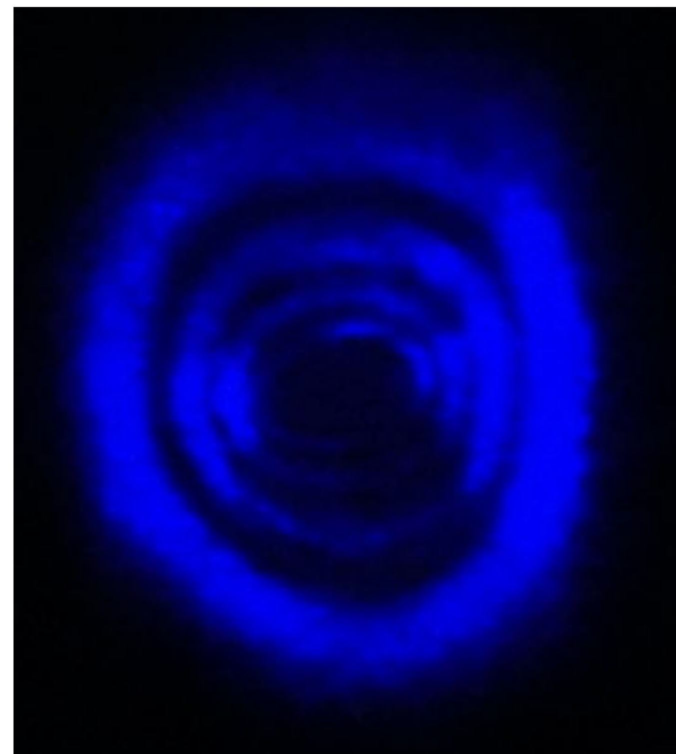
RUSSIA

Problem №9

«Soy sauce optics»

Using a laser beam passing through a **thin layer** (about 200 μm) of soy sauce the **thermal lens** effect can be observed. Investigate this phenomenon.

