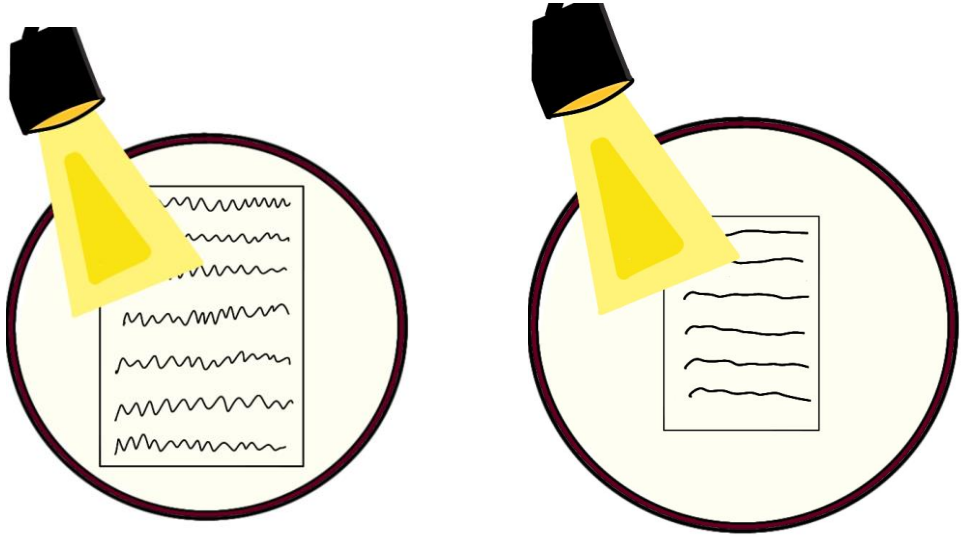
10. Blurred text

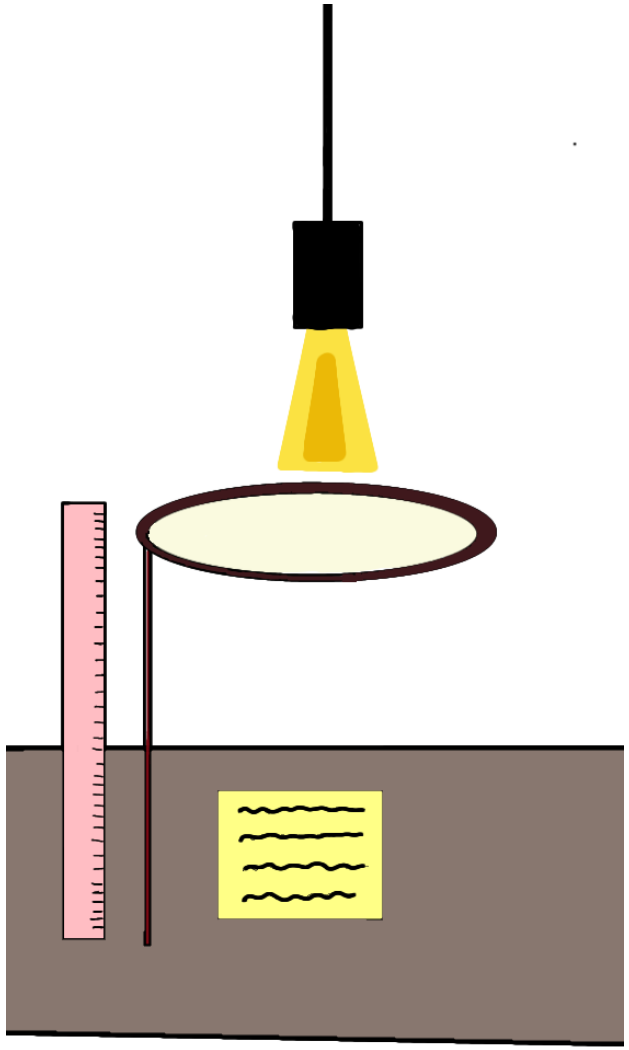
Printed text is well visible if covered with a piece of transparent film. As the film is lifted, the text becomes blurred and may gradually disappear. What parameters of the film are relevant? Investigate this phenomenon.

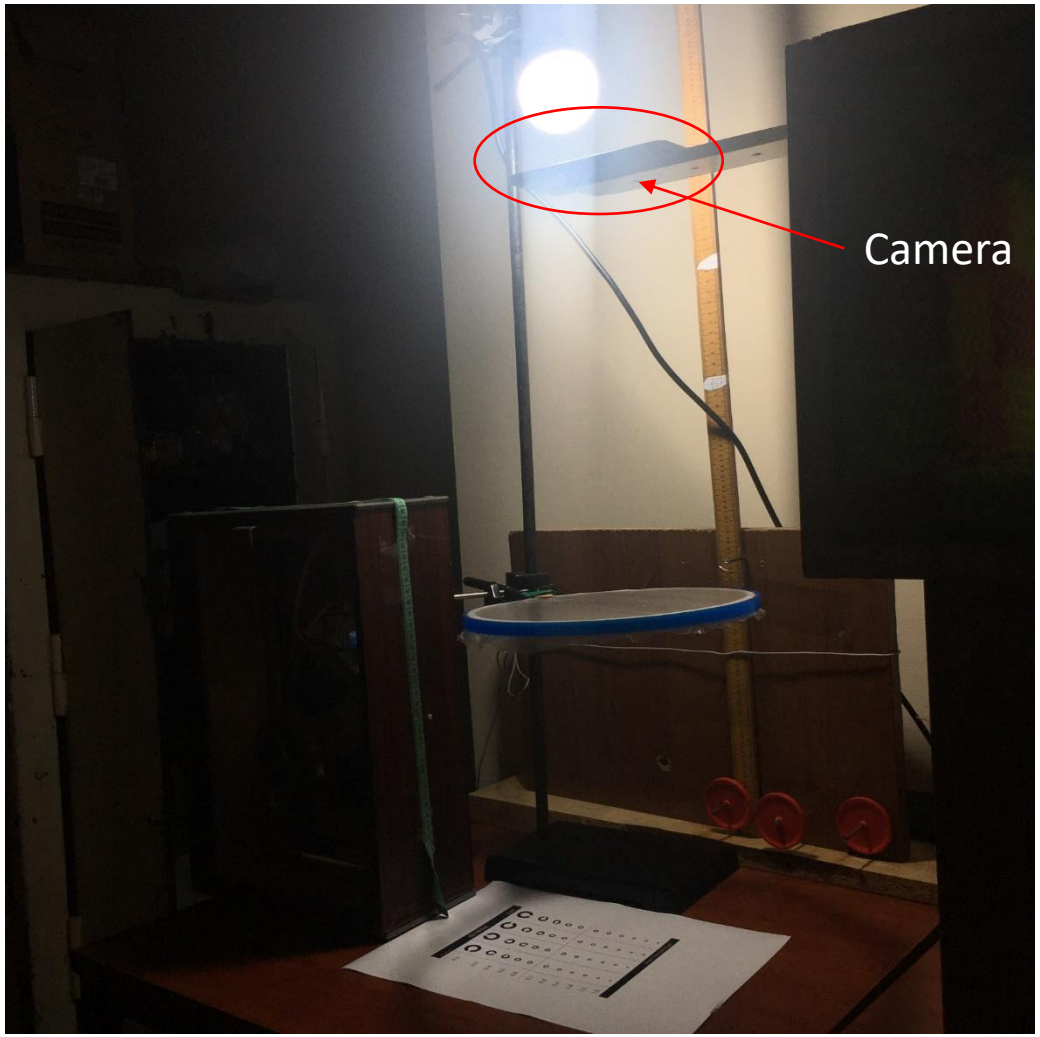


Presentation plan

- Theory
  - Why blurring occurs;
  - Calculation of light distribution from optical axis on any distance, building theoretical graph.
  - Relationship between maximum visibility and distance from optical axis
- Experiment
  - Blurring calculation for different film layers and different distance between script and film.
  - Measurement of light intensity distribution.
  - Observation on laser light for different film layers.
- Conclusion

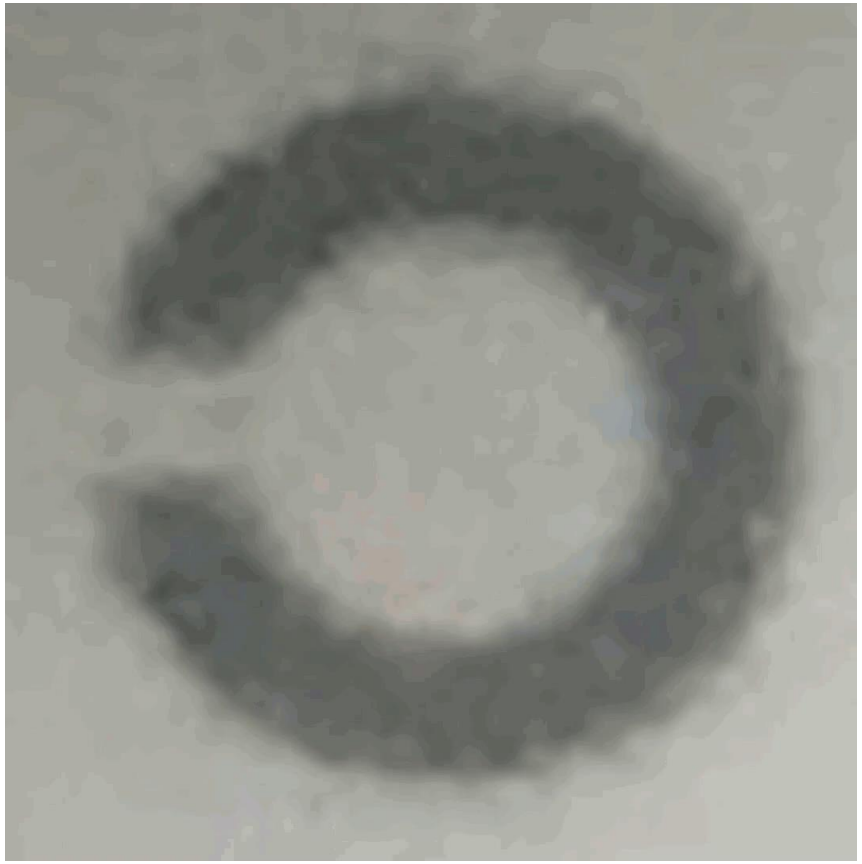
Experimental setup



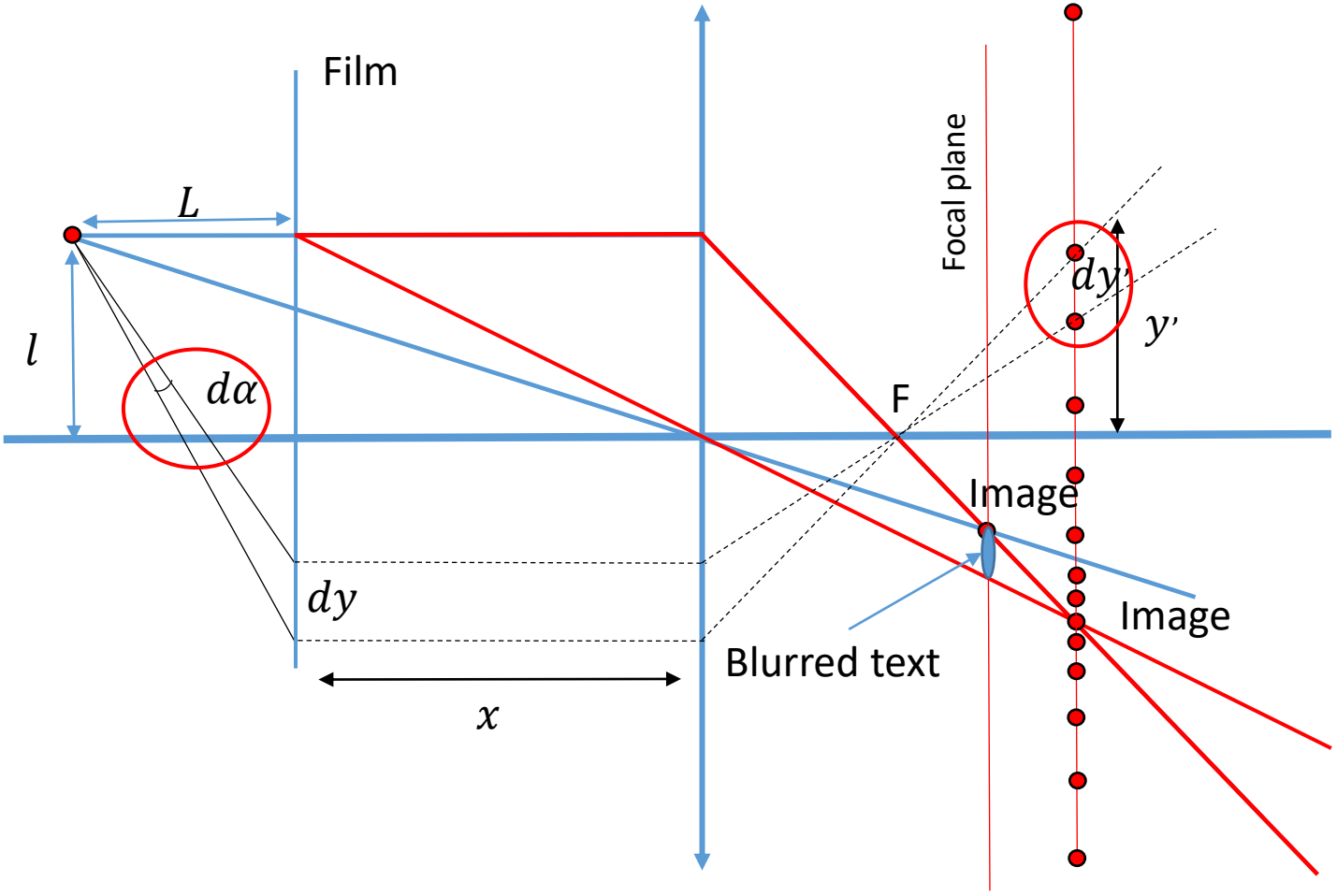


blurring caused by distance changing between film and script.

