Optical Time Domain Reflectrometery

In optical fiber communication, optical time domain reflectometery (OTDR) is a commonly used technique for characterization and fault location of optical fiber transmission systems. It involves measuring the fraction of a probe pulse that is scattered back (by Rayleigh scattering) from a silica fiber. Because of the very small levels of backscatter in single-mode fiber at long wavelengths, very sensitive optical detection is necessary to achieve adequate range performance. Unlike sources and power meters which measure the loss of the fiber optic cable plant directly, the OTDR works indirectly. The source and meter duplicate the transmitter and receiver of the fiber optic transmission link, so the measurement correlates well with actual system loss. The OTDR, however, uses a unique phenomenon of fiber to imply loss. The biggest factor in optical fiber loss is scattering. It is like billiard balls bouncing off each other, but occurs on an atomic level between photons (particles of light) and atoms or molecules. If you have ever noticed the beam of a flashlight shining through foggy or smoky air, you have seen scattering .This scattering of light results in depreciation in light intensity at the receiving end of the fiber. Figure 1 illustrates how light is scattered within a fiber optic cable due to air bubble, impurities and microbends.

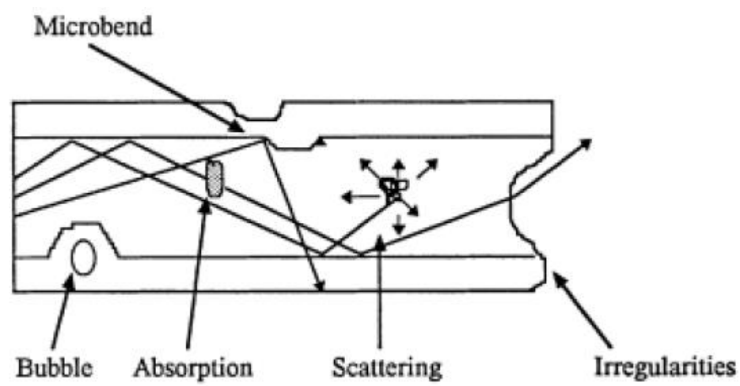
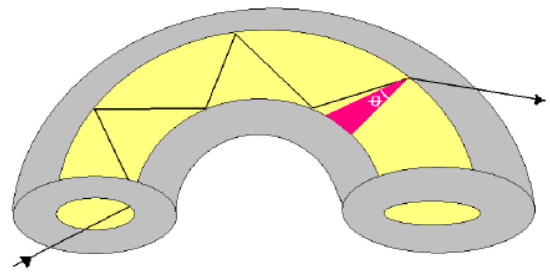


Figure 1



Macrobend loss.

Figure 2

OTDRs can find faults, breaks, bends and splices in fiber optic cables. This enables a technician to measure the quantity of light loss as well as identify the exact point at which the loss is occurring as shown in figure 2 where a fiber-optic cable is bend to 180 degrees. Light loss in fiber cable is a serious issue because it can hamper or completely stop data transmission. With so many communications networks dependent on fiber optic cabling to transmit data, having a way to quickly diagnose problems means repairs can occur much more rapidly leading to less network downtime. An OTDR works by injecting a series of optical pulses through the fiber which are reflected back to the injection point and measured for deviations or aberrations in the light wave. Based on the measurement of the deviation the trouble spot can usually be precisely located.

FPGA Implementation of OTDR

The algorithm for OTDR measurement is implemented on a Altera's Cyclone FPGA .This embedded FSM machine generates a logic pulse of varying width from 10ns to 10us to analyze fiber optic cable from 10 meters to 10 Km. This pulse will turn the laser LED on for the set duration. The user can also set delay of this pulse in steps of +/-1.25us. The set delay of Laser firing pulse is in reference to start of data acquisition from ADC (Analog to Digital Converter). After the master unit which can be a microprocessor sets the pulse width and pulse delay step the Acquisition State Machine (OTDR Core) will turn the Laser LED on for the set parameter. The laser pulse travelling into the fiber-optic cable will generate back-scatter radiation (Rayleigh scattering). The intensity of back-scatter light from the travelling-pulse will vary as it encounters joints and splices throughout the length of fiber-cable. ADC will sample voltage generated from high performance photo-diode installed at the same end of fiber-cable as the Laser diode. Figure 3 shows block diagram of FPGA based OTDR hardware implementation. The optical MUX/DEMUX will select optical input when transmitting laser pulse and optical output when doing OTDR measurements. Data acquired over a million iterations will be saved and re-written on to a ZBT RAM which can be retrieved by a master controller.

