Introduction to Photonics
Professor Balaji Srinivasan
Department of Electrical Engineering
Indian Institute of Technology, Madras
Manipulation of Light Electro Optic Modulator (EOM)
Lab Demonstration

Hello, welcome to the lab session of introduction to photonics, I am Bhagat, today I will be demonstrating to you the experiment of Mach-Zehnder modulator, so through the theory classes we have been learning about modulation of light and density by modifying different aspects of light such as phase polarization, etc. So this modulator which I am going to demonstrate today is based on the nonlinearity property which is nothing but the Pockels effect of light and it is (())(0:51) effect, we are giving a high voltage across the nonlinear crystal it will effectively add a delay in the light phase.

And what I am handling is a Mach-Zehnder modulator here which is nothing but an electro optical device. So the main aim for today is to first to characterize this Mach-Zehnder modulator, then I will show you what all operation points it can be biased on and how we can give a modulation signal and I will show you how the modulation frequency (())(1:27) and the frequency modulation principle of the Mach-Zehnder modulator.

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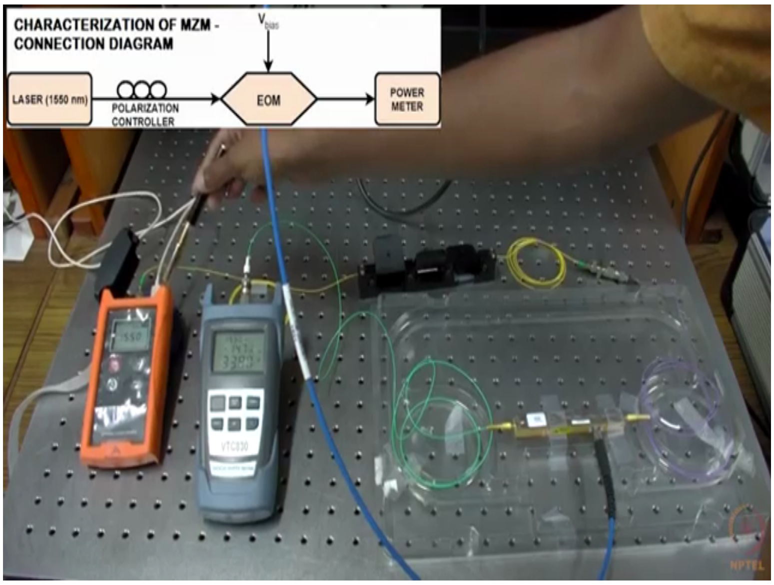

Let me go into explain the components that we are using for characterizing the Mach-Zehnder modulator, here in this left side of your screen you can see the source this is nothing but a hand held power source of a 1550 nanometer wavelength and it can generate a power of maximum upto minus 5 dBm value.

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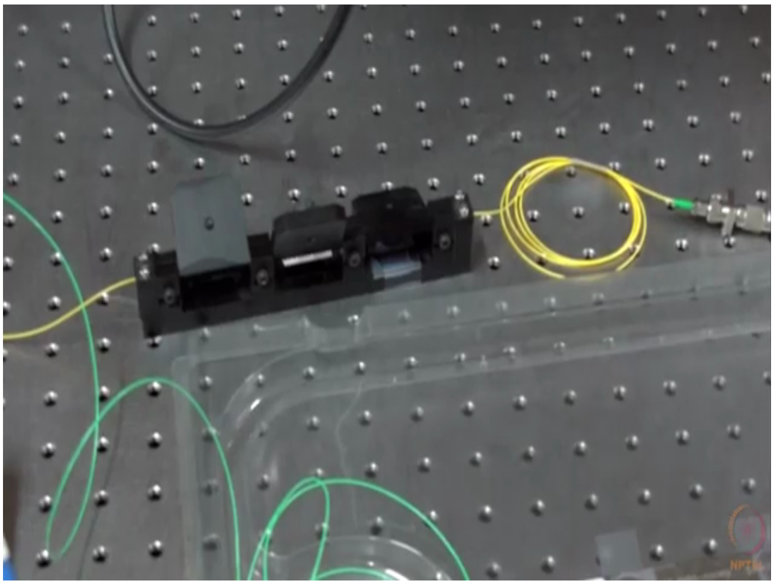

And the source is now connected to this device which here you can see which is nothing but a polarization controller a fiber polarization controller, this is very essential for Mach-Zehnder modulator because this Mach-Zehnder modulator which we have here it is a polarization sensitive device. So we need to adjust whatever polarization given by the source we need to adjust using this polarization controller to give as an input to the Mach-Zehnder modulator.

So this polarization controller basically contains this paddles which we can turn it around. Now this contains three components basically one quarter wave plate, one half wave plate, and again another quarter wave plate with the combination of these three devices we can align the orientation of this quarter wave plate and half wave plate by (turning) rotating these paddles here.

So by aligning the quarter wave plate, half wave plate and the quarter wave plate essentially we can move from any polarization state to any other required polarization state, we cannot see which polarization it is giving an output but ideally it can convert any random polarization input to any random polarization output. So this is an essential device before giving the light input to the Mach-Zehnder modulator.

