

# iMS4-P -xxx

## Compensation Function and LUT Generation for iMS4 - Rev-C

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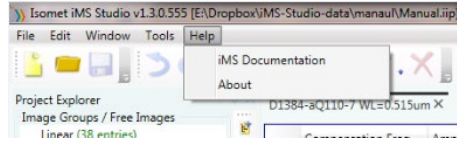
### Definitions

<b>Acronym</b>	<b>Meaning</b>
AOD	Acousto Optic Deflector
DCAL	Diffraction efficiency level for Calibration
DDS	Direct Digital Synthesizer
DE	Diffraction Efficiency
FAP	Frequency – Amplitude – Phase triad
GUI	Graphic User Interface
LUT	Look Up Table
SDK	Software Development Kit

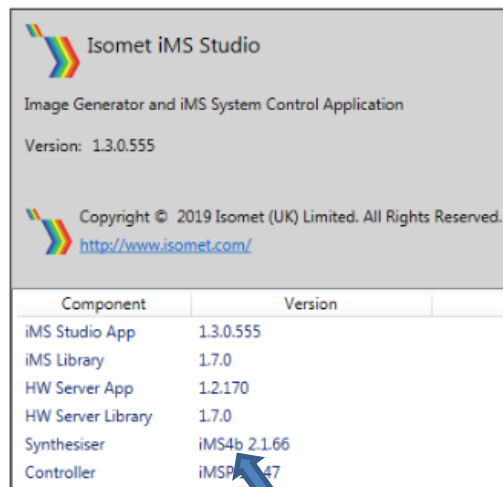
**Rev-B or Rev-C ?**

To determine your IMS4 build revision, run the Isomet iMS Studio.

From the upper Tool Bar select **Help > About**



The revision ident is listed in the Synthesiser Version part number.



Component	Version
iMS Studio App	1.3.0.555
iMS Library	1.7.0
HW Server App	1.2.170
HW Server Library	1.7.0
Synthesiser	iMS4b 2.1.66
Controller	iMSP 1.47

## 1. Description

The compensation look-up-table (LUT) contains frequency dependent phase and amplitude data. This is automatically applied to the "Image data" to maximize diffraction efficiency and improve the uniformity across the scan. The LUT is a fixed length file comprising 2048 points for each channel, covering the full frequency range of the iMS4-. (12.5MHz - 200MHz).

[The LUT can also be programmed with a user defined 12-bit data word. This is synchronously output on iMS4 connector J7 when the specified frequency(s) is called. It is an alternative to the point defined Synchronous data field programmed in the Image data].

## 2. Background Theory

Maximum diffraction efficiency exists when the laser beam and acoustic column in the AO crystal are at the Bragg angle. This angle is a function of the RF drive frequency and laser wavelength. In an AO deflector, the frequency defines the output scan angle. Consequently, when the scan angle is changed so too is the ideal input precise Bragg angle.

For optimum performance, the Bragg angle needs to be readjusted according to the RF drive frequency (= scan angle). A fast and dynamic method to achieve this angle correction is to steer the acoustic beam in the crystal using a phased array transducer. Such transducers feature multiple RF inputs, driven with a progressive phase shift. The magnitude of this phase shift depends on the transducer geometry (constant) and the applied RF frequency (variable).

At the mid frequency, the phase difference between the two AOD inputs is zero. At all other frequencies, there is a positive (+ph) or negative phase (-ph) difference. At any given moment, the frequency and amplitude applied to each AOD has the same value. Only the phase is different between the two or more inputs of the AOD

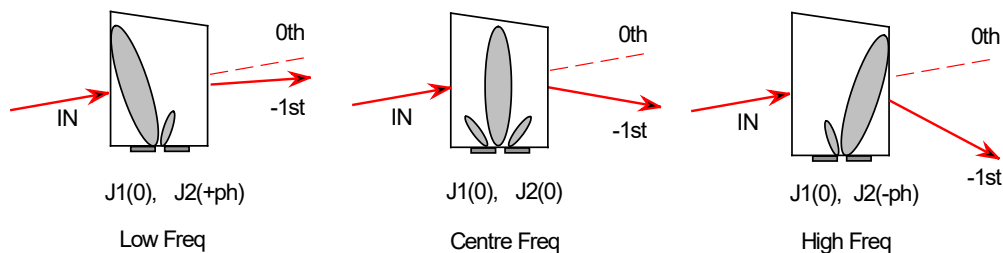


Figure 1: Beam Steering

### 3. Compensation LUT's.

#### Phase Value

A frequency dependent phase offset between the AO deflector RF inputs compensates for the input Bragg angle error. These phase values are appended to the downloaded Image file according to the channel number and frequency value of each image point. (Note: these are not the phase values that can be downloaded in the Image file)

Phase can be calculated. The calculation assumes that the Bragg angle is adjusted at the AO geometric mean frequency. This is a near mid-frequency that will give a balanced positive and negative phase shift value at the min/max scan limits.

Phase calculation (add 360 degrees to negative phase values):

$$\varphi(f) = -180 \cdot \left[ \frac{G \cdot \lambda_0 \cdot 10^{-3}}{no} \cdot f^2 \cdot \left( 1 - \frac{f1}{f} \right) \right]$$

where:

$G$	=	Device specific Geometric Constant
$f$	=	frequency (MHz)
$fc$	=	AO device centre frequency
$f1$	=	mean frequency for balanced +/- phase shift
	=	$fc \times fc^2 / [fmax \times fmin]$
$\lambda_0$	=	free space wavelength (nm)
$no$	=	refractive index

The calculation of these theoretical phase values does not take account for errors introduced by the transducer matching network, RF amplifier and coax cable characteristics.

#### Amplitude Value

A frequency dependent amplitude weighting compensates for variations due to conversion losses in the transducer, gain variations in the RF amplifier and coax cable characteristics. The LUT amplitude factor is multiplied with the Image file amplitude data This is applied to all channels according to the point frequency.

Unlike phase, the amplitude data is not easy to estimate in advance and is initially set at a constant level. The final values will depends on the frequency response of a specific RF amplifier model and cable length.

As you may conclude, a basic LUT file with calculated phase and a constant amplitude value is an approximation and is unlikely to provide the optimum uniformity.

#### LUT application

The LUT is downloaded into the iMS4-P at start up by the user.

A default start-up LUT can also be programmed into non-volatile memory within the iMS4-L (or -P) Subsequently the LUT is automatically applied following DC power-on of the iMS4. This latter function is not available via the GUI, please refer to C++ SDK.

**4. iMS4 revisions**

Comparison of the iMS4 build revision is given below.

**The remainder of this manual applies to Rev-C only**

<b>iMS4 build</b>	<b>Rev-A, Rev-B</b>	<b>Rev-C</b>	<b>Comment</b>
<b>Feature / Control</b>			
DDS <i>Power Setting</i> level <sup>1</sup>	✓	✓	Fine power control. Common to all outputs
<b>Channel Amplitude <i>Power Setting</i> level <sup>2</sup> (coarse control)</b>			
Common to all channels	✓	X	Selectable source; W1 or W2
Independent	X	✓	One source per channel
LUT files and function <sup>3</sup>	Single. Common to all channels	1,2 or 4 independent file(s). Selective application to 1, 2 or 4 channels	
Use with X-Y AO deflector	Acceptable	Optimal	

Notes:

1:,2: The DDS *Power Setting* level and Channel Amplitude *Power Setting* levels will depend on the iMS4 build revision, the RF power amplifier, the AO deflector model and wavelength.

Recommended settings will be provided on the AO test data sheet and non-specific guide line settings provided on the Isomet website.

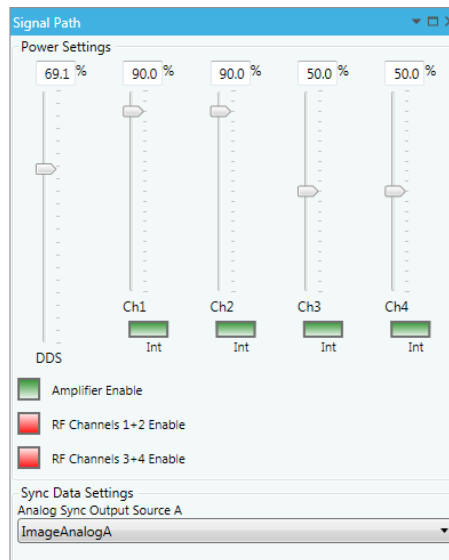
2: In addition to these software controls, the user can select an external control source via connector J8

3: Generic LUT files are provided on the Isomet website.

Signal Path Control Panels

**Rev-C**

Independent controls



## 5. Creating a LUT.

The laser characteristics and beam alignment will be specific to a given installation. These are unlikely to be identical to the Isomet test set-up. The example LUT files available on the Isomet website should provide reasonable performance and demonstrate operation. However for optimal performance, LUT generation should be undertaken during system integration.

A proficient C++ programmer will be able to develop an automatic calibration routine employing the ADC inputs of the iMS4-L (or-P).

Alternatively, the empirical method described below uses the Isomet GUI.

### LUT Phase & Amplitude Determination

Please refer to the iMS4-P (or -L) manual and the Isomet GUI Software Guide. Download the latest SDK from the Support page from ISOMET web site

#### Method Overview

- Set the Bragg angle for the AOD.
- Step through selected frequencies across the required LUT frequency range.
- At each point, adjust the Phase and then Amplitude to achieve the calibration diffraction efficiency level, "DCAL level".(see Provisos below)
- Record the values into the Compensation Function Table provided in the GUI.
- Use the built-in curve fitting routine to interpolate LUT values across all frequencies of interest.
- Generate, Save and Download the LUT file.

#### Provisos

1: The DCAL level should be set to avoid saturation in the AO deflector and/or RF power amplifier. The efficiency should be peaked using the phase (with amplitude set at a low level) and then the amplitude.

Remember: Phase then Amplitude.

Recommended 'DCAL' level = 85% x maximum diffraction efficiency.

*Tip: It may be easier to place an optical power meter in the zero order beam path and measure the residual power. The zero order beam remains stationary. The zero order kick out (KO) efficiency is the inverse of the first order diffraction efficiency (DE). Provided the AOD is NOT overdriven the power remaining in the zero order is thus 100%-DE%. Caution. When overdriven, optical power will be diffracted into higher orders and not the desired first order beam.*

#### Explanation

For ease of explanation, this app note begins with a description of the procedure for determining a Compensation LUT file for a single axis AO scanner.