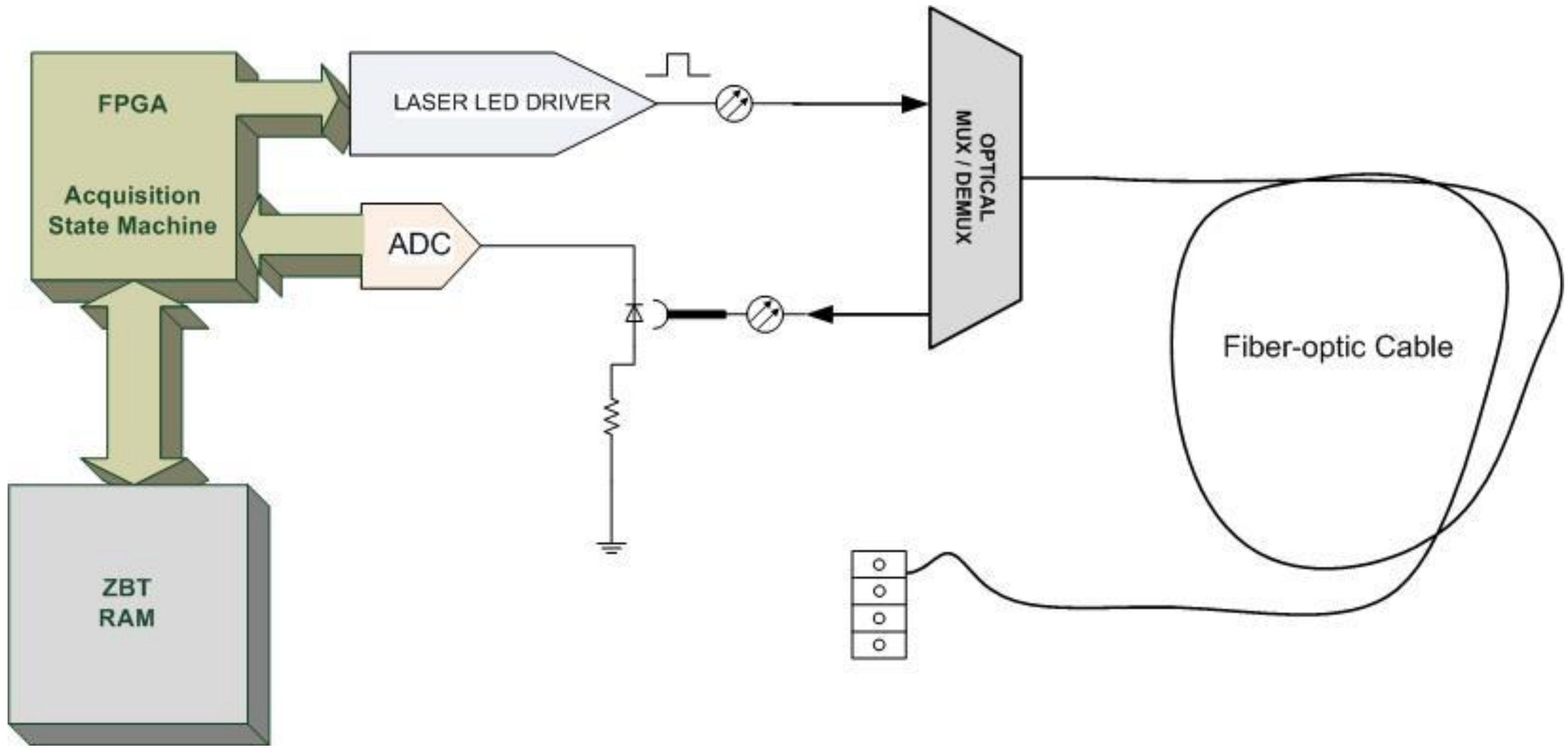


Figure 3 : FPGA based OTDR

Light returned consists of two components:

- Reflections from connectors, breaks, open ends and other such localized discontinuities of the refractive index, referred to as , Fresnel Reflections.

- Backscatter from the fiber itself, due to small scattering centers throughout the fiber material (small perturbations of the refractive index), referred to as Rayleigh Backscatter.

