Subject:	**Date:**	**From:**
MZM-LORTM Operation Notes	April 13, 2014	Derek Kubo
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References: MZM-LORTM Upgrade (ppt file)

1. Introduction

The MZM-LORTM instrument was developed to support the 2nd test line at EA-FEIC. The goal for this instrument is to replicate the performance of the existing baseline LORTM developed by TeraXion.
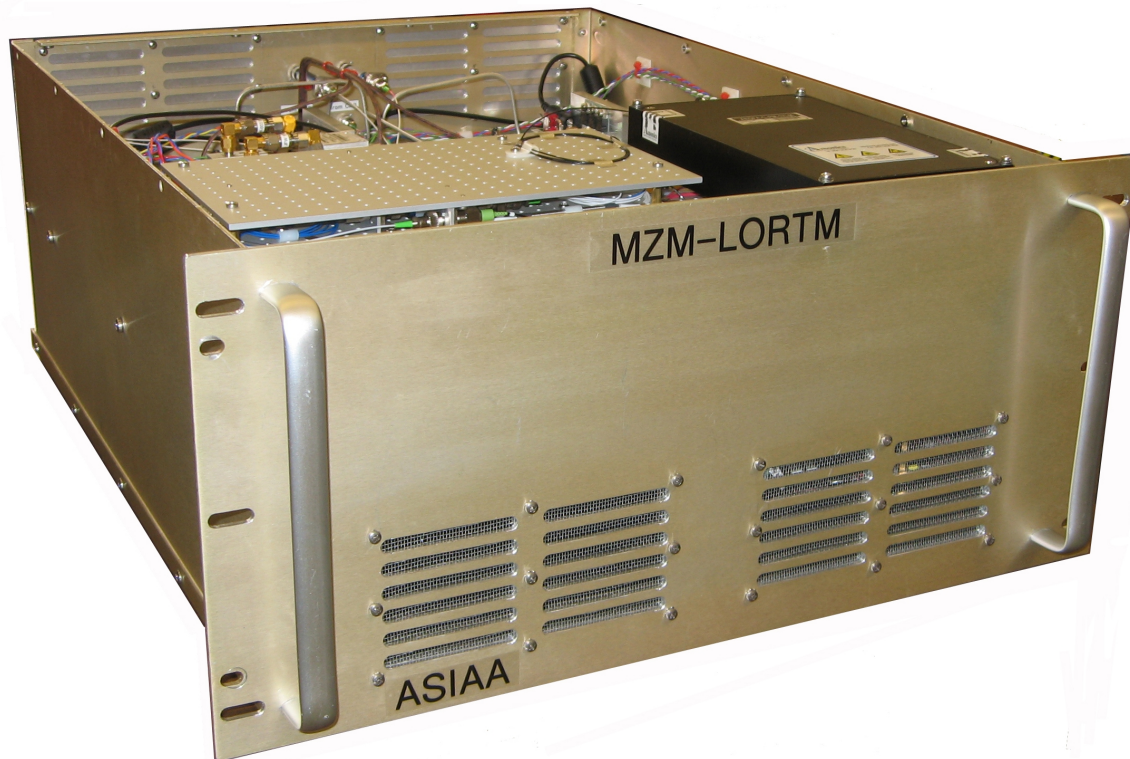

Figure 1 *Front panel view of MZM-LORTM with top cover removed. Note the air exhaust vents located toward the bottom of the front panel. The physical dimensions of this unit, including the front panel rack mounting holes, are identical to the baseline TeraXion LORTM unit.*

2. Unit Function

Figure 3 does NOT show the upgrades for Band 1, please refer to the full schematic

The MZM-LORTM instrument functions to generate 3 optical tones denoted as LSB1, LSB2, and USB (LSB = Lower Side Band, USB = Upper Side Band). Refer to the spectral plot shown in the upper right of *Figure 2*, and actual spectral plots shown in *Figure 3*. LSB1 and LSB2 optical tones are produced by MZ2, while the single USB tone is produced by MZ1. The 3 desired optical tones are combined via an optical summer located in the combiner plate assembly. The undesired carrier at 1556.21 nm is removed by a set of FBG filters within the combiner plate assembly. An EDFA (Erbium Doped Fiber Amplifier) is used to boost the signal prior to the final outputs at J1 and J2. Both outputs provide identical signals and are interchangeable.

The optical output signals from J1 and J2 are processed by the WCA LO and Signal Source assemblies as follows:

LO reference = $F_{LSB2} - F_{USB}$
Signal Source reference = $F_{LSB1} - F_{USB}$

Where the LO and Signal Source references are generated by the photomixer outputs of the WCA (Warm Cartridge Assembly) and Signal Source assembly, respectively.
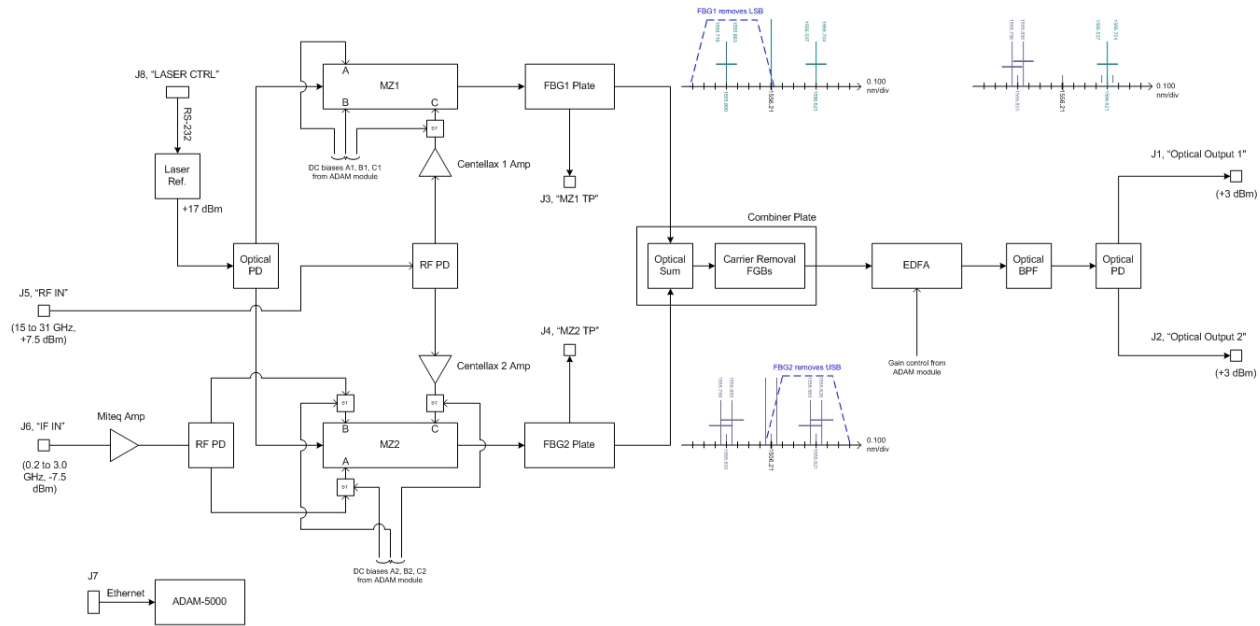

Figure 2 *Simplified functional diagram for MZM-LORTM unit. This design employs 2 MZM devices to separately produce the LSB and USB.*
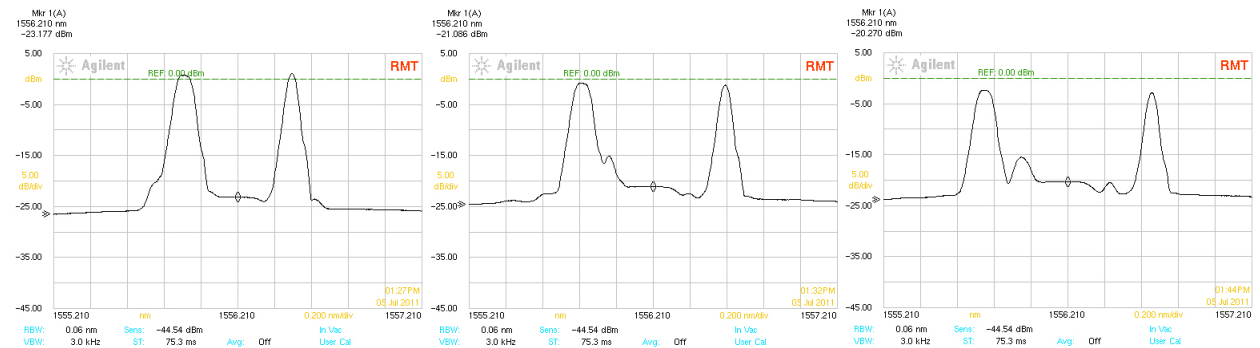

Figure 3 *Typical output spectrum of MZM-LORTM as seen on the Agilent OSA. Left Ref1 = 18 GHz (69/75 GHz photomixer output), center Ref1 = 24 GHz (93/99 GHz), right Ref1 = 30 GHz (117/123 GHz). Note the LSB on the OSA actually consists of 2 tones (LSB1 & LSB2) but is not visible due to limited resolution bandwidth. For all examples above Ref2 = 3.0 GHz.*

3. Operation Notes

3.1 Unit Interfaces, Electrical (rear panel)
The MZM-LORTM unit requires 4 electrical interfaces (refer to *Figure 4*):

   J10 - 120VAC power input, 50-60 Hz, 1.1 A typical
   J5 - Reference 1 input, 16 – 31 GHz, nominal power of +7.5 dBm
   J6 - Reference 2 input, 0.2 – 3.5 GHz, nominal power of -7.5 dBm
   J7 - Ethernet communication, RJ-45
   J8 - Laser control, RS-232 (optional)

The Reference 1 input (J5) originates directly from the Agilent E8257D where the frequency and output power are controlled by the LabView software (no manual adjustment necessary). The Reference 2 input originates from the LORTM Ref 2 Interface chassis (also known as the Extra IF Plate) and is collocated on the same tilt table rack as the LORTM. Careful amplitude tuning of this Reference 2 power is require and is described in paragraph 3.4 subparagraph 2). The MZM-LORTM does not require use of the 125 MHz Reference 3 signal. The J8 RS-232 laser control is interface is normally not used. The internal TeraXion laser powers up when the MZM-LORTM unit is powered on. We have found on occasion that the laser module does not power up properly when the MZM-LORTM unit it turned on. If this occurs the optical tones shown in *Figure 3* will be missing. To solve this problem simply turn the unit off for 30 seconds and then turn it back on. Alternatively, if the laser is missing, one may use the TeraXion control software to turn the laser on. We have left the TeraXion PureSpectrum Narrow Linewidth Laser controller software CD at your facility.

3.2 Unit Interfaces, Optical (rear panel)

The MZM-LORTM provides 4 optical output interfaces (refer to *Figure 4*):

  J1 - Optical output, nominal wavelength 1556 nm, nominal power 2 mW (+3 dBm)
  J2 - Optical output, nominal wavelength 1556 nm, nominal power 2 mW (+3 dBm)
  J3 - MZ1 output test point (used only for reconditioning of MZ1 device)
  J4 - MZ2 output test point (used only for reconditioning of MZ2 device)

J1 and J2 optical outputs are equivalent and interchangeable. These 2 outputs are normally connected the blue OzOptics fibers that go to the FE LPR module and the signal source. Care should be taken to not look directly into J1 and J2 to prevent possible eye damage. Please keep the protective caps on J3 and J4 when not in use.
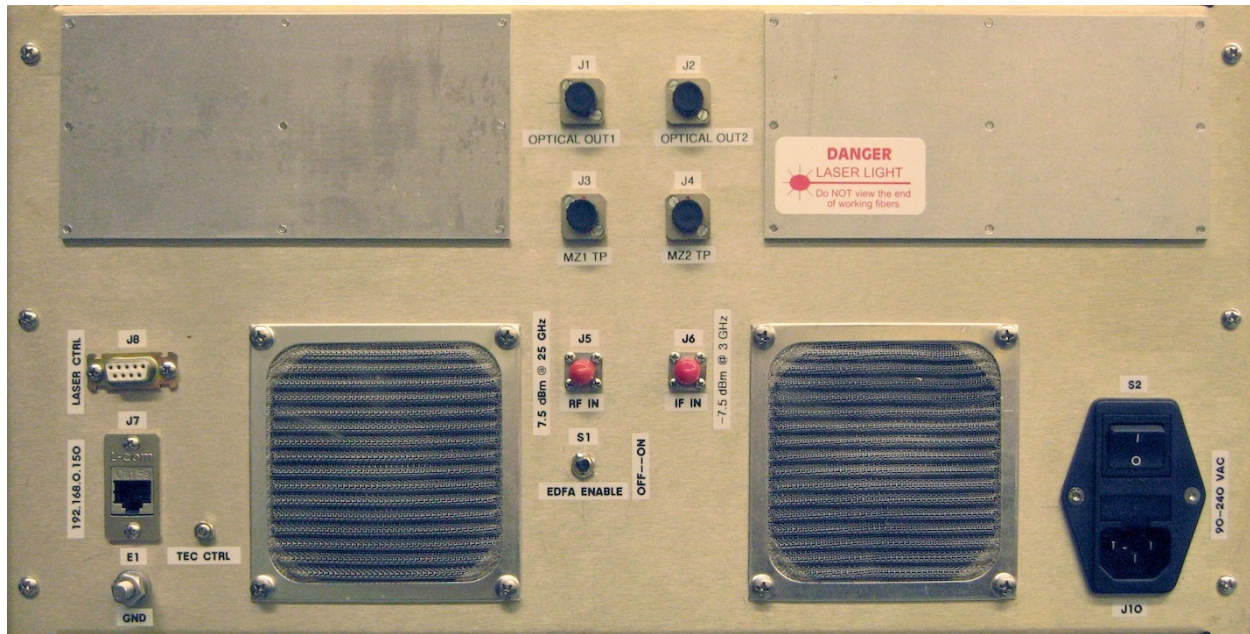
Figure 4 Rear panel of MZM-LORTM. Note the 2 intake air vents provide cooling for the unit. It should be noted that air turbulence in the vicinity of these intake air vents causes phase instability for this unit.

