

Pop In Monitor Test at European XFEL GmbH

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Abstract

This report presents the testing of type II-45 pop in monitor with avA 1900-50 gm Basler camera and LM35SJC1M and LM25SC lenses. We briefly calculate the parameters like magnification, contrast transfer function, modulation transfer function & field of view and compare some of them with the theoretical and manufacturer data. The images are taken with the help of an own built control & data acquisition software of XFEL called Karabo while images are processed with imageJ.

Table of contents

1. Introduction	4
2. Theory	6
3. Steps to take an image from Karabo software and analysing it with imageJ.....	8
3.1 Configuration to open the image in imageJ	11
4. Experiment.....	13
4.1 Magnification.....	12
4.2 Resolution & Image correction.....	13
5. Results & Discussion.....	14
5.1 Magnification and field of view of type II-45 monitor.....	14
5.2 Spatial Resolution.....	14
5.3 Discusion.....	18
6. Conclusions	19
References	21

1. Introduction

The invention of laser in IR, visible & near UV has led to exciting discoveries and applications. The synchrotron radiations are the bright emission of highly collimated electromagnetic waves from electrons (or positrons) orbiting at ultrarelativistic energies in storage rings with diameters of tens to several hundreds of meters.

synchrotron radiations cover not only the IR and visible region but also the whole UV & X-rays regime even below 0.05 nm.

Free Electron Lasers are the fourth-generation sources which brought a revolution in synchrotron source intensities due to a recent progress in accelerator technologies, developed in connection with high-energy linear colliders. The history of FEL starts from the paper by Pantell, Soncini, and Puthoff [3], which contains the complete set of distinctive features of the FEL. The XFEL (X-ray Free Electron Laser) has had more than 20 years of development after the work of Madey and co-authors [4] on the first FEL oscillator and theoretical work by Kroll and Mc Mullin on the possibility of single-pass gain [5]

European XFEL is a powerful X-ray light source being constructed in Hamburg. The European XFEL has some distinct features like a wide energy range (from 0.28 keV up to 25 keV) with a peak brilliance of 10^{33} photons/s/mm²/mrad²/0.1%BW. The generation of ultrashort X-ray flashes with brilliance which is billion times higher than conventional X-ray sources can help in amazing scientific research like 3-D images of nanoworld or filming the chemical reaction [6]. XFEL will generate macro-bunches with a repetition rate of 10 Hz and a train of 2700 pulses separated by 220 ns [7,8].

There are two approaches for photon diagnostics like invasive and non-invasive. The invasive means that most part of the beam is absorbed or severely distorted by the detector. The invasive mode is good for commissioning but can't be used for on-line diagnostics.

The topic of X-ray photon diagnostics is covered by the X-Ray Photon Diagnostics group (WP74) in XFEL. Apart from the large energy range of operation of the facility the another challenge for the European XFEL diagnostics is the high intra bunch train photon pulse repetition rate of 4.5MHz. Photon diagnostics techniques at XFELs will have to accomplish the Photon beam-based alignment, Characterization of SASE (Self-Amplified Spontaneous Emission) radiation and Diagnostics for user operation [9].

2. Theory

The magnification was calculated by using the formula,

$$\text{Magnification} = \frac{\text{Image height } y}{\text{Object height } x} \quad (1)$$

Image height can be calculated by using imageJ software and formula,

$$\begin{aligned} y &= \text{image height} \\ &= \text{number of pixels} \times \text{size of single pixel} \end{aligned} \quad (2)$$

Error in the result can be calculated by using the formula,

$$\text{Error} = \frac{\text{Calculated} - \text{Measured}}{\text{Calculated}}, \quad (3)$$

The image correction (dark and gain correction) can be calculated by using a formula,

$$I_{cor} = \frac{\text{Object image} - \text{Dark image}}{\text{Source image} - \text{Dark Image}}, \quad (4)$$

Where source image is obtained by removing the object to take the image of light source behind the object. Dark image is obtained by switching off all light sources i.e. there is no light exposure on CCD.

The contrast at a particular spatial frequency is calculated by using - on the corrected image - the following formula

$$C = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}, \quad (5)$$

Where I_{max} is the maximum amplitude, gray value, for a pixel on image and I_{min} is the minimum amplitude, gray value, for a pixel on image. I_{max} and I_{min} are obtained by 1st applying the correction on the image then finding the maximum and minimum gray value from profile plot.

