AX Image Calibration and Tuning Guide

Version: V1.1

Release Date: 2024/01/26

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Contents

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Introduction

Applied for

AX620E series (AX630C and AX620Q)

Intended Readers

- End users
- Pre-sales engineers
- Post-sales engineers
- Developers

Description of Symbols and Formats

Symbol/Format	Description
`xx`	Stands for command lines that you can execute.
☞ **Notes:**	Provides additional information to emphasize or supplement important points of the main text.
! Notes:	Provides additional information that needs to pay attention to.

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Revision History

Version	Release Date	Description
V1.0	09/04/2023	Initial release.
V1.1	01/26/2024	Added the description of the supplemented part.

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1 Tool Overview

1.1 Introduction

- Tool version: ISPTuning_V1.23.53.1
- Offline Calibration Mode: Mainly generates basic calibration parameters by importing raw images of objective scenes and confirming their objective effects.
- Online Debugging Mode: Online debugging and parameter saving, confirming subjective effects through preview and snapshot.
- Common Auxiliary Tools: Basic image viewing combined with testing functionality to help analyze images.

1.2 Environment Preparation

1.2.1 Hardware Preparation

- Hardware: A standard PC is sufficient.
- Software: Windows 10 operating system.

1.2.2 Installing and Running Software

1. Install MCRInstaller.exe.

1) Recommended link for downloading the installation program:

https://www.mathworks.com/products/compiler/matlab-runtime.html

2) Version: R2013a（8.1）64bit。

2. Run ISPTuning.exe.

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1.3 Interface of Tool

1.3.1 Interface of Tool

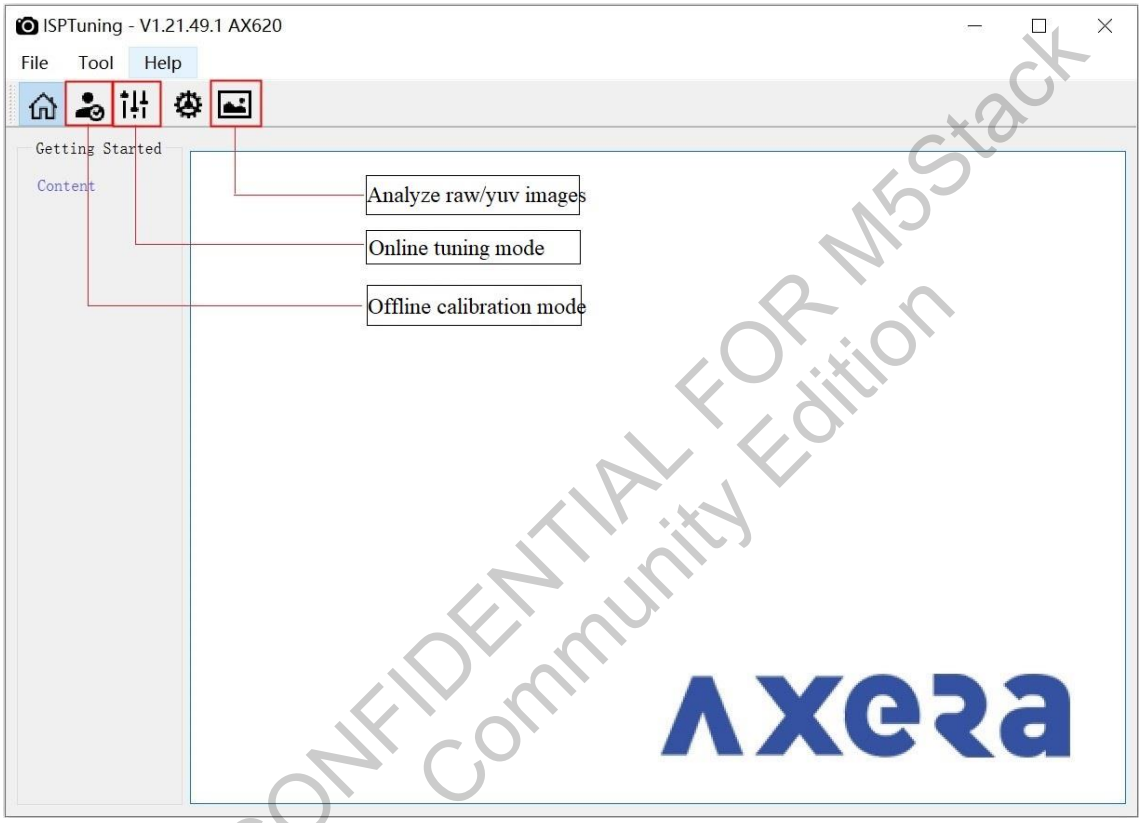

Figure 1-1 Interface of Tool

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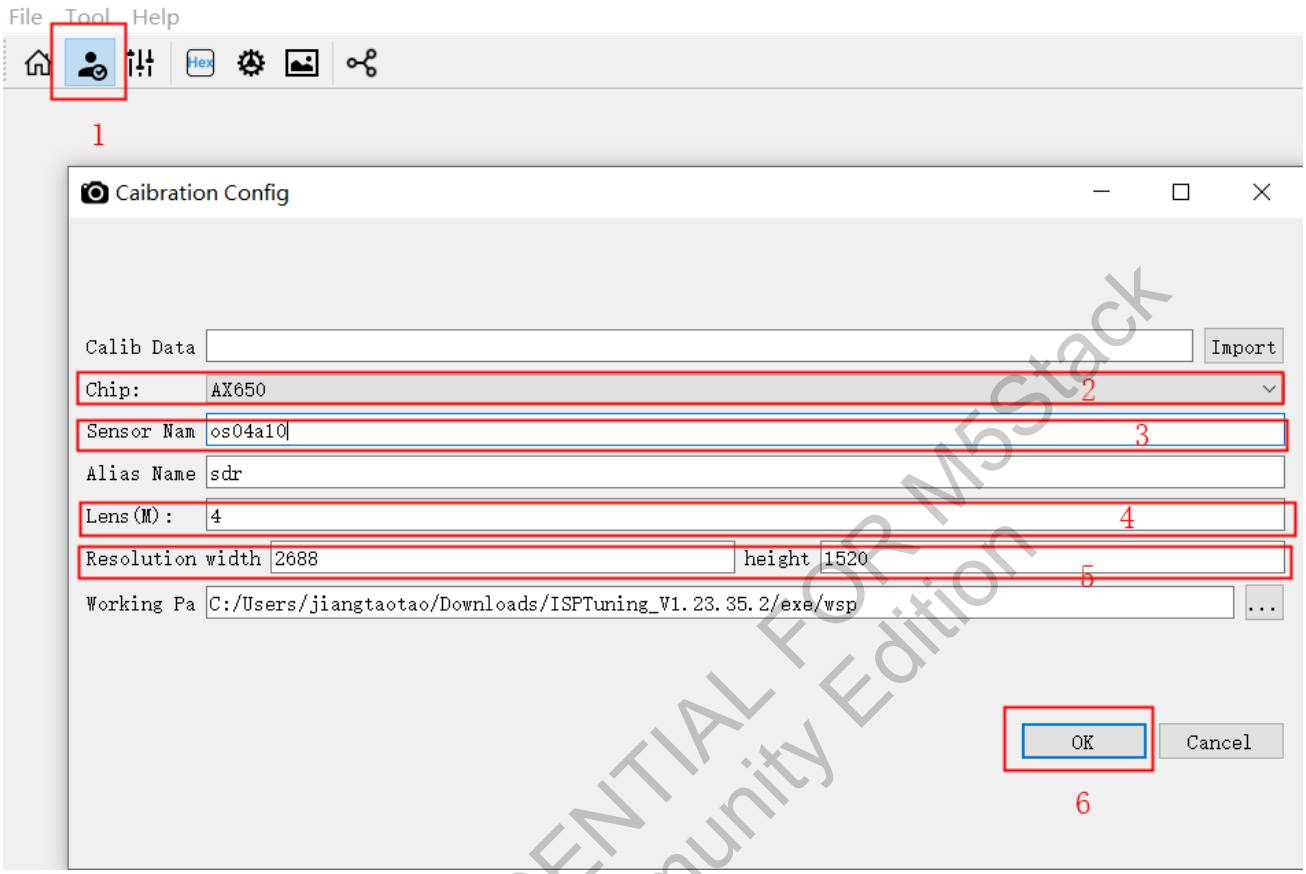

Figure 1-2 Creating a New Project

1.3.2 Interface Description

- New Project: Create new project engineering effect parameters.
- Offline Calibration Mode: Offline calibration.
- Online Tuning Mode: Online IQ Tuning.
- Auxiliary Testing Tools: Parsing raw/yuv format images.

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1.4 Debugging Flowchart

1.4.1 Debugging Flowchart

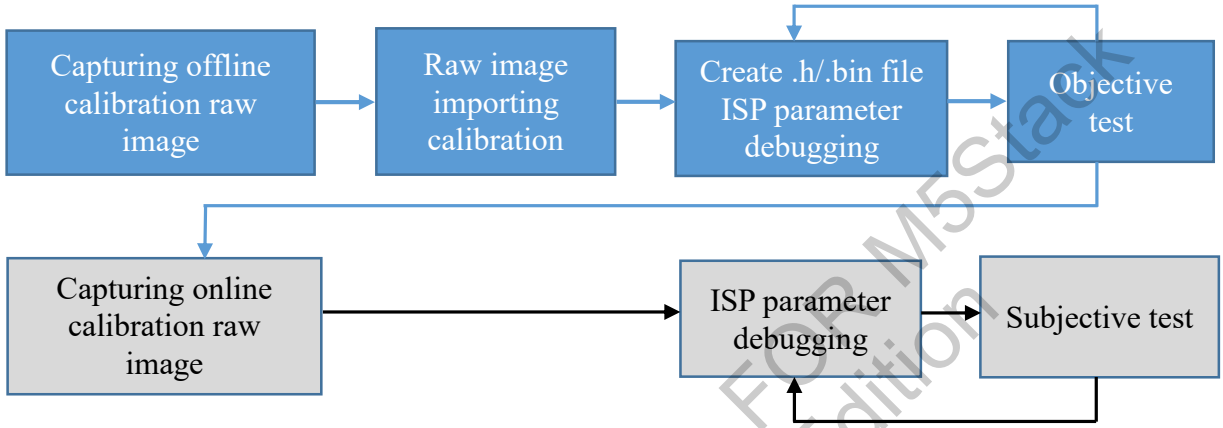

Figure 1-3 Debugging Flowchart

1.4.2 Flowchart

1. Capture raw images under different color temperatures.
2. Import the corresponding raw images into offline calibration tools for debugging.
3. Generate H parameter files and import them into online Tuning Tools for objective testing.
4. Based on the test results, recapture raw images to optimize parameters.
5. Conduct repeated subjective tests.

1.5 Debugging Environment

- Environment: Darkroom.
- Hardware:
  - QC light box (H/A/CWF/TL84/D50/D65/D75)

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- DNP light box
- Diffuser
- Color temperature illuminance meter
- PC

- Graphic Cards:
  - Color chart
  - White/Gray chart
  - Noise chart
  - Dot/Chessboard chart
  - ISO12232
- Tools: ISP tuning tools
- Display: Recommended resolution FHD or above, standard colors (e.g., NEC-2K resolution, or Apple Notebook)

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Figure 1-4 Graphic Cards

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2 Offline calibration mode

2.1 Debugging Calibration Process

2.1.1 Preview Camera Setting

Refer to *AX Image Online Tuning Guide*.

2.1.2 Offline Calibration Process

Step 1: Open ISPtuning.exe file, start “offline Tuning”.

Step 2: Debug the Pipeline process: DPC → BLC → LSC → AWB → AF → CAC → CCM → H.

