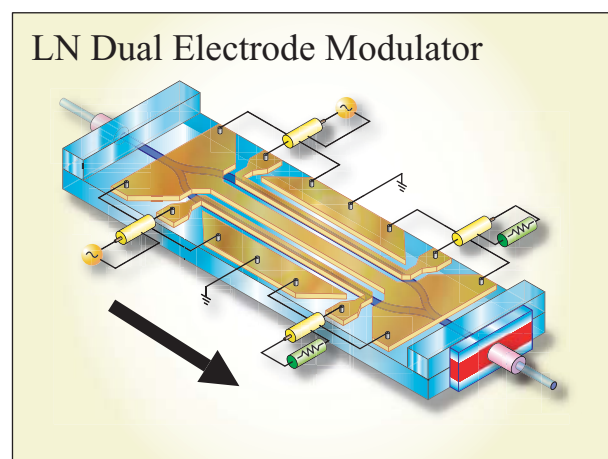
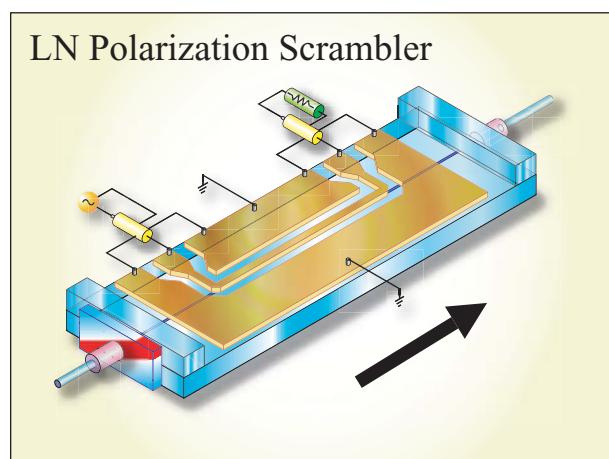
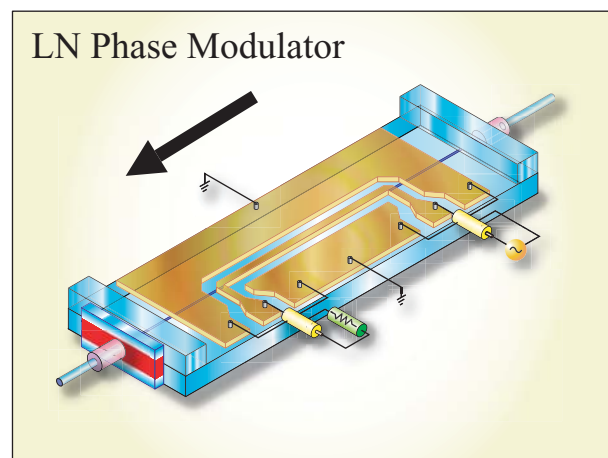
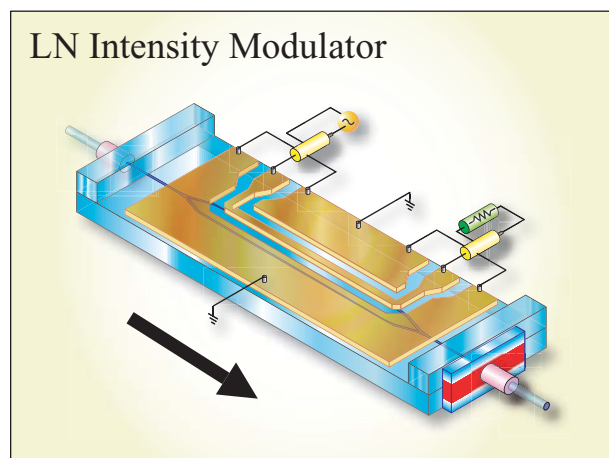