3.3 Auxiliary Mechanical Control (rear panel)

The MZM-LORTM has 2 mechanically adjustable controls, the "EDFA ENABLE" switch, S1, and the "TEC CTRL". Refer to *Figure 4* for the location of these 2 items. The S1 switch is normally kept in the up or on position. To quickly turn the optical output off simply flip this switch to the off position.

The TEC CTRL potentiometer (lower left corner of *Figure 4*) provides adjustment of an internal Peltier Thermo Electric Cooler (TEC) attached to MZ2. A clockwise turn of this potentiometer increases the drive to the TEC device and lowers the temperature of MZ2. The voltage drive to the TEC as well as the resultant MZ2 temperature can be monitored using the ADAM controller software or the custom web interface located on the ASIAA Linux laptop computer. Typical values for control voltage and MZ2 temperature are 2.1V and 20C, respectively, for

J5 = 25.742125 GHz @ +7.5 dBm and J6 = 3.0 GHz @ -7.5 dBm. The temperature of MZ2 is strongly dependent on the presence of Reference 1 and Reference 2 signals, therefore, one should not attempt to set the MZ2 temperature without these 2 signals present. CAUTION: Operation of the MZM-LORTM without Reference 1 and Reference 2 signals can result in a very low MZ2 temperature (< 12 C) and can lead to damaging water condensation if operating in a warm and humid environment. Operation without Reference 1 and Reference 2 signals within the chamber environment is considered safe because of the low humidity.

3.4 Suggestions for Improved Phase Stability

There at 4 important parameters to control for the MZM-LORTM instrument to provide good phase stability:

1) The first is to provide stable inlet air temperature for the rear panel of the MZM-LORTM unit. The chamber provides a very stable temperature environment, however, when tilted to 60 and 90 degrees the rear panel is exposed to large cold air turbulence from the chamber AC system. We attempted to mitigate this effect with the use of a cardboard shroud to prevent the turbulent airflow from directly reaching the MZM-LORTM. Refer to *Figures 5 and 6* for a comparison of phase at 0 and 60 degrees. The cardboard shroud may require some further "tuning" to optimize the balance between cooling and shielding. This test should be done by performing overnight runs with the BeaSTS test plate at 100/106 GHz and tilt table angle of 60 degrees.

2) The second item of importance is to provide an ultra stable Reference 2 input signal to the MZM-LORTM. Small variations in Ref2 power result in measurable amounts of phase movement. The Reference 2 signal emanates from the "LORTM Ref 2 Interface" chassis (also know as the Extra IF Plate). This chassis receives a typical 6 GHz IF signal from an Agilent E8257D synthesizer and provide the functions of: divide-by-2; divide-by-N, and variable attenuation. Variable attenuation is provided by an internal Hittite HMC-C053 device that is manually controlled via an external Agilent E3631A DC power supply.

   During the course of testing we discovered that the Agilent E3631A DC power supply drifted a small amount in voltage and translated to a small drift in Ref2 power and thus a non-trial phase drift. To mitigate this issue we replaced the E3631A with a Kikusui precision DC bias source. In addition, we added a large 18 dB pad at the end of the Ref2 cable and set the Kikusui to 3.155V to achieve -7.50 dBm. The large pad served to operate the Hittite attenuator in a flatter Voltage versus Attenuation portion of the curve.

3) The cardboard shroud mentioned above shields all of the tilt table rack equipment and includes: DC power supply; Agilent switch controller; Extra IF Plate; Ref1 synthesizer; and MZM-LORTM. Since the MZM-LORTM phase is extremely sensitive to Ref2 input power variations, it is believed that small temperature variations of the "Extra IF Plate" may be responsible for small Ref2 power variations. Some "tuning" of this cardboard shield may be necessary for further improvement. Operating with too much shielding will cause increased air temperature in the tilt table rack vicinity (Ref2 synthesizer operates warm without any shielding), too little shield has already been shown to cause poor phase stability.
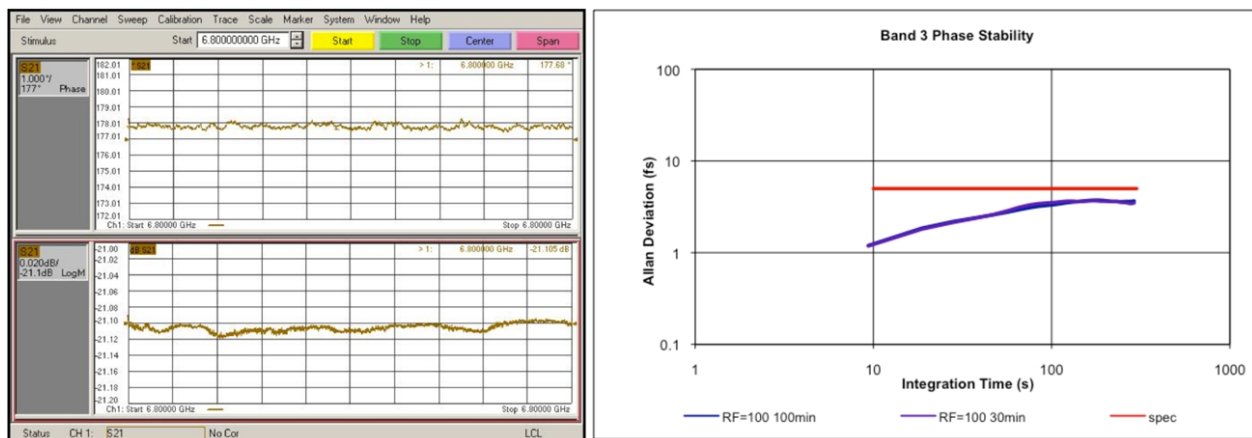

Figure 5 *Phase stability with Band 3/7 BeaSTS test plate, 100/106 GHz, 0 degree tilt table angle.*
Blue trace represents the full 100 minute data, 1.5 and 3.1 fsec for 10 and 300 seconds, respectively.

4) A final suggestion which sometimes yields small improvements in phase stability is to manually adjust the DC bias values to MZ2 ports A, B, and C. It is best to start with bias C and make small changes (100 mV) while observing phase stability. Instructions for how to access the bias controller are provided in paragraph 3.5.1 (slot1).
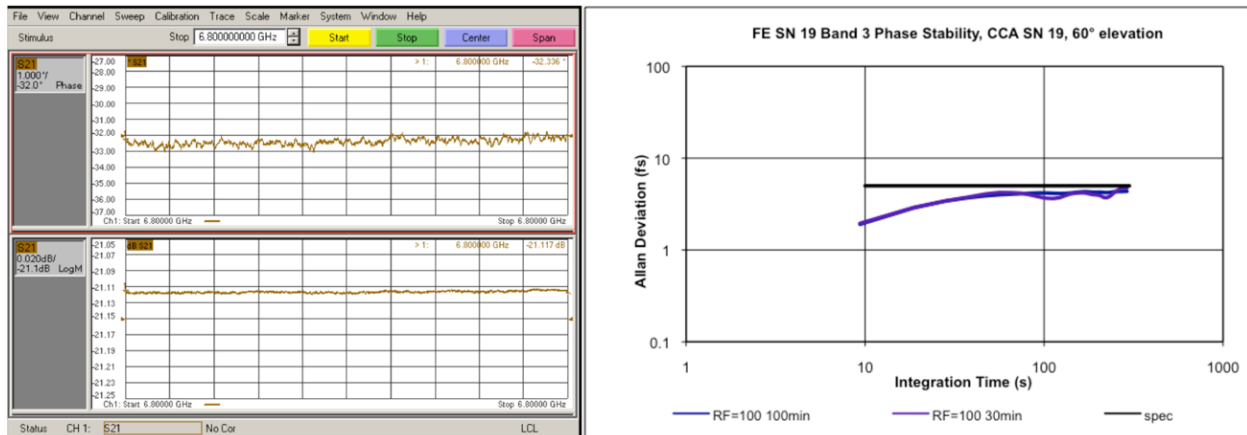

Figure 6 *Phase stability with Band 3/7 BeaSTS test plate, 100/106 GHz, 60 degree tilt table angle, with air shield around tilt table rack. Blue trace represents the full 100 minute data, 1.9 and 4.4 fsec for 10 and 300 seconds, respectively. Note the performance degradation relative to the 0 degree tilt table angle even with the air shield installed.*
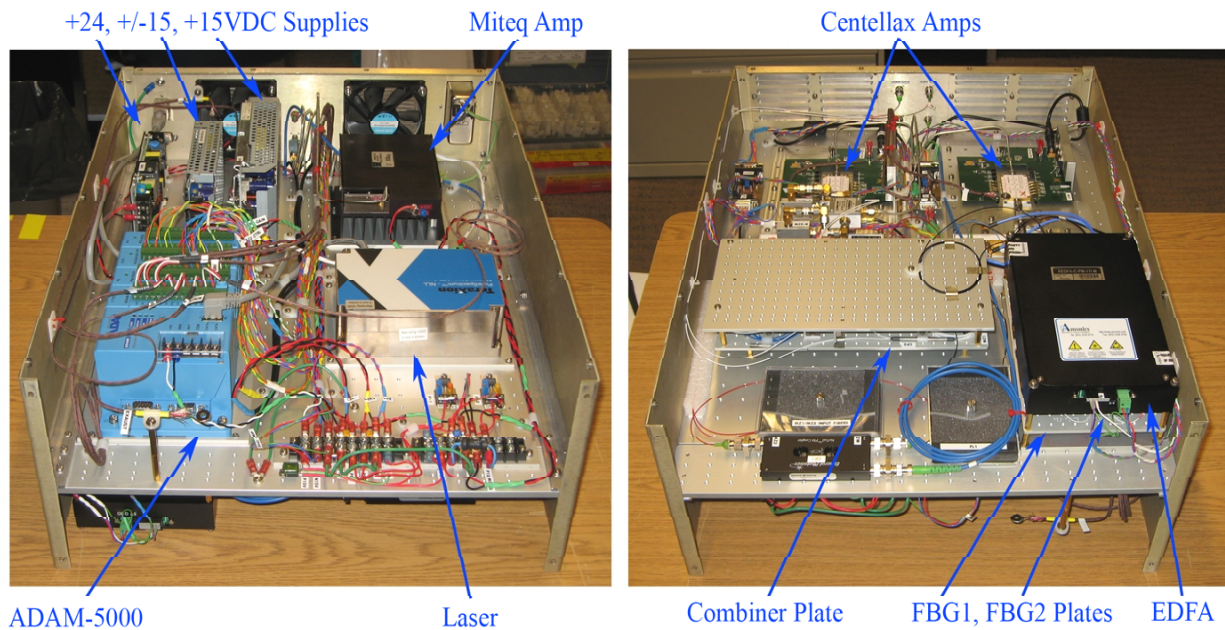

Figure 7 *Reference photos of MZM-LORTM. Left – bottom view, right – top view. Note only the bottom portion is force air cooled by the 2 rear panel fans, the top portion is sealed (no convection cooling). The 2 key MZM devices are located on the top portion but are not visible in this photo.*
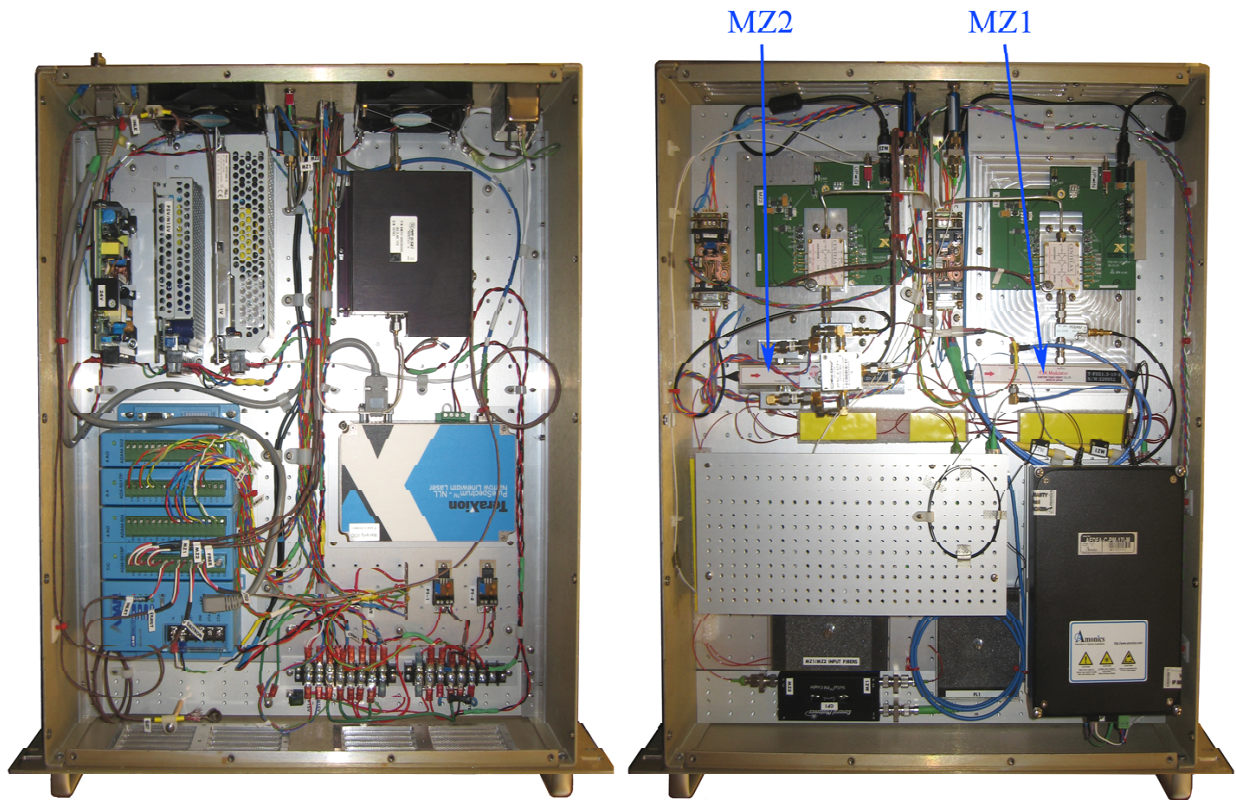
Figure 8   Reference photos of MZM-LORTM. Left – bottom view, right – top view. MZ1 and MZ2 devices are visible as long rectangular devices on the top deck.