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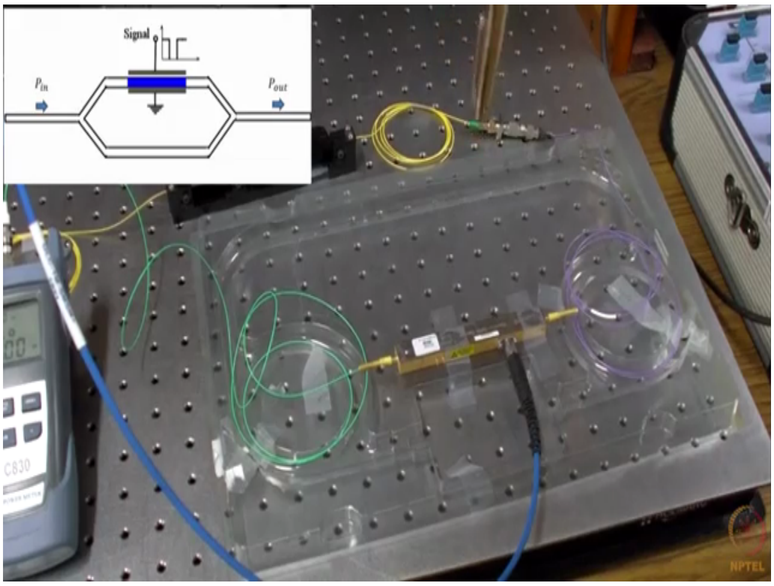

So as you can see the output of the polarization controller is connected to the input side of the Mach-Zehnder modulator here. So this is nothing but the electro optic modulator which we have which is an electro statistically sensitive device ESD device we need to have proper (()) (3:48) ground protection to touch it, so I am not touching it at the moment. So the cable which is connected here is nothing but the DC voltage which we are giving at the electro optic modulator.

So the input comes from this side which is already polarization controlled and the output is given coming through the other end of the Mach-Zehnder modulator. So you can see the configuration inside this module in the inset, there you have a Mach-Zehnder modulator configuration in which one (())(4:21) in one (())(4:22) there is a lithium niobate crystal, which is nothing which is having a highly nonlinearity, its electro optic coefficient is pretty high.

So according to the voltage given across the crystal it will add a phase delay to one (())(4:40) of the Mach-Zehnder modulator and that will essentially control the light output of this particular device. So you can give a frequency to this particular modulator and you can modulate the light intensity output of the modulator, for this particular module we can go even upto 10 gigahertz, so we are not in a state to check the bandwidth of that this particular device but what we will go ahead is to characterize this particular device and where are the (())(5:11) points.

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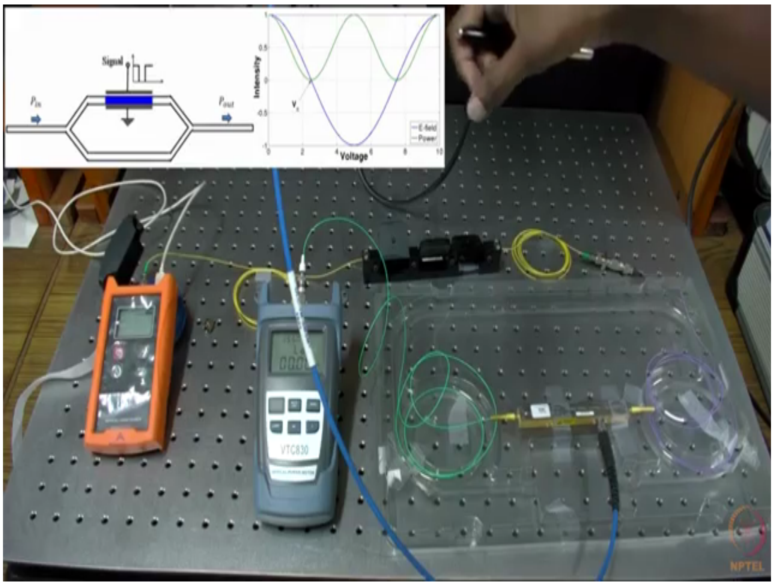

So the output is connected to a power meter which is nothing but a hand held power meter, we can see how much power is fed into this system and what I am going to do is first turn on the system, then I will adjust the polarization controller such that a sufficient amount of power is going we are seeing at the power meter, then I will vary the DC power voltage DC voltage that is given to the lithium niobate crystal or the electro optic modulator which will essentially vary the output power we are getting. So this is the characterization step, so let me go ahead to demonstrate that.

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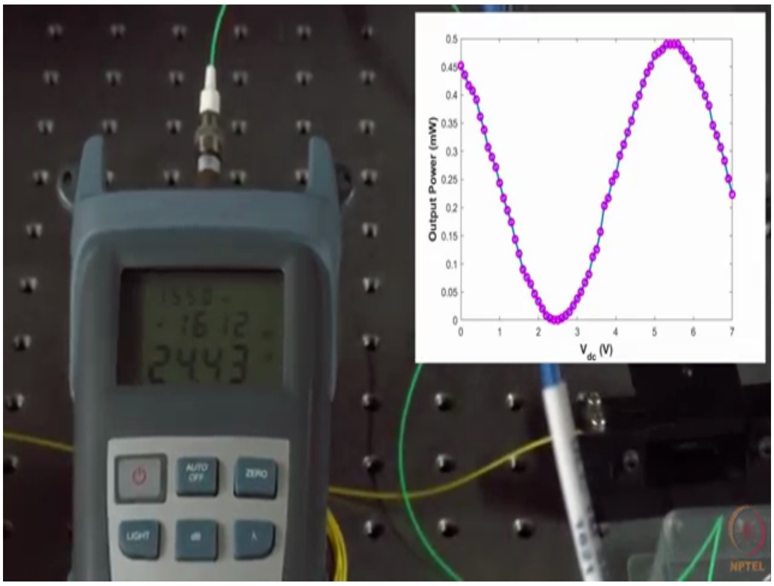