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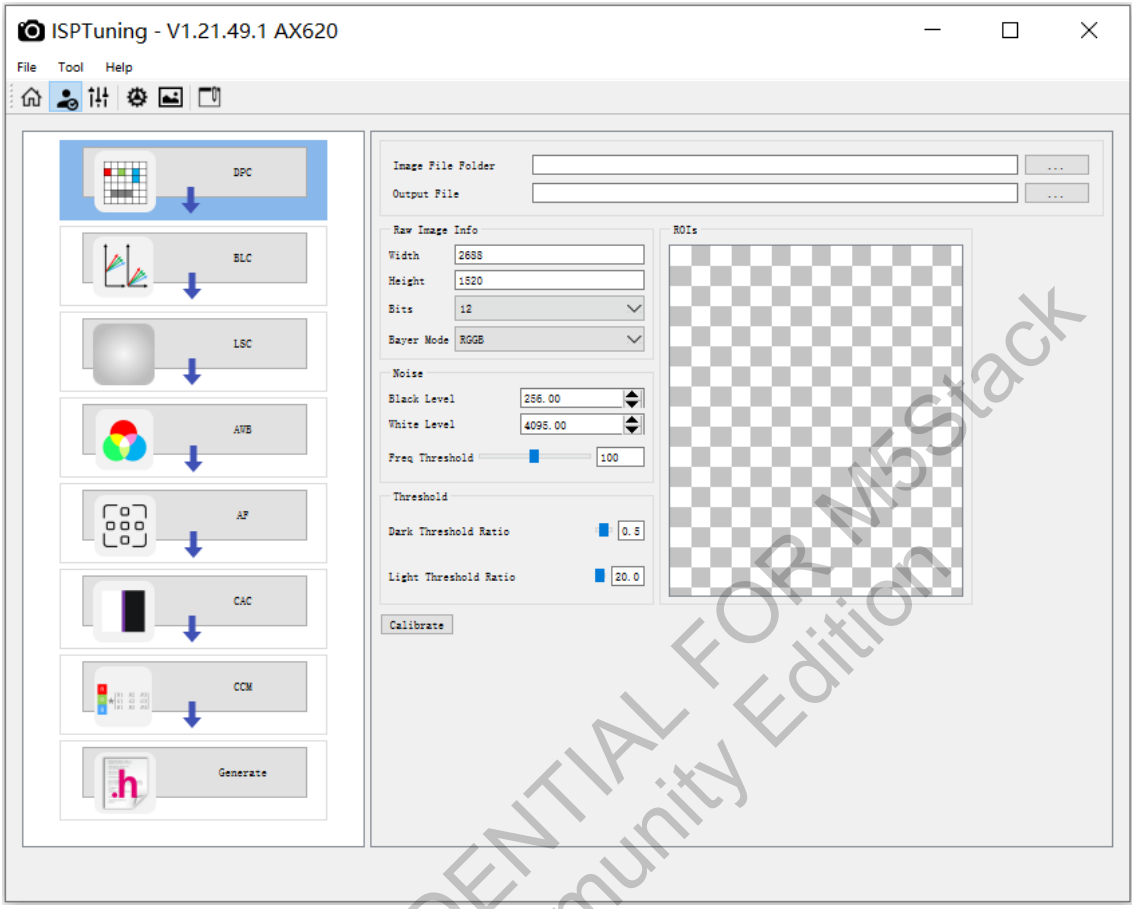

Figure 2-1 Tuning Process

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3 Calibration of Various Modules

3.1 BLC Module Calibration and Debugging

3.1.1 BLC Raw Image Capture

- Environment: Darkroom.
- Hardware: Black mirror cover, opaque black cloth, dark box.

Figure 3-1 BLC

- Raw Photos: Non-sequential raw.

1. Set AGain from 1x to maximum, step by 1x.
2. Set shutter from 1ms, 5ms, 10ms to maximum, step by 10ms.
3. Capture 10 Raw images per group, all placed in the same path.

☞ **Notes**

If there are HCG/LCG, they need to be photographed separately in both modes.

Example:

- Photo file naming 0_dark_LCG_exp_1.0_again_1.0_000:

  Represents LCG mode, Gain=1X, shutter=1ms, the 1st photo.

- Photo file naming dark_HCG_exp_30.0_again_43.0_009:

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Represents HCG mode, Gain=43X, shutter=30ms, the 10th photo.

Gain=1X, shutter=1ms, 5ms, 10ms, 20ms… max

Gain=2X, shutter=1ms, 5ms, 10ms, 20ms… max

……

Gain=15X, shutter=1ms, 5ms, 10ms, 20ms… max

Gain=43X, shutter=1ms, 5ms, 10ms, 20ms… max

☞ Notes

If there is no distinction between HCG/LCG modes or only LCG mode is available, all should be named as 0_dark_LCG_exp_x_again_x_xxx.raw.

3.1.2 BLC Calibration

Steps

1. Open ISP tuning tools, and select BLC tuning module.
2. Select BLC image path (Output File path defaults to the same as the image path).
3. Set Raw Image Info: Width, Height, Bit; if sensor spec provides BLC, it can be ticked and filled in, otherwise it can be left unticked.
4. Set Dark Shading parameters:
    A. With SBL: Indicates that the Raw image has been subtracted from the dark current, recommended not to tick.
    B. Kernel Size: Statistical intensity of denoising before horizontal texture Shading.
    C. Mesh Table H: Horizontal nodes number for Dark Shading, recommended to use

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24.

D. Mesh Table V: Vertical nodes number for Dark Shading, recommended to use 24.

5. BLC enters the calculation process and generates a blc.json file in the Output File path.

Tools

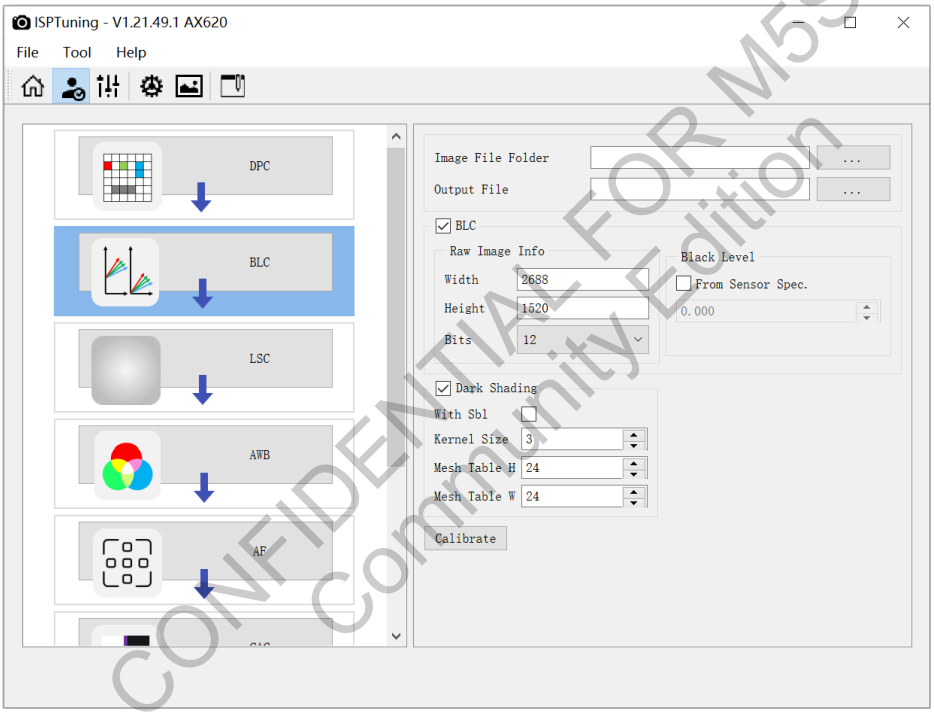

Figure 3-2 BLC Interface

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3.2 DPC Calibration and Debugging

3.2.1 DPC Raw Image Capture

Figure 3-3 DPC

Figure 3-4 Graphic Cards:

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- DPC All-black Image (not supported in all bright environment)
  - Environment 1: Darkroom.
  - Hardware1: Black mirror cover, opaque black cloth, and dark box.
  - Raw Photos: Non-sequential raw.

1. Set Gain from 1x to maximum, step by 1x.
2. Set shutter from 1ms, 5ms, 10ms to maximum, step by 10ms.
3. Capture 10 Raw images per group, all placed in the same path.

Notes

If there are HCG/LCG, they need to be photographed separately in both modes.

- Example:

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- Photo file naming dark_LCG_exp_1_again_1.0_000:

  Represents LCG mode, Gain=1X, shutter=1ms, the 1st photo.

- Photo file naming dark_HCG_exp_30_again_43.0_009:

  Represents HCG mode, Gain=43X, shutter=30ms, the 10th photo.

  Gain=1X, shutter=1ms, 5ms, 10ms, 20ms… max

  Gain=2X, shutter=1ms, 5ms, 10ms, 20ms… max

  ……

  Gain=15X, shutter=1ms, 5ms, 10ms, 20ms… max

  Gain=43X, shutter=1ms, 5ms, 10ms, 20ms… max

☞ Notes

If there is no distinction between HCG/LCG modes or only LCG mode is available, all should be named as 0_dark_LCG_exp_x_again_x_xxx.raw.

➢ Noise Profile

- Environment 2: TL84 light source
- Hardware 1: Bidirectional grayscale card or light box walls (with a gray background having light and dark differences)
- Raw Photos:

1. Set Gain from 1x to maximum; from 1x to 8x, increase by doubling; from 8x to 32x, step by 4x; from 32x to 64x, step by 8x.
2. Set the shutter fixed at 20ms, ensuring the brightest part of the image is at 80% of maximum brightness. If this is not achievable, increase ND filter use or decrease the light box brightness (not below 100 lux). It is recommended to use a high brightness ND filter in the light box.
3. Capture 32 raw images per group.

☞ **Notes**

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Keep the AF in a defocused state. If HCG/LCG modes are available, they should be photographed separately under both modes.

- Example:
  - Photo file naming noise_LCG_exp_1_again_1.0_000:

    Represents LCG mode, Gain=1X, shutter=1ms, the 1st photo.
  - Photo file naming noise_HCG_exp_30_again_43.0_031:

    Represents HCG mode, Gain=43X, shutter=30ms, the 32nd photo.

    Gain=1X, shutter=1ms, 5ms, 10ms, 20ms… max

    Gain=2X, shutter=1ms, 5ms, 10ms, 20ms… max

    ……

    Gain=15X, shutter=1ms, 5ms, 10ms, 20ms… max

    Gain=43X, shutter=1ms, 5ms, 10ms, 20ms… max

☞ Notes

If there is no distinction between HCG/LCG modes or only LCG mode is available, all should be named as 0_noise_LCG_exp_x_again_x_xxx.raw.

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3.2.2 DPC Calibration

Steps

1. Open ISP tuning tools, and select DPC tuning module.
2. Set Raw Image Info: Width, Height, Bit, and Bayer Mode.
3. Select DPC image path (Output File path defaults to the same as the image path).
4. ROI Noise Profile for a bidirectional grayscale card image, it is necessary to align the upper and lower borders of the card. For a light box wall, the ROI in the image should include areas of light and dark, covering about 70% of the frame.
5. Set Black Level according to the sensor specifications or use the average parameters from the

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blc.json file generated by BLC.

Set White Level to [2 raised to the power of (bit depth) minus 1]. For a 16-bit system, this would be 65535.

Set Frequency Threshold, default is 100 and should not be changed.

6. Set Dark Threshold Ratio and Light Threshold Ratio, with default settings of 0.5 for dark and 20 for light, no changes needed.

7. Click “Calibrate”.

Notes:

The calculation process takes about 5 minutes.

8. DPC enters the calculation process and generates a dpc.json file in the Output File path.

Tools

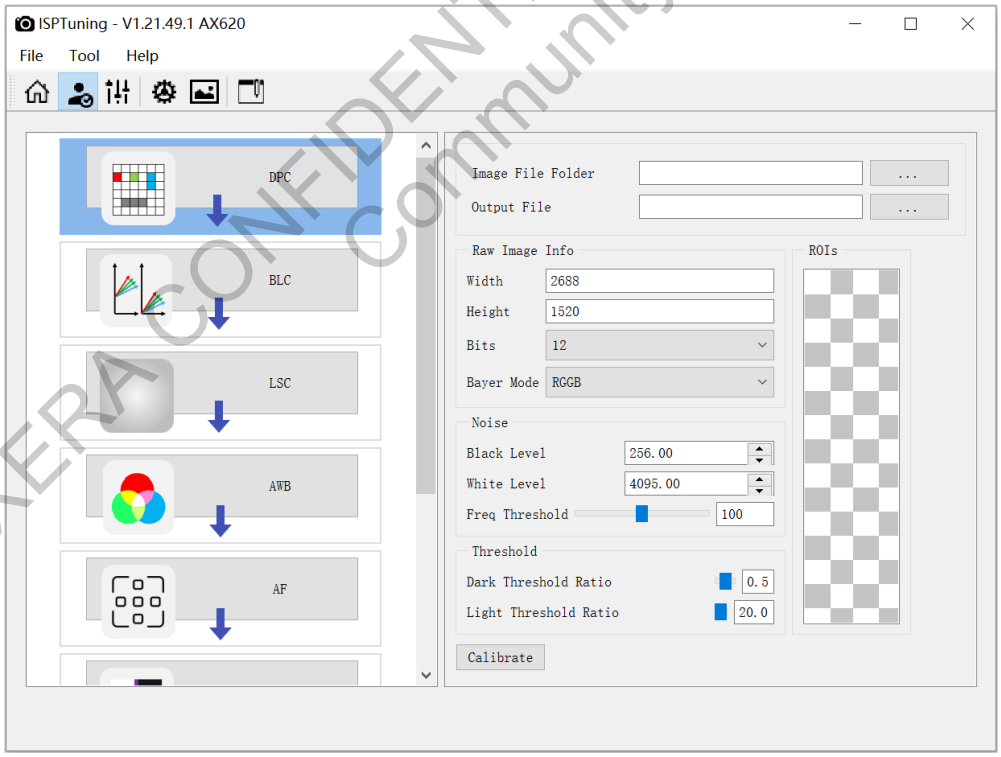

Figure 3-5 DPC Interface

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3.3 LSC Module Calibration and Debugging

3.3.1 LSC Raw Image Capture

Figure 3-6 LSC

- Environment: Light box environment
- Hardware: DNP light box/IQ light box
- Raw Photos:
  - Cover the lens with a uniform glass cover, aim at the IQ light source, and adjust the Integration Time and gain to set the G channel's average value between 10 and 128 (referring to 8 bits) to capture Raw photos.

