ADJUSTABLE TIME DELAYS FOR OPTICAL CLOCK RECOVERY SYSTEMS

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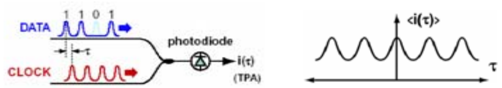
INTRODUCTION

- Clock recovery is the process of synchronizing a clock signal to a random stream of data

- Clock recovery is one of the first stages in any optical receiver, transceiver, 3R regenerator, and demultiplexer
- Future high-speed optical networks will require optical clock recovery systems rather than electronic techniques

TWO-PHOTON ABSORPTION (TPA)

- Two-photon absorption (TPA) is a nonlinear process that can be used for clock recovery
- Optical clock and data signals can be coupled to a TPA photodetector to produce TPA current
- Time-averaged TPA current is greatest when the clock and data are temporally aligned (τ=0)

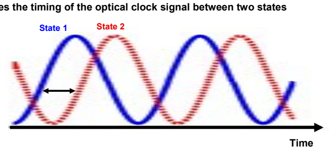


- A phase-locked loop (PLL) must then be used to synchronize the clock and data
- One key element that is needed before the PLL is an optical time dithering system

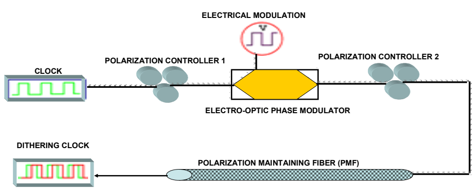
OPTICAL TIME DITHERING SYSTEM

- Periodically modulates the timing of the optical clock signal between two states

GOAL:



DESIGN



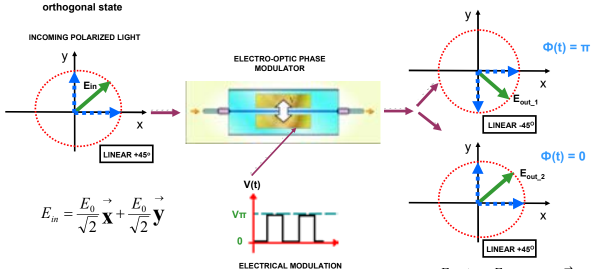
ELECTRO-OPTIC PHASE MODULATOR (PM)

- Periodically changes the phase of an optical signal by applying an electric field along one of the crystal's principal axes:

$$\Phi(t) = m \sin(\Omega t)$$

where $\Phi(t)$ is the change in phase, m is the modulation index, and Ω is the modulation frequency

- V_π, the voltage required to produce a phase shift of π radians, for this PM is 3.93 Volts
- By applying V_π to only one of the two perpendicular axes of the PM, the polarization of light changes to its orthogonal state



$$E_{in} = \frac{E_0}{\sqrt{2}}\vec{\mathbf{x}} + \frac{E_0}{\sqrt{2}}\vec{\mathbf{y}}$$

$$E_{out} = \frac{E_0}{\sqrt{2}}\vec{\mathbf{x}} + \frac{E_0}{\sqrt{2}}e^{j\phi(t)}\vec{\mathbf{y}}$$

POLARIZATION MAINTAINING FIBER (PMF)

- Is a birefringent material with orthogonal slow and fast axes
- We align these axes with the +45 and -45 linearly polarized light coming from the PM
- Light travels at different speeds through the axes creating a timing delay between the two components
- The amount of delay can be calculated from: $\tau = \dfrac{\Delta n L}{c}$

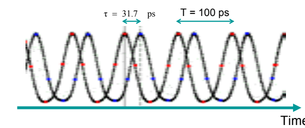
Where Δn is the difference between indices of refraction of the slow and fast axes, L is the length of the PMF, and c is the speed of light in vacuum

- The phase modulator periodically changes the input polarization between the blue and red states and therefore creates a dithering on the output of the PMF

EXPERIMENTAL VALUES AND RESULTS

Ω = 200 KHz	L = 18 m	Δn = 4.91*10^{-4}	τ = 29.5 ps
Dithering Frequency	PMF Length	PMF Birefringence	PMF Time delay

- The output of our dithering system on the sampling oscilloscope

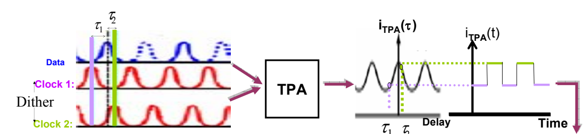


ADVANTAGES OF THIS DITHERING SYSTEM

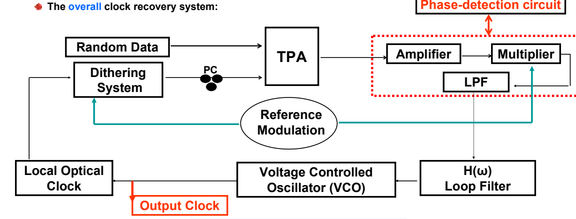
- No moving parts as opposed to traditional mechanical methods
- Ability to provide very high dithering frequencies up to 10 GHz
- Modulates the clock in the optical domain rather than the electrical domain
- Satisfies the requirements of high data rate communications

OPTICAL CLOCK RECOVERY SYSTEM USING TIME DITHERING AND TPA

- Time dithering and TPA can be combined to provide a polarization-insensitive optical clock recovery system
- TPA output, produced by time-dithered clock and data signals, can be used with a phase-detector circuit in a PLL to synchronize clock and data
- We have built the phase-detector circuit which includes an amplifier, mixer, and a low-pass filter (LPF)
- The mixer multiplies the TPA output by the reference electrical modulation signal
- The LPF produces a zero output when the clock and data are synchronized



- The overall clock recovery system:



CONCLUSIONS

- We introduce an optical clock recovery system based on Two-Photon Absorption
- The novel idea of an optical time dithering makes the system polarization-insensitive
- The system is also compact, broadband, and scalable to very high bit-rates required for future optical networks