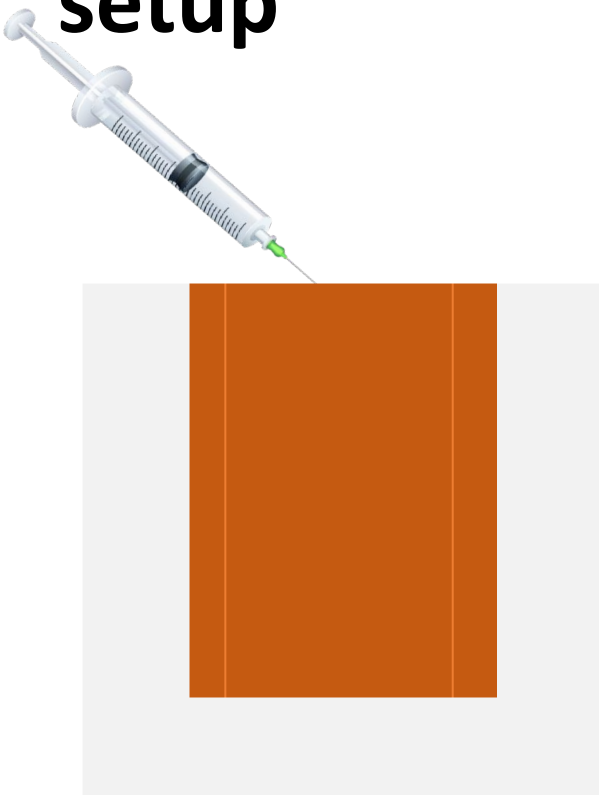


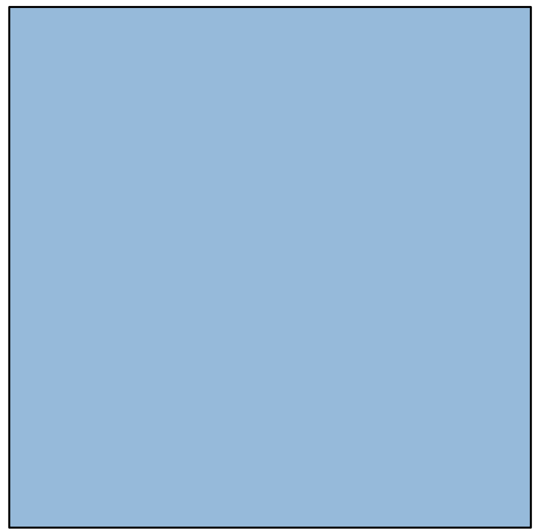
Team Russia

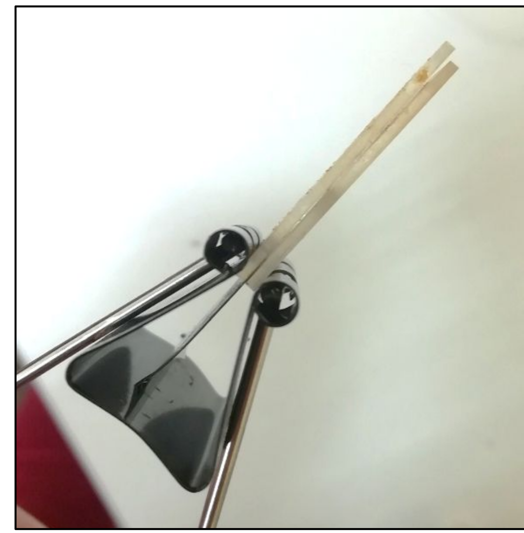
Reporter: Katerina Zamaraeva

1. Experimental setup

Distance between glasses - from 0.13 to 1mm

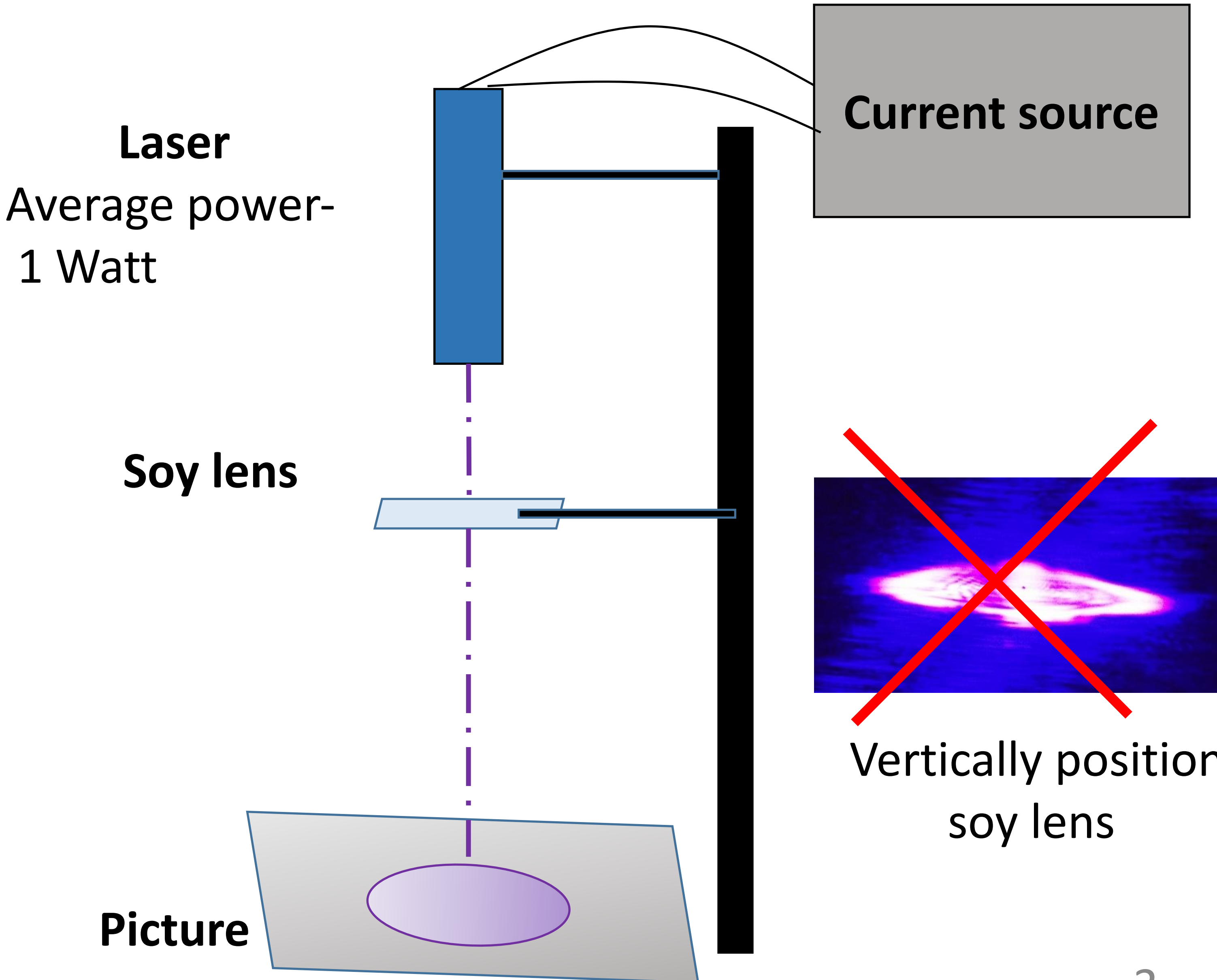






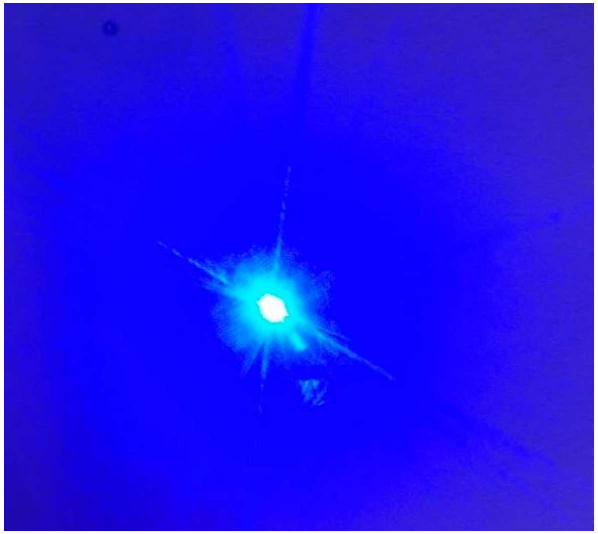
Clamping the glasses

2. Experimental setup

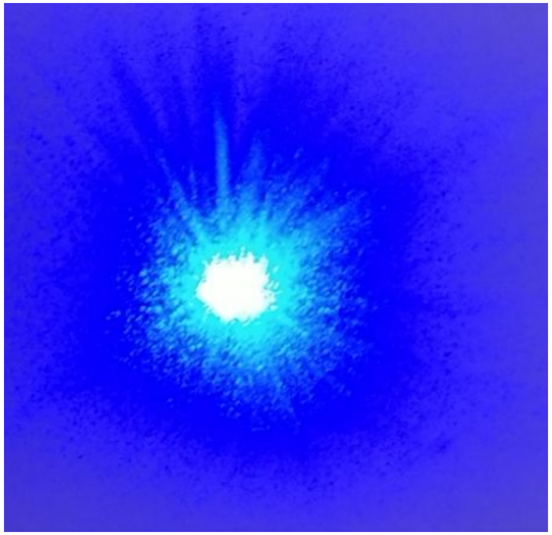


Vertically position soy lens

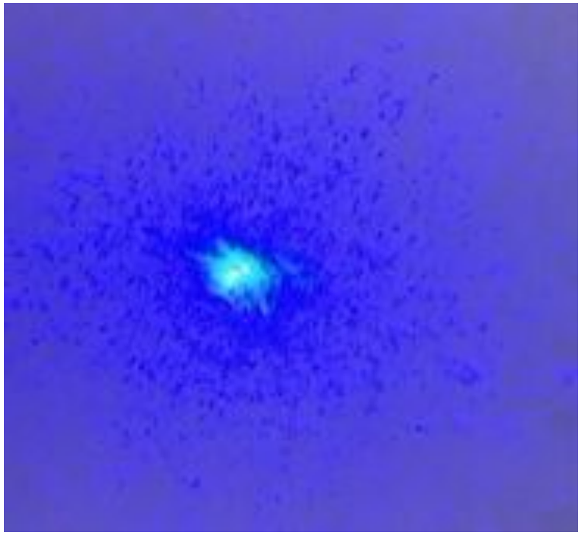
1. First observations



Without lens

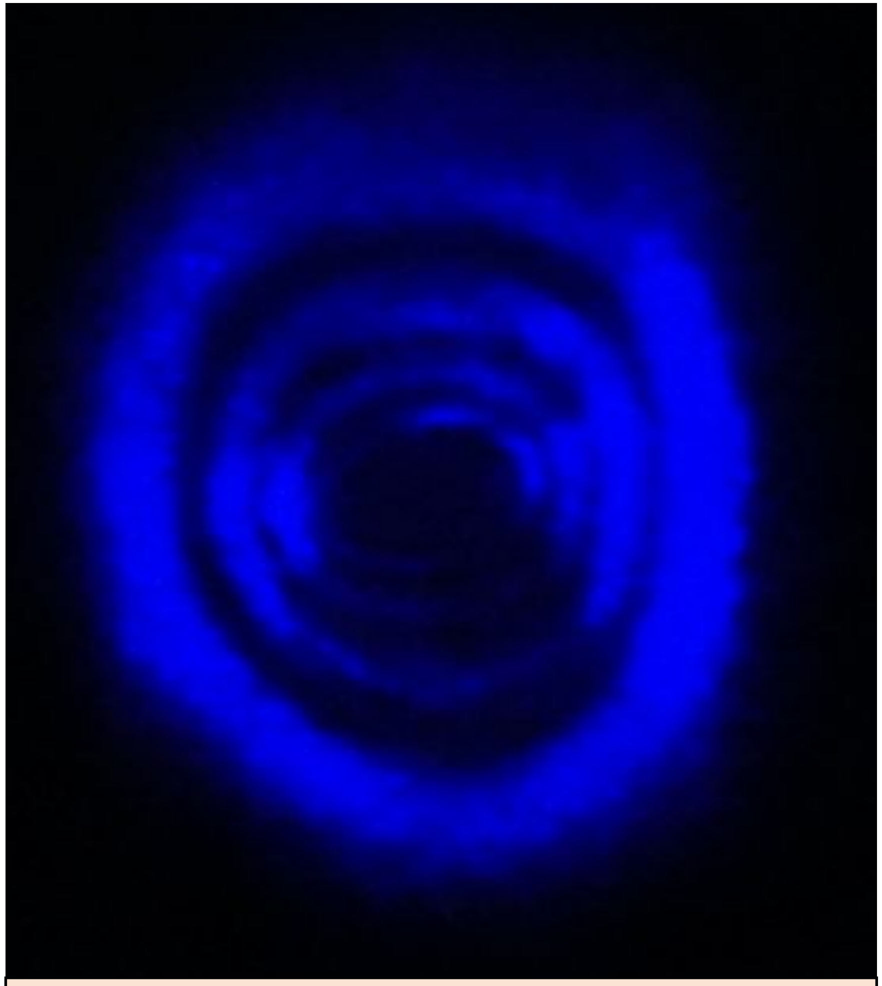


In the beginning with lens



After some time

2. First observations



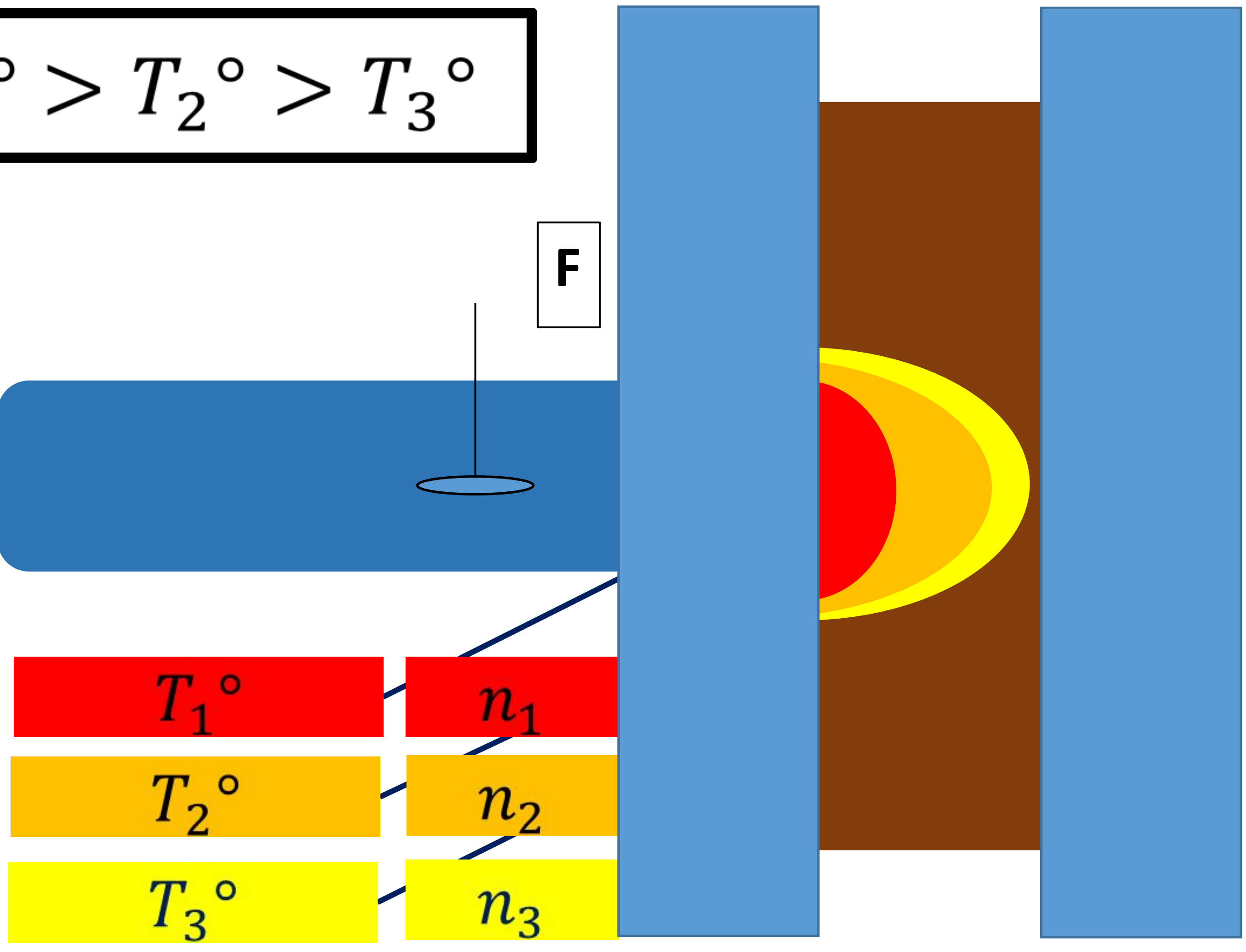
The rings formed

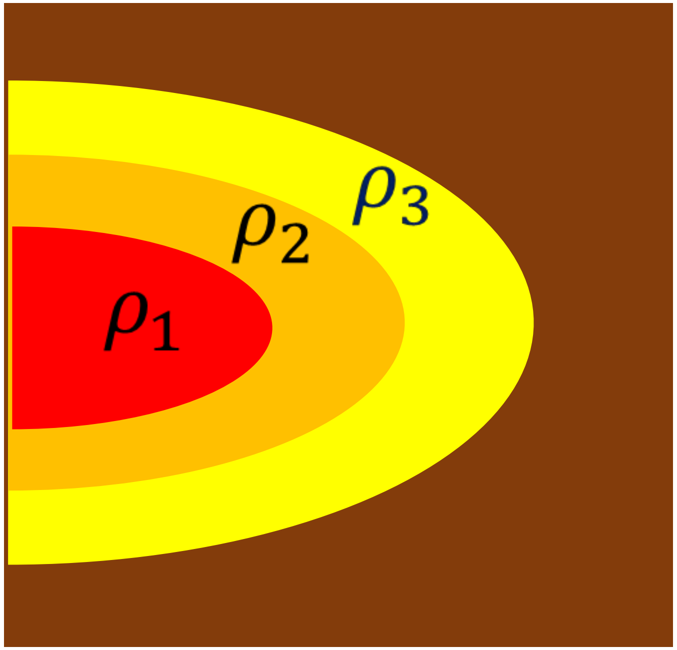
Main point

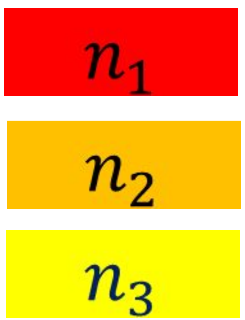
- Absorption

Qualitative explanation

$$T_1° > T_2° > T_3°$$







Due to thermal expansion of liquids:

