GROUP: C03 NAME: Filip Slezak 286557, Gaspard Leroy 287178

# Pinhole camera

## 5. Summary of tasks of the experimental work

### 4.2. Imaging with a pinhole camera (40 min)

Make a series of at least 4 images like in the example given in the description (start at pinhole touching the camera window, write down the distance camera chip pinhole). Use always the same exposure conditions. Print all 4 images in the report. Describe your findings.

Picture1–
Position: 0.8mm

Picture2–
Position: 1.3mm

Picture3–
Position: 1.7mm

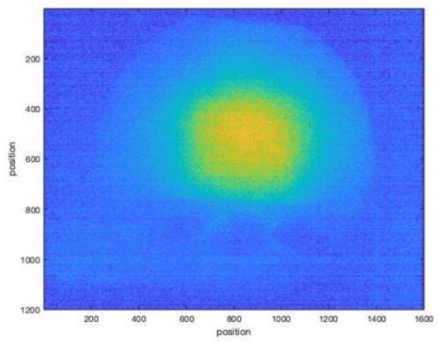
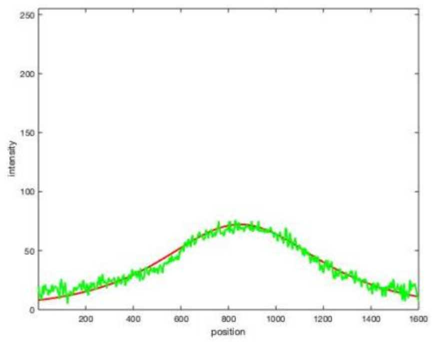
Picture4–
Position: 2.3mm

Discussion (compare and interpret):
We notice is that the further we are from the pinhole, the brighter is the image and the lower is the resolution.
All the images are upright so they must have been rotated afterwards or taken upside down.

In Pictures 3 and 4 the pinhole is visible. From what we see in these images we are inclined to believe that the pinhole is larger than the camera detector as the viewing angle seems to increase as the distance increases.

### 4.3 Intensity distribution over the field (20 min)

Take an image of a uniform scene (white paper) and evaluate the intensity distribution of the field of view by plotting the two-dimensional intensity distribution. Print it in the report. Compare a horizontal line plot at highest intensity with the $\cos^4\theta$ law by presenting a plot that contains both measurements and theory. Adjust the plot parameters if necessary to have a good match. Print it in the report. Do not forget to give the plot parameters (distance pinhole – detector, center position) and discuss them.

| Picture1– | Picture2– |
| --- | --- |
|  |  |

In your experiment:

Set distance pinhole detector (to be read and calculated with micrometer screw):

**d = adjusted-initial = 7.8mm - 7.15mm = 0.65mm** 2.1

From Matlab code with adjusted parameters

**Line_number = 525**

**distance = 1.7mm**

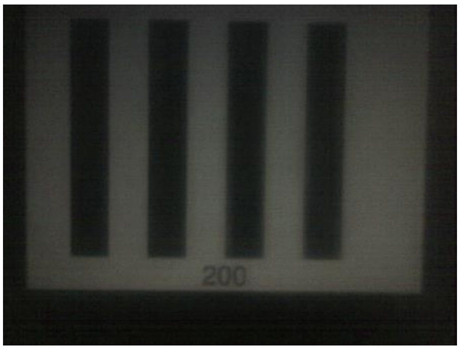
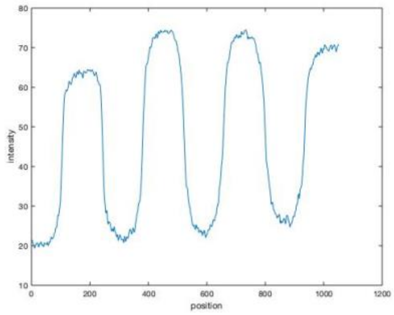
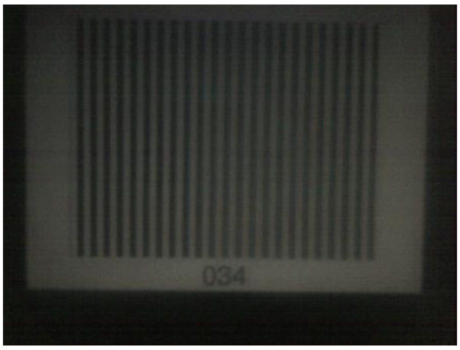
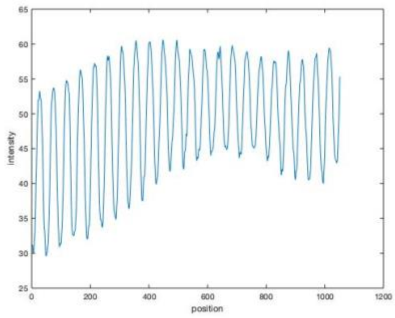
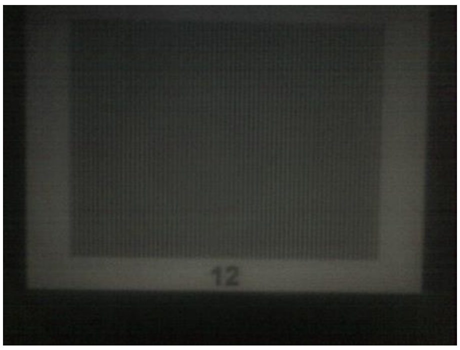
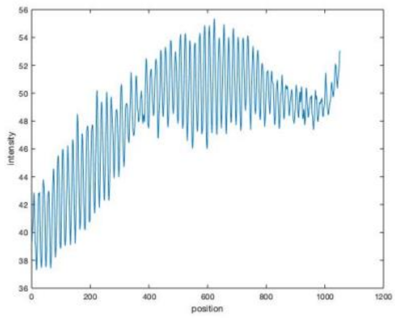
**peak_position_x = 850**