3.5 Software Interfaces

3.5.1 ADAM Controller Interface

The MZM-LORTM is controlled and monitored using an Advantech ADAM-5000/TCP controller (refer to *Figures 7 and 8*). The ADAM controller may be accessed using the ADAM software utility via the J7 Ethernet port located on the rear panel. The ADAM utility program, called 'Adam.NET Utility' is located on the Desktop and once opened, the ADAM controller for the MZM-LORTM needs to be located on the network by using the Search function under Tools. Once the ADAM controller is found, you can access any of the modules by just clicking on it.

It will ask for a password which is '00000000'

The ADAM-5000 controller has the following 4 plug-in modules (slot 0 through slot 3):

ADAM-5018 (slot 0): This is a temperature module and receives inputs from 7 thermocouple sensors monitoring temperature (Celsius) inside the MZM-LORTM chassis. The 7 temperature monitor points listed in order are:

Channel 0: Centellax 1 (RF amplifier 1)
Channel 1: Centellax 2 (RF amplifier 2)
Channel 2: MZ2, note this device is actively cooled by a Peltier thermo-electric cooler
Channel 3: Intake air
Channel 4: Exhaust air
Channel 5: 12V Daitron power supply
Channel 6: Miteq (IF amplifier)

ADAM-5024 (slot 1): This is an analog voltage output module with 4 channels (0 through 3). Each of the outputs can be programmed from 0 to +10VDC. The 4 outputs are configured as follows:

Channel 0: MZ2 port A (0 to +10V)
Channel 1: MZ2 port B (0 to +10V)
Channel 2: MZ2 port C (0 to +10V)
Channel 3: EDFA gain (0 to +5V)

Note the actual output range of the ADAM-5024 module is 0V to +10V, however, for channels 0 through 2 this voltage is processed by a DC amplifier board which provides an output range of -10V to +10V for an input range of 0V to +10V. The ADAM-5024 analog output module can be set manually if fine tuning of the biases are required.

**ADAM- 5017 (slot 2):** This is an analog input module that provides voltage measurements (0 to +10V) for 8 channels (0 through 7). The 8 inputs are configured as follows:

Channel 0: MZ1 port A
Channel 1: MZ1 port B
Channel 2: MZ1 port C
Channel 3: MZ2 port A
Channel 4: MZ2 port B
Channel 5: MZ2 port C
Channel 6: Drive voltage to TEC
Channel 7: Not used

Note the TEC drive voltage is set by adjusting the potentiometer located on the rear panel of the MZM-LORTM chassis (refer to the lower left corner of *Figure 4*).

ADAM-5024 (slot 3): This is an analog voltage output module with 4 channels (0 through 3). Each of the outputs can be programmed from 0 to +10VDC. The 4 outputs are configured as follows:

Channel 0: MZ1 port A (0 to +10V)
Channel 1: MZ1 port B (0 to +10V)
Channel 2: MZ1 port C (0 to +10V)

Channel 3: Not used

The mapping between the Analog Output modules S1 and S3 to the Analog Input module S2 is shown (refer to *Figure 9* and *Figure 10*).

Note the actual output range of the ADAM-5024 module is 0V to 10V, however, for channels 0 through 2 this voltage is processed by a DC amplifier board which provides an output range of -10V to +10V for an input range of 0V to +10V as shown in the following two figures. The ADAM-5024 analog output modules can be set manually if fine tuning of the biases are required.
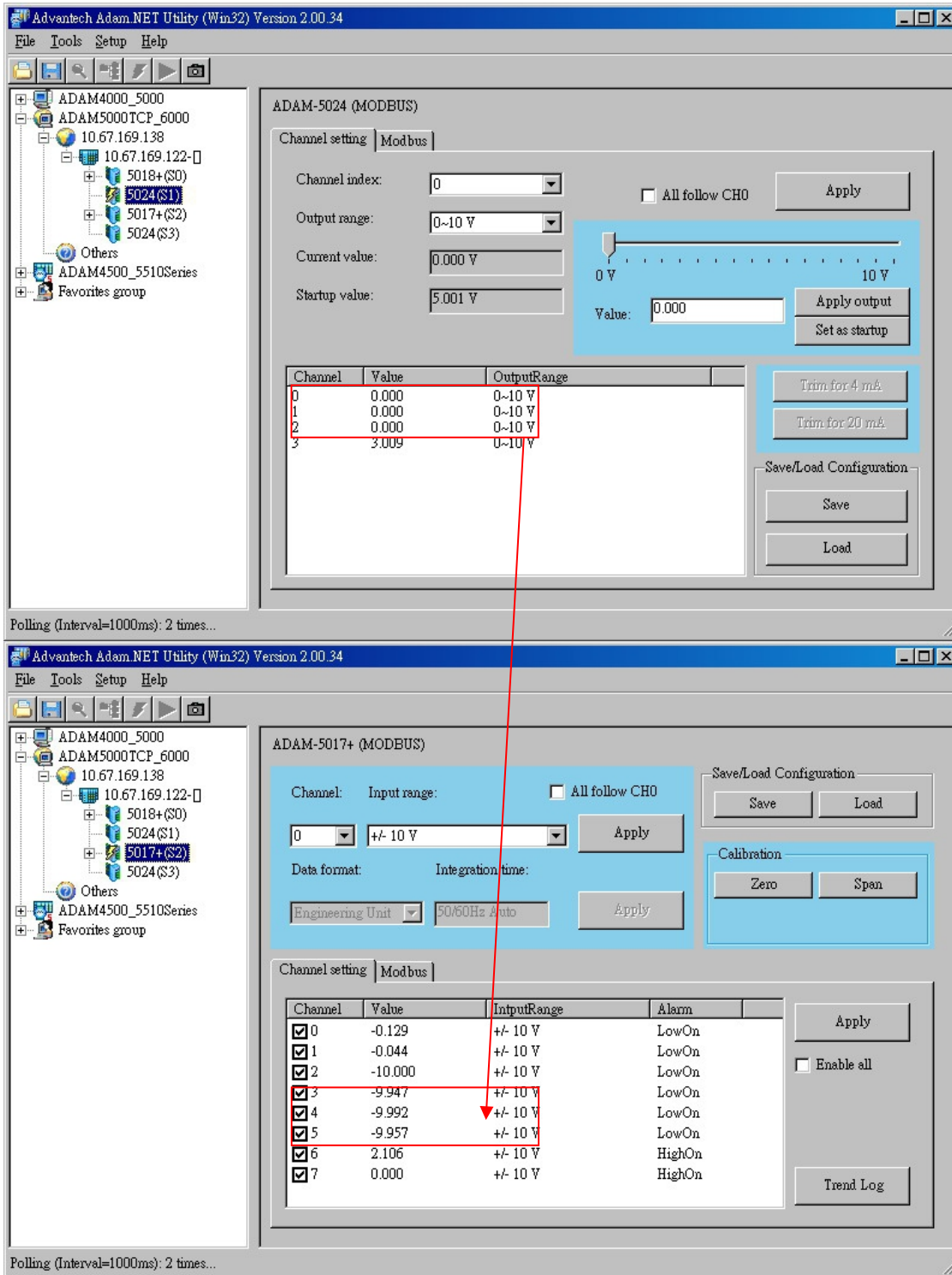
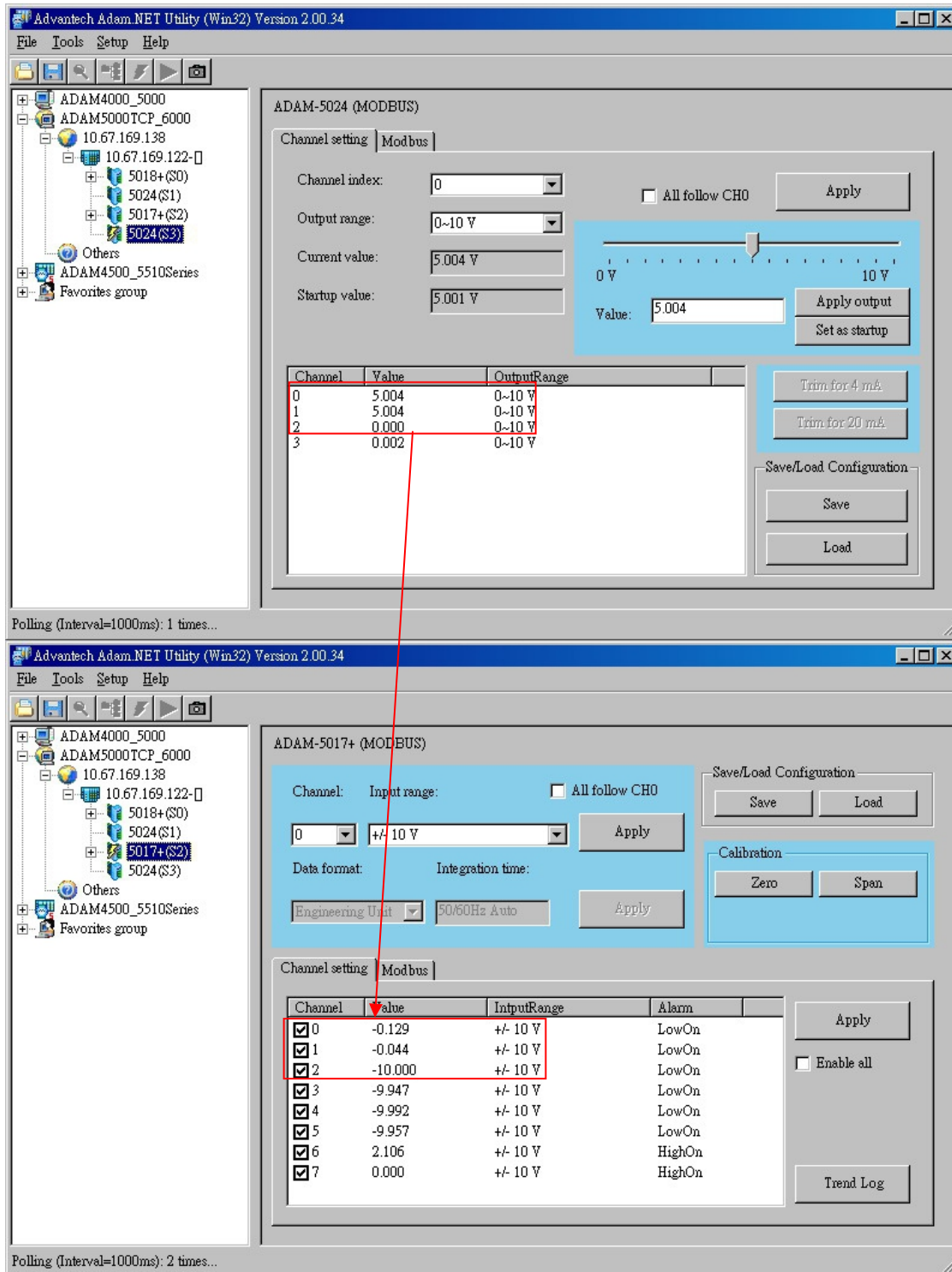*Figure 9 Screenshot of the mapping of the S1 to the S2 module*

Figure 10 Screenshot of the mapping of the S3 to the S2 module

3.5.2 LabView Interface

The primary interface for the MZM-LORTM is conducted through the LabView control panels as shown in *Figure 11*. The following information provides basic usage instructions for operating the LabView interface:

1) All the basic source code lives in L:\cpp, including the Bias and Gain tables. The source codes have been converted into a dll, which is accessed by the LabView interface.

2) The modbus driver that communicates to the ADAM controller via Ethernet is located in L:\modbus.

3) The 'ini' file for the MZM-LORTM model is located in L:\data

4) The highest level of the LabView interface lives in L:\labview\apps\LO Reference. The LO Reference MZM.vi is the interface which does an automatic setup of the MZM-LORTM given LO1, LO2, FLOOG, etc.

5) The new FrontEnd control will have the MZM-LORTM interface which will be called directly from it using a lower level driver layer which currently lives in L:\labview\Tests\models\t_MZM_LORTM\t_MZM LORTM model standalone.vi. This layer has all the individual functions that can be accessed, including the 'reset MZM-LORTM' which needs to be done at the end of completion of any task to restore all the Biases back to 0.

6) For now, please open up 't_MZM LORTM model standalone.vi', which has a shortcut from the Desktop to access the reset function or to see all the Bias values, synthesizer values returned from the basic code. This can be checked against the actual values being set on the synthesizers and the Bias and Gain values on the ADAM controller by using the ADAM utility.