The contrast transfer function (CTF) is converted into modulation transfer function (MTF) by applying the formula [2]

$$\begin{aligned}
 MTF(f) = \frac{\pi}{4} [CTF(f) + \frac{1}{3}CTF(3f) - \frac{1}{5}CTF(5f) + \frac{1}{7}CTF(7f) \\
 - \frac{1}{11}CTF(11f) \dots
 \end{aligned}
 \tag{6}$$

The field of view of a lens is calculated by,

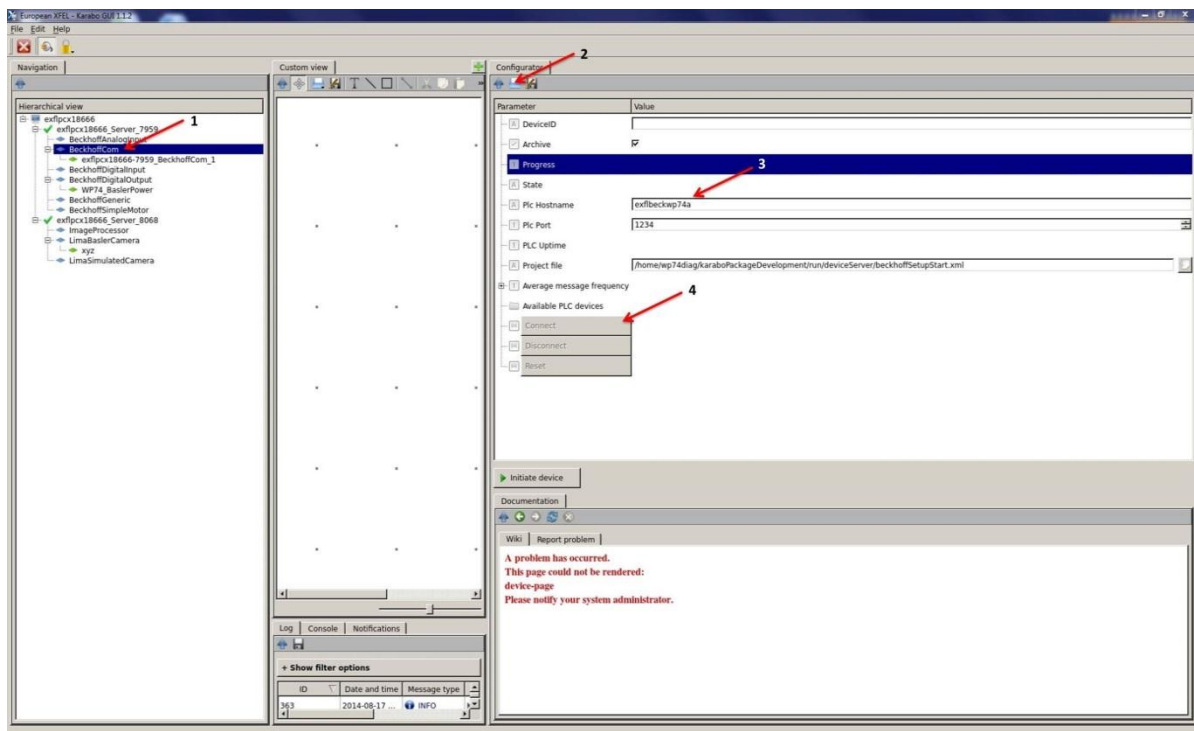
$$FOV = \frac{\textit{Pixel size} \times \textit{no.of pixels in a horizontal or vertical direction}}{\textit{Magnification}}
 \tag{7}$$

3. Steps to take an image from Karabo software and analysing it with imageJ

Karabo software was developed by the WP-74 group of XFEL to make the image acquisition easy for a user. It is equipped with the tools like image processing, exposure adjustment, remote computer access e.t.c.

Here are the steps to access the camera from remote computer, using Karabo software.