Discussion (compare and interpret):
We have a very good fit with our values. We explain the difference with the theory by noise coming from the environment and light homogeneity which impact the camera measure. We don't believe the distance measured is to blame here.

Nevertheless, the dependence in $\cos^4\theta$ of the intensity is clearly respected.

### 4.4. MTF measurement with the basic method (60 min)

Document the procedure by showing typical pictures and line plots (three images – max contrast, medium, no contrast). Measure the MTF and find a plot as a function of **image frequency** on the detector (**lines/mm**) similar to the plot in the description. Find the spatial frequency for 10% contrast and compare the value with the pinhole diameter by writing a short comment!

| | |
|---|---|
| Picture1–<br>Maximum contrast 200<br> | Graph1–<br>Maximum contrast<br> |
| Picture2–<br>Medium contrast 34<br> | Graph2–<br>Medium contrast<br> |
| Picture3–<br>Low contrast 12<br> | Graph3–<br>Low contrast<br> |

To **find the special frequency** you measure for a single structures it widths on the detector (i.e 200 corresponds to 250 pixels, period is 500 pixels) and with the pixel size (0.002835 mm) find the spatial frequency (1/p). Please be careful with the units. Spatial frequency is measured in lines per millimeter. If you have determined one spatial frequency that others can be calculated (i.e. 100 is double of 200) in frequency space)

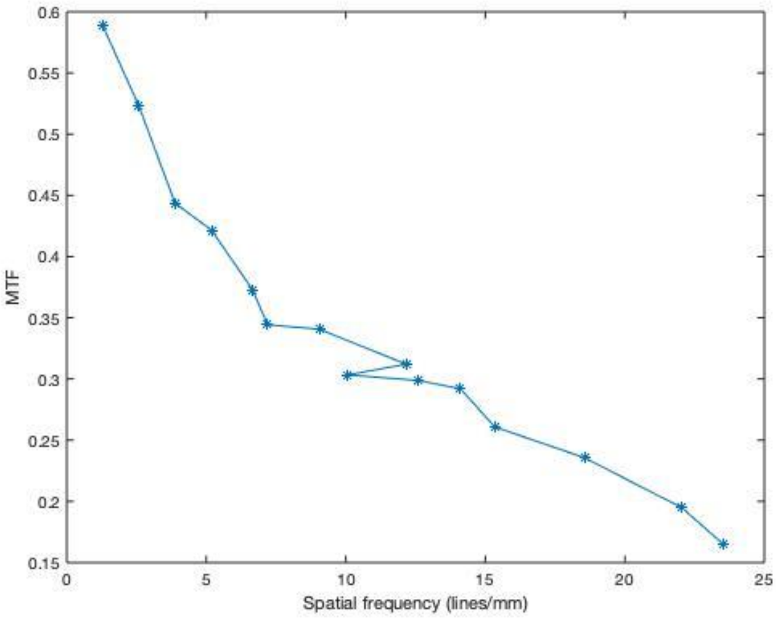
Fill out the table with your measurement results.

| **Frequency of picture in object space** | **Size on detector in pixels** | **Spatial frequency in image space (l/mm)** | **Contrast** $C = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$ |
|---|---|---|---|
| 200 | 275 | 1.2827 | 0.5888 |
| 100 | 137 | 2.5747 | 0.5235 |
| 66 | 91 | 3.8762 | 0.4438 |
| 50 | 68 | 5.1873 | 0.4215 |
| 40 | 53 | 6.6554 | 0.3730 |
| 34 | 49 | 7.1986 | 0.3442 |
| 28 | 39 | 9.0445 | 0.3407 |
| 24 | 29 | 12.1632 | 0.3121 |
| 22 | 35 | 10.0781 | 0.3034 |
| 20 | 28 | 12.5976 | 0.2988 |
| 18 | 25 | 14.1093 | 0.2920 |
| 16 | 23 | 15.3362 | 0.2609 |
| 14 | 19 | 18.5649 | 0.2356 |
| 12 | 16 | 22.0459 | 0.1948 |
| 10 | 15 | 23.5156 | 0.1653 |
| 8 | X | X | 0.1484 |
| 6 | X | X | 0.1489 |
| 4 | X | X | 0.1525 |
| 2 | X | X | 0.1600 |

