



# Picosecond Pulses for Test & Measurement

## White Paper

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### Distribution in the UK

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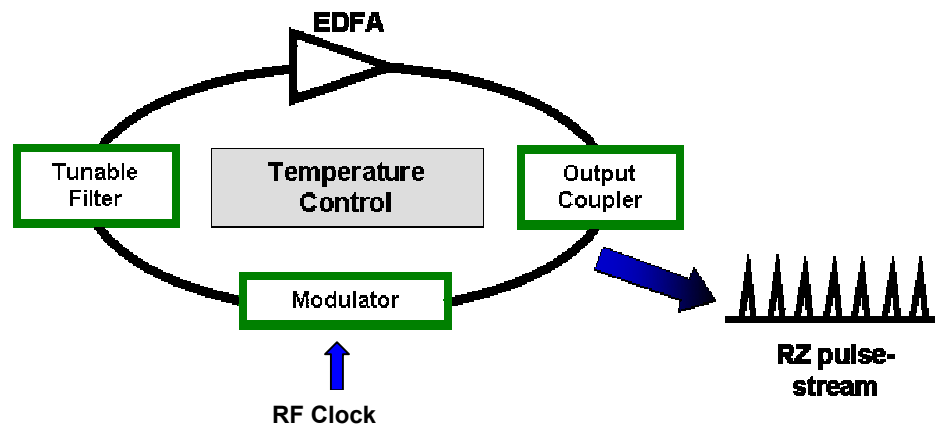
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## Overview

Calmar's picosecond laser sources are actively mode-locked fiber lasers. Active mode-locking enables users to have greater control over pulse repetition rate, since mode-locking is driven by an external RF clock, and adjustments to the frequency of the RF clocking signal affect the modulator used to achieve mode-locking. Figure 1 is a schematic showing an active mode-locked fiber laser.

Since fiber lasers are manufactured from discrete components, dispersive and non-linear effects can be carefully controlled. Furthermore, fiber lasers, which usually include an EDFA, are typified by low timing jitter and low amplitude noise, a benefit stemming from the fact that EDFAs have lower noise and longer excited state lifetimes than alternatives.



**Figure 1 - Simplified Schematic for a Fiber Laser**

Pulse widths for Calmar's 10 GHz Picosecond Lasers range from approximately 1 ps to 15 ps. Pulse shape benefits from the high extinction ratio and low chirp characteristic of fiber lasers.

The unique design of Calmar's lasers allows for the following features:

- Widely adjustable repetition rate
- Wavelength tunability over 1550 nm range
- Widely adjustable pulse width

All lasers in Calmar's family of active mode-locked fiber lasers can be mode-locked manually or automatically. The automatic mode-locking feature enables users to start the laser without needing to manually optimize modulator phase lock.

## Features

- Pulse widths < 1.0 ps
- Repetition rate adjustment 5 – 11 GHz
- Wavelength tunability 1535 – 1565 nm
- Average output power > 20 mW
- Low timing jitter
- Automatic and manual mode-locking
- Easy operation



## Applications

Picosecond fiber lasers, which can be used in a wide variety of high speed testing applications, are ideally suited for component and transmission network testing at bit-rates of 10 Gb/s, and higher.

The high extinction ratio, short pulse width, and low chirp make fiber lasers an ideal source for Optical Time Division Multiplexing (OTDM). Optical Code Division Multiple Access (O-CDMA), an emerging technique used in high bandwidth data transmission, requires a stable spectral comb as well as very short pulse width. Calmar's lasers provide the highly stable spectrum and high quality pulses that this application demands.

Optical Analog-to-Digital (A/D) conversion greatly expands the capabilities of A/D conversion beyond what is achievable using electronics, because optical pulses widths are an order of magnitude narrower than the pulse widths attainable using electronics. Fiber lasers, in particular, are ideally suited to this application due to their low amplitude noise, along with very narrow pulse widths.

Ultrafast lasers sources are used in a wide range of material diagnostic applications, including analysis of semiconductor materials used in telecom components, and bio-medical analysis. The high peak powers, short pulse widths, and clean pulse shapes that are hallmarks of fiber lasers, are of great benefit in material diagnosis.

## Technical Specifications

The following table provides specifications for the four fiber lasers in Calmar's family of 10 GHz Picosecond lasers.