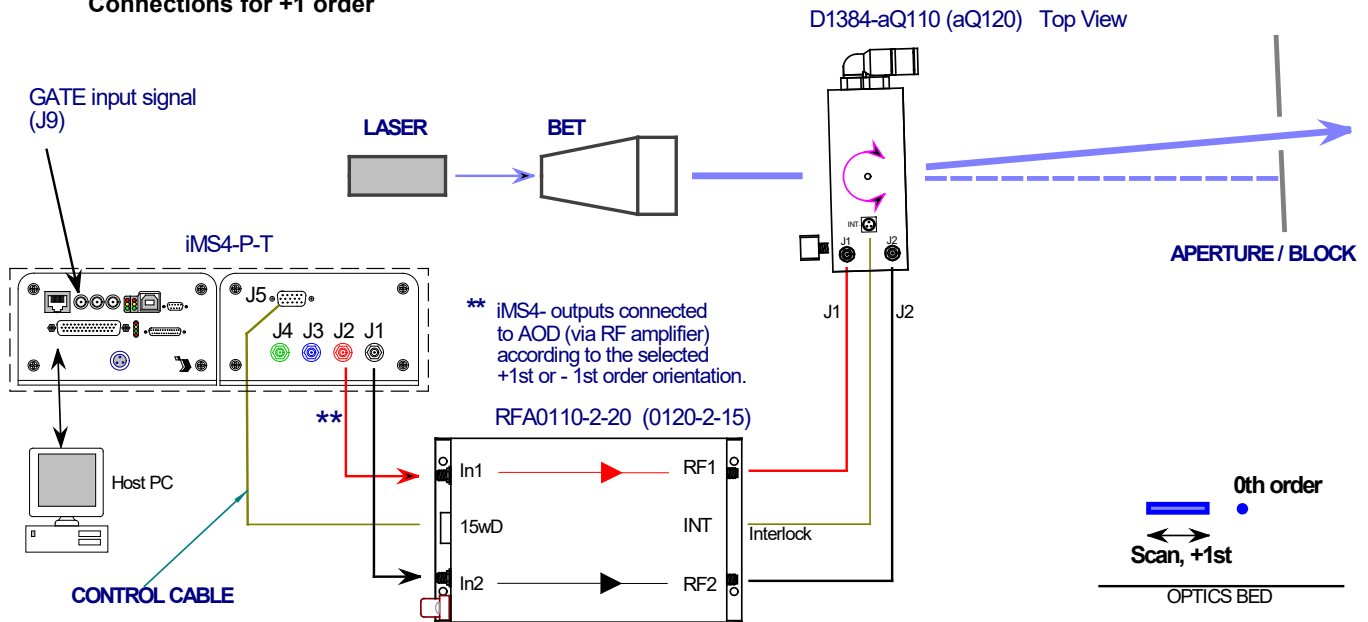
Subsequent sections explain the additional steps required to develop LUT files for dual axis scanner applications.

**IMS4 driving a single axis beam steered Acousto-Optic Deflector (AOD)**

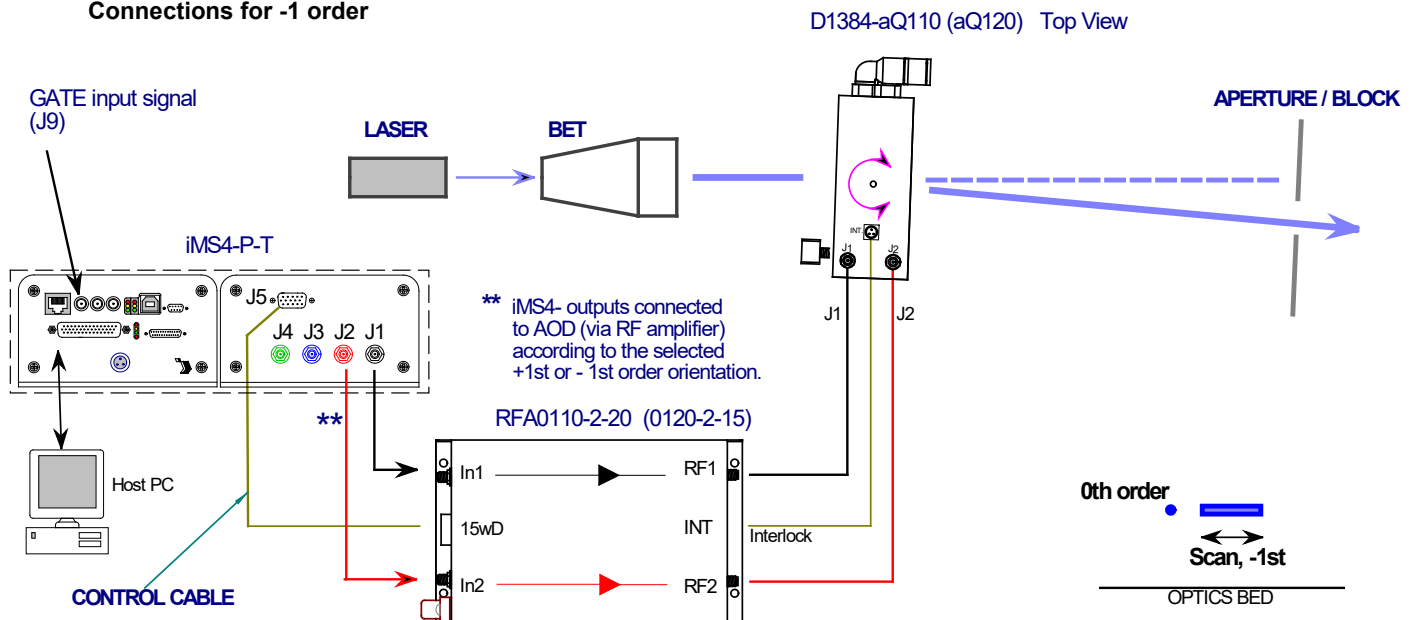
The RF connection order is important . It will define the preferred diffraction order; **+1** first order (= away from the RF connector end) or **-1** first order (= towards the RF connector end). Refer to Figure 1 below.

The following description will use the D1384-aQ110-7 and RFA0110-2-20 amplifier to illustrate the procedure.

**Connections for +1 order**



**Connections for -1 order**



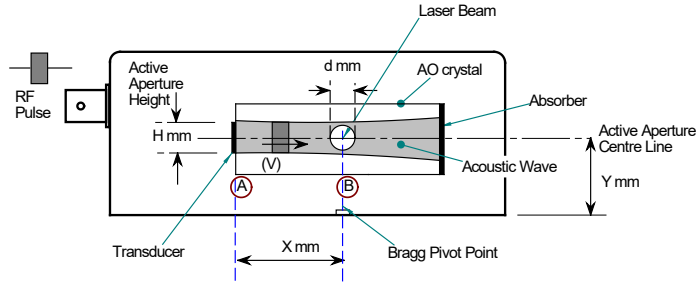
**Note: the different connection order between the two IMS4 outputs to the RFA0110-2 inputs.**

Figure 3: Typical AO scanner set-up



**Step 1: Optical alignment**

Ensure the laser beam is aligned centrally in the AO active aperture.  
 This alignment is especially important if the beam diameter approaches the active aperture height dimension H



If in doubt, please refer to app note: Optimizing Efficiency.pdf

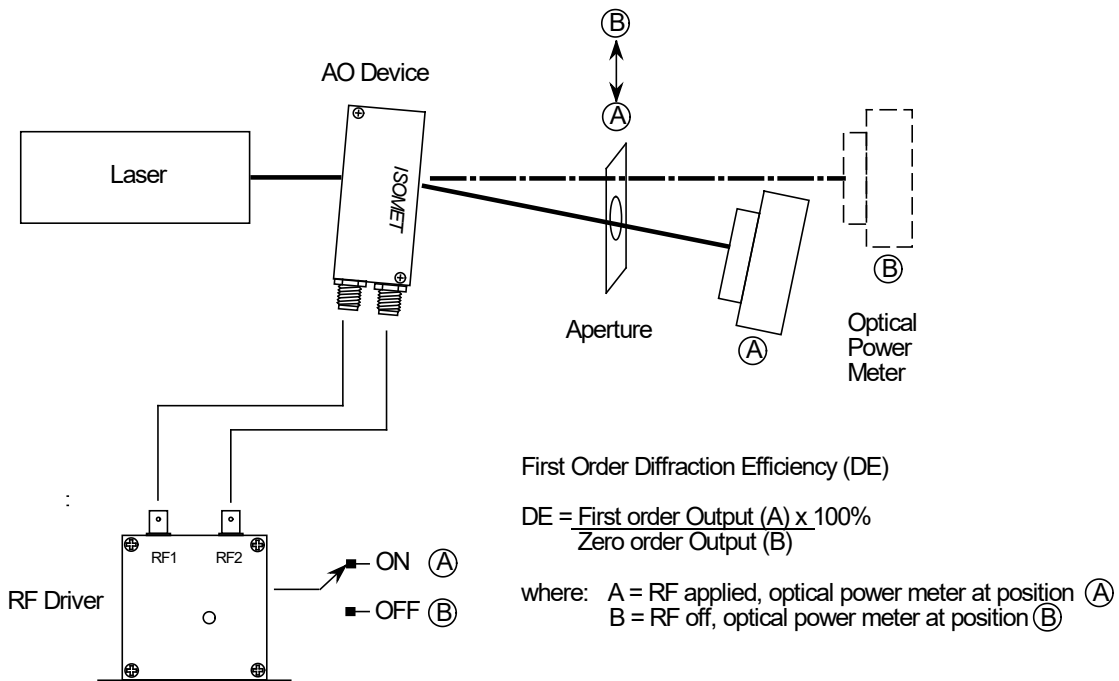


Figure 2: Basic Diffraction Efficiency Measurement

## Step 2: Setting the Power Level Wipers

The maximum output power level is set by a combination of the **DDS** and channel **Amplitude** Wipers. We will assume Channel-1 and Channel-2 of the iMS4 are used.

- 1: Set the maximum RF power limit <sup>1</sup>

### Rev-C

Select **Signal Path** panel and set the power control wiper values.

**DDS** Power: **80%** <sup>2</sup>

See the **INT (EXT)** buttons beneath each channel wiper control.