- Install the Karabo on PC.
- Select the terminal from the start menu (Install Win32 if you are working on Windows 7).
- Once the terminal is opened, type the command



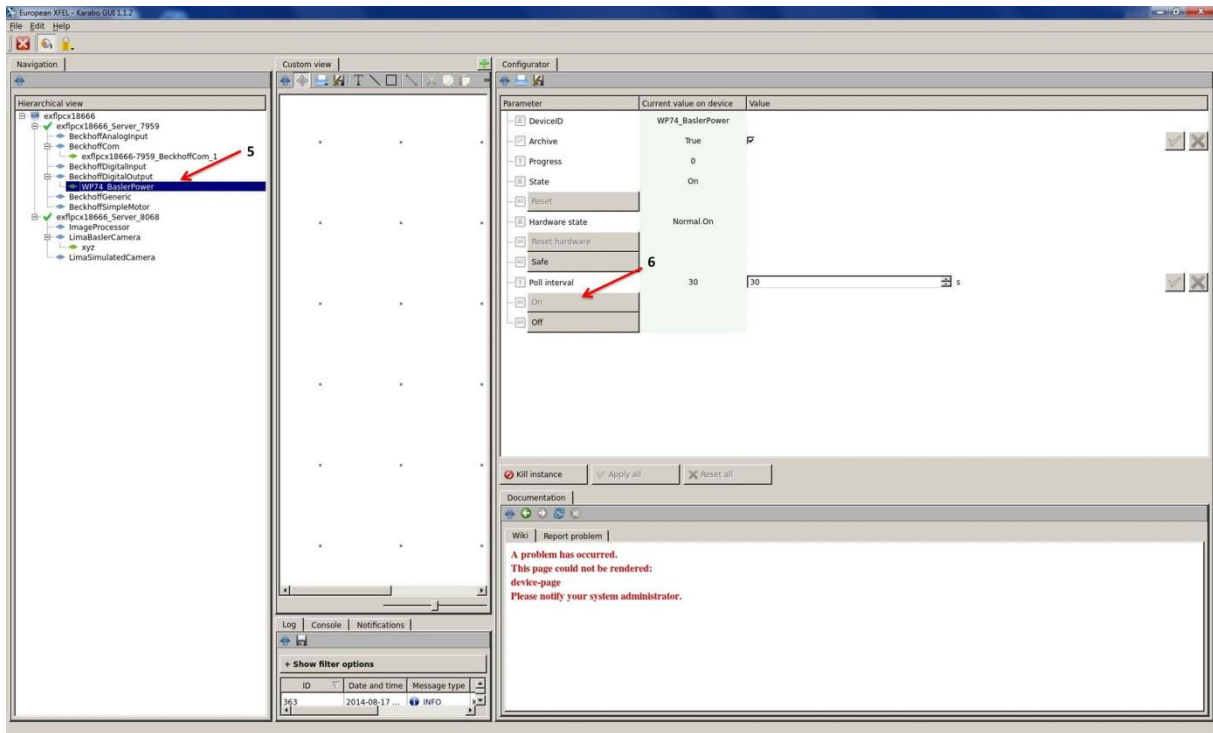
cd karaboPackageDevelopment/run/ on terminal.

- Now you are in karaboPackageDevelopment folder. Now, to run the software type the following command. **./allStart**. The Karabo software will appear on the screen.
 - Karabo GUI screen, click **connect to server**. (top left corner), login window, click **connect**
1. On left side, under the **Hierarchical views**, of Karabo GUI select **BeckhoffCom** under **exflpc18666_Server_7959** and **exflpc18666**.

2. Now, on the right side of window select **Open Configuration** under the configurator dialogue box.

Now a new window opens to select the configuration file. The path of the file, **beckhoffComConfiguration.xml**, is **/home/wp74diag**.