blurring caused by changing of film layers for fixed distance



Theoretical model



$$T = \frac{d_\alpha}{dy'} \qquad \boxed{T \sim I}$$

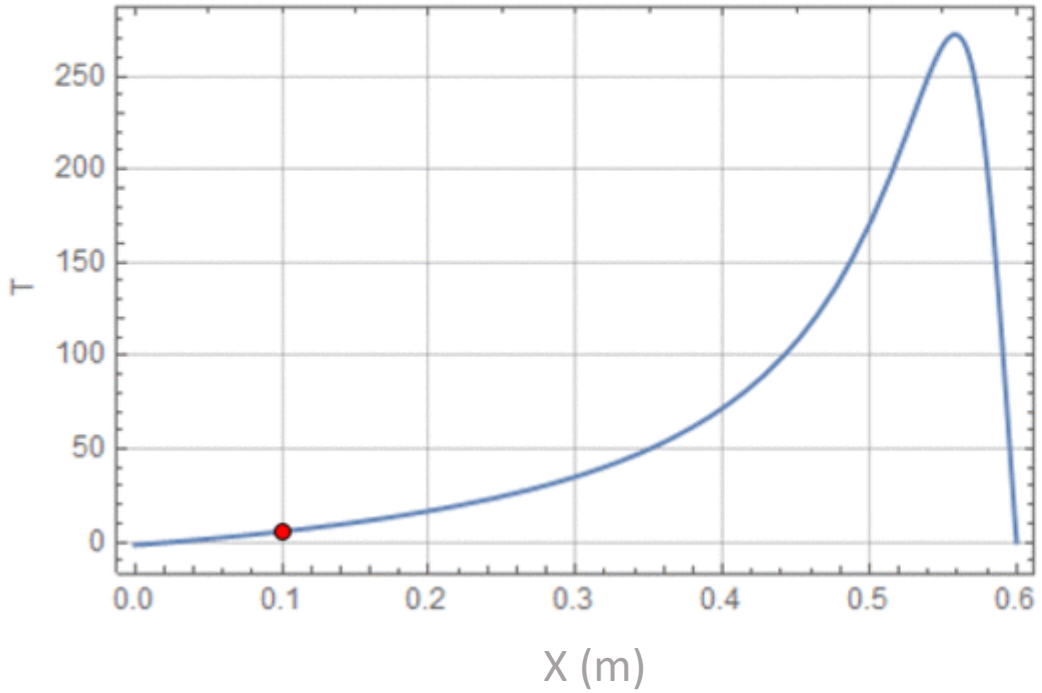
$$d_\alpha = \frac{L \;\; dy}{L^2 + (l + \frac{y'(x-F)}{F})^2}$$

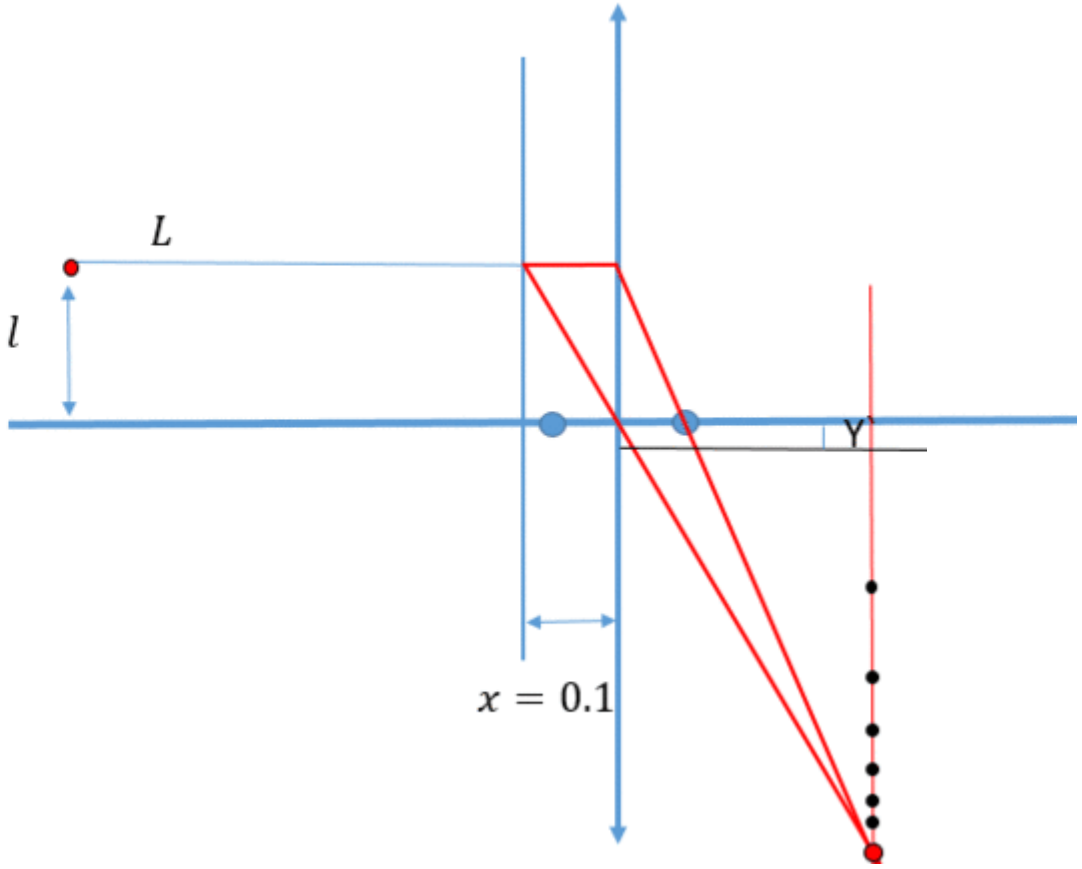
$$dy' = \frac{F \; dy}{x - F}$$

$$T = \frac{d_\alpha}{dy'} = \frac{L(x-F)}{F(L^2 + \left(l + \frac{y'(x-F)}{F}\right)^2)}$$

How distribution depend on distance between film and camera

$$T = \frac{(L_0 - x)(x - F)}{F\left(L^2 + \left(l + \frac{y'(x-F)}{F}\right)^2\right)}$$



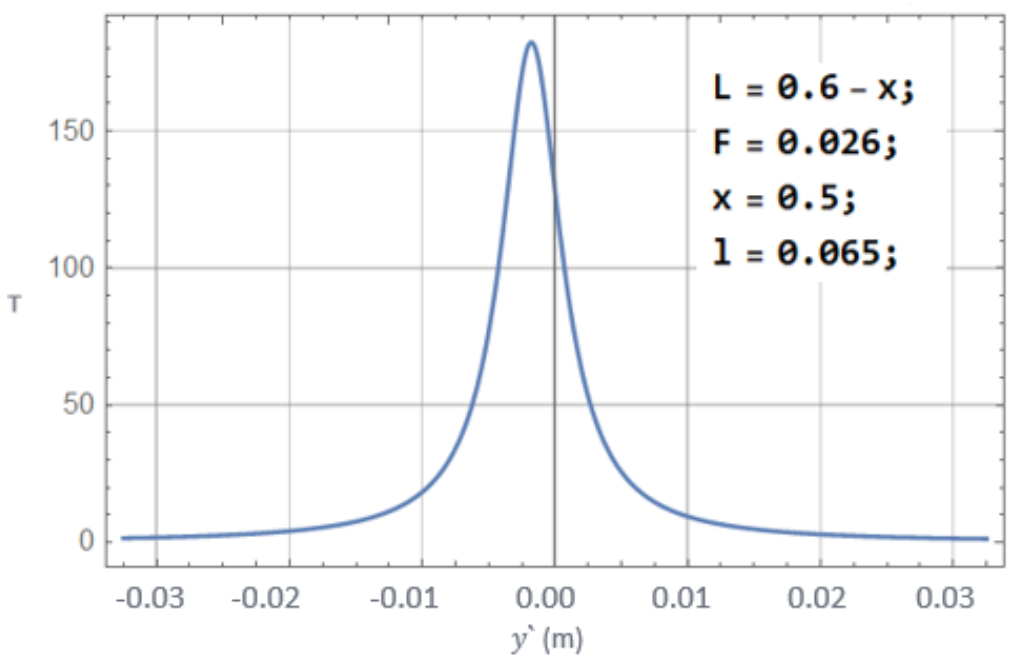


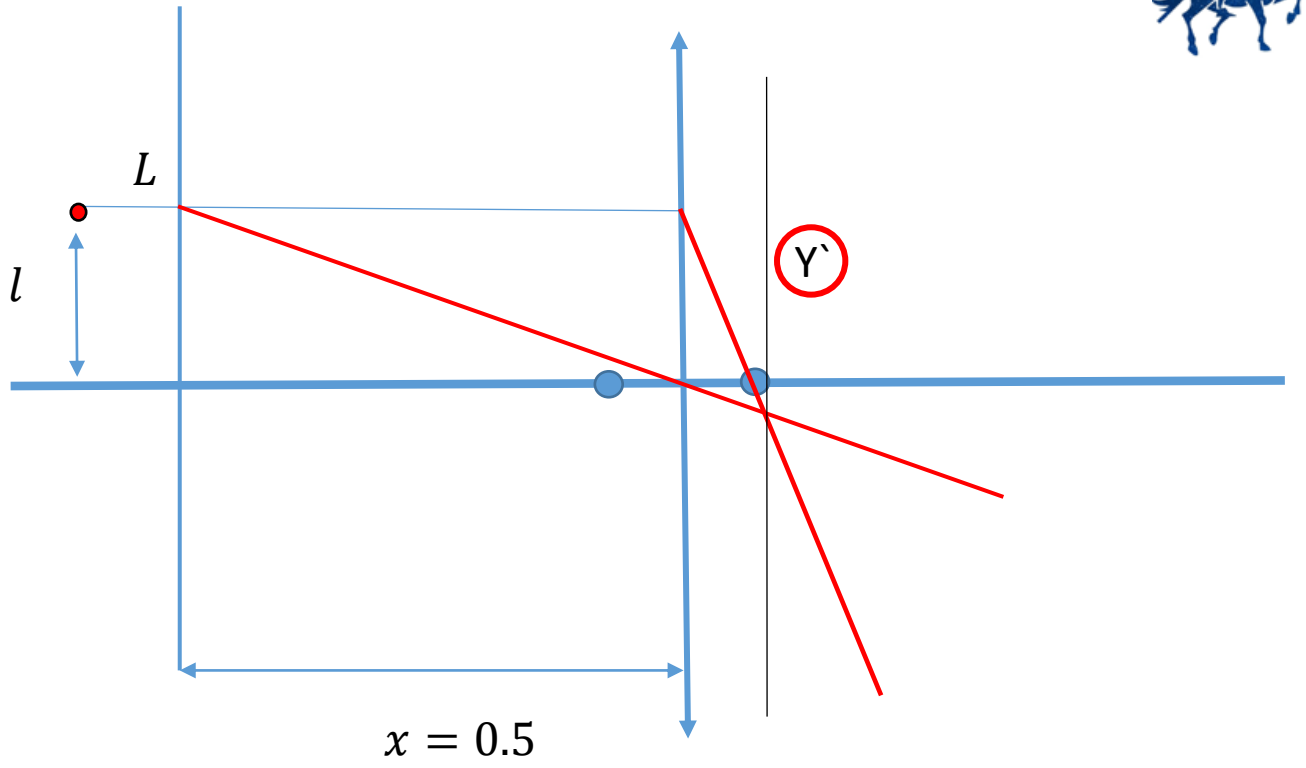
$L = L_0 - x$; $l = 0.065$; F=0.026;
y`=-0.0025; $L_0 = 0.6$;

0.00654216...

How distribution depend on distance from optical axis

$$T = \frac{(L_0 - x)(x - F)}{F\left((L_0 - x)^2 + \left(l + \frac{y`(x-F)}{F}\right)^2\right)}$$





Find maximum of y`

$$T` = \left(\frac{L(x-F)}{F\left(L^2 + \left(l + \frac{y`(x-F)}{F}\right)^2\right)}\right)` = 0 \qquad |y`| = \frac{F\sqrt{l^2+L^2}}{|F-x|} \qquad y` = -0.00364216...$$

Determining visibility

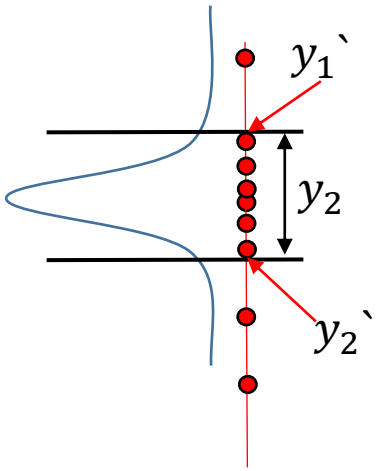
If $T > B$ *we can read the text*

$$T > B$$

$$\frac{L(x-F)}{F\left(L^2+\left(l+\frac{y'(x-F)}{F}\right)^2\right)} > \mathrm{B}$$

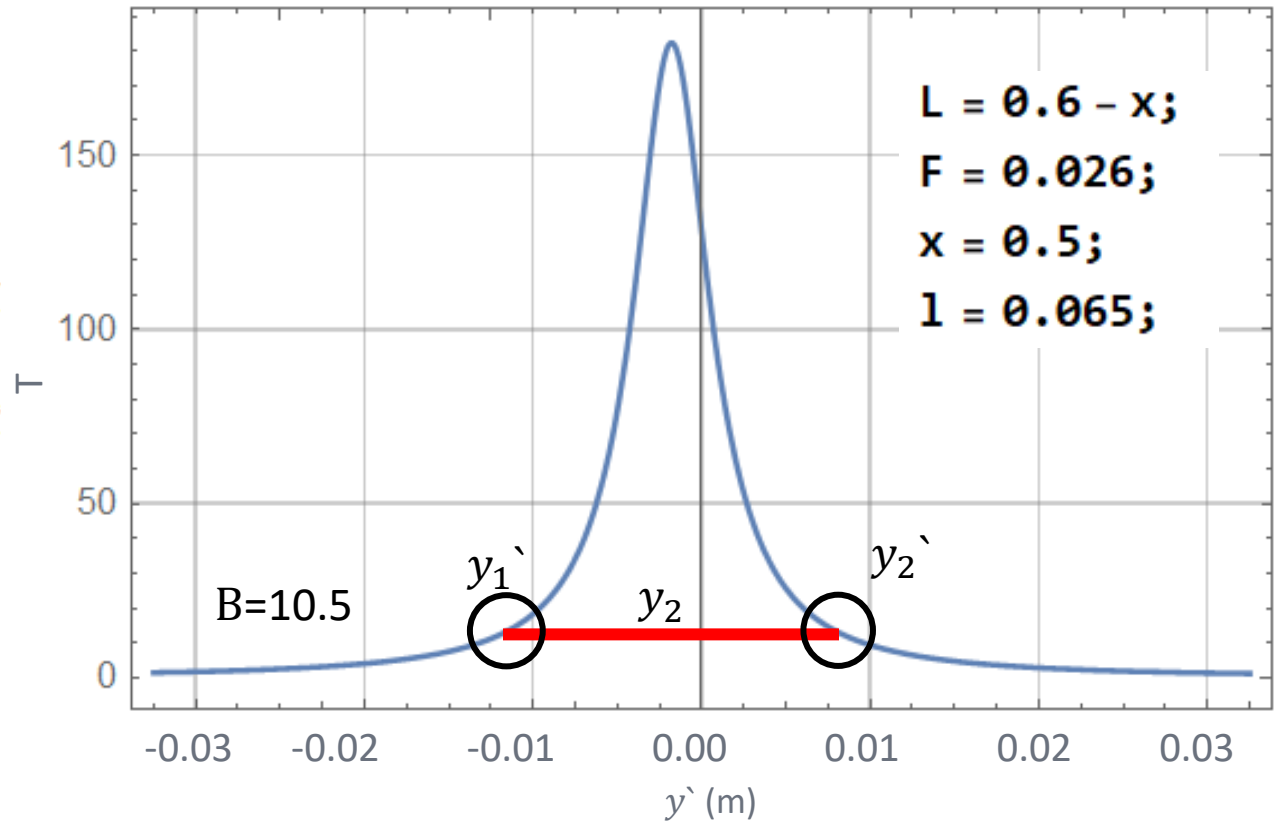
$$\frac{D}{4} = B^2 l^2 (x-F)^2 - \frac{B(x-F)^2(BFl^2 + BFL^2 + LF - Lx)}{F}$$