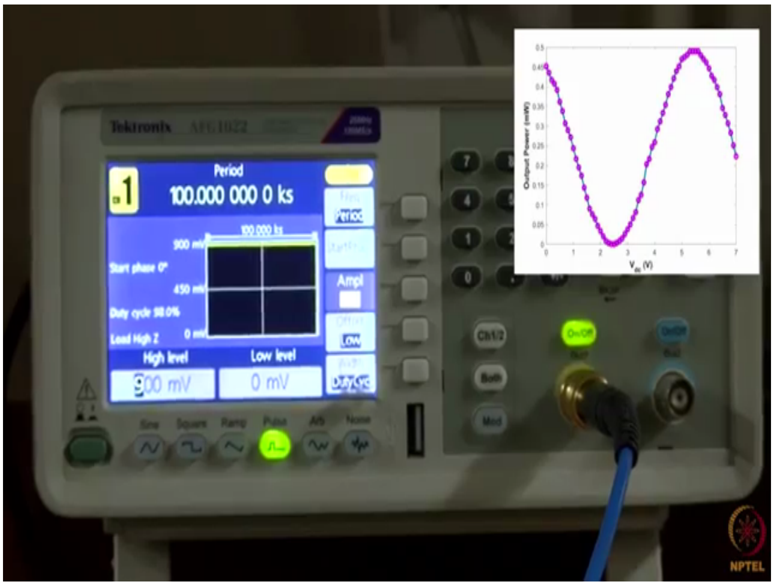

So for characterizing this electro optic modulator I made the connections as shown in the inset, so what I have here is signal generator where I can vary the voltage bias that is given to the Mach-Zehnder modulator. So the signal generator I configure in such a way that I can increment the voltage in steps of 100 milli volt, I can go to 100, 200, etc even upto say 7 volts or 5 volts, so this data I have already taken, this increment I will be doing parallelly and this output power from the Mach-Zehnder modulator is measured using this power meter.

So you can notice that why light change the voltage here, the power will be varying on the power meter and the power meter variations can be noted down for each steps of increment of the voltages for 100 milli volt, you can decide the steps and the data is already collected and the graph is plotted with the data collected is spread on the screen. So these variations of output voltage by the change in the output light by changing the input bias voltage you can see that in this particular curve is say cosine square is curve and you can see therefore what particular voltage bias the output light is varying and you can see when it is going to minimum and when it is going to maximum.

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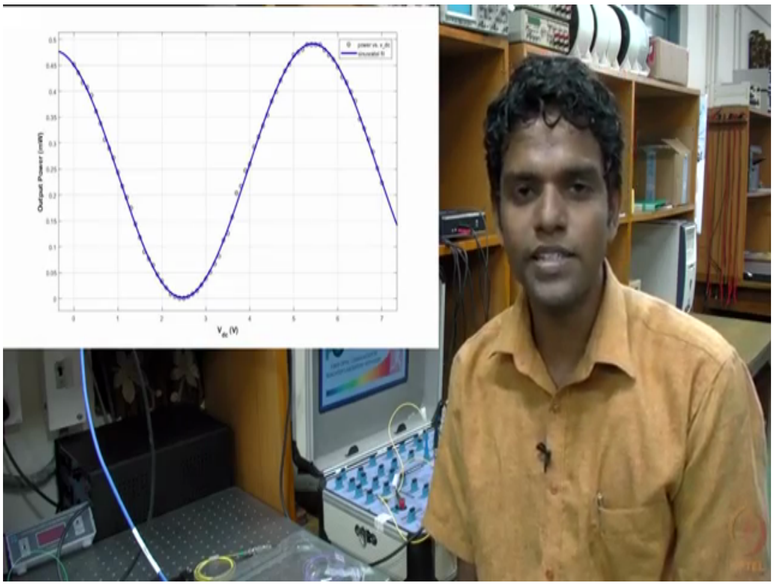

As I mentioned the data is already collected and you can see the curve plotting on the screen, so this curve is nothing but a cosine square curve and you are varying the voltages and the power output is varying power output is changing as shown in the curve, you can fit this curve with a sinusoid and you can get a smother curve, the main idea of characterizing this Mach-Zehnder modulator is that you will get a knowledge of where to bias this particular Mach-Zehnder modulator.

