RUSSIA

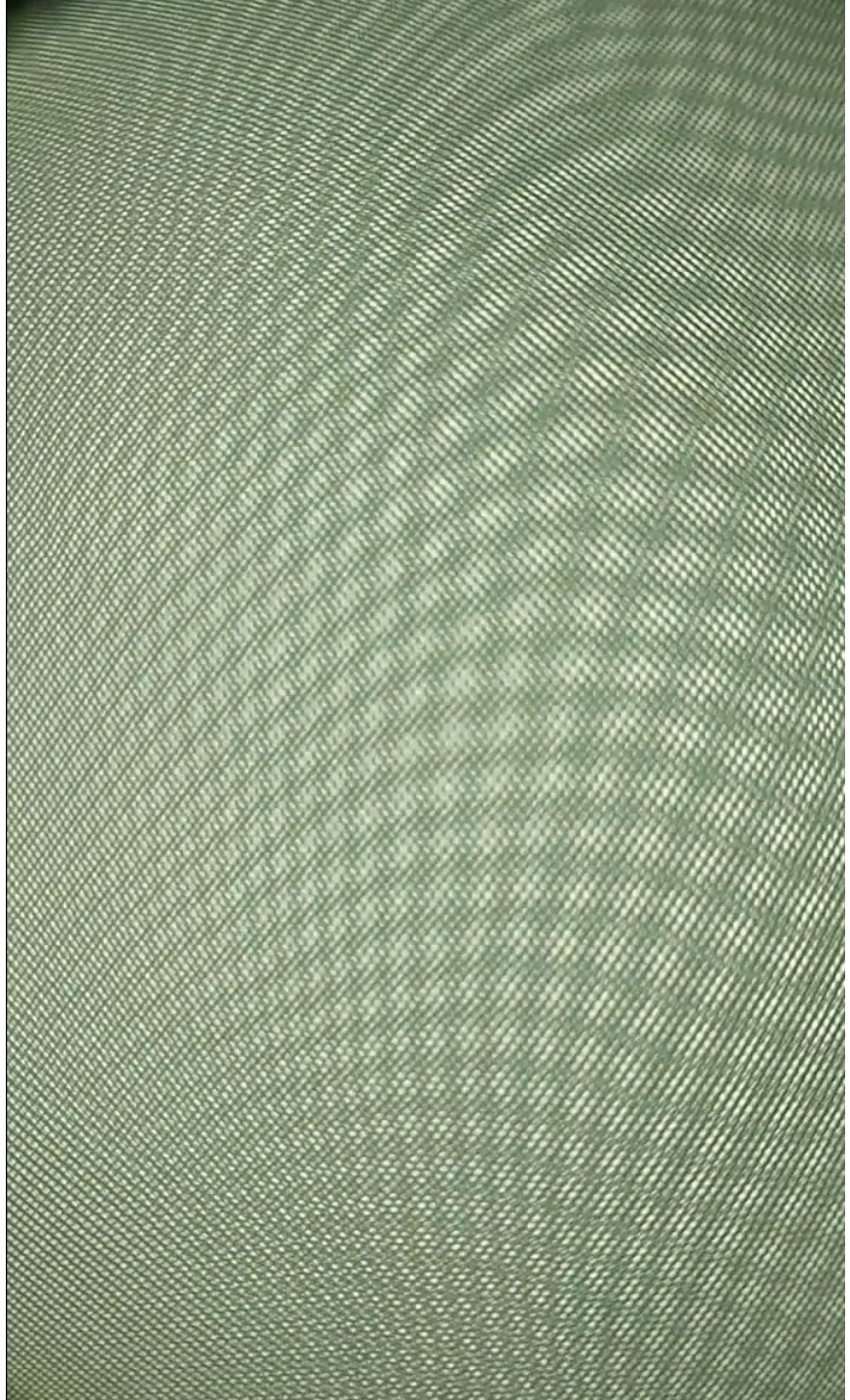
Problem № 13

“Moiré Thread Counter”

When a pattern of closely spaced non-intersecting lines (with transparent gaps in between) is overlaid on a piece of woven fabric, characteristic moiré fringes may be observed. Design an overlay that allows you to measure the thread count of the fabric. Determine the accuracy for simple fabrics (e.g. linen) and investigate if the method is reliable for more complex fabrics (e.g. denim or Oxford cloth).