Here's the code used for further analysis:

```
size = [275 137 91 68 53 49 39 29 35 28 25 23 19 16 15]'
T=size*2.835/1000
f=1./T

myDir = uigetdir;
myFiles = dir(fullfile(myDir, '*.jpg'));
contrast = zeros(length(myFiles), 1)
for k = 1:length(myFiles)
    j = length(myFiles)+1-k;
    baseFileName = myFiles(k).name;
    fullFileName = fullfile(myDir, baseFileName);

    I = imread(fullFileName);
    I = mean(I,3);

    x = 270;
    y = 200;
    w = 1050;
    h = 400;
    I = I(y:y+h,x:x+w);

    M = mean(I);
    mi = min(M);
    ma = max(M);
    contrast(j) = (ma-mi)/(ma+mi);
end

figure
contrast2 = contrast(1:15)
plot(f, contrast2, '-*')
xlabel('Spatial frequency (lines/mm)')
ylabel('MTF')
```

Plot the values in graph like the one below.



Find the spatial frequency for 10% contrast and compare the value with the pinhole diameter by writing a short comment!

Our measures and calculations do not allow us to determine this directly. We suppose a more or less linear relationship between the two in that region and expect that value to be reached at around 27lines/mm.

Spatial frequency at 10% contrast

**$f_{10\%}$ = 27lines/mm** (see explanation above)

The pinhole has a diameter of 100 micron.

What is the optical regime for our pinhole camera – geometric or far field diffraction (lecture!!)

We are pretty close to the pinhole and so we would think we function in the geometric regime where the resolution is similar to the pinhole diameter but as shown by the calculation below, our values are closer to what we would get in the diffractive regime.

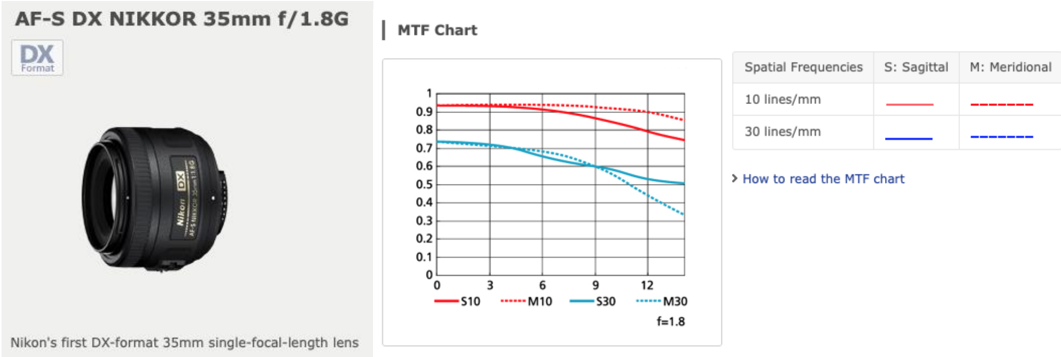
Comparison and discussion of spatial frequency at 10% contrast with pinhole diameter!

The pinhole has a diameter of 100um. With a spatial frequency of 27lines/mm, one line takes about 37um on our camera (13px) which is definitely not linear, not the geometric regime. Let's take $\lambda = 500nm$, $z = 7mm$ as in Question 4.3 and we get $\delta = 35um$ which corresponds to a resolution taken in the diffractive regime and is coherent with our supposed spatial frequency.

6.1

### 4.5 Example from the WEB

Find a MTF chart and the corresponding objective in the www web and print both the chart and an image of the objective (not an image taken with the objective!) in your report. Be prepared to explain the parameters given in the chart. Cite correctly!




**Source: https://imaging.nikon.com/lineup/lens/f-mount/singlefocal/normal/af-s_dx_35mmf_18g/**

There are two spatial frequencies (red/blue), the red curve at 10lines/mm is better as we get a greater contrast and so the smaller the spatial frequency the greater the contrast we get.

Also, the x-axis represents the distance from the center of the camera, the further we are the worse is the contrast, it is not homogeneous. It diminished on the borders no matter the spatial frequency.

This is part of the reason why cameras have a hard time capturing stripes on a t-shirt or other periodic patterns well and why those should be avoided in professional shootings.

**Personal feedback:**

Was the amount of work adequate? Very repetitive

What is difficult to understand? No

What did you like about it? --

How can we do better? By doing real TP ☺

# Index of comments

1.1 This is the blind test if you read the manual carefully... the labels are wrong... Generally the longer the distance, the larger the images would be, but the images will be fainter.

2.1 For this part, you did very well but not carefully. There is still a small cover on top of the camera, which is additional 0.78mm.

6.1 The formula in the manual shows that the distance to differentiate the geometric and diffraction is z=D^2/lambda = 100^2/500=20mm. Therefore the working region is still geometric region.