$$Y_2 = \frac{F\left(-Bl(x-F) + 2\sqrt{\frac{D}{4}}\right)}{B(x-F)^2}$$

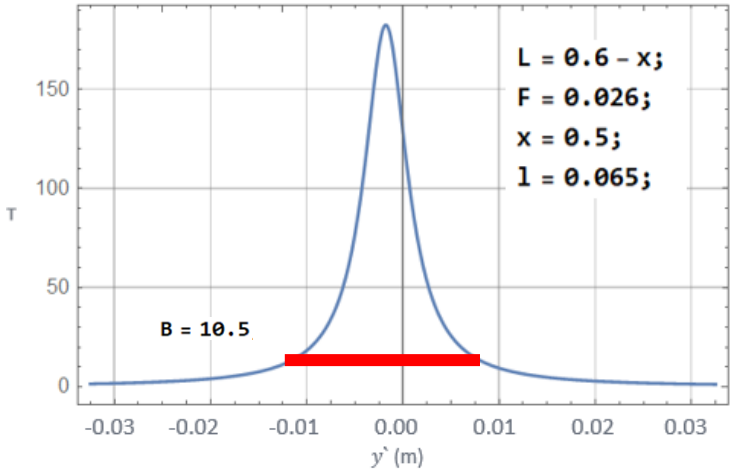


when $B = 10.5$ and X=0.5

$y_2 = 0.02811$

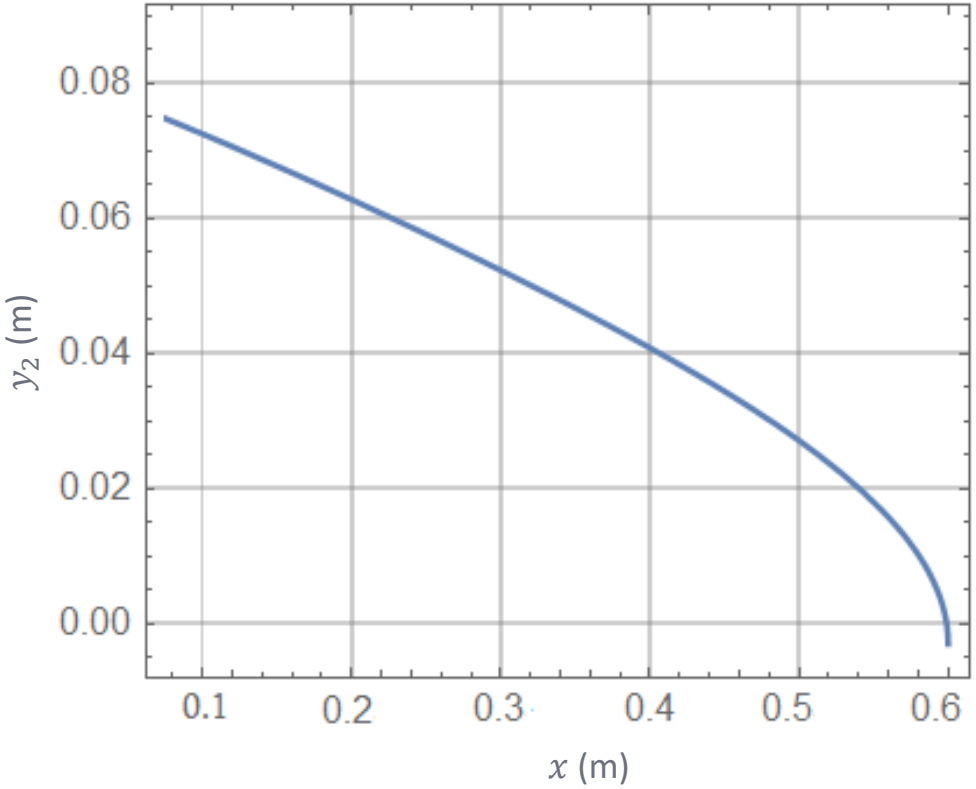


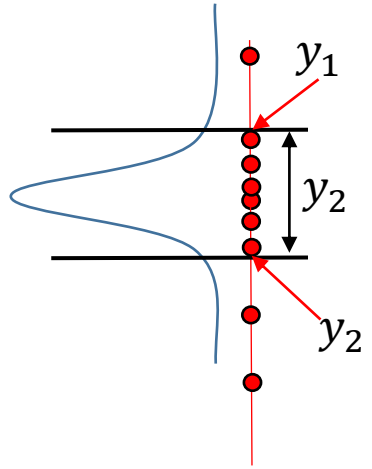
How Resolution depend on x



$$Y_2 = \frac{F(-Bl(x-F) + 2\sqrt{\frac{D}{4}})}{B(x-F)^2}$$

```
L = 0.6 – x;
B = 10.5;
F = 0.026;
l = 0.065;
```

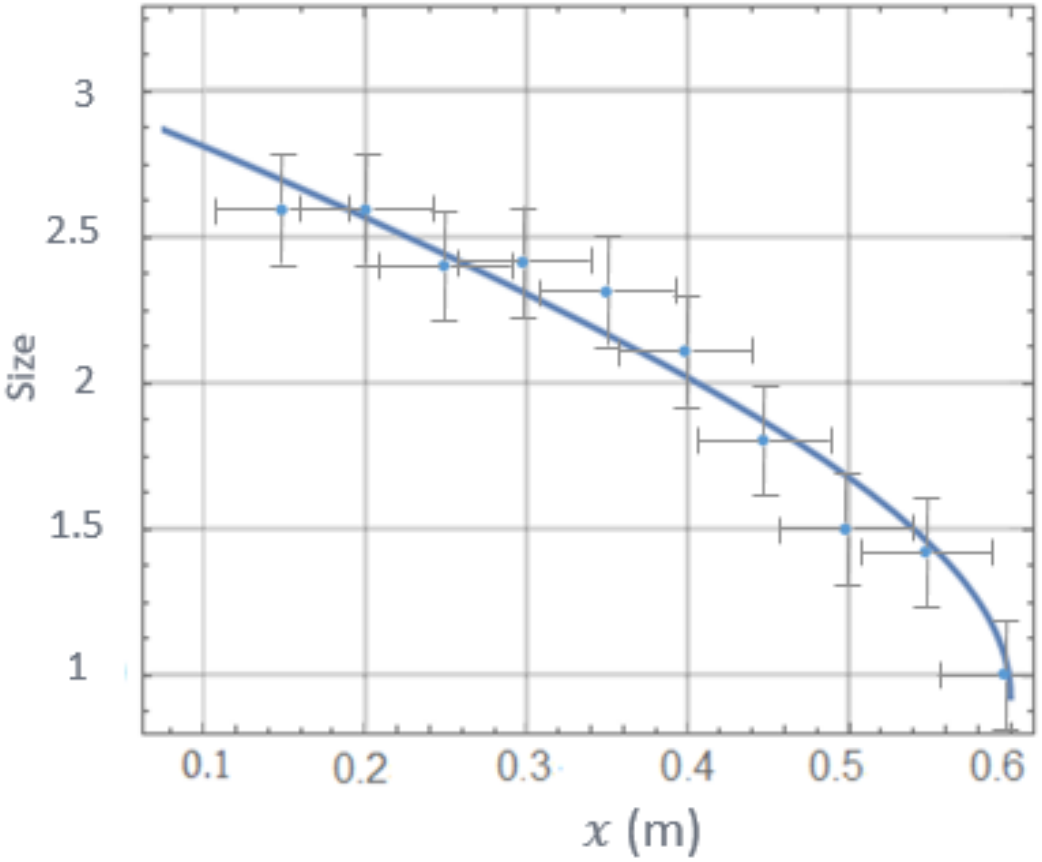




How letters expansion depended on distance between film and camera

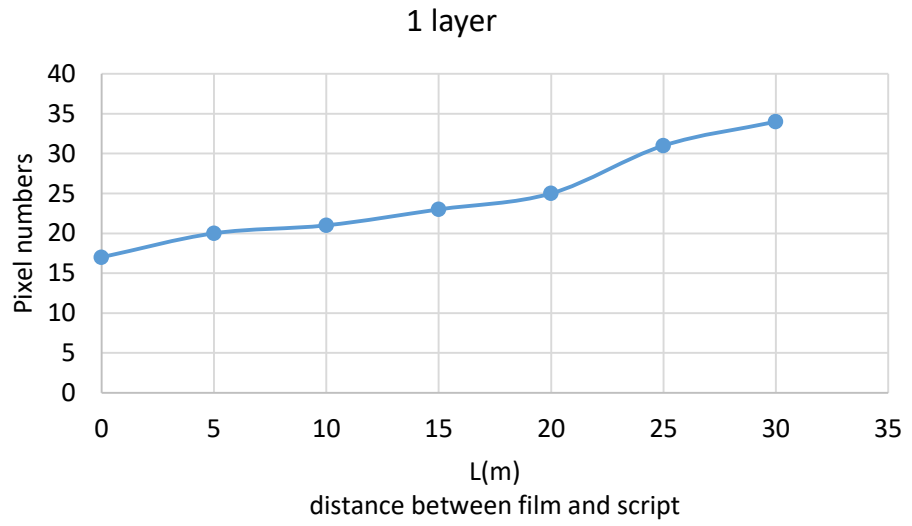
X-Distance between film and camera
n-ring number

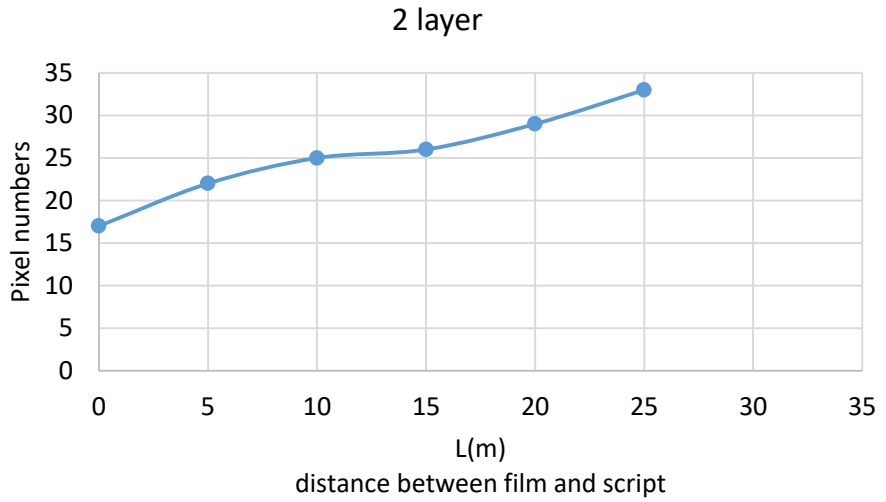
x \ n	I	II	III	IV	V
0.6	17	12	9	8	7
0.55	20	13	10	9	8
0.5	21	14	11	10	9
0.45	23	15	12	11	10
0.4	25	16	14	11	11
0.35	31	20	15	12	11
0.3	34	25	19	13	12
0.25	37	26	28.8	14	X
0.2	39	30	X	X	X
0.15	44	31	X	X	X



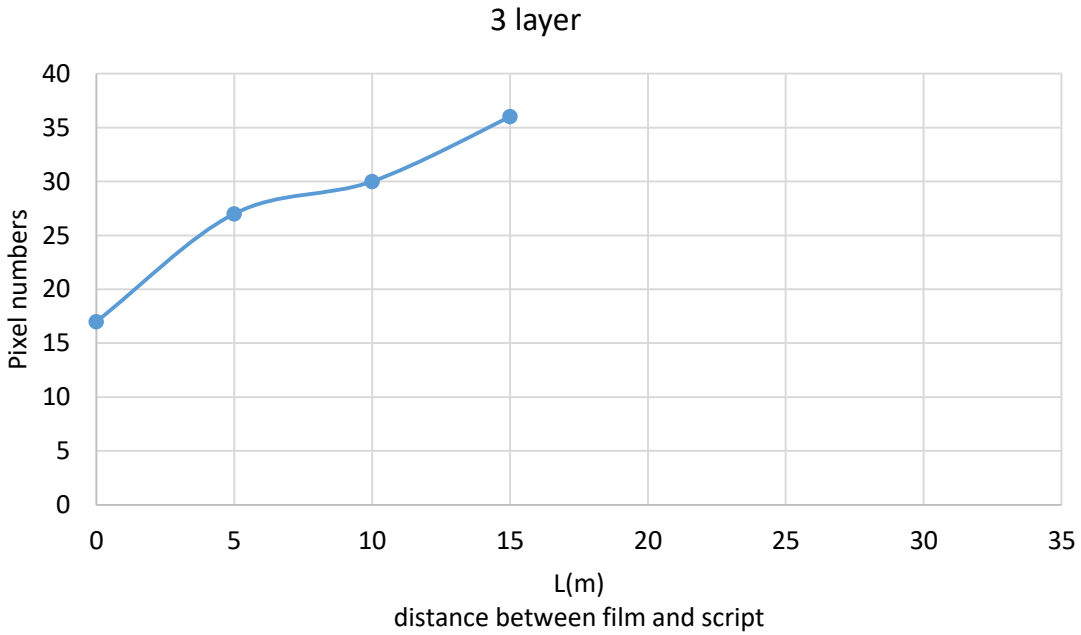
How Script expansion depended on distance between film and script

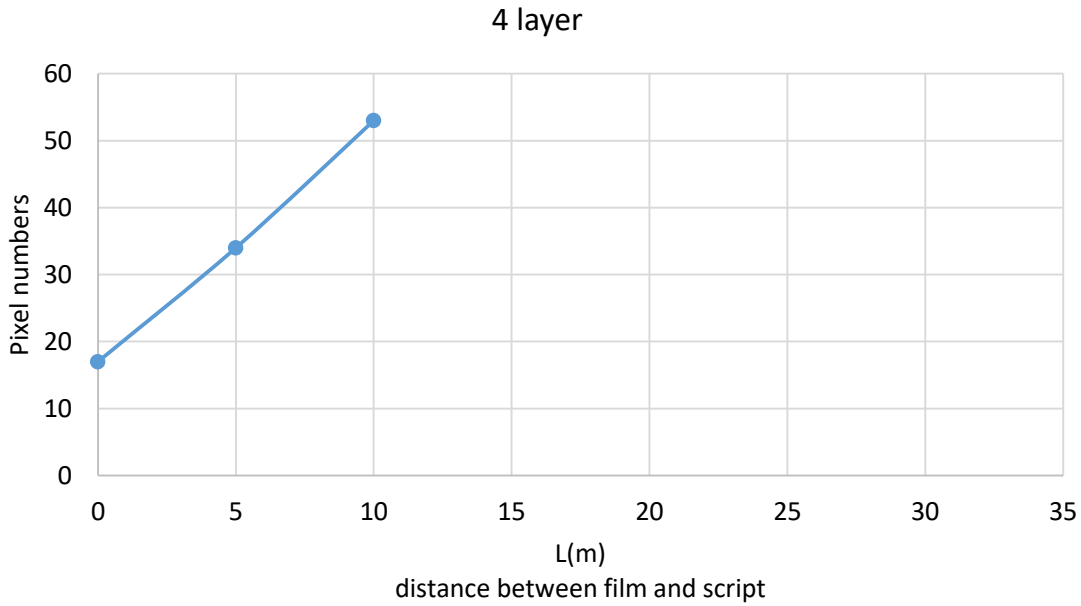
height	Pixel numbers			
	1 layer	2 layer	3 layer	4 layer
0	17	17	17	17
5	20	22	27	34
10	21	25	30	53
15	23	26	36	
20	25	29		
25	31	33		
30	34			