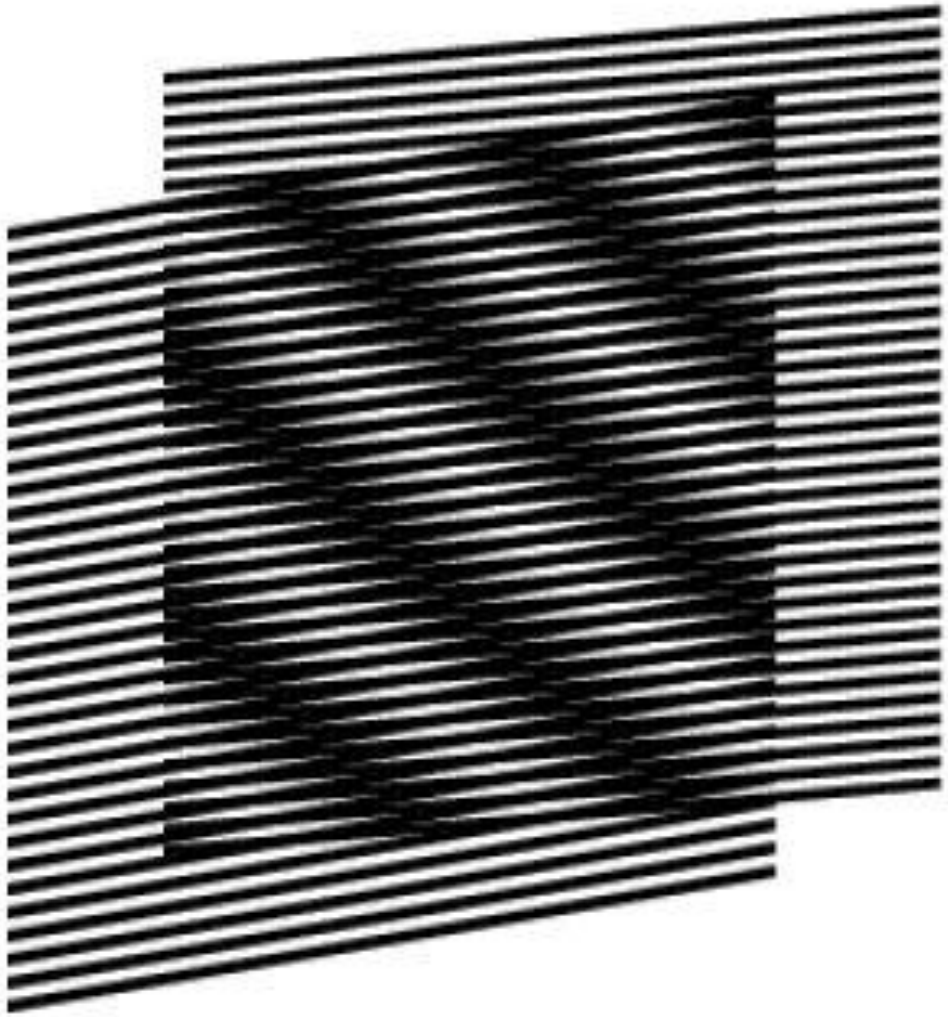
Team Russia

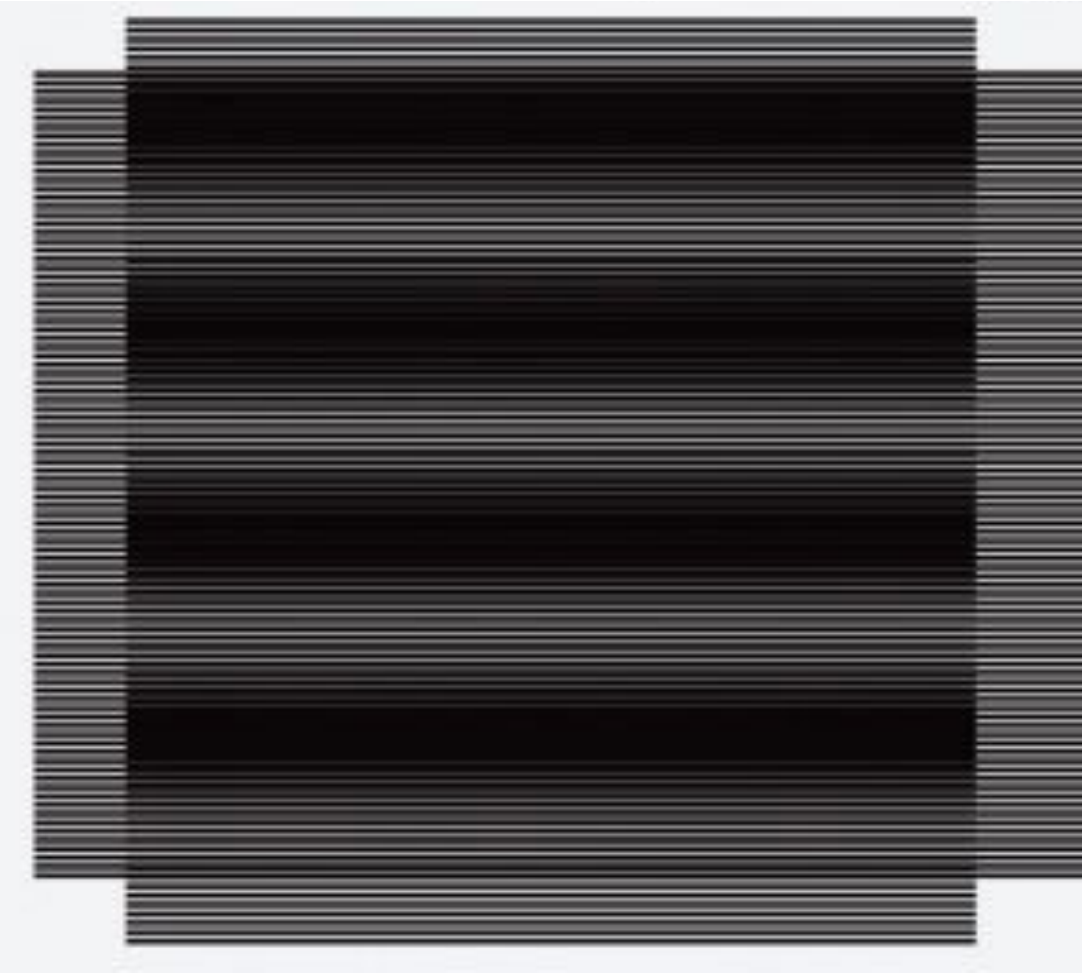
Reporter: Nika Gribova



Basic concept

Moiré pattern is a pattern that occurs when two periodic grids are overlapped.