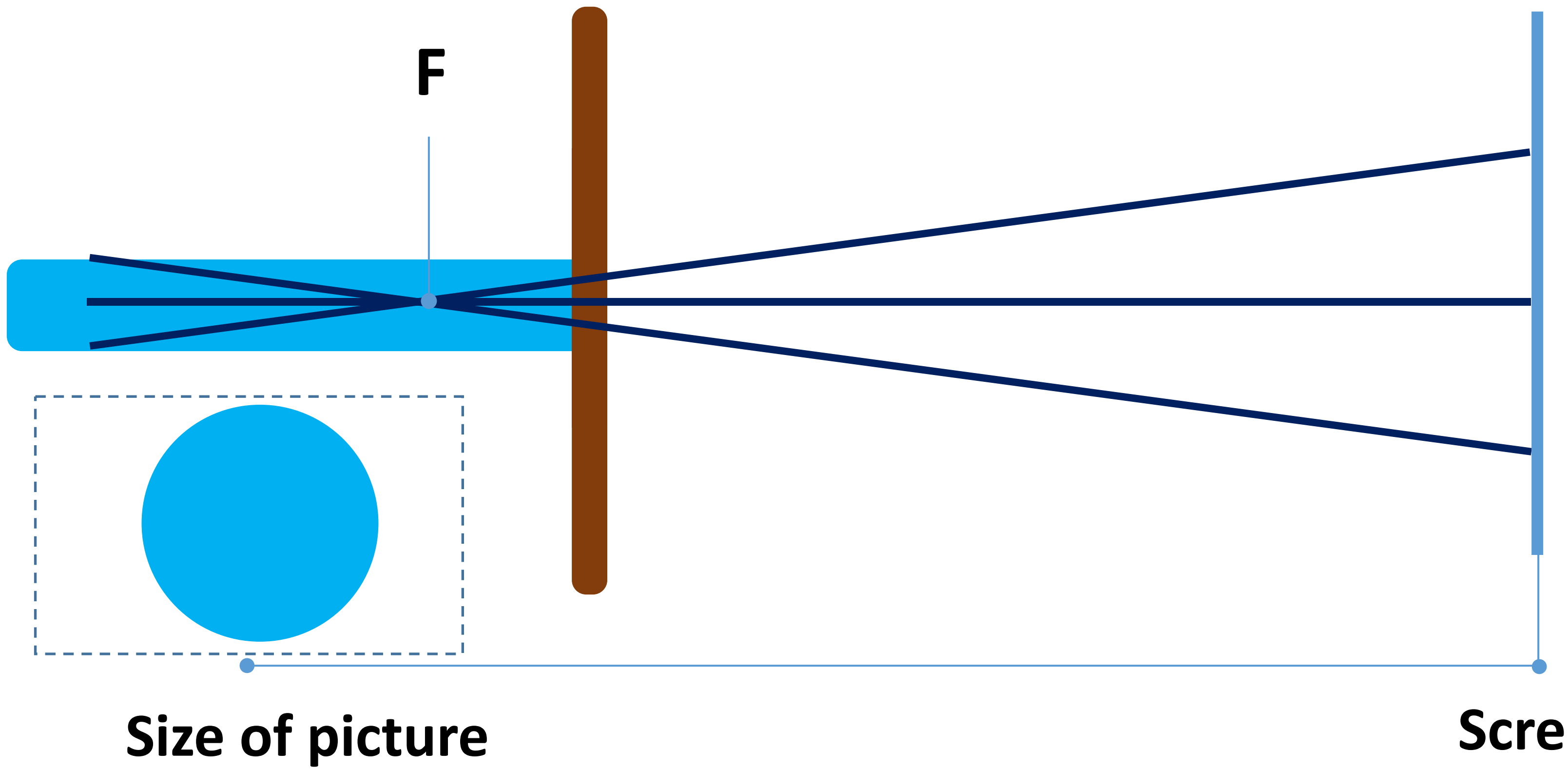
$$\rho_1 < \rho_2 < \rho_3$$

$$n_1 < n_2 < n_3$$

Rays are deflected to the side with a large refractive index.

Dispersive lens

Why image gets smaller?



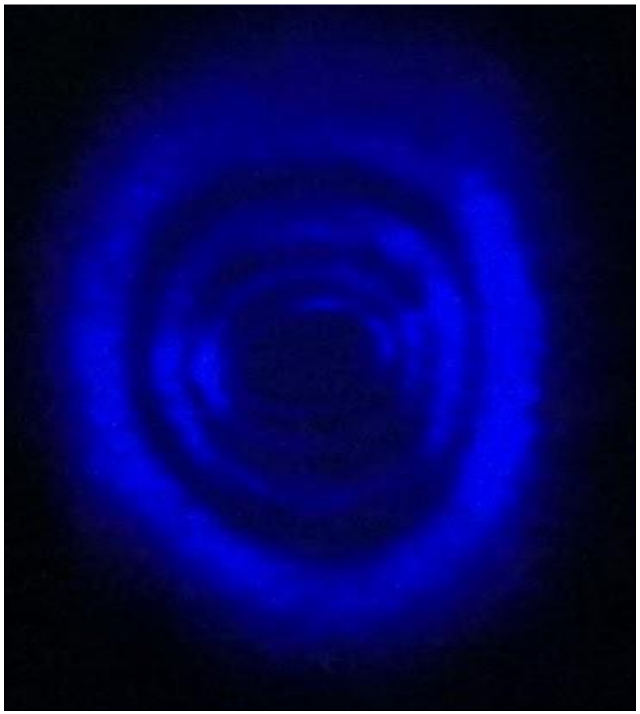
After some time all soy sauce heating

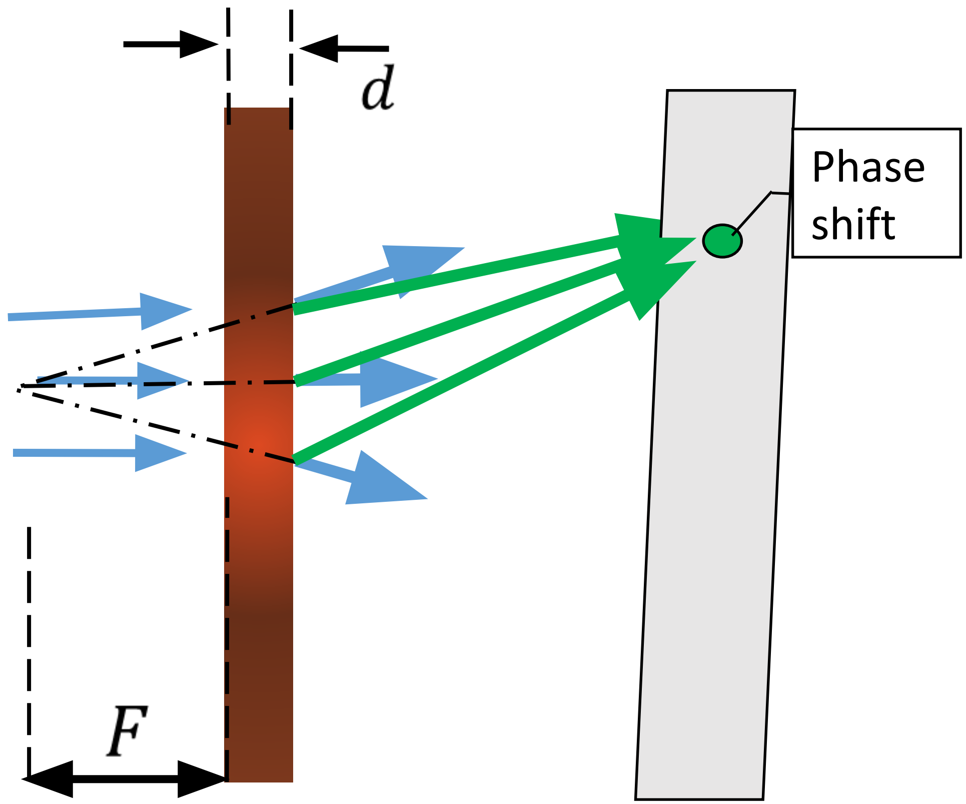
No temperature difference

No change in the refractive index

Ring formation

$$\varphi(r) = kn(r)\mathrm{r}$$



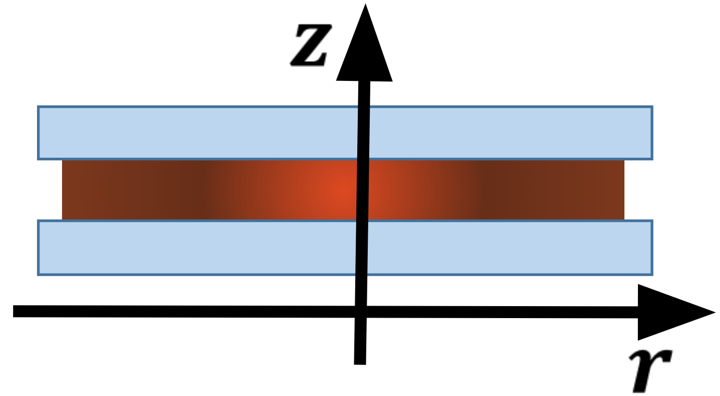


Characteris
tically
distance
soy lens-

Rays are different distances and changing the reflective index therefore there is a phase shift

Mathematical model

The temperature distribution



<u>Heat equation</u>

Heat capacity coefficient

Capacity per unit volume

$$c\rho \frac{\partial T}{\partial t} = \varkappa \Delta T + Q(\boldsymbol{r}, t)$$