7) At the end of every test, please use the 'reset MZM-LORTM' to set all biases to the modulators to 0V. The operating point of the modulators drifts with time, so when not in operation, it is best to reset all the biases back to zero to minimize this drift. Once the reset function is applied the spectrum on the OSA will look like that shown in *Figure 12*. Contrast this optical spectrum with those shown in *Figure 3* or *Figure 21* where the DC biases are set correctly for operation.
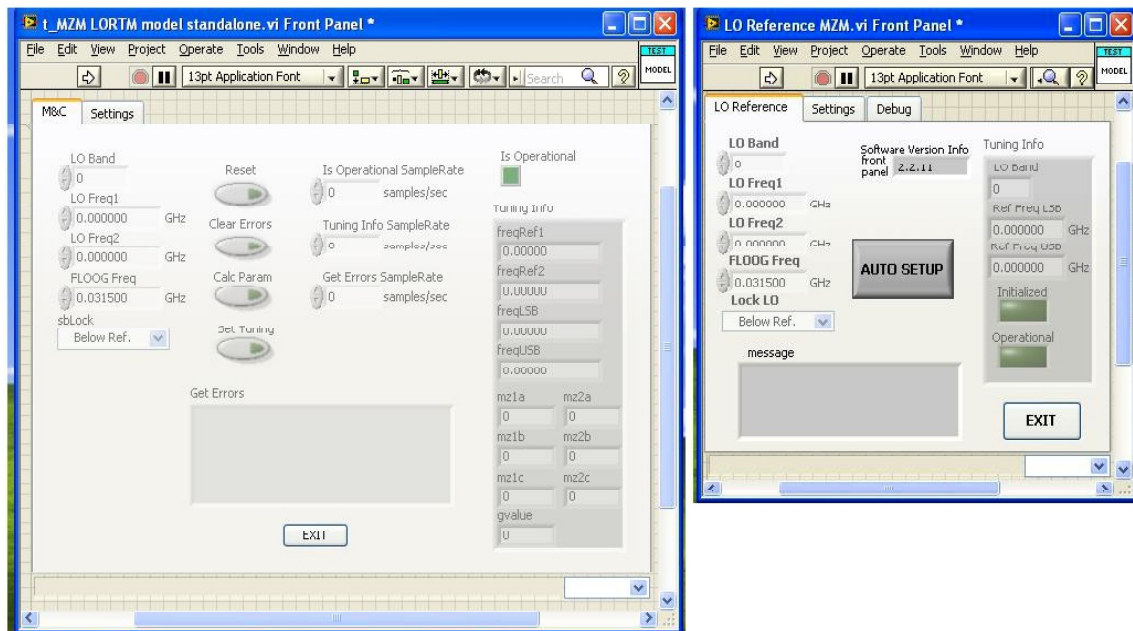
Figure 11   Screen shots of LabView interfaces. Left panel - MZM-standalone is the screenshot of the LabView interface t_MZM LORTM model standalone.vi which shows all the individual functions used to set the MZM-LORTM. Please note, that this is the interface that provides the reset function to restore both the MZM biases to 0. Right pan-

el - MZM-Auto is screenshot of the LO reference MZM.vi which does the automatic setup given all the input parameters.
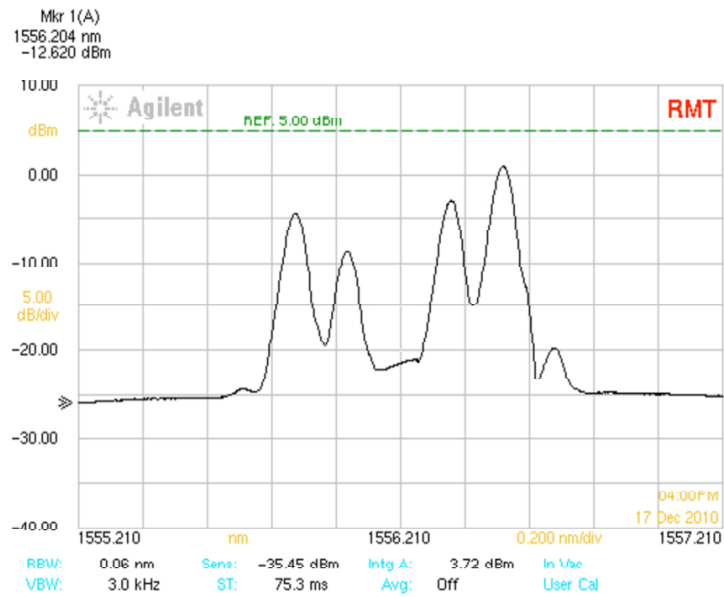

Figure 12 Output spectrum as seen on the OSA after performing a "reset MZM-LORTM" where the DC biases for MZ1 and MZ2 are all set to 0V at the devices themselves (5V at the ADAM-5024 module). Note the imbalance between the LSB verses USB tones as well as large first harmonic tones.

3.5.3 Web Interface

The MZM-LORTM can be controlled and monitored using the Linux laptop PC via a local web interface. Please make sure that the laptop and the GPIB/Ethernet interfaces are connected to the network.

1)   On Firefox, the basic web page is under bookmarks and it should bring up the page -------http://alma-mzm/LORTM_tasks.html

2)   The first link opens up an interface that sets the MZM-LORTM given LO1, LO2, FLOOG etc., just like the LabView interface. Output on the successful completion shows all the Bias values, Gain, and Ref1 and Ref2 values (not in a pretty tabular format!!, but it is all there).

3)   The second link is an interface that monitors the thermocouple module and the Analog input module for a maximum duration of 30 minutes and updates continuously. The only input needed for this interface is the length of time to monitor the above two modules.

4)   The third link is an interface that logs the temperature of all 7 thermocouples inside the chassis for the length of time you specify on the interface for a maximum of up to 48 hours. On completion, the code deposits the graph and the text file of the recorded data into the TEMPERATURE folder located on the Desktop.

5)   The fourth link is the Re-bias interface, using the OSA

⌒ MZ2 needs to be re-biased about twice a week(this includes the weekend). Please connect the OSA to MZ2 Test Point 2 (J4) on the rear panel for re-biasing MZ2, and select 2 from the drop down menu. You can turn the RF and IF output off, otherwise it will be automatically done by the code. *Figure 13* shows an example output optical spectrum from MZ2 during a re-bias routine.

⌒ MZ1 needs to be re-biased once every week or so. Please connect the OSA to MZ1 Test Point 1 (J3) on the rear panel for re-biasing MZ1, and select 1 from the drop down menu. You can turn the RF and IF output off, otherwise it will be automatically done by the code.

⌒ The re-biasing code will automatically terminate, once it is done, and it will say so on the web interface. HOWEVER, if you notice that the code is still running, you will need to kill the re-biasing code manually, and here is the procedure:

- Please open up a terminal by right-clicking on the mouse.

- Please type 'ps –ef | grep rebias' on the command line.
- Any process with 'rebias' in the name will be listed on the terminal including the command that you just typed in. Please ignore that process.

- Please type "kill #" on the command line in the terminal just ONCE. The process that needs to be killed will appear as "./set_rebias_osa_mzm*   *", where the * is either 1 or 2 depending on which mzm is being rebiased. The web interface will be automatically killed which could take up to a minute or so. The log file will be written to the Desktop folder 'LOGDIRDESKTOP'. The name will have the following format "log_rebias.*.osa_UTCtimestamp", where * again is 1 or 2 which refers to MZM1 or MZM2.

6)   The fifth link is the Re-bias interface, using the PM, and all the subsequent steps follow step 5.

7) The fifth link does not lead to any interface and will just reset the MZM-LORTM similar to the action from the LabView interface.
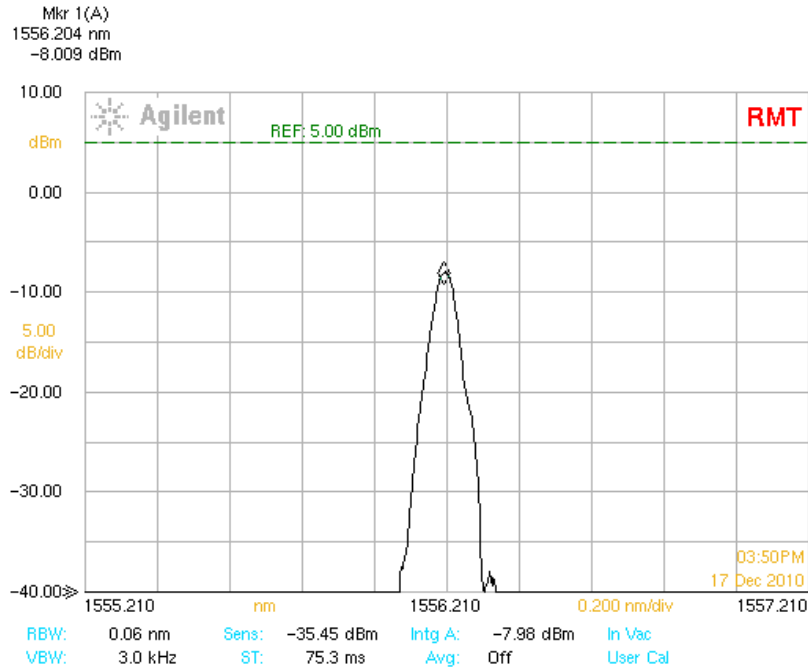
Figure 13 Optical output at rear panel MZ2 Test Point (J4) during a re-bias routine. Note that this output consists of just the unmodulated laser carrier because both the RF and IF signals have been removed or turned off.
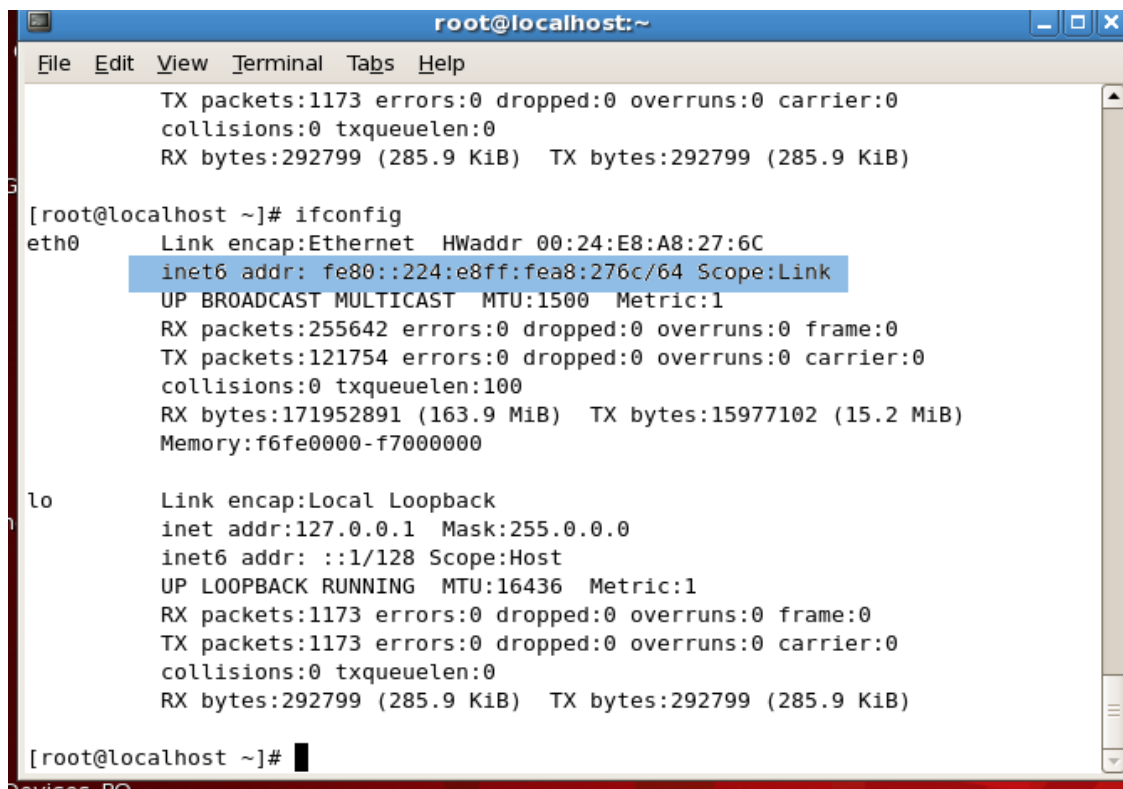
3.5.4 Calibration Routines

If re-biasing has not been performed for a long time, the bias tables will be inaccurate and will have to be regenerated. Clicking on the Bias Table link will take you to an interface which is self explanatory. Generating bias tables for both MZ1 and MZ2 takes about 2 hours. The output of J1 or J2 needs to be connected to the OSA. Regenerating the bias tables can be avoided by regularly re-biasing both the MZ1 and MZ2 devices. Please MAKE SURE that the band switch is set to "Band 3".

If the bias tables change, the gain tables have to be regenerated as well, and this takes about 5 hours. The output of J1 or J2 needs to be connected to the OSA. I recalibrated the OSA power levels before I left, but it seems to drift significantly with time. Therefore, I would not recommend doing the gain tables, since the power levels as shown on the OSA may be significantly off from the correct values (the OSA unit itself needs to be recalibrated at the Agilent factory). It should be noted that the connection to the Agilent OSA is an FC/PC connection (blue boot) as opposed to an FC/APC connection (green boot). Using an FC/APC connector at the OSA will result in ~8 dB of additional loss.

3.5.5 Restarting the network on the Linux laptop

A few additional notes on the operation of the linux laptop. If the network cable is unplugged and then replugged, the network services are not automatically restored. This is what you need to do in order to get the laptop networked again:

1) Open a terminal by right clicking the mouse

2) login as root. In order to do that, type "su -". It will ask for the password, which is the same one written on the machine which is "Eafeic2009"

3) With the network disconnected, in the root window type "ifconfig". The output will look like the screenshot below (refer to *Figure 14*). The highlighted part should contain the IP address of the machine. As you can see, it is missing.