Review

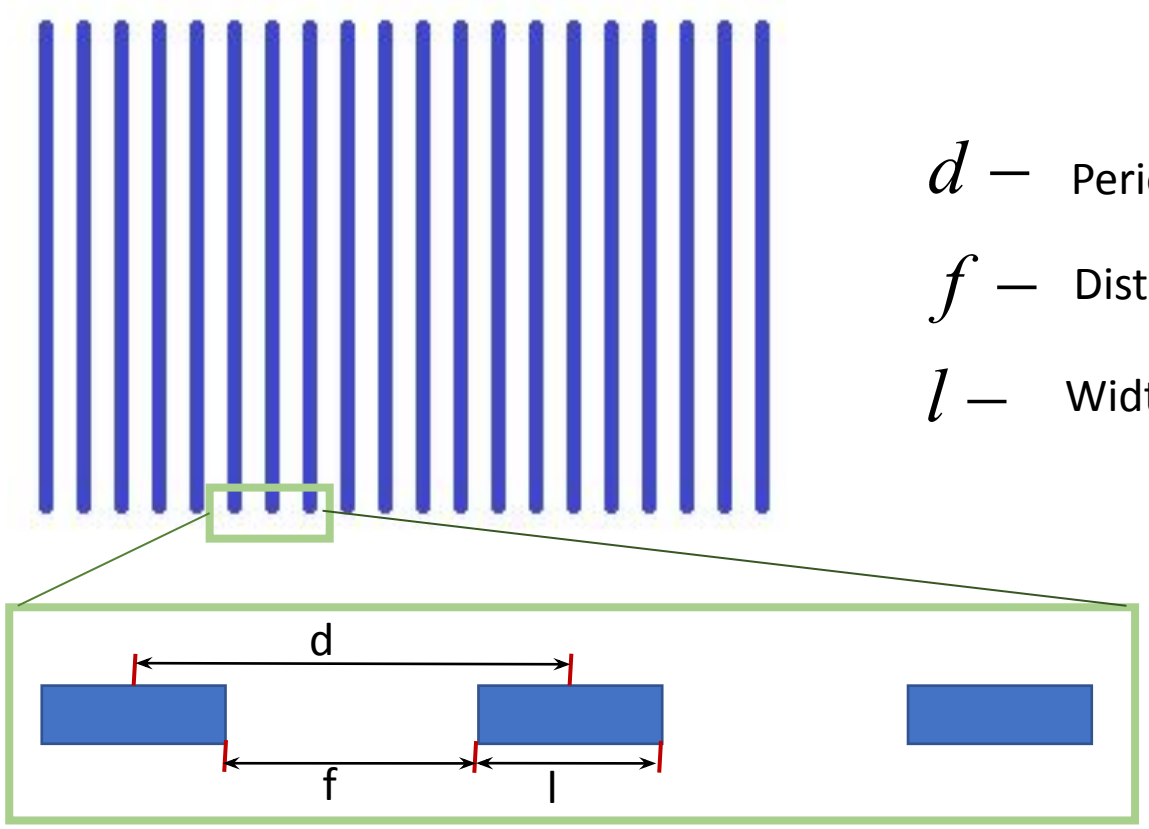
Theoretical model

- Basic concepts(grid, period)
- Qualitative explanation of the moiré`s pattern
- Geometric moiré
- Determination of the formula`s accuracy
- Mathematical model and special cases
- Experimental comparison(direct and indirect measurement)

- calculate the number of threads
- Checking our method for complex fabric
- dependences(period of the moiré pattern on angle and overlay`s period)

