increasing the current, we can see a threshold and we can actually the power would increase linearly and the slope of the graph if you extra polite to the x axis; where, the x axis would be the current of the laser diode. We can actually find the exact threshold value.

(Refer Slide Time: 03:29)



Now, we come to the second part of the today’s demonstration.

(Refer Slide Time: 03:37)



Experiment 2: Single Mode Fiber Attenuation Measurement

S. Mirg (IIT Kanpur) Lab Demonstration 3 / 4

So, instead of the laser diode which we manually controlling the current, we can actually have a programmable laser source, where we can actually control the amount of power. Even the wavelength can also be automated by programming the laser current and the cavity length. So, the first component is a tunable laser source as I mentioned and the second component as you can as you would have seen in the slides, which is 3 dB coupler.

So, 3 dB coupler is if you have to make analogy it is a power splitter as well as a power combiner. It is a split 3 dB means half power. So, it is a 15 50 coupler and so, if you have an input coming, it would actually split the input into equal halves. It would split the input into equal halves. So, we can see the current input power to this fiber spool which I will explain next is 0.48 dBm and equal amount of power is also going in the other arms.

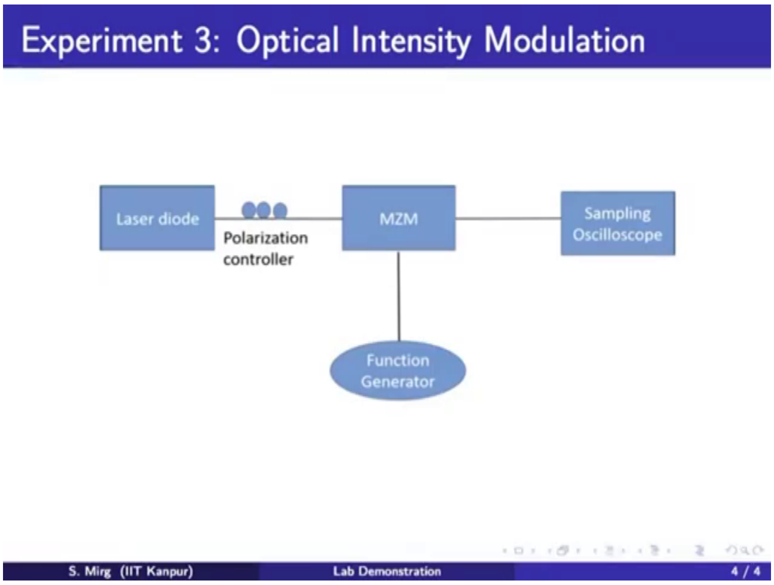
So, which is in the fiber spool which would again be 0.48 dBm and so, this is a 50 kilometer fibers spool. So, what we gone do is we actually going to measure the amount of power loss in this fiber spool and we will try to show you that when we say that the fiber loss is around 0.2 dB per kilometer. So, if you can measure the net loss over 50 kilometer fiber. Then, we can calculate what would be the actual loss of this particular fiber spool ah.

So, since we now I know that the input power is 0.4 dBm; please keep that in mind you can write it, probably write it somewhere and. So, if I disconnected and (Refer Time: 05:23) and it connected to the output of the fiber spool and I will show you what the power is and then will finally, make. So, the input power was 0.48 and as you can see the output power is minus 9.52 dBm which is receive over to actually yeah, yeah if you can see so which is minus 9.52 dBm.

So, the input power is 0.48 dBm and the output power is minus 9.52 dBm. If you over to subtract the net power which would be around 10 dB, which is very very close to 10 dB. This slightly more lose which can be attributed to the connectors here with these connector which FCBC connectors. So, as you can see the net loss can be approximate to almost 10 dB.

So, what does that mean? So, we have 50 kilometer fiber and the net loss we are observing is 10 dB. So, per kilometer loss of the fiber is 0.2 dB which is the number that we have been providing you in the lectures and so, this specific loss is around the wavelength of 15 50 nanometer and its one of the. So, this low amount of loss per kilometer actually helps to helps us to employee optical fibers over long distance communication. So, we come to the final part of this demonstration.