Figure 14 *Screenshot of the terminal with the output of the command 'ifconfig' with the IP missing*

4) In order to restore the network connectivity of the machine , reconnect it to the network and then type in the root window
"service network restart", and then type "ifconfig" again

5) The new screenshot should look like the following (refer to *Figure 15*), where the highlighted part should now show the machine's IP address which, for the FEIC laptop I set to "10.67.169.121", I think. I maybe off by a digit.

Figure 15 *Screenshot of the terminal with the output of the command 'ifconfig' with the IP highlighted*

6) Sometimes, firefox reverts to the Offline mode if it does not detect a network, and you may have to go the "File" tab and unclick the "Work Offline" option if it is clicked.

3.6.1 Procedures for rebiasing the MZM from Linux Laptop

OSA – Optical Spectrum Analyzer
PM – Oz Optics Power Meter

All commands are highlighted in red. All screen output is highlighted in green. Files and folders are highlighted in yellow. Web links are highlighted in blue. Please use the root login ONLY to restart network as described in the Addendum. Once done, type "exit". Please do not leave yourself logged in as root.

Go to the main web interface page which is bookmarked on Firefox.

There are now two links for rebiaising on that page. One web interface which uses the OSA and the other interface which uses the PM.

The links will open in a separate tab. Please select the MZM needed to be rebiased: 1 (MZM1) or 2 (MZM2). Please make sure that the OSA or the PM are connected to MZ1 Test Point which is J3 or MZ2 Test Point which is J4. Please switch OFF the ref1 and ref2 synthesizers. The test points, the respective MZMs and the analog output modules that control them are shown (refer to *Figure 21*).

The OSA needs to be connected to the GPIB/ENET interface which in turn is connected to the linux laptop via an Ethernet cable (refer to *Figure 16*).

The PM needs to be connected to the RS232/USB interface through a phone cable which in turn is connected to a USB port of the linux laptop (refer to *Figure 17*). Please make sure the PM is always connected to AC power, although it can operate for short periods of time from its internal battery pack. PLEASE make sure to turn on the power for the PM.

Please choose the MZM that needs to be rebiased by selecting 1 or 2 from the drop down menu and hit submit.

Please open the link on the main page which is titled 'Unit Health' and type in a monitor time of 2 minutes in the new page that opens in another tab and hit submit. A third tab will open with a table which displays values from the Analog Input module and the Thermocouple module. This page is continuously refreshed. You can see the Bias values applied to ports A, B, and C of MZM1 and MZM2 and the TEC voltage. If you are rebiasing MZM2, you should see port C, A, and B of MZM2 being dithered between -2.5 V and +2.5 V in that order. At the same time, you will see the 'sweep' LED on the OSA flash on and off. The power level of the laser tone on the OSA will change as well. Once the algorithm is complete, rebiasing voltages will be set for the MZM as shown (refer to *Figure 18*). They will be either +10 V or -10 V for MZM1. They will be set to -10 V for MZM2. The program then goes to sleep for 15 minutes, after which the whole process is repeated again and so on until rebiasing is complete, when all ports are set to 0 Volts.

Please note that you will see the above information as discussed in step 7 displayed on the ADAM utility on the Windows machine outside the chamber on S2 (Analog Input Module). The ADAM utility of course, continuously polls the ADAM controller.

Please wait for about 5 minutes and make sure that the jobs are still active by opening a terminal window and typing "ps –ef | grep rebias". You should see ONLY processes with 'rebias' in their names. The two processes that are of interest will be (refer to *Figure 19*)

a) "./set_rebias_osa_mzm#   #" or "./set_rebias_pm_mzm#   #", where the # is either 1 or 2. This is the C script which is the main rebiasing script and

b) "/usr/bin/perl   \var\........\set_rebias_osa.cgi" or
"/usr/bin/perl   \var\…….\set_rebias_pm.cgi".
This is the corresponding web interface.

This is what you should see on the web interface, if everything is going well

Rebiasing…….
Rebiasing…….

and so on every 60 seconds until the rebiasing is done and then this message should appear.

Rebiasing Done

when the program quits after setting all the ports of the MZM to 0 V.

The logfile for every COMPLETED job is deposited in the folder 'LOGDIRRESKTOP' along with the time stamp in UTC.

The optical fiber going into the OSA always has to be FC/PC. The optical fiber going into the PM can be either FC/PC or FC/APC.
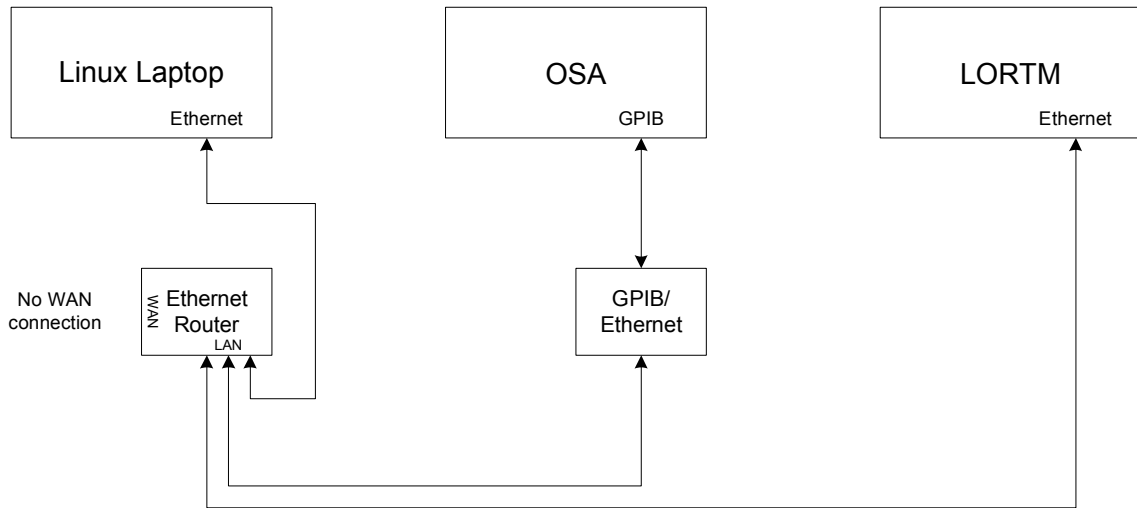
Figure 16 Network setup using the Optical Spectrum Analyzer (OSA)
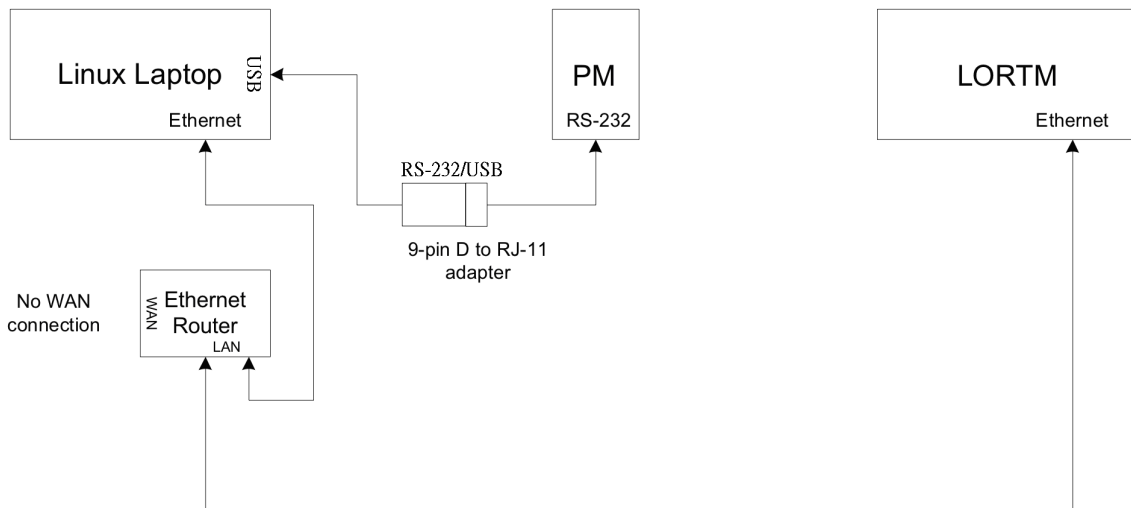
Figure 17 Network setup using the Power Meter (PM)
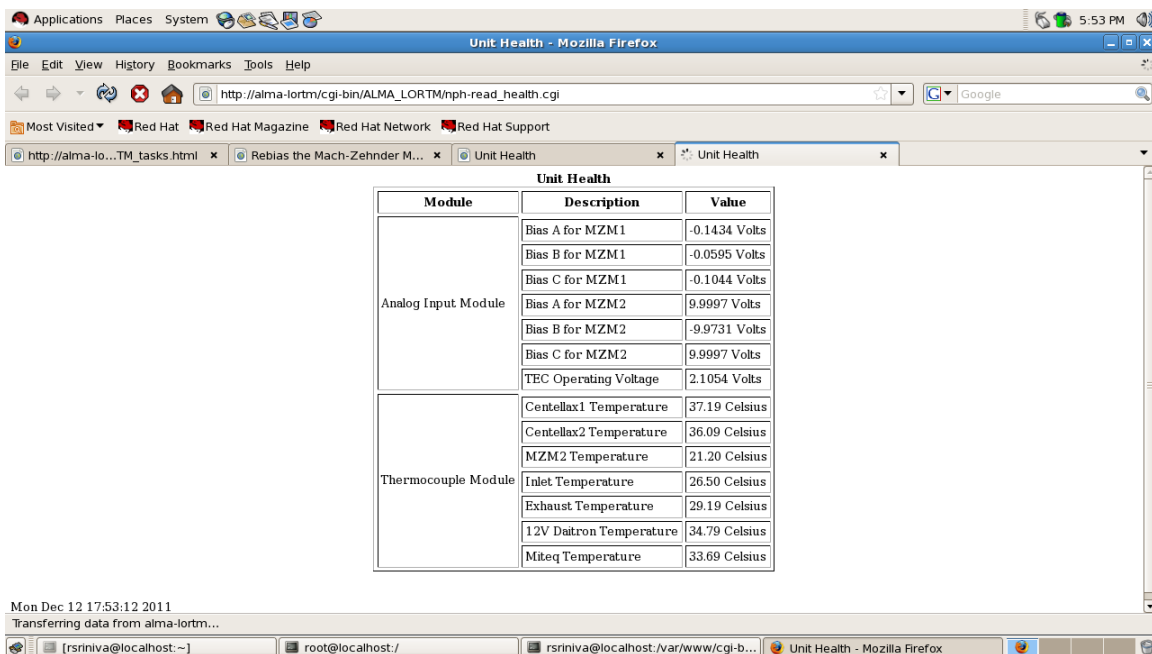
Figure 18 Monitoring the Analog Input and the Thermocouple modules
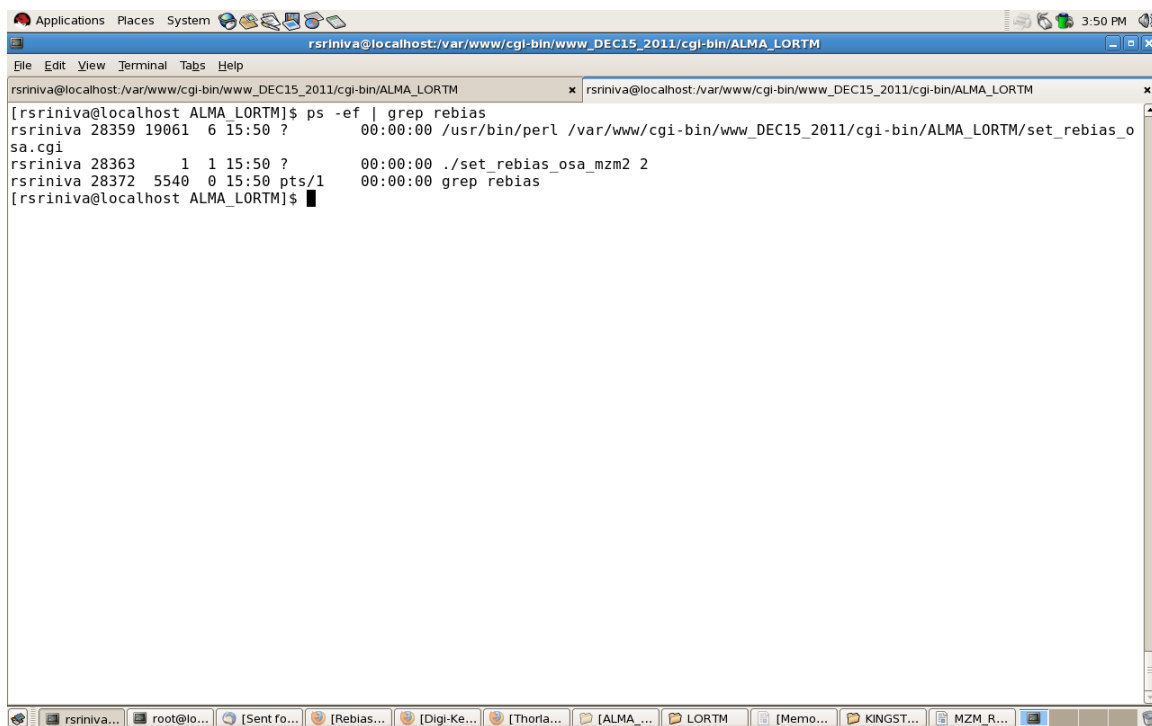
Figure 19 Correct output for a 'ps –ef | grep rebias' command