3. Open the file and change the **Plc Hostname** to **exflbeckwp74a**.



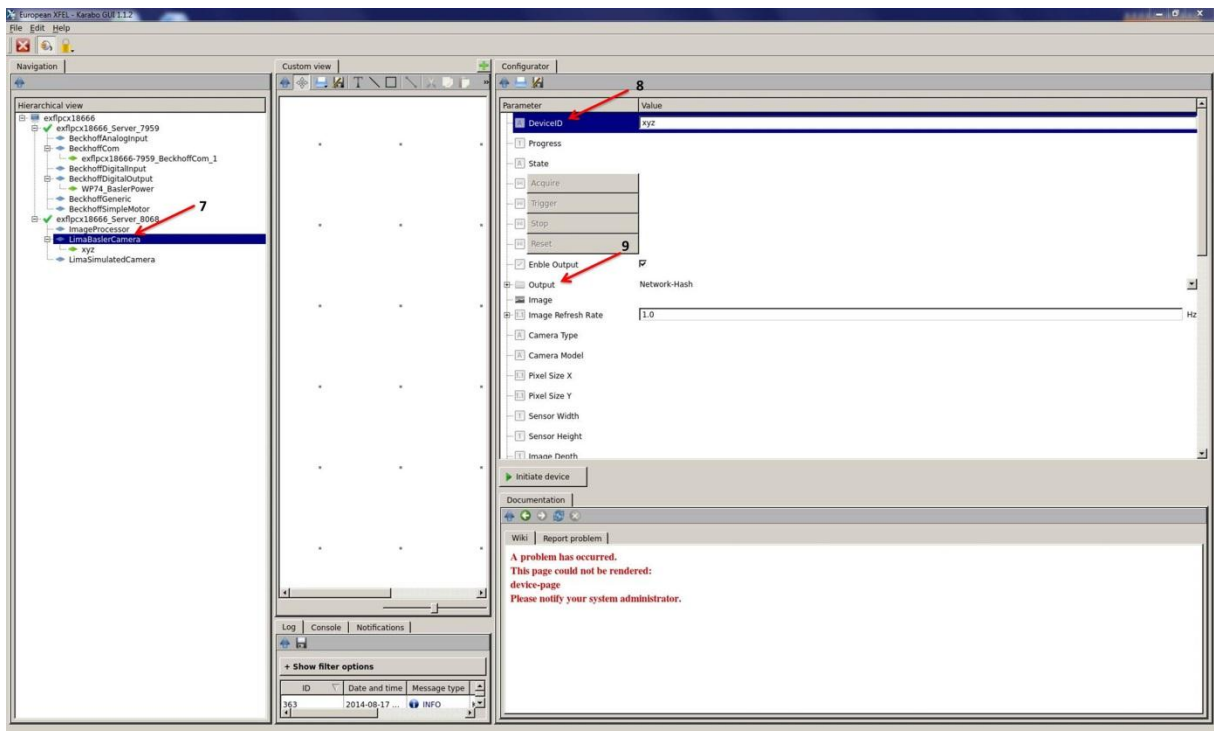
click **initiate**.

4. Now connect the camera device by clicking **Connect** under **Available Plc devices**. A new window name **WP74_BaslerPower** will appear under **BeckhoffDigitalOutput**.

5-6. Select the **WP74_BaslerPower** and click **on** if the camera is in off state.

7. Now from **Hierarchical views**, select **LimaBaslerCamera** by expanding **exflpc18666_Server_8068**.

8-12 Once the **LimaBaslerCamera** is selected then type a **Device ID**, (arbitrary name) change the **Output** to **Network-Hash**, enable the **Write File**. It's better



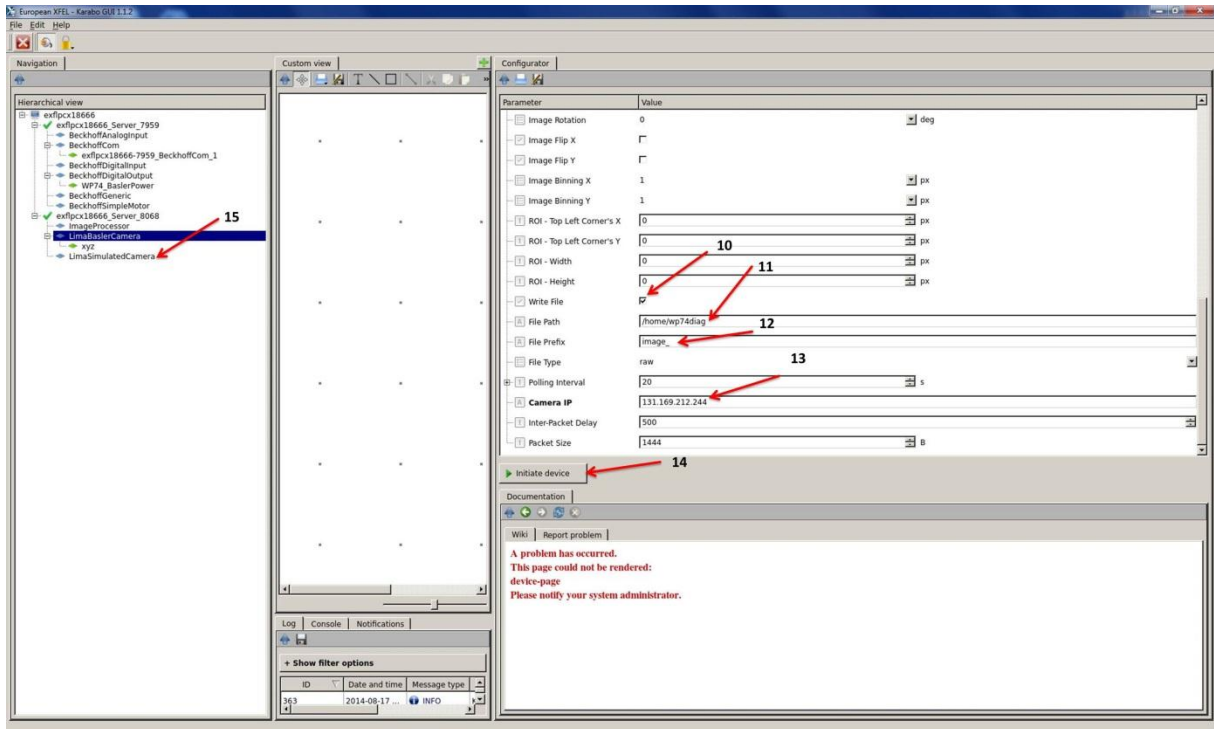
to change the **File Path**, **File Prefix** and **File Type** if required.