OTDR trace data consists of samples of light intensity taken at equal time intervals. Data is accumulated for the duration of the time that it takes the light to travel to the end of the fiber and back. Since the reflections or changes in backscatter are time resolved, their distance into the fiber can be calculated, since the speed of light in the fiber is known:

$$L = 0.5*c/n$$

Where c is the speed of light in vacuum and n is the refractive index of the fiber. The factor of 0.5 accounts for the fact the light traverses the fiber twice before it is detected.

As a rule of thumb, 1m of fiber corresponds to 10ns of delay (round trip).

The resolution of the localization of a fault is a function of the probe pulse width. Narrower pulses provide higher resolution. Fresnel reflections depend only of on the peak intensity and are not affected by the lower energy content of the narrower pulses. Rayleigh backscatter, however, is directly proportional to the total energy in the pulse. Narrow pulses then, limit the dynamic range for Rayleigh backscatter related events (such as splice losses, macro bends etc).Narrow pulses also require amplifiers with wider bandwidth, increasing the amount of noise included thus lowering the signal to noise ratio. Figure 3 shows a typical OTDR trace identifying different events in measurement . Figure 4 shows OTDR trace from a commercially available handheld OTDR from EXFO inc.

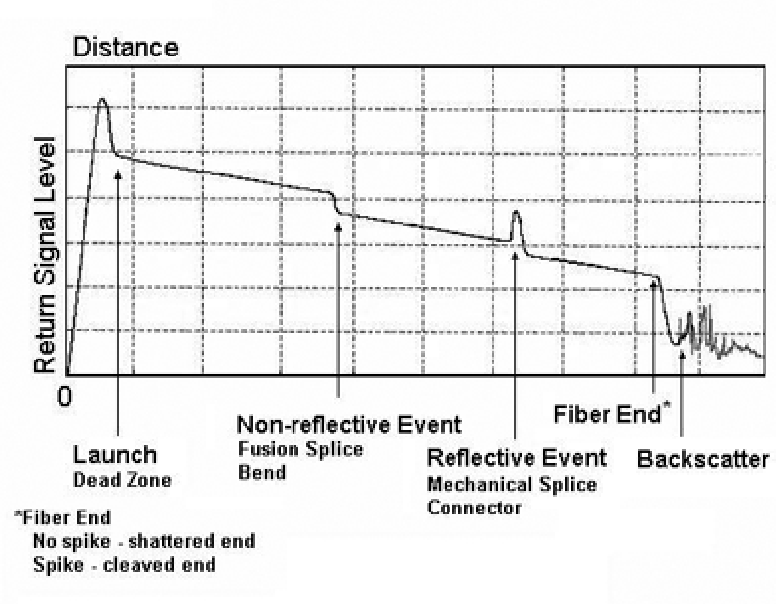


Figure 3 : OTDR Trace

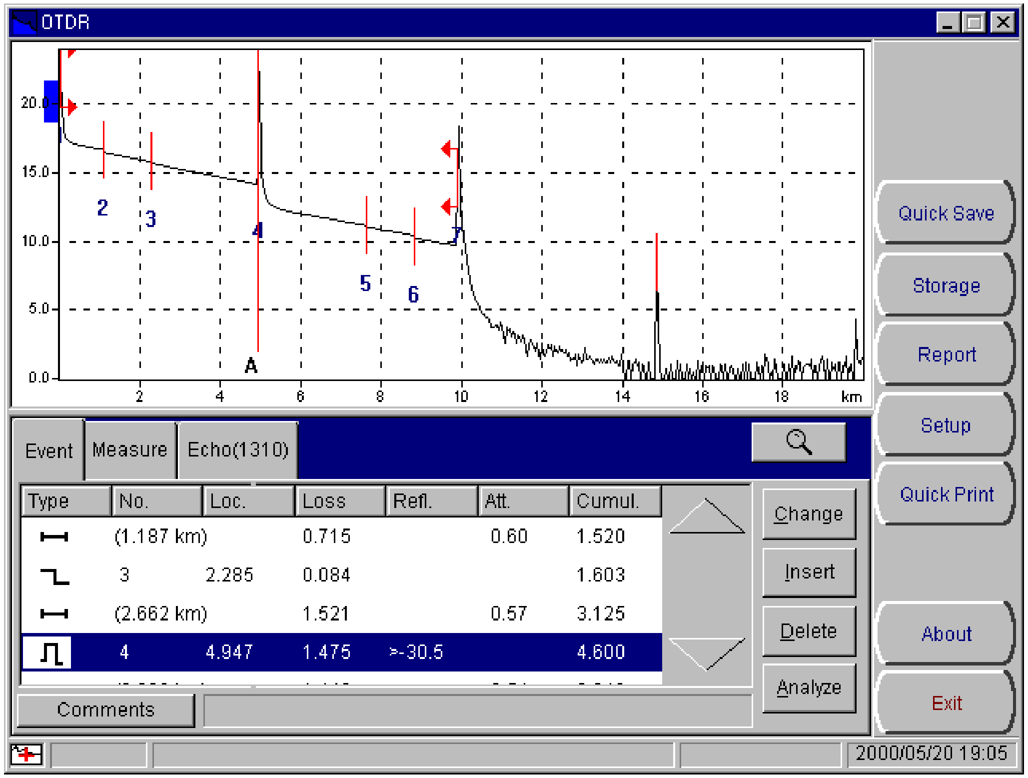


Figure 4: OTDR Trace of EXFO

FPGA Implementation of OTDR

Figure 5 shows different components in an actual implementation of OTDR and their interconnections. Master unit (microcontroller / microprocessor) interface signals are shown on the left-hand side e.g. Read, Write , Chip Select , Address Bus and Data bus . Master unit can configure and set multiple parameters to registers via these signals and also start a measurement. After a measurement is initiated by Master unit , Acquire & Accumulate Data State Machine (AAD Fsm) starts a measurement cycle . AAD Fsm starts by firing a laser pulse and capturing its reflections from a high-speed ADC. Laser pulse width and delay stepping of this pulse is controlled by LASER PULSE Drive Logic. A dual-port embedded Fifo is used to update trace measurement for the Master unit.