(Refer Slide Time: 07:06)

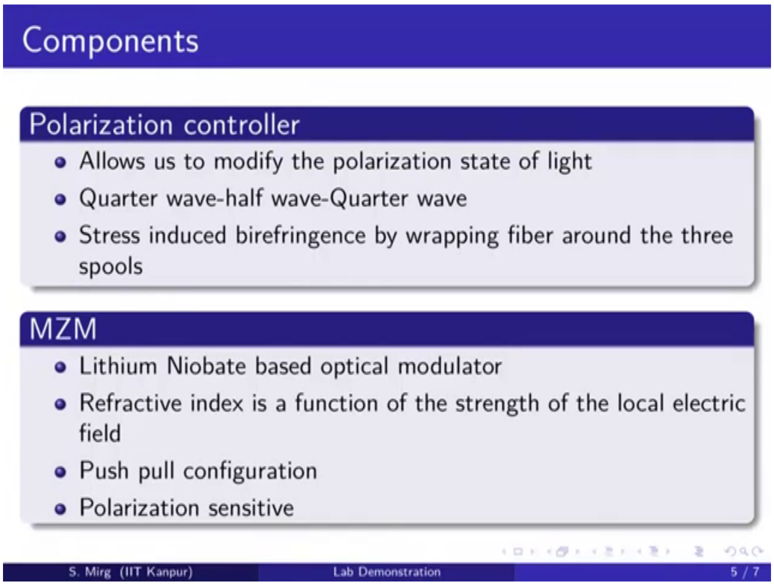


Experiment 3: Optical Intensity Modulation

S. Mirg (IIT Kanpur) Lab Demonstration 4 / 4

As you can see on your screen, we have the final setup which contains a Laser diode, a Polarization controller and MZM which is a magazine the moderator which has an RF input from the function generator and a sampling oscilloscope. So, we would like to give an introduction before we proceed to actually CBS component. So, as we have already seen laser diode we have a DFB laser diode and I have already explained that component.

(Refer Slide Time: 07:33)



Components

Polarization controller

- Allows us to modify the polarization state of light
- Quarter wave-half wave-Quarter wave
- Stress induced birefringence by wrapping fiber around the three spools

MZM

- Lithium Niobate based optical modulator
- Refractive index is a function of the strength of the local electric field
- Push pull configuration
- Polarization sensitive

S. Mirg (IIT Kanpur) Lab Demonstration 5 / 7

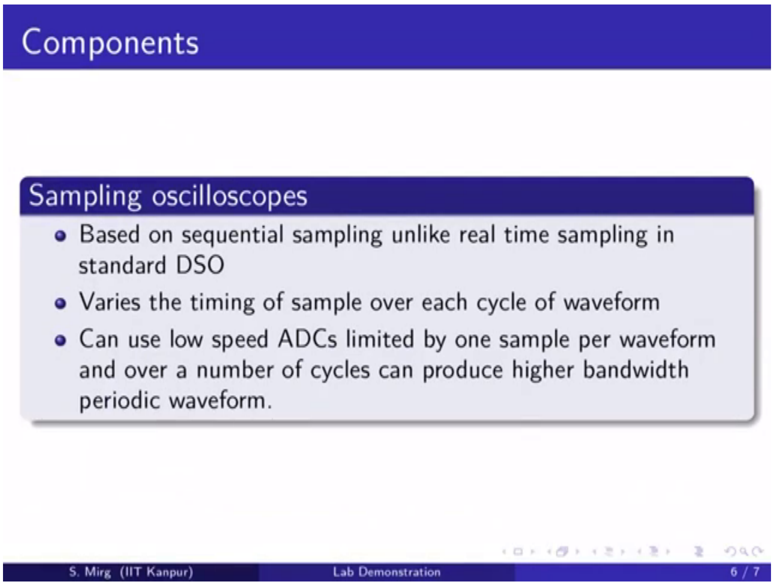
Next, we follow at with a Polarization controller. We will see in a moment what Polarization controller looks like. So, the Polarization controller, the function of the polarization controller allows us to modify the polarization state of life. So, it contains 3 places which is a quarter wave plate followed by a half wave plate and a quarter wave plate again.

So, by modifying the angles of the plates, we can actually control the polarization of the light. So, it works on the stress induced birefringence by rapping fiber around the three spools, in the 3 puzzles respectively. So, then the next component we have a Mack Zehnder Modulator is. So, the one that would be present in the lab is a Lithium Niobate based optical modulator.