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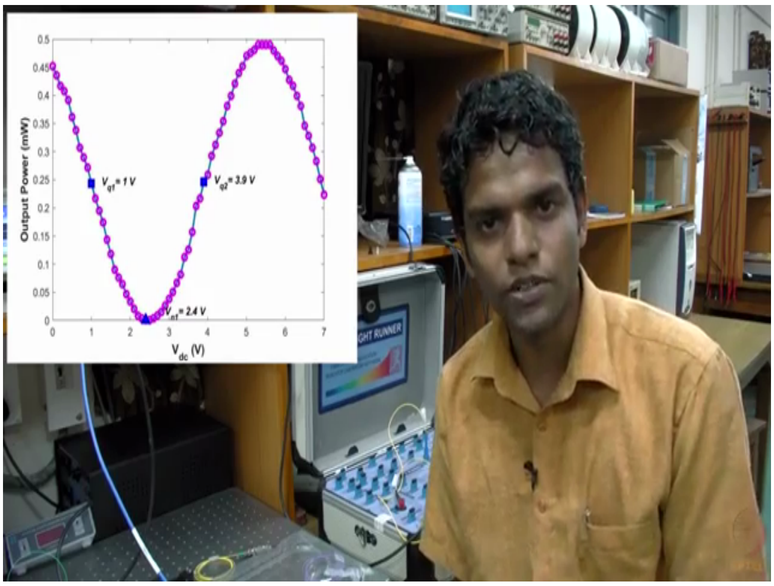

So you can see that in the curve shown in the inset I already highlighted the two points which is nothing but the quadrature points where the sinusoid goes almost linearly and I highlighted another point now which is coming in between where the output light (())(8:32) is 0. So these points are nothing but the bias points and keeping that as an offset you can give a sinusoid signal to the Mach-Zehnder modulator.

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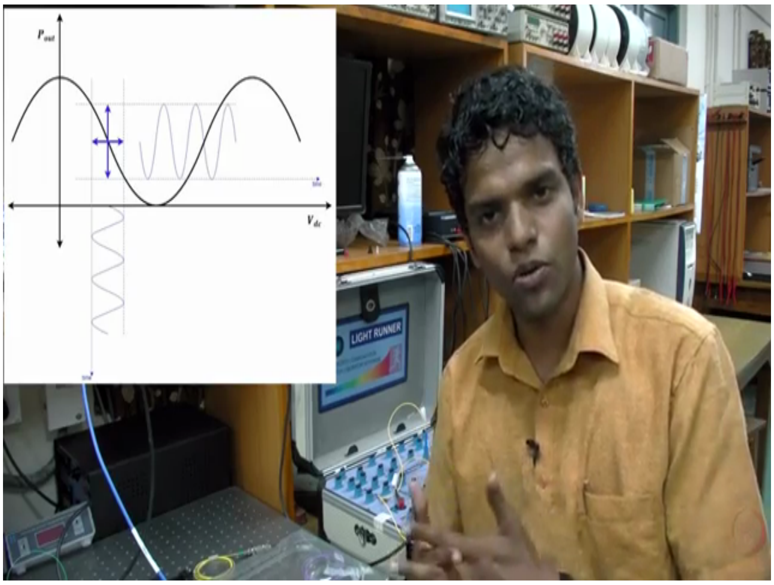

The operation of this output Mach-Zehnder light output can be explained further using the help of some other figures. Consider if the Mach-Zehnder modulator is biased in the quadrature point as one of the quadrature point as shown in the figure and if you are giving a sinusoid over it, you can see the variations will be happening on the bias voltage and according to that the output light and density also changes. You can see since it is biased on a linear region of the cosine square curve the output is also having the same frequency.

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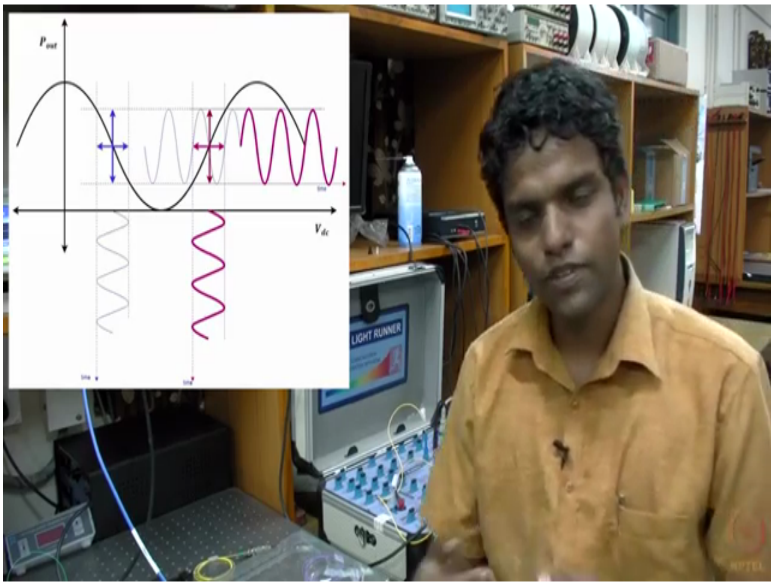

Similarly in the curve you can go for the another quadrature point also, where also you can put a sinusoid over it, it will again yield a sinusoid light output in the same frequency.

