An Experimental Setup to measure the phase stability of a fiber optic link

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I. Introduction:

This report is about building an experimental setup in the laboratory to measure the effect of various parameters on the phase stability of a signal transmitted over long fiber optic link. The experimental setup created in laboratory uses LABVIEW software for interface, control and data recording.

II. Brief description of Experimental setup:

Figure 1. Shows the experimental setup for studying the phase stability of a signal transmitted over 20 km and retransmitted back in the same fiber using optical circulators.

Figure 1.

Experimental setup to measure phase stability in a bi-directional fiber optic link

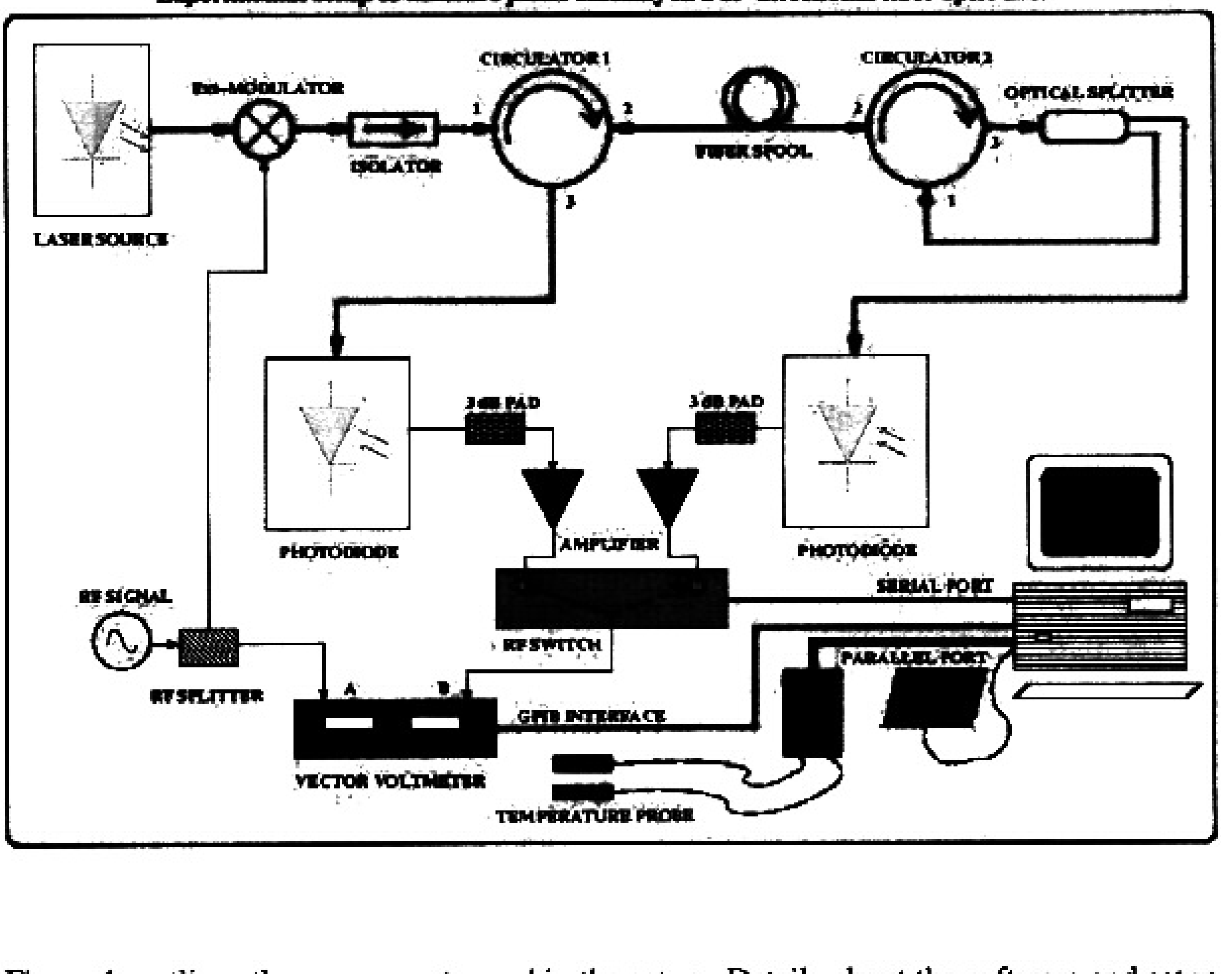


Figure 1 outlines the components used in the setup. Details about the software and setup are explained in the later section of this report.

