# Modelling and Measurements of 10 Gb/s RZ Integrated Optical Modulators

***Yi Huang****, *P. Jiang and I. Croston*

*JDS Uniphase*
*Electro-optics Product Division*

*** *Department of EEE, University of Liverpool, L69 3GJ, UK*
*Yi.Huang@liv.ac.uk*




JDS Uniphase

# Contents



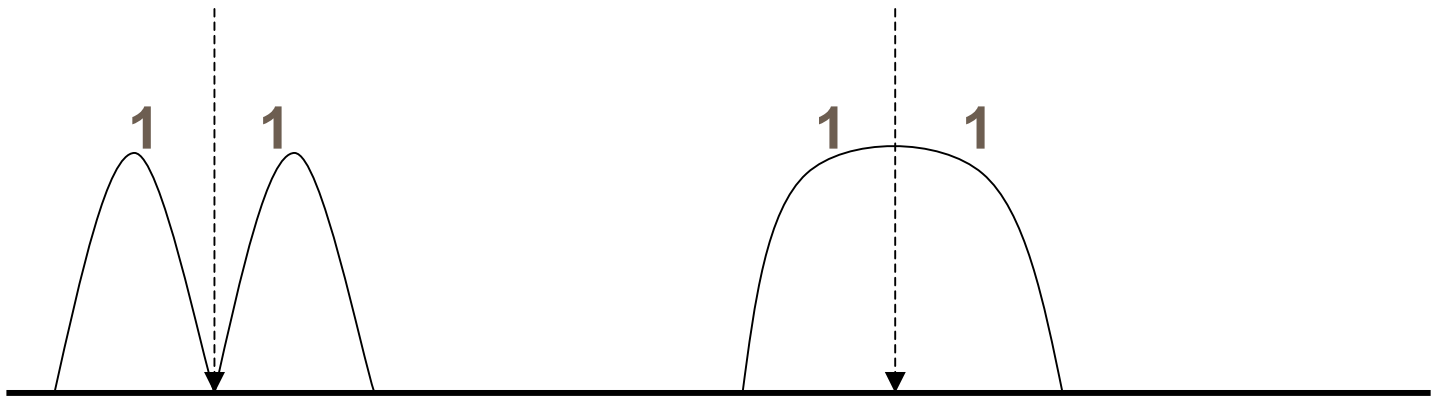



JDS Uniphase

# Introduction

## *What is a RZ Integrated Optical Modulator ?*

- **RZ**: Return to Zero
- **NRZ**: Not Return to Zero




**Modulator:** $LiNbO_3$ , X-cut, CPW

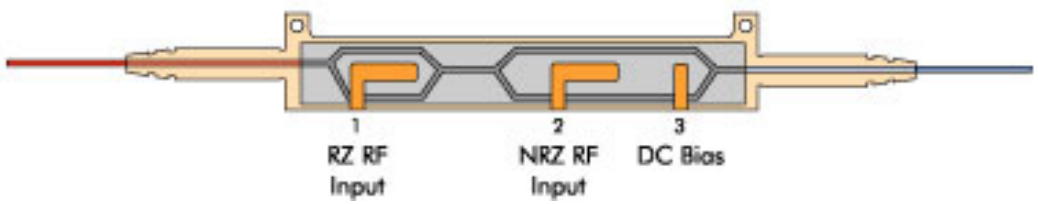


JDS Uniphase

# Introduction

## *A typical integrated RZ and NRZ modulator*

- Integrated RZ-pulse & NRZ within same package
- Single part for C & L-band operation
- Packaging technology
  - based on JDSU's existing hermetic product
  - qualified true-hermetic to Telcordia-468
- Chip design based on JDSU's X-cut 10Gb/s technology building blocks.



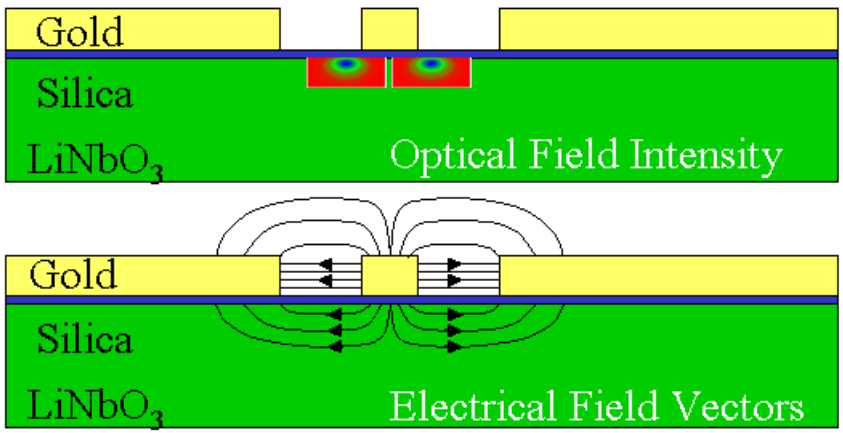



JDS Uniphase

# Introduction

## *Advantages of RZ modulator*

- Longer transmission distance
- Smaller in size
- Suitable for high data-rate applications
- Easy for integration