☞ It is recommended that the central brightness of the G channel be around 128 (referring to 8 bits).

  - Adjust each group of IQ light sources (H/A/TL84/D50/D65), capturing 3 to 5 images per group.
  - Name the images as LSC_illumName_illumCCT.raw

Example: *LSC_H_2300.raw*

LSC_A_2800.raw

LSC_TL84_3800.raw

LSC_D50_5000.raw

LSC_D65_6500.raw

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3.3.2 LSC Calibration

Steps

1. Open ISP tuning tools, and select LSC tuning module.
2. Import the LSC Raw photos, configure the corresponding size, bit depth, and endianness, then click “OK”.
3. Set the BLC values (as determined by the BLC module), ensuring they correspond to the bit width.

! Note: By default, changes will only apply to one raw image. All raw images must be manually set individually.

4. Click “Calibrate” to generate the lsc.json file.

☞ **Notes:**

The maximum compensation multiplier for LSC is 4x.

! Note: The generated lsc.json will be used in subsequent AWB calibration. Therefore, it is best to import all LSC raw images at once to create a json file that includes calibration data for all color temperatures.

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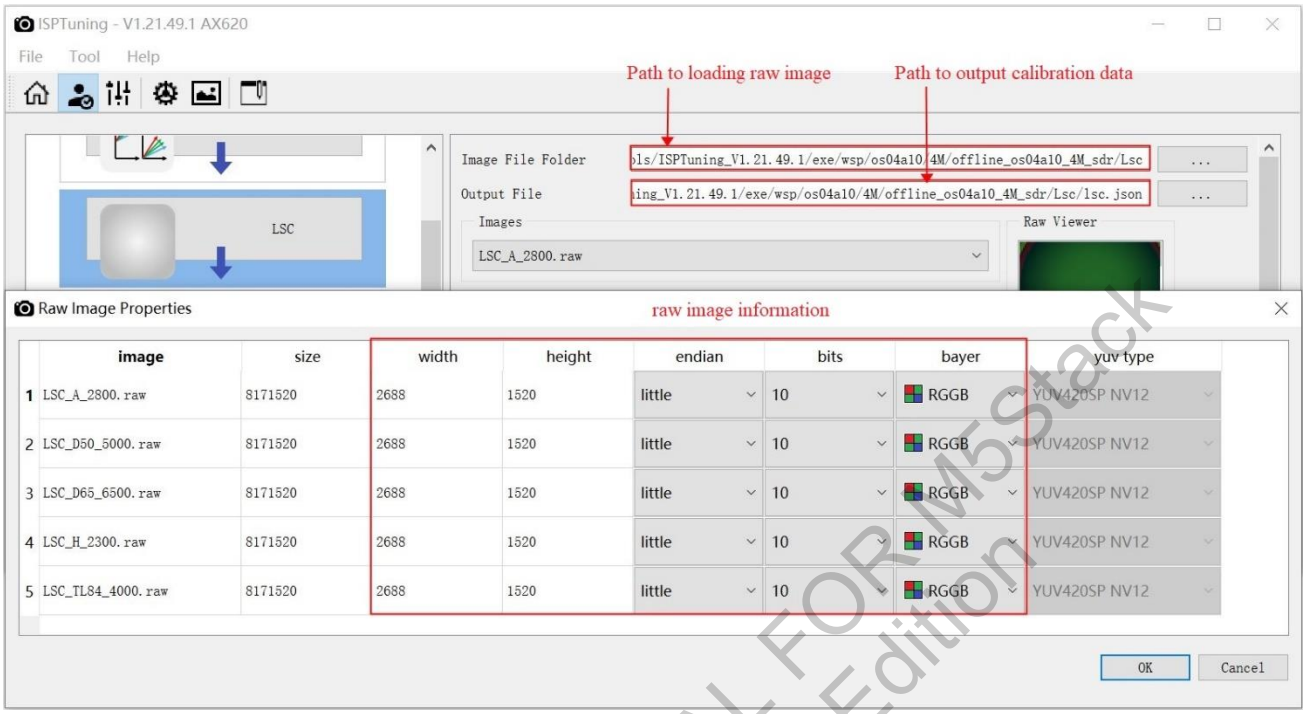

Figure 3-7 LSC Calibration Loading Raw Image

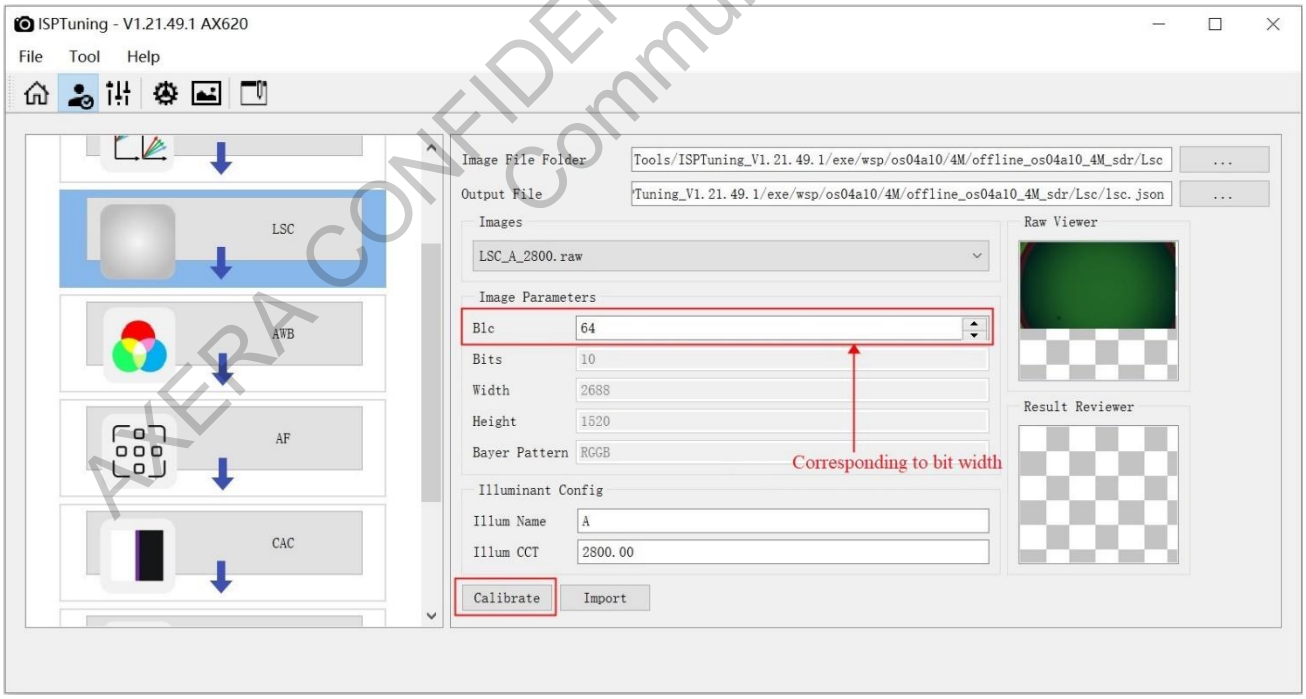

Figure 3-8 LSC Calibration

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Tools

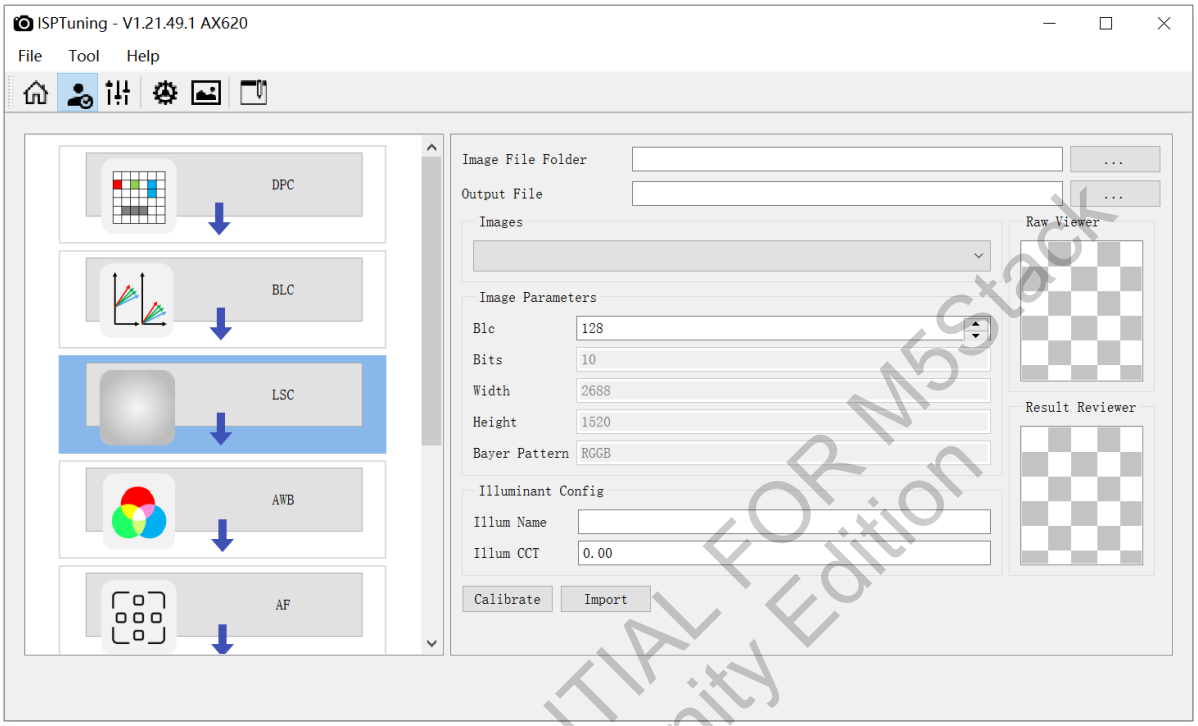

Figure 3-9 LSC Interface

3.4 AWB Module Calibration and Debugging

3.4.1 AWB Raw Image Capture

Figure 3-10 AWB Image Capture

- Environment: Light box environment

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- Hardware: QC light box (H, A, CWF, TL84, D50, D65, D75)
- Graphic Cards: Gray or White card, Color Checker
- P0 node unpacked Raw

Step 1: Select raw preview mode.

Step 2: Place the gray card on the light box wall, covering 100% FOV.

Step 3: Set the appropriate Integration Time & Again to ensure the brightness levels under different color temperatures are between 80 and 150 (8bit).

☞ It is recommended that the central brightness of the G channel be around 128 (referring to 8 bits).

Step 4: Collect gray card Raw images for each light setting (H, A, CWF, TL84, D50, D65, D75).

Step 5: Capture 3~5 raw images per group, select the best state of raw images, and place all under the AWB path.

Example: D:\Tools\ ISPTuning_V1.23.3.1\exe\wsp\os04a10\4M\offline_os04a10_4M_sdr\AWB

Step 7: Name the raw images as AWB_Gray_illumName_illumCCT.raw.

Example: *AWB_Gray_H_2300.raw*

AWB_Gray_A_2800.raw

AWB_Gray_CWF_4100.raw

AWB_Gray_TL84_3800.raw

AWB_Gray_D50_5000.raw

AWB_Gray_D65_6500.raw

AWB_Gray_D75_7500.raw

! Note: illumCCT refers to the actual measured color temperature value.

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3.4.2 AWB Calibration

Steps

1. Open ISP tuning tools, and select AWB module.
2. Select the fitting light source and load the AWB_Gray_illumName_illumCCT.raw images for each color temperature.

! Note: During the raw loading process, rg and bg values are calculated. It is necessary to set the BLC parameters in advance.

3. Copy the lsc.json file generated from the LSC calibration to the path where the AWB images are loaded. *Example:*
   D:\Tools\ ISPTuning_V1.23.3.1 \exe\wsp\os04a10\4M\offline_os04a10_4M_sdr\AWB

   Click LSC to load lsc.json

! Notes:

Ensure that the color temperatures included in the LSC calibration cover those required for AWB calibration. This ensures that the lsc.json file generated from LSC calibration contains the necessary color temperature data for AWB calibration.

You may choose not to perform LSC calibration and use the AWB raw images directly for AWB calibration, but the results may be slightly inferior without the LSC correction. Simply do not load the LSC json file in this case.

4. Add and select an independent light source; here, CWF can be chosen.
5. Fill in the actual measured color temperature values in the CT column.
6. Set “CCT Min”, “CCT Max”, “In Low CCT Cut”, “In High CCT Cut”, “In Left Width”, “In Right Width”, “Out Left Width”, and “Out Right Width” to define the shape of the range. Also adjust “Low Adjust Knee CCT”, “High Adjust Knee CCT”, “Low Adjust Distance”, and “High Adjust Distance” to help shape the high and low color temperature curves.
7. Click “Refresh” to fit and generate the grey area.