III. Optical spectrum in a Bi-directional link:

The usefulness of a bi-directional link using single wavelength and single laser source was doubted since the back feeding of optical signal increase the intensity noise in the RF output. But the RF spectrum of the bi-directional link was clean and did not show any periodic noise ripple due to back feeding of the optical signal. There is no significant increase in the noise floor affecting the carrier to noise ratio of the signal. To confirm further the optical spectrum at various stages of the experimental link was recorded and found no degradation down the link due to bi-direction transmission.

Figure 2: Optical output spectrum at Laser diode and Modulator output port in a Bi-directional fiber optic link using circulators and single laser source

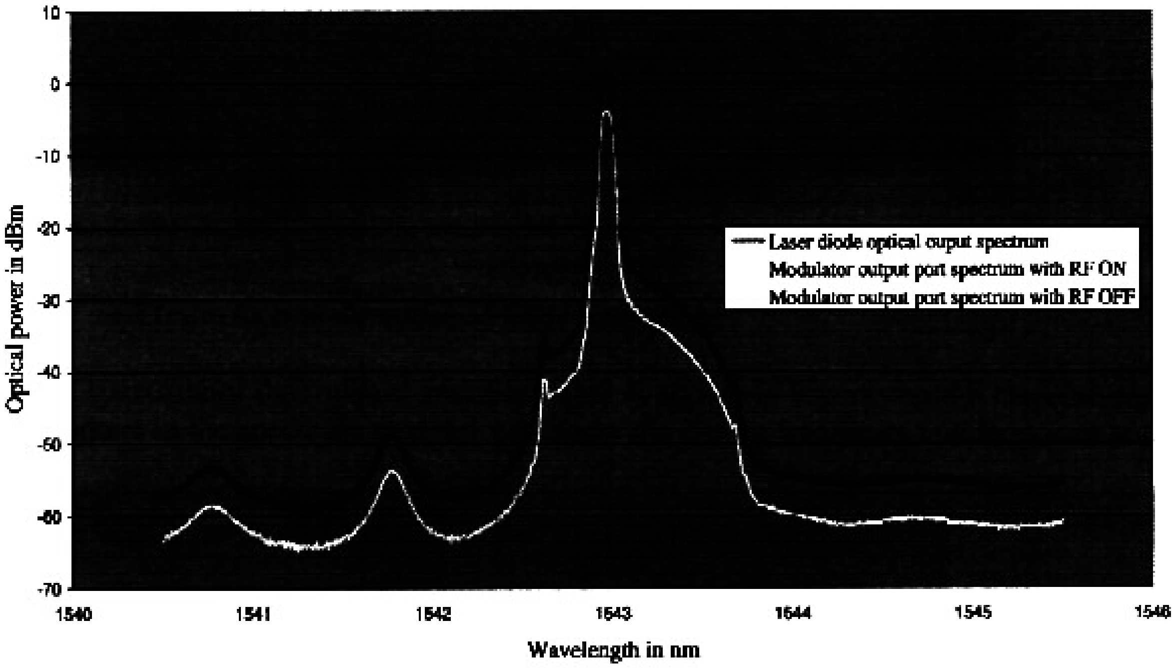
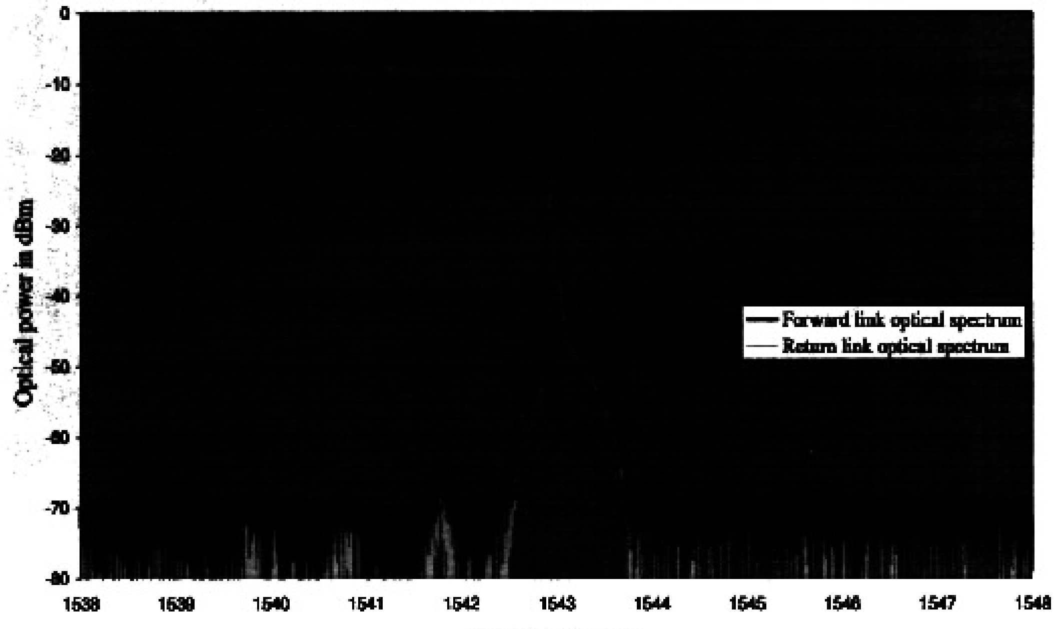