Basic concepts

grid

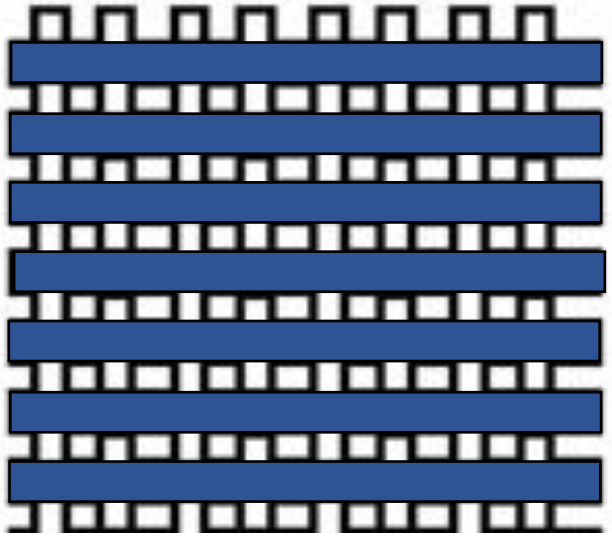


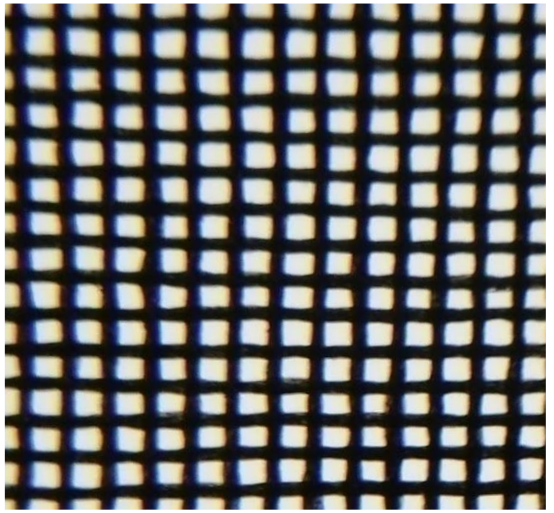
$$d = f + l$$