OTDR System Architecture

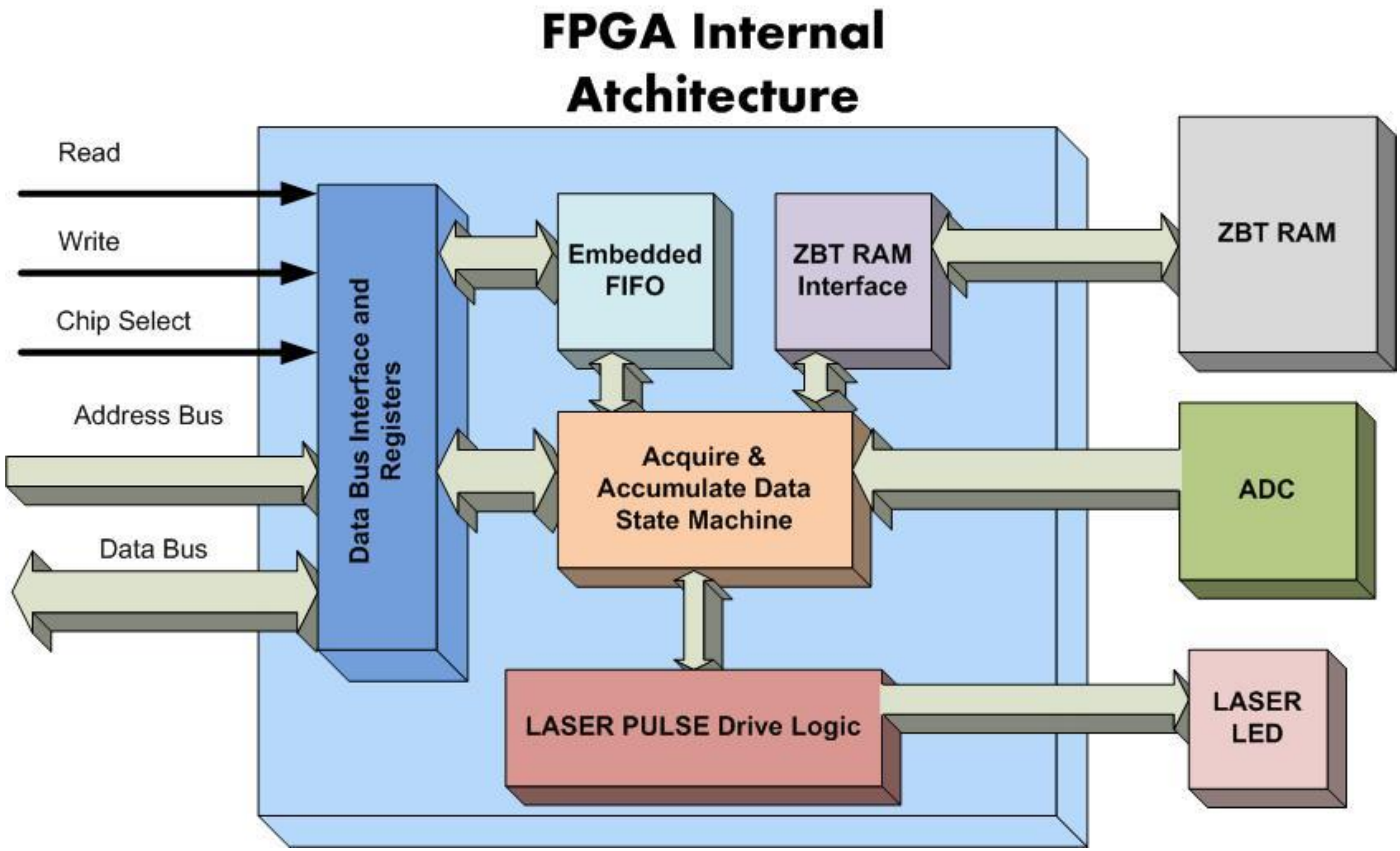