13. The **camera IP** for the Basler camera avA1900-50gm is **131.169.212.244**.

14. Now initiate the device by clicking on **Initiate device**.

15. To acquire the image click on the **Acquire**.

To Stop the Karabo type **./allStop** on terminal window



3.1 The configuration to open the image in imageJ

The configuration to open the image of object and source with raw format is shown in Fig. (2) & Fig.(3)

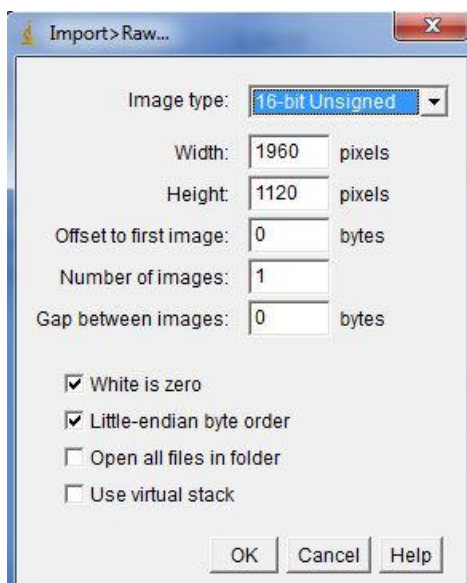


Fig. (2) Configuration for opening object image

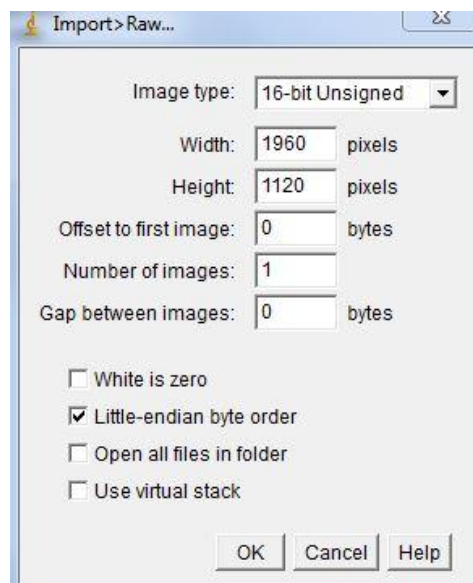


Fig. (3) Configuration for opening source image

4. Experiment

4.1. Magnification

XFEL's WP-74 work package group has to install 14 Pop In monitors, shown in Table. 1, for X-ray detection. And our aim was to test the monitors by measuring the magnification and resolution using white light source.

Pop In monitors	Lens	Camera
7 x type I	LM35SJC1M	avA 1600-50 gm
5 x type II-45	LM25SC	avA 1900-50 gm
1 x type II-90	LM16SC	avA 1600-50 gm
1 x type III	2 LM35SC	avA 1900-50 gm 2x

Table. 1 Pop In monitors to be installed in European XFEL

In our experimental setup, shown in Fig. (1), we tested only type II-45 monitor. The schematic diagram for the experimental setup is shown in Fig. (1). The optical setup consists of fibre lamp, object (test pattern) and a camera with lens and aperture. x_1 is the distance of object from the lens of camera. The Karabo controller was used for image acquisition and camera control.