Figure 2 shows the optical signal spectrum at the Laser diode output and the external modulator output port with the modulating signal ON and OFF. The optical spectrum at the output of the external modulator is the same as the output from the Laser but for the drop in level due to the attenuation in the external modulator. With the RF signal ON and OFF the optical spectrum remain the same.

Figure 3 shows the optical spectrum at the output of a 20 km fiber optic link. One spectrum shows the forward link and the other shows the return link spectrum were the link distance is twice that of the forward link. There is no degradation of the spectrum or any inter-modulation due to bi-directional transmission. The attenuation in the return link was due to double the link distance.

Figure 3: Optical spectrum output in a Bi-directional fiber optic link using Circulator and single laser source



IV. RF spectrum in a bi-directional fiber optic link:

The RF spectrum of the forward and return link is shown in Figure 4 and 5 respectively. The markers in the spectrum analyzer plot show the carrier frequency and its power level.

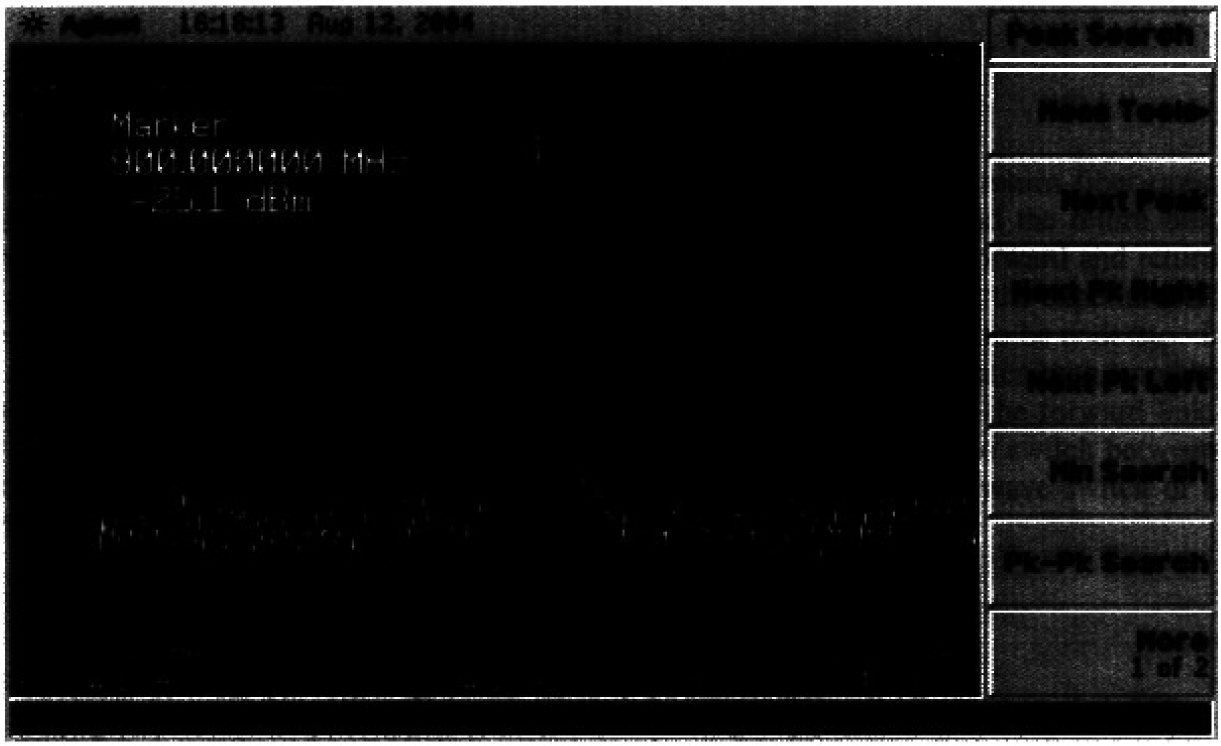


Figure 4: Forward link - Output RF spectrum

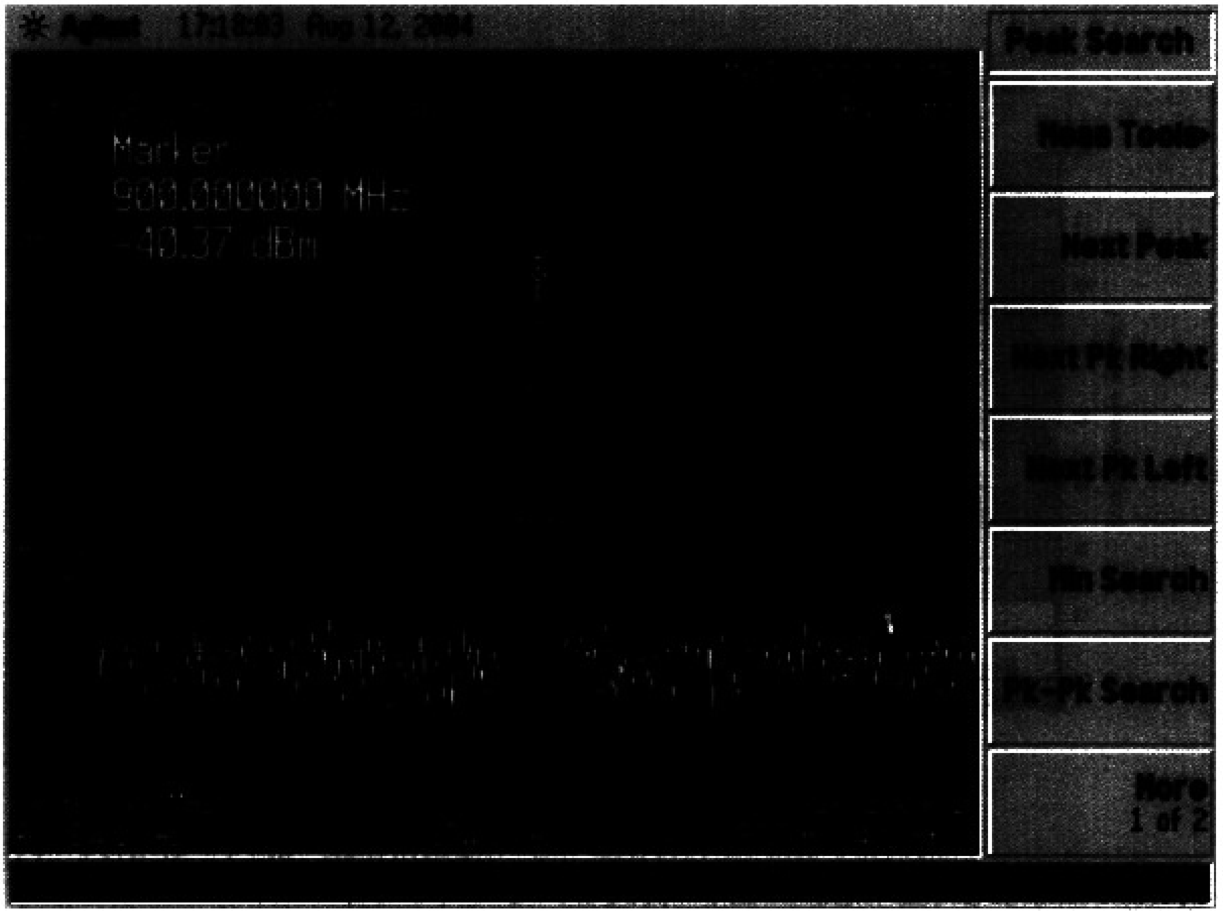
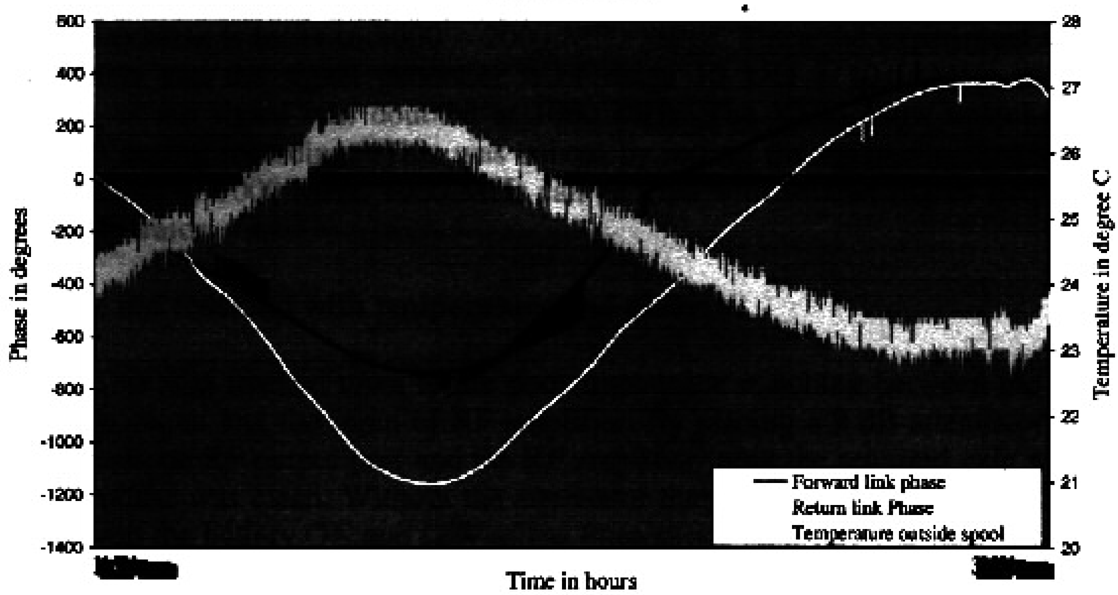