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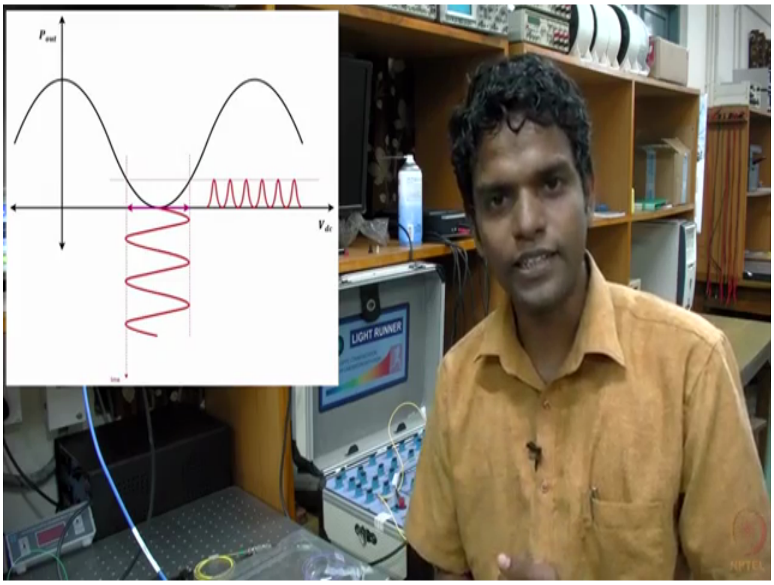

But considering the null point here in the centre if we are giving a sinusoid here, what you can observe is that you will again get a sinusoid curve but please keep in mind that the frequency will be twice the frequency. So you can have these two main modes of operation for this electro optic modulator, you can bias either on the quadrature points or in the null points. But please keep in mind that while going for the null point the output light and density peak to peak will be very low.

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So this frequency you can go upto even 10 gigahertz so it is a pretty faster device. So now I am going to demonstrate to show you in the oscilloscope how the frequency is varying while we are going from one quadrature points to the null point, so that will give a sense of light modulation using an (())(10:45) frequency which is connected to the electro optic modulator.

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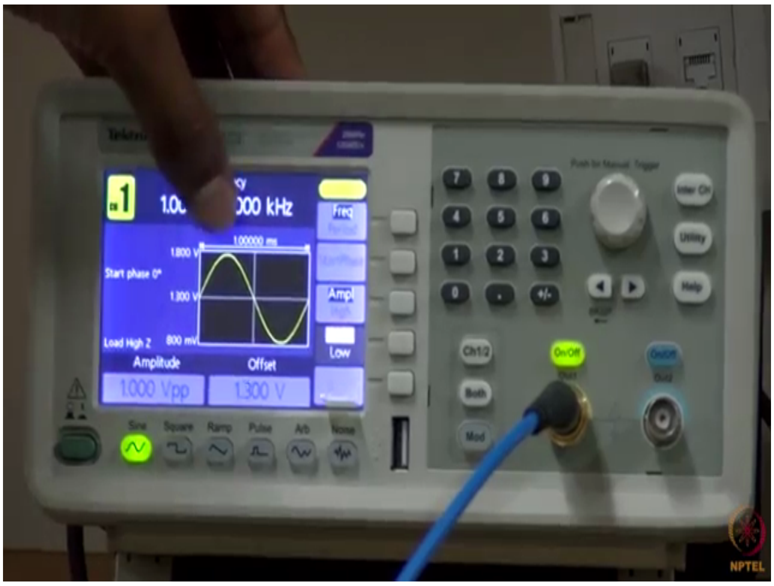

I went on connecting this particular setup to modulate this light output using this electro optic modulator. So while connecting to this electro optic modulator please keep in mind the precaution like you should give the light input first, then you need to give the bias voltage later. So first we need to ensure that the light is turned on, then you go for the bias voltage. So what I have here is I give a sinusoid signal keeping the offset voltage at whichever point you want to bias this electro optic modulator.

So in this case I am giving a offset voltage of 1.3 volt which is nothing but a quadrature point, so it is operating I ensure that it is operating somewhat on the linear region of the transfer characteristic of the electro optic modulator. So you can go on increasing this offset voltage by turning this nob here and you can see the corresponding output on the (())(11:55). So you please notice the output waveform that I am obtaining here while connecting while giving this offset of 1.3 voltage in this (())(12:07).

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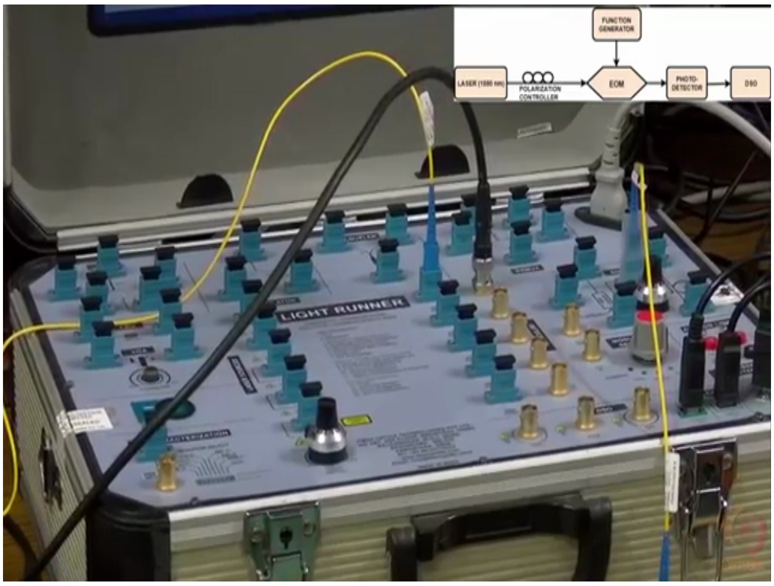