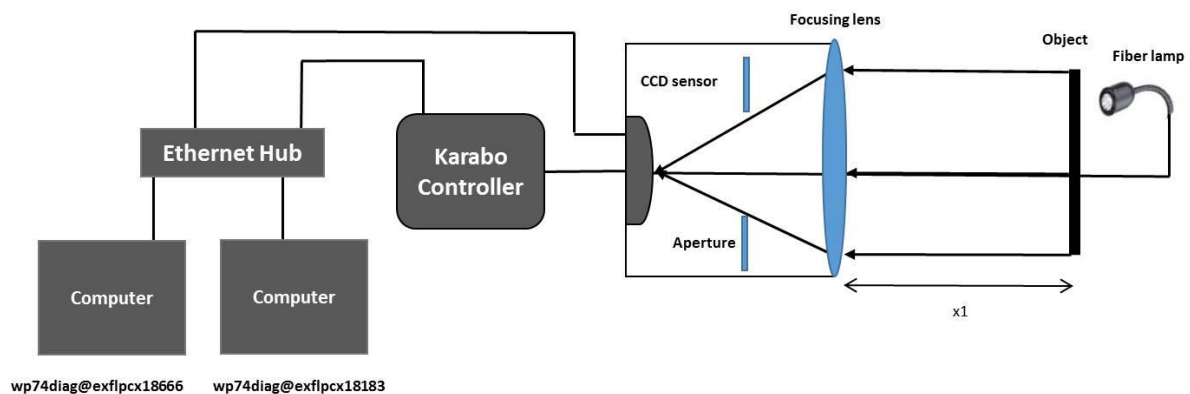


Fig. (1) Schematic diagram for measuring magnification and resolution for avA 1900-50 gm Basel camera

The experiment was repeated with two lenses of focal length 25 mm and 35 mm. For 25 mm lens the object was placed at distance, x_1 , 337 mm from the lens while for 35 mm the object was placed at distance, x_1 , 205 mm from the lens. The image was taken for both experiments. These distances correspond to the used distances of the lenses within the monitors.

4.2 Resolution and Image correction

The experimental setup for resolution was same as shown in Fig. (1). A 1951 USAF resolution test chart was used as a resolution test pattern. The test pattern was illuminated by a fibre lamp through an optical diffuser and the images were taken with a avA 1900-50 gm Basel camera. First the image of the test pattern was taken then the image of source, by removing the test pattern, was taken finally a dark image was taken for both experiments. The experiment was performed with a 25 mm lens and then a 35 mm lens with a distance of 337 mm and 205 mm between object and the lens.

5. Results and Discussion

5.1. Magnification and field of view of type II-45 monitor

For 1960x1120 pixels camera the magnification was calculated by using the Eq. (1) and Eq. (2). Results for the magnification (both for LM35SJC1M and LM25SC) are shown in the Table. 2. The measured magnification is quite close to the calculated one. It was found that by changing, increasing, distance x_1 for lens LM35C1M the measured magnification moved closer towards the calculated value as shown in Table. 2. For LM25SC we got best focus at 0.3.

Lens	x_1 (mm)	Measured Magnification	Calculated Magnification
LM25SC	337	0.071	0.070
	(nominal)		
LM35C1M	205	0.175	0.165
	(nominal)		
	215		
	220		

Table. 2 Measured & calculated Magnification for 25 mm and 35 mm lens

Field of view (FOV) was calculated from Eq. (7). For type II-45 (25 mm lens) with camera avA 1900-50gm, the FOV was found to be 0.15 m and 0.086 m for horizontal and vertical directions having pixels 1960 and 1120. Similarly the FOV for type-I (35 mm lens) with a avA 1600-50gm camera was found to be 0.050 m and 0.03 m for horizontal and vertical directions having pixels 1600 and 1200 and magnification of 0.175 (measured for type-II).

5.2. Spatial resolution

The corrected image was found by using the Eq. (4) with the help of imageJ .The images of the test pattern after (both for LM35SJC1M and LM25SC) the correction, are shown in Fig. (2) & Fig. (3). The Contrast Transfer Function (CTF) curve was

calculated -by using Eq. (5)- for the groups 0, 1, and 2 for the 25 mm lens and for groups 0, 1, 2, and 3 for the 35 mm lens with element 1 for each group. The contrast vs line pairs (black and white line) per millimetre [1], for both lenses, is shown in Table. (2) and Table. (3). The 25 mm lens was well focused, the results for the 35 mm lens need optimisation.