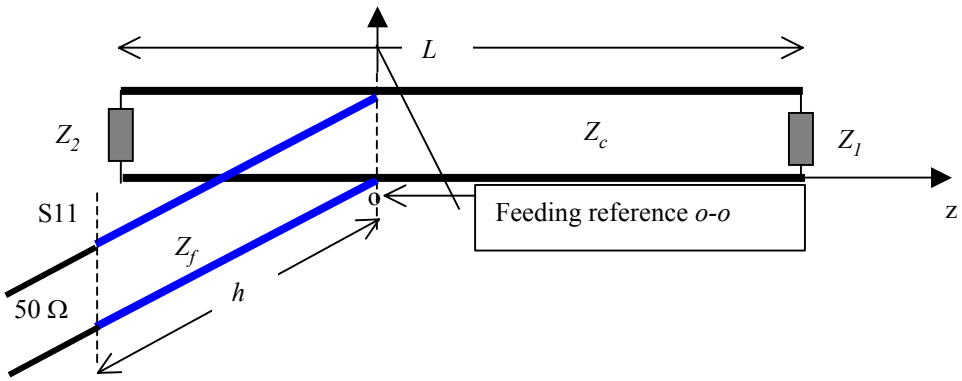





JDS Uniphase

# Theoretical Model

- Based on transmission line theory




- It can be used to find:
  - The voltage/current distribution, input impedance
- **Objective:**
  - to make it resonate at the desired operation frequency



JDS Uniphase

# Theoretical Model

– **Phase shift:**

$$\Delta\phi(\varphi_0, f) = \mathrm{Re}\left[\int_0^L \frac{\pi}{\lambda} r_{33} {n_o}^3 \frac{V(z)}{g} \Gamma e^{j(\varpi z / v_0 + \varphi(z) + \varphi_0)} dz\right]$$

$\lambda$ is the optical wavelength,

$r_{33}$ the electro-optical coefficient ($30.8\times10^{-12}$m/V for $LiNbO_3$),

$n_o$ the optical extraordinary index, $g$ the gap of the CPW,

$v_0$ the speed of optical wave,

$\varphi_0$ the reference phase of the standing wave,

$\omega$ the angular frequency of microwave,

$\Gamma$ is the overlap integral factor, between 0 – 1

# Theoretical model

## Calculation of S11, S21, and Vπ

- S11: the electric reflection coefficient at the microwave input, *i.e.*, $V_{in}/V_{out}$
  - the smaller, the better at the operation frequency
- S21: the optical transmission coefficient, or optical frequency response

$$S21 = OR(f) = 20\log_{10}\left(\left|\frac{\Delta\phi(f)}{\Delta\phi(0)}\right|\right)$$