## Application Note for LN Modulators

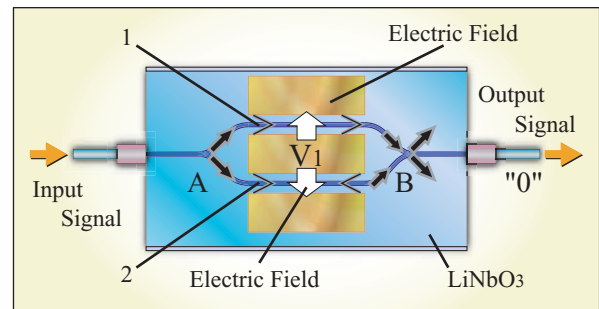
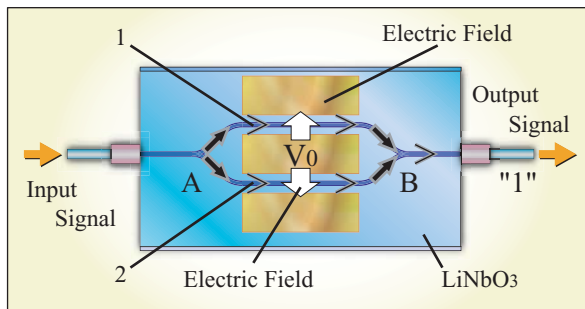
### 1. Structure



### 2. Parameters

<i>Parameters</i>	<i>Sample Spec.</i>	<i>Comments</i>
Modulation speed	10 Gbit/s	Capability to transmit digital signals (e.g. 10 billion times per second)
Insertion Loss	Max 5dB	Defined as the optical power loss within the modulator
Driving Voltage	Max 4V	The RF voltage required to have a full modulation
Optical Bandwidth	Min 8GHz	3dB roll-off in efficiency at the highest frequency in the modulated signal fs spectrum
ON/OFF Extinction Ratio	Min 20dB	The ratio of max optical power (ON) and min optical power (OFF)
Polarization Extinction Ratio	Min 20dB	The ratio of two polarization states (Tm mode and Te mode) at output

### 3, How the Intensity Modulator Works



#### Part. 1

Basic structured LN modulator comprises of 1) two waveguides 2) two Y-junctions 3) RF/DC electrode.

Optical signals coming from the LD is launched into the LN modulator through the PM fiber, then it is equally split into two waveguide at the first Y-junction on the substrate.

When the voltage IS NOT applied to the RF electrode, the two signals are re-combined at the second Y-junction and coupled into a single output as two separated signals are in phase. In this case output signals from the LN modulator is recognized as "ONE".

When voltage IS applied to the RF electrode, due to the electro-optic effects of LN substrate, refractive index is changed, and the phase of the optical signal in one arm is advanced though retarded in the other arm. When two signals are re-combined at the second Y-junction, they are transformed into higher order mode and lost as a radiation mode. In the case two signals are completely out of phase, all signals are lost into the substrate and the output signal from the LN modulator is recognized as "ZERO".

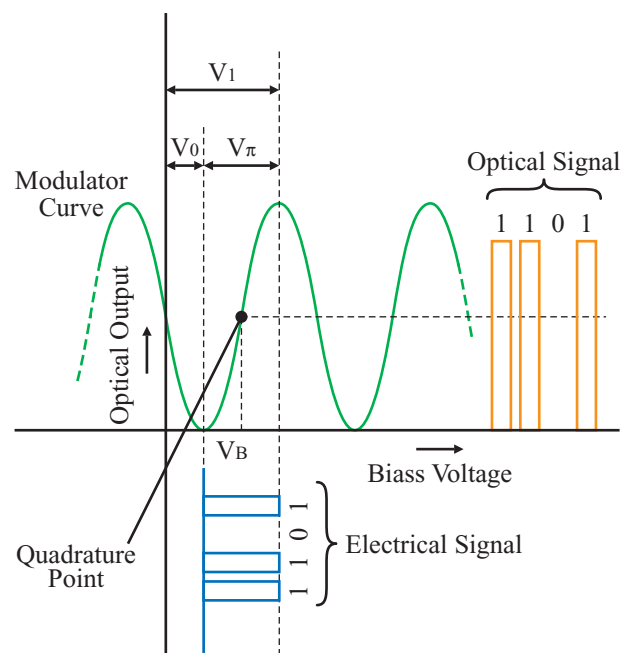
The voltage difference which induces this "ZERO" and "ONE" is called the driving voltage of the modulator, and is one of the important parameters in deciding modulator's performance.