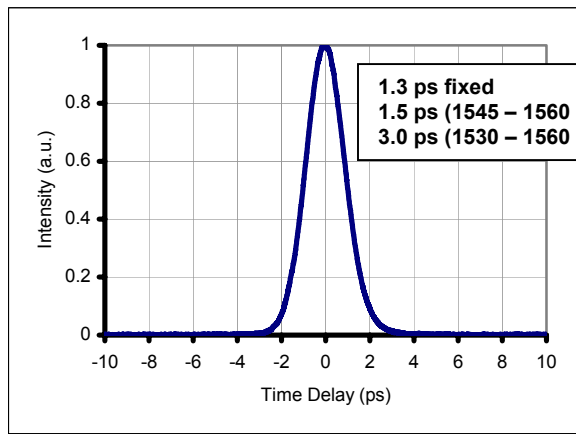
These specifications are subject to change without notice.

Model Number	PSL-10-1T	PSL-10-2T	PSL-10-3T	PSL-10-6T
Pulse Width (ps)	1.0 at one $\lambda$ 1.5 across $\lambda$ range	< 2.0	< 3.0	< 6.0
Output Wavelength (nm)	1545 - 1560	1535 - 1565	1530 - 1565	1525 - 1565
Repetition Rate (GHz)	5 - 11	5 - 11	5 - 11	5 - 11
Timing Jitter (fs)	< 75	< 75	< 75	< 75
Amplitude Noise (%)	< 1.0	< 1.0	< 1.0	< 1.0
Output Power (mW)	> 20	> 20	> 20	> 20
Operating Temp (°C)	15 - 30	15 - 30	15 - 30	15 - 30
Operating Voltage (V)	85 - 264 AC	85 - 264 AC	85 - 264 AC	85 - 264 AC
Dimensions (cm)	48(w) x 42(d) x 9(h)	48(w) x 42(d) x 9(h)	48(w) x 42(d) x 9(h)	48(w) x 42(d) x 9(h)

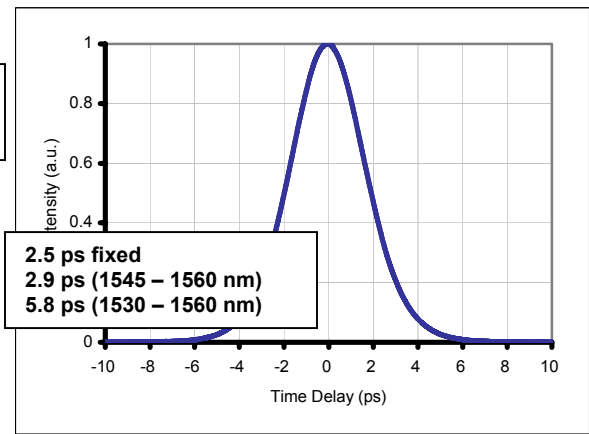
**Table 1 – Specifications for 10 GHz Picosecond Lasers**

## Performance

The following test results give an indication of the performance of Calmar's 10 GHz Picosecond Lasers. The first pair of results, shown in figures 2 and 3, shows the pulse width measured using an autocorrelator, and displayed on a linear scale. Figure 2 shows a pulse width of 1.3 ps, obtained using Calmar's PSL-10-1 fiber laser, while figure 3 shows a 2.5 ps pulse width obtained from Calmar's PSL-10-2 fiber laser.