Thermal conductivity

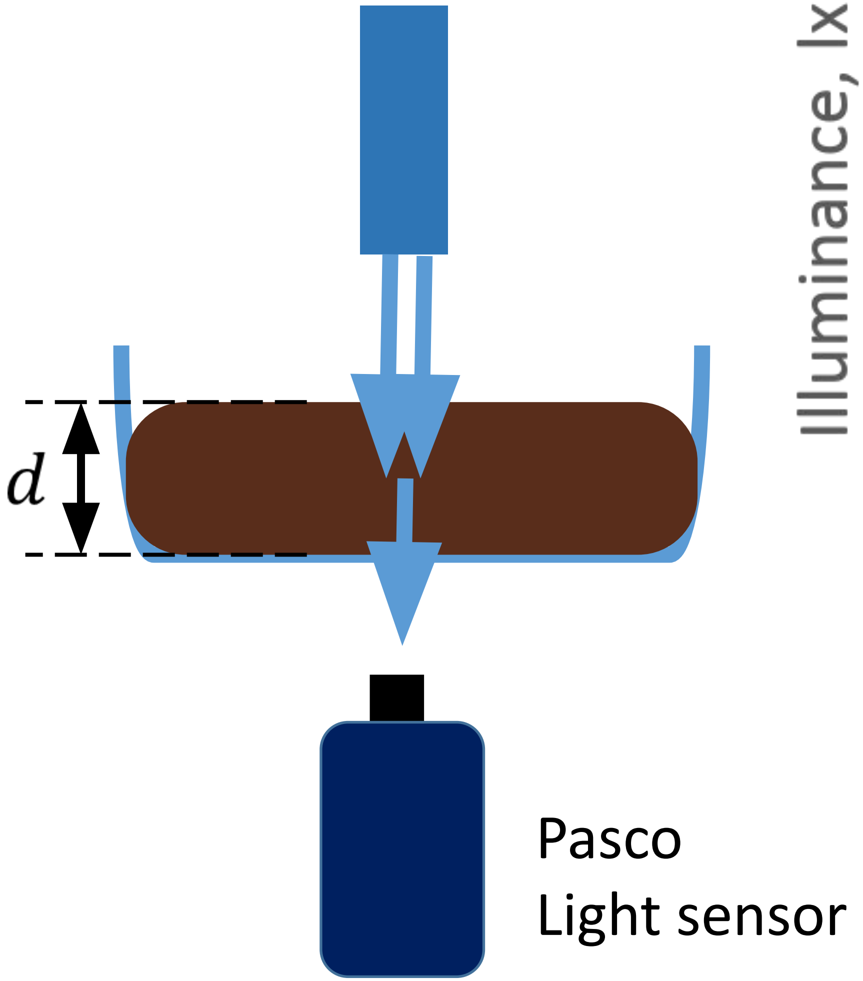
Ray absorption

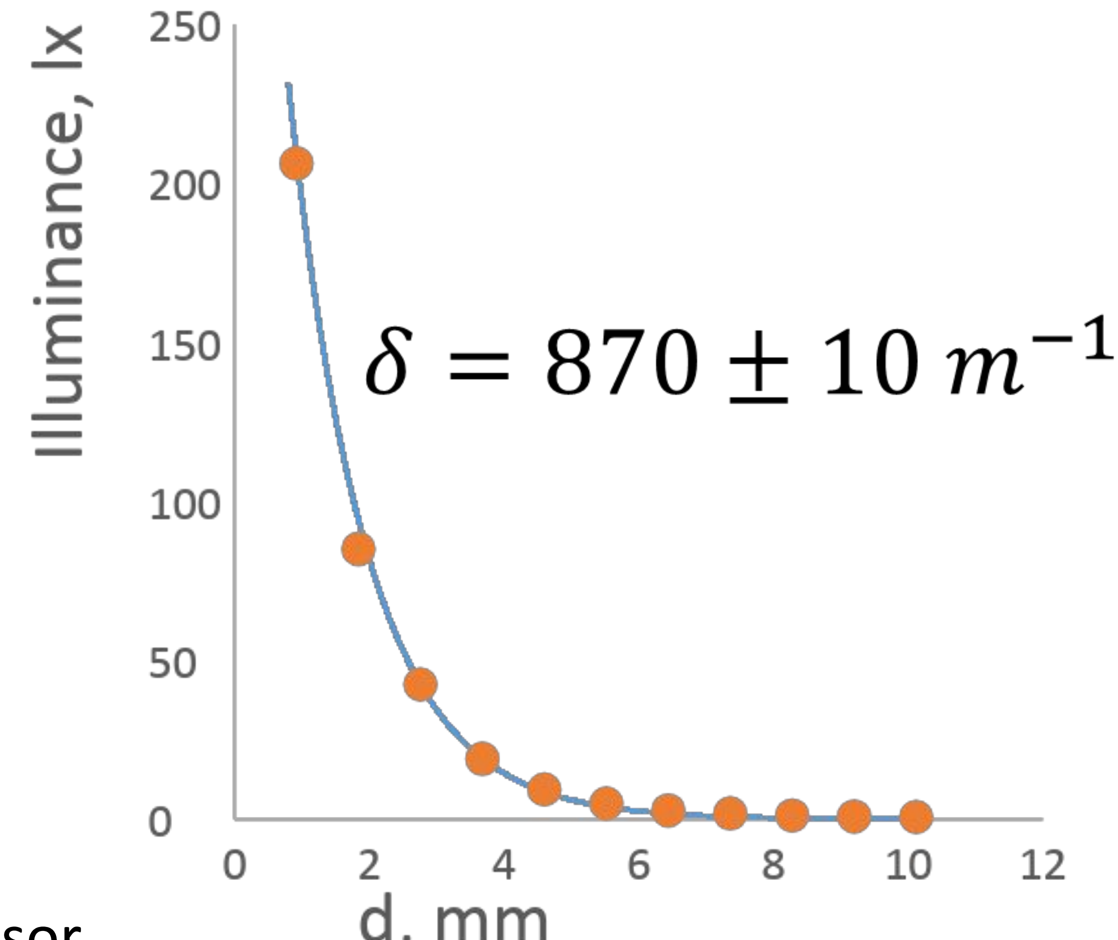
$$I = I_0 \exp(-\delta z)$$

Intensity

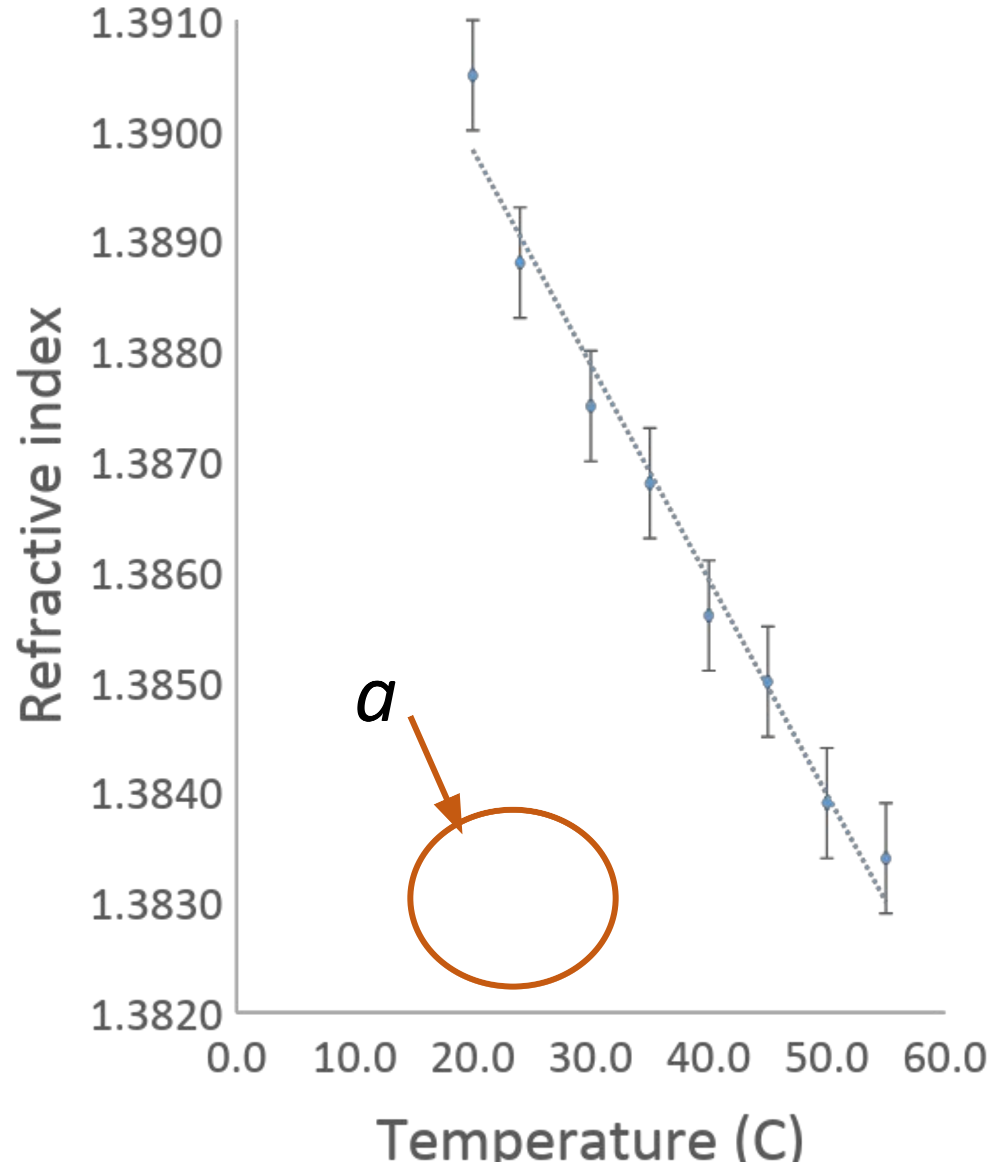
Absorption coefficient

Absorption coefficient $\boldsymbol{\delta}$:





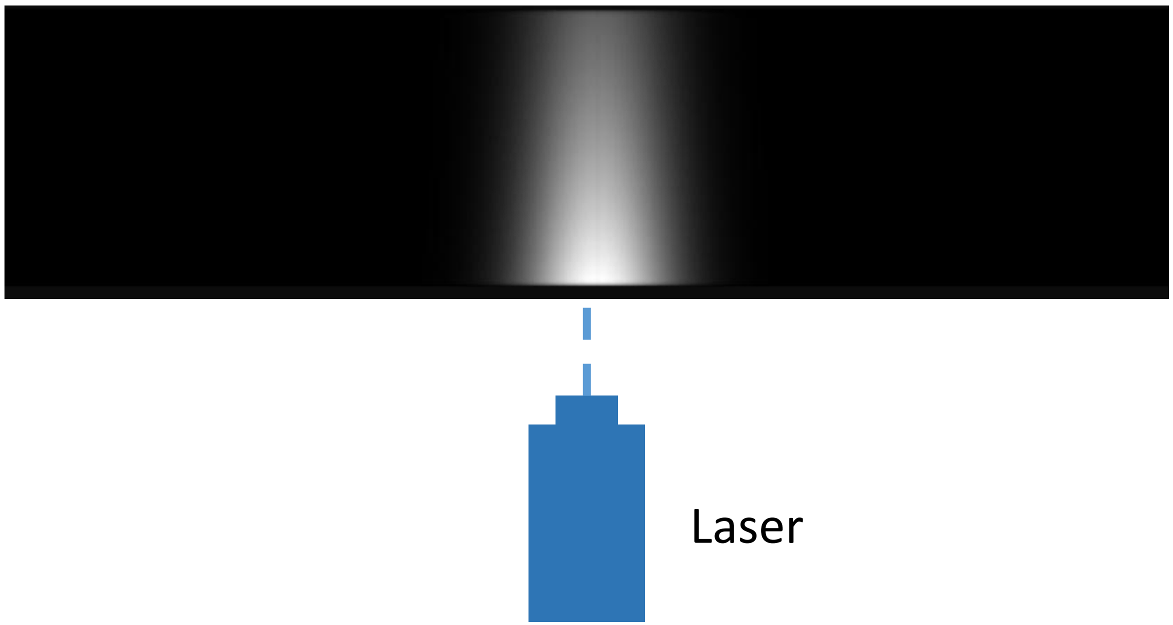
Coefficient- changing reflective index with the temperature



Refractometer *- device measuring the refractive index of light*

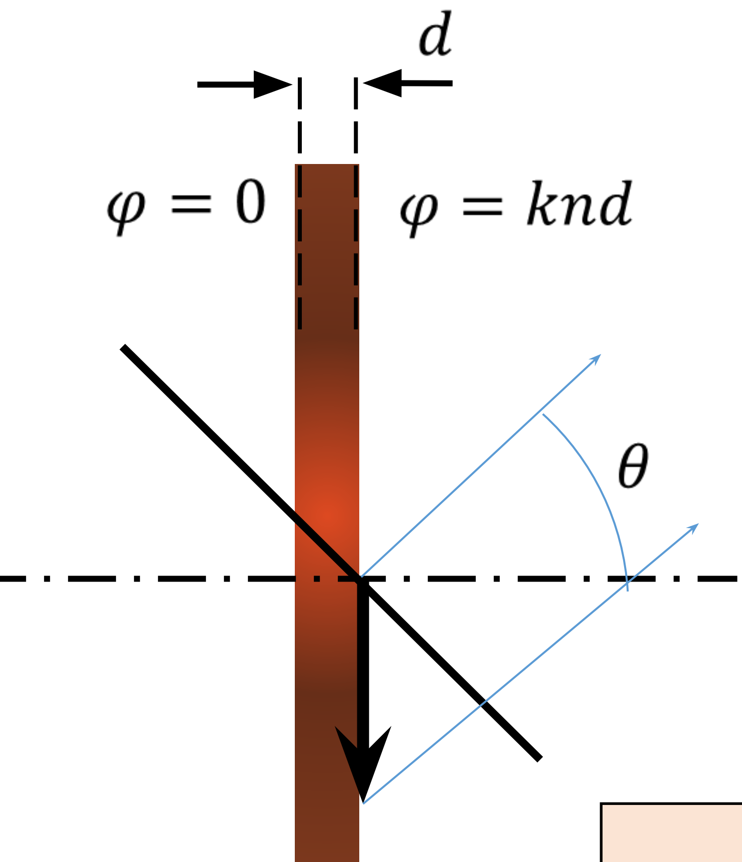
$$T = \begin{cases} T_0 + \dfrac{\delta I_0}{4\varkappa}(R^2 - r^2), r \leq R \\ T_0, r > R \end{cases}$$

IMPORTANT!