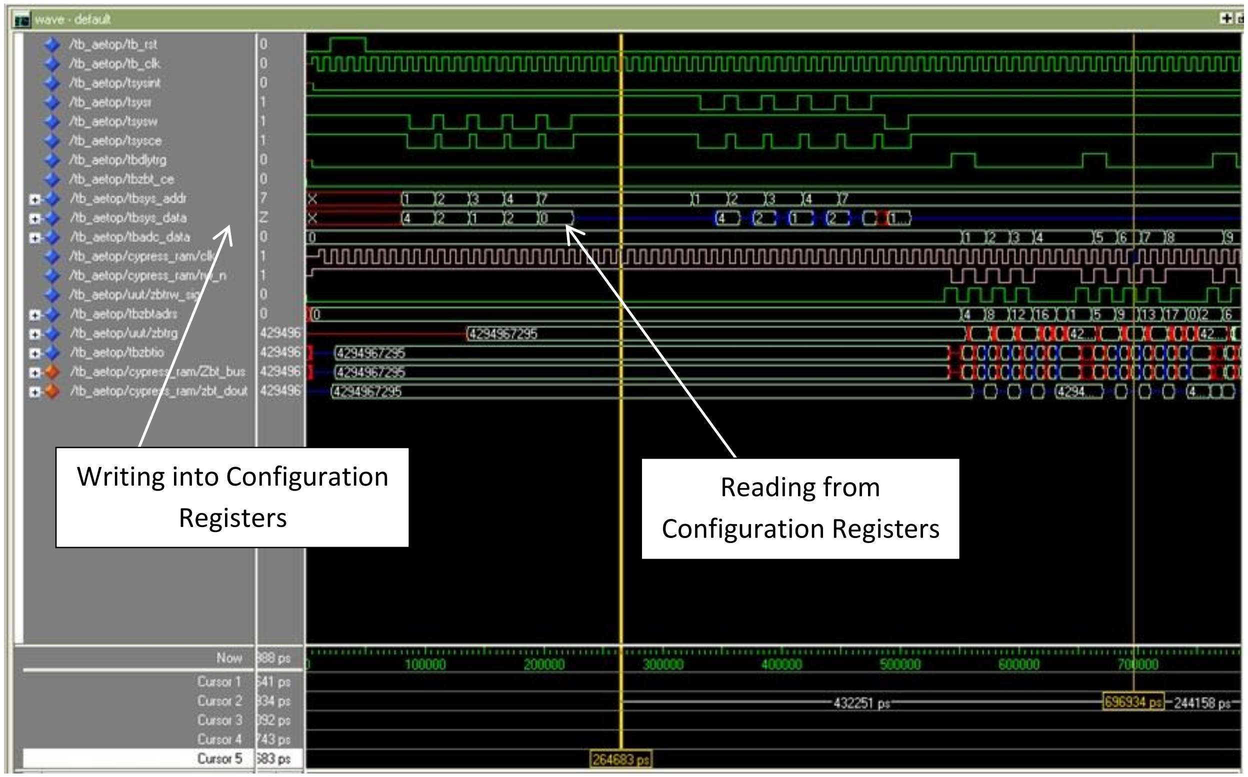
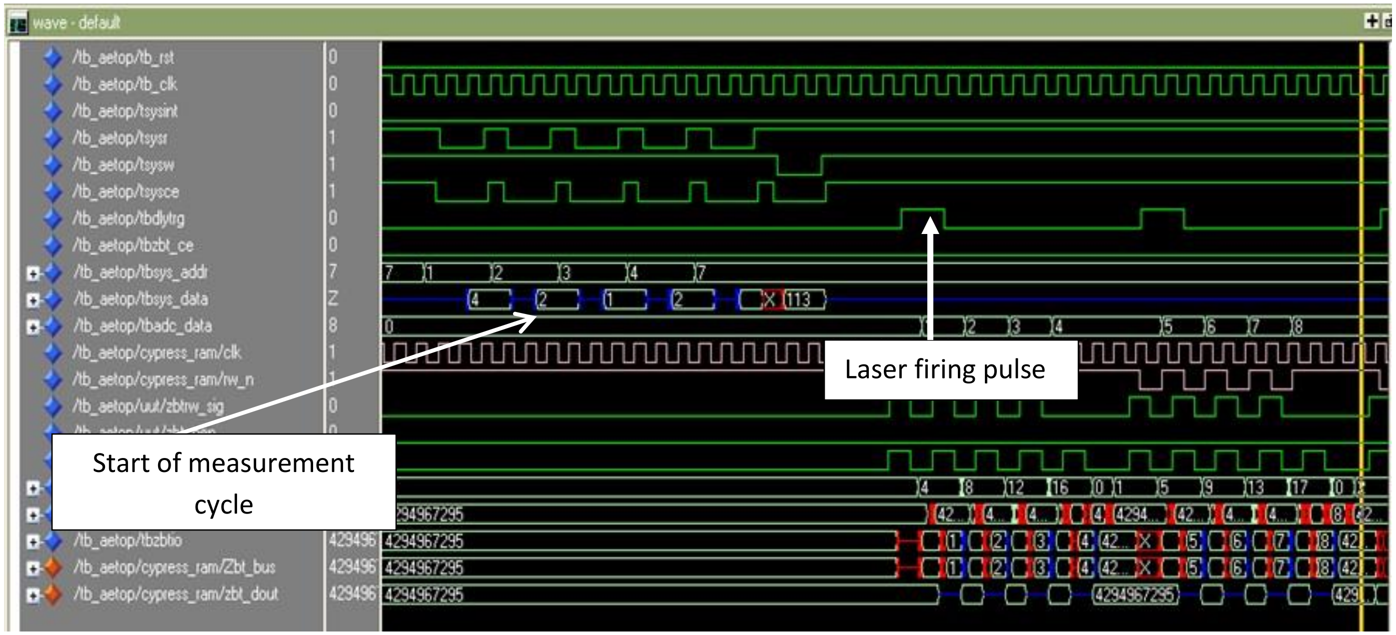