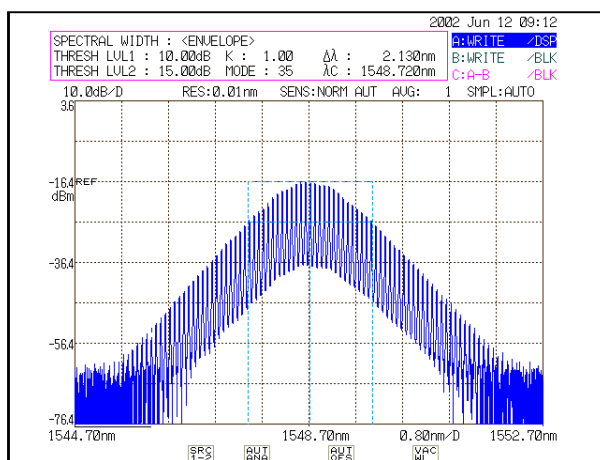


**Figure 2 - Pulse Width FWHM of 1.3 ps (Calmar PSL-10-1)**

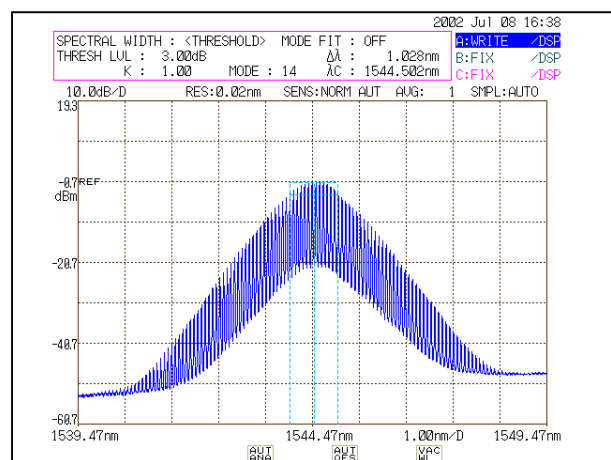


**Figure 3 - Pulse Width FWHM of 2.5 ps (Calmar PSL-10-2)**

Figures 4 and 5 show the results of spectral width measurements. Figure 4 shows a spectral width of 2.1 nm, obtained from Calmar's PSL-10-1 laser, while figure 5 shows a 1.0 nm spectral width, obtained using Calmar's PSL-10-2 laser.

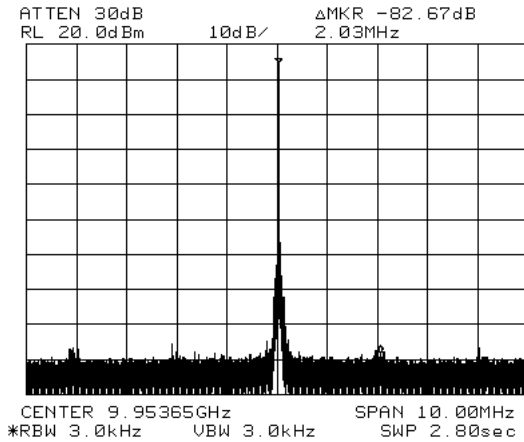


**Figure 4 – Spectral Width of 2.1 nm (Calmar PSL-10-1)**

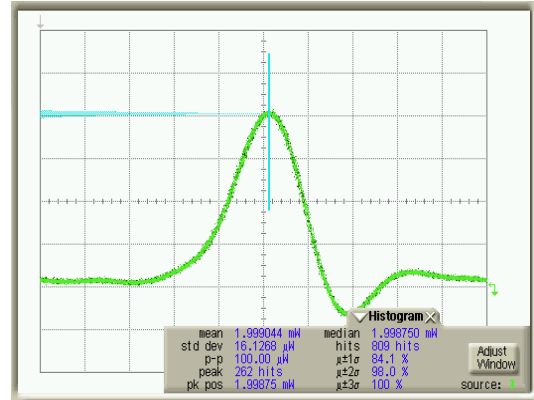


**Figure 5 – Spectral Width of 1.0 nm (Calmar PSL-10-2)**

An RF spectrum analyzer was used to produce the result shown in figure 6. Sidemode suppression of 82 dB was achieved. Figure 7 shows amplitude noise of 0.8 %, measured on an optical sampling scope.