Program model

Intensity distribution in the image



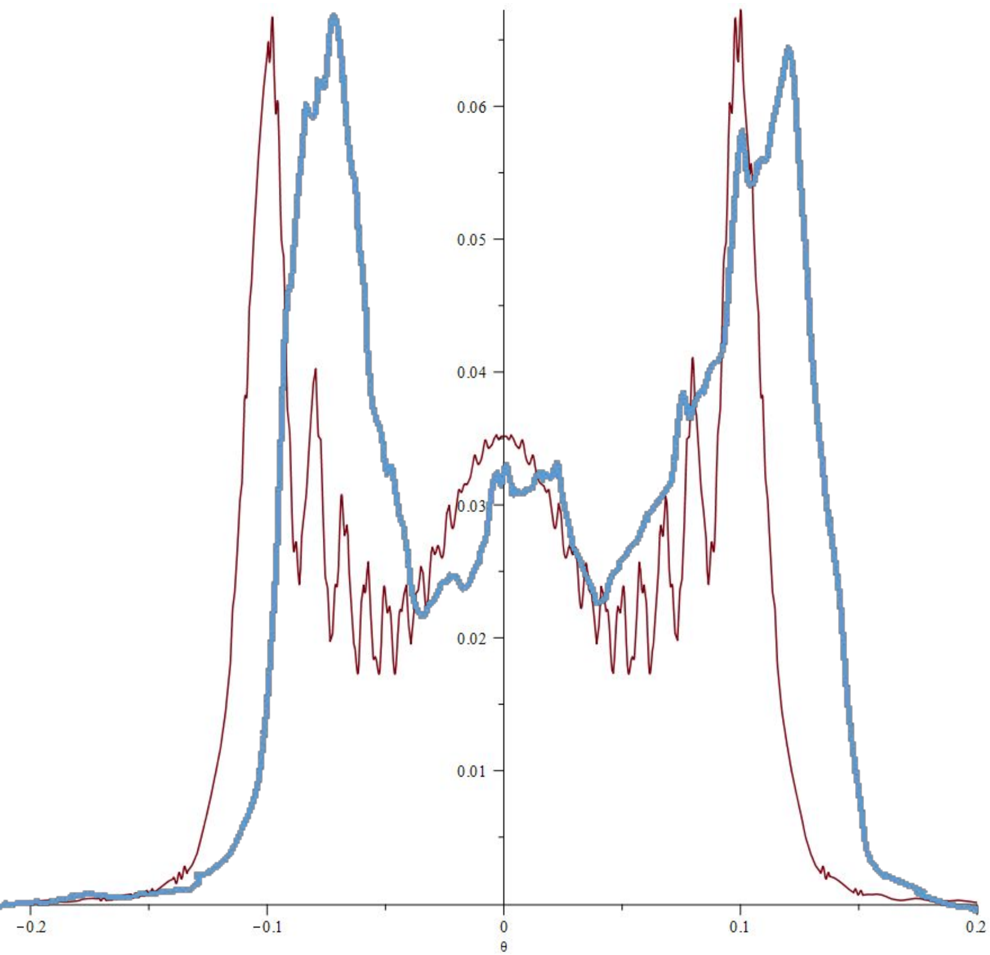
Area element

$$A = A_0 \int_0^R \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} e^{\frac{-1}{2}\frac{r^2}{R^2}} e^{i\varphi} \boxed{r d\psi dr}$$

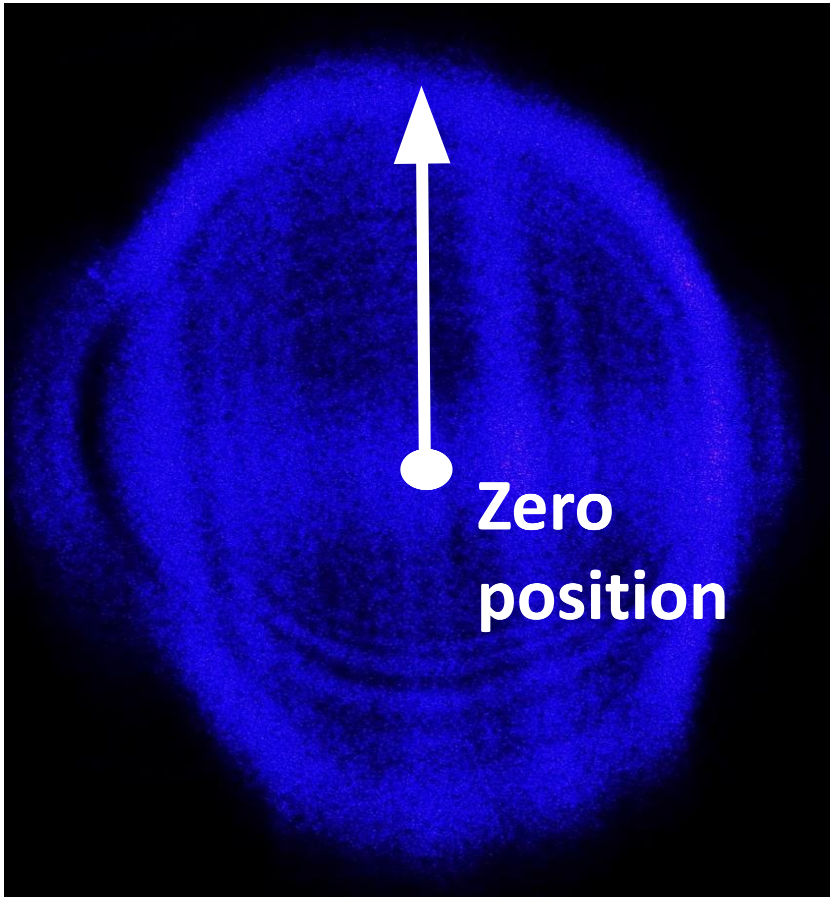
$$\boxed{\varphi} = k(n(r)d + r sin(\theta) \sin\psi)$$

$$\boxed{I = I_0 \exp(-\delta z) \, |A|^2}$$

Theory VS practice

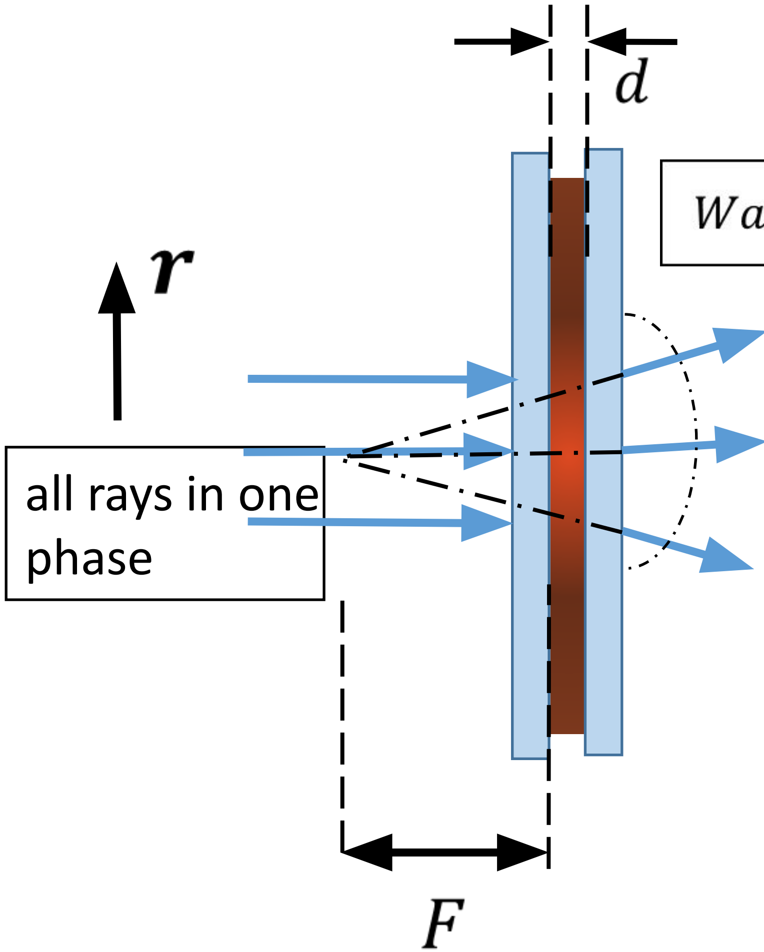


Program Maple VS Practice



Experimental

Focal length



Refractive index without heating

$$n = n_0(1 + \alpha T) = n_{ex} - \frac{n_0 \alpha \delta I_0}{4\varkappa} r^2$$

coefficient of thermal conductivity

Wave vector

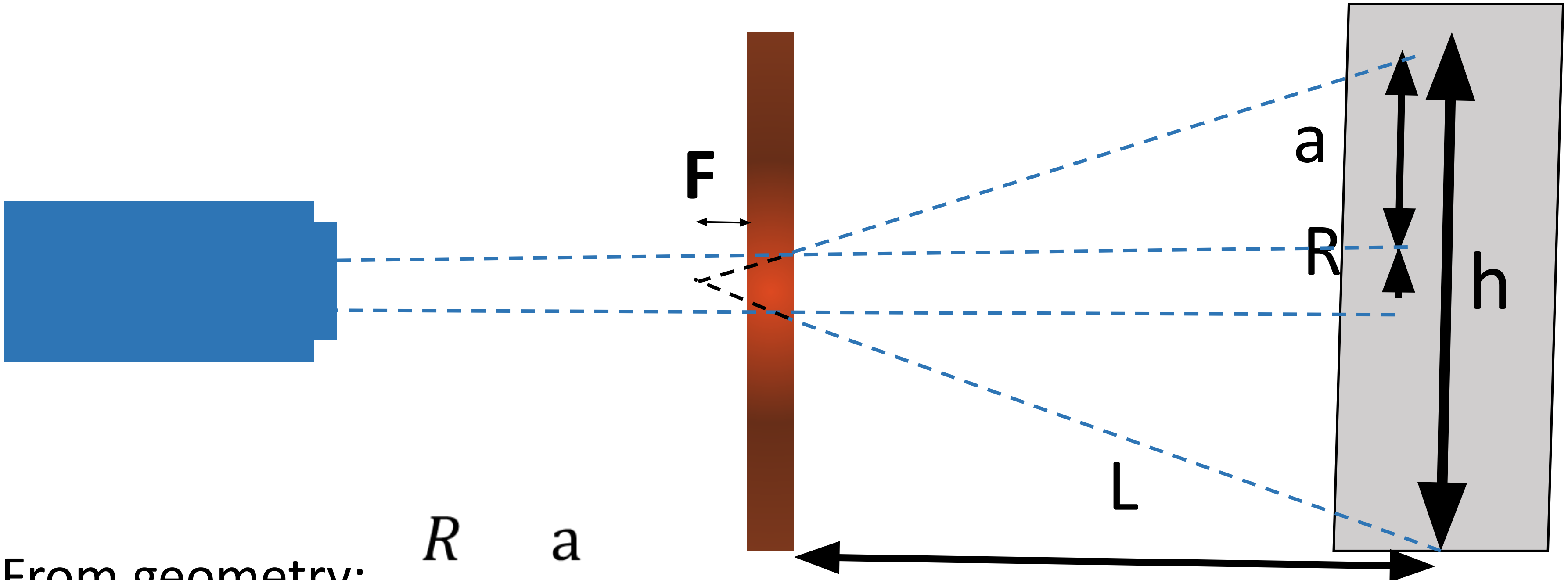
$$\varphi(r) = kn(r)\mathrm{d} + k\sqrt{F^2 + r^2} \approx$$