Figure 5 : OTDR System Architecture

Simulation Results of OTDR FPGA Core



Simulation of reading and writing to configuration registers



Start of measurement cycle

Simulation of a complete measurement cycle

Laser Pulse width variation

Figure 6, 7 and 8 shows how LASER Pulse drive logic generates digital pulse of varying duration for different lengths of fiber-optic measurements. The pulse width can be in the range of 10ns to 10.0us with 10ns increment.

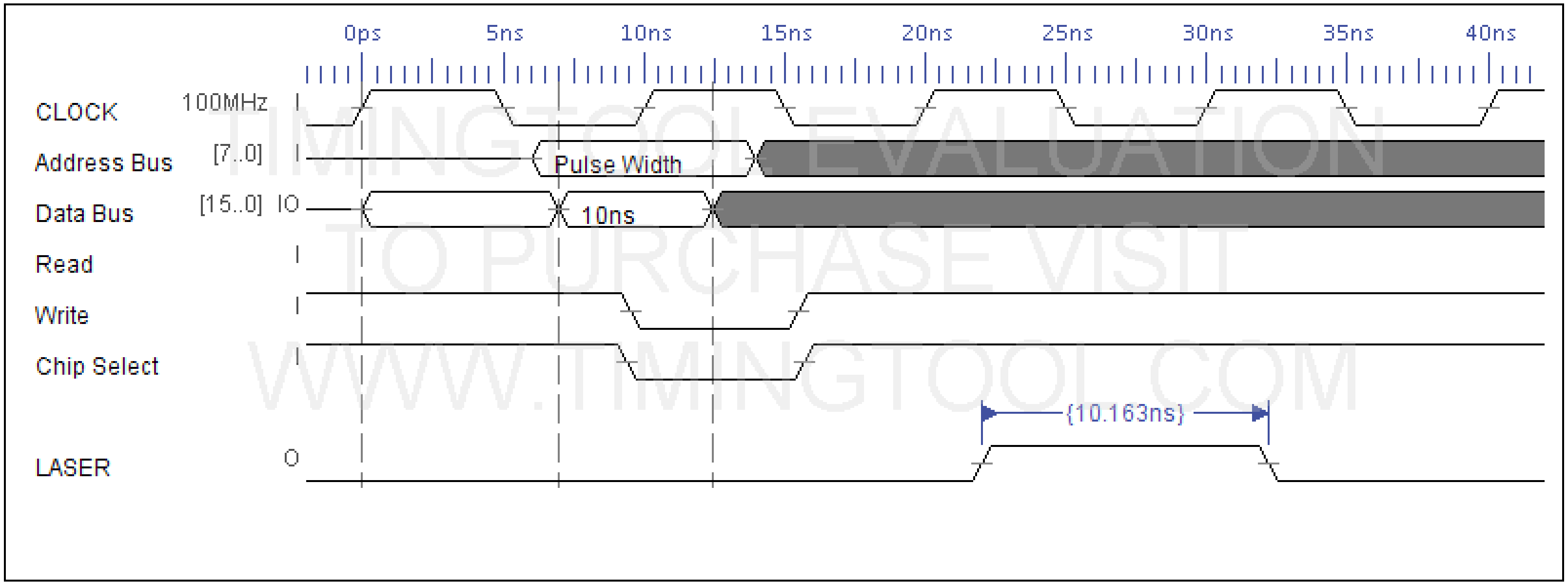