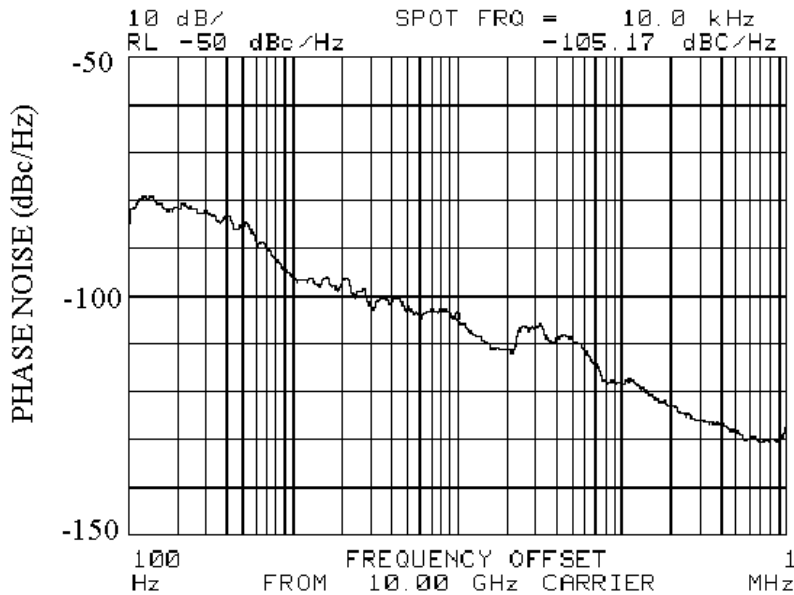


**Figure 6 - Sidemode Suppression of 82 dB**



**Figure 7 - Amplitude Noise of 0.8 %**

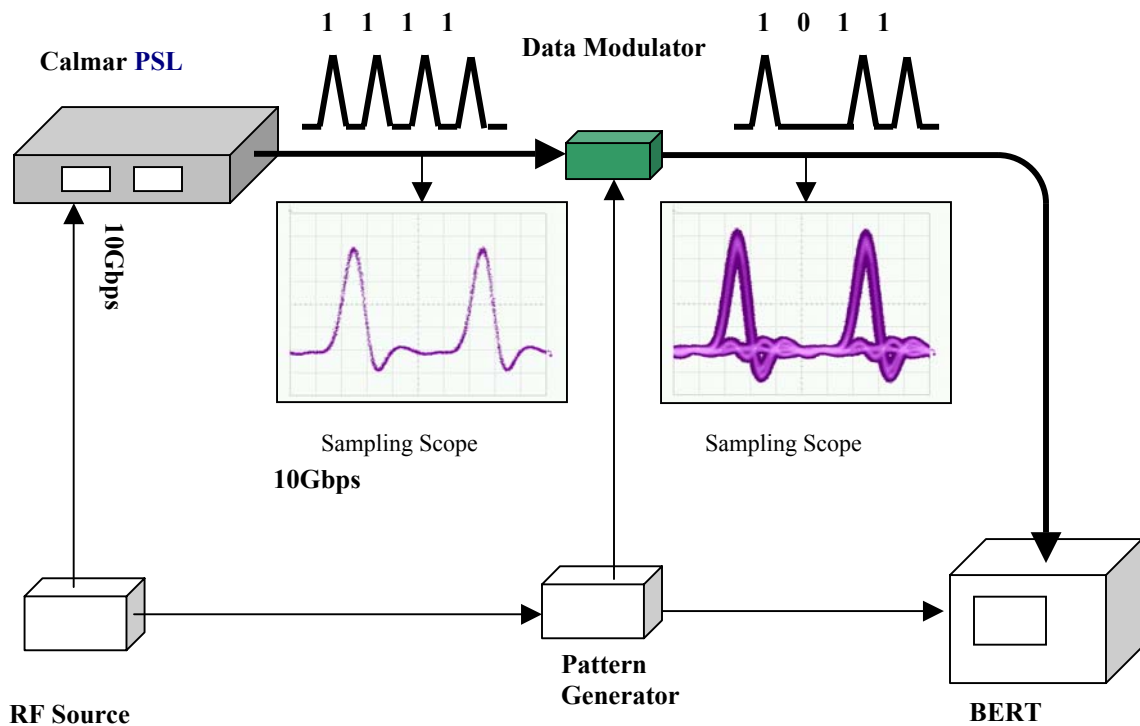
Finally, figure 8, obtained from a spectrum analyzer, shows phase noise of 0.16°. Timing jitter can be calculated from this result to be 45 fs.



**Figure 8 - Timing jitter of 45 fs**

## Error Performance

Exceptional stability of the laser source used in test and measurement applications is critical, especially when such equipment is used in experiments to measure bit error rates. Many telecom applications require bit error rates of  $10^{-12}$ ,  $10^{-15}$ , or better, and any laser source used for testing these system transmission systems, must provide error free performance to match. Figure 9 displays a set-up used to measure the error performance of Calmar's Picosecond Lasers.



**Figure 9 – Test Set-up for BER Measurement**

The results obtained using this experimental set-up are shown in figures 10 and 11, and are representative of the typical performance obtained from any of Calmar's Picosecond Lasers. Figure 10 shows a Bit Error Rate Tester display after twenty four hours of testing, while figure 11 provides Q measurement and Eye Analyzer results.