d – Period of fabric

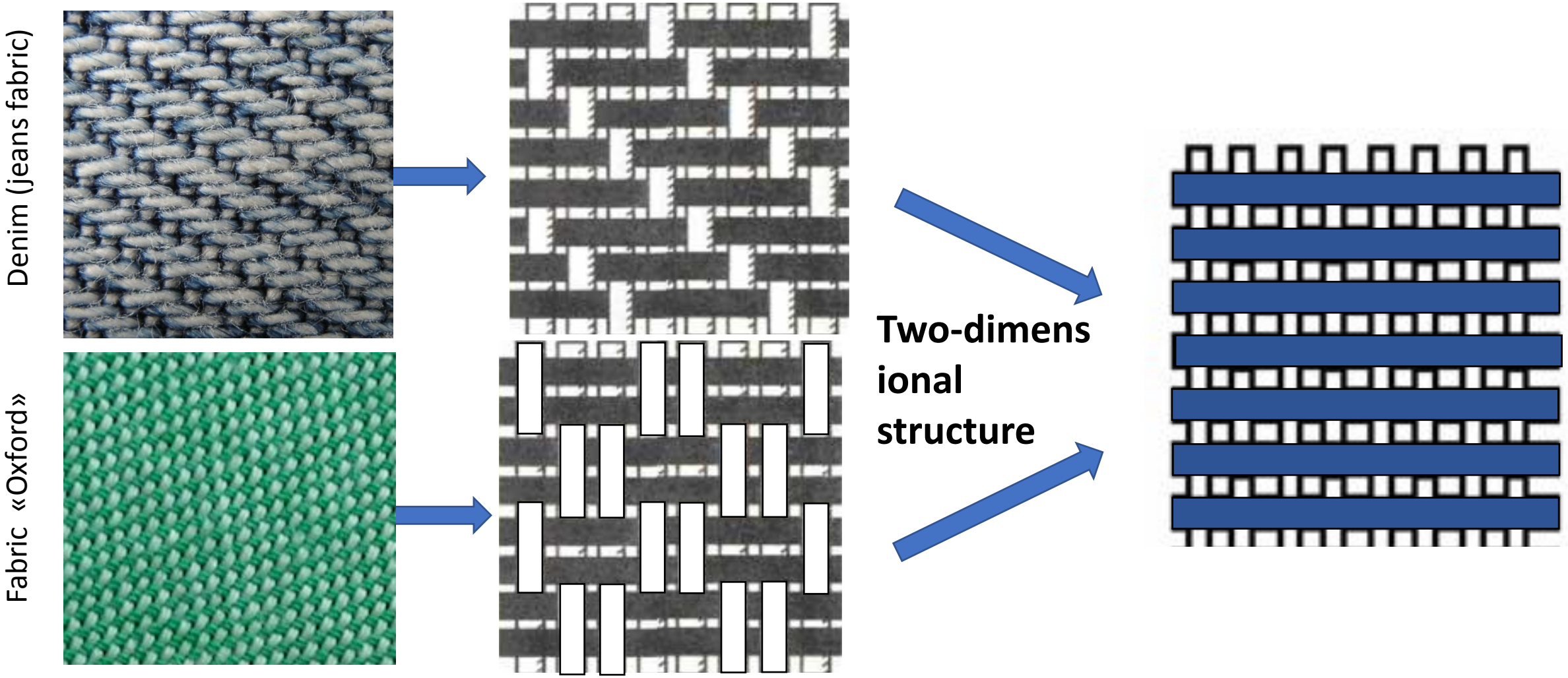
f – Distance between the threads