! Notes:

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If the selected image is overexposed, or if the fitting shape is unreasonable, a warning box will pop up.

8. Gray Area Shape Modification:

1) You can fine-tune the shape of the “gray area” by dragging points within the image or by holding down the left mouse button to select multiple points for batch dragging.

2) On the left side, the “White Area Adjustment Toolbar” allows you to adjust the width of the white area and the upper and lower color temperature limits of the inner and outer frames (supporting a maximum range of 1200K to 12000K). This facilitates the batch modification of point positions.

3) After modifications are complete, click “Export” to save the awb_calib_params.json file.

9. Click “Export” to generate the calibration file awb_calib_params.json.

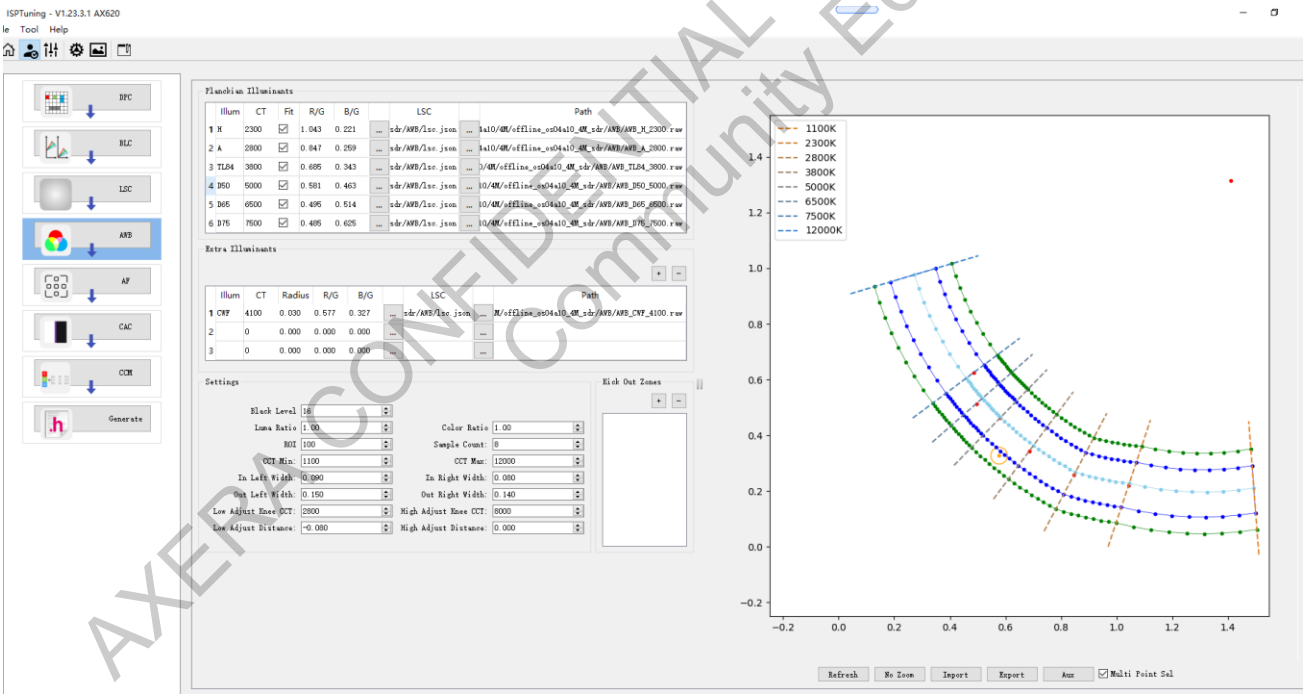

Figure 3-11 Tool entry of Step 1

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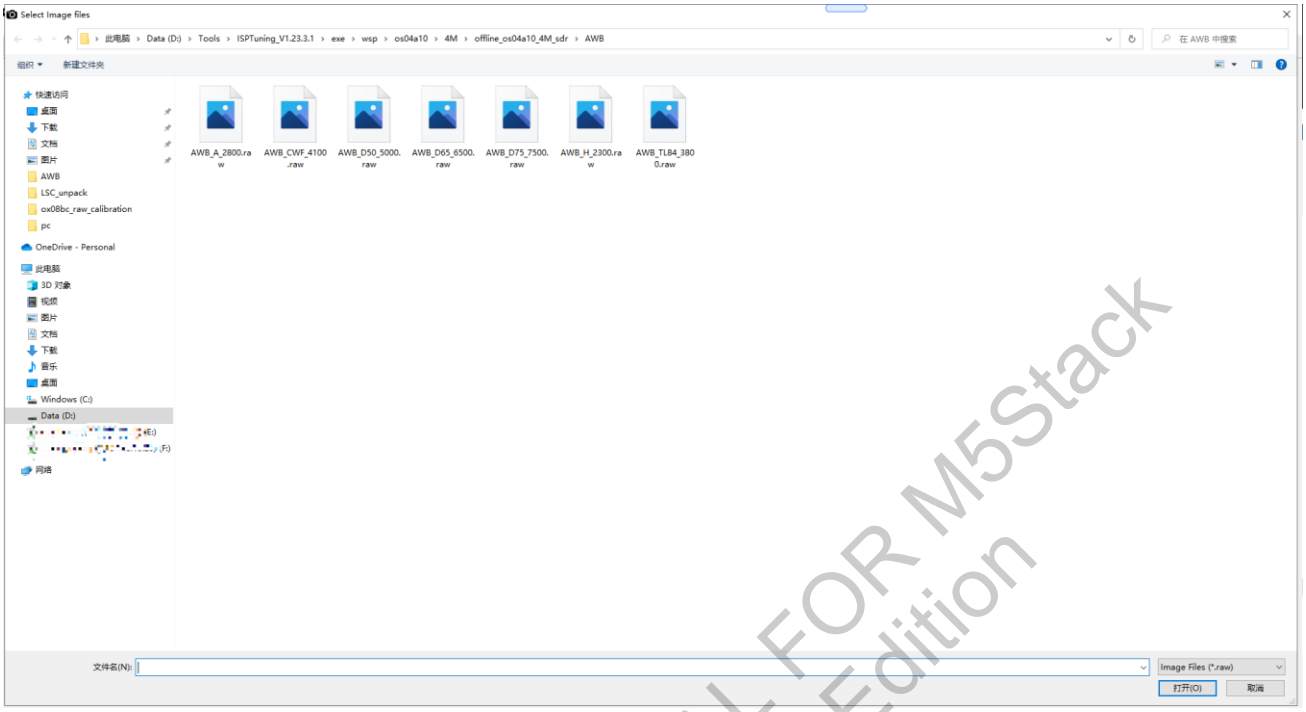

Figure 3-12 Interface of Steps 2 and 4

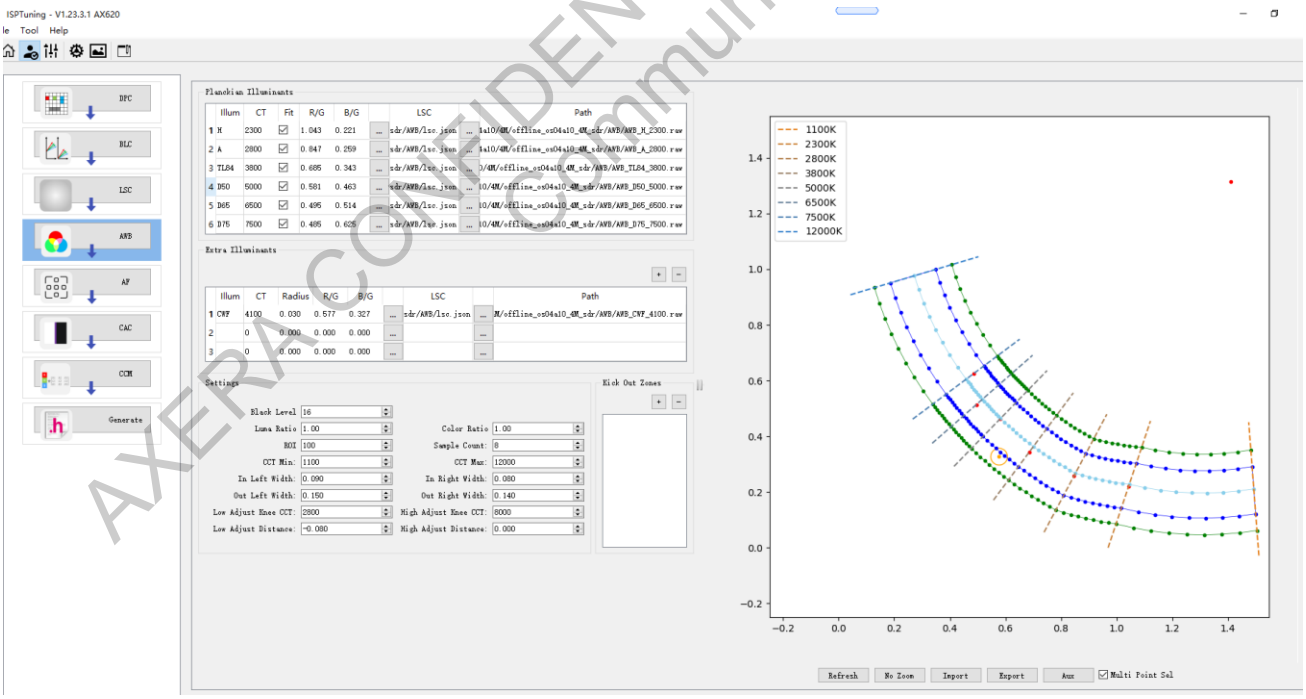

Figure 3-13 Generating the Gray Area

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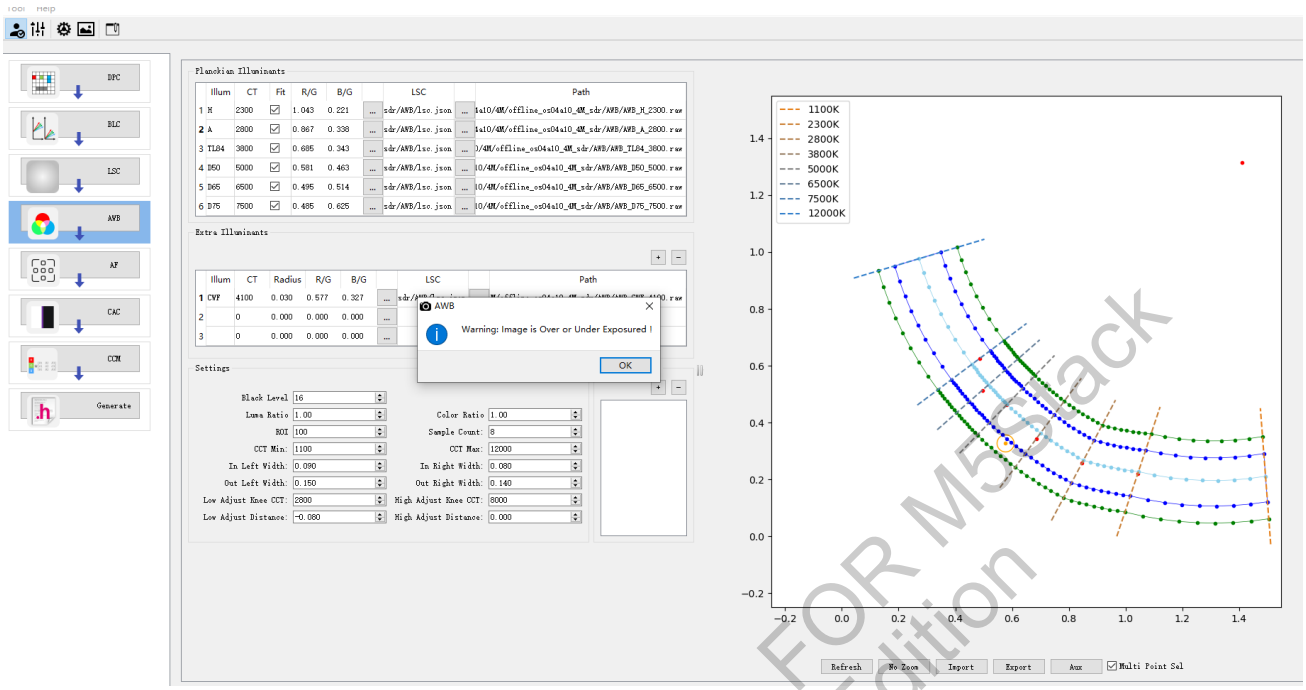