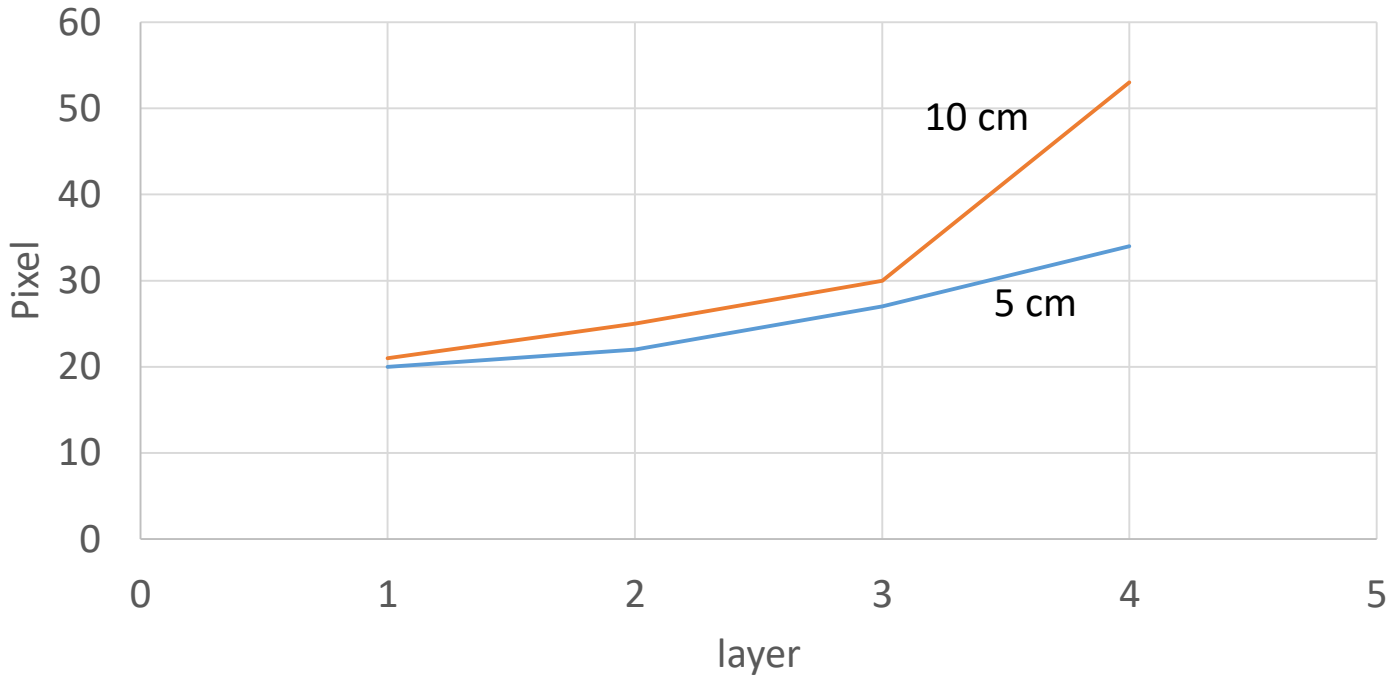
How Script expansion depended on distance between film and script



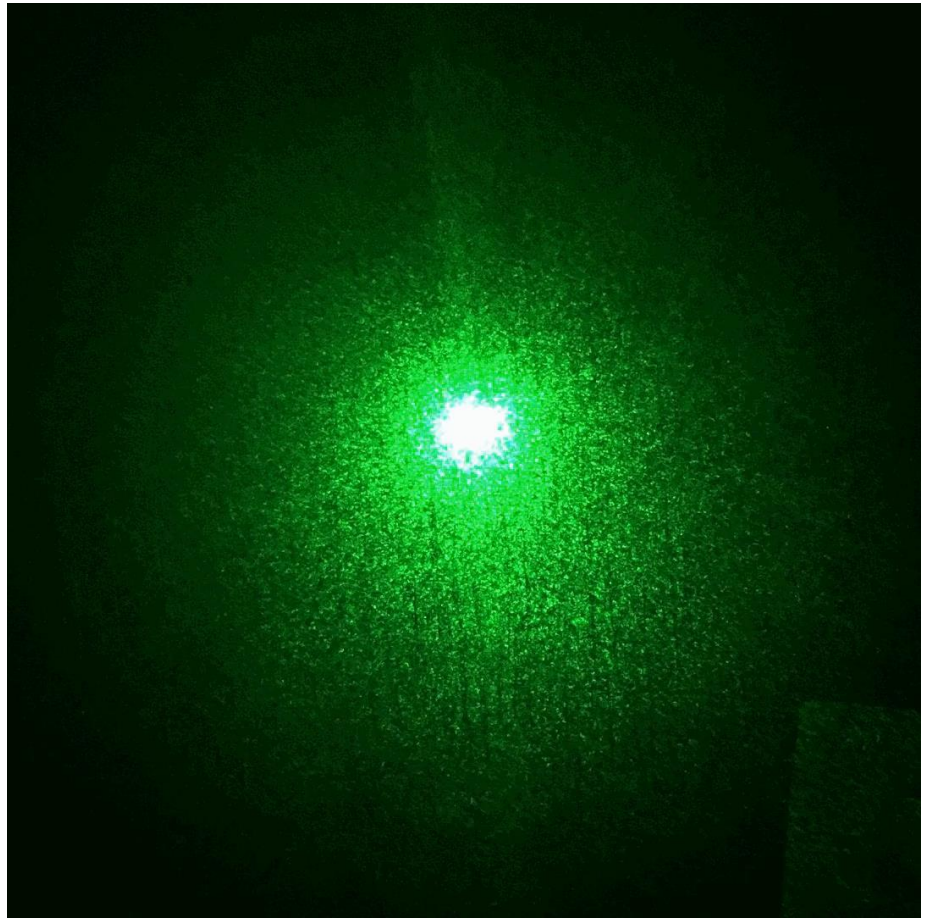


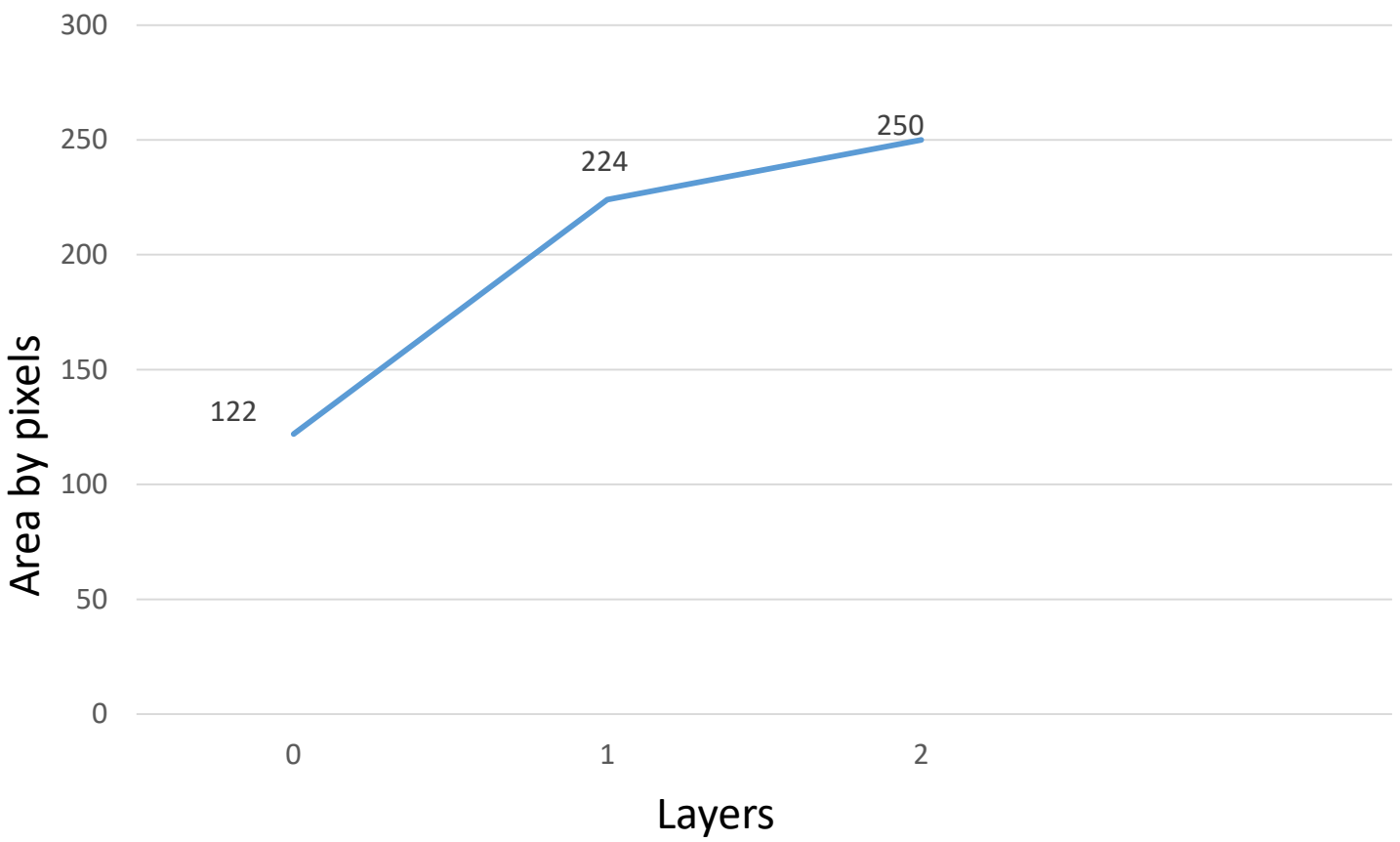
How Script expansion depended on layers

Distance	5 cm	10 cm
layer	pixel	
1	20	21
2	22	25
3	27	30
4	34	53



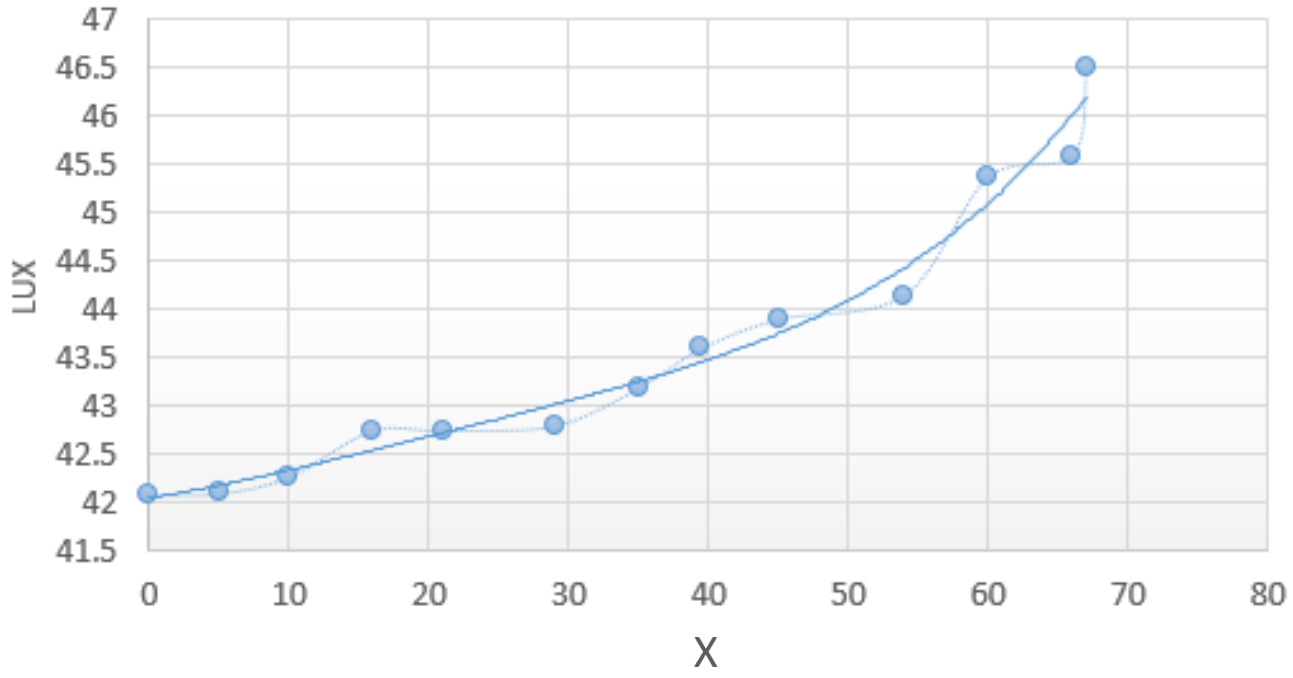
How light scattering is depended on layers number