Figure 5: Return link - Output RF spectrum.

V. The Phase stability of a Bi-directional link:

The Phase and temperature was recorded for the forward and return fiber optic link. It was found that the phase moves well with the temperature and the return link phase is larger than the forward link as expected. Figure 6 shows the forward and return phase stability of the bi-directional link with temperature recorded using the experimental setup. The noise in the forward link phase plot and a slight jump are yet to be understood. The noise and jump were not seen in the return link phase plot. Later with another recording the similar phenomenon is seen in the return link and not in the forward link. This could be some jitter or malfunction of the reed relay switch used to switch between the forward and the return link. Replacing the reed relay with a microwave switch or a PIN diode switch will be a better solution.

Figure 6: Temperature and Phase stability of a bi-directional fiber optic link using circulators and single laser source



VI. Problems and solutions:

1. Phase Jumps:

a. Laser source:

Initially a tunable laser source was used to measure the phase stability, but showed phase jumps. The tunable laser did not have a temperature control interface the laser emission wavelength was drifting with temperature. This was corrected by using an EML laser with a built in cooler and thermistor. The EML laser was connected to a temperature controller for constant temperature operation of the laser. The laser diode was connected with the constant current source and the back photodiode was not connected in the experimental setup. With no automatic power control the laser output power can vary and show change in the signal level with aging and with rapid temperature changes.

b. Temperature setting:

The EML laser was operated at 25 degrees, and found to have phase jump when the temperature was below 25 degree. The room temperature was mostly between 19 and 26 degrees and the controller may not be active below the set temperature. The controller was set to 20 degree Celsius and the phase was found to be stable. The temperature controller in general will have a heat and cool arrangement. Hence it is better to re-look this with a temperature controlled chamber.

c. 1000 MHz Vs 900 MHz:

The Vector Voltmeter locks with the signals in different ranges. If the signal is less than 1000 MHz it locks to 500 – 1000 MHz range. If the signal is slightly greater than 1000 MHz it locks to 1000 – 2000 MHz range. Since the experiment was tried at 1000 MHz and the signal generator is of range 10 kHz – 1010 MHz the frequency stability of the signal was doubted at 1000 MHz. The VVM show unlocked for short intervals during recording. This was solved by setting the measuring frequency to 900 MHz instead of 1000 MHz. 1000 MHz can be tried with another higher frequency range signal generator.

2. Phase not tracking with temperature and noisy:

This was tracked town to the poor impedance matching between the Photodiode receivers output and the input of RF amplifier. By placing a 3 dB attenuator in between the photodiode RF output port and the RF amplifier input the required gain was obtained and the phase was clean. Without the attenuator there was no effect on the signal output power with the battery ON and OFF of the Photodiode receiver. The receiver chassis was acting like an antenna and was picking up local TV and Mobile communication signals. All these vanished with the 3 dB attenuator.

3. Noisy Temperature data:

The temperature sensor connected to the Dr.DAC I.O card was giving a noisy reading and it shows about 2 degree temperature fluctuation in a second. This was found to be the interference to the sensor cable with the AC power line cables running cris cross over it connecting various instruments in the setup. The cables were cleared a little from the power cables and the noise on the temperature data was reduced. This is not done completely because of lack of space around the experimental setup. The I.O card is also kept open and they are near the power cable and PC. They introduce noise at the input of ADC in the I.O card. Hence enclosing the card in a shielded box will be of help in reducing the noise in temperature data.

4. Polarization sensitivity of the External Modulator:

The laser source passed through a Polarization controller and connected to the External modulator. The output optical power of the external modulator varied 2 to 3 dB by varying the polarization of the light source at its input Even though polarization maintaining cables were used to connect the laser to the controller and the controller to the external modulator the remaining input fiber of the modulator is a non-polarization maintaining fiber. This made the fibers more sensitive to vibrations and the phase was not stable. The system became more sensitive to vibration and gave lot of phase jumps.