#### Part. 2

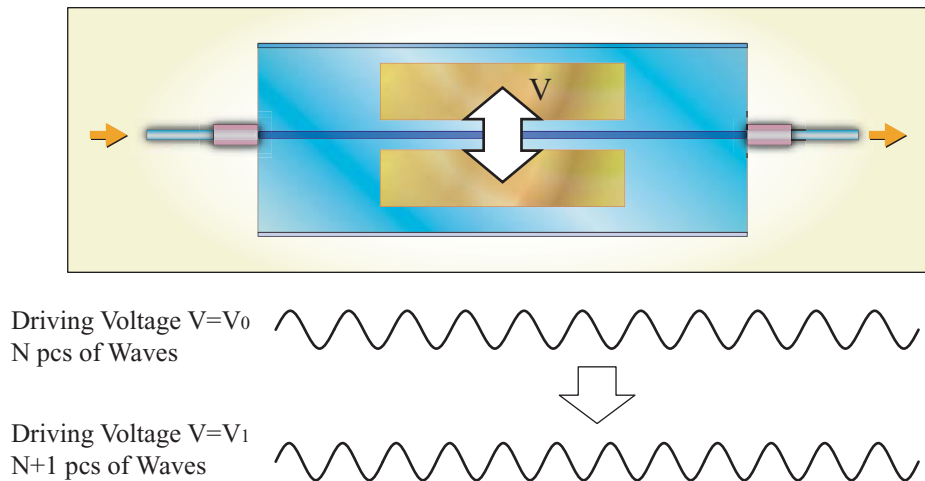
The transfer function of Mach-Zehnder modulator is expressed as

$I(t) = \alpha I_0 \cos^2(V(t)\pi/2V\pi)$ , where  $I(t)$ =transmitted intensity,  $\alpha$ =insertion loss,  $I_0$ =Input intensity from LD,  $V(t)$ =applied voltage,  $V\pi$ =driving voltage. It is necessary to set the static bias on the transmission curve through Bias electrode. It is common practice to set bias point at 50% transmission point, Quadrature Bias point. As shown here, electrical digital signals are transformed into optical digital signal by switching voltage to both end from quadrature point.

DC drift is the phenomena, where this transmission curve gradually shift in the long term.



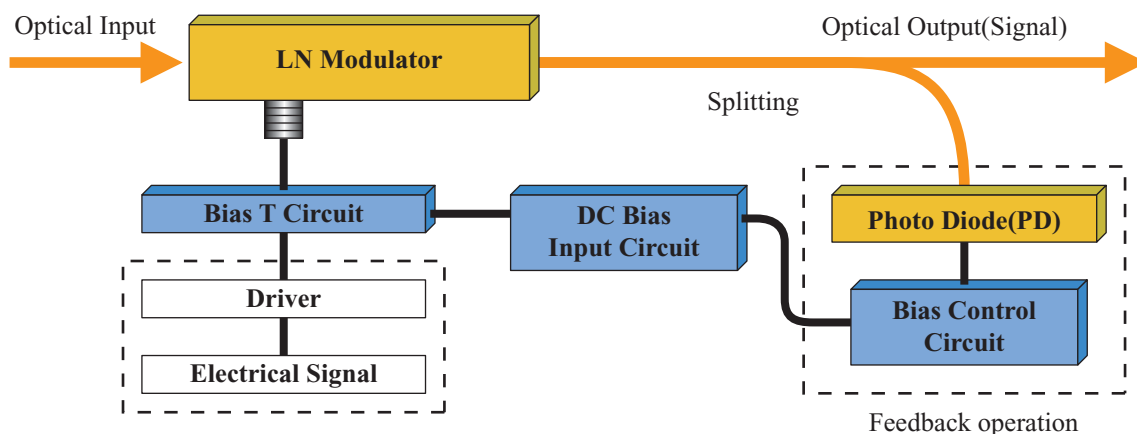
## 4, How the Phase Modulator Works



The Phase modulator is a device which changes the "phase" of optical signals by applying voltage. Let's assume the following case. When voltage is not applied to the RF-electrode,  $n$  number of waves exist in the certain length. When voltage is applied to the RF-electrode, one more wave is added, which now means  $n+1$  waves exist in the same length. In this case, the phase has been changed by  $2\pi$  (360degree) and the half voltage of this is called the driving voltage.

