Testing with Femtosecond Pulses

White Paper

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Overview

Calmar's femtosecond laser sources are passively mode-locked fiber lasers. Passive mode-locking makes these lasers easier to operate than actively mode-locked lasers, as no external RF clock signal is required, and little or no warm-up time is needed. Temperature control is also less of an issue with passive mode-locked lasers.

Calmar's passively-mode-locked lasers produce pulses as narrow as 80 fs wide. Repetition rates are fixed in the range 10 - 100 MHz. The peak output power of a femtosecond laser is, of course, high due to the short pulse durations, and peak powers up to 10 KW can be achieved using an integrated EDFA. Figure 1 shows a simplified schematic of a passively mode-locked fiber laser.

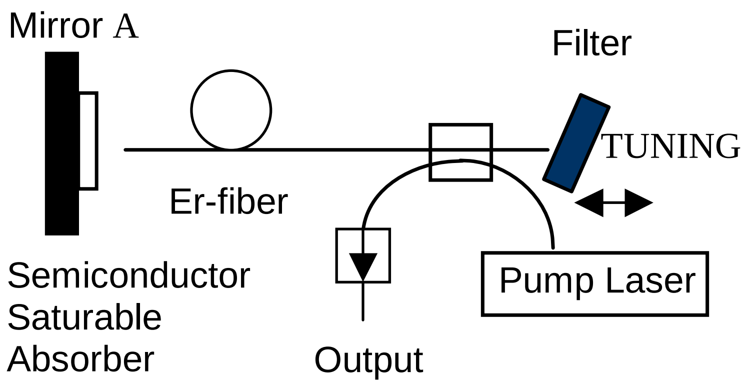

Figure 1 – Schematic of Passive Mode-locked Fiber Laser

Since Calmar's fiber lasers are manufactured from discrete components, dispersive and non-linear effects can be carefully controlled. Pulse shape is transform-limited, and the pedestal is typically 20dB lower than the signal.

The RZ pulses from Calmar's lasers are ideally suited for testing and characterization at 40 Gb/s and higher. Wavelength can be tuned from 1535 nm to 1560nm with a simple adjustment from the front panel of the laser.

The capability to phase-lock the repetition rate to an external clock is available as an optional upgrade. In this scenario, a low jitter phase lock loop precisely tracks the laser repetition rate to an external clock. This feature is particularly useful for optical sampling applications.

Calmar's lasers are recognized for their stability, as demonstrated by their low timing jitter and low amplitude noise, thereby ensuring that the quality of the laser output meets even the most stringent test requirements.

Features

- Pulse widths < 100 fs
- Repetition rate 10 – 100 MHz
- Wavelength tunability 1535 – 1565 nm
- Peak output power >10 KW
- Spectral Width 5.0 nm
- Pedestal < -20dB
- No warm-up time required
- No external RF source required
- Easy configuration and operation
- Long term stability

Applications

Femtosecond fiber lasers are an ideal source for testing the impulse response of optical receivers. Calmar’s femtosecond lasers, which can have a pulse width as low as 150 fs, can be used to test optical receivers with bandwidths larger than 200 GHz.

High-speed sampling, which requires sub-picosecond pulse widths, along with low timing jitter and amplitude noise, is a popular application for femtosecond fiber lasers.

The femtosecond pulses that Calmar’s Femtosecond Fiber lasers produce can also be used for optical networking R&D. The short pulse width and the high peak powers of these laser sources are ideal for high resolution optical time domain reflectometry (OTDR), and fiber non-linearity measurements, and fiber dispersion characterization.

Technical Specifications

The following table provides specifications for the two fiber lasers in Calmar's family of Femtosecond Fiber lasers.

These specifications are subject to change without notice.

Model Number	**FPL-01-AF**	**FPL-02-TT**	**FPL-03-TF**
Pulse width (ps)	0.5	0.3 ~5 adjustable*	0.1 ~ 1 Selectable
Wavelength (nm)	Fixed within 1535 – 1560	1535 – 1560 1525 ~ 1565 (typical)	Fixed within 1535 – 1560
Repetition Rate (MHz)	20 (Other repetition rate within 10 ~ 100 MHZ available)		
Peak Output Power (W)	40	300	10K at 0.1 ps
Average Output Power (mW)	0.4 (typical)	5 (typical)	20 (typical)
Timing Jitter (fs)	<70 (Carrier offset 100 ~ 1M Hz)		
Spectral Width (nm)	5.0 (at 0.5 ps, transform limited)		2~40 (Near transform limited)
Operating Temp (°C)	5 - 40		
Operating Voltage (V)	85 - 264 AC		
Dimensions (cm)	34(w) x 42(d) x 9(h)		

Table 1 – Specifications for Femtosecond Fiber Lasers

Performance

The following test results give an indication of the performance of Calmar's Femtosecond Fiber Lasers.