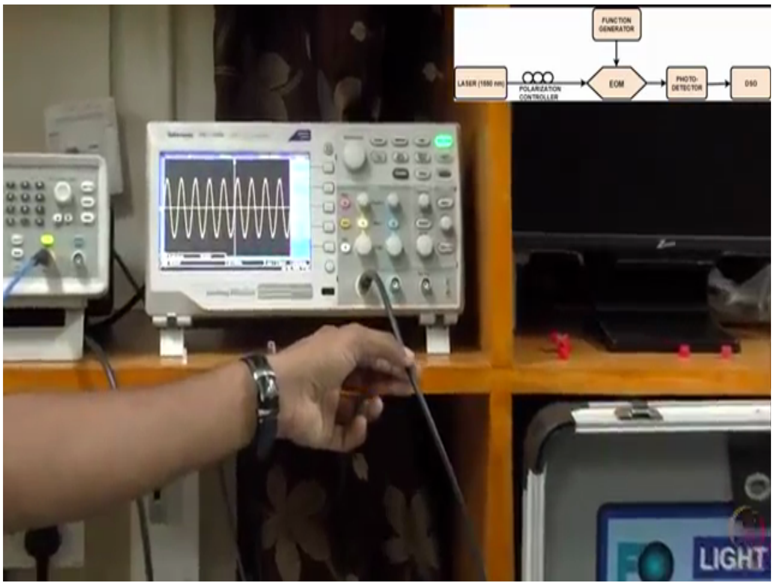

So this particular curve I obtained by connecting the Mach-Zehnder modulator output, I connected the Mach-Zehnder output to a photo detector which is which is already in the light runner kit and I am taking a photo detector output connected back to the DSO here, so it is nothing but the modulation light output while you converted into an electrical signal which in turn we are seeing in the DSO.

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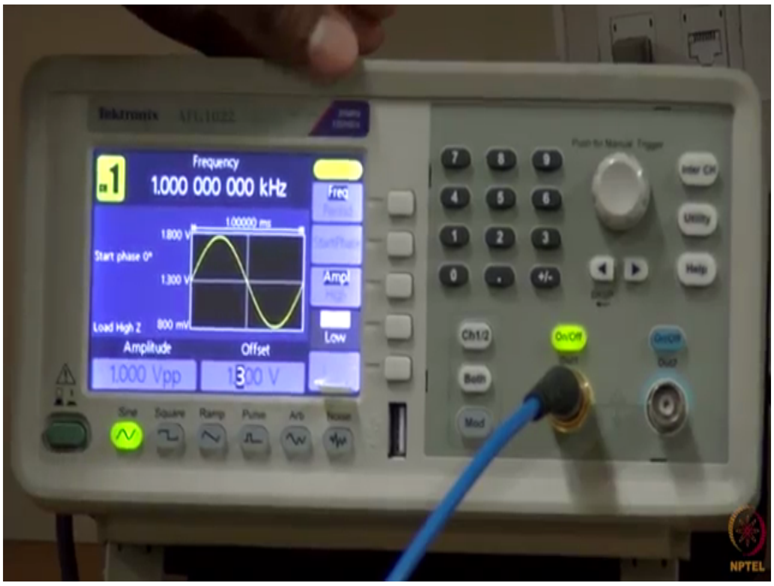

So please notice that the offset voltage given is 1.3 volt and I am giving a peak to peak voltage of 1 volt and it is a sinusoid of frequency of 1 kilohertz.

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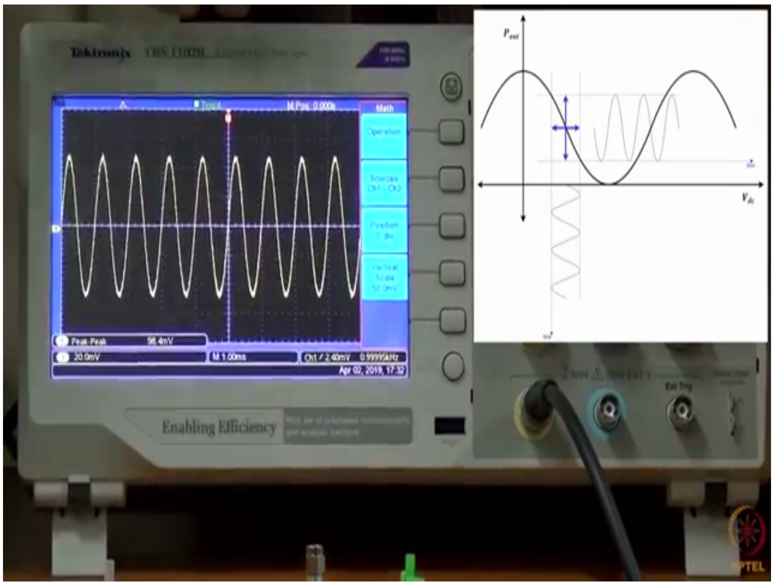

So this particular when this particular bias signal is given to the Mach-Zehnder modulator electro optic modulator, I am getting this particular output as you see. So this is again a clean sinusoid almost working on the linear region that is why you are seeing a clean sinusoid.

