Using the Phoenix 1400 Tunable Laser for Characterization of a WDM Filter

A Luna Technologies Application Note

www.lunatechnologies.com
3157 State Street • Blacksburg, VA 24060 • Phone 1.540.961.5190 • Fax: 1.540.961.5191

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1 Introduction

In Wavelength Division Multiplexing (WDM) systems multiplexers mix multiple signals at separate carrier frequencies into one optical fiber. At the receiving end a system of demultiplexers separates and routes the signals. Essential to this process is a device called the WDM filter which is designed to pass or suppress light within a specified frequency band. Therefore measuring the insertion loss characteristics of a WDM filter over a range of wavelengths is of practical interest.

Luna Technologies' Phoenix 1400 laser is ideally suited for this type of measurement with full C-band tunability, low noise, built in wave meter, power monitors and 2 optical detectors.

This application note details two setups and procedures for measuring insertion loss (IL) as a function of wavelength through a WDM filter. The basic arrangement allows for fast and simple insertion loss information via measurements of the input optical power and transmitted optical power. The second arrangement allows higher dynamic range IL measurements through use of a modulated input optical beam and simple data processing techniques.

2 Basic Measurement Setup

The Phoenix 1400 system and accompanying PC will need to be powered on and the USB 2.0 data transfer cable from the Phoenix 1400 system plugged into an available USB port on the computer. The user should ensure that FC/APC connections are used to mate the WDM filter to the Phoenix 1400 as shown below in figure 1.

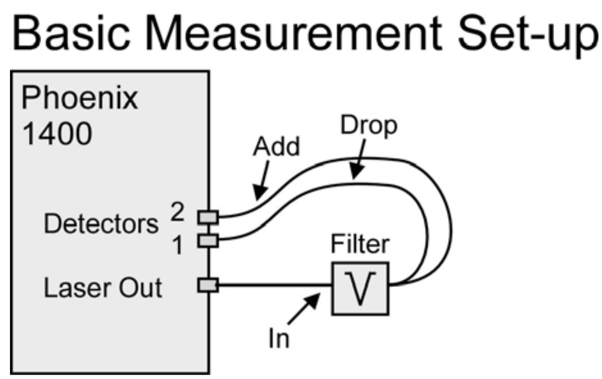

Figure 1. The basic measurement setup for characterization of a WDM filter. Output of the Phoenix is connected via FC/APC connector to the input of the WDM filter. Similarly, FC/APC connections must be used to mate 'add' and 'drop' channels exiting the filter to the Phoenix 1400 system.

Once the device is connected, the user should open the Phoenix 1400 software and specify the parameters of the measurement. This will include the start and end wavelengths, laser sweep rates, laser power, trigger settings and number of sweeps. The Phoenix 1400 GUI is pictured below in Figure 2.

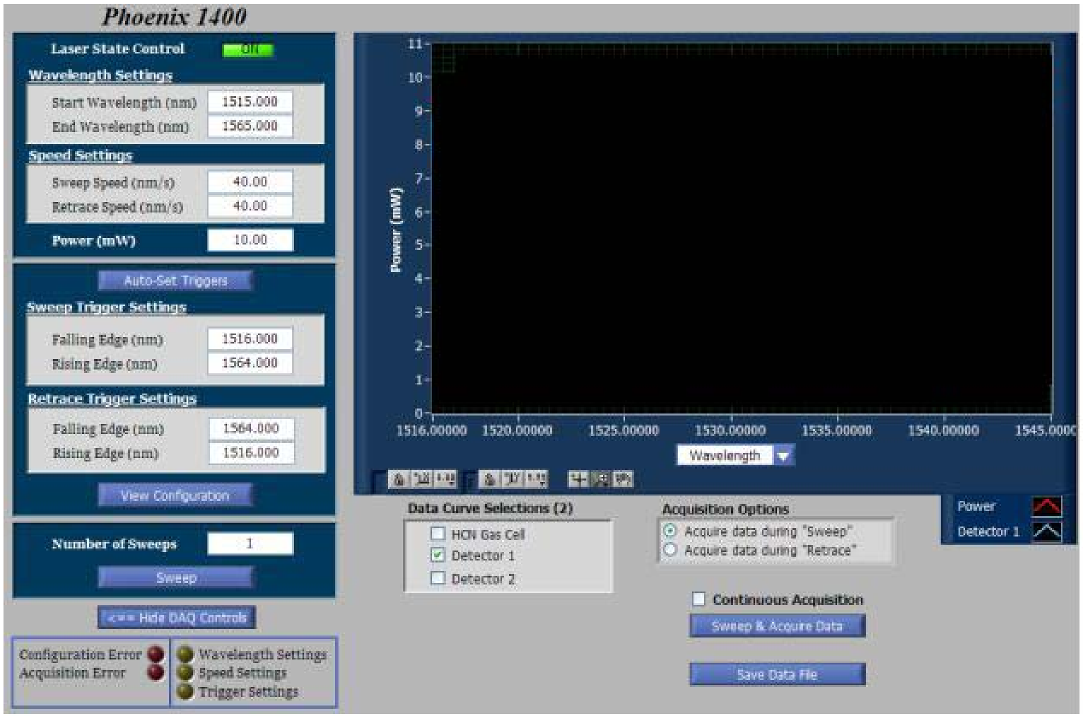

Figure 2. The Phoenix 1400 GUI. The user input settings are on the left, including wavelength, sweep rate, power and trigger settings. To the right is the graphical display, below which is the data curve selection interface.