$$kn_{ex}\mathrm{d} - k\frac{n_0 \alpha \delta I_0 d}{4\varkappa} r^2 + kF + \frac{kr^2}{2F}$$

$$\frac{k}{2F} - k\frac{n_0 \alpha \delta I_0 d}{2} = 0$$

$$\boxed{D = \frac{1}{F} = \frac{n_0 \alpha \delta I_0 d}{2\varkappa}}$$

Experimental finding of focal length



From geometry: $\frac{R}{F} = \frac{a}{L}$

$$h = 2a + 2R$$

$$h = \frac{2LR}{F} + 2R$$

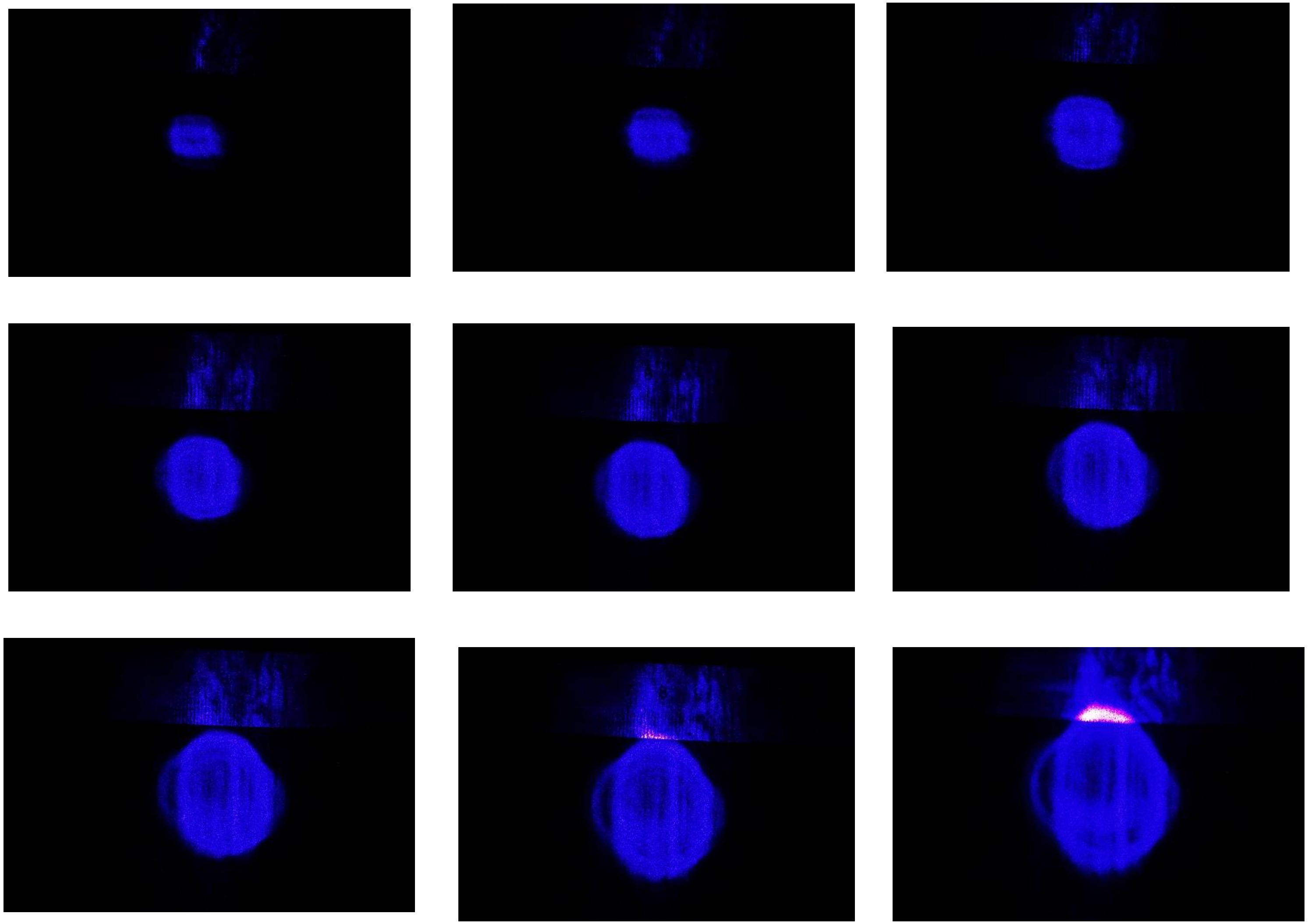
$$\boxed{F = \frac{2LR}{h - 2R} = \frac{1}{D}}$$