5. FFT spectrum dump:

It was decided to record the FFT spectrum of the Phase detector output using a digital storage oscilloscope. But the VVM gave only the digital display readings in analog form. It did not give the analog voltage of the phase detector output inside VVM. High speed measurements will require an analog phase measuring system (mixers and phase detectors)

VII. Details of settings for the experiment

Parameter	Setting
Laser diode current	*60 mA*
Temperature set for Laser	*20 degree Celsius*
Modulator bias-voltage	*9.0 Volts*
RF power input to the Ext - modulator	*+ 5 dBm at 900 MHz*

VIII. User Guide for Labview programs

Introduction:

The labview programs are developed for recording Phase and amplitude stability from VVM. In addition the program has facilities to record temperatures using DrDAQ and generate a TTL pulse from Serial port of the computer. This switching can be used in selecting an RF port for measurement. There is a second program to dump FFT spectrum from Tektronix TDS1012. These two programs dump data in a file specified by the user.

Details in brief:

The program uses GPIB address of "4" for VVM and "COM1" port for serial port. For the DSO the program uses "1" as its address.

i. **GPIB program for VVM:** The Labview program uses driver files of HP 8508A. It resets the instrument and sets parameters like auto frequency selection for locking to the signal, measurement set-up like 50 ohms input, units in dB, Polar mode, Phase (B-A) and power B/A etc. The program then acquires the data in string and converts to suitable format to write to a file specified by the user. The program writes the date, time, and power in dB and Phase in degrees.

The program prompts to select the following input parameters like file name with full path to which the data is to be recorded, if it is multiple dumps then the time interval desired between measurements is to be mentioned in multiples of millisecond. Say 10 seconds implies 10000 to be typed in the field on the screen. If it is a multiple dump the green logical button on the front screen has to be clicked to turn it ON. Otherwise it runs only for single recording. Figure 6. Shows the Labview program.