Figure 3-14 Warning

Tools

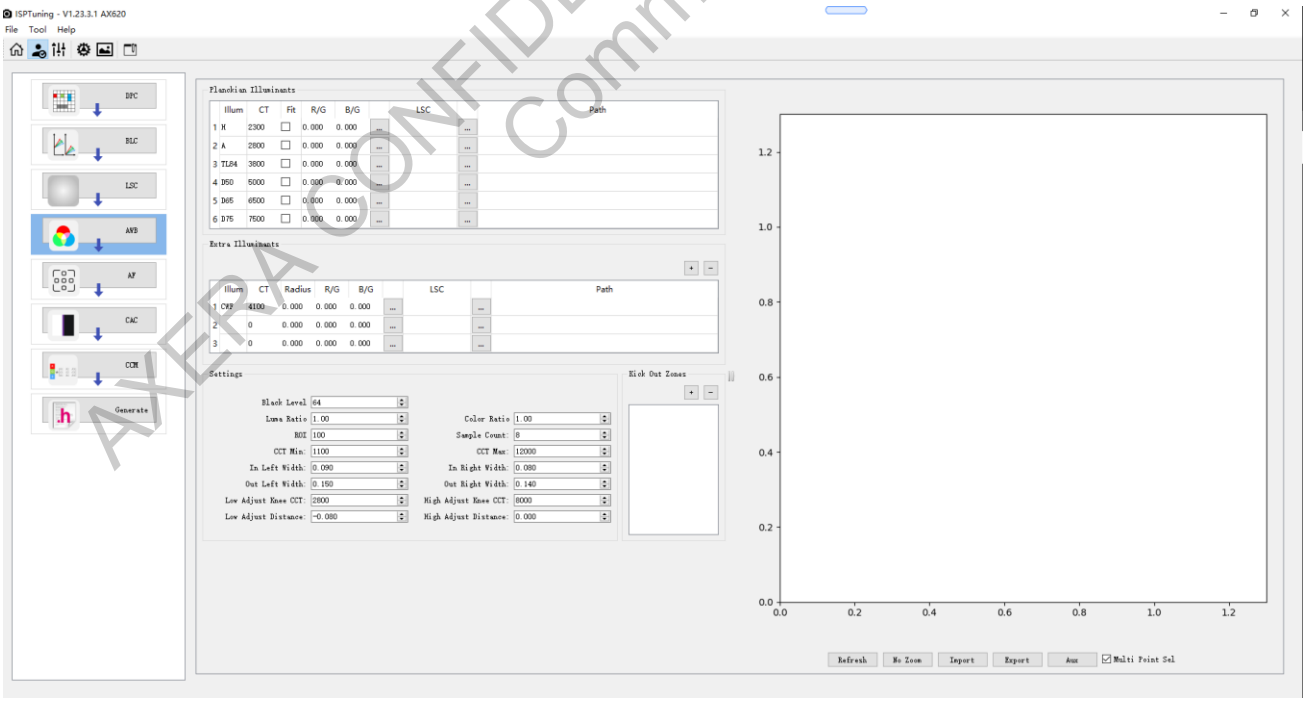

Figure 3-15 AWB Interface

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3.4.3 Tuning Techniques

Exceeding the Calibration Range for Extreme Color Temperatures

For example, if the color temperature is too high and exceeds the maximum range of the white area as shown in the figure below.

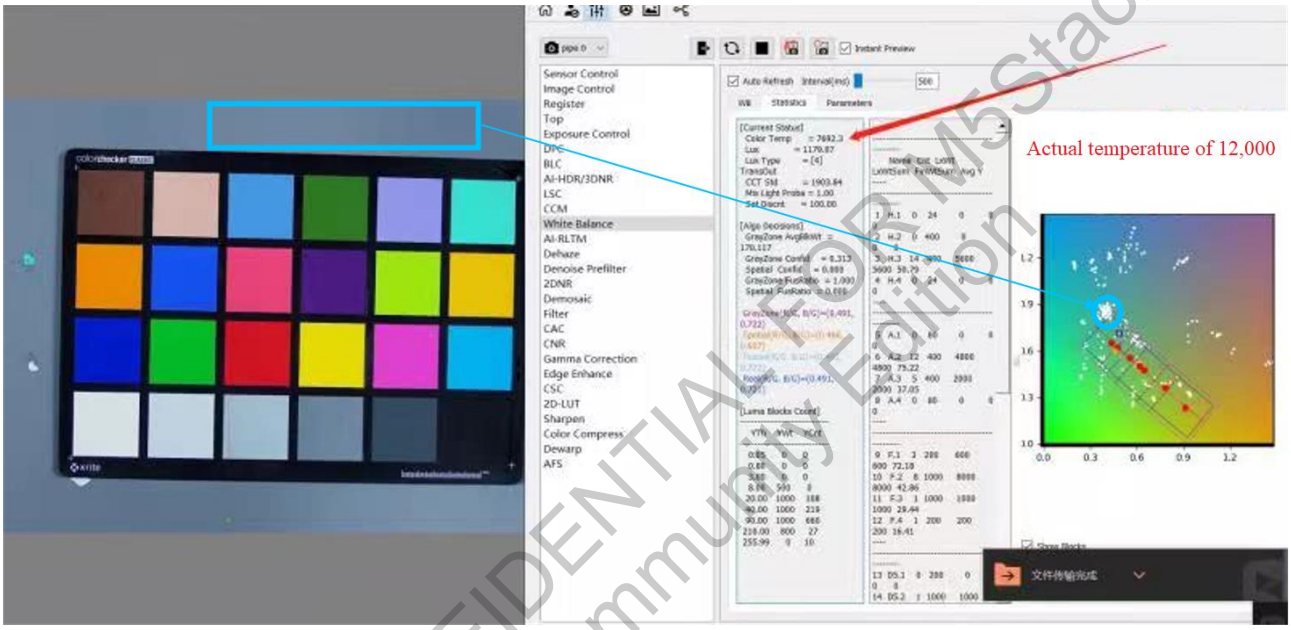

Figure 3-16 Too High Color Temperature

During calibration, adjust the maximum range of the color temperature to cover it. The location for adjustment is indicated in the figure below.

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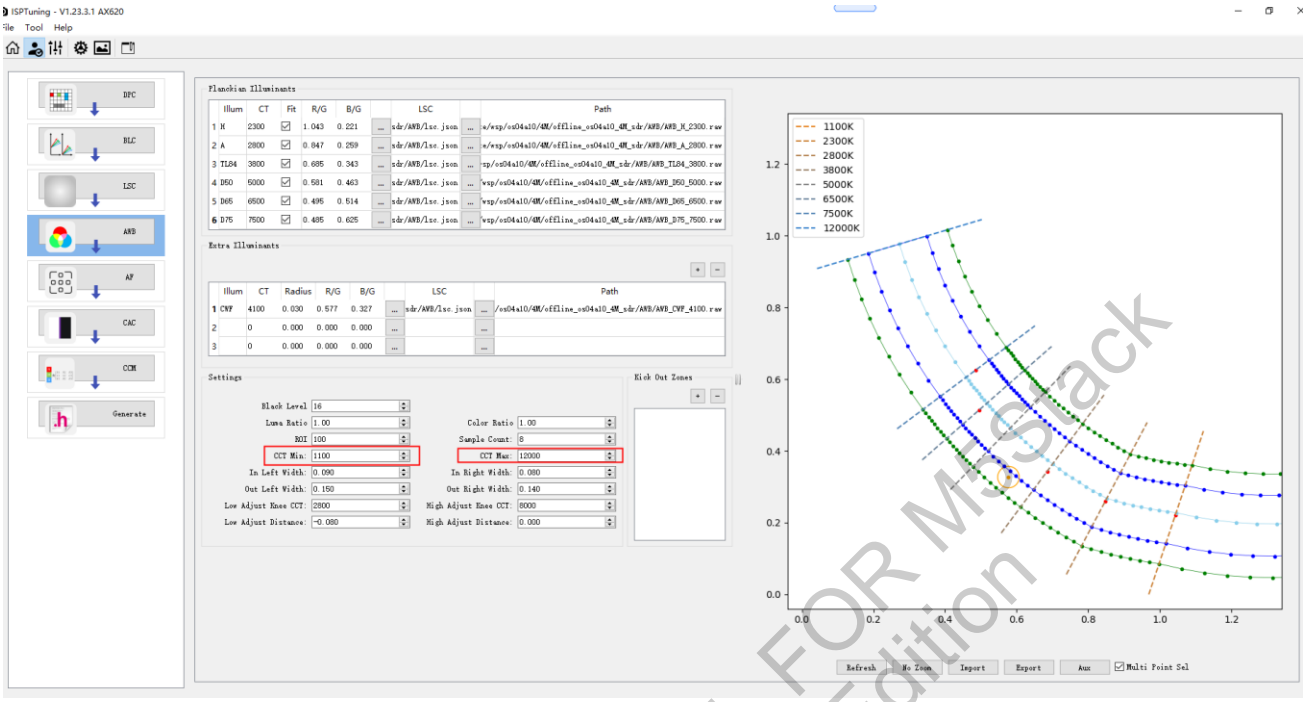

Figure 3-17 Parameters Affecting the Gray Area Coverage:

For excessively high color temperatures, you can adjust the CCT Max to increase the range of high color temperatures in the white area. The figure below shows a significant increase in the high-temperature range.

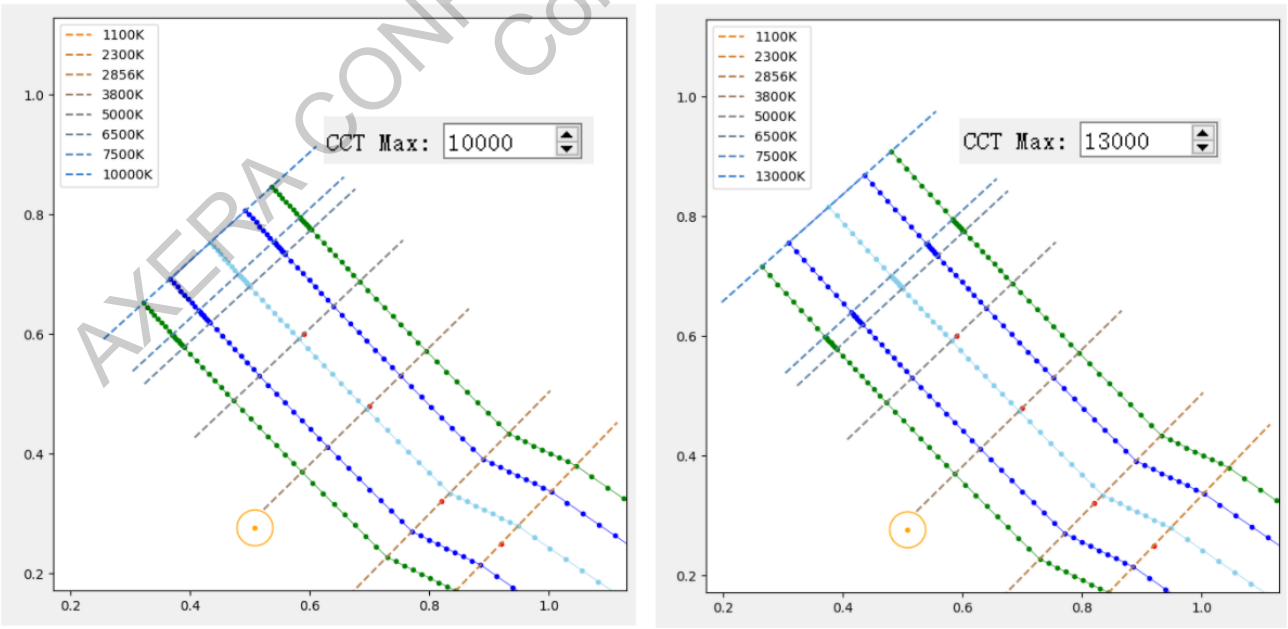

Figure 3-18 Increasing the High-Temperature Gray Area Coverage:

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If expanding the coverage still does not encompass the target white point, you can modify the High Adjust Distance and Low Adjust Distance to change the curvature direction of the extremely high and low temperatures. Fine-tune the gray area coverage by dragging the points at the edges.