Figure 20 Output for a 'ps –ef | grep rebias' command with only the web interface active
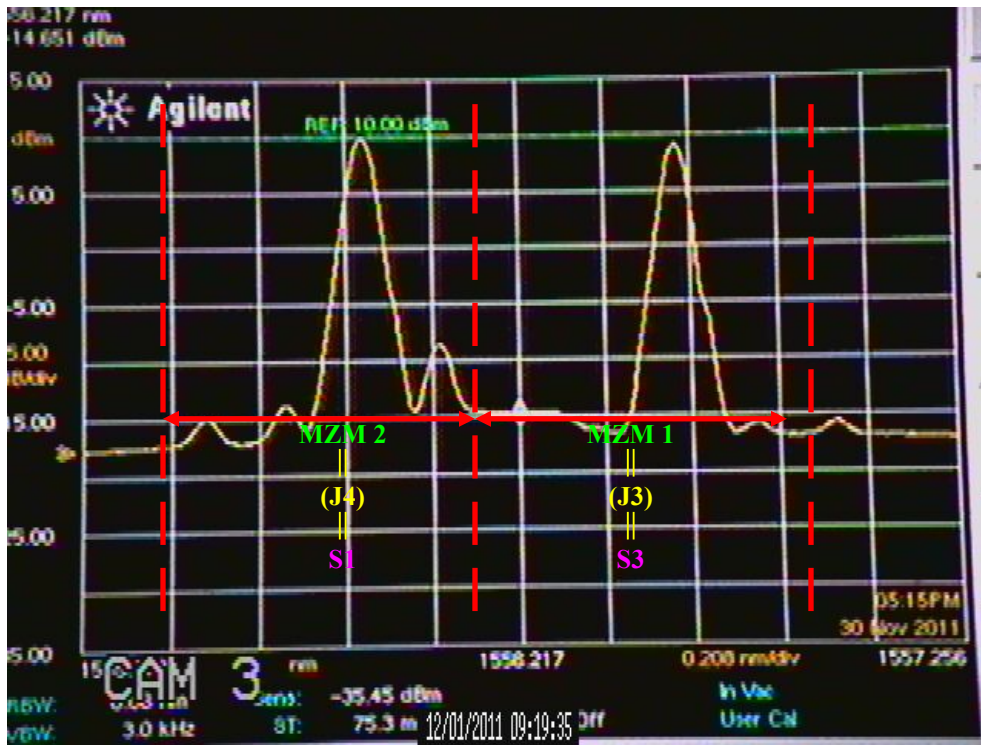
Figure 21 OSA output with the breakdown of optical tones contributed by MZM1 and MZM2 and the corresponding test points for rebiasing and the respective Analog Output modules.

3.6.2 Procedures for rebiasing the MZM from the Windows machine

The main perl scripts for rebiasing are located on the REBIAS_MZM folder on the Desktop.

The two main scripts are 'rebias_mzm.cgi' and 'reset_mzm.cgi' Their functions are self explanatory.

The REBIAS_MZM folder has an 'ini' file which has the IPs of the ADAM and the two synthesizers.

Test points J3 or J4, do not need to be connected to the OSA or the PM, since power levels are not queried by the scripts.

Two files install in the cgi-bin folder. The Perl script that selects if you want to rebias or not has the url 'http://IP(localhost)/cgi-bin/rebias_mzm_web.cgi'. Once you select 'no' on the web interface, the rebias will NOT automatically resume the next night. You have to go and select 'yes'. However, once you have chosen 'yes', the rebiasing will proceed automatically every night according to your scheduler setup. PLEASE make sure that the 'ini' file in the cgi-bin folder has the full path to the REBIAS_MZM folder.

If the web script detects that 'LO Reference MZM.vi' is open, it will automatically choose 'no' and write it to the 'rebias_condition.txt' in the REBIAS_MZM folder. Therefore, please make sure that the above labview interface is closed if you want auto rebiasing to be on.

Please note that both MZM1 and MZM2 are rebiased.

The recommended schedule for rebiasing is as follows: Monday, Tuesday, Wednesday and Thursday. This is set by the Scheduler as shown in the screenshots (refer to *Figure 22* and *Figure 23*). The 'rebias_mzm.cgi' sets the rebiasing voltages at 8 PM, and the 'reset_mzm.cgi' resets the voltages back to 0 Volts at 2 AM. You can change the schedule if you skip days etc.

Every time the rebias or reset script runs, a log file is written in the REBIAS_MZM folder. You can check to see, if the correct voltages were set on the S1 and S3 modules. They should be as follows for the rebias script

S3 MZM1	Ch 0:	5.5	V
	Ch 1:	5.5	V
	Ch 2:	3.75	V
	Ch 3:	0.0	V
S1 MZM2	Ch 0:	0.0	V
	Ch 1:	2.5	V
	Ch 2:	3.75	V
	Ch 3:	0.0	V

and for the reset script

S3 MZM1	Ch 0:	5.0	V
	Ch 1:	5.0	V
	Ch 2:	5.0	V
	Ch 3:	0.0	V
S1 MZM2	Ch 0:	5.0	V
	Ch 1:	5.0	V
	Ch 2:	5.0	V
	Ch 3:	0.0	V

The corresponding S2 screenshot should look like

S2	Ch 0:	1.0	V
	Ch 1:	1.0	V
	Ch 2 :	-2.5	V
	Ch 3 :	-10.0	V
	Ch 4:	-5.0	V

Ch 5   -2.5 V

for the rebias script and all channels 0 V for the reset script.
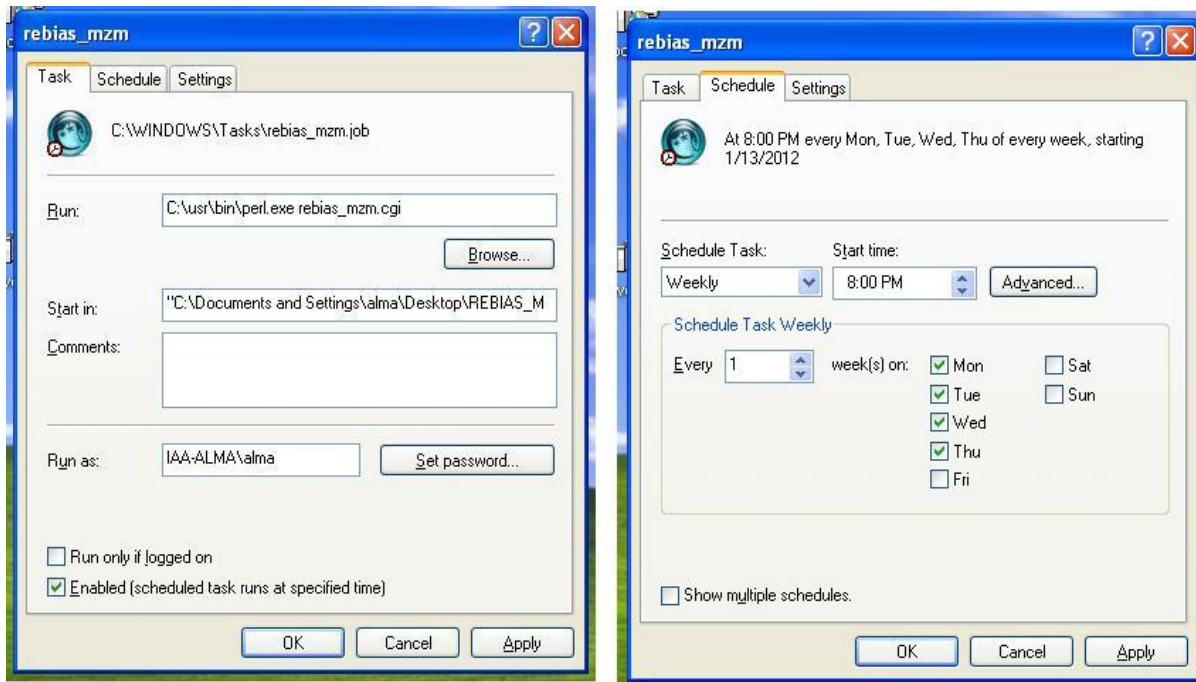

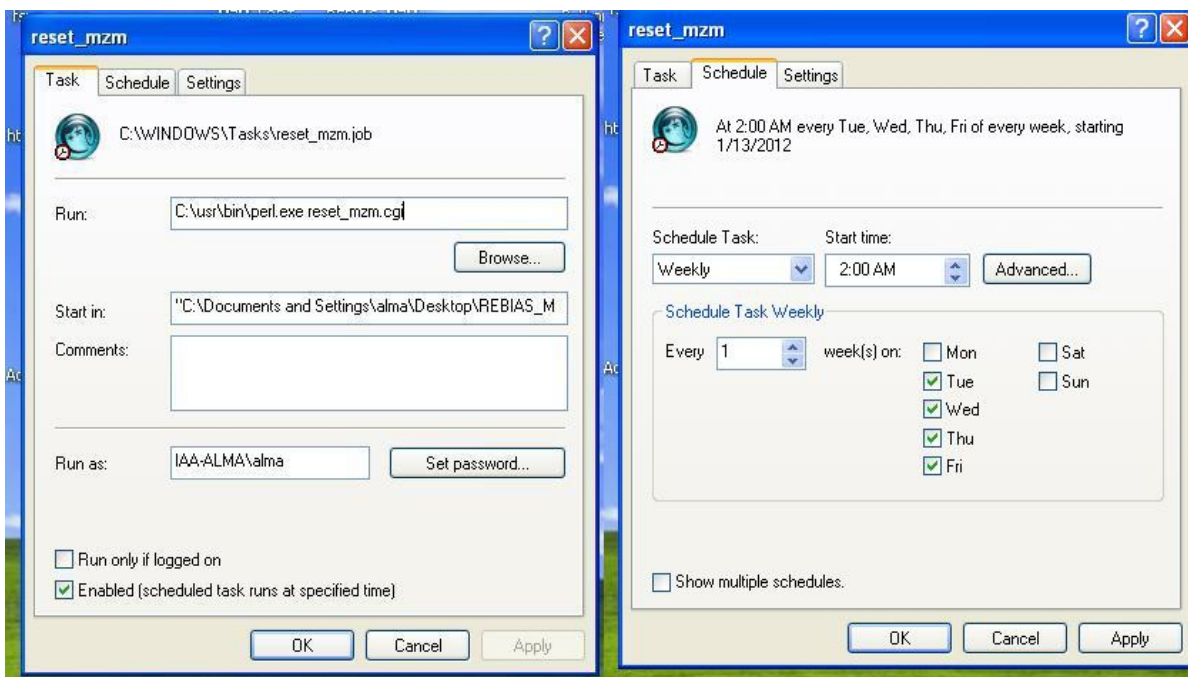*Figure 22* Scheduler settings for 'rebias_mzm.cgi' script.

Figure 23 Scheduler settings for 'reset_mzm.cgi' script.

3.7 Troubleshooting

1. **OSA looks frozen, and the 'sweep' LED is dark. The laser tone on the OSA looks frozen as well:**

Solution: The OSA while rebiasing is set to the single sweep mode. It is not in the continuous sweep mode where the LED will keep flashing every time it executes a sweep which takes typically 75 ms.. The code checks the power levels on the OSA only once every 15 minutes. Therefore you will see the 'sweep' LED flash on and off for about 30 seconds ONLY once every 15 minutes. To make sure that the processes are active, please type "ps –ef | grep rebias" and check the output as before.

2. **The web interface has an error message, but it is still active and the *'Rebiasing….'* message keeps appearing on the web page:**

Solution: The main program has crashed and the web interface should have quit as well. Please type "ps –ef | grep rebias" on the terminal. Only the following process "/usr/bin/perl \var\…….\set_rebias_osa.cgi" should be visible on the process list (refer to *Figure 20*). Use the "kill #" command to kill the web interface, where # is the process id.

3. **The Rebiasing code crashed over the weekend and the error message on the web interface reports "Could not connect to ADAM controller"**

Solution: Very recently, I have become aware of some problems with the modbus driver which communicates with the ADAM controller. Until, I figure this out, please restart the rebiasing code as soon you are done testing.

4. **The power levels on the OSA do not match the power levels on any power meter**.

Solution: The OSA needs to be sent for repairs to fix the power level calibration. For rebiasing, only the relative power levels are required. Therefore, please DO NOT use the absolute power levels as reported by the OSA.

5. **I want to see some details of the rebiasing procedure including timestamps. Where can I get this information?**

 Solution: The logfile for rebiasing is deposited in the directory   'LOGDIRDESKTOP' on the Desktop along with the time stamps. To open these files, just double click on them. They will open up in a default text editor.

6. **Since we have both the PM and the OSA, why cannot we rebias both MZM1 and MZM2 at the same time?**

Solution: This is a logical use of resources. However, as mentioned before, the   modbus driver seems to be buggy. Therefore, until I can figure out the problem and implement a solution if possible, rebiasing MZM1 and MZM2 simultaneously is not an option.

7. **I am to trying to see the spectrum when I set LO from the labview interface. The 'sweep' LED is dark, and even though I have connected J1 or J2 to the OSA, I do not see the two tone spectrum.**

Solution: From the OSA front panel, choose the Bandwidth/Sweep key. It will bring up further options one of which enables you to choose the 'Continuous Sweep' mode.

8. **How do I reset the MZM-LORTM from the labview interface on the Windows machine?**

Solution: The labview *vi* which is located in the following directory 'L:/labview/Tests/drivers/t_MZM LORTM/t_MZM LORTM driver.vi', has a reset function which will set all ports of MZM1 and MZM2 to 0 Volts. The reset is also available from this interface, which is in the following directory L:\labview\Tests\models\t_MZM_LORTM\t_MZM LORTM model standalone.vi.