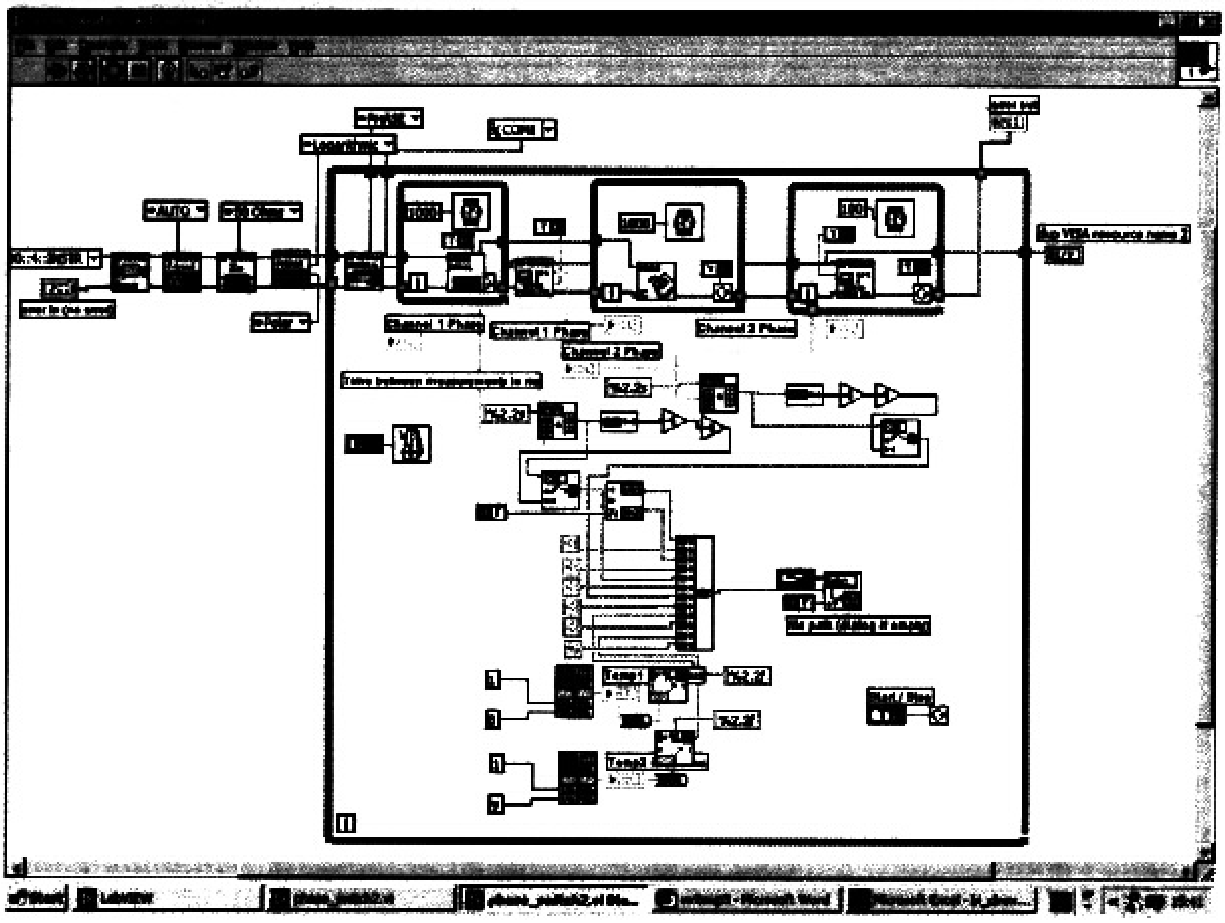


Figure 6. Shows the program file of phase_switch2.vi

ii. Parallel **port program for DrDAQ**: DrDAQ card and driver files for Labview are being used to record the temperature inside and outside the fiber spool. The port number in the program is specified to read the ports the sensors is connected. Change in port numbers will read some other sensor. Hence the port numbers are made as constants in the program and not visible in the front panel.

iii. Serial **port program for RF switch control**: An RF switch was used to select one of the two RF outputs of the experimental setup and measure phase using single VVM. The RF switch is controlled by a TTL signal generated using the available Serial port on the computer. Figure 6 shows the interface diagram with the level conversion RS232 to TTL signal. The serial port is controlled from the Lab view program. This helped in building all measurement modules in one single Labview program.

iv. Front **panel outputs**: The program outputs the temperatures being read in degrees and it reads the phase of two RF signals connected to the VVM through the RF switch. There is also a graphical display to display Time Vs Phase as and when it is being acquired. Figure 7. Shows the front panel of the program.