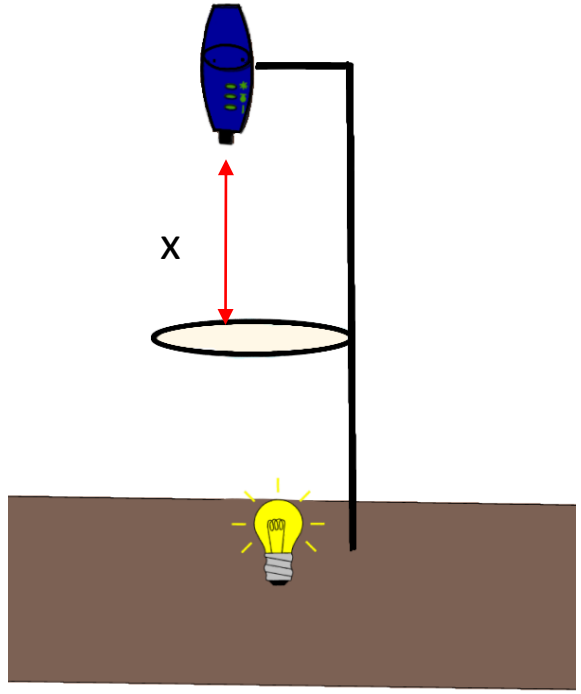




How luminosity is depended on distance

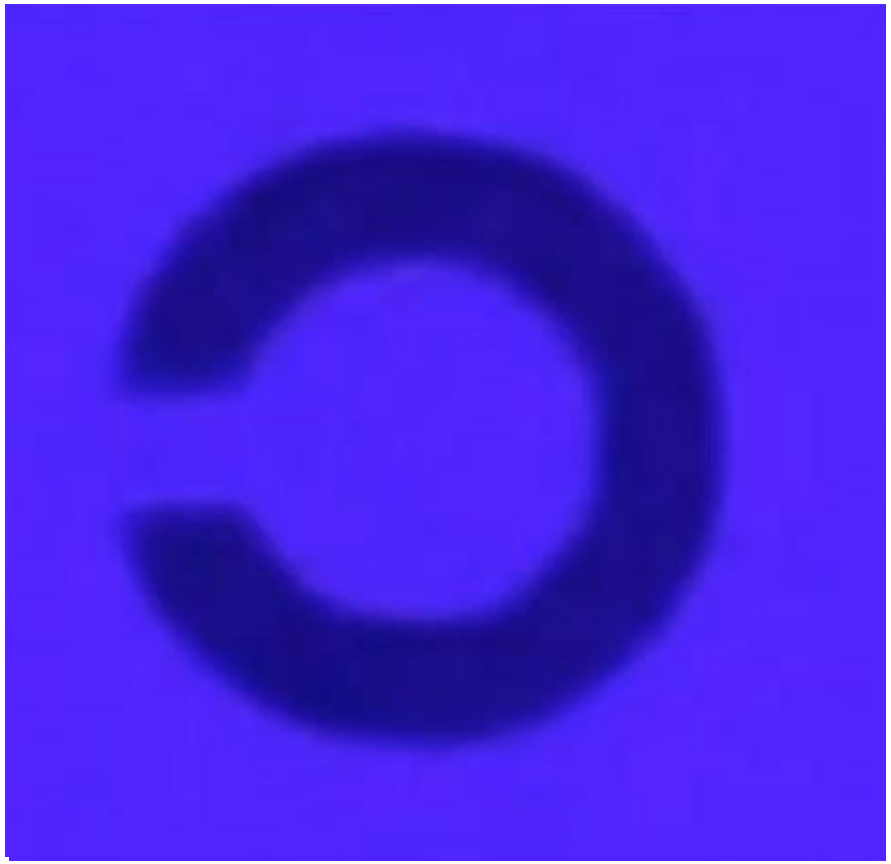
LUX	Distance
42.09	0
42.1	5
42.27	10
42.75	16
42.75	21
42.8	29
43.19	35
43.6	39.5
43.9	45
44.15	54
45.37	60
45.59	66
46.5	67





Blue paper

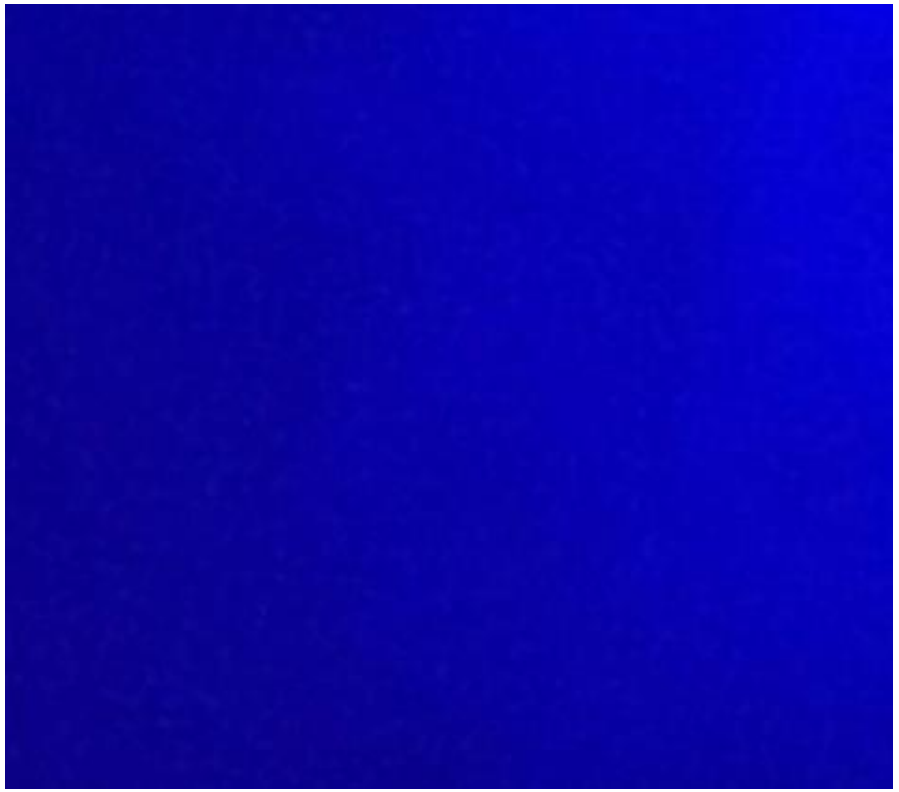
Blue light



Red light

Red paper

Blue light



Red light

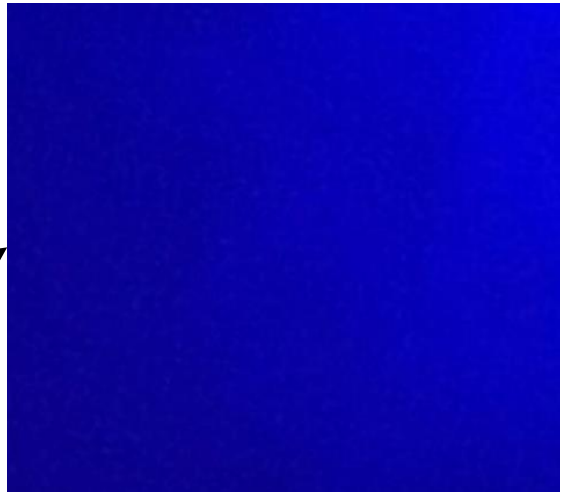
Contrast

Finding RGB for each experiment

				red	green	blue	
Blue paper	Blue light	letter	black	25	12	131	137.0365
		paper	blue	80	37	254	
	Red light	letter	black	85	13	11	64.57554
		paper	red	144	30	31	
Red paper	Blue light	letter	black	9	1	152	63.13478
		paper	blue	5	0	215	
	Red light	letter	black	91	6	10	166.4061
		paper	red	250	33	51	

$$A = \sqrt{(R_2 - R_1)^2 + (G_2 - G_1)^2 + (B_2 - B_1)^2}$$

Min Contrast

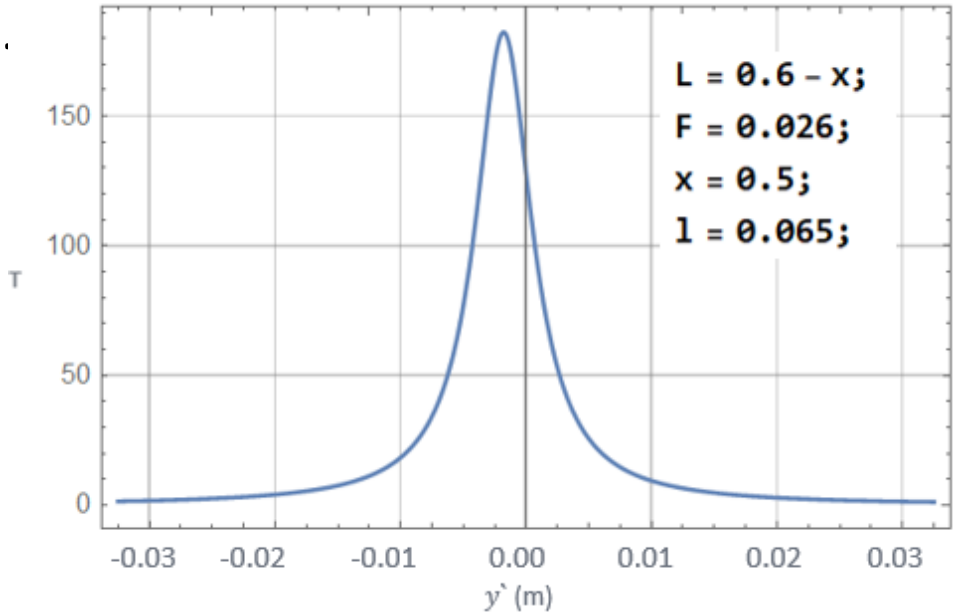


Max Contrast

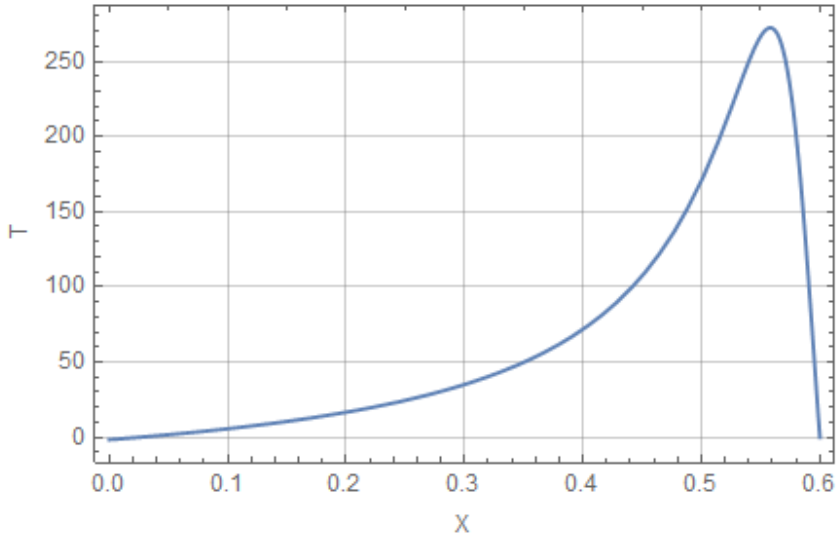
Conclusion

- Theory
  - Explained why blurring occurs.
  - Determined light distribution from optical axis on any distance.
  - Determined how is the visibility depended on file location.

How points distribution depend on distance from optical axis

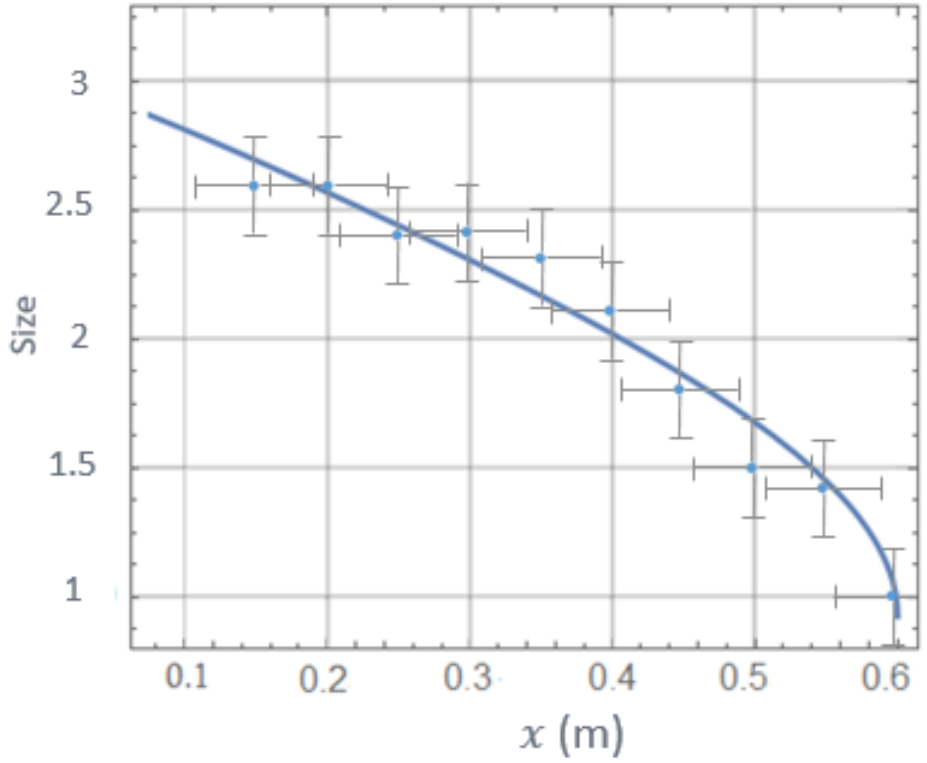


How points distribution depend on distance between film and camera

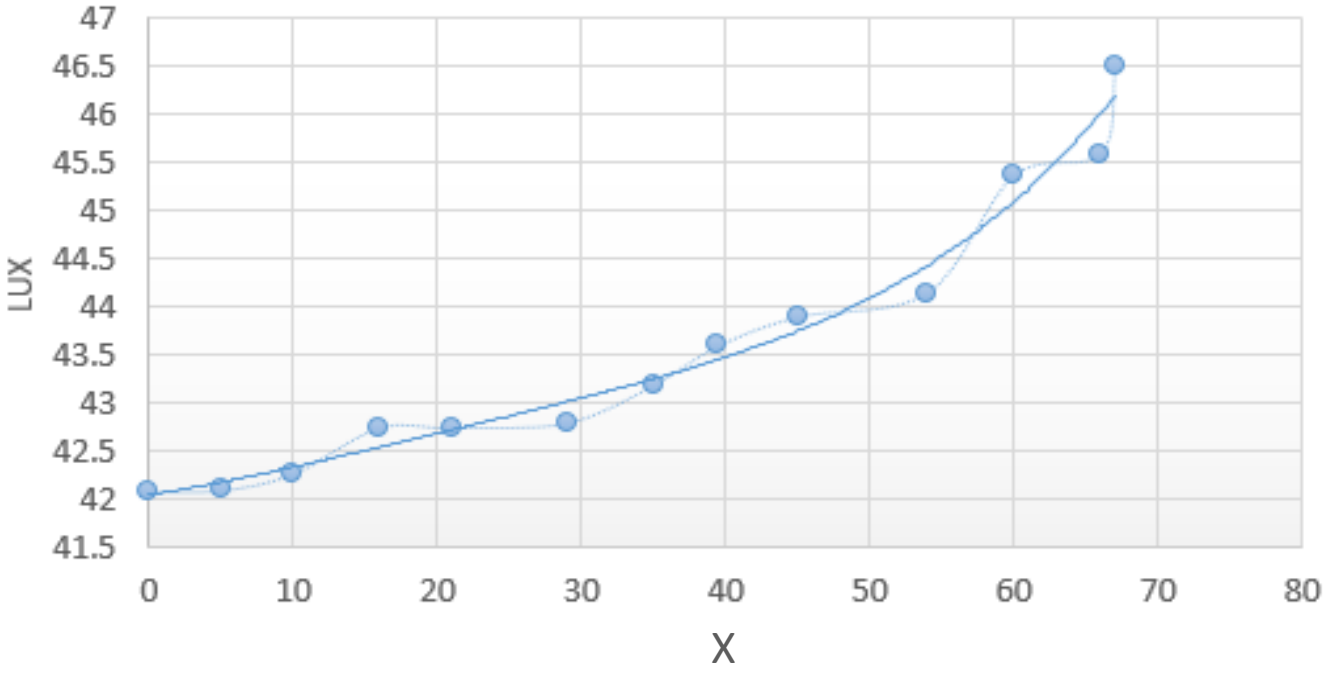


- Experiment
  - Calculated letters expansion for different film distance and layers.
  - Measured light changes with laser and light sensor.
  - Made an observation for different light and paper.