In case of long distance optical transmission, waveform is susceptible to degradation due to non-linear effect such as self-phase modulation etc. The phase modulator is applied to compensate for this degradation and makes it possible to transmit long distance.

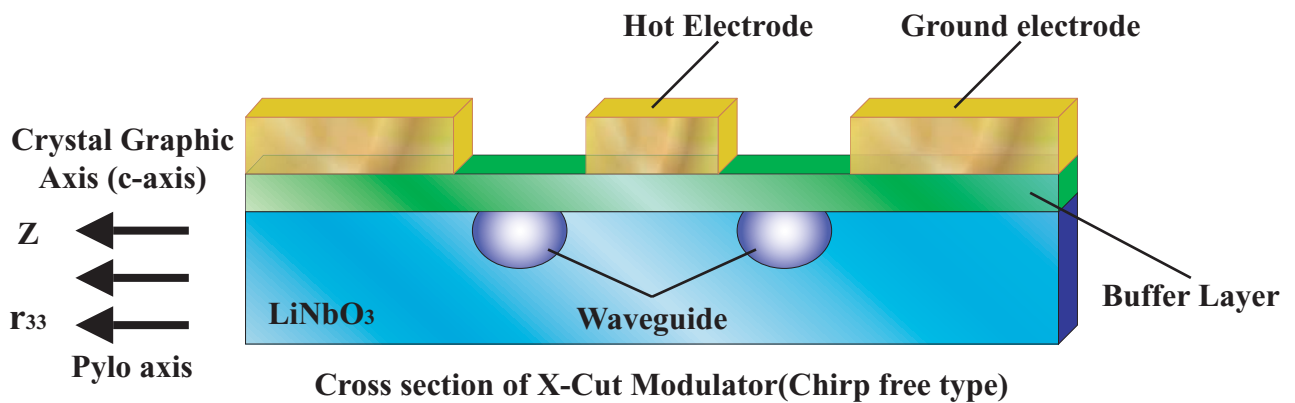
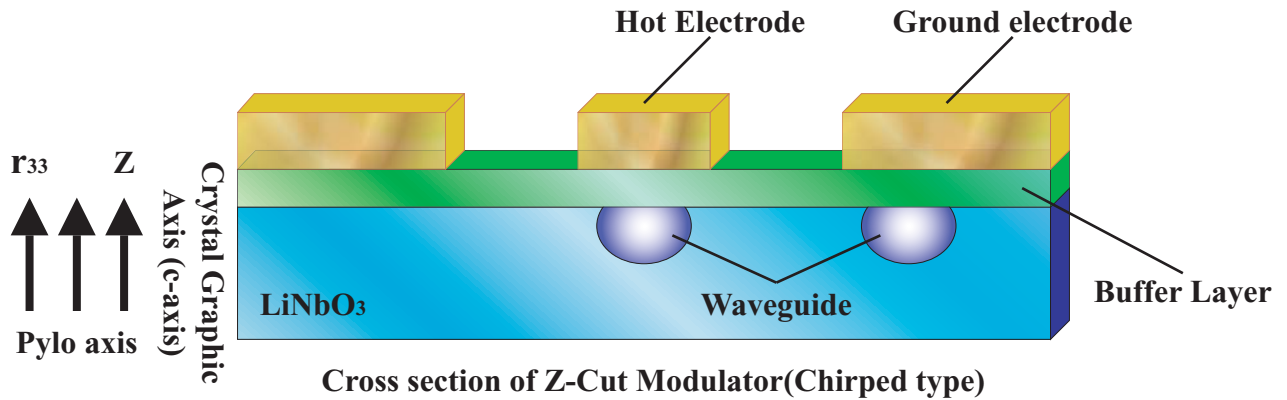
## 5, Bias Control Configuration



In the case of the LN modulator, the bias point control is vital as the bias point will shift long term. To compensate for the drift, it is necessary to monitor the output signals and feed it back into the bias control circuits to adjust the DC voltage so that operating points stay at the same point (e.g. quadrature point). It is the manufacturer's responsibility to reduce DC drift so that DC voltage is not beyond the limit throughout the life time of device.