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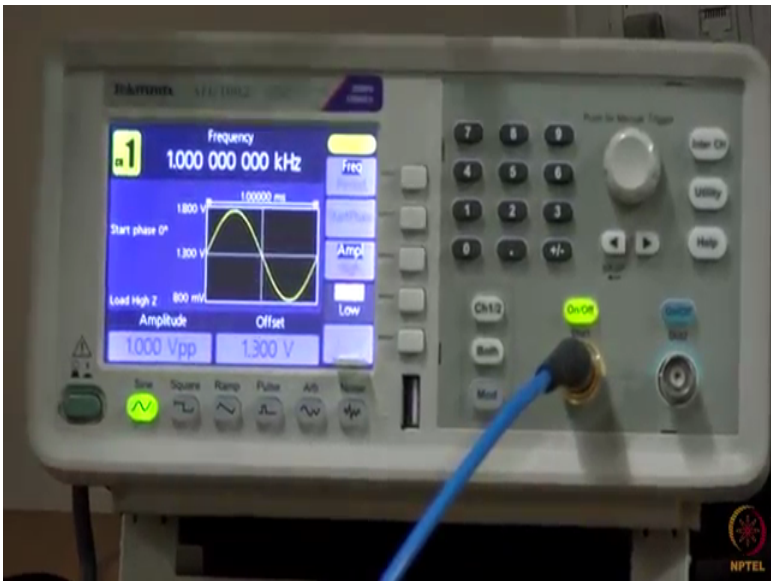

So I am going now to increase the voltage from this quadrature point to a null point.

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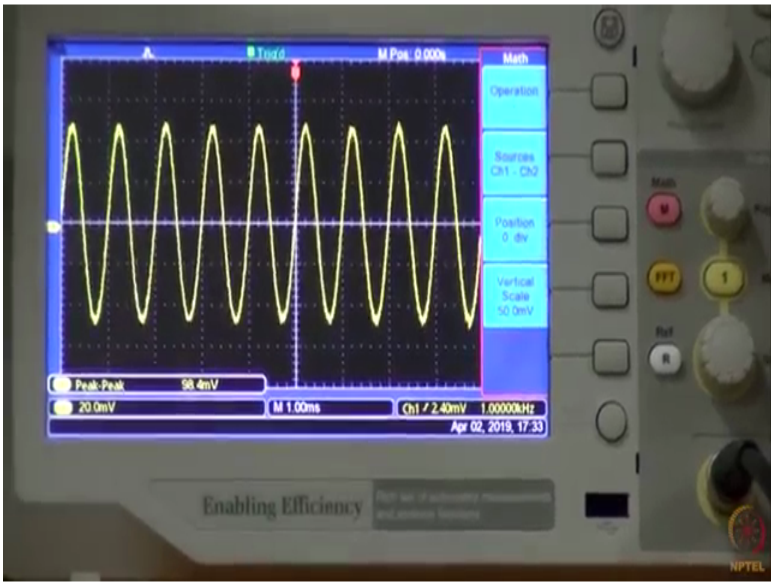

So while I am going through you can clearly see in this screen you can clearly see the frequency is varying.

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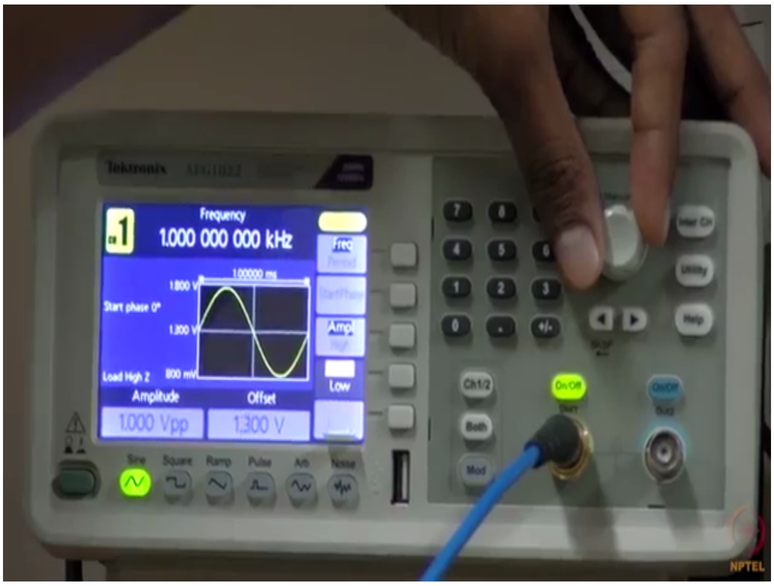

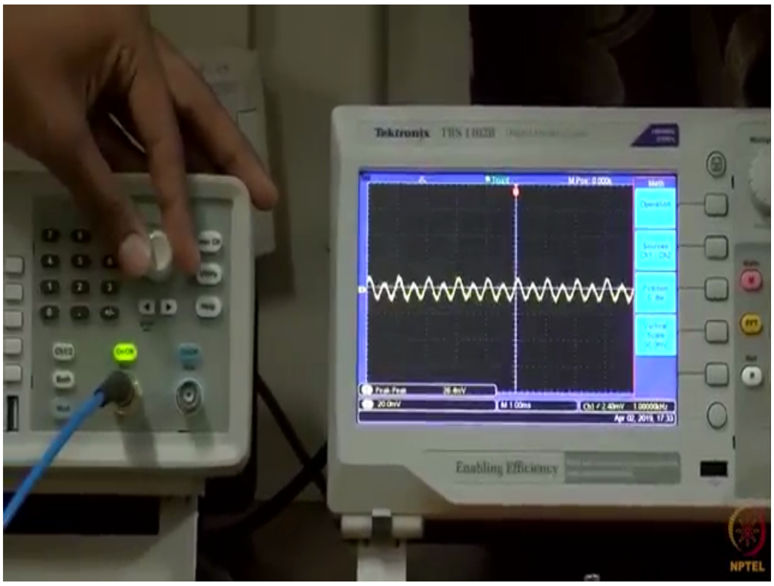

So I am going to increase so please keep notice on this particular screen here, so I am going to increase and you can see the voltage is coming down while you are going towards the bottom part of your transfer characteristics and you can see when I am increasing the voltage to 2.4 volt you can see a second frequency coming up on the output, second frequency coming up on the output.