Figure 6

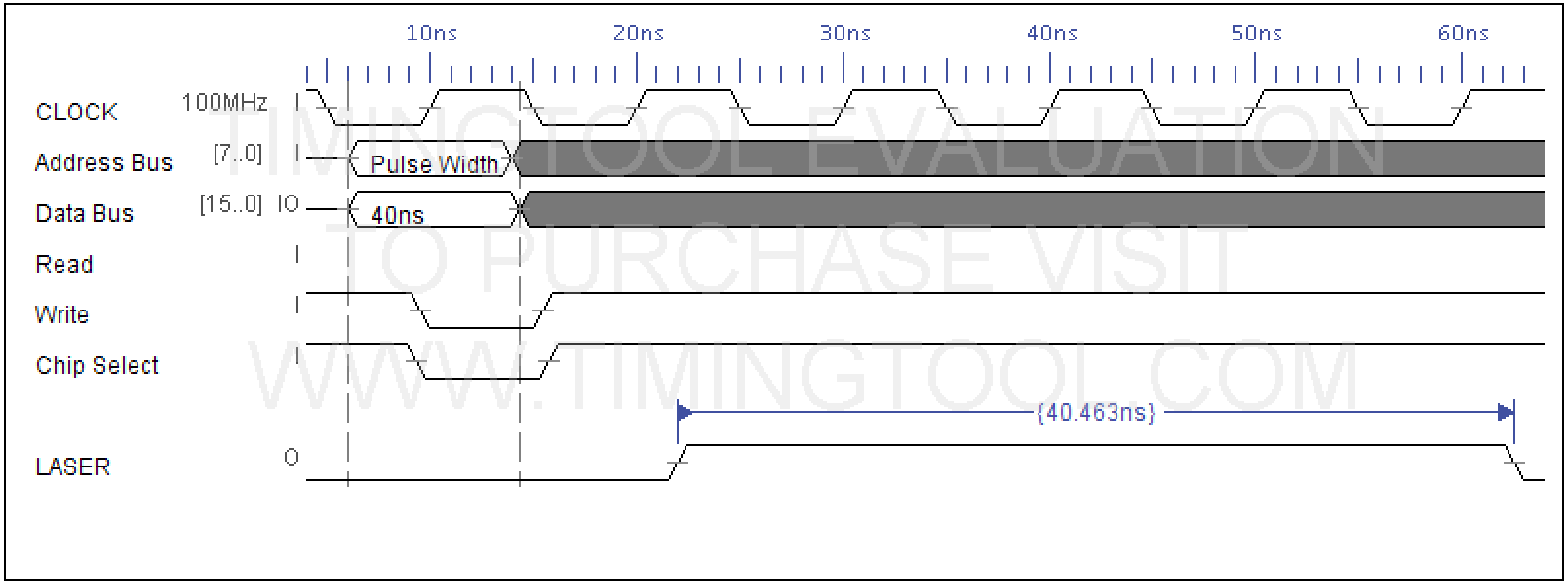

10ns
20ns
30ns
40ns
50ns
60ns
CLOCK
100MHz
I
Address Bus
[7..0]
I
Pulse Width
Data Bus
[15..0]
IO
40ns
Read
I
Write
I
Chip Select
I
{40.463ns}
LASER
O
TIMINGTOOL EVALUATION
TO PURCHASE VISIT
WWW.TIMINGTOOL.COM

Figure 7

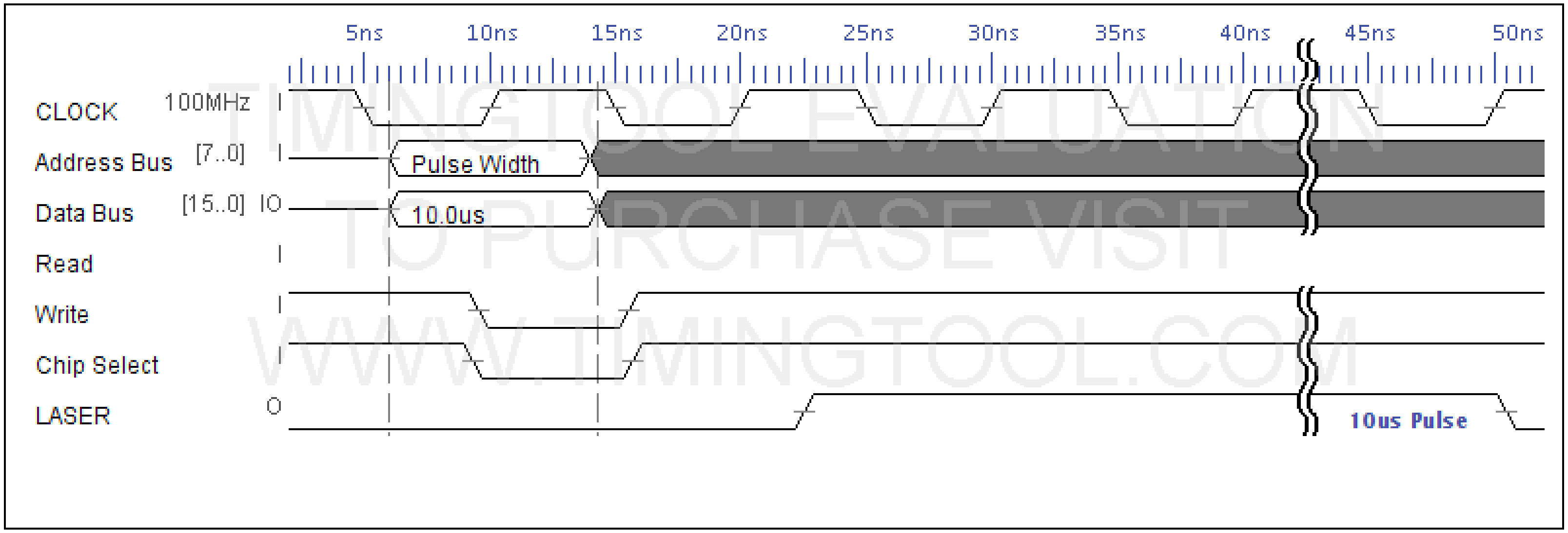


Figure 8

#Note : To acquire and get this core ip customized please contact at : asimghr@yahoo.com

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