For an AOD connected to Ch1 and Ch2,

Button **green =INT** <sup>4</sup>

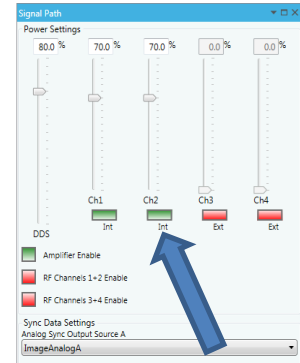
**CH1** Wiper Power: **70%** <sup>3</sup>

**CH2** Wiper Power: **70%** (**must be same as CH1**)

Button **red =EXT** <sup>4</sup>

**CH3** Wiper Power: **0% or OFF**

**CH4** Wiper Power: **0% or OFF**



- 2: Enable the RF power amplifier **\*\*\***.

Click on **Amplifier Enable** button **Green** (On)

RF power will be applied to the AOD, when the **Amplifier Enable** button is active.

### Notes:

**1 CAUTION: THERE IS A RISK OF SERIOUS DAMAGE TO THE AO DEVICES IF OPERATED AT EXCESSIVE (CW) RF POWERS.**

<sup>2</sup> These values will depend on connected power amplifier (PA) and AO device. In this example, W1 level of 50% assumes a ~1m coax cable length from the RF amplifier to AOD. For longer cable lengths, this value will need to be increased. (60% for 4m+). Please contact Isomet, if uncertain. Recommended values are provided on the test data sheet

<sup>3</sup> Depends on the amplifier model.

<sup>4</sup> **EXT** means selecting an externally applied modulation source. The inputs are connector J8. A value of 0% (OFF) assumes no signal is applied to these inputs.

**INT** means selecting the internal power level source e.g. the GUI Wiper controls Ch1,2,3,4

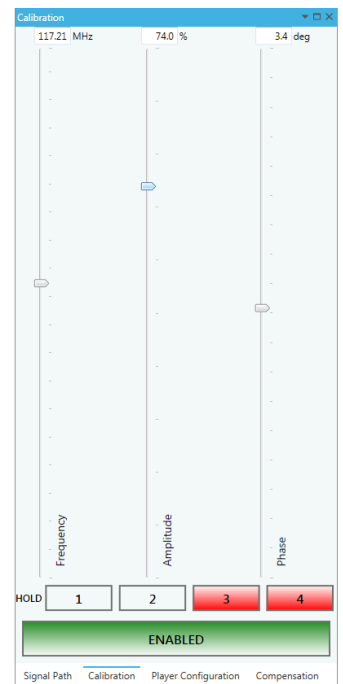
**Step 3: Setting BRAGG angle**

- 1: Place a detector at first order beam position. See Figure 2
- 2: Select **Calibration panel** tab

**Rev-C**

Slider values apply to all channels simultaneously UNLESS channel **HOLD** button(s) is active.

There is one HOLD button for each channel  
 If the HOLD button is active, the channel output is frozen and the output is set to the FAP (Frequency-Amplitude-Phase) value at the time the HOLD button was initiated.



**Select Bragg Frequency**

The D1384-aQ110 AOD has a maximum frequency tuning ranges of 90 – 130MHz. Set Frequency slider to either:

- Geometric Mean Frequency  $f_1$  (114MHz)
- .....OR.....
- Centre frequency  $f_c$  (110MHz).

Bragg at the Mean Frequency  $f_1$  balances the magnitude of +ve / -ve beam steering angles as illustrated in Figure 1. However when the scan range to be used is less than maximum for the AOD, then the centre frequency is often selected for simplicity.

**Adjust Calibration panel sliders for the Bragg Adjustment**

Ensure the HOLD Buttons are deselected for the AOD channels being set. In this example Ch1 and Ch2.

- 1: Set **Frequency** to  $f_c$ . (in this example 110MHz).
- 2: Set **Phase** to Zero. The Phase is always Zero at the Bragg angle.
- 3: Set **Amplitude** to a starting value of 50%.

*Tip: Drag the wiper position using a mouse or enter the value directly in the window and click on the wiper button to activate. Wiper position will then update to the frequency value.*

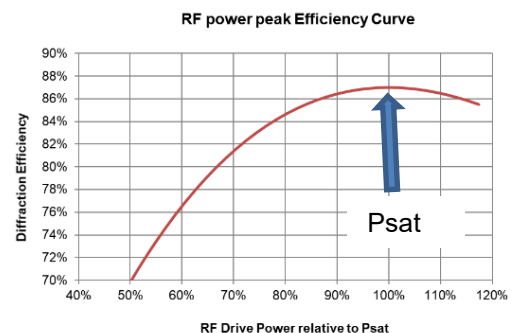
4: Adjust the AOD Bragg angle to find the peak efficiency.

5: Re-adjust the **Amplitude** slider, (Calibration panel) to maximize efficiency (DE). The peak efficiency is typically in the range of 85-90% and will be recorded on the test data sheet.

- 6: Record the peak **DE, Amplitude** and **Frequency** values.
- 7: Secure mechanical Bragg angle adjusters.

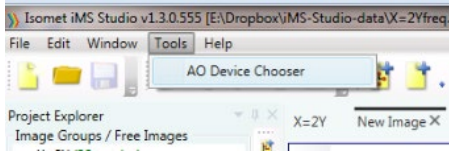
*Tip: DO NOT overdrive and exceed  $P_{sat}$  @ 100%. Better to operate at < 95% and NOT > 100%.*

*As noted from the curve above, a small sacrifice in diffraction efficiency of ~2%. will reduce the RF drive power by 10%. This will help to minimize thermal dissipation in the AOD.*



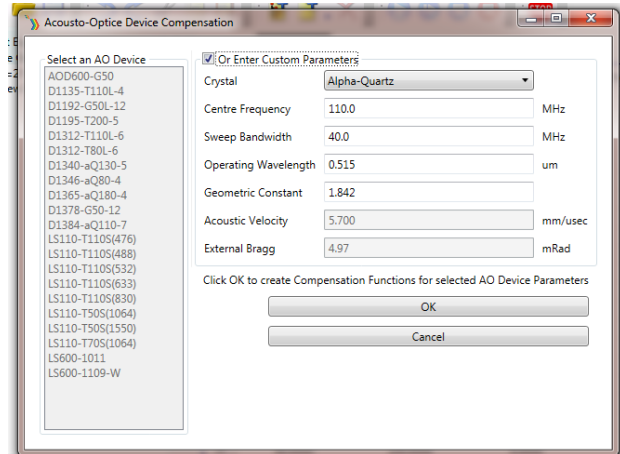
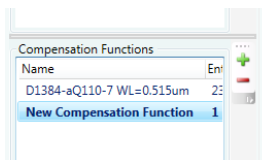
### Step 4: Generating a New Compensation Table (LUT)

Default LUT “starter” files are provided. Select the **AOD Device Chooser** from the **Tools** pull down menu



If necessary, edit the default values by checking the **'Or Enter Custom Parameters'** box.

The table name is added to the **Compensation Functions** window. The name can be changed.



The default LUT values are displayed in a worksheet format. There are 23 rows. In most cases, this is sufficient for accurate calibration.

#### Compensation Frequency

Except the first and last row (see 'book-end rows' below) additional compensation frequency rows can be added or rows removed if required. The frequencies must increase monotonically.

#### Amplitude

The amplitude values are pre-set to 50%. This is a safe value, intended to avoid overdriving the AO device on first use. Depending on the Power Level Setting (Step 2) the typical amplitude values will be between 60-95% after calibration.

#### Phase

The phase values are calculated and for most applications there is no need to edit.

#### Sync Data (Dig) / (Anlg)

Optional data fields for outputting digital /analog signals synchronized to specific LUT frequencies. These signals appear on connector J7

	Compensation Freq...	Amplitude (%)	Phase (deg)	Sync Data (Dig)	Sync Data (Anlg)
0	55.0000	0.0000	46.3930	0x0000	0.000
1	80.0000	50.0000	46.3930	0x0000	0.000
2	83.0000	50.0000	43.3200	0x0000	0.000
3	86.0000	50.0000	39.8980	0x0000	0.000
4	89.0000	50.0000	36.1290	0x0000	0.000
5	92.0000	50.0000	32.0110	0x0000	0.000
6	95.0000	50.0000	27.5460	0x0000	0.000
7	98.0000	50.0000	22.7330	0x0000	0.000
8	101.0000	50.0000	17.5720	0x0000	0.000
9	104.0000	50.0000	12.0620	0x0000	0.000
10	107.0000	50.0000	6.2050	0x0000	0.000
11	110.0000	50.0000	0.0000	0x0000	0.000
12	113.0000	50.0000	-6.5530	0x0000	0.000
13	116.0000	50.0000	-13.4540	0x0000	0.000
14	119.0000	50.0000	-20.7030	0x0000	0.000
15	122.0000	50.0000	-28.3000	0x0000	0.000
16	125.0000	50.0000	-36.2450	0x0000	0.000
17	128.0000	50.0000	-44.5380	0x0000	0.000
18	131.0000	50.0000	-53.1780	0x0000	0.000
19	134.0000	50.0000	-62.1670	0x0000	0.000
20	137.0000	50.0000	-71.5040	0x0000	0.000
21	140.0000	50.0000	-81.1890	0x0000	0.000
22	220.0000	0.0000	-81.1890	0x0000	0.000

#### Book-end rows

The first row (0) is at half the centre frequency.

The last row (22) is at double the centre frequency.

Both these “book-end” rows are set at zero amplitude and predefined phase.

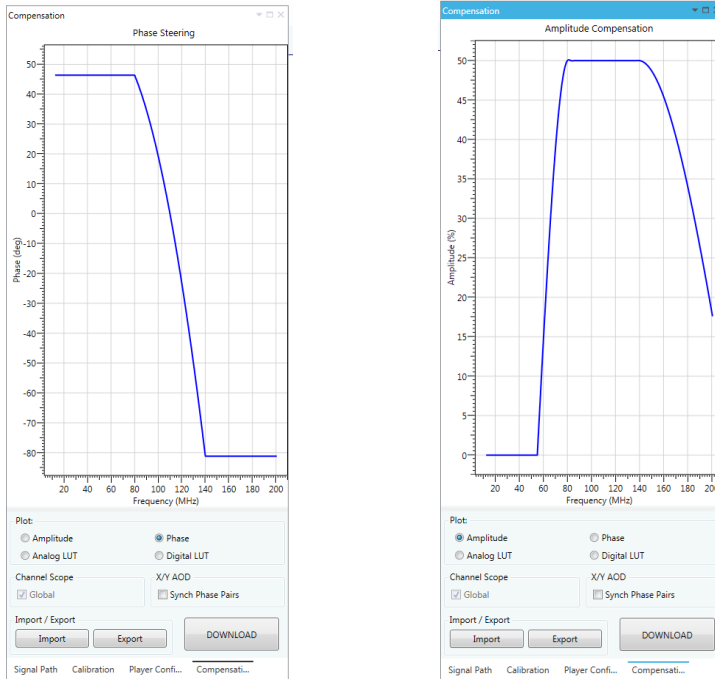
These values should not be modified. Row-0 and Row-23 are included to facilitate the interpolation function.