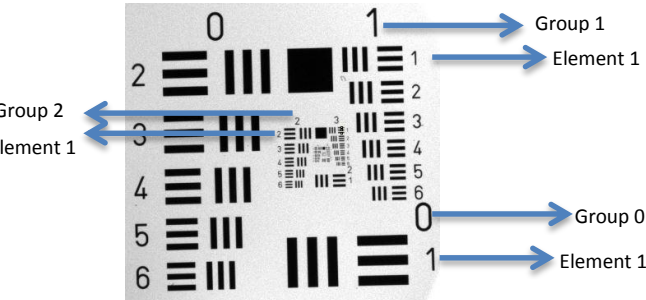


Fig. (2) Test pattern after correction for 25 mm lens

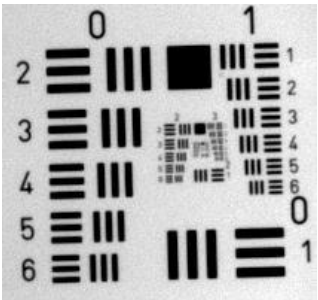


Fig.(3) Test pattern after correction for 35 mm lens (slightly out of focus)

Group	lp/mm (Number of Line Pairs / mm)	Contrast
	0	1
0	1	0,86
1	2	0,69
2	4	0,30

Table. 2 Contrast of 35 mm lens for the group 0, 1, 2 of test pattern

Group	lp/mm (Number of Line Pairs / mm)	Contrast (C)
	0	1
0	1	0,92
1	2	0,91
2	4	0,81
3	8	0,54

Table. 3 Contrast of 25 mm lens for the group 0,1,2,3 of test pattern

A graph for CTF of both lenses is shown in Fig. (4) and Fig. (5).

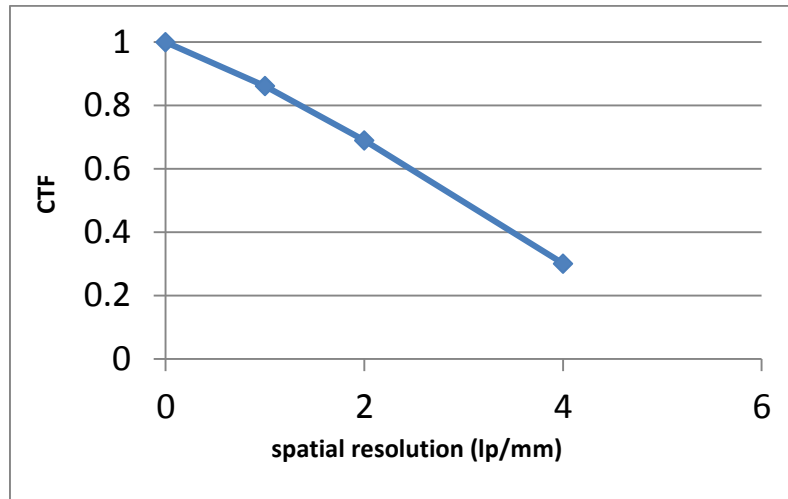


Fig. (4) Contrast transfer function for 35 mm lens

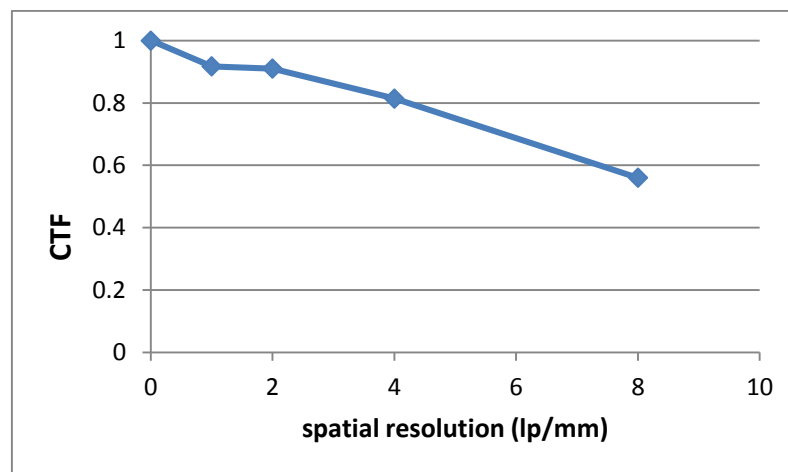


Fig. (5) Contrast transfer function for 25 mm lens

We also found the MTF, for 25 mm lens, from CTF by using the Eq. (6). The approximated MTF is shown in Fig. (6) & in Table. (4). We interpolated the data to obtain the MTF for missing spatial resolution terms.