So, the Lithium Niobate crystals are actually the refractive index of these crystals, as a function of the strength of the local electric field and we have the crystals in a Mack Zehnder Modulator configuration. So, as we vary the voltage across these crystals in a push pull configuration as already discussed in the lectures. We can actually achieve in density modulation and the other thing is the polarization sensitive. So, it is imperative for us to have a polarization controller before the optical modulator and then, we have a function generator which actually provides an RF input.

So, this can be pulses; this can be are data or this can be infact the modulated data as well.

(Refer Slide Time: 09:03)



Components

Sampling oscilloscopes

- Based on sequential sampling unlike real time sampling in standard DSO
- Varies the timing of sample over each cycle of waveform
- Can use low speed ADCs limited by one sample per waveform and over a number of cycles can produce higher bandwidth periodic waveform.

S. Mirg (IIT Kanpur) Lab Demonstration 6 / 7

And the last component in the slide that you can see is a Sampling oscilloscope. So, Sampling oscilloscopes are actually different from the standard digital storage oscilloscopes. They are based on sequential sampling; unlike real time sampling in the standard digital storage oscilloscopes. So, in a normal in a conventional digital storage oscilloscope, what we will have?

We will have an ADCs and it will sample each cycle and its limited by its speed and it would it would have consecutive samples periodically. But however, in the sequential sampling, we will vary the timing of the sample over each cycle of the waveform and over a number of cycles; we can actually reproduce the waveform in the sampling oscilloscope.

So, this actually allows us to use low speed ADCs which are just limited to sampling, they form data at one sample per cycle. So, that is the limit of the ADC that we can have. And we can actually over a time, we can actually would have a reproduction of a high bandwidth signals and so, we can actually go up to 20 gigahertz even though the adc might be at a lower speed.

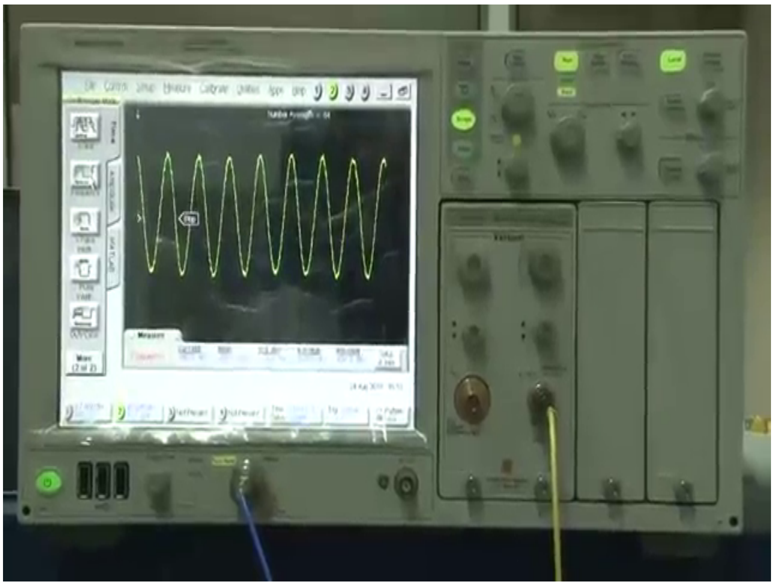
So, that sampling oscilloscope in that sense helps us to actually capture wave form data at the even a higher frequency as compared to standard digital storage oscilloscopes which are limited by this speeds of the ADc itself. Now, come to the set up here. I will run you through all the set up that we have here. So, first we have the standard DFB 15 50 nanometer laser diode, then we move on to polarization controller. So, as you can see it has a 3 parallel as I mentioned. So, this is a polarization maintaining fiber. So, in each of this parallel, the fiber is wrapped around these spools and we can actually has stressed induced birefringence.

And so, as we will vary these angles of this parallel, we can actually change the polarization of the light and the next is the Mack Zehnder Modulator. So, with if we can zoom in on this picture, it is inside this box it is very compact and so, it is not bi-direction which uni-directions. So, we need to take care of where to where to provide the input and where to take the output from and then, there is in RF signal that is being applied through this function generator.

(Refer Slide Time: 11:24)

We are actually applying a 400 megahertz signal and so, it goes, it comes, it goes into power splitter and like one part goes into the Mack Zehnder Modulator; the other part we used for triggering the oscilloscope, which I will also explain in a moment and then, we have another patch cord connecting the output of the Mack Zehnder Modulator to the white band oscilloscope ah. So, the currently there is no data worth, you just look at the data.