The laser sweep speed is the rate at which the laser is sweeping from the start wavelength to the end wavelength, while the retrace speed is the rate at which the laser is sweeping on the down scan. The user may acquire data on the up sweep, down sweep or continuously. The exact sweep rate should be chosen by the user based on their specific requirements (data acquisition rate, power stability, etc). The acquisition rate can be selected by the user through a menu option up to a maximum of 1.25 MHz. Please see the system specification sheet for more detailed performance data.

After all settings are specified, the user simply clicks on the Sweep and Acquire Data button. This results in a plot similar to Figure 3 below, with the input optical power in red, and the transmitted power of both the add and drop channels in purple and green respectively.

This data can be saved to a text file and imported to the desired processing software (Lab View, MatLab, etc.) where the insertion loss in dB is calculated using the following formula at each wavelength.

$$IL_{DET\_A} = 10\log_{10}\left(\frac{Power_{DET\_A}}{Power_{INPUT}}\right)$$

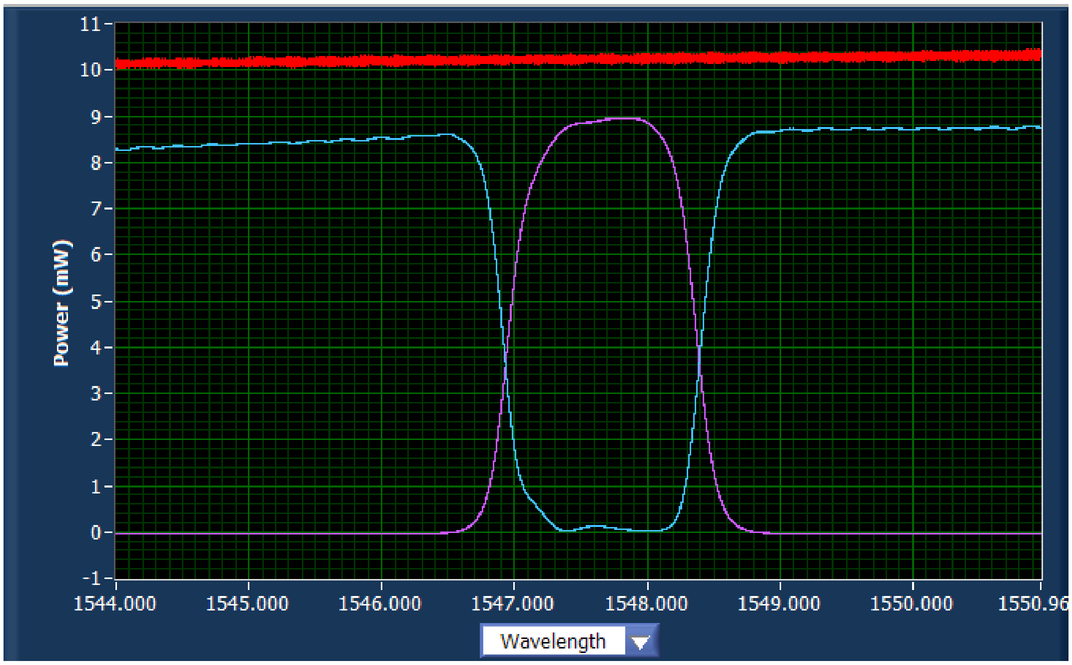

Figure 3. Measurement displayed from the Phoenix 1400 GUI. Input optical power is in red. Detector 1 (drop channel) is in green and Detector 2 (add channel) is in purple.

3 Modulated Measurement Setup

The modulated measurement setup is shown below in Figure 4.

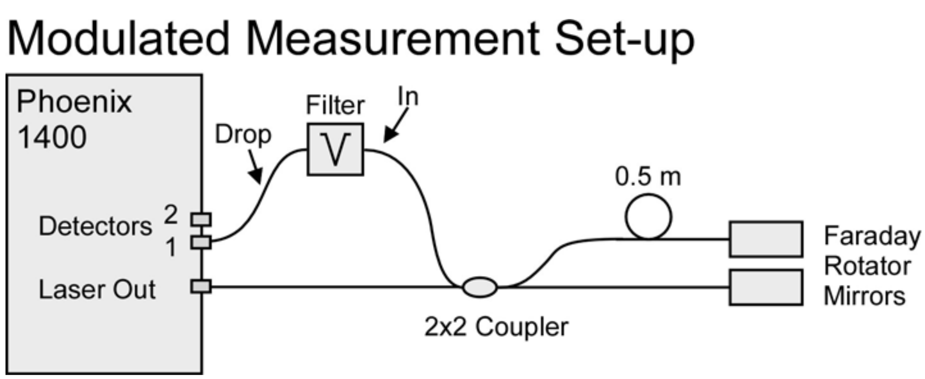

Figure 4. The modulated measurement setup for characterization of a WDM filter. Output of the Phoenix 1400 is connected via FC/APC to a Michelson Interferometer comprised of a 2x2 coupler and 2 Faraday Rotator Mirrors.