#### Active rows

Row-1 to Row-21 cover an extended frequency range equal to the selected AOD bandwidth x 120% (approximately).

In this example, the maximum theoretical AOD operating sweep range is 90-130MHz and the default LUT file extends from 80 -140MHz. The additional frequency range allows the same LUT file to be used should minor adjustments be made to the operating centre frequency.

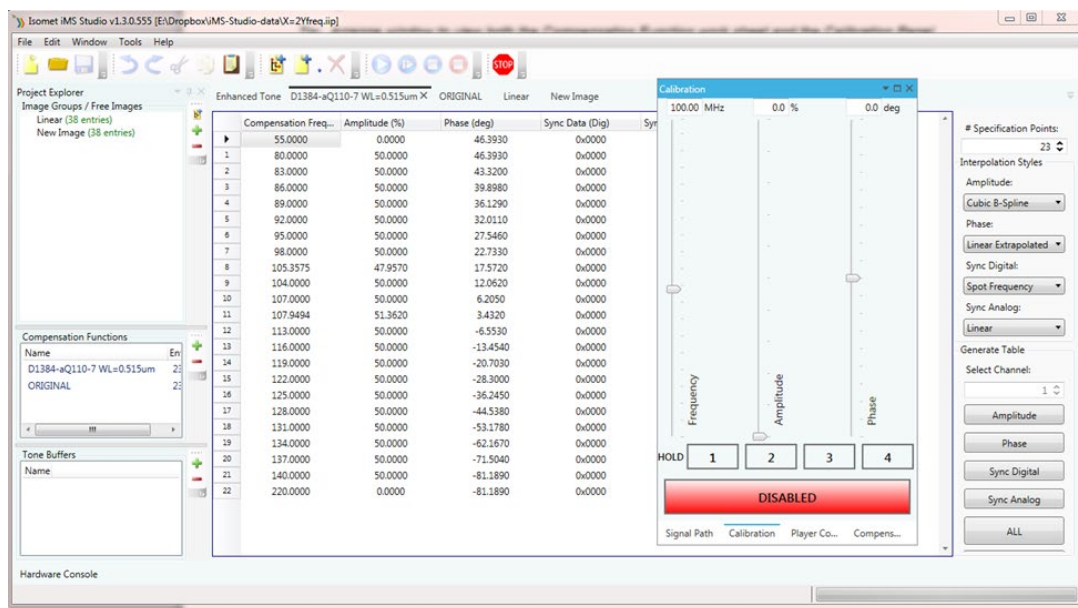
At this point you may wish to view the default values. Select the **Compensation Tab** to view the interpolated plots. Click the **Amplitude** and **Phase** radio buttons to select the desired parameter.



(Operating the AOD directly with these values would generate a sweep response similar to that shown on page 20).

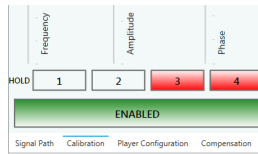
To begin calibration, select the **Calibration tab**

*Tip: Arrange window to view both the Compensation Function work sheet and the Calibration Panel*

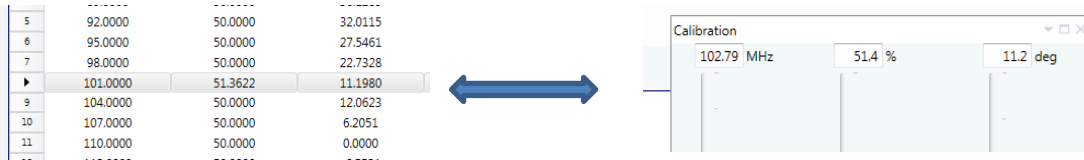


### Editing data

Enable the Calibration Sliders :

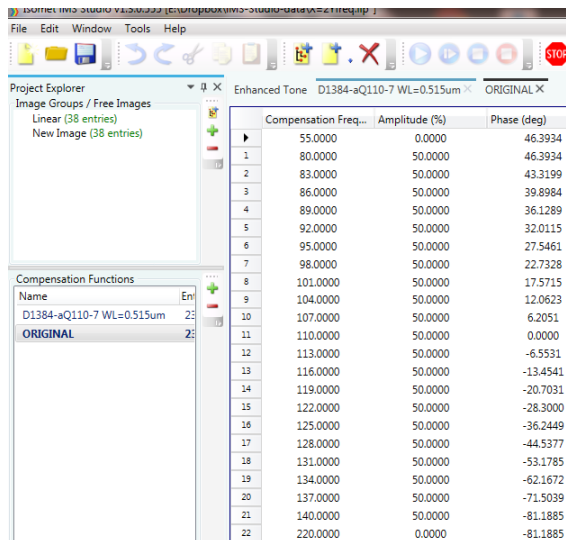


Selecting a row in the **Compensation Function** table will automatically update the **Calibration** Slider values.



Conversely changing a wiper value will update the respective parameter value in the Compensation Function table

*Tip: To recall the starting values, open another Compensation table for the same device and rename. Refer to these values if you make an error and need a reminder of the original figure.*



**Step 5: Determining “DCAL”**

Place a detector at first order beam position. See Figure 2

**The goal is to achieve the highest uniform efficiency at the lowest average RF drive power.**

Decide on an efficiency target level for calibration.

This level should be ~10% below the peak efficiency recorded at Step 3 .

e.g. Step 3, if the peak DE = 88% then the recommended target level is 78%.

We will call this the “**DCAL**” efficiency level.

Select **Calibration** tab

First step is to check that DCAL efficiency can be achieved at the extremes of the required scan range.

*Tip: For applications where the required scan range is less than the maximum sweep range for the AOD, it is not necessary to achieve the DCAL level beyond the required frequency range. A narrower operating frequency range will often allow a higher DCAL value and thus provide greater overall efficiency.*

Select the Bragg Frequency, **fc** (110MHz)  
Adjust **Amplitude** to maximize the efficiency.

The **Amplitude** and **DE** should be the same value as determined in Step3.

Reduce **Amplitude** to the **DCAL** efficiency figure.

Select **LF** (in this case 92MHz)  
Adjust **Amplitude** to achieve **DCAL** efficiency or higher.

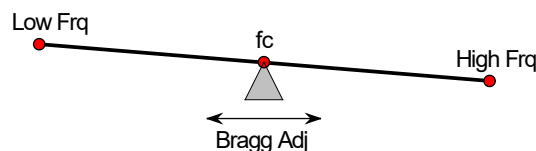
....then.....

Select **HF** (in this case 128MHz)  
Adjust **Amplitude** to achieve **DCAL** efficiency or higher.

	Compensation Freq...	Amplitude (%)	Phase (deg)
	55.0000	0.0000	46.3930
1	80.0000	50.0000	46.3930
2	83.0000	50.0000	43.3200
3	86.0000	50.0000	39.8980
4	89.0000	50.0000	36.1290
5	<b>LF</b> 92.0000	50.0000	32.0110
6	95.0000	50.0000	27.5460
7	98.0000	50.0000	22.7330
8	101.0000	50.0000	17.5720
9	104.0000	50.0000	12.0620
10	107.0000	50.0000	6.2050
11	<b>fc</b> 110.0000	50.0000	0.0000
12	113.0000	50.0000	-6.5530
13	116.0000	50.0000	-13.4540
14	119.0000	50.0000	-20.7030
15	122.0000	50.0000	-28.3000
16	125.0000	50.0000	-36.2450
17	<b>HF</b> 128.0000	50.0000	-44.5380
18	131.0000	50.0000	-53.1780
19	134.0000	50.0000	-62.1670
20	137.0000	50.0000	-71.5040
21	140.0000	50.0000	-81.1890
22	220.0000	0.0000	-81.1890

Compare Amplitude values and efficiencies at the **fc**, **LF** and **HF** points  
These will give an indication if the DCAL level is set too high or too low.

*Tip: A minor re-adjustment of the Bragg angle may help balance the RF powers required at the scan extremes. Imagine the sweep like a see-saw. Minor readjustment of the Bragg “pivot” can have a significant impact on the scan extremities.*



Similarly, minor readjustment of the sweep range centre frequency can improve the overall efficiency. This is particularly true when the full sweep bandwidth of the AOD is used. (40MHz BW for the D1384-aQ) e.g. 88 – 128MHz may result in a higher overall sweep efficiency than the design range of 90-130MHz.



### Step 6: Compensation Procedure

Place a detector at first order beam position. See Figure 2

*Tip: Recheck the detector position as the frequency is incremented and/or decremented . The beam may be scanned off the detector face .*

Step through Row1 – Row 21 of the Table 9

At each Compensation Frequency:

- 1: Ensure the amplitude slider starting value is **~50%** (to avoid overdriving)
- 2: Peak the efficiency using the **PHASE** slider \*
- 3: Set the efficiency to the DCAL level using the **AMPLITUDE** slider

(\* You may choose to leave the Phase at its default value)

It may not always be possible to achieve the DCAL level. This is to be expected near the scan limits. If necessary, reduce the DCAL level and repeat.