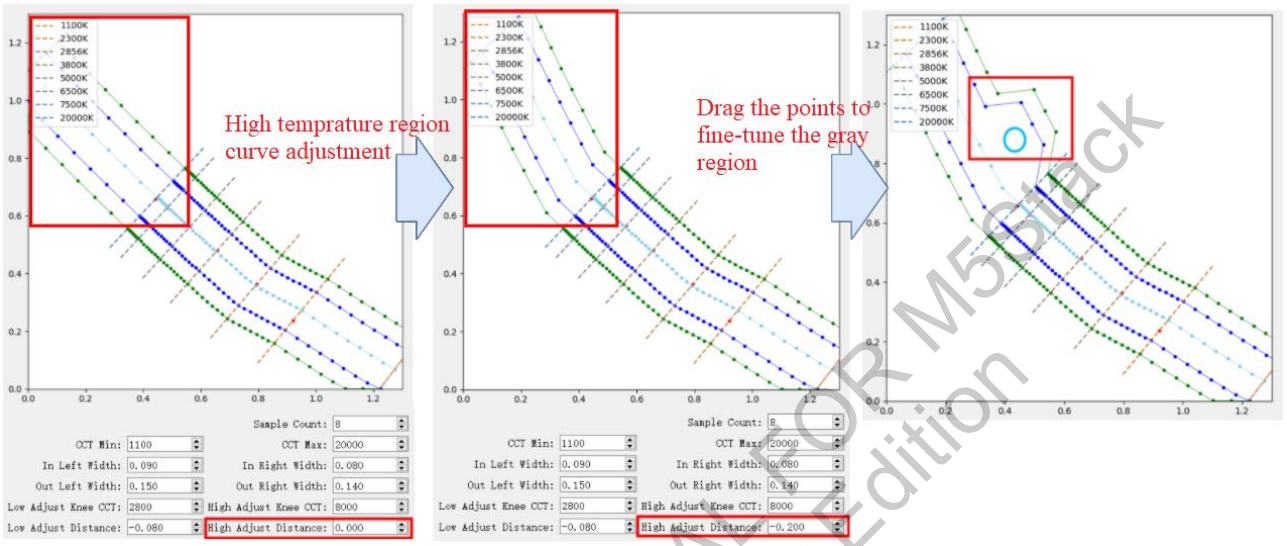

Figure 3-19 Adjustment of the Coverage Area

3.5 CCM Calibration and Debugging

3.5.1 CCM Raw Image Capture

Figure 3-20 CCM Image Capture

- Environment: Light box environment
- Hardware: QC light box (H, A, CWF, TL84, D50, D65, D75)

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- Graphic card: Color Checker
- Raw Photos:
  - 24-Color Checker Raw Images: The 24-color Color Checker should occupy approximately 1/2 to 4/5 of the center of the FOV. The brightness of the 19 white blocks should be less than 208 (8 bits), and the brightness of the 24 color blocks should be greater than the value set by BLC. Capture Raw images for each color temperature.

☞ It is recommended that the brightness of the G channel in the 19 white blocks should be around 180 (referring to 8 bits).

  - Maintain the same environment but remove the color checker card, and then capture raw images for each color temperature.

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3.5.2 CCM Calibration

Steps

1. Open ISP tuning tools, and select CCM module.
2. Import the captured 24-color card raw images for each color temperature.
3. Drag to select the color blocks of the 24-color card using the yellow ROI selection box.
4. Set the Black Level and White Level.
5. Select the images to be calibrated and the corresponding Calibration Illuminant.
6. Alternatively, check “Apply to All Images” if applicable.
7. Set the saturation calibration coefficient “Sat Control”.
8. By default, select “White Balance Correction” and “Luma Correction”.
9. Click “Calibrate” to generate the ccm.json file.

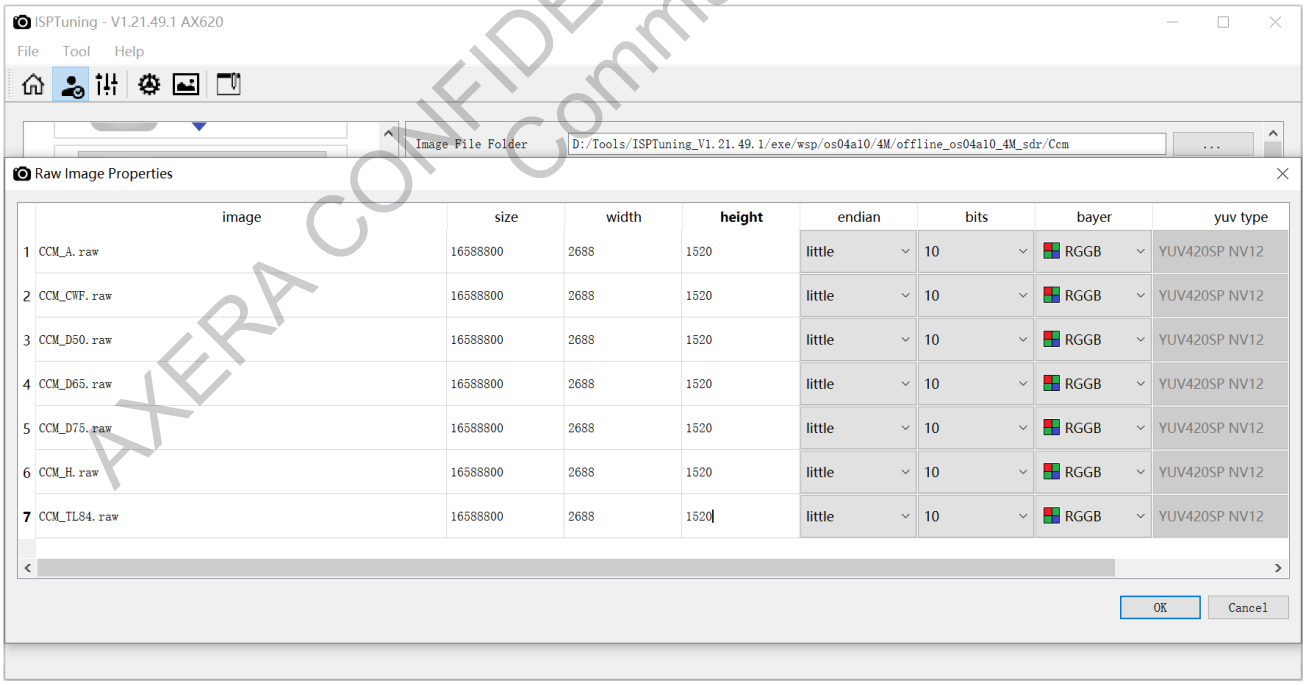

Figure 3-21 CCM Raw Information Settings

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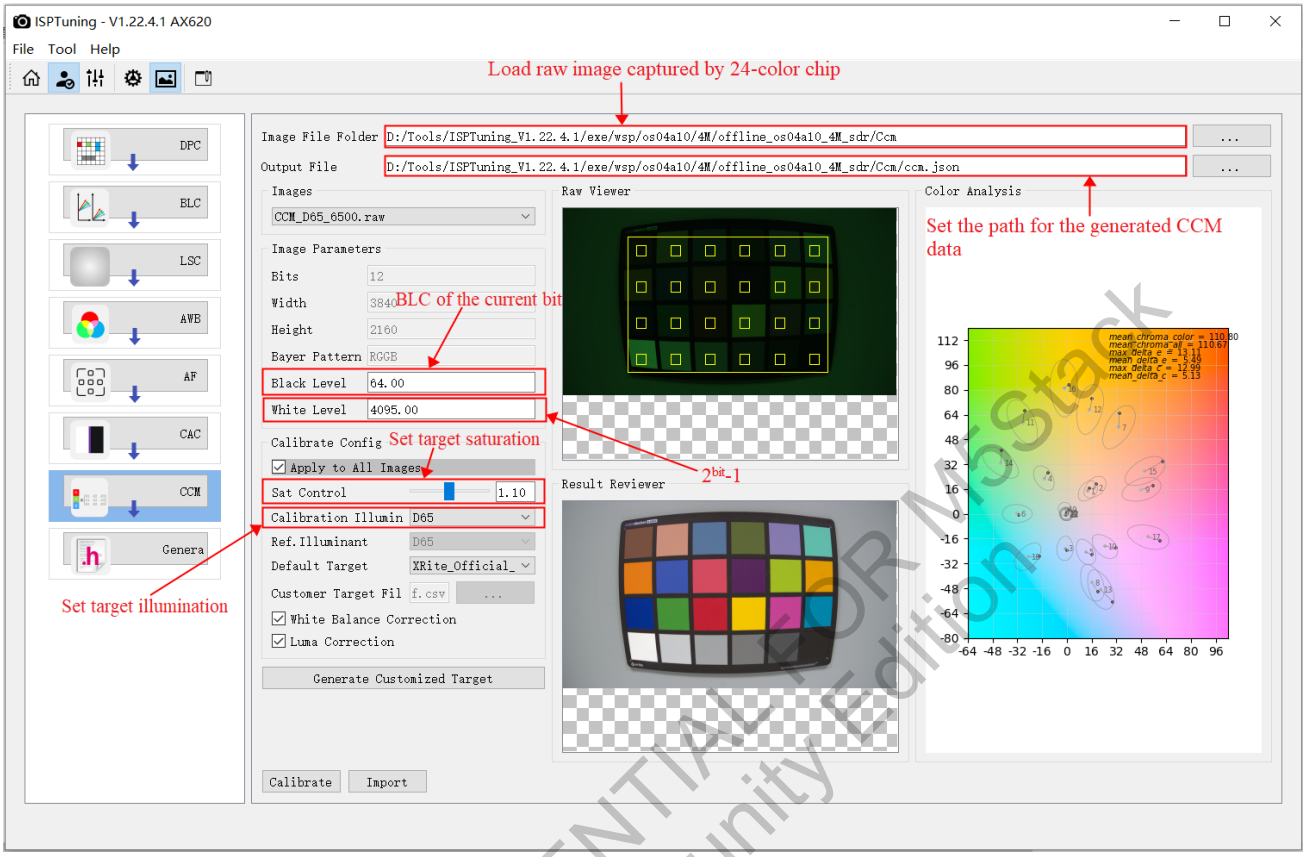

Figure 3-22 CCM Calibration Parameter Settings

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Tools

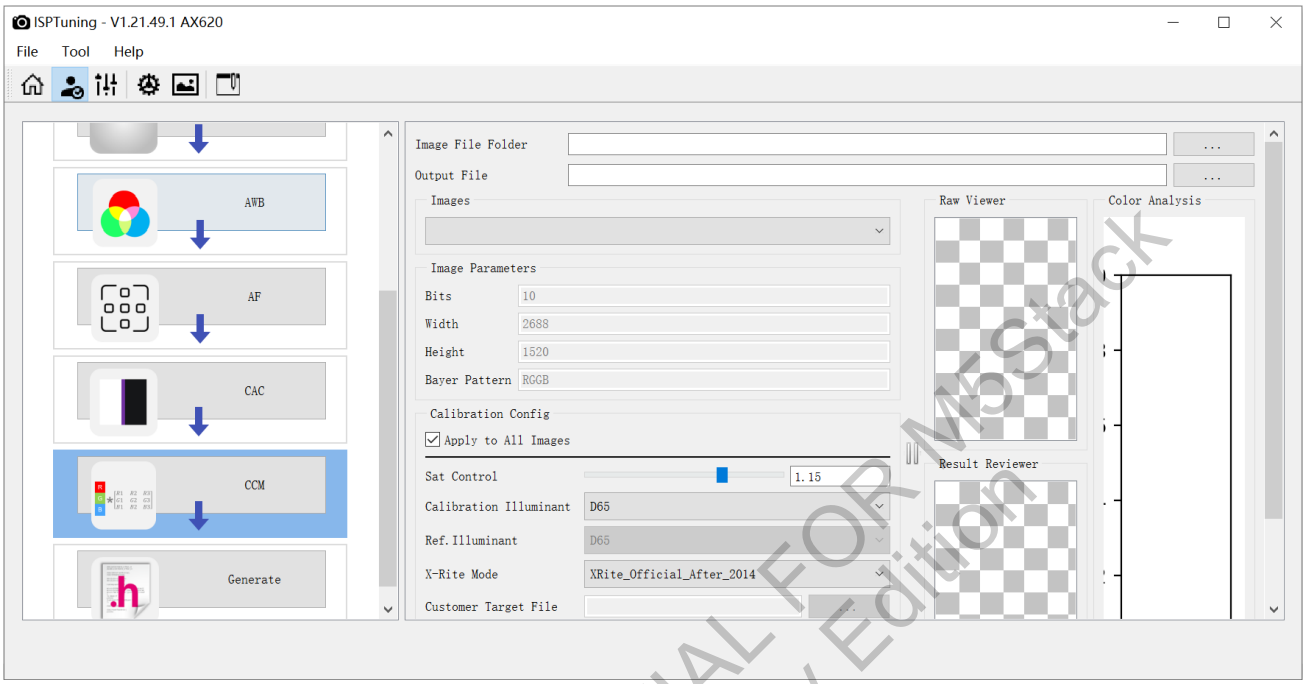

Figure 3-23 CCM Interface

3.6 AF Calibration and Debugging

3.6.1 AF Raw Image Capture

- Environment: *Not required.*
- Hardware: *Not required.*
- Graphic Cards: *Not required.*
- Raw Photos:
  - *Not required.*

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3.6.2 AF Calibration

Steps

1. Select a filter; available options include V1, V2, H1, and H2 filters.
2. Set the required filter frequency band.
3. Click “Generate AF Parameters” to produce the filter parameters.
4. Click “Add to Reference List” to display the generated filter parameters in the list. “Clear Reference List” can be used to clear the list of generated filter coefficients and the filter frequency characteristic graph.
5. Click “Export” to export filter coefficients.