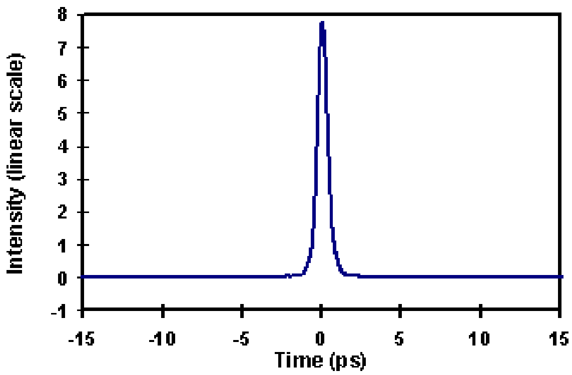

Figure 2 – Autocorrelation trace of output wavelength at 1550nm (500 fs pulse)

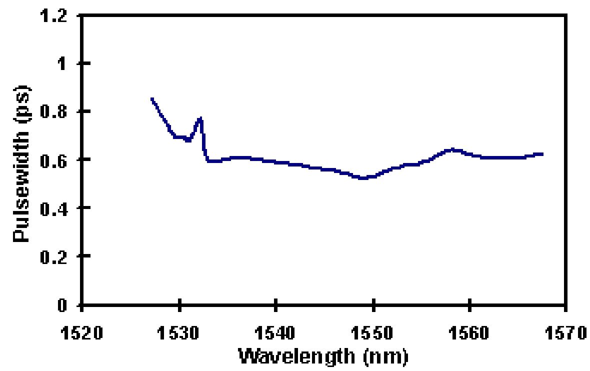

Figure 3 – Pulse width vs. wavelength. Pulse width is < 900 fs across the 1550nm range

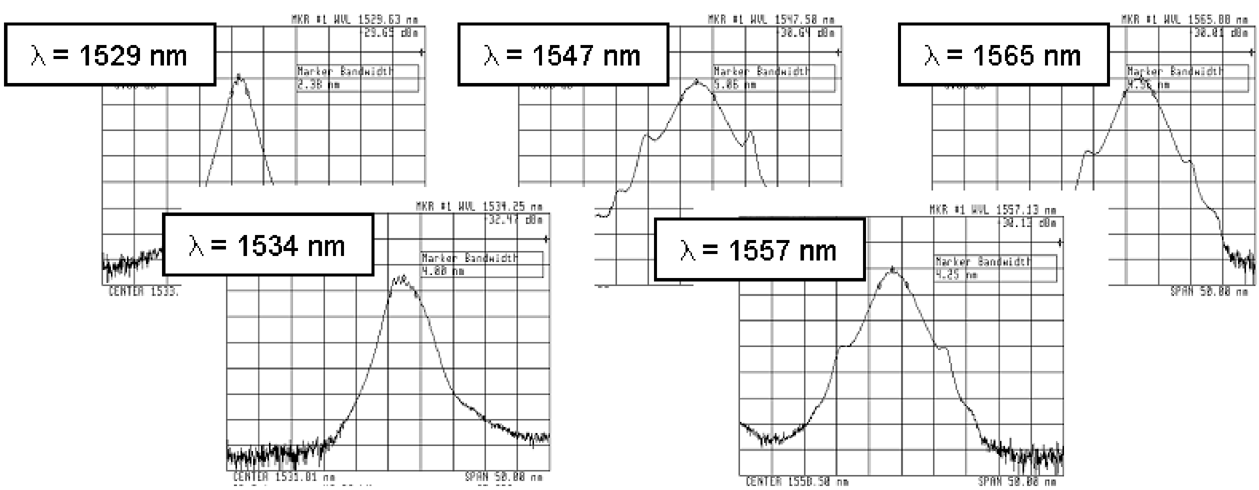

Figure 4 – Output spectra at five different wavelengths. Plots are in log scale (5 dB/div). Peak wavelengths are shown n the boxes