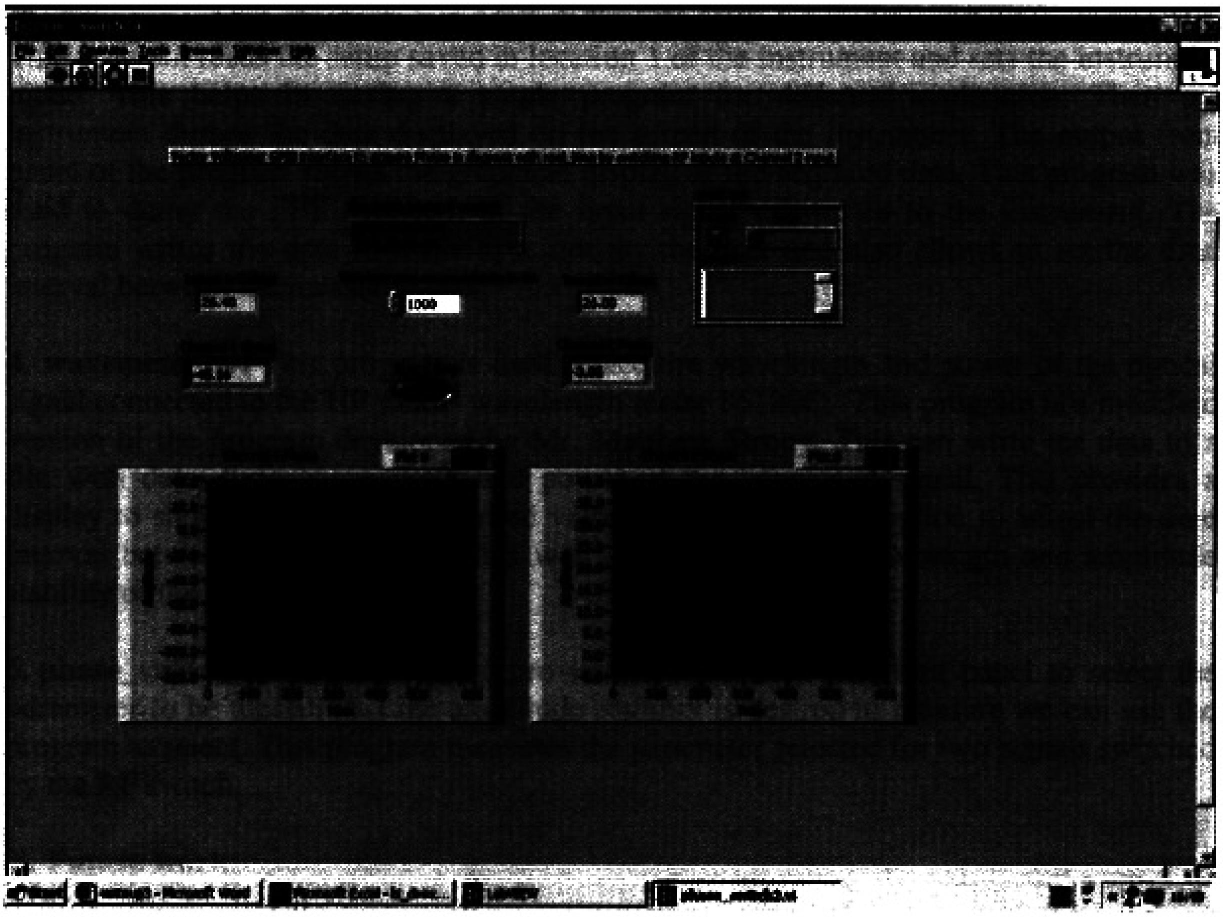


Figure 7. Shows the front control panel and display of the Labview program (phase_switch2.vi)

IX. List of Labview programs

The data acquiring program is modified for the following application.

1. **vector3.vi** *To* record Amplitude and Phase Vs Time of a single link with one RF output. This program records temperatures from two probes connected to Dr.DAC. The data file contains Date, Time, Amplitude, Phase, Temperature1 and Temperature 2.

2. **phase_switch2.vi** To record Phase Vs Time of two links having two fiber spools one for a forward link and other for a return link. Also for a bidirectional link shown in figure 4. This program controls the RF switch as well as record Phase and Temperature. The data file contains Date, Time, Phase of one link, Phase of other link, Temperature1 and Temperature 2. The amplitude of the signals is skipped to save time. The program is tuned with proper delay so that it give about 1 second settling time for the

signal to settle when they are connected to the VVM through the RF switch. In addition the interval between measurements can be set from the front panel in multiples of ms.

3. dso3c.vi This program is to acquire the data from the Textronix DSO - TDS 1012. This program reads the setup saved in location 1 of the instrument and sets the instrument mode. This helps in having a single program for different application. Then the instrument dumps the data displayed on the screen of the instrument. The output front panel of the program shows the graphical display of the acquired data. This program was used to dump the FFT spectrum of the input signal connected to the instrument. The program writes the data in a file specified by the user and also allows to set the time interval between the measurements.

4. wavemeter1.vi *This* program is used to acquire wavelength and power of the optical signal connected to the HP multi- wavelength meter 86120C. This program is a modified version of the program developed by Mr. Matthew Strong. This can write the data to a file with date, time, wavelength and power of the connected signal. This provides a display to show the currently acquired values and provides an option to select the time interval between measurements. This was used to study the wavelength and amplitude stability of the optical signal.

5. phase_switch.vi This program provides a control on the front panel to select the parameter to be measured. Like amplitude stability is desired to measure we can use the program to select. This program measures the parameter selected for two signals switched by the RF switch.

X. Future work:

The phase stability of the link should be studied with more data to isolate the contribution of each optical and RF component in the setup to the total phase change seen with the link.

An environmental chamber will help in doing a control and accelerated experiment on each component of the link to improve their specification.

Acknowledgement:

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I thank Mr. Matthew Strong for the data analysis and feedback which helped in sorting out problems with the setup and its improvement.

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Appendix:

Details of components used in the experimental setup

[redacted]				
1.	Tunable Laser	Photonetics	3645 HE 15	10 1248
2.	EML Laser	Toshiba	TOLD3872-EAD	N.A
3.	External Modulator	Ramer Corporation	500-20-15	208-469-8
4.	Fiber Spool	Corning fiber	20.079 km length	DE-69184
5.	Optical splitter	FOCI	Standard single mode coupler	C-NS 78614
6.	Optical isolator	O-NET communication ltd	ISO-D-P-55-2-1-1	SN-ISO-001200
7.	Optical Circulator 1	FOCI	M-CN-5W-L-E-1-FC/FC	02000899
8.	Optical Circulator 2	FOCI	M-CN-5W-L-E-1-FC/FC	02000900
9.	Photodiode Receiver	THORLABS	InGaAs, D400FC	N.A
10.	RF signal generator	Marconi Instruments	10 kHz – 1.01 GHz, 2022E	
11.	RF amplifier	Minicircuits	ZFL-1000LN	04921 & 04918 J.B I.D number
12.	Vector Voltmeter	HEWLETT PACKARD	HP 8508A	
13.	Current Source	ILX Lightwave	LDX 3207	
14.	Temperature Controller	ILX Lightwave	LDT 5910	