A completed table will look similar to that shown below

	Compensation Freq...	Amplitude (%)	Phase (deg)	Sync Data (Dig)	Sync Data
0	55.0000	0.0000	46.3930	0x0000	0.1
1	80.0000	50.0000	46.3930	0x0000	0.1
2	83.0000	100.0000	43.3200	0x0000	0.1
3	86.0000	100.0000	39.8980	0x0000	0.1
4	89.0000	100.0000	38.0000	0x0000	0.1
5	92.0000	97.0000	32.0110	0x0000	0.1
6	95.0000	97.0000	25.0000	0x0000	0.1
7	98.0000	68.0000	22.7330	0x0000	0.1
8	101.0000	62.0000	17.5720	0x0000	0.1
9	104.0000	60.0000	12.0620	0x0000	0.1
10	107.0000	62.0000	6.2050	0x0000	0.1
11	110.0000	70.0000	0.0000	0x0000	0.1
12	113.0000	75.0000	-6.5530	0x0000	0.1
13	116.0000	86.0000	-13.4540	0x0000	0.1
14	119.0000	84.0000	-22.0000	0x0000	0.1
15	122.0000	82.0000	-28.3000	0x0000	0.1
16	125.0000	78.0000	-36.2450	0x0000	0.1
17	128.0000	80.0000	49.0000	0x0000	0.1
18	131.0000	82.0000	-53.1780	0x0000	0.1
19	134.0000	90.0000	-62.1670	0x0000	0.1
20	137.0000	100.0000	-71.5040	0x0000	0.1
21	140.0000	100.0000	-81.1890	0x0000	0.1
22	220.0000	0.0000	-81.1890	0x0000	0.1

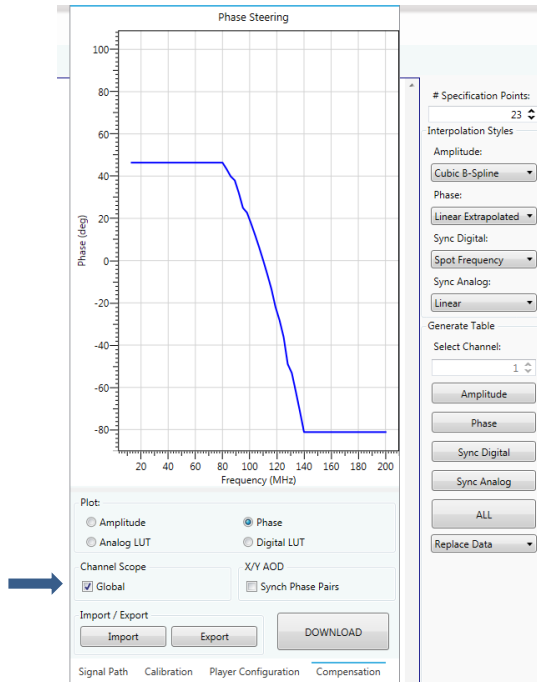
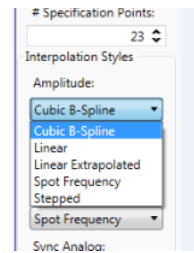


### Step 7: Generating the LUT file

Once the compensation table is finalized, the LUT file is generated for the intermediate frequencies using the in-built interpolation function.

Recommended **Interpolation Styles**.

Amplitude: Cubic-B Spline  
Phase: Linear Extrapolated



Select the **Compensation Tab**

**Rev-C:** With a single axis AOD connected to the iMS4, check the **Global button** ✓. All channels are then selected (**Select Channel** box is inactive)

Locate the **Generate Table** panel; Compensation Worksheet, right hand side tool bar.

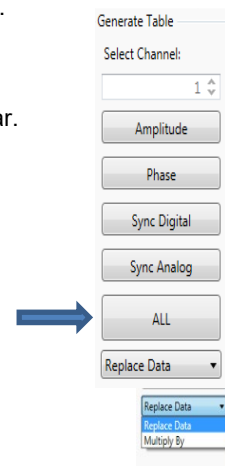
In most cases, use **Replace Data** i.e. make a new file. then hit **ALL** to generate a full LUT file.

Alternative options include:

**Amplitude** - generate/update amplitude values only

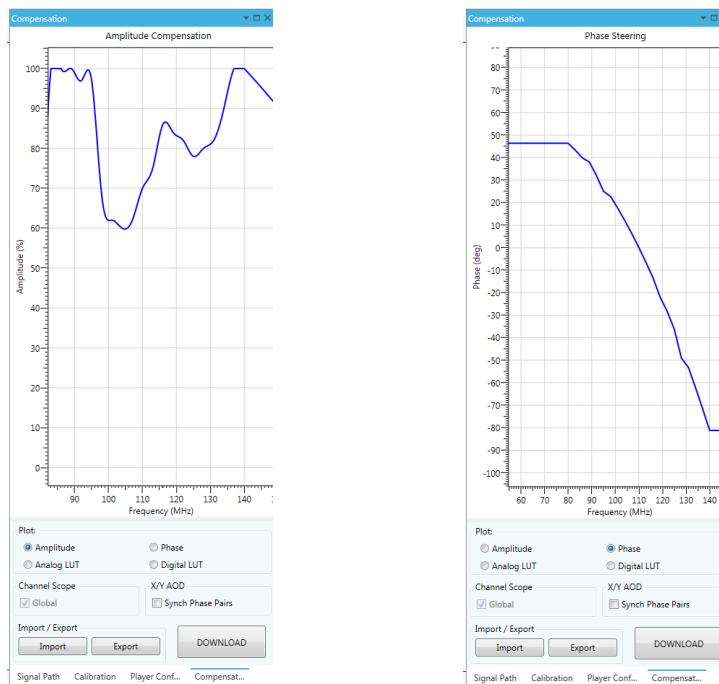
**Phase** - generate/update phase only

**Sync Dig / Ang** - generate/update Sync data only



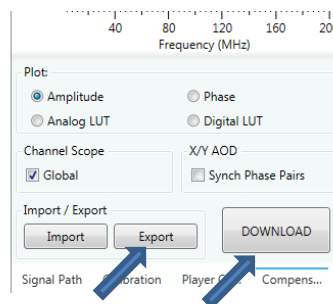
To view the optimized values:

Select the **Compensation Tab** to view the interpolated values  
 Click the **Amplitude** and **Phase** radio buttons to select the desired plot



*Tip: Right click-scroll on the chart axis to zoom scale  
 Left click-scroll on the chart axis to shift scale centre left/right*

### Step 8: Save / Recall LUT files



To save the LUT generated above, hit **Export** button and name the file. It will be saved with the extension \*.LUT

To recall a previous LUT file, hit the **Import** button and navigate to the file location.

At this point the LUT is not downloaded into the iMS4.

### Step 9: Download LUT file

To download the LUT files into the iMS4, hit **DOWNLOAD** button

## 6. Running a Test Scan

To test scan uniformity, create an Image file that generates a line scan over the frequency of interest. Run the desired Image file and record the scanned detector output.

If undesirable variations still exist you can make appropriate changes to the Compensation Function table and repeat steps 6 – 9.

*Tip: Use the Compensation plots for comparison*

Adjust the global power level to reach the desired efficiency.  
Select **Signal Path** panel and readjust the **DDS Power** and/or **Ch1, Ch2** wipers

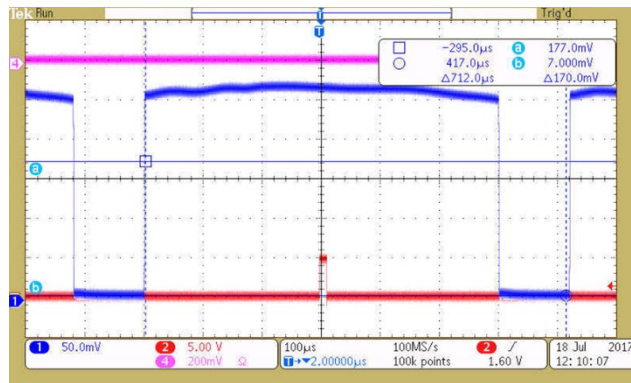
**Take care not to apply excessive RF.**

For the D1384, good efficiency sweep should be witnessed with the following wiper levels (Rev-C).

**DDS level = 80%**  
**Ch1 / Ch2 Wiper = 80%**

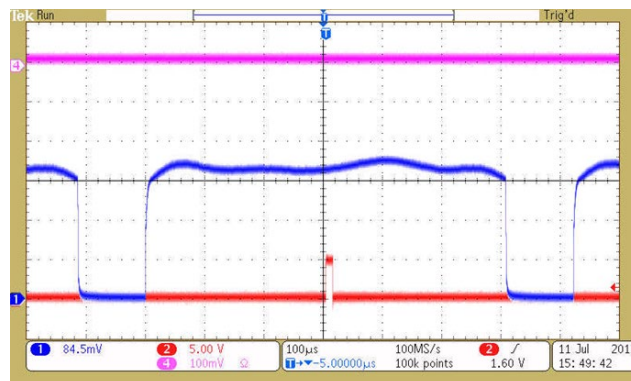
Example of a single axis scan,  
532nm, 40MHz sweep

*Trace 4: = 100% efficiency level*  
*Trace 2: = 0% efficiency level*  
*(and sync pulse)*  
*Trace 1: = detector output*



A good LUT will also give a uniform response at lower RF powers  
e.g. reduce the DDS level to (say) 40%

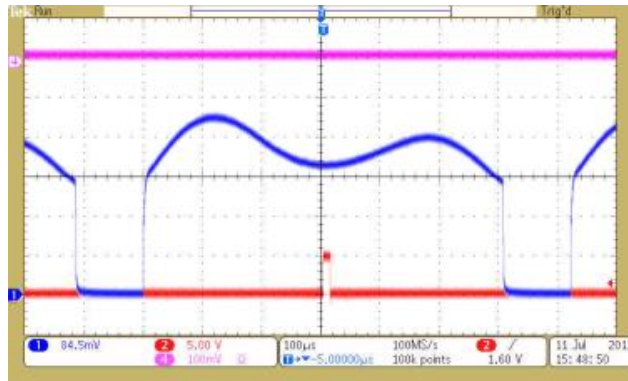
*Trace 4: = 100% efficiency level*  
*Trace 2: = 0% efficiency level*  
*(and sync pulse)*  
*Trace 1: = detector output*



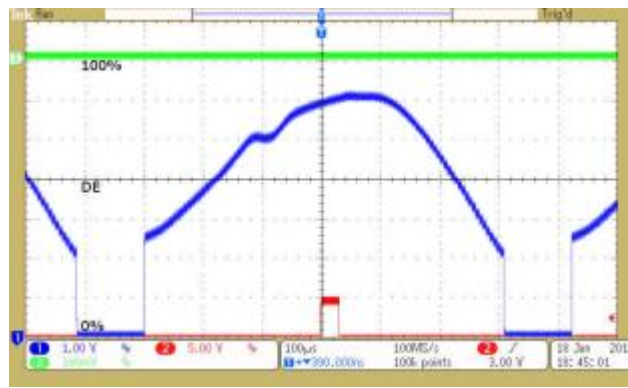
**For comparison**

Sweep using default LUT values :