9. **Where are the Bias tables located on the Windows machine?**

Solution: The Bias tables are located in . 'L:/cpp/MZM LORTM/TABLES.

10. **What is the parent directory on the linux machine?**

Solution: The main directory where all the source codes are located is 'Computer/Filesystem/var/www/cgi-bin/ALMA-LORTM'. The Bias Tables are located in the 'TABLES' directory in the above directory.

3.8 Bias Drift for the MZM

The operating point of the MZM drifts with time. If a constant positive voltage is applied to the ports, the drift is in the positive direction and vice versa. Therefore in order to get a good (undesired tones suppressed) optical spectrum, one needs to apply a larger and larger voltage as time progresses. Rebiasing counteracts this drift by applying an opposite DC bias to the ports for extended periods of time. The more the drift, longer it takes for the operating point to be restored to its original value. The approximate movement of the operating point is about ± **0.2 V/24** hours for an applied DC bias of ± **10 V**. Please note, that larger the applied DC bias, faster the drift.

Therefore, it is necessary to rebias MZM2 much more frequently (preferably every two days) than MZM1, since ports A and B of MZM2 have large positive biases applied to them constantly while in operation. I would recommend the following bias schedule, when not in operation:

Monday	night	-	MZM1
Tuesday	night	-	MZM2
Wednesday	night	-	MZM2
Thursday	night	-	MZM1
Friday	night	-	MZM2

Please note the differences between the rebiasing procedures as implemented from the linux laptop vs. the Windows machine:

Rebiasing from Linux laptop:
- All the rebiasing voltages are +10 V or -10 V for MZM1, and -10 V for MZM2
- Test points J3 (for MZM1) or J4 (for MZM2) have to be connected to either the OSA or the PM to monitor power levels, since this is the metric used to determine if the rebiasing procedure is finished.
- The script auto terminates once rebiasing is complete, and the original bias point is reached.
- The large rebiasing voltages applied, implies that bias drift accumulation from the regular operation of the LORTM is reversed faster.

Rebiasing from Windows:
- All the rebiasing voltages are different and their values as shown is *Section 3.6.2*. The different values are concomitant with the different operating voltages for the different ports of the two MZMs.
- Test points J3 (for MZM1) or J4 (for MZM2) do NOT have to be connected to either the OSA or the PM to monitor power levels.
- The script has no feedback procedure to check if the original bias point is reached and therefore the reset script has to be applied a few hours after the rebias voltages to prevent overcompensation.
- The smaller rebiasing voltages applied implies that bias drift accumulation from the regular operation of the LORTM is reversed slower, and therefore needs to be in scheduled as often as possible.

The conclusion one draws from the above analysis is that the rebiasing procedure from the Windows machine is NOT sufficient to reach the original bias point. It merely provides ease of operation(rebiasing) during the week. It has to be used in concert with the rebiasing routine from the linux laptop(operating over weekends, at least periodically) to determine if the original bias point is reached.

3.9 Installing Apache and Perl for Windows

   To install Apache web server please click on the following link

http://httpd.apache.org/docs/2.2/platform/windows.html

The Windows installer is :
httpd-2.2.21-win32-x86-no_ssl.ms, which is a 32 bit installer which should run fine on 64 bit machines.

Please just follow these sections on the page. These sections should be enough for the default installation.
1. Downloading (Please make sure that the md5 checksum requirement is met)
2. Installing
3. Testing

If your network setup differs from what is described on the page (port number etc.), you may have to change parameters around for your configuration, otherwise the procedure is very straightforward. When you type http:\\localhost as the url, if you get a web page with "it works" on it, then the installation has been successful.

   To install Perl please click on the following link

http://www.ricocheting.com/how-to-install-on-windows/perl

The Active Perl installer is:
ActivePerl5.14.......x86...., which is also a 32 bit installer.

While installing, please follow the instructions on that page very carefully, since you NEED TO CHANGE the folder where the Perl executable is located to C:\usr. Please also make the changes in the httpd.conf file as described in the instructions. Make sure that the test program runs when located in
C:\ProgramFiles\Apache......\Apache2.2\cgi-bin\helloworld.cgi

4.0 Hardware for the MZM-LORTM

For the simple schematic, please refer to *Figure 2* near the beginning of the document. The full schematic is the pdf attachment included with this document. The main components and their functions:

   Ref1 frequencies for the MZM-LORTM range from about 16-31 GHz
   Ref2 frequencies for the MZM-LORTM range from 0.222 to about 3.0 GHz (Ideally Ref2 frequencies should go up to 6.0 GHz, but the Ref2 amplifier AR3 is limited to about 3.2 GHz or so).
    All optical components are Polarization Maintaining (PM), which means that light only propagates along one of the allowed axes. For the MZM-LORTM all the components are keyed such that light travels along the slow axis.

i) MZM1 (MZ1), and MZM2 (MZ2) are the heart of the MZM-LORTM which modulate the input laser light at 1556.21 nm by applying RF signals. Laser output at +19 dBm is power divided using a 3 dB coupler CP1, and each MZM is supplied an optical input of approximately +14.0 dBm.

a)   MZ1 is modulated ONLY at port C by Ref1 frequencies and DC bias is applied to port C which   is operated near 0 V (more like ~ 1 V) which is known as operating in the full bias mode. This process retains the second harmonics generated by the phase modulation of the input laser signal and suppresses the undesired harmonics, namely the first harmonics (more generally the odd harmonics). Ports A and B are set to 0 V for MZ1 always. PLEASE note that the central carrier that is undesired is still present from the output of MZ1. The Ref1 signal produced by the Agilent E8257D synthesizer is power divided and amplified by AR1 going into port C of MZ1. A Bias-T BT1, couples the DC bias and the amplified Ref1 output (about +28 – 29 dBm) from AR1 and applies it to port C.

        The final output then, from MZ1 (depicted just below IS2) consists of the central carrier + second harmonics where the central carrier is about 10-15 dB (frequency dependent value) higher than the desired second harmonics, when the correct biases to all three ports are applied. Also, please note that both the upper and lower sidebands of the second harmonics are present in this output. The separation between the lower and upper sidebands is 4 x Ref1. The range of suppression values arises from the fact that the efficiency of the MZM drops off with frequency and less power is retained in the harmonics as the Ref1 frequency increases.

b)   MZ2 is modulated by both Ref1 and Ref2 frequencies. Just as with MZ1, an amplifier AR2   supplies the amplified Ref1 output of +28 - 29 dBm to be applied to port C along with the DC bias coupled through a Bias-T BT2. Ref2 signals are amplified by amplifier AR3, power divided, and then applied to ports A and B along with DC biases. Bias-Ts, BT3 and BT4 couple Ref2 and the DC biases applied to ports A and B of MZ2. The power level of Ref2 is ~ +29 dBm going into ports A and B each. Ports A and B are operated near 5 V (actual values will differ from the nominal value of 5 V because of other effects), which is referred to as operating in the Null Bias mode. In this mode, the carrier and second harmonics are suppressed and the first harmonics (more generally the odd harmonics) are the dominant tones. Port C of MZ2 is operated in the Full Bias mode.

        The final output from MZ2 (depicted above IS4) then, comprises of pairs of tones clustered around the carrier frequency, a lower sideband and an upper sideband frequency. The small separation between the main tones is 2 x Ref2. The separation between the center frequencies of the upper and lower sidebands is 4 x Ref1. PLEASE NOTE THAT THESE PAIRS ARE NOT SEEN AS SEPARATE TONES ON THE OSA DUE TO THE LIMITED RESOLUTION BANDWIDTH OF THE OSA. However at the maximum Ref2 values of approximately 3 GHz, the aggregate nature of the lower sideband originating from MZ2 is clearly seen in *Figure 3*.

ii)   The next stage is the Fiber Bragg Grating (FBG) (optical filter) assembly which is comprised of several stages:

a)   The first FBG stage (FB1 and FB2) for MZ1 is the removal of the lower sideband by using wideband FBGs that cover the entire tuning range of Ref1. In addition, two of them are cascaded to provide > 50 dB suppression of the lower sideband. This deep level of suppression is required to prevent amplitude modulation (via interference) at the output of the summer CP4, which in turn would produce phase fluctuations at the output of the photomixer which we want to minimize as much as possible. Just to expand on the above point somewhat, the amplitude modulation would consist of the lower sideband (LSB) from MZ1 (undesired) causing amplitude fluctuations to the

LSB from MZ2 (desired), and vice versa. PLEASE also note, that the FBG bandpass removes a significant chunk of the carrier laser that is undesired.

b) The first FBG stage (FB3 and FB4) for MZ2 is the removal of the upper sidebands. Again, cascaded FBGs provide a > 50 dB level of suppression. Again, please note that that these FBGs remove a significant chunk of the central pair of undesired tones centered about the carrier.

c) The output from the two FBG stages is summed using a 3 dB coupler CP4. Attenuators AT1, and AT2 are used to equalize the power levels of the upper and lower sidebands obtained from the different MZMs at a midrange Ref1 tuning frequency of about 23 GHz. The second stage employs a pair of cascaded FBGs (FB5 and FB6) that have a much narrower bandpass in order to completely suppress the central carrier and the Ref2 modulated pair. These FBGs are wide enough that they also remove a significant fraction of the first harmonic especially at the lower end of the tuning range of Ref1 frequencies.

d) Finally a note on components labeled 'Iso/Polarizers'. These are combinations of optical isolators and polarizers. The isolators have a return loss of approximately 55 dB (these are double stage isolators), which prevents any back propagation of light along the optical path. As mentioned before, the entire optical path in the MZM-LORTM is PM. Light along the orthogonal axis is periodically eliminated by the inclusion of polarizers. This allows the PER (Polarization Extinction Ratio) to degrade as little as possible, where PER = light power along desired axis/light power along undesired axis. For e.g. a 25 dB PER output would be considered very acceptable.

iii) As seen from the schematic, at the end of the FBG assembly, the optical spectrum power level is at approximately -15 dBm. Please keep in mind that this number will be different for different Ref1 frequencies. The optical signal is amplified by an EDFA (Erbium Doped Fiber Amplifier) AR4. The EDFA introduces a large incoherent noise pedestal, which is mostly removed by the 4 nm optical bandpass filter FL1. The 3 dB coupler CP5 provides two outputs at J1 and J2 at ~ +8 dBm.

General Notes: Couplers CP2 and CP3 which are 90/10 couplers provide direct output from the MZMs to conduct rebiasing via J3 and J4 for MZ1 and MZ2 respectively. MZM1 dissipates approximately 0.6 Watts, and MZM2 dissipates approximately 1.9 Watts. The large power dissipation within MZM2 as heat causes a degradation in the phase stability. A thermoelectric cooler (TEC) is therefore used to keep MZM2 cool at approximately 20 degrees Celsius. The drive voltage for the TEC can be adjusted externally. The ADAM control module, which consists of 2 DAC units, 1 ADC unit and 1 thermocouple unit is described in detail in *Section 3.5*.

Finally, from the schematic, LO = 4 x Ref1 – Ref2, and TS = 4 x Ref1 + Ref2.