l – Width of the thread

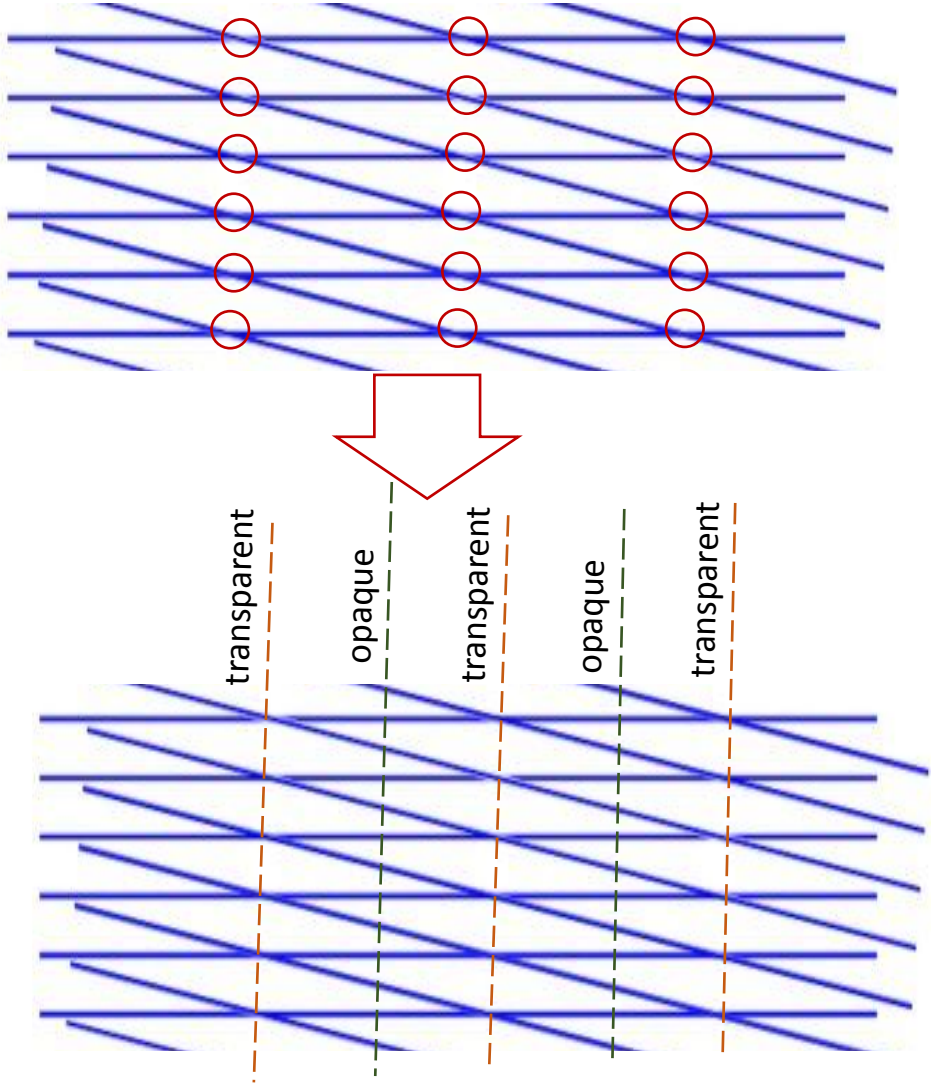


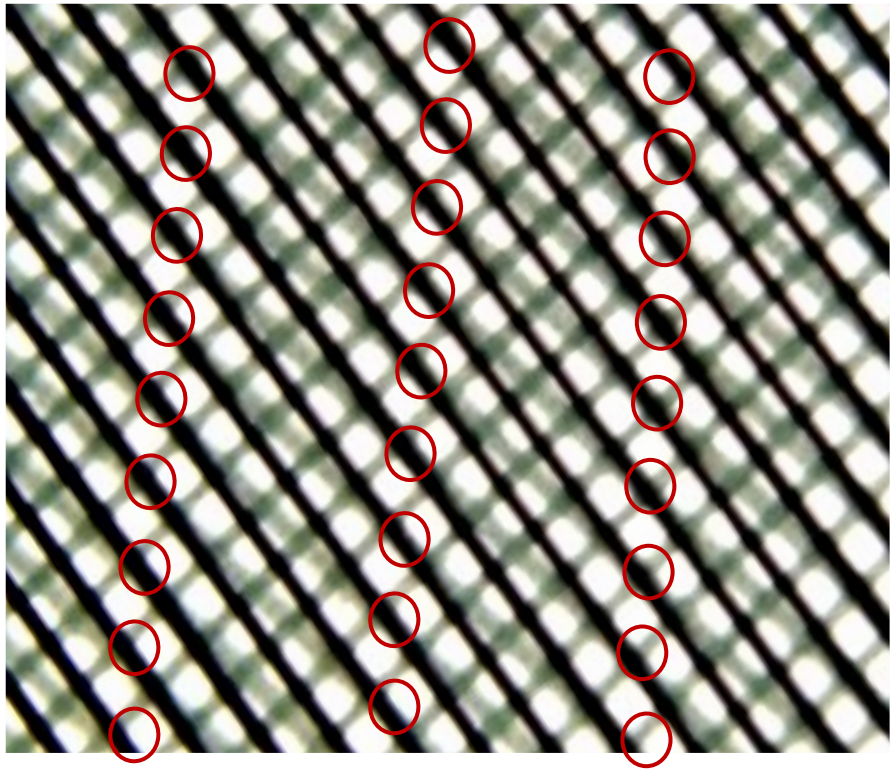


Complex weave