Tools

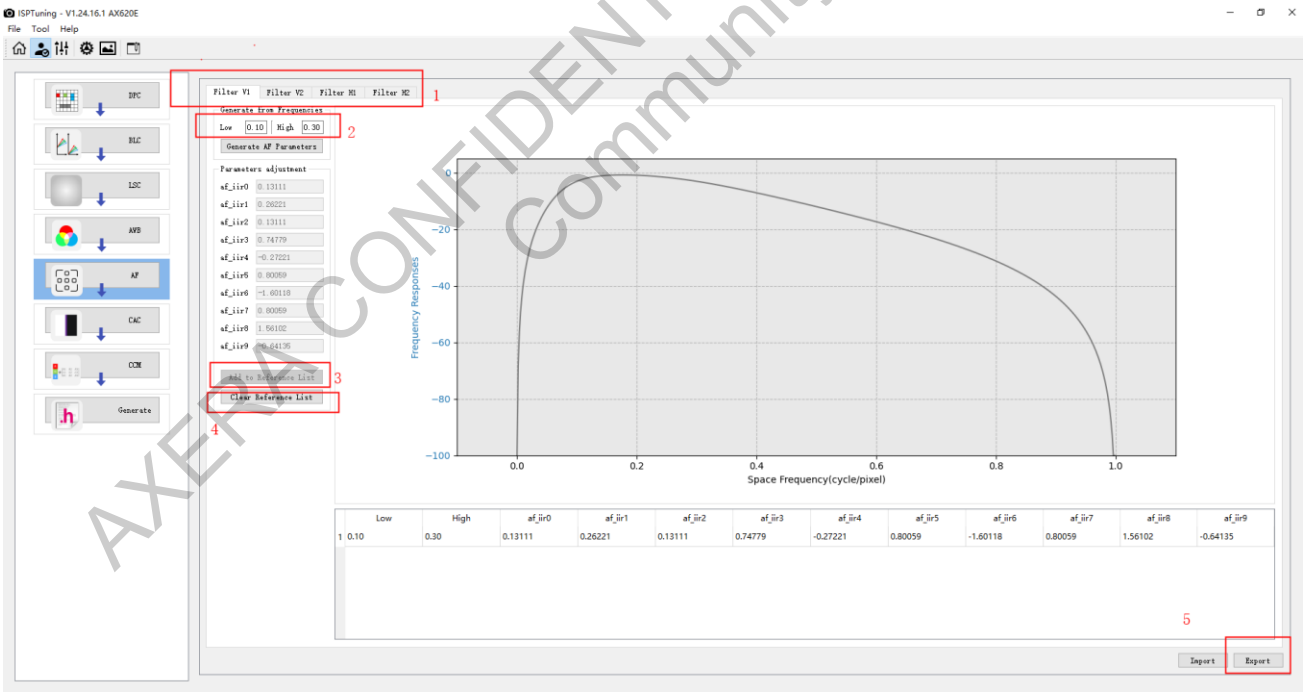

Figure 3-24 AF Interface

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3.7 CAC Calibration and Debugging

3.7.1 CAC Raw Image Capture

- Environment: Light box
- Graphic Card: Dot pattern test chart, a homemade printed dot chart is also acceptable (total number of dots >300).

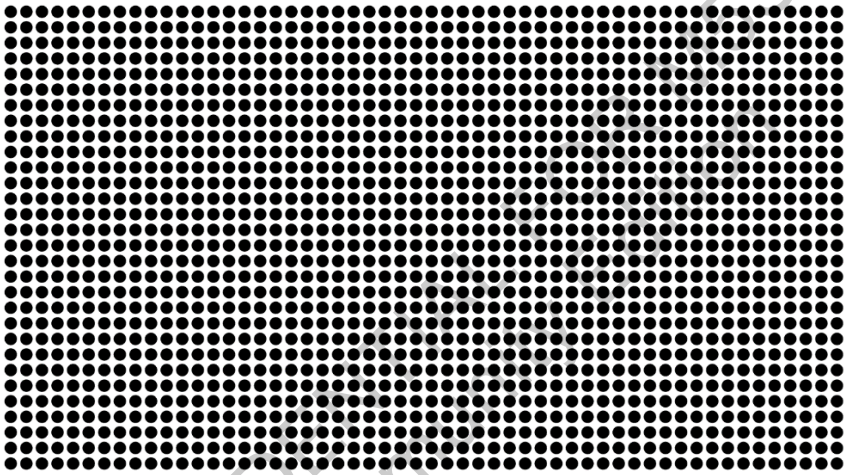

Figure 3-25 CAC

- Capture Method:

Step 1: Select raw preview mode.

Step 2: Ensure the lens is parallel to the dot pattern test chart, with the chart occupying 100% of the FOV.

Step 3: Ensure the image brightness is neither too dark nor overexposed.

☞ Recommended brightness for the G channel around 180 (refering to 8bit).

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Step 4: Name the raw images in the format: F_xx_ct_xx.raw

Example: F_10_ct_3800.raw

3.7.2 CAC Calibration

Steps

1. Open ISP tuning tools, and select CAC module.
2. Import the captured dot pattern card raw images.
3. Drag to select the area of the dot pattern card.
4. Set the parameters as follows by default:
5. Click “Calibrate”. After successful calibration, a “Calibrate Success” pop-up will appear.
6. Observe the shapes formed in the R and B channels. Channels that do not form circular shapes do not require correction.
7. Click “Export” to generate the cac.json file.

Parameter Description

CAC Config:

minArea (0, 1000000): The minimum pixel area of detectable circles.

maxArea (0, 1000000): The maximum pixel area of detectable circles.
minCircularity [0, 1.0]: The minimum concavity of detectable circles.
minInertiaRatio [0, 1.0]: The minimum roundness of detectable circles.
minConvexity [0, 1.0]: The minimum convexity of detectable circles.
minDistBetweenBlobs (0, 100000): The minimum pixel distance between two detected circles.

CAC Regress:

exam_size [0, 20]: Divides the deviations of circles in different color channels from the G channel into exam_size groups for regression analysis to derive the same elliptical parameters.

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min_num_to_fit [100 - 10000]: During the automatic calculation of parameters, the number of circles in a group used for regression must be greater than min_num_to_fit. If the number is less, the group of circles is considered invalid.

Tools

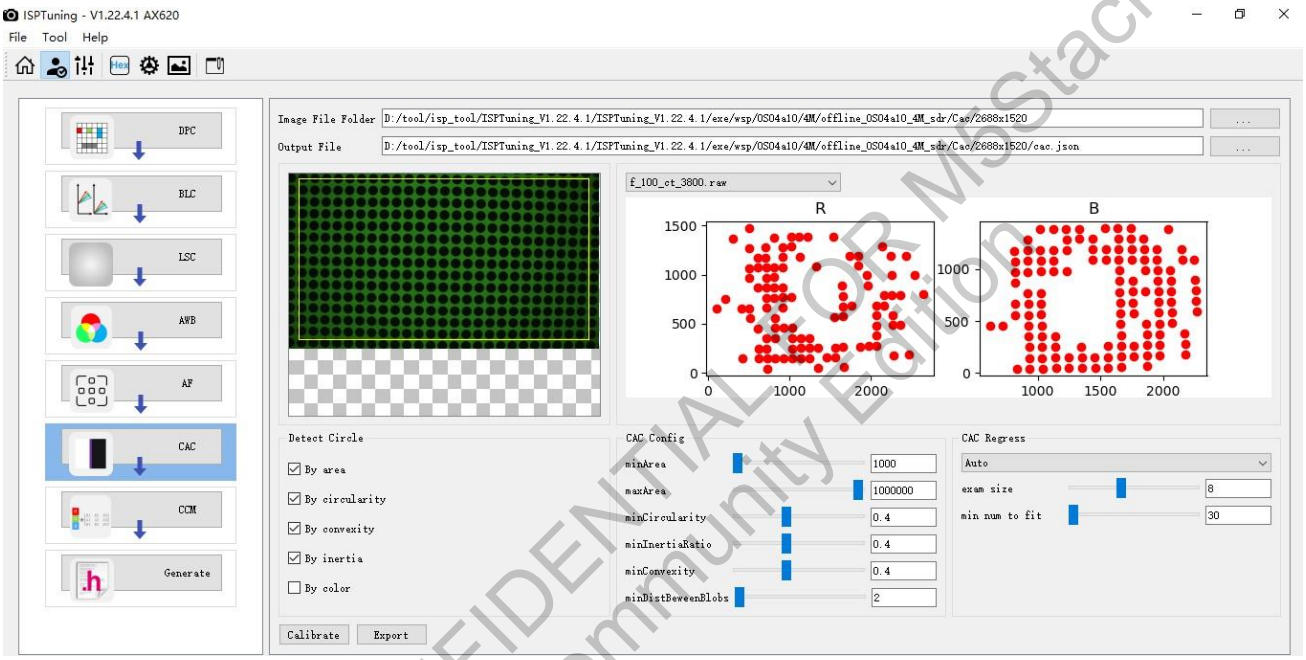

Figure 3-26 CAC Interface

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3.8 AE Module LuxK Calibration and Debugging

3.8.1 LuxK Capturing

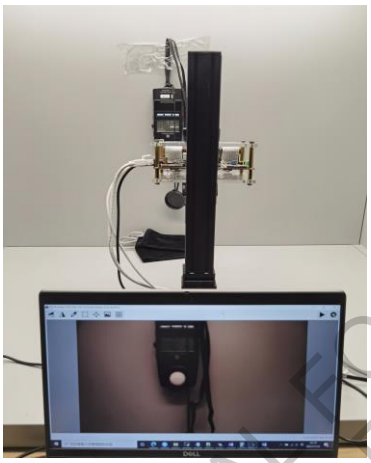

Figure 3-27 LuxK Capturing

- Environment: Light box environment
- Hardware: QC light box with TL84 and other adjustable brightness light sources, illuminance meter, camera equipment.
- Graphic Card: The light box wall where the illuminance meter is attached.
- H264 or YUV Preview:

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3.8.2 LuxK Calibration

Steps

1. Open the light box and adjust to the TL84 light source.
2. Attach the illuminance meter to an appropriate position in the middle of the light box wall.
3. Set up the camera equipment.
4. Open the ISP tuning tools, and select H264 or YUV420SP preview.
5. Click on the AE module Algorithm page.
6. Set a reasonable Tolerance to ensure that the AE convergence's mean luma is as close as possible to the target.
7. Click the "Cali Lux K" button to enter the LuxK calibration interface.
8. Adjust the TL84 light source in the light box so that the mean luma is as close as possible to the target's lowest brightness.
9. Click "get" to obtain the Exposure and Luma of the current environmental brightness and simultaneously enter the actual measured lux value from the illuminance meter into the "Lux" column.
10. Adjust the light box brightness and repeat step 9.
11. Click the "Set" button to generate the LuxK value.
12. Incorporate the generated LuxK values into the effect file to compile the firmware SO upgrade.
13. Assess the accuracy of the calibrated LuxK values by comparing the lux displayed on the tool

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interface with the lux measured by the illuminance meter.

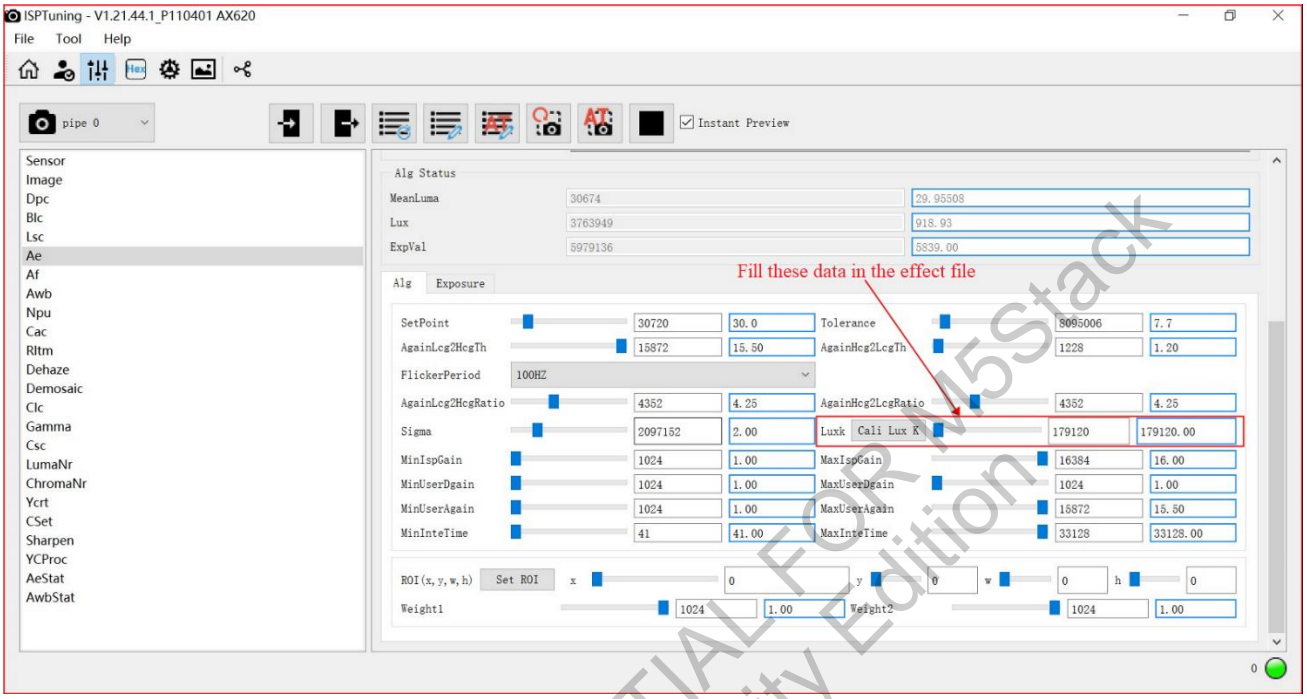

Figure 3-28 LuxK Entry

Figure 3-29 LuxKCalibration

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3.9 Create H

3.9.1 SPI Serial Transfer Steps

➢ Generating a New Effect .h File

1. Place the .json files generated from various calibration modes into the following directory: ~wsp/os04a10/4M/offline_os04a10_sdr/xx/2688x1520/.