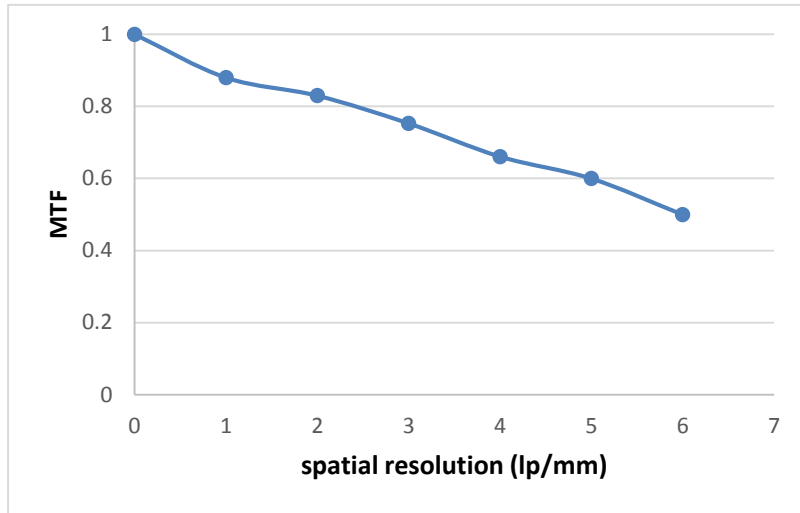


Fig. (6) Modulation transfer function for 25 mm lens

spatial resolution (lp/mm)	CTF	Spatial resolution for Kowa lens (lp/mm)	MTF
0	1	0	1
1	0.92	14	0.88
2	0.91	28	0.83
3	0.82	42	0.753
4	0.81	56	0.661
5	0.77	70	0.6
6	0.64	84	0.5

Table. 4 MTF for 25 mm lens, with spatial resolution multiplied by 1/magnification

5.3. Discussion

We compared the MTF obtained by us, shown in Fig. (7) , with the MTF of Kowa lens shown in Fig. (8). It was found that our MTF is comparable to the MTF of Kowa lens. While comparing the MTF of 25 mm lens we multiplied the spatial resolution with $1/Magnification$ i.e. 14 in order to make the spatial resolution scale equal to the Kowa lens scale.

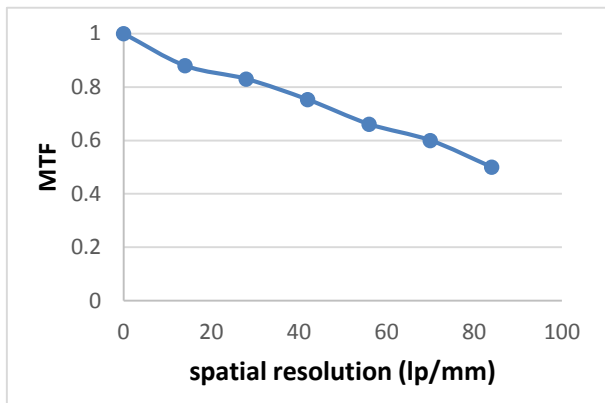


Fig. (7) MTF for LM25SC (type II-45) lens

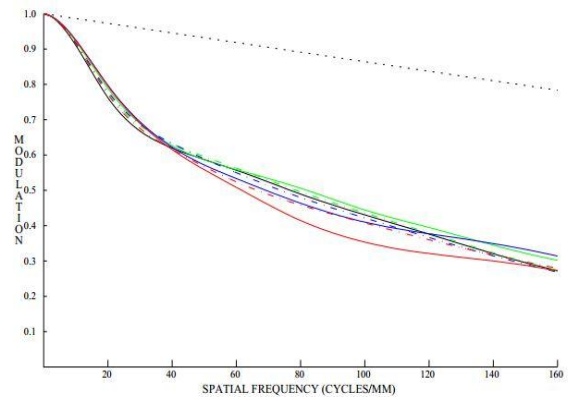


Fig. (8) MTF for LM25SC Kowa lens

6. Conclusion

The type II-45 pop in monitor was tested by measuring the magnification and finding Contrast transfer function and field of view for LM35SJC1M & KM25SC. The MTF for 25 mm lens was measured and results were comparable to the MTF provided in Kowa lens data sheet. The measured magnification was very close to the calculated one.

References

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