Phase: Calculated  
 Amplitude: Constant 50%



If the RF connection are reversed or the incorrect Bragg angle is selected (+1 instead of -1, say) then the efficiency profile may look something like this:

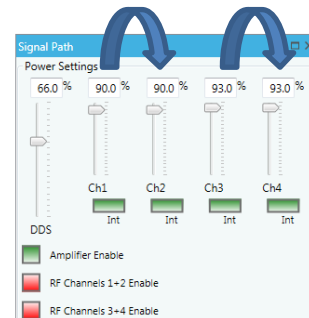


**Dual Axis Considerations**

- **iMS4 Rev-C.**

For optimum uniformity,

- Separate LUT files for the X and Y axis.  
 e.g. X-axis LUT = Ch1-LUT and Ch2-LUT  
 Y-axis LUT = Ch3-LUT and Ch4-LUT
- Independent RF power control for the X and Y axis  
 e.g. X-axis power: Ch1-Wiper + Ch2-Wiper  
 Y-axis power: Ch3-Wiper + Ch4-Wiper



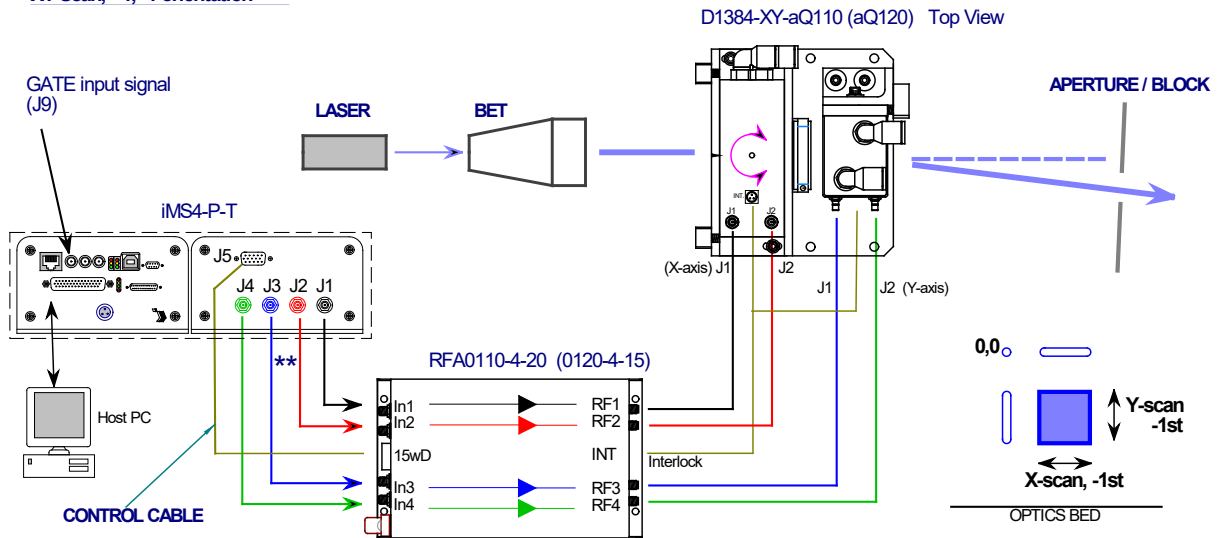
Paragraph 7 extends the above calibration procedure for dual axis X-Y deflectors.

### 7. X-Y dual Axis AOD

#### Method Overview

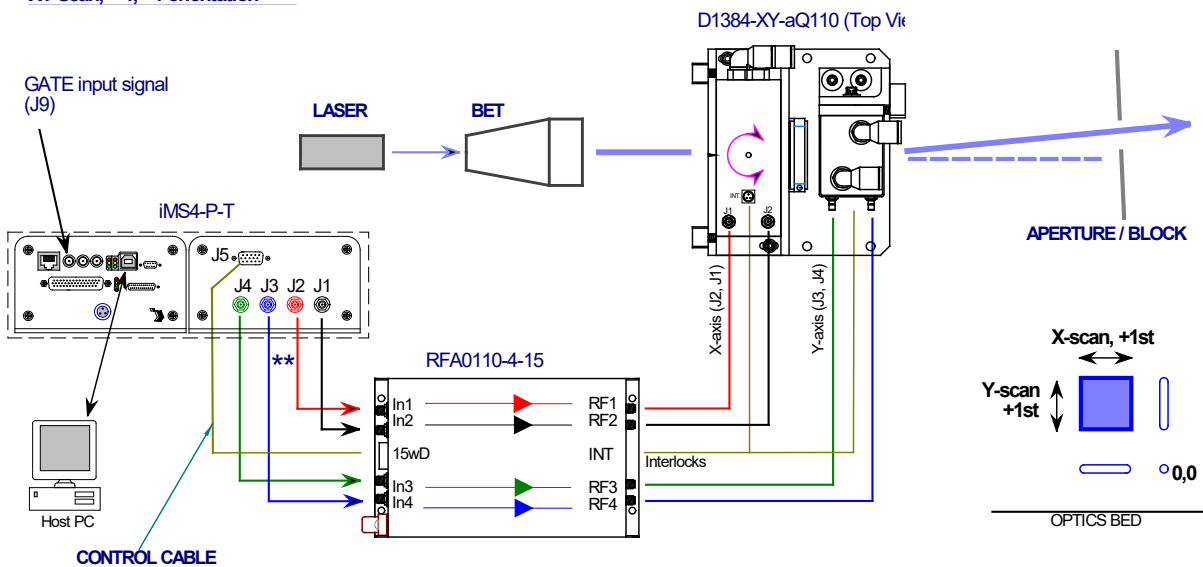
- Set the Bragg angle for X and Y axis AOD.
- Step through selected frequencies across the required LUT frequency range.
- At each point, adjust the Phase and then Amplitude to achieve the calibration diffraction efficiency level, "DCAL level"
- Record the values into the Compensation Function Table provided in the GUI.
- Use the built-in curve fitting routine to interpolate LUT values across all frequencies of interest.
- Generate, Save and Download the LUT file.

Connections for -1, -1 XY scan  
[XY Scan, -1, -1 orientation](#)



\*\* iMS4- outputs connected to AOD (via RF amplifier) according to the selected +1st or -1st order orientation.

Connections for +1, +1 XY scan  
[XY Scan, +1, +1 orientation](#)



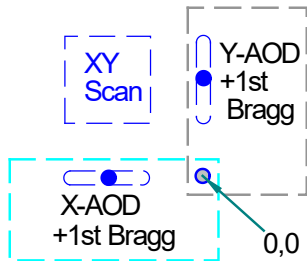
**Note:** the different connection order between the four iMS4 outputs to the RFA0110-4 inputs.

8. iMS4 rev-C

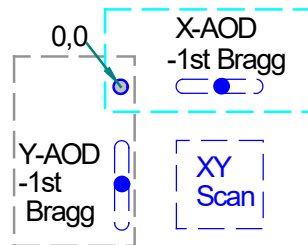
**Setting X & Y AOD Bragg Angles**

Possible X-Y output beam orientations

“plus” Bragg



“minus” Bragg



Rev-C has independent power control for each channel.

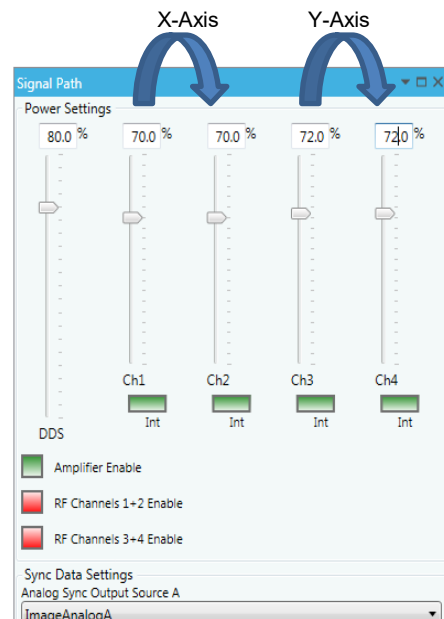
Select **Signal Path** tab

Ensure all channels are active **Int** (green)

Always ensure values driving each AOD axis are identical

i.e. Ch1 = Ch2  
and  
Ch3 = Ch4

*Tip: Easier to enter number into window(s)  
than use sliders*

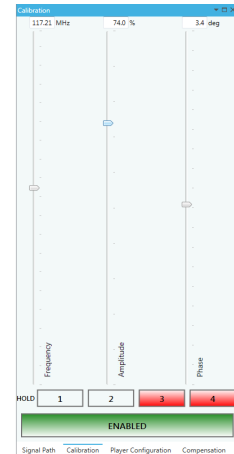


### X-axis

a: Drive X only

To disable Y-axis, reduce calibration Amplitude slider to 0% then hit the **HOLD** buttons on Ch3 and Ch4 (=red). Ch3 and Ch4 FAP values are now fixed

- Place a detector at X-axis first order beam position.
- b: Follow the procedure in Para.5 Step 3 for a single axis AOD.
- c: Record the peak efficiency (DE-X), amplitude and frequency values.
- d: Secure mechanical X and Y-axis Bragg angle adjusters.

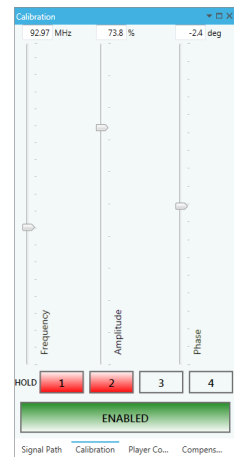


### Y-axis

e: Drive Y only

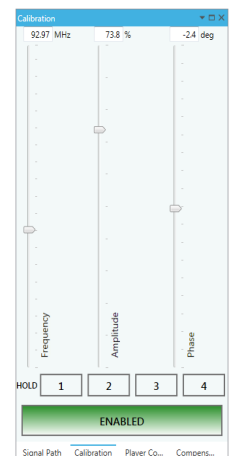
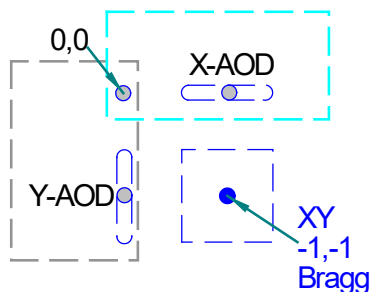
To disable X-axis, reduce calibration Amplitude slide to zero hit the **HOLD** buttons on Ch1 and Ch2 (=red)

- Place a detector at Y-axis first order beam position.
- f: Follow the procedure in Para.5 Step 3 for a single axis AOD.
- g: Record the peak efficiency (DE-Y), amplitude and frequency values.
- h: Secure mechanical X and Y-axis Bragg angle adjusters.