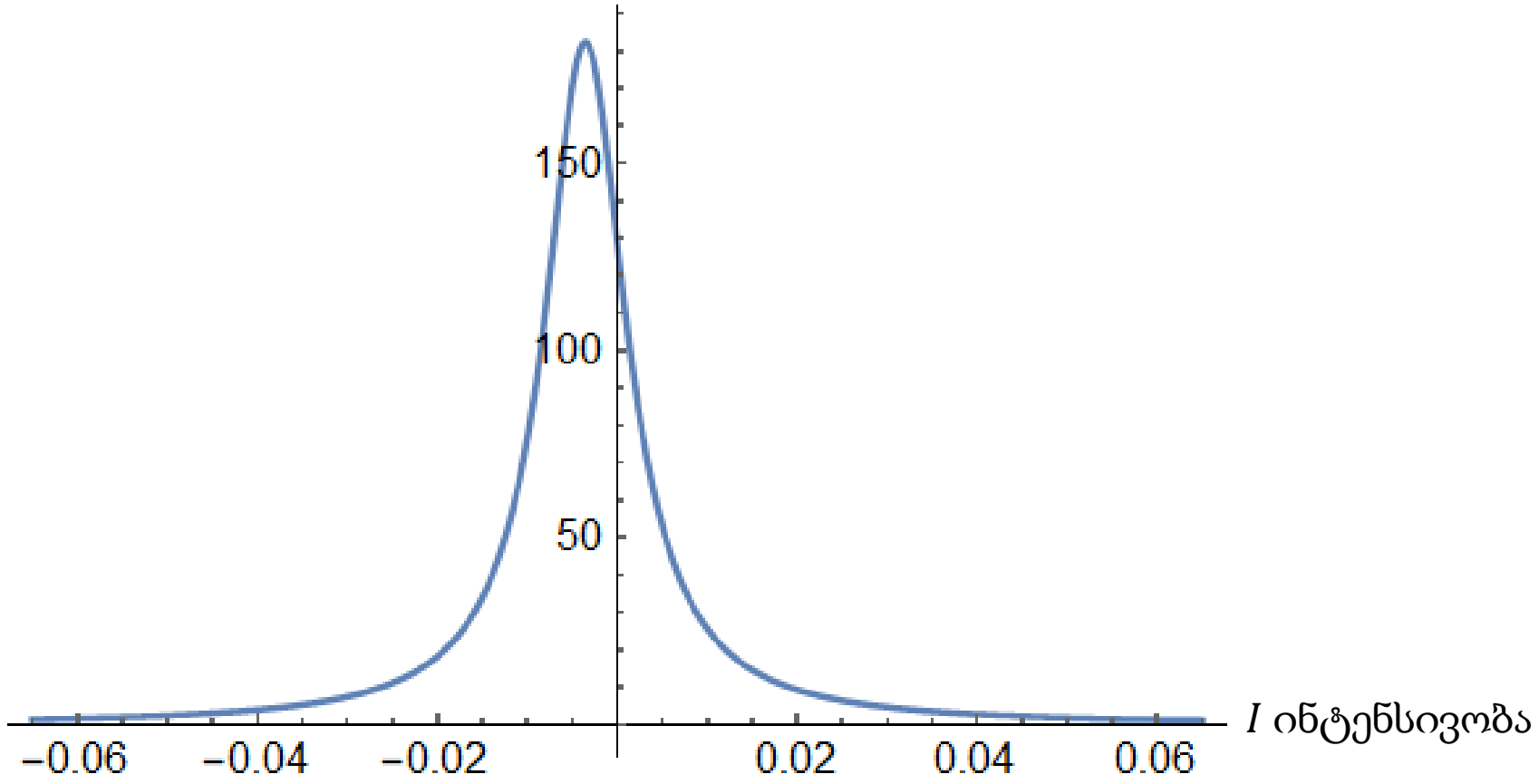
How changes letters size when we change distance between film and camera



How luminosity is depended on distance



Thanks for your attention!

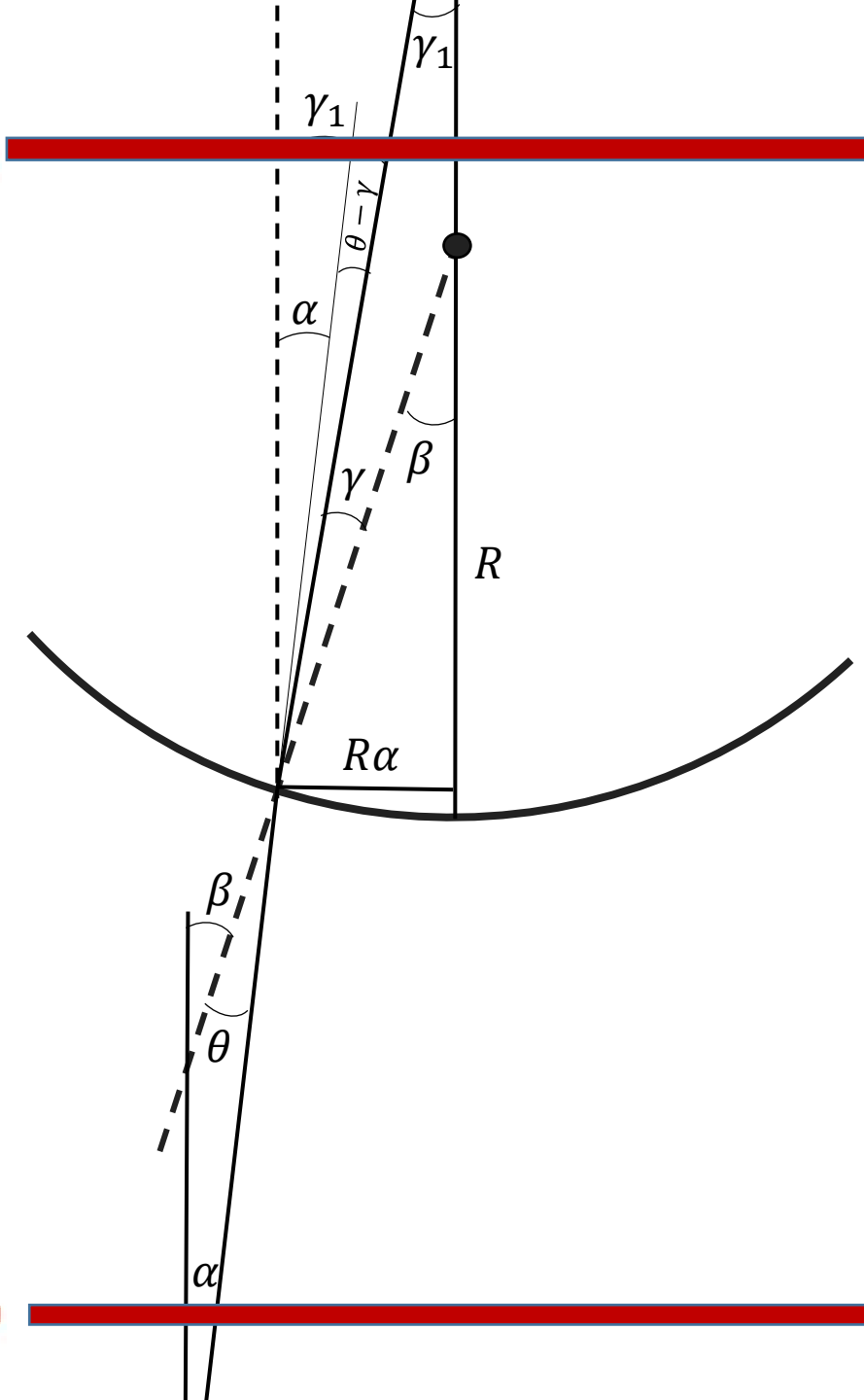

y` ოპტიკური ღერძიდან მანძილი
150
100
50
−0.06
−0.04
−0.02
0.02
0.04
0.06
I ინტენსივობა

$$I = \frac{L(x-F)}{F(L^2+\left(l+\frac{y'(x-F)}{F}\right)^2)} \qquad I > B$$

$$\frac{L(x-F)}{F(L^2+\left(l+\frac{y'(x-F)}{F}\right)^2)} > B$$

$$\frac{D}{4} = B^2l^2(x-F)^2 - \frac{B(x-F)^2(BFl^2+BFL^2+LF-Lx)}{F}$$

$$y' \in \left(\frac{F(-Bl(x-F)-\sqrt{\frac{D}{4}})}{B(x-F)^2}, \frac{F(-Bl(x-F)+\sqrt{\frac{D}{4}})}{B(x-F)^2}\right) \qquad Y_2 = \frac{F(-Bl(x-F)+2\sqrt{\frac{D}{4}})}{B(x-F)^2}$$



$$\theta - 180 - (\alpha + 180 - \beta) = \beta - \alpha$$

$$\sin\theta = n\sin\gamma$$

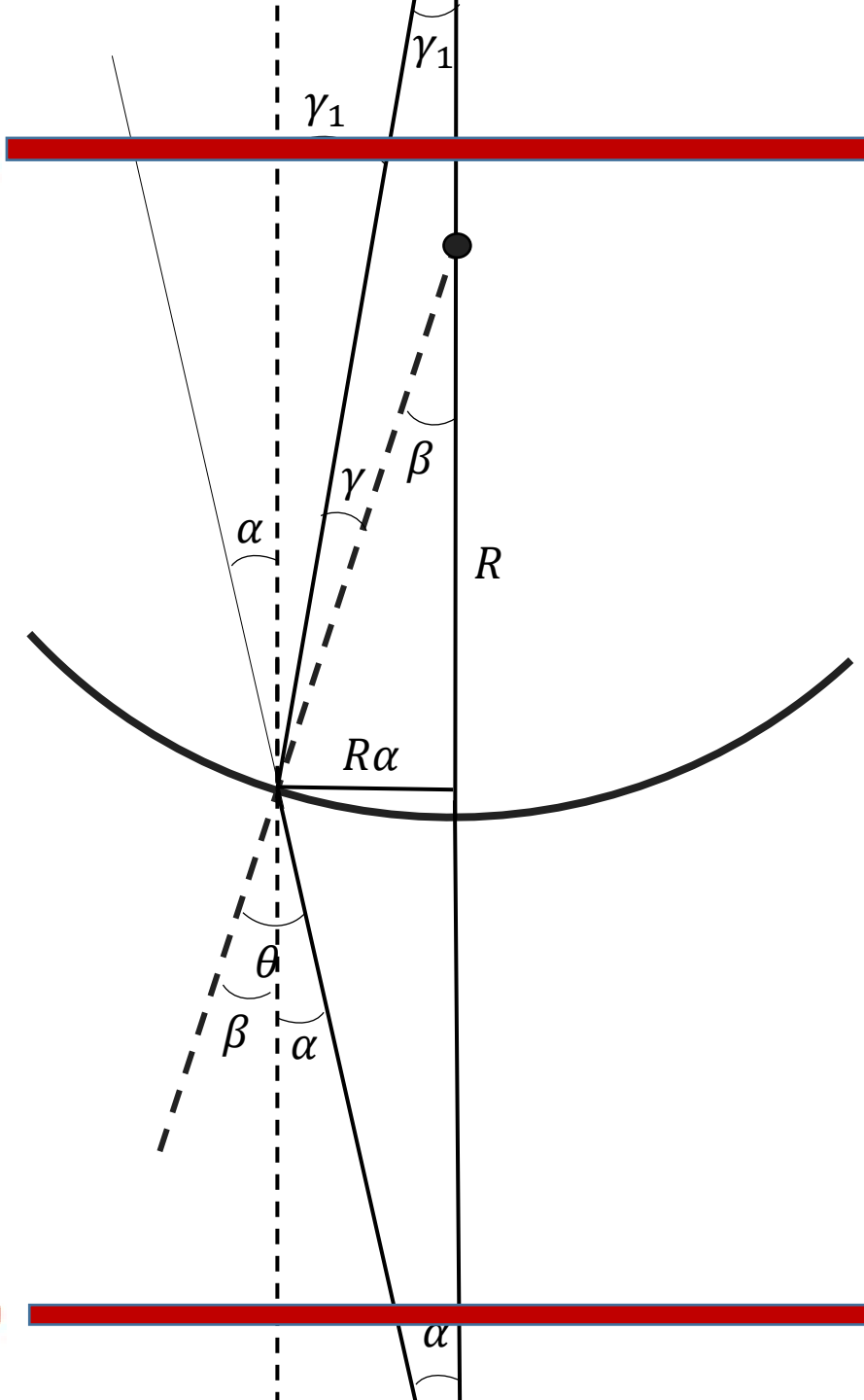
$$\sin(\beta - \alpha) = n\sin\gamma$$

$$\beta - \alpha = n\gamma$$

$$\gamma = \frac{\beta - \alpha}{n}$$

$$\theta - \gamma = \beta - \alpha - \gamma = (\beta - \alpha)\left(1 - \frac{1}{n}\right)$$

$$\gamma_1 = \alpha + \theta - \gamma = \alpha + (\beta - \alpha)\left(1 - \frac{1}{n}\right) = \beta\left(1 - \frac{1}{n}\right) + \frac{\alpha}{n}$$