Compeering

$$F = \frac{2LR}{h - 2R} = \frac{1}{D}$$

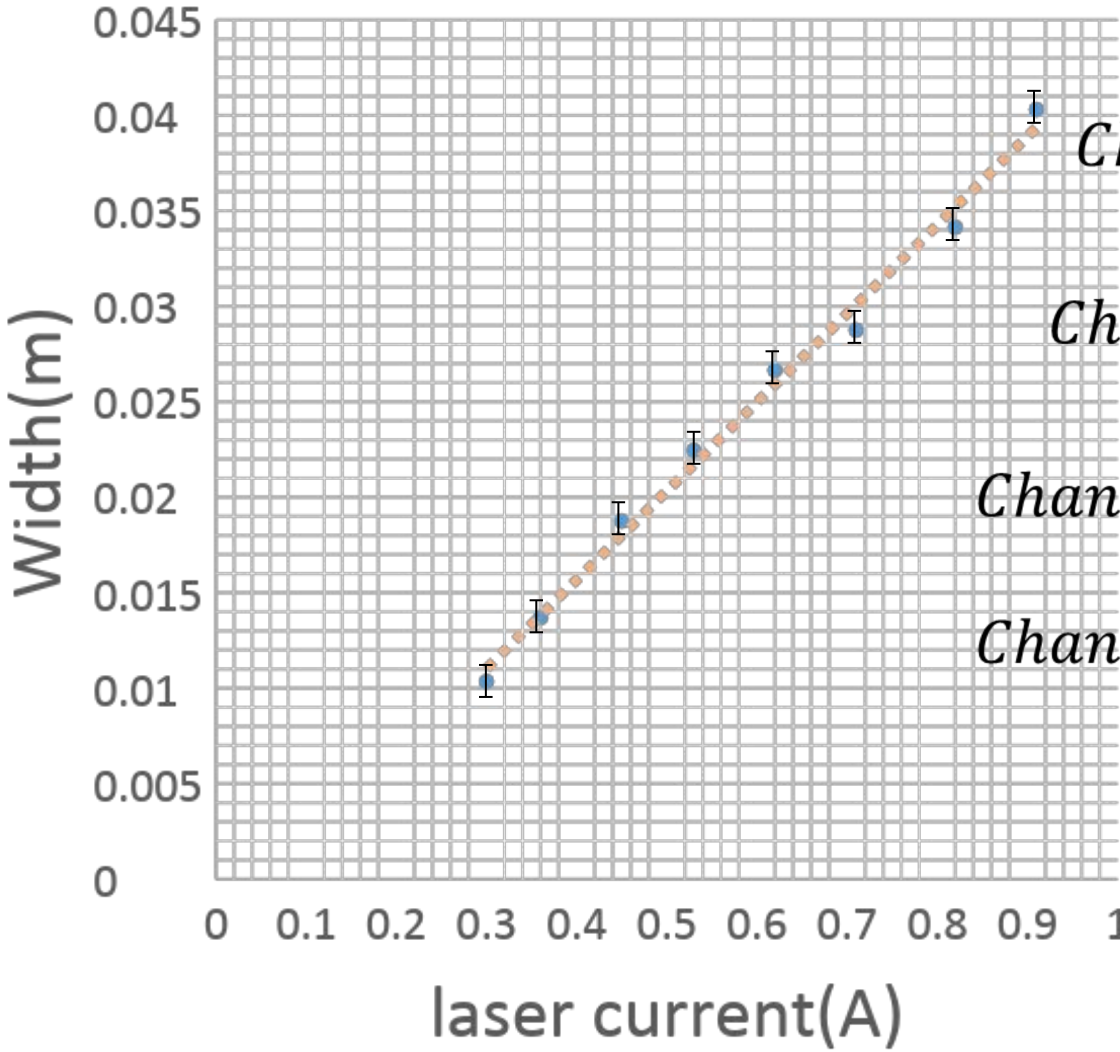
Parametric studies

The effect of laser current on image size



With increasing current increases the image

Image width from laser current



Changing laser current

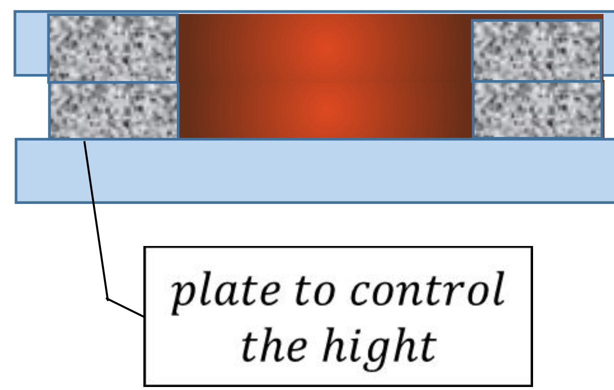
Changing temperature

Changing reflective inde

Changing size of image

Optical power VS thickness of soy sauce

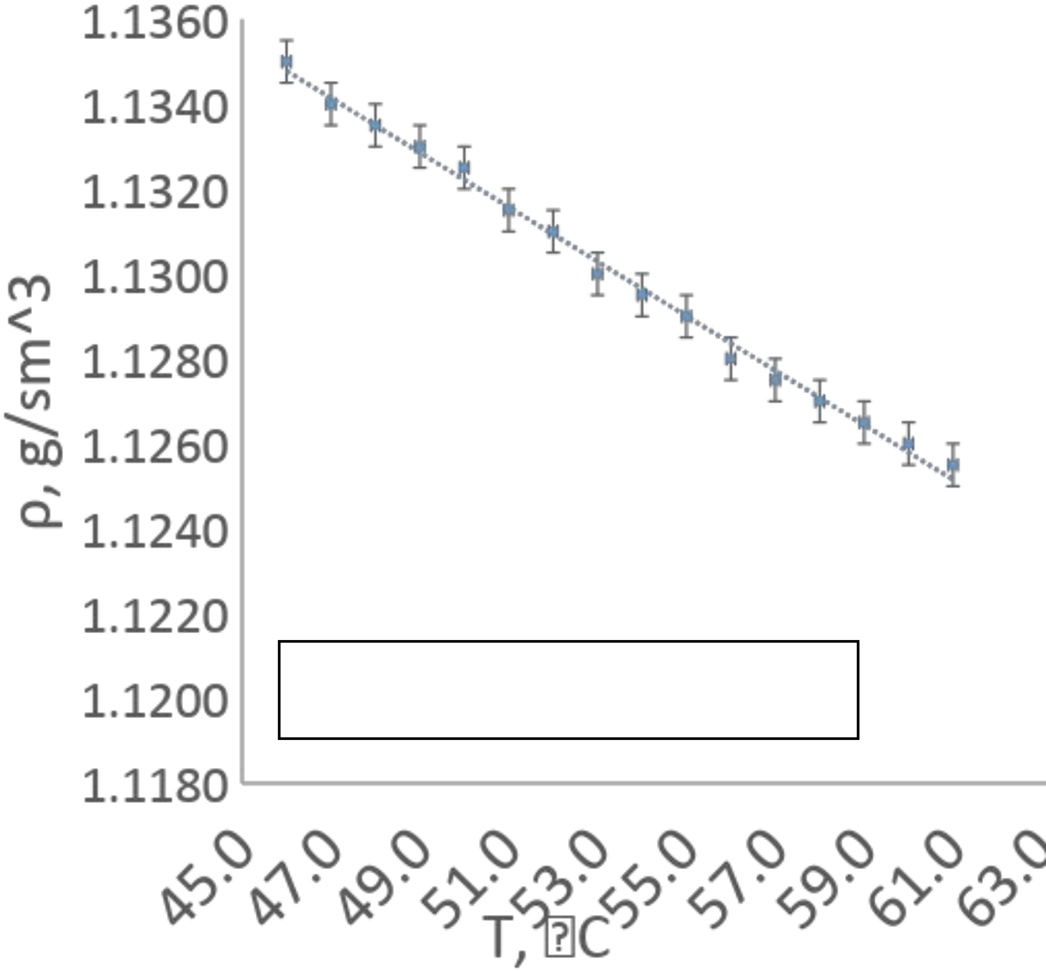
$D\ (m^{-1})$



$d\ (m)$

Density VS Temperature

Refractometer



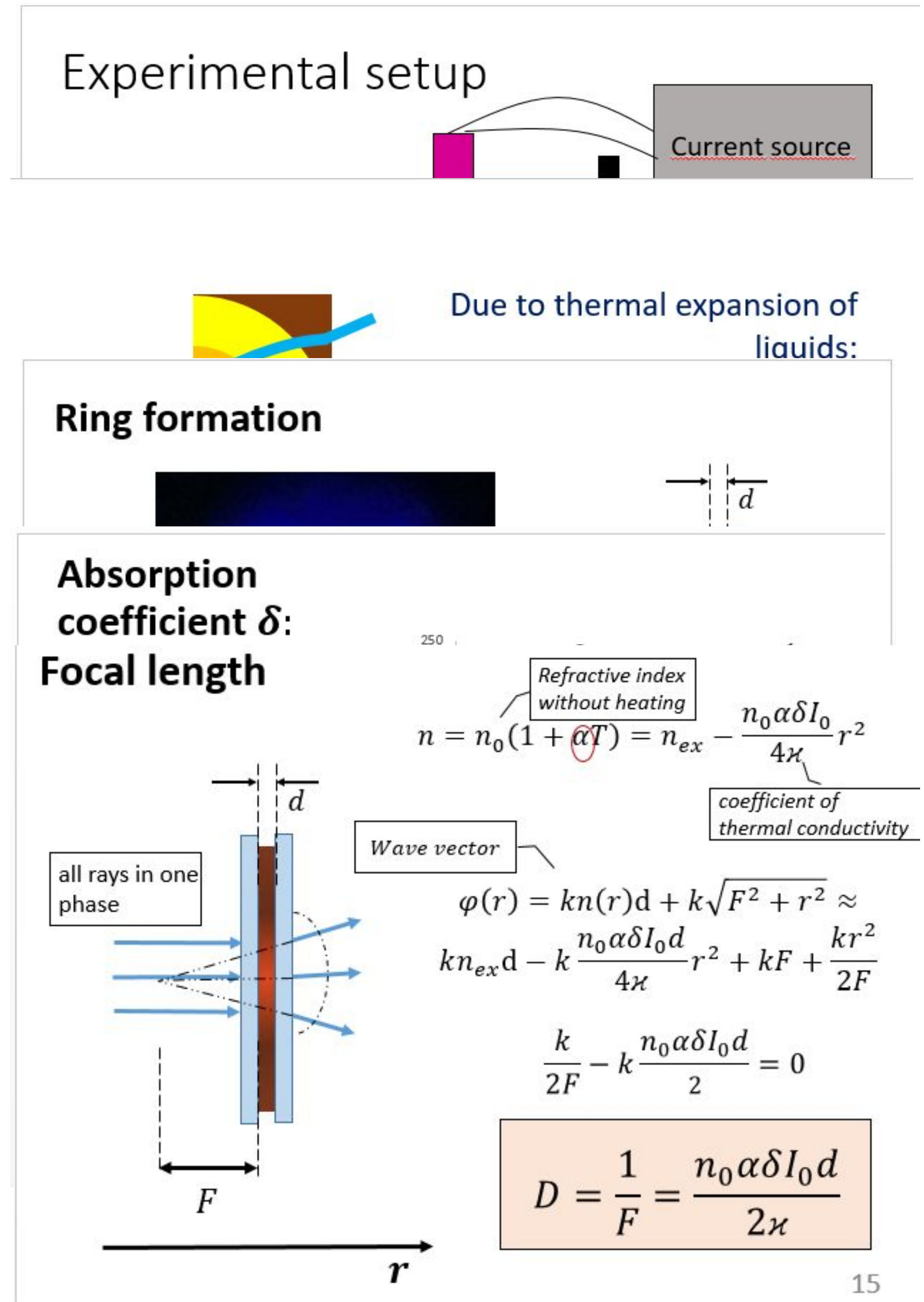
Conclusion

Experimental setup. Laser with constant power

Qualitative explanation(different hitting soy sous , different phase of beam)