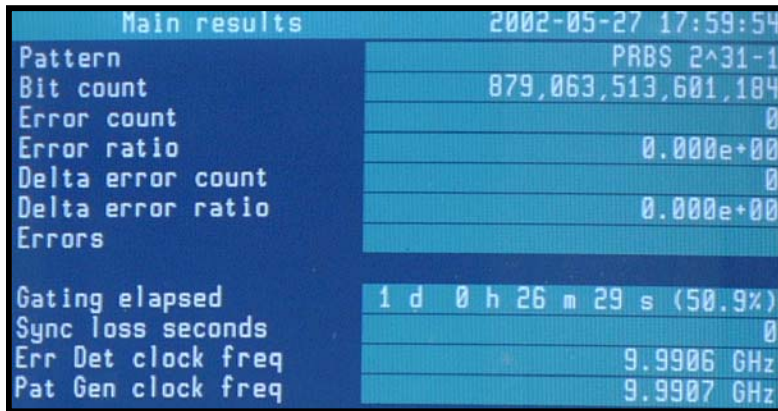


Figure 10 – BERT Display after 24 Hours

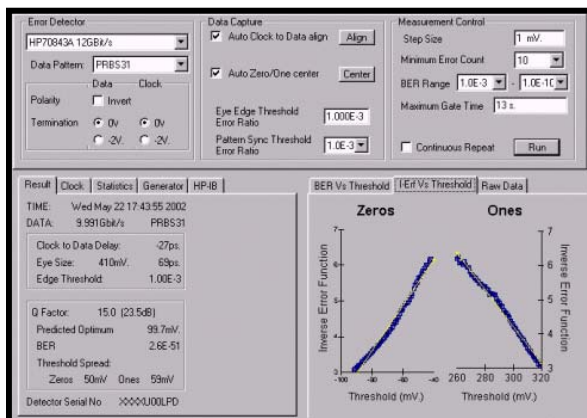


Figure 11 – Q and Eye Analyzer Results

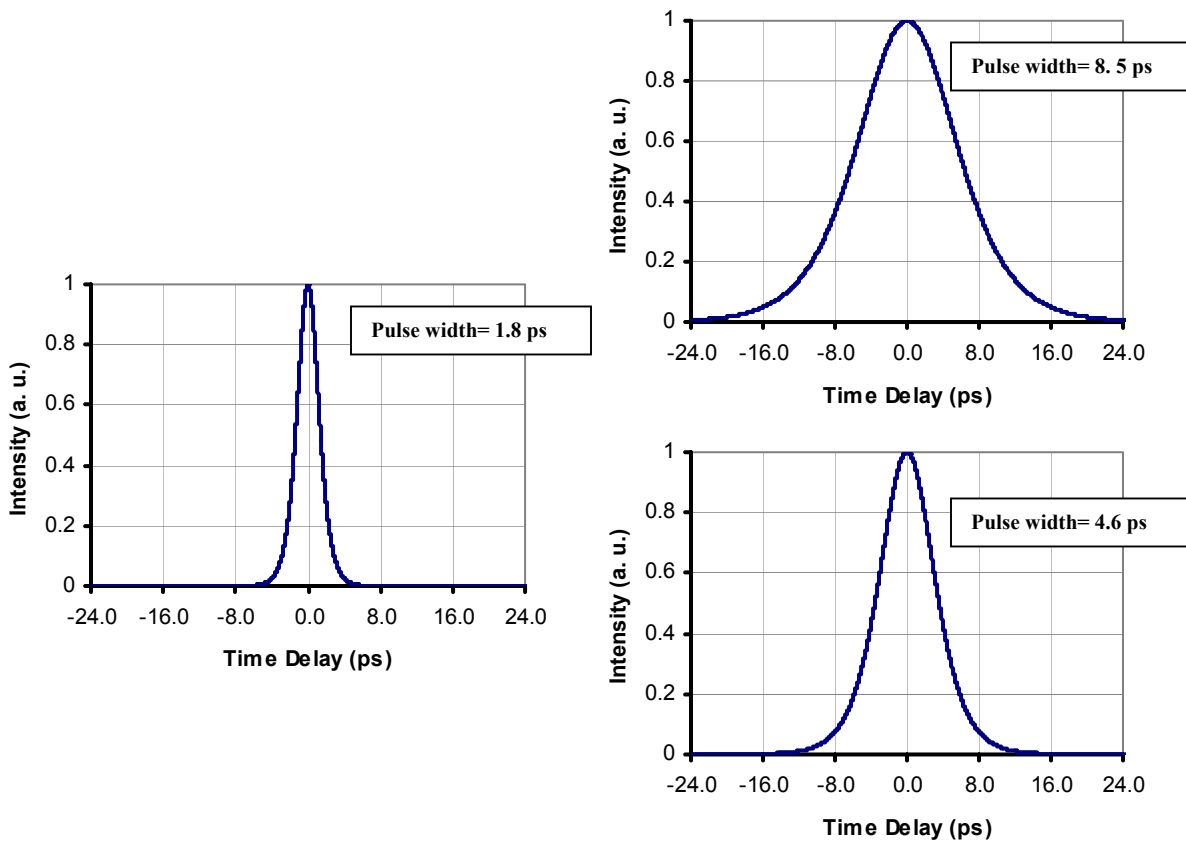
The Bit Error Rate tester (BERT) display shown in figure 11, indicates that there were no errors after 24 hours. Q Factor is shown in figure 10 to be 15, at 23.5 dB. From this measurement, the BER can be extrapolated to be  $1.0 \times 10^{-50}$ .