- Vπ: the half-wave driving voltage

$$V_\pi = \frac{\pi V_0}{2\Delta\phi(f)}$$

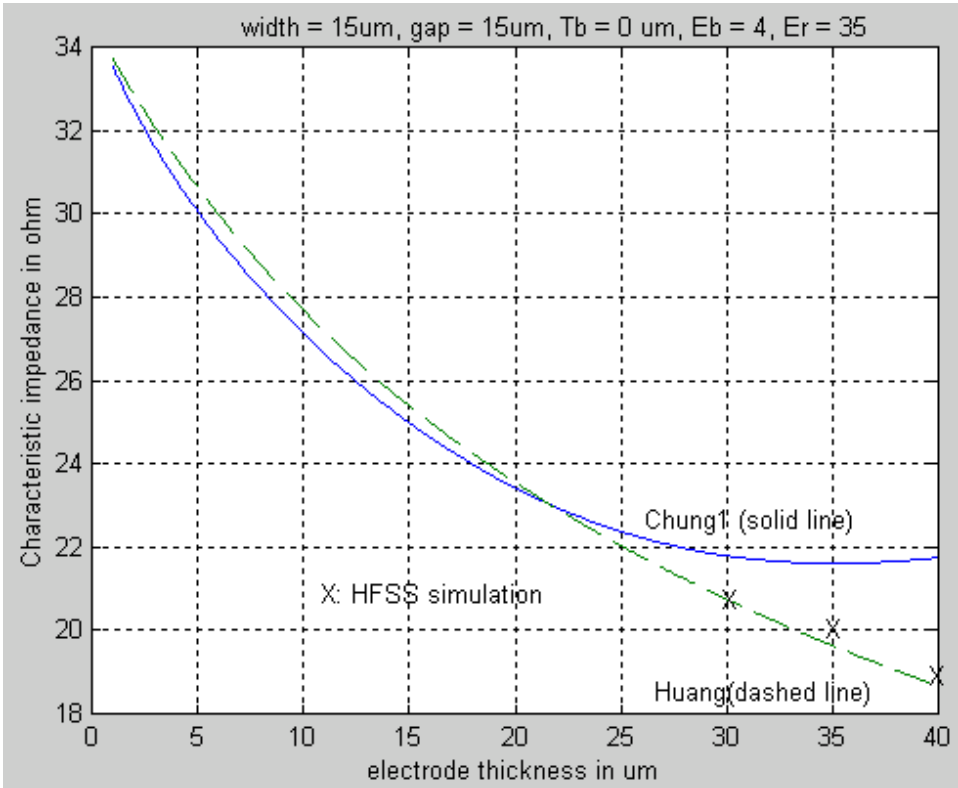



JDS Uniphase

# Theoretical model

## Calculation of Zc

- Formula for thin CPW available, but not for thick CPW






JDS Uniphase

# Measurements

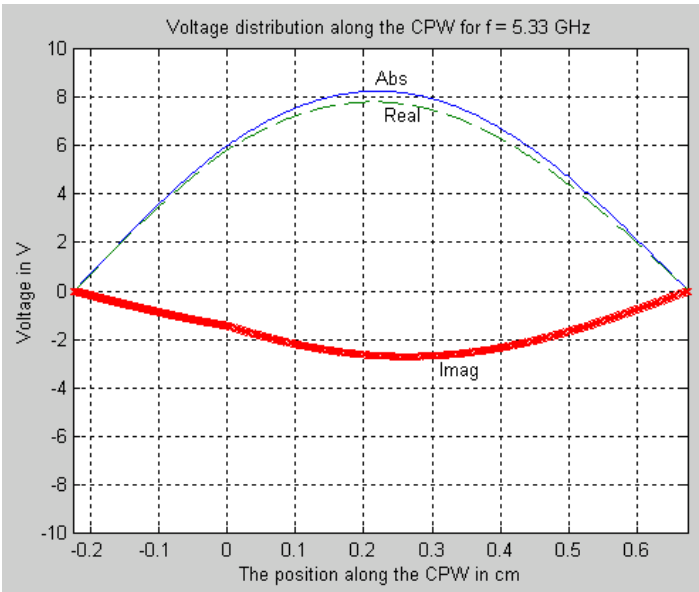
- S11 were measured using Network Analyser
- S21 were measured using Electro-optic Network Analyser
- $V\pi$: normalised to 50 $\Omega$, were obtained by measuring the extinction ratio at the DC and RF

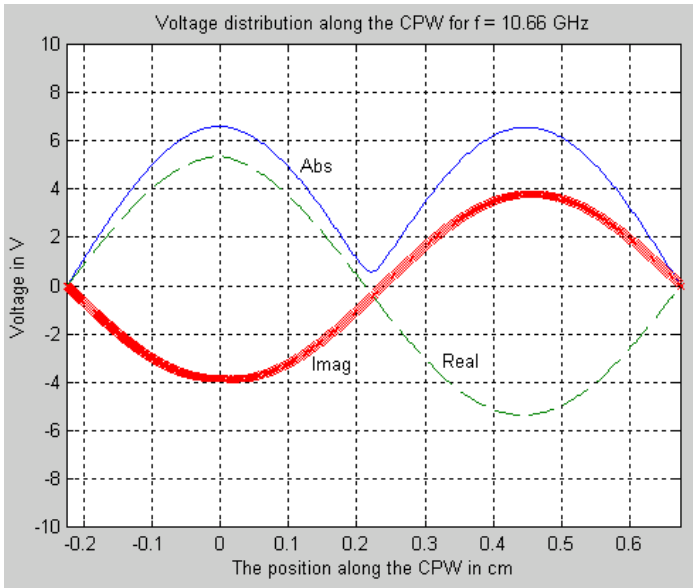



JDS Uniphase

# Results and Discussion

- Voltage distribution along the chip (short-end):