Temperature distribution and absorption coefficient

Theoretical formula for focal length and got method for experimental

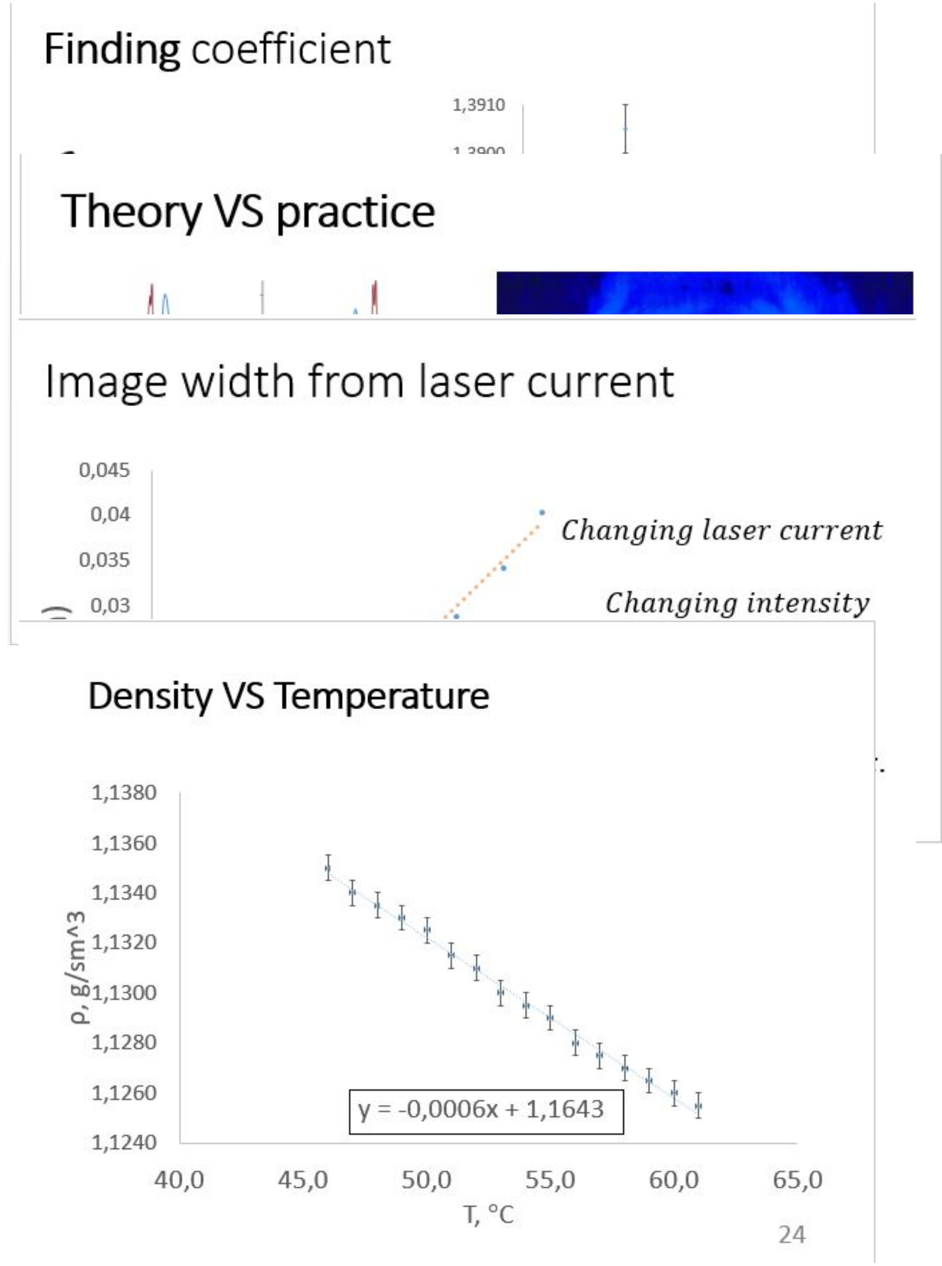


Finding coefficient showing the change reflective index with temperature

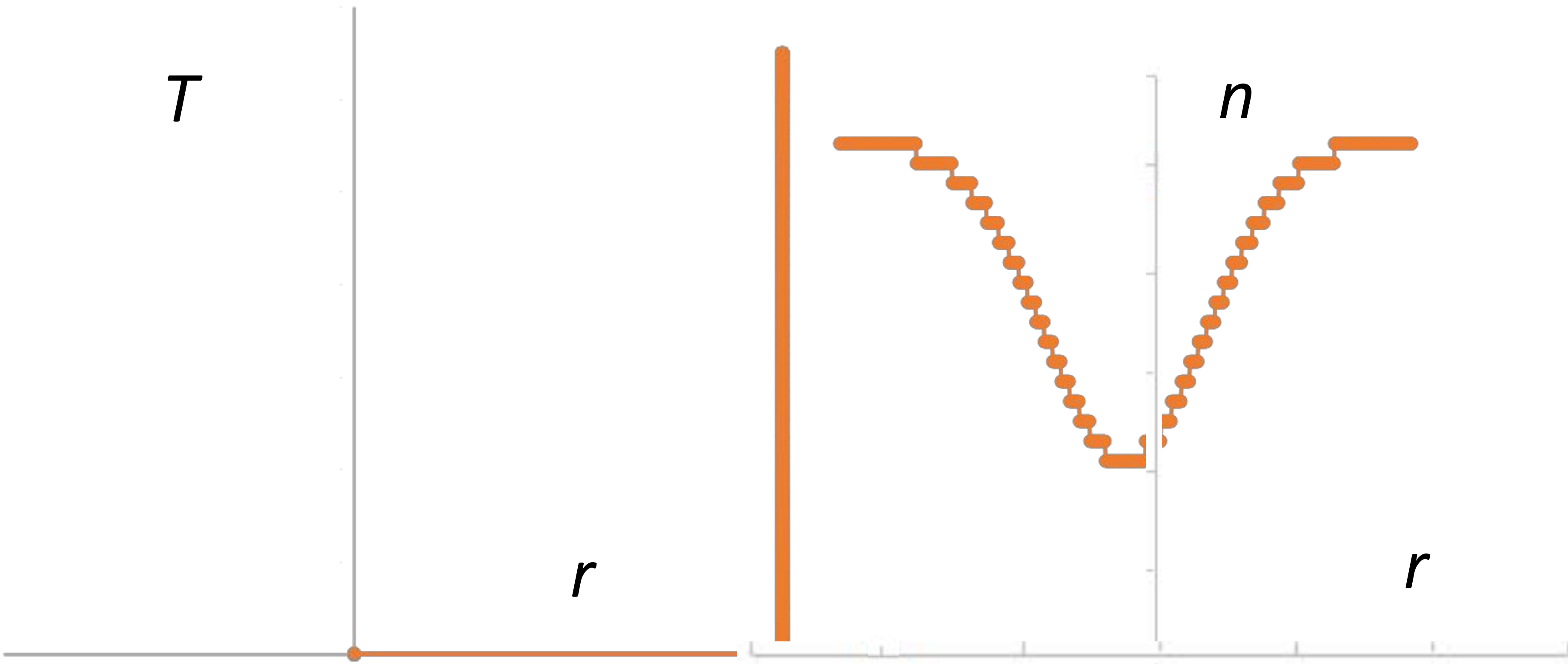
Got comparing practice and theory and explain the errors

The dependents image width from laser current

Changing density with temperature

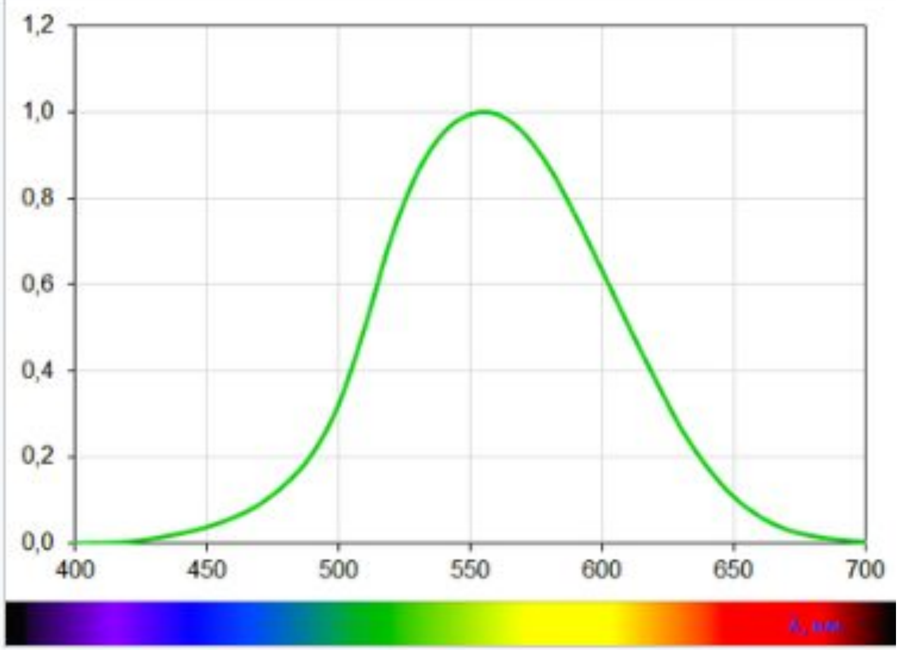


Qualitative graphs



In the center-maximum temperature and minimum refractive index

Освещенность

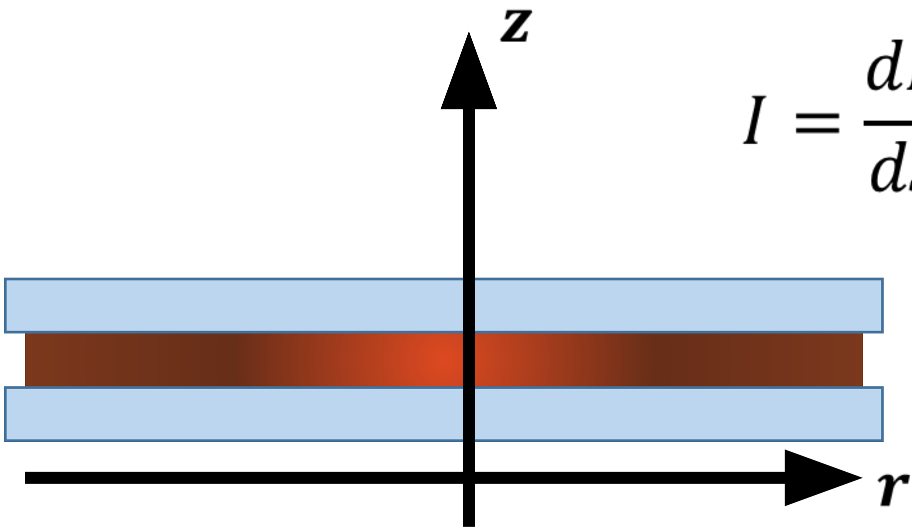


Относительная спектральная световая эффективность монохроматического излучения для дневного зрения.

$$n = n_0(1 + \alpha T) = n_0\left(1 + \alpha\left(T_0 + \frac{\delta I_0 d}{4\gamma}R^2\right)\right) - \frac{n_0 d\alpha\delta I_0}{4\gamma}r^2$$

$$= n_{ex} - \frac{n_0 d\alpha\delta I_0}{4\gamma}r^2$$

$$I = I_0 \exp(-\delta z)\,; \quad \delta = \delta(\lambda, T) \approx \delta(\lambda) \qquad c\rho\,\frac{\partial T}{\partial t} = \varkappa \Delta T + Q(\boldsymbol{r}, t)$$



$$I = \frac{dP}{dS} \qquad Q = -\frac{dP}{dV} = -\frac{d}{dz}\left(\frac{dP}{dS}\right)$$

$$= \delta I_0 \exp(-\delta z)$$

$$c\rho\,\frac{\partial T}{\partial t} = \kappa \Delta T + Q(\boldsymbol{r}, t) \rightarrow \qquad \Delta T = \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) + \frac{\partial^2 T}{\partial z^2} + \frac{1}{r}\frac{\partial^2 T}{\partial \varphi^2}$$

$$\Delta T = -\frac{Q(z)}{\kappa} = -\frac{\delta I_0 \exp(-\delta z)}{\kappa} \qquad \rightarrow \frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right) + \frac{\partial^2 T}{\partial z^2}$$

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right)+\frac{\partial^2 T}{\partial z^2}=-\frac{\delta I_0\exp(-\delta z)}{\kappa}$$

В приближении $\delta \mathrm{h} \ll 1,\ \exp(-\delta z) \approx 1,\ \frac{\partial^2 T}{\partial z^2} \approx 0$

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right)=-\frac{\delta I_0}{\kappa}, r \le R$$

$$\frac{1}{r}\frac{\partial}{\partial r}\left(r\frac{\partial T}{\partial r}\right)=0, r > R$$

$T(r)$ непрерывна

СПЕКТР ВИДИМОГО СВЕТА ПО ДЛИНЕ ВОЛНЫ

Цвет	Диапазон длин волн, нм	Диапазон частот, ТГц
Фиолетовый	380—440	790—680
Синий	440—485	680—620
Голубой	485—500	620—600
Зелёный	500—565	600—530
Жёлтый	565—590	530—510
Оранжевый	590—625	510—480
Красный	625—740	480—405

Laser 450 нм

- Стекло 1,52

Перевод из люксов в СИ

200 люкс = 0.00002928257686676 ватт на кв. см (при 555 нм)

* 5/7

• ХАРАКТЕРИСТИКА ДАТЧИКА

PASPort

Light Sensor

PS-2106A

Sensor Specifications

Sensor Ranges:	0-2.6 lux 0-260 lux 0-26,000 lux
Accuracy	Better than ±1db of max value of selected range
Resolution:	0.01% of max value of selected range
Max Sample Rate:	1,000 sps
Default Sample Rate:	5 sps
Operating Temperature	0-40°C

PASCO®

Light Sensor Quick Start

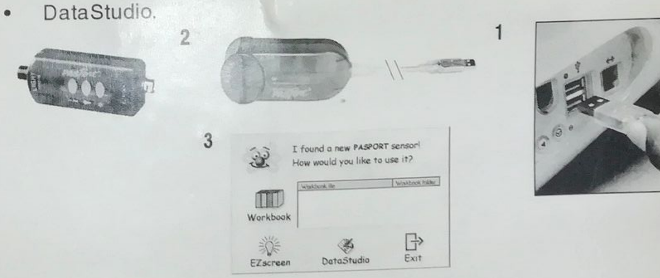
The PS-2106 Light Sensor measures Illuminance in units of lux.

Additional Equipment Needed

- PASPORT Link Device (USB Link, **Xplorer**, etc.)
- EZscreen or DataStudio™ software (version 1.5 or later)

Equipment Setup

1. Connect the PASPORT Link Device to a USB port on your computer or USB hub.
2. Connect the sensor to a PASPORT Link Device.
3. The software launches when it detects a PASPORT sensor. From the PASPORTAL screen, select a point of entry:
   - an activity in the Workbook window,
   - EZscreen, or
   - DataStudio.



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