## 6, Chirped vs Chirp Free Modulator

### \*\*\*Z-Cut structure vs X-Cut structure\*\*\*



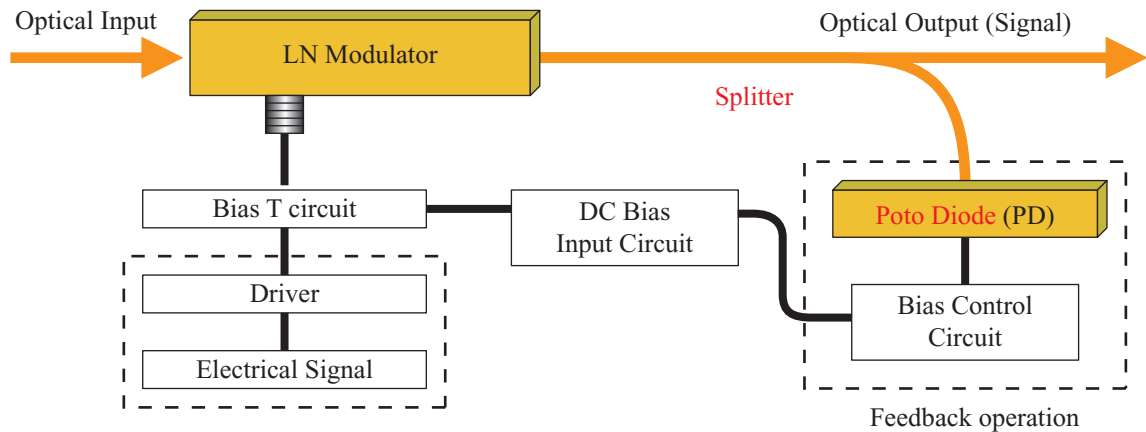
The crystal cut affects both modulator efficiency, denoted as driving voltage and modulator chirp.

In the case of the Z-cut structure, as a hot electrode is placed on top of the waveguide, RF field flux is more concentrated, and this results in the improvement of overlap between RF and optical field. However overlap between RF in ground electrode and waveguide is reduced in the Z-cut structure so that overall improvement of driving voltage for Z-cut structure compared to X-cut is approximately 20%.

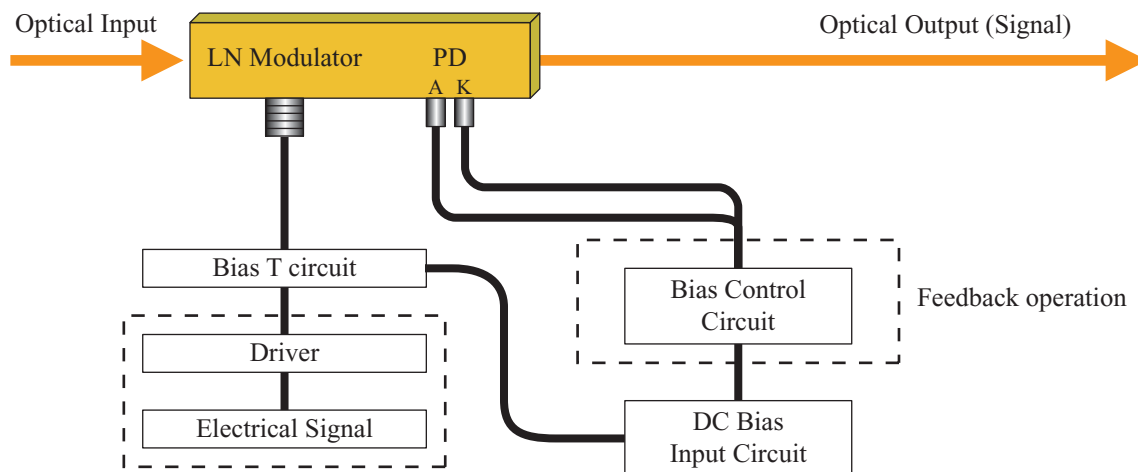
The different overlap between the two waveguides for the Z-cut structure results in a chirp parameter of 0.7 whereas X-cut has almost zero-chirp due to its symmetric structure.