$$\theta = \alpha + \beta$$

$$\sin\theta = n\sin\gamma$$

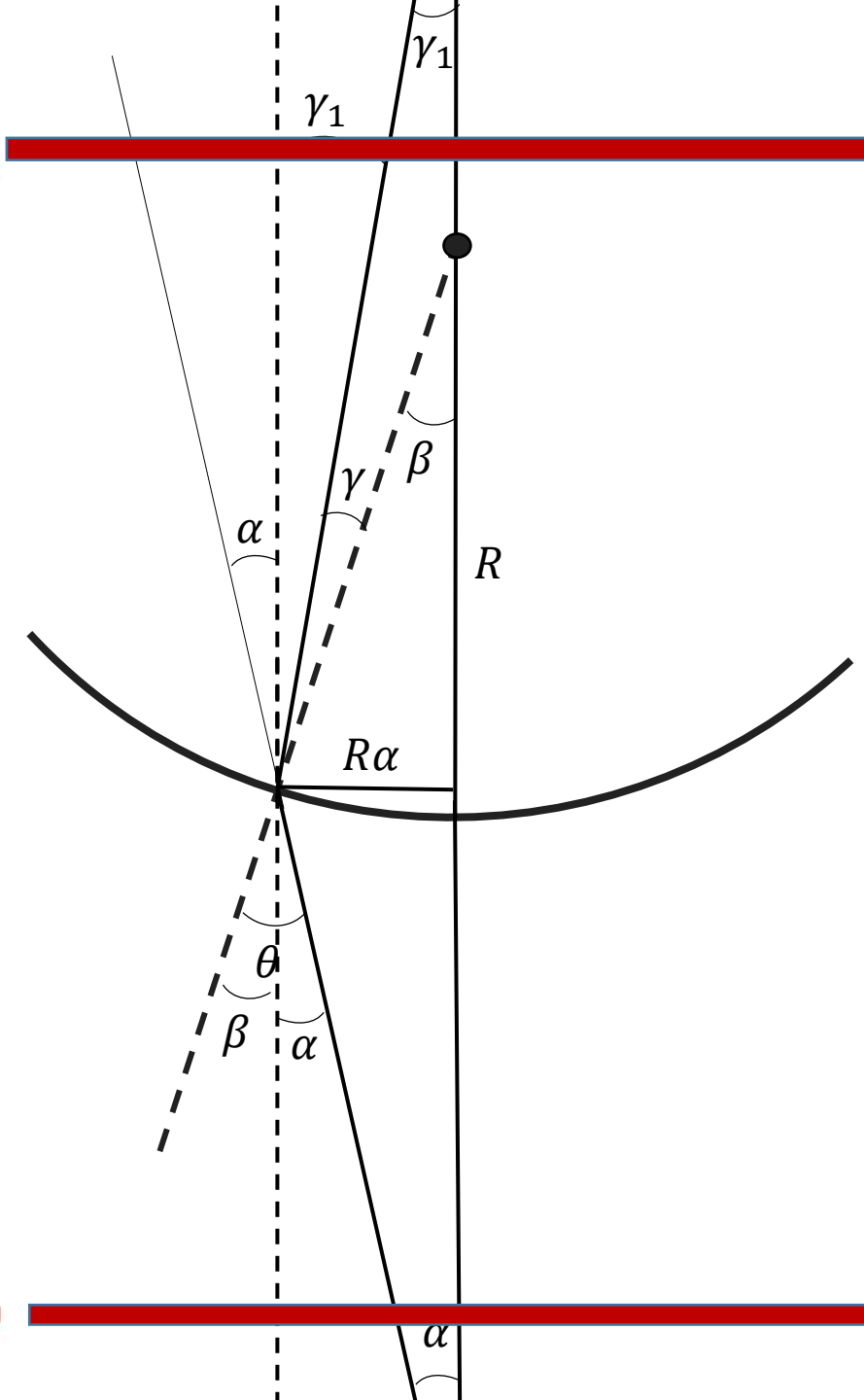
$$\sin(\beta - \alpha) = n\sin\gamma$$

$$\beta - \alpha = n\gamma$$

$$\gamma = \frac{\beta - \alpha}{n}$$

$$\theta - \gamma = \alpha + \beta - \gamma = \alpha + \beta - \frac{\beta - \alpha}{n}$$

$$\gamma_1 = \theta - \gamma - \alpha = \beta - \frac{\beta - \alpha}{n} =$$



$$\theta = \alpha + \beta$$

$$\sin\theta = n\sin\gamma$$

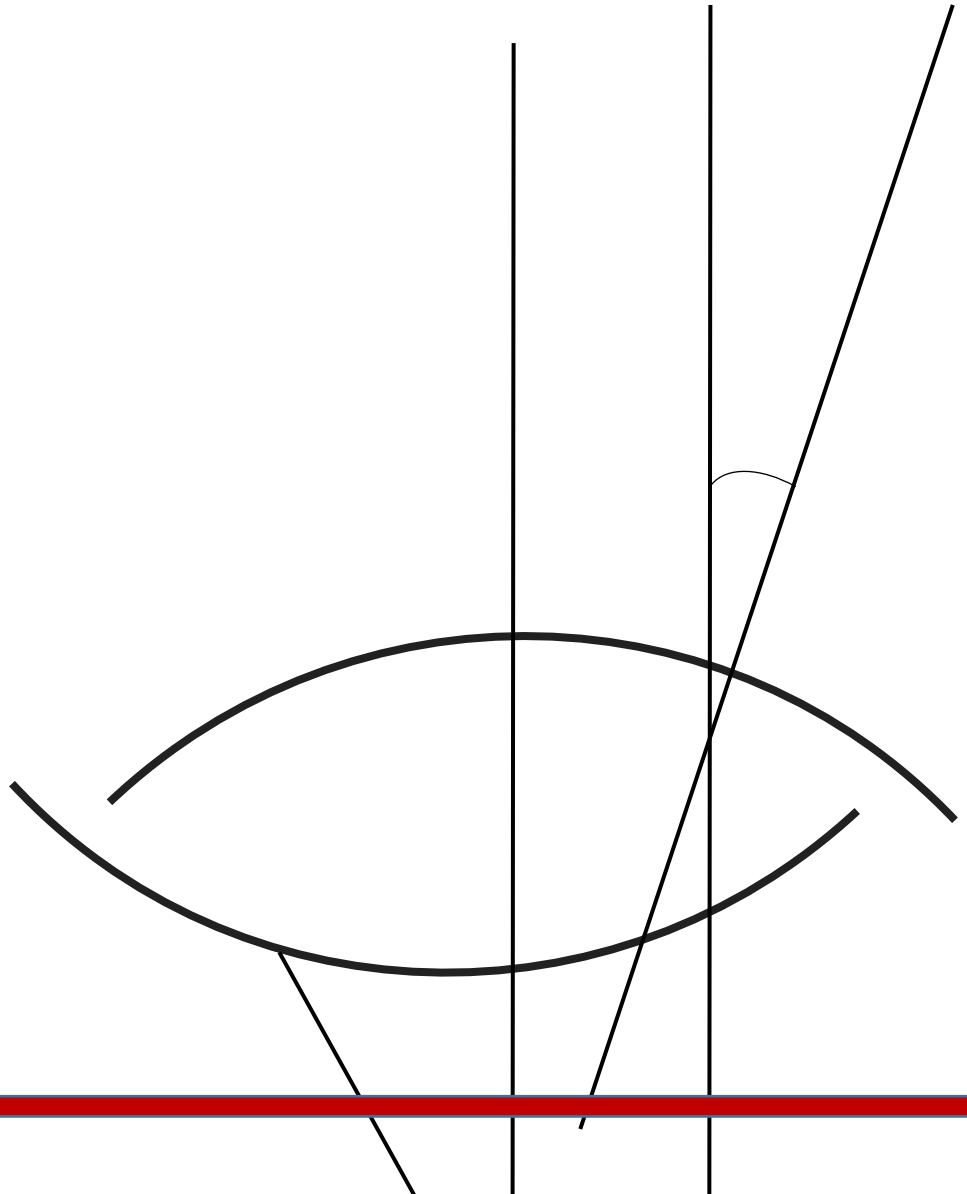
$$\sin(\beta + \alpha) = n\sin\gamma$$

$$\beta + \alpha = n\gamma$$

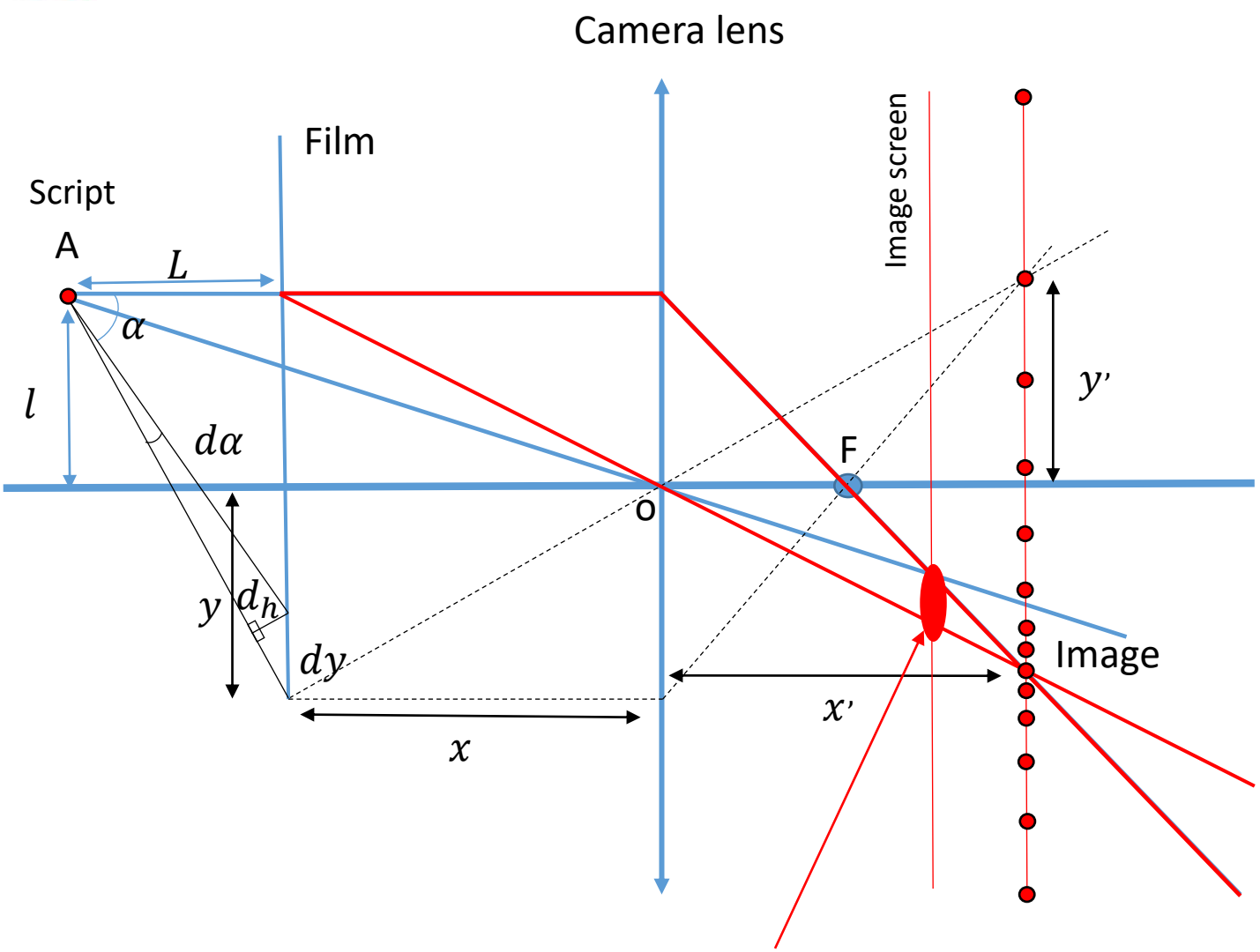
$$\gamma = \frac{\beta + \alpha}{n}$$

$$\theta - \gamma = \alpha + \beta - \gamma = \alpha + \beta - \frac{\beta + \alpha}{n}$$

$$\gamma_1 = \theta - \gamma - \alpha = \beta - \frac{\beta + \alpha}{n} =$$



ფაილის მდებარეობით გამოწვეული გაბუნდოვნება



$$dh = dy\sin(90 - a) \Rightarrow dh = dy\cos a$$

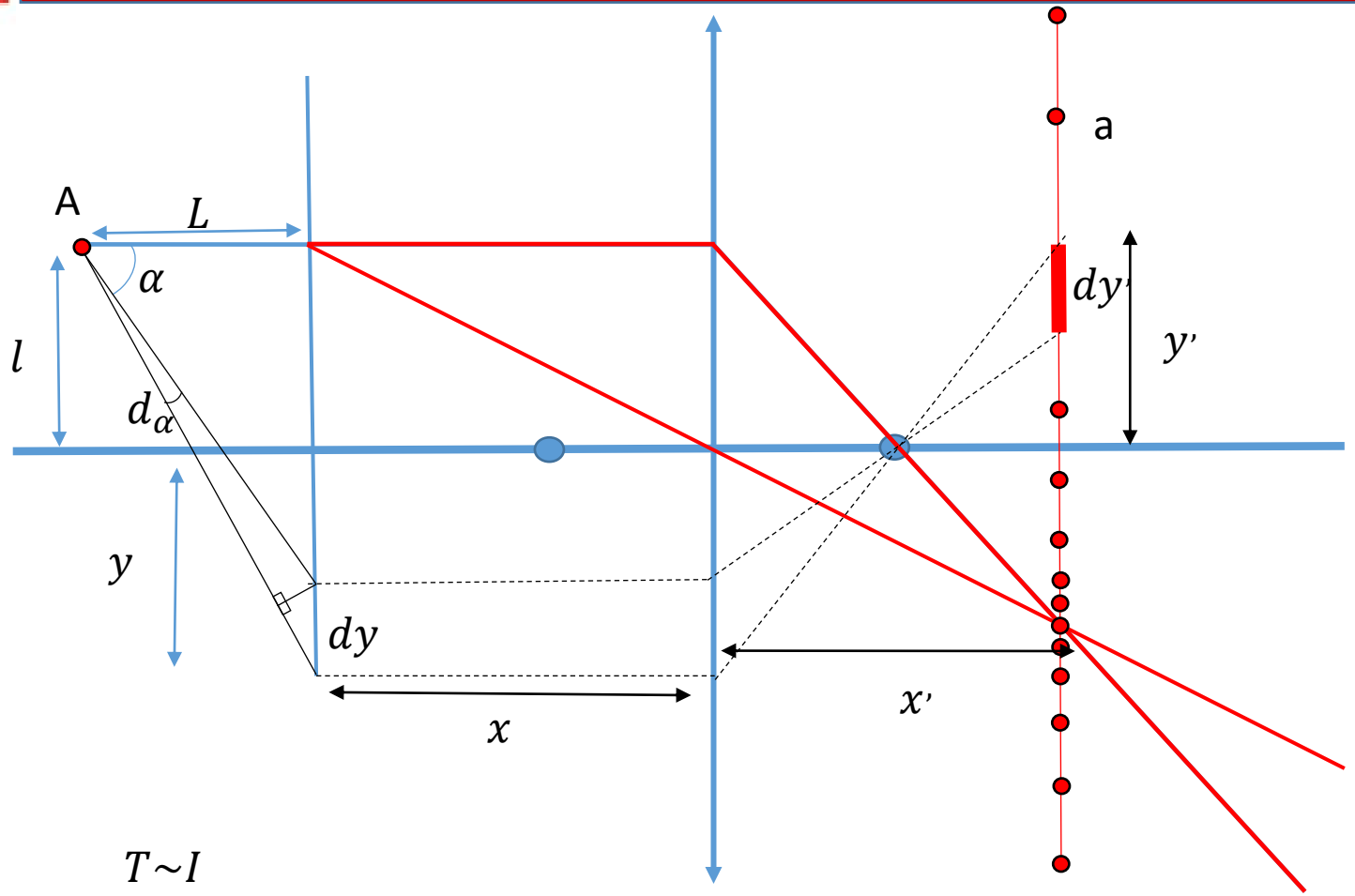
$$\begin{cases} d_\alpha = \dfrac{dy\cos a}{\sqrt{L^2 + (l+y)^2}} \\ \cos a = \dfrac{L}{\sqrt{L^2 + (l+y)^2}} \end{cases} \Rightarrow \quad d_\alpha = \frac{L\ dy}{L^2 + (l+y)^2}$$

$$\frac{y'}{y} = \frac{(x' - F)}{F} \Rightarrow y = \frac{Fy'}{(x' - F)} \Rightarrow \ y = \frac{y'(x - F)}{F}$$