Depending on the AOD model, a half-wave plate may be fitted between the X and Y axis. It will be necessary to check the rotation and align the polarization for the orthogonal Y-axis

- i: Enable both X and Y  
 Ste to drive levels recorded at (c:) and (g:) above.
- Place a detector at XY first order beam position e.g. -1,-1



j: Check orientation of the ½ wave plate.  
Loosen the lock or clamp screw and carefully rotate the ½ waveplate ring for maximum efficiency.

k: Check Bragg alignment by carefully making minor adjustments to X or Y axis Bragg angle adjusters.

The efficiency at Bragg should be the product of the X axis and Y-axis measured values.  
e.g. 85% x 87% = 74%

Typically, the efficiency at or near the centre frequency of the AO devices is the highest value.  
Therefore, the target level for LUT calibration (DCAL) cannot exceed this value.

Decide on an efficiency target level for calibration.  
This level should be ~10% below the peak efficiency recorded at (k:) above.

e.g. 62% for the combined X-Y

### Determine rev-C (independent) LUTs

#### Multiple LUT files

IMS4- revC allows the user to create independent *Compensation Functions* ideally suited for optimizing X-Y AO deflectors. One function would apply to the X-axis and the other function to the Y-axis.  
Each axis calibration follows the procedure in Para. 5 Step 4, with appropriate Channel selection.

Firstly, generate two Compensation Functions , one for each axis.

See **Step4:**. Repeat **AOD Device Chooser** and rename one or both functions.  
In the screen shots below, *X-Axis Compensation Fn* and *Y-Axis Compensation Fn*.

Each channel has a specific LUT file. When a single IMS4 is used to drive a dual axis AOD, these are typically paired as follows:

X-axis Compensation Function downloaded into Ch1-LUT and Ch2-LUT  
Y-axis Compensation Function downloaded into Ch3-LUT and Ch4-LUT

#### X-axis

**X-axis Compensation Function Data:**

Compensation Freq...	Amplitude (%)	Phase (deg)
55.0000	69.6326	
1 80.0000	50.0000	
2 83.0000	50.0000	
3 86.0000	80.0000	
4 89.0000	68.2390	
5 92.0000	78.7000	
6 95.0000	79.0000	
7 98.0000	71.8000	
8 101.0000	71.5000	
9 104.0000	73.4000	
10 107.0000	70.2000	
11 110.0000	70.1000	
12 113.0000	75.6000	
13 116.0000	76.8000	
14 119.0000	75.6000	
15 122.0000	77.0000	
16 125.0000	90.0000	
17 128.0000	95.0000	
18 131.0000	99.0000	
19 134.0000	100.0000	
20 137.0000	100.0000	
21 140.0000	50.0000	
22 220.0000	0.0000	

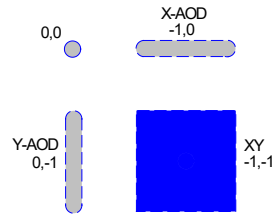
**Y-axis Compensation Function Data:**

Compensation Freq...	Amplitude (%)	Phase (deg)
55.0000	0.0000	46.3934
1 80.0000	50.0000	46.3934
2 83.0000	50.0000	43.3199
3 86.0000	50.0000	39.8984
4 89.0000	50.0000	36.1289
5 92.0000	50.0000	32.0115
6 95.0000	50.0000	27.5461
7 98.0000	50.0000	22.7328
8 101.0000	50.0000	17.5715
9 104.0000	50.0000	12.0623
10 107.0000	50.0000	6.2051
11 110.0000	50.0000	0.0000
12 113.0000	50.0000	-6.5531
13 116.0000	50.0000	-13.4541
14 119.0000	50.0000	-20.7031
15 122.0000	50.0000	-28.3000
16 125.0000	50.0000	-36.2449
17 128.0000	50.0000	-44.5377
18 131.0000	50.0000	-53.1785
19 134.0000	50.0000	-62.1672
20 137.0000	50.0000	-71.5039
21 140.0000	50.0000	-81.1885
22 220.0000	0.0000	-81.1885



Two methods to determine the X and Y axis LUT files:

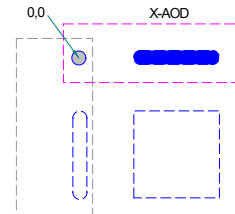
For the following explanation, we will use the -1, -1 first order scan orientation illustrated right.



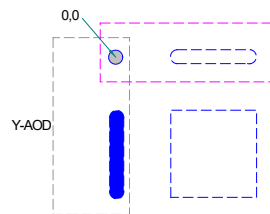
**Method #1: Orthogonal AOD OFF**

Driving one AOD at a time

**Calibrating X-axis LUT, Y-axis OFF.**  
 Detector needs to be located under the (-1,0) X-axis sweep position



**X-axis OFF, Calibrating Y-axis LUT.**  
 Detector needs to be located under the (0, -1) Y-axis sweep position

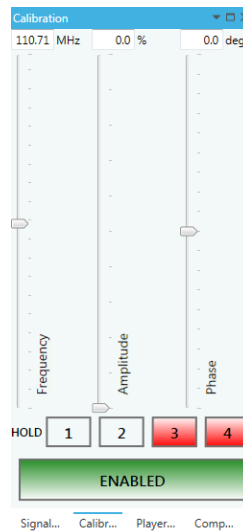


In Method #1, the pair of channels not being calibrated are both set to 0 power. The diffraction efficiency of the AOD axis being calibrated is unaffected by the orthogonal axis, which is OFF.

To disable the Y-axis:

Reduce calibration **Amplitude** slider to 0% then hit the **HOLD** buttons on Ch3 and Ch4 (=red) Ch3 and Ch4 output are now fixed at 0%

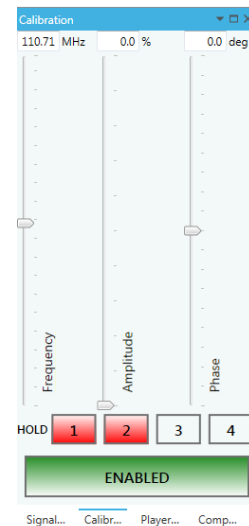
Ch1 and Ch2 adjustable.



In a similar fashion, to disable the X-axis:

Reduce calibration **Amplitude** slider to 0% then hit the **HOLD** buttons on Ch1 and Ch2 (=red) Ch1 and Ch2 output are now fixed at 0%

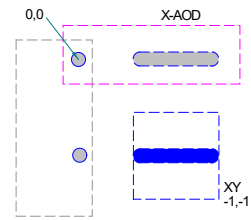
Ch3 and Ch4 adjustable.



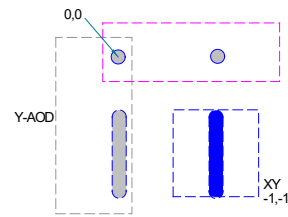
**Method #2: Orthogonal AOD driven at fixed frequency**

This method allows calibration measurement to be made in the X-Y field. Detector position is set to capture the beam in the -1, -1 field and thus good for the calibration of both axis.

**Calibrating X-axis LUT, Y-axis driven at fc**



**X-axis driven at fc, Calibrating Y-axis LUT.**



In this method #2, the channel pair NOT being calibrated are set at a fixed frequency. The diffraction efficiency of the AOD axis being calibrated is scaled by the (fixed) efficiency of the orthogonal axis driven at constant FAP. The fixed frequency is usually set at the centre point = Bragg angle setting frequency,  $f_c$ .

e.g. For X-axis LUT calibration

Set the Y-axis to a fixed frequency  $f_c$  (110MHz).

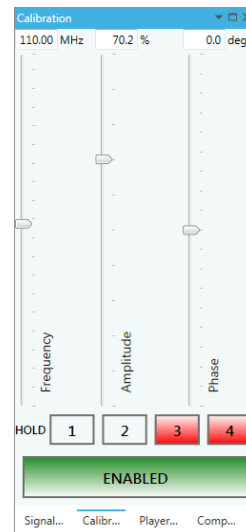
Set the calibration Amplitude slider to achieve peak DE-Y as determined at Y-axis Bragg Angle adjust. (see Para.9.g:)

..... then .....

hit the **HOLD** buttons on Ch3 and Ch4 (=red)

Ch3 and Ch4 output are now fixed for peak Y-axis DE-Y

Ch1 and Ch2 adjustable.



In a similar fashion, for Y-axis LUT calibration

Set the X-axis to a fixed frequency  $f_c$  (110MHz)

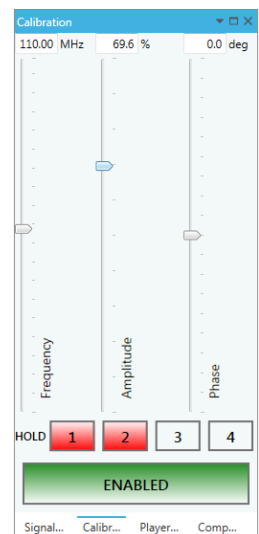
Set the calibration Amplitude slider to achieve peak DE-X as determined at X-axis Bragg Angle adjust. (see Para.9.c:)

....then....

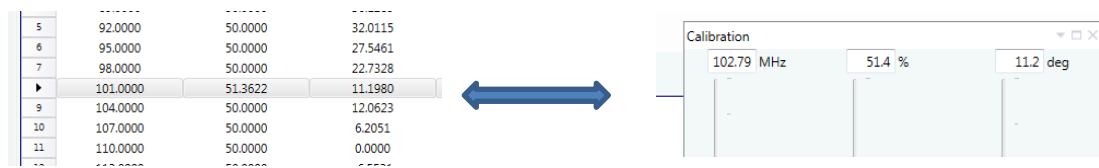
hit the **HOLD** buttons on Ch1 and Ch2 (=red)

Ch1 and Ch2 output are now fixed for peak X-axis DE-Y

Ch3 and Ch4 adjustable.