(Refer Slide Time: 11:54)

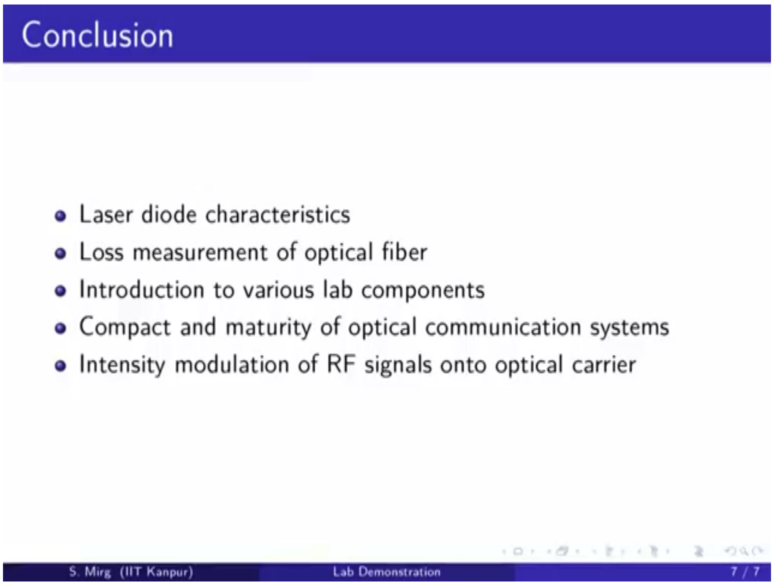


So, in the function generator as we can see we have a 400 megahertz inputs signal to the Mack Zehnder Modulator and it actually modulates the incoming optical input to the Mack Zehnder Modulator and as we can see it goes into the oscilloscope which has a photodiode and we can actually recover those pulses. As you can see the reading here is 400 megahertz which is around that has if you can see that we actually recover a sinusoidal RF input as a sinusoidal optical input.

So, this actually shows how a basic modulation of the optical input can be done and the another important thing is that this Mack Zehnder Modulator as a previously mentioned is polarization sensitive. So, now, if I were to vary the angles or the controller, we will see that the optical input actually starts coming down.

So, this shows the polarization dependency of the input to the Mack Zehnder Modulator; so which important for us to have a polarization controller beforehand. So, we can align the incoming light polarization according to the access of the Mack Zehnder Modulator itself, which is a Lithium Niobate crystal base Mack Zehnder Modulator which base and this modulation is on the basis of the electro optic modulation effect and there were other types of modulator as well. But Lithium Niobate gives you very high frequency performance and so, and a good dynamic range as well. To conclude, with a 3 experiments today.

(Refer Slide Time: 13:30)



Conclusion

- Laser diode characteristics
- Loss measurement of optical fiber
- Introduction to various lab components
- Compact and maturity of optical communication systems
- Intensity modulation of RF signals onto optical carrier

I showed you how a 15 50 nanometer Laser diode operates and then, we moved on to the loss measurement of 50 kilometer fiber and as we have seen in a lecture itself that the laws measured is around 0.2 dB per kilometer and in the lab conditions we can actually show that the loss came out to be 0.2 dB per kilometer. Hence, agreeing with the theory.

And we also saw what various component looks like and how compact the technology the fiber optic technology has become a no commercialize it is and how mature the technology has become over a period of time and also the last we actually should a very simple modulation we actually had an RF include of a sinusoidal wave of 400 megahertz.

Then, we provided this modulation RF modulation input to the Mack Zehnder Modulator which had an optical input continuous optical input coming. So, the because the refractive index of the Lithium Niobate crystal changed according to the electric field, which the electric field was provided by the RF signal itself. We could actually see that the modulation because of the push pull configuration of the Mack Zehnder Modulator, the optical input was intensity modulated and then, we connected to a sampling oscilloscope we actually also.

So, what the difference between a sampling oscilloscope and the real time oscilloscope and we have actually recovered precisely the RF input that we sending which was a 400 megahertz sinusoidal input and we are recovering a 400 megahertz sinusoidal input. And also if you were to vary the frequency, we will see that that frequency would be reflected on the oscilloscope itself. So, if I were to make 400 let say 800 megahertz. This is a very basic modulation scheme, we have a sinusoidal input to the MZM and in practical applications, we actually go to even higher order modulations. Then, we have INQ arms modulation. In this is which is 4 QAM and QPSK modulations which schemes.

Thank you.