## Pulse Width Adjustment

Calmar's optionally pulse width adjustment feature enables users to change the signal pulse width quickly via the front panel. Pulse shape and quality are not impacted.

Figure 12 provides three examples of different pulse width that were obtained from one picosecond fiber laser. Pulse width is 1.8 ps in the first example, 4.6 ps in the second example, and 8.5 ps in the third example.

Calmar's lasers are designed for optimum stability, and, as a result, pulse width adjustments are stable and repeatable.



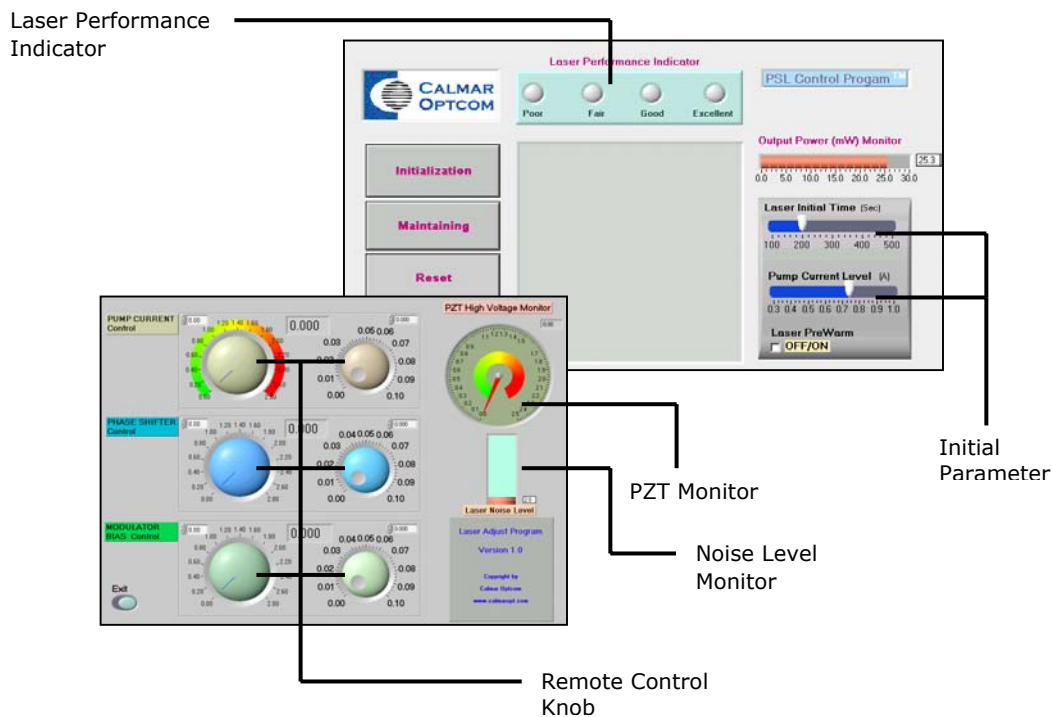
**Figure 12 – Sample Results for Pulse Width**

## Remote Control

The advanced computer control feature of the 10 GHz Picosecond Fiber Laser uses the laser output to control laser status, and lock the laser for optimum performance. The control software ensures ease of use via readily accessible graphical controls viewable on the computer monitor.

The automatic mode-locking feature is especially advantageous for users that are not familiar with the operational requirements of actively mode-locked fiber lasers. As soon as the Picosecond Fiber Laser is turned on, the computer analyzes the laser status and locks it for best performance, a procedure accomplished in just a few minutes.

The computer automatically maintains the laser status, which is of special interest for life or long term testing of 10 Gb/s to 160 Gb/s transmission systems. Graphical laser performance indicators allow the user to monitor laser performance without the need for a sampling scope or equivalent instrument.



**Figure 13 - Remote Control Interface**

For more information on our Picosecond Fiber Laser series, Femtosecond Fiber Laser series, or any other Calmar products, please contact us.

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