This setup pre-modulates the data acquired with a local oscillator frequency that is dependent on the delay of the interferometer. Thus one should ensure the sampling frequency is at least twice that of the local oscillator (LO). For the above interferometer this results in a LO with frequency, f_{LO} in Hz approximated by the following equation

$$f_{LO} \approx \frac{2Rnd}{\lambda^2}$$

where R is the one way sweep rate of the laser in m/s, n is the group index of the fiber, d is the one way delay of the interferometer in m, and λ is the center wavelength of the laser sweep in m. Assuming a central wavelength of 1550nm, a delay of 0.5 m, scan rate of 40 nm/s and goup index of 1.5 this results in a local oscillator near 25 kHz. Nyquist sampling criterion implies then a minimum sample rate at the detector of 50 kHz. In addition, the interferometer delay should be chosen to encompass the full impulse response of the DUT, all the way down to the noise floor.

With an adequate sampling rate in place the user may now fill in the required scan parameters (as outlined above in section 2: Basic Measurement Setup) and acquire data on detector 1. Subsequently, this data should be saved to a text file. For IL measurements one also must know the input power, the user should thus acquire data directly from the output of the interferometer and save to text as well. During this reference scan the same Phoenix settings that were used for the filter measurement should be used.

The two text files can now be loaded into the desired processing software where the following algorithm is used:

1. Perform a Fast Fourier Transform (FFT) on both the filter scan data and the reference scan data. The FFT of the reference scan will have a delta function at the LO frequency.

2. Window the data around this peak, including the full impulse response down to the noise floor.

3. Window both sets of data around this peak, including the full impulse responses down to the noise floor. The magnitude of these data sets are the amplitude responses, now filtered about the local oscillator frequency.

4. Calculate the insertion loss in dB using the formula

$$IL = 10\log_{10}\left(\frac{filter}{reference}\right)$$

3 Summary

The Phoenix 1400 is ideally suited for fast, accurate and simple IL measurements of a WDM filter over the full C band with linear tunability, low noise, unique built-in wavemeter, gas cell, power meter and optical detectors. Furthermore, with a few easy modifications to the measurement network and a short post processing algorithm IL sensitivity can be greatly increased. Below in figure 6 is a comparison of the two measurement setups outlined in the application note, along with the same measurement taken with Luna Technologies' Optical Vector Analyzer (OVA).

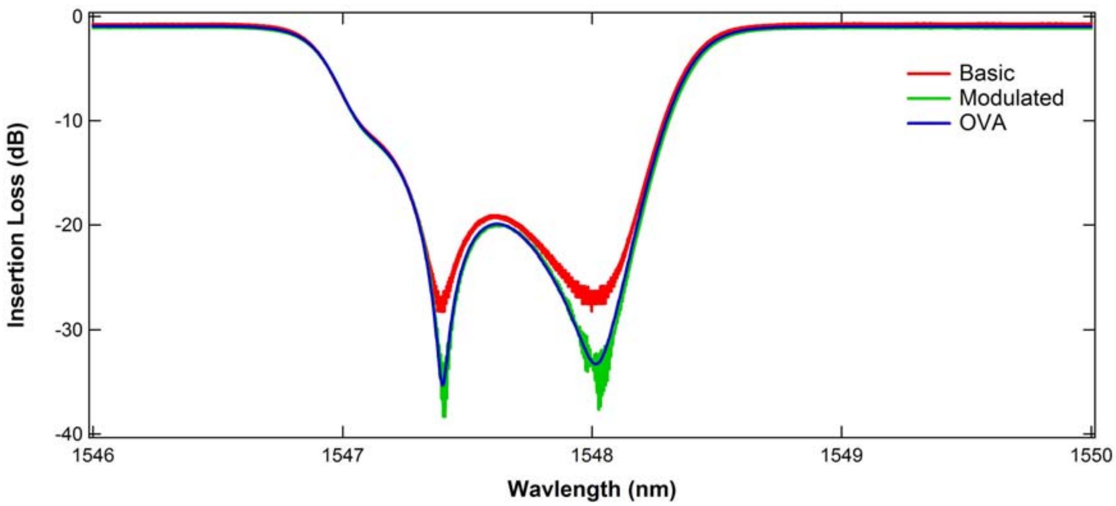

Figure 5. IL data for a WDM filter taken with the Phoenix 1400 system and OVA.