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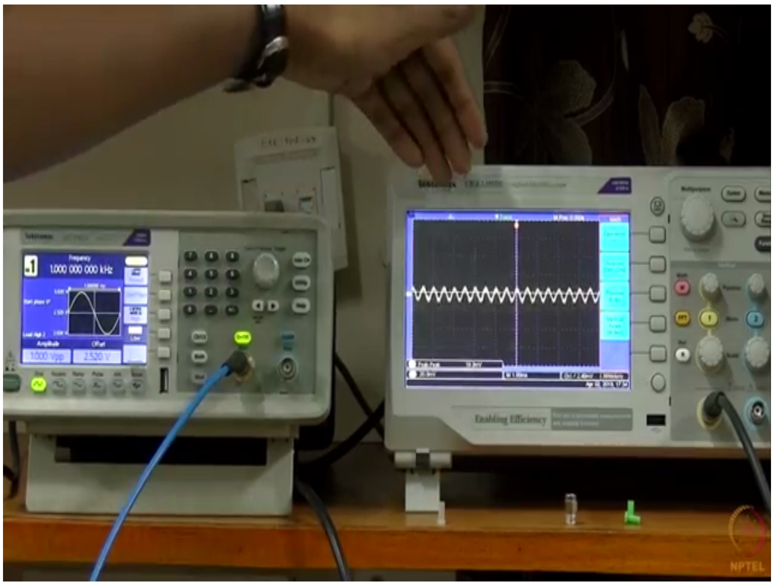

So if I am go on biasing on a perfect null point say this is somewhat coming to a null point which is nothing but a 2.5 volt yeah 2.52 volt, so this is a null point for this particular Mach-Zehnder modulator please keep in mind that the data I shown is corrected from some other Mach-Zehnder modulator but it is similar one, this can vary from one configuration to another configuration, so according to the polarization controller adjustments and all these points can be varied but please keep in mind that you get a dual frequency here, the frequency of this particular signal here is nothing but a 2 kilohertz, while we are giving an input signal of 1 kilohertz.

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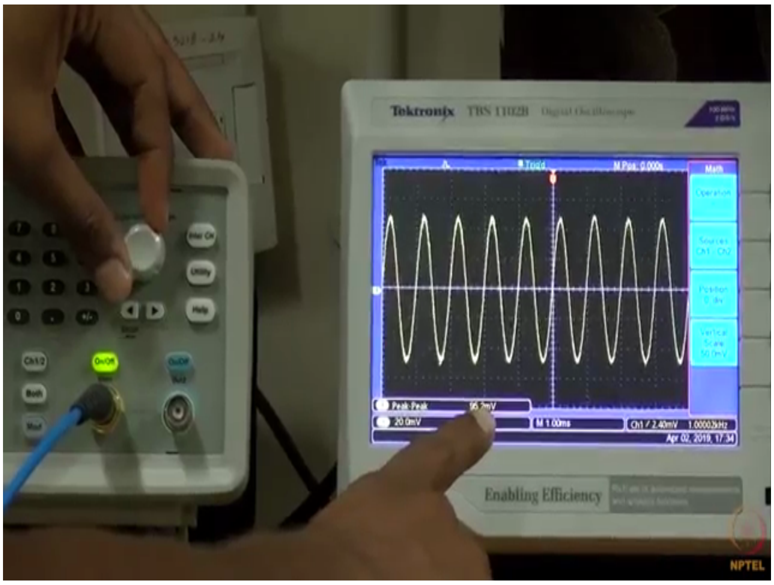

So again to show you I am going back the voltage to our earlier point, you can see the frequency is coming back to our original signal frequency here. So this essentially concludes the operation this essentially concludes the operation of this Mach-Zehnder modulator, so what I have here we can first characterize the Mach-Zehnder modulator electro optic modulator and you can tell which are the biasing points and you can configure this particular modulator such that you can get a null point biasing or a quadrature point biasing and in the quadrature point biasing you will get the same frequency as the light output while we are connecting on the null point you will get a dual frequency as the light output.

So in today's session we have learned that the light output can be controlled using an electro optic modulator which is working on the principle of Pockels effect which is we are having a lithium niobate crystal and we will be controlling the phase on one (())(15:57) of a Mach-Zehnder modulator which in turn changes the intensity, by this method you can control the light output, you can modulate a light signal of laser source and we characterize this particular electro optic modulator here and we show the changes in the frequency operation while we are biasing on the quadrature point and on the null point.

So this concludes this particular session I want to thank you, thank Freddy and I want to thank Akshay also for shooting this, thank you.