## 7, Photo Detector Integrated LiNbO3 Modulator

PD integrated Modulator reduces the parts which bias control circuit needs. Fig1 is the general idea of Bias Control configuration.



a) Bias Control Configuration by TAP Coupler



b) Bias Control Configuration by PD integrated modulator

Fig.1 Bias Control Configuration by TAP Coupler and PD integrated modulator

## Features

Our LiNbO<sub>3</sub> modulator picks up radiation mode from Y-Cnbiner junction by monitor PD. Output power is stable because it picks up a radiation mode. PD Output is inversely monitored to a main signal output (See Fig.3).

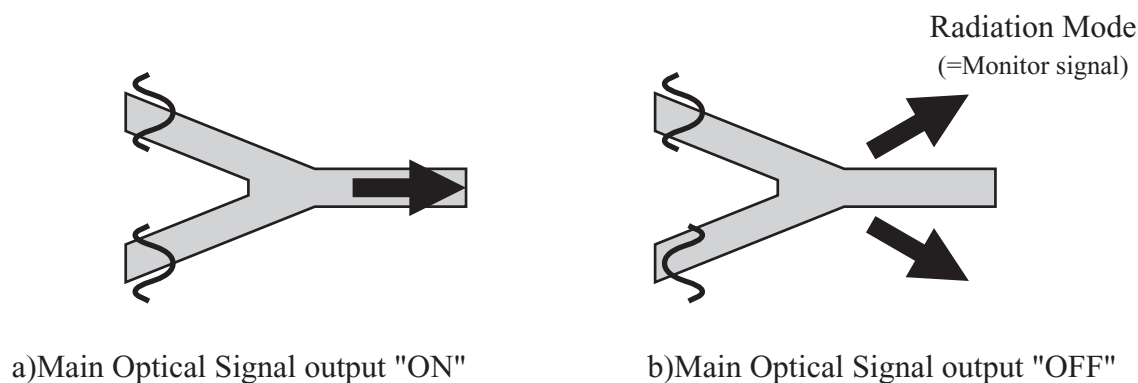


Fig.2 Y-Combiner junction

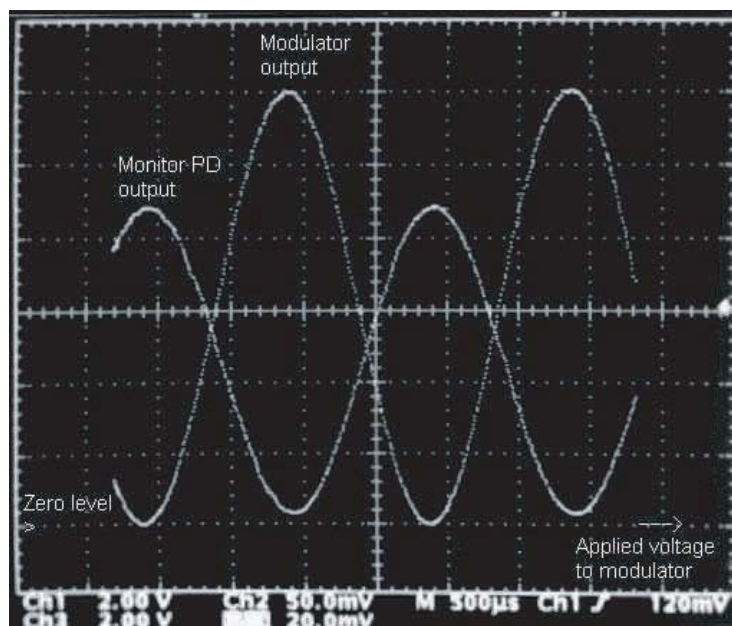


Fig.3 Main Optical output and Monitor signal