4.1 Hardware upgrades for the MZM-LORTM for Band 1 and Band 5

Please refer to the full schematic for the upgrades made to the MZM-LORTM to enable its functionality for Band 1 and Band 5 as well. The new components are highlighted in yellow. A DPST switch on the rear panel selects Band 1 or the other Bands. When in Band 1 mode, the switch turns off the RF amplifier AR1 to MZ1, and couples in the light from the laser from the 10 dB coupler CP4 through an optical switch SW1. This has the effect of turning off the upper side band derived from MZ1, and adding the master laser back into the optical path. The variable optical attenuator AT3, is used to adjust the laser optical tone to be within 3 dB of the lower side band at both edges of the band. The lower sideband from MZ2 and the laser tone are combined via another 10 dB optical coupler CP5, and amplified by the EDFA to produce the desired 3 tone output as seen in the figure below, *Figure 24*. *Figure 25* shows the output when the switch is NOT in Band 1 mode.
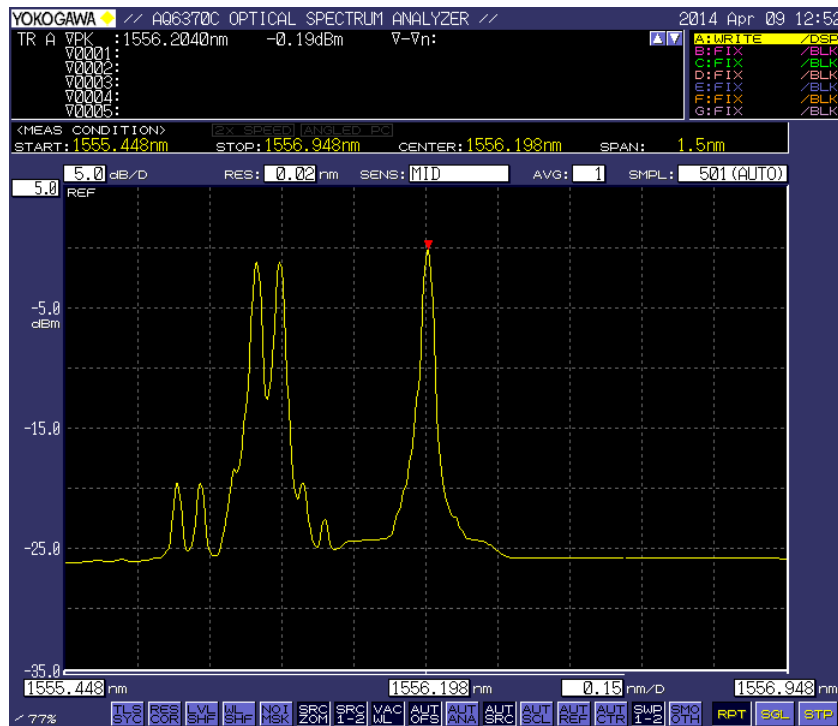
Figure 24 *Typical output spectrum of MZM-LORTM as seen on the Yokogawa OSA. Ref1 = 20.5 GHz (38/44 GHz   photomixer output). As opposed to* Figure 3, *note the LSB on the OSA is clearly observed to be composed of 2 tones (LSB1 & LSB2) Ref2 = 3.0 GHz. The difference between the two LSB tones is equal to the IF = 2 x Ref2 = 6   GHz. The central tone is the master laser coupled back into the optical path as described above. The higher optical resolution of the Yokogawa OSA permits us to see the two individual optical tones comprising the lower sideband.*
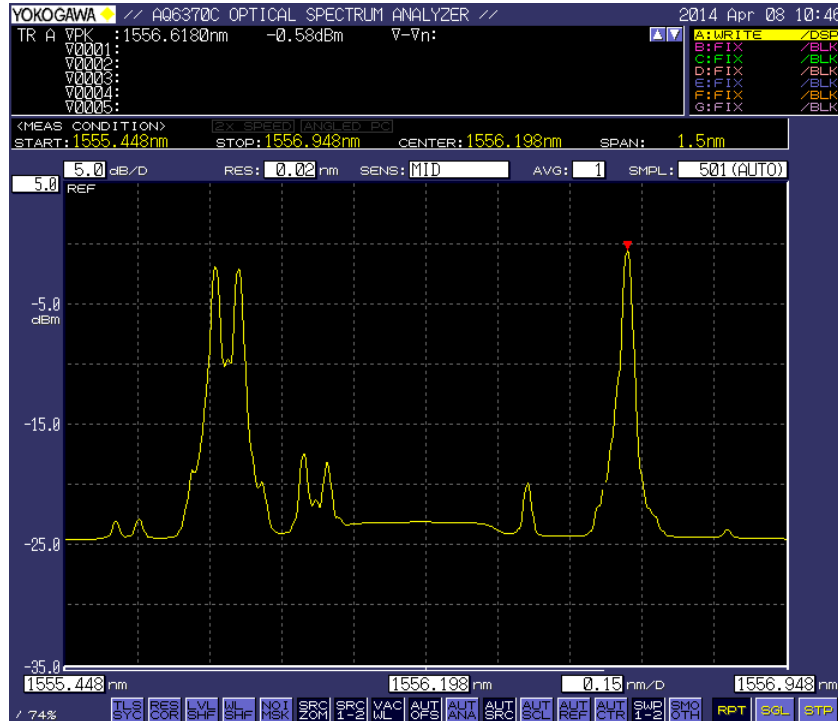
Figure 25 *Typical output spectrum of MZM-LORTM as seen on the Yokogawa OSA. Ref1 = 25.75 GHz (100/106 GHz photomixer output). Ref2 = 3.0 GHz. The difference between the two LSB tones is equal to the IF = 2 x Ref2 = 6   GHz. As usual, the lower side band from MZ2 is composed of two separate tones. The central laser is now absent and the output from MZ1 is added back into the optical path.*

3.5.3 Web Interface (Redone for Taipei Lab operations)

The MZM-LORTM can be controlled and monitored using the Linux laptop PC via a local web interface. Please make sure that the laptop, the synthesizers and the LORTM are connected to the network.

1) On Firefox, the basic web page is under bookmarks and it should bring up the page -------http://alma-mzm/LORTM_tasks.html
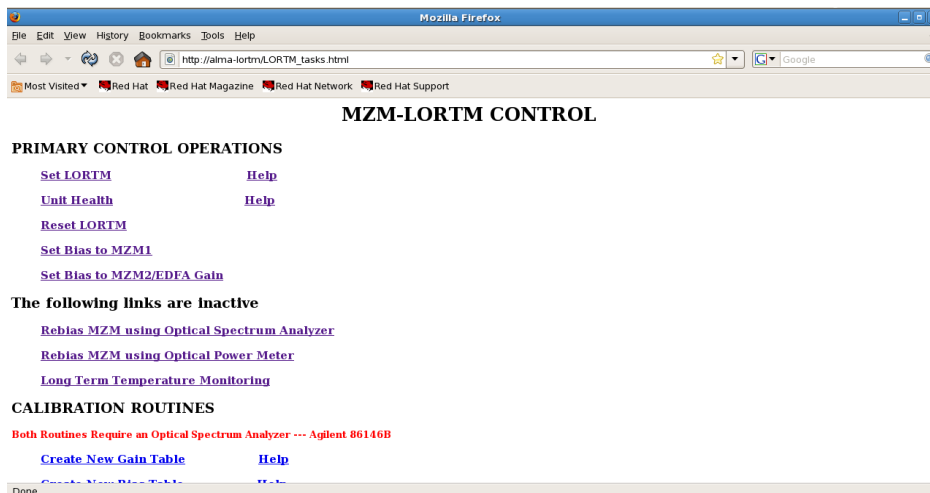
2) The first link opens up an interface that sets the MZM-LORTM given LO1, TS, FLOOG etc.. Output on the successful completion shows all the Bias values, Gain, and Ref1 and Ref2 values (not in a pretty tabular format!!, but it is all there).
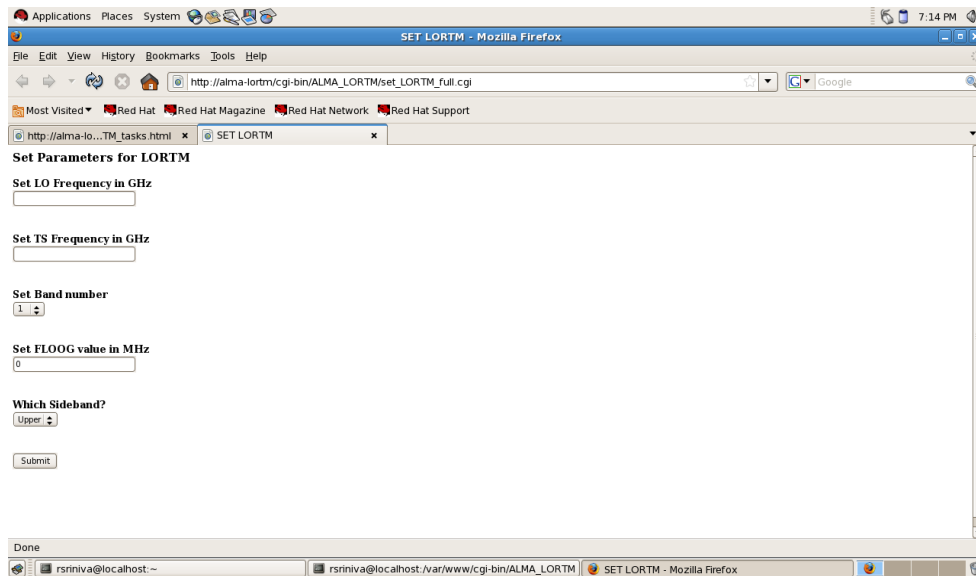

3) The second link is an interface that monitors the thermocouple module and the Analog input module for a maximum duration of 30 minutes and updates continuously. The only input needed for this interface is the length of time to monitor the above two modules.
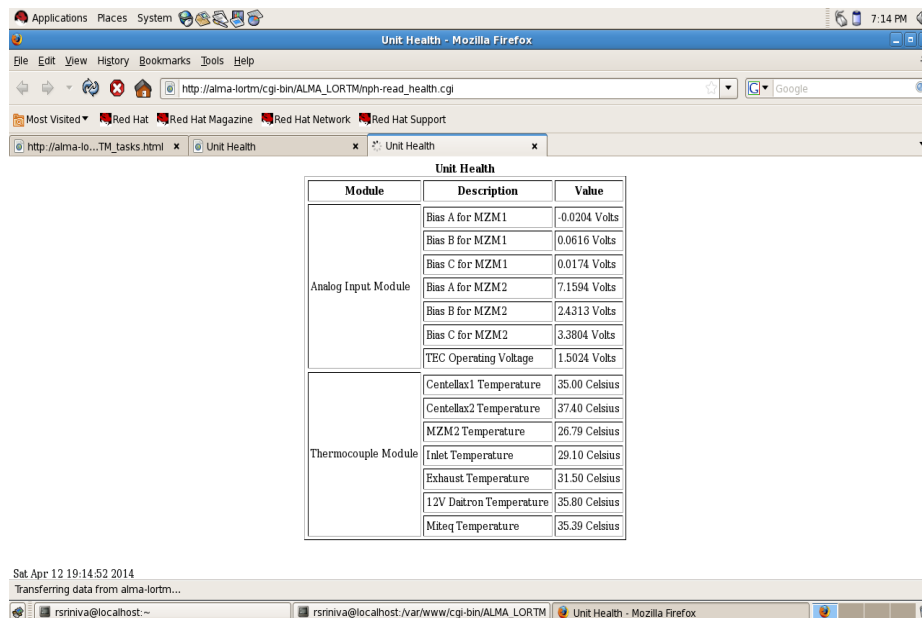

4) The third link requires no input and clicking on the link will set all the DC biases for the two modulators to 0 and turns down the gain of the EDFA as well.

5) The fourth link provides a separate page to set the DC biases to Ports A, B and C individually for MZM1. This is only required for non Band 1 operations. In addition, adjusting the biases to the individual ports is only required , if the undesired harmonics are too strong relative to the desired sideband. To reiterate, the desired harmonics are the second harmonics and the undesired harmonics are the first and the third harmonics.
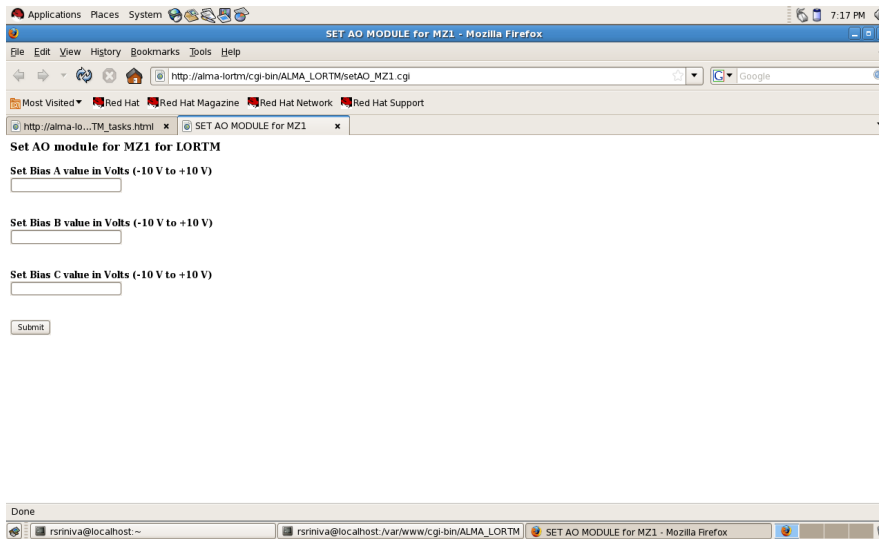
6) The fourth link provides a separate page to set the DC biases to Ports A, B and C individually for MZM2. MZM2 derived optical tones are used both for Band 1 and other Band operations. Some adjustment might be necessary to suppress the first harmonic adequately. The 'set_LORTM' link will get the DC biases close, but it might be necessary to fine tune the biases for the higher frequencies in Band 1. The fourth textbox can be set to adjust the control voltage to adjust the gain of the EDFA.
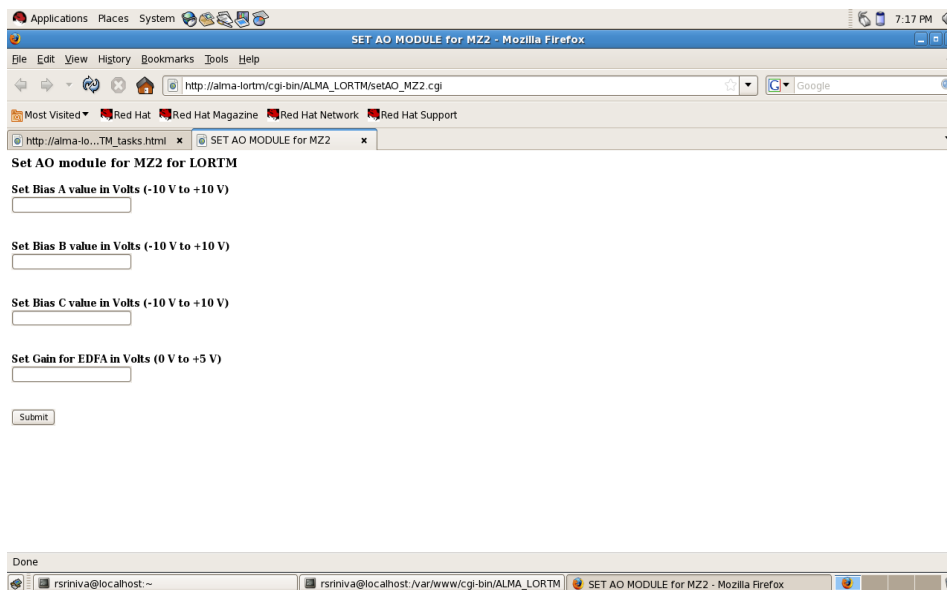
7) The rest of the links are inactive.

Please read Section 3.8, paragraph 1 on DC Bias drift. To minimize the effects of the drift, please use the 'reset LORTM' link at the end of every day. Please do NOT switch off the two synthesizers. Please keep the MZM-LORTM on, if it is scheduled to be used on a continuous basis (everyday). Everything can be switched off, if the MZM-LORTM is not going to used for an extended period (~ 1 week or more).