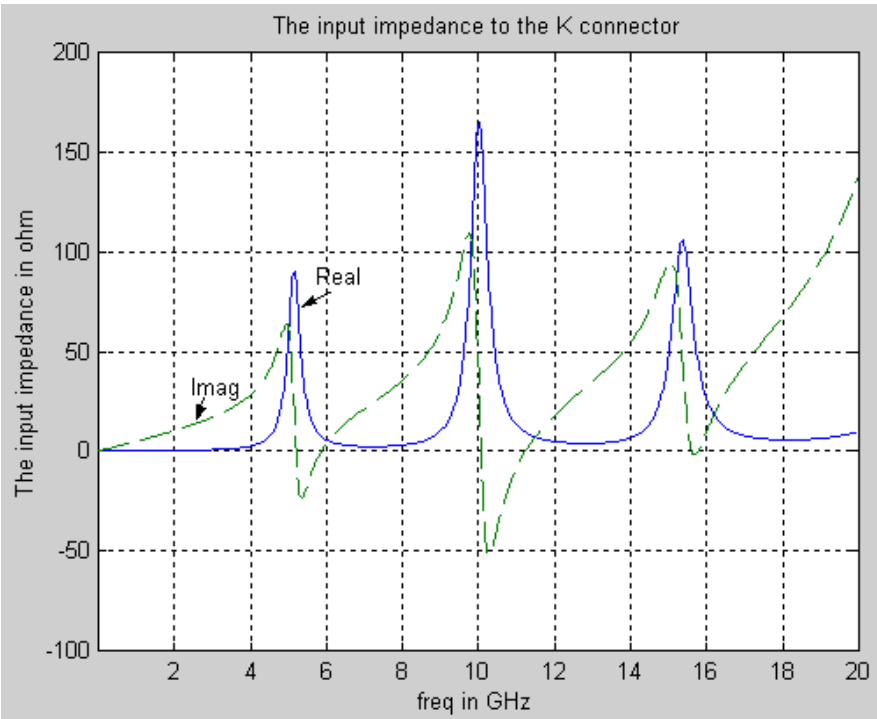






JDS Uniphase

# Results and Discussion

- Impedance vs. Frequency

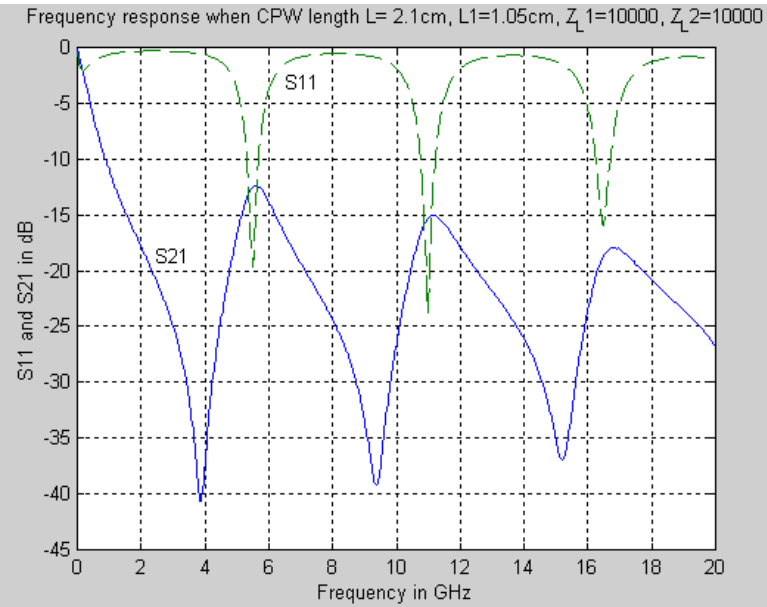


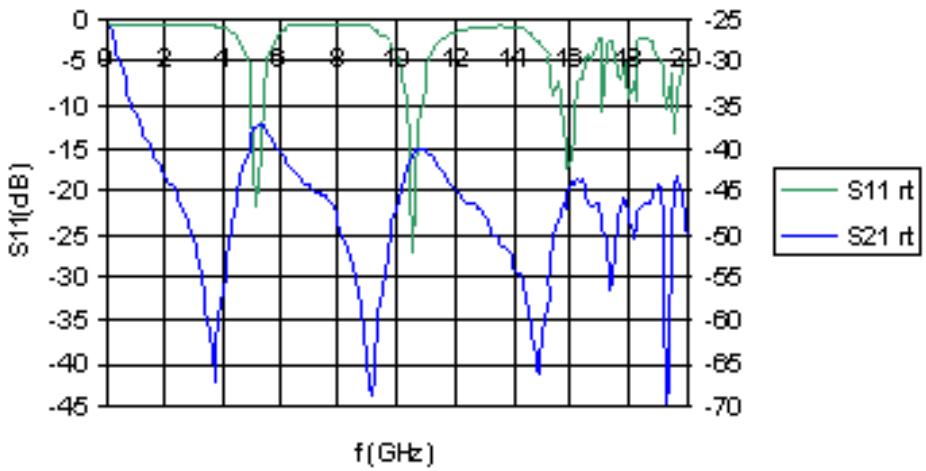



JDS Uniphase

# Results and Discussion

- Simulated and Measured S11 (<-10 dB) and S21



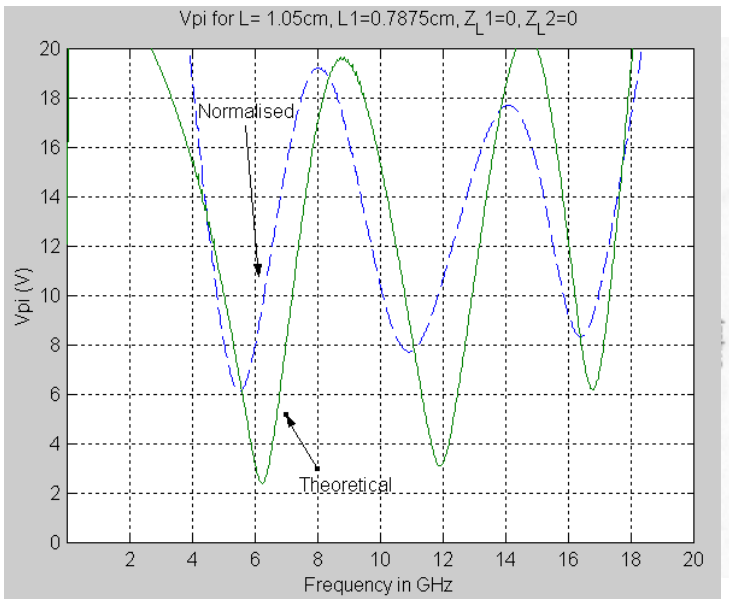



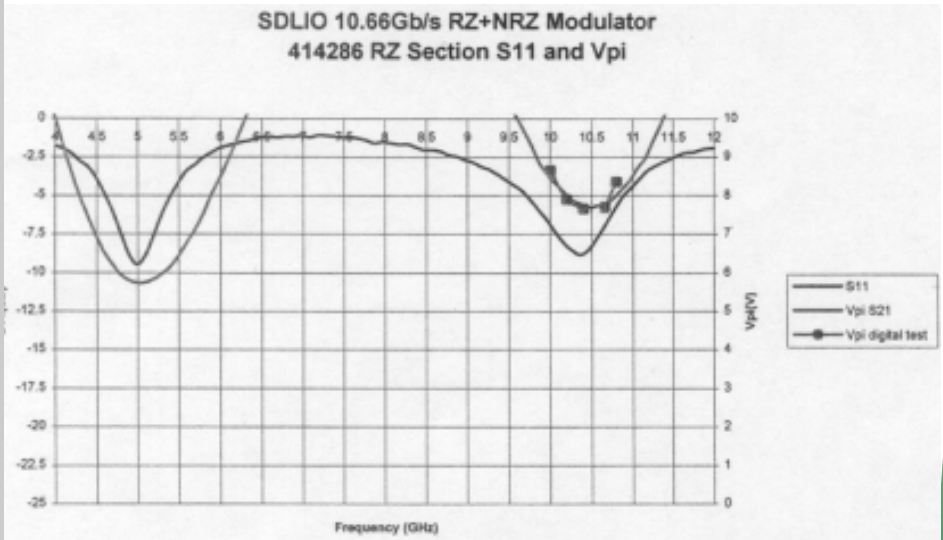



JDS Uniphase

# Results and Discussion

- Simulated and measured $V\pi < 8V$



# Conclusions

- A theoretical model based on transmission line theory has been developed.
- It has been used to obtained important parameters, such as S11, S21, and $V\pi$
- The predicted and measured results are in good agreement:
  - Typical S11 < -10 dB at the operation frequency
  - Typical $V\pi$ < 8 V




JDS Uniphase