### Completing the Compensation LUT



For each axis Compensation Function, the basic procedure for the determining the LUT value is the same regardless of the method chosen for measuring the diffracted laser power.

Follow the procedure described for a single axis AOD in Para. 5 and follow Step 5 and Step 6 only. Select the appropriate X-Axis or Y-Axis Compensation Function.

HOWEVER setting of the DCAL calibration level does depend on the measurement method. .

#### DCAL - Method #1

Decide on an efficiency target level for X-Axis calibration, DCAL-X  
This level should be ~10% below the peak efficiency recorded at Para.9(c).

e.g.  $DCAL-X = (DE-X) 88\% - 10\% = 78\%$

Decide on an efficiency target level for Y-Axis calibration, DCAL-Y  
This level should be ~10% below the peak efficiency recorded at Para. 9(g).

e.g.  $DCAL-Y = (DE-Y) 87\% - 10\% = 77\%$

#### DCAL - Method #2

Decide on an efficiency target level for X-Axis calibration, DCAL-X  
This level should be ~10% below the peak efficiency recorded Para.9(c), MULTIPLIED by peak efficiency recorded at Para. 9(g).

e.g.  $DCAL-X = [(DE-X) 88\% \times (DE-Y) 87\%] - 10\% = 66\%$

Decide on an efficiency target level for Y-Axis calibration, DCAL-Y  
This level should be ~10% below the peak efficiency recorded at Para. 9(g), MULTIPLIED by peak efficiency recorded at Para.9(c).

e.g.  $DCAL-Y = [(DE-X) 88\% \times (DE-Y) 87\%] - 10\% = 66\%$

### 9. iMS4 rev-C Generating the LUT file

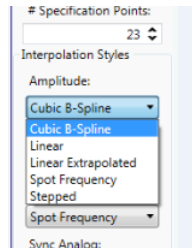
Once the compensation table is finalized, the LUT file is generated for the intermediate frequencies using the in-built interpolation function.

To view the optimized values.  
Select the appropriate X-Axis or Y-Axis Compensation Function.

Select the **Compensation** tab to view the interpolated values

Recommended **Interpolation Styles**.

Amplitude: Cubic-B Spline  
Phase: Linear Extrapolated



With a dual axis AOD connected to the iMS4, uncheck **Global button**   
The **Select Channel** box will become active. Use the up-down arrows to select the channel.

Check the X/Y AOD > **Sync Phase Pairs**

**X-Axis**

Locate the **Generate Table** panel; Compensation Worksheet, right hand side tool bar.

In most cases, use **Replace Data** i.e. make a new file.

For illustration, Amplitude plots are shown below.

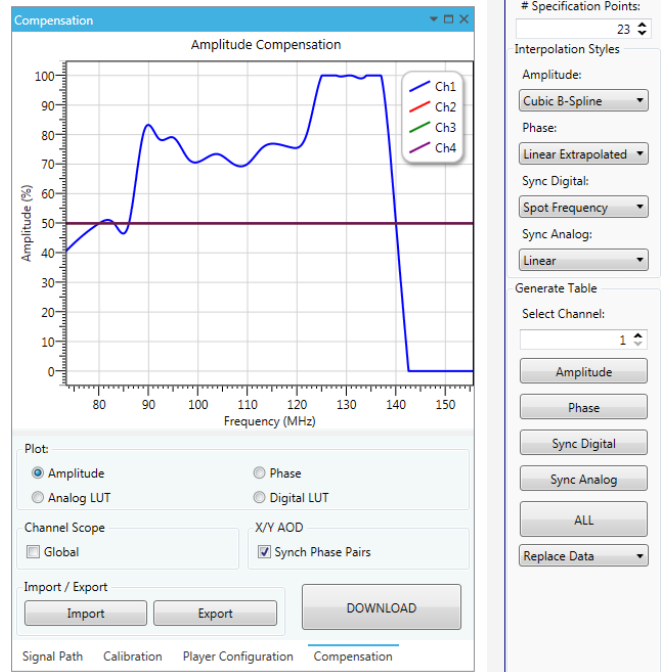
Select the **X-Axis Compensation Function**.

	X-Axis Compensation Fn	Y-Axis Compensation Fn
	Compensation freq...	Amplitude (%)
0	55.0000	69.6326
1	80.0000	50.0000
2	83.0000	50.0000
3	86.0000	80.0000
4	89.0000	68.2390
5	92.0000	78.7000

Set **Select Channel** to **1** then hit **ALL** to generate a Ch1 LUT file.

Channel 1 = Blue trace  
all other channels are 50% amplitude at this point

... then ...

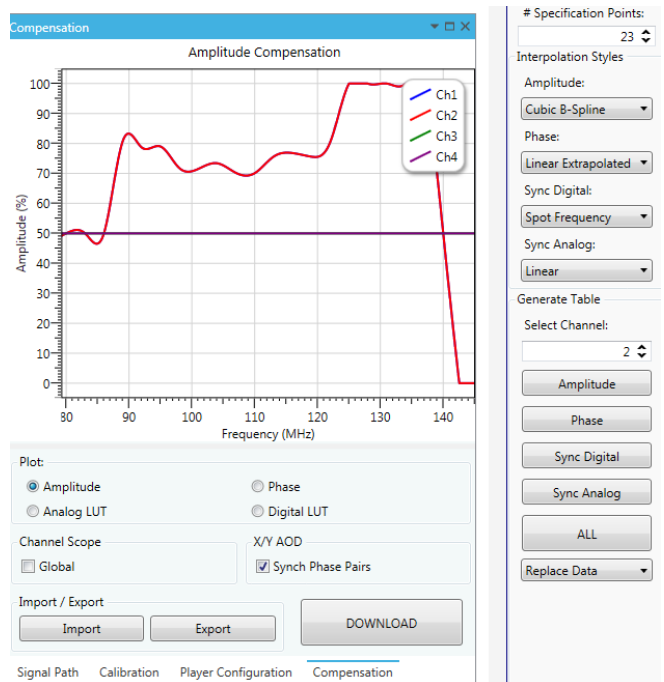


Set **Select Channel** to **2** then hit **ALL** to generate a Ch2 LUT file.

The same data is now applied to both Ch1 and Ch2 for the X-axis

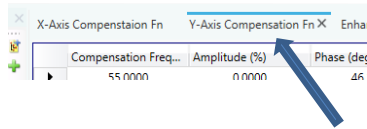
Channel 2 = Red trace  
This is overlaid onto channel 1 blue trace  
Ch1 and Ch2 are the same data.

All other channels are 50% amplitude at this point



**Y-Axis**

Select the **Y-Axis Compensation Function**.



Set **Select Channel** to 3 then hit **ALL** to generate a Ch3 LUT file.

Y-axis has a different amplitude calibration (exaggerated for clarity)

Channel 3 = Green trace

Ch4 channel is 50% amplitude at this point

Ch1 and Ch2 show X-Axis LUT data

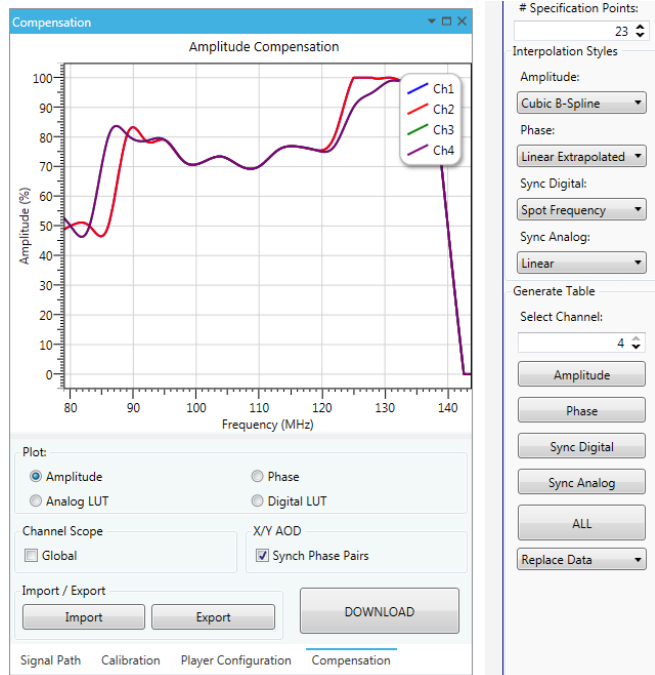
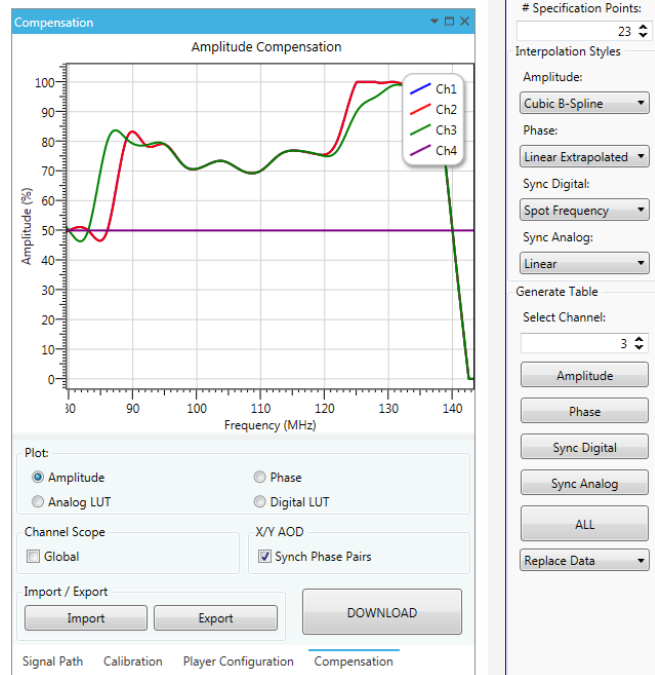
... then ...

Set **Select Channel** to 4 then hit **ALL** to generate a full Ch4 file.

The same data is now applied to both Ch3 and Ch4 for the X-axis

Channel 4 = Purple trace  
This is overlaid onto channel 3 green trace  
Ch3 and Ch4 are the same data.

Ch1 and Ch2 show X-Axis LUT data



**Download LUT Files**

Check the X/Y AOD > **Sync Phase Pairs**

Follow Para.5 ,Step 9