Applications

Femtosecond laser sources are used in a wide variety of application. These include the following:

- Optical Receiver Characterization
- High Speed Sampling
- Optical Impulse Stimulus
- Optical Networking R&D

Optical Receiver Characterization

Femtosecond fiber lasers are an ideal source for testing the impulse response of optical receivers. The impulse response enables the response of a receiver to an arbitrary input waveform to be calculated. For example, the 500 fs pulses generated by Calmar's lasers are ideal for testing receivers with a bandwidth less than 200 GHz. By comparison, semiconductor lasers, which are generally limited to pulse widths of 20 ps, assuming a reasonable pedestal, are limited to testing receivers with a bandwidth below 5 GHz.

An experimental set-up for testing high speed optical receivers in shown in Figure 5.

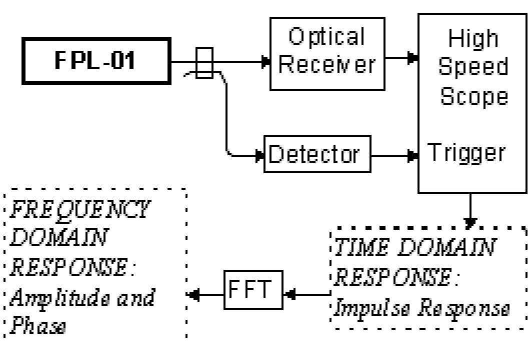

Figure 5 - Measuring High Speed Receiver Performance

The frequency domain responses (amplitude and phase) can be derived form the impulse response using a PC-based Fast Fourier Transform algorithm.

Low pedestals and low noise are hallmarks of Calmar's lasers, making them ideal for this type of test application.

Figure 6 shows an experimental arrangement for characterizing the impulse response of an optical receiver. The output of the femtosecond fiber laser is split into two signals at a fiber coupler. One signal is delivered to the optical receiver under test, while the other signal is fed to a detector and generates a trigger signal for the high-speed oscilloscope. The power level of the optical pulse is adjusted appropriately to avoid receiver and detector saturation.

The reading from the high-speed oscilloscope is the impulse response of the optical receiver, plus the oscilloscope response. Using the response data of the oscilloscope, the response of the optical receiver can be calculated. A frequency domain response (amplitude) can also be obtained.

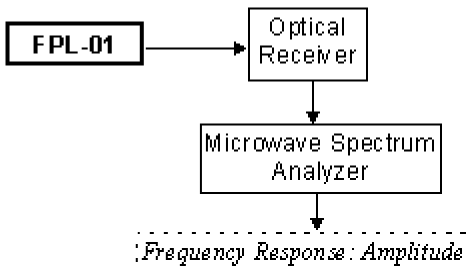

Figure 6 – Measuring Frequency Response of an Optical Receiver

High Speed Sampling

Femtosecond Fiber Lasers can be used for high speed sampling of electro-optics, all-optical sampling, and photoconductive switching.

The 500 fs pulse width of Calmar's Femtosecond Fiber Lasers is ideal for most applications. Low amplitude noise (typical RIN is - 120dBc/Hz) and low timing jitter (<0.2 ps), ensure that time resolution and detection sensitivity meet even the most stringent requirements.

In addition, an option for phase-locking the pulse repetition rate to an external clock increases the utility of Calmar's femtosecond laser sources.

Optical Impulse Stimulus

Femtosecond pulses are used as a stimulus source for testing the high speed optical response of a device with a streak camera, or an optical spectrum analyzer. A typical experimental set-up is shown in Figure 7.

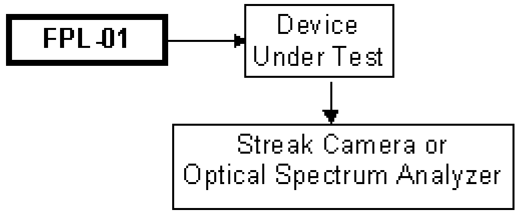

Figure 7 – Using A Femtosecond Fiber Laser as Stimulus Source

The short output pulses of Calmar's Femtosecond laser sources are especially useful for this type of application.

Optical Networking R&D

The femtosecond pulses that Calmar's Femtosecond Fiber lasers produce can be used for high speed communication research and development. The short pulse width, and the high peak powers, of these laser sources are ideal for high resolution optical time domain reflectometry, and fiber non-linearity measurements and dispersion characterization.

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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