



# «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.

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Distance between glasses from 0.13 to 1mm





Clamping the glasses



# 1. First observations



Without lens

In the beginning with lens After some time

# 2. First observations



The rings formed

## Main point

Absorption

## **Qualitative explanation**





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?



#### Size of picture

#### Screen

After some time all soy sauce heating

No temperature difference

No change in the refractive index



Characteris tically distance soy lensRays are different distances and changing the reflective index therefore there is a phase shift

# Mathematical model



#### Absorption coefficient $\pmb{\delta}$ :



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#### **Coefficient- changing reflective index with the temperature** 1.3910



$$T = \begin{cases} T_0 + \frac{\delta I_0}{4\kappa} (R^2 - r^2), r \le R \\ T_0, r > R \end{cases}$$

## Program model

#### Intensity distribution in the image



### **Theory VS practice**





#### **Program Maple VS Practice**

Experimental



#### **Experimental finding of focal length**



## 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

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### Image width from laser current



### Optical power VS thickness of soy sauce



#### **Density VS Temperature**



## 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



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

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

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

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

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



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

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

$$\begin{aligned} \frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial T}{\partial r} \right) &= -\frac{\delta I_0}{\kappa}, r \leq R \\ \frac{1}{r} \frac{\partial}{\partial r} \left( r \frac{\partial T}{\partial r} \right) &= 0, r > R \end{aligned}$$
  $T(r)$  непрерывна

## СПЕКТР ВИДИМОГО СВЕТА ПО ДЛИНЕ ВОЛНЫ

Laser 450 нм

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

• Стекло 1,52

## Перевод из люксов в СИ

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

\* 5/7

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