$$\frac{1}{F} = \frac{1}{x} + \frac{1}{x'} \Rightarrow x' = \frac{Fx}{x - F}$$

$$d_\alpha = \frac{L\ \ dy}{L^2 + (l + \frac{y'(x - F)}{F})^2}$$

სინათლის გადანაწილების განსაზღვრა



$$\frac{1}{F}=\frac{1}{x'}+\frac{1}{x} \Rightarrow x'=\frac{Fx}{x-F}$$

$$\frac{y'}{y}=\frac{x'}{x}=\frac{F}{x-F}$$

$$y'=\frac{Fy}{x-F}$$

$$dy'=\frac{F\,dy}{x-F}$$

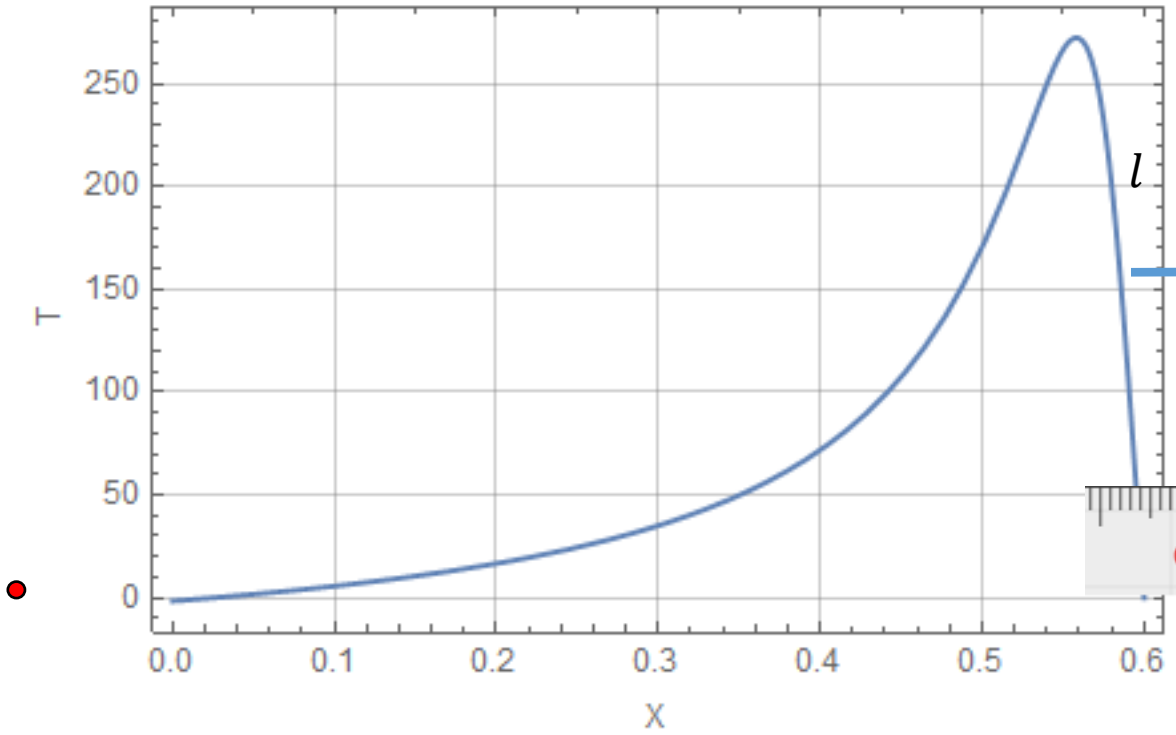
$$d_\alpha=\frac{L\ \ dy}{L^2+(l+\frac{y'(x-F)}{F})^2}$$

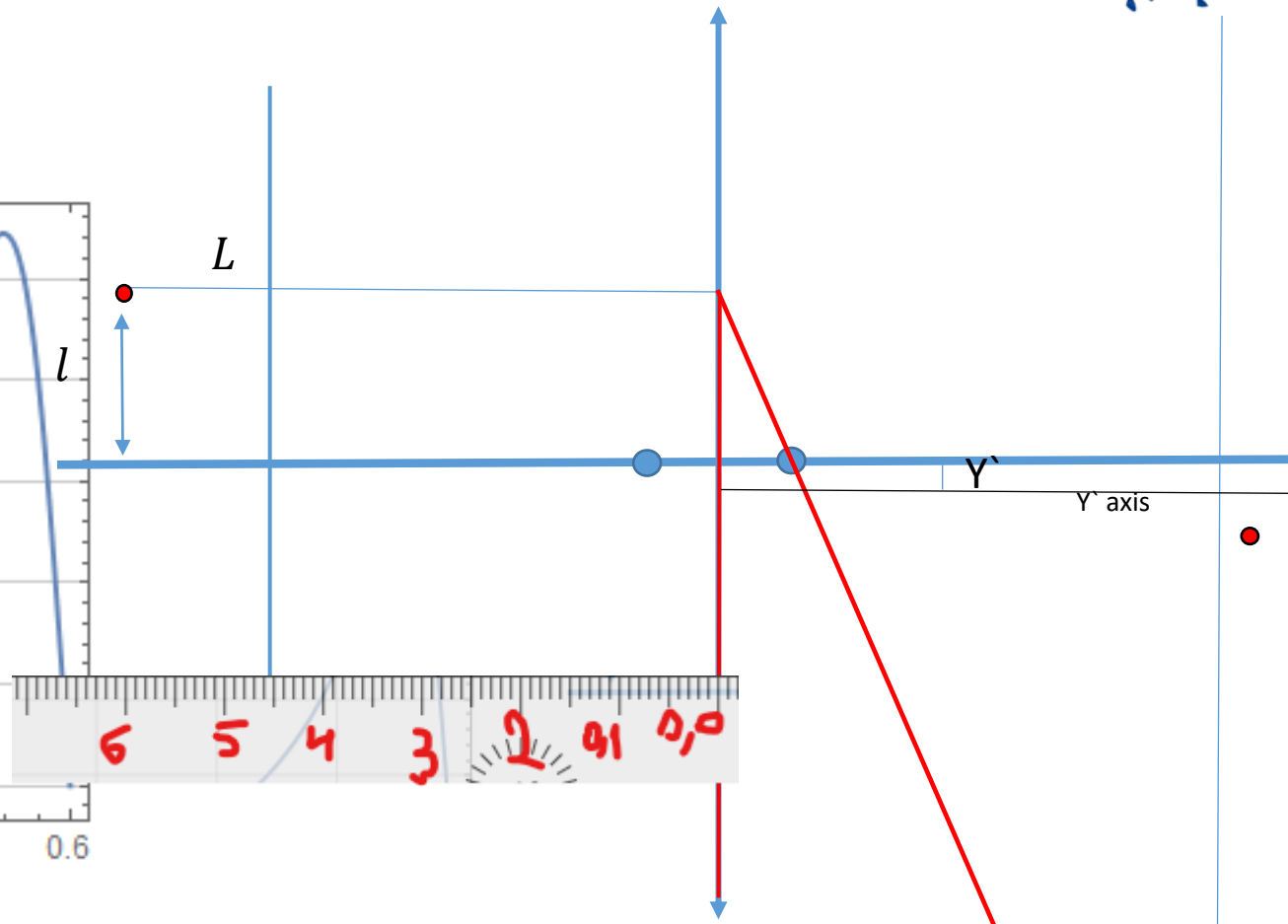
$T \sim I$

$$T=\frac{d_\alpha}{dy'}=\frac{L\ \ dy}{L^2+(l+\frac{y'(x-F)}{F})^2}\times\frac{x-F}{F\ dy}=\frac{L(x-F)}{F(L^2+\left(l+\frac{y'(x-F)}{F}\right)^2)}$$

გადანაწილების X კოორდინატზე დამოკიდებულების გრაფიკი

$$T = \frac{(L_0 - x)(x - F)}{F\left(L^2 + \left(l + \frac{y'(x - F)}{F}\right)^2\right)}$$





$L = 0.6 - x;$

v`=-0.005;

=

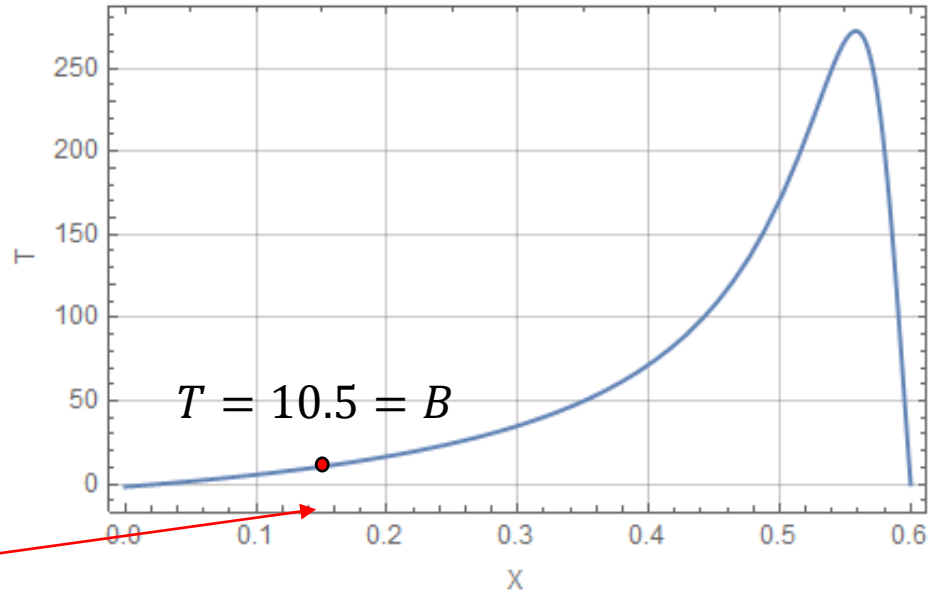
$\iota = 0.065;$

10.5103854170213474997989638852203319595261777999621834767873921 74
…

How calculated B coefficient

X-Distance between film and camera

x \ n	I
0.6	17
0.55	20
0.5	21
0.45	23
0.4	25
0.35	31
0.3	34
0.25	37
0.2	39
0.15	44

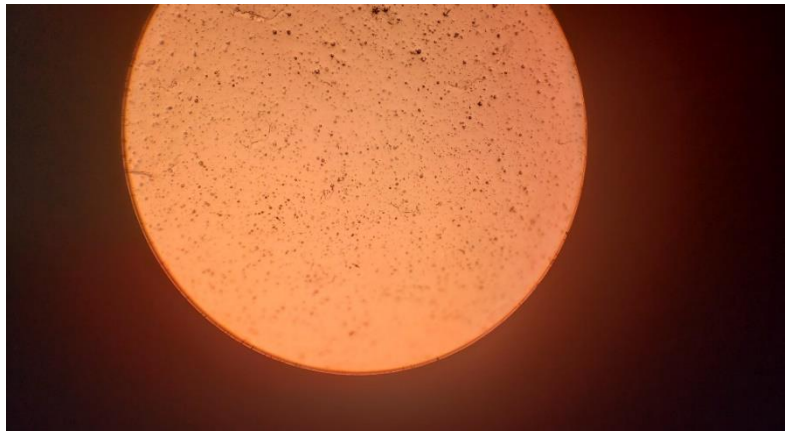
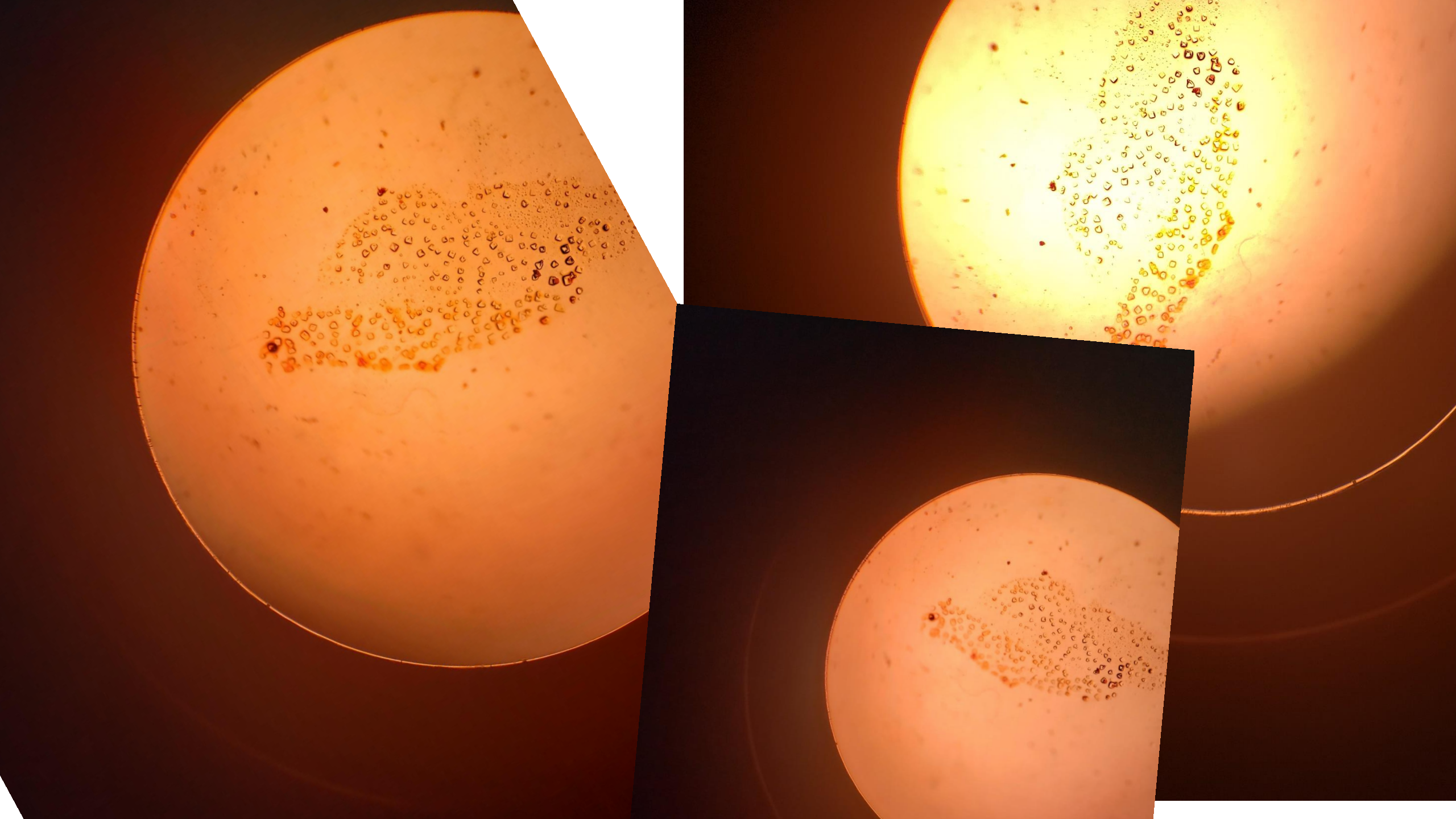


$$\frac{(0.6 - 0.15)(0.15 - 0.026)}{0.026\left((0.6 - 0.15)^2 + \left(0.065 - 0.005 \times \frac{0.15 - 0.026}{0.026}\right)^2\right)}$$

- B=10.5103854170213474997989638852203319595261777999621834767873921 74..

Two types of transparent films

High blurring



Isn’t blurring