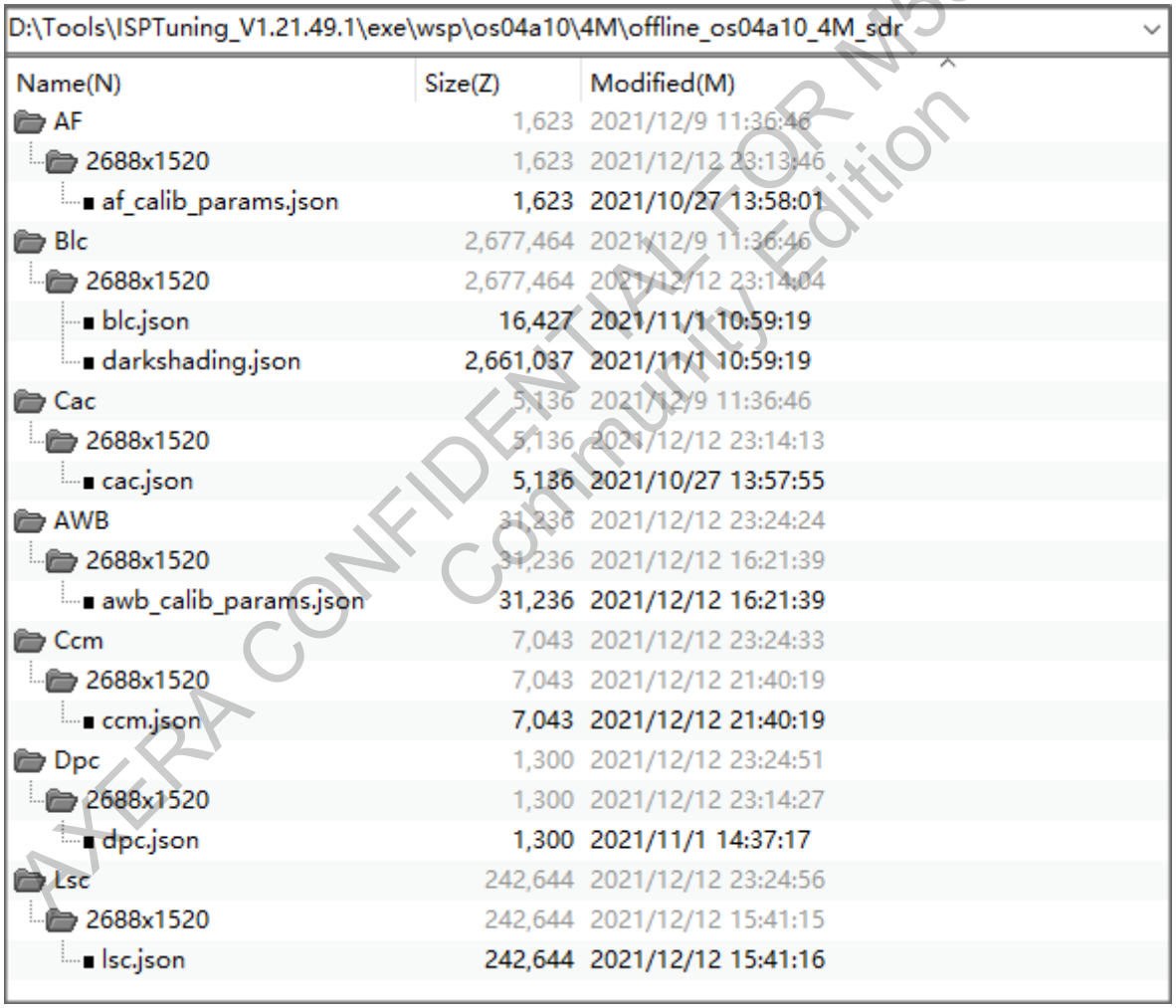

Figure 3-30 Calibration Data.json

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2. Open the ISP tuning tools and select the Generate module.

3. Choose the loading path for “Calibration Results” at ~wsp/os04a10/4M/offline_os04a10_sdr.

4. Check the modules that need to use calibration data to participate in generating the effect .h file.

5. Click “Generate” to produce the os04a10_2688x1520_sdr.h file.

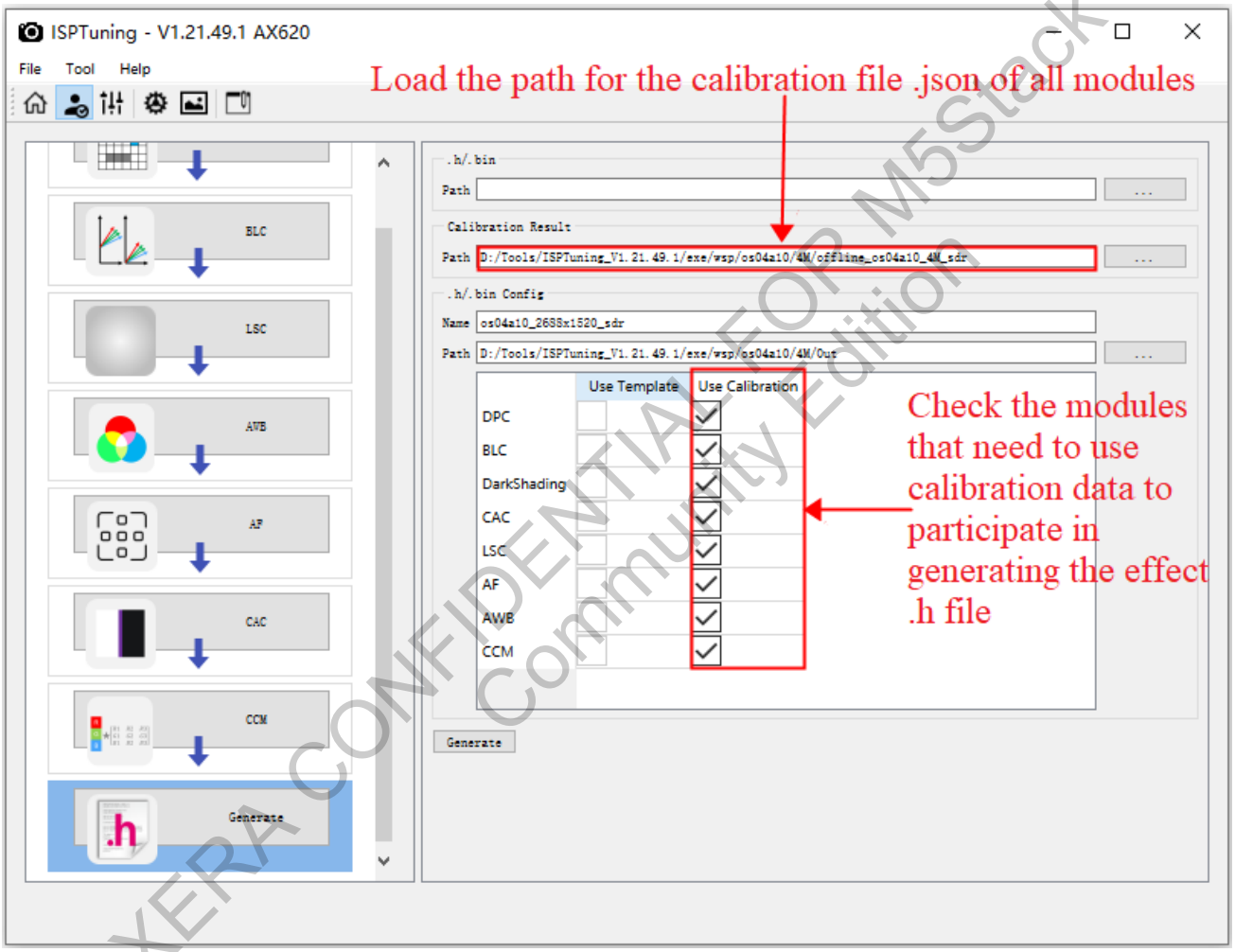

Figure 3-31 Generate a new effect .h file.

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➢ Updating Modules Based on an Existing Effect .h File

1. Load the path where the existing effect H file is located.

2. Load the path where the .json files of the modules requiring calibration are located.

3. Check the modules that need calibration.

4. Click “Generate” to create a new effect .h file.

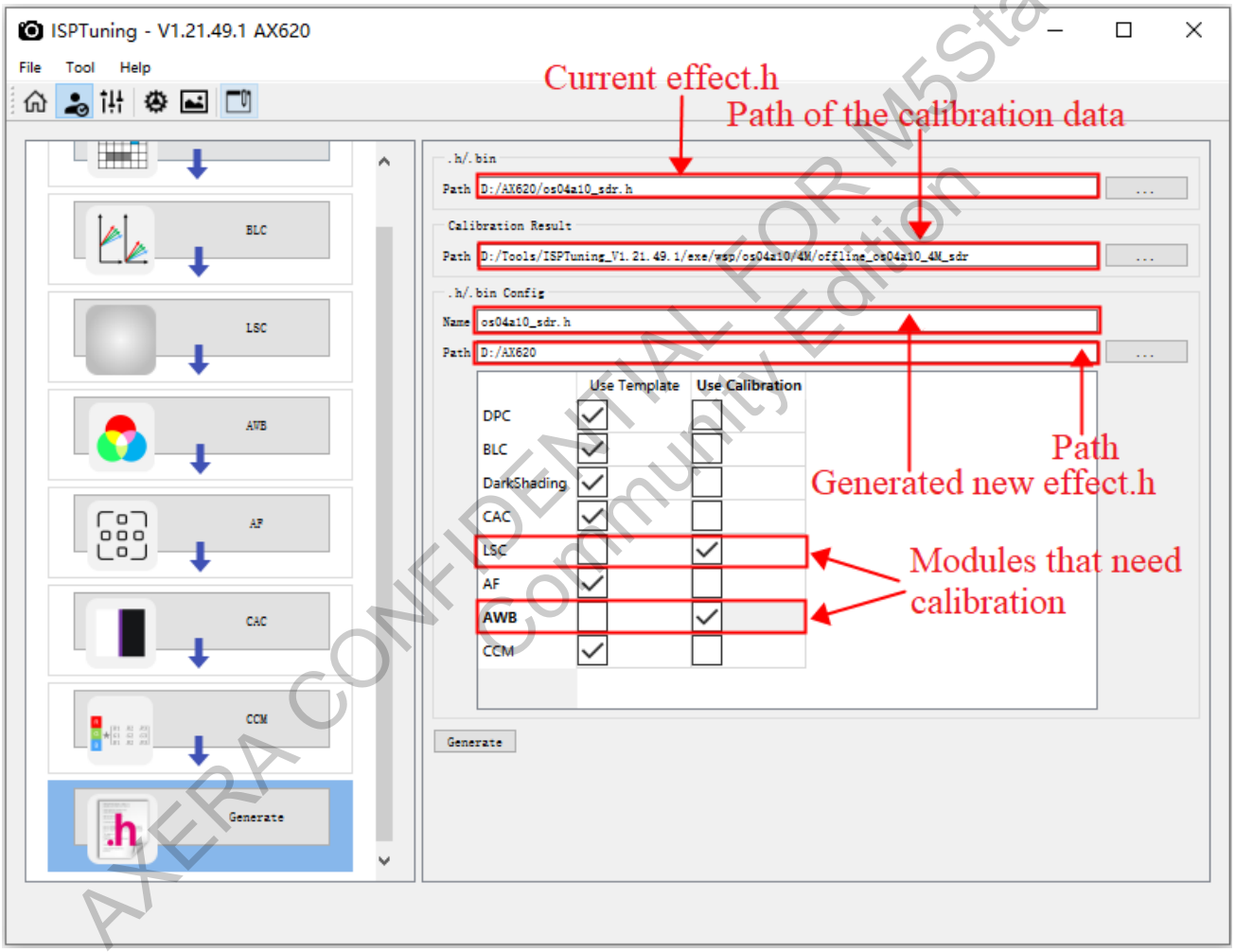

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Figure 3-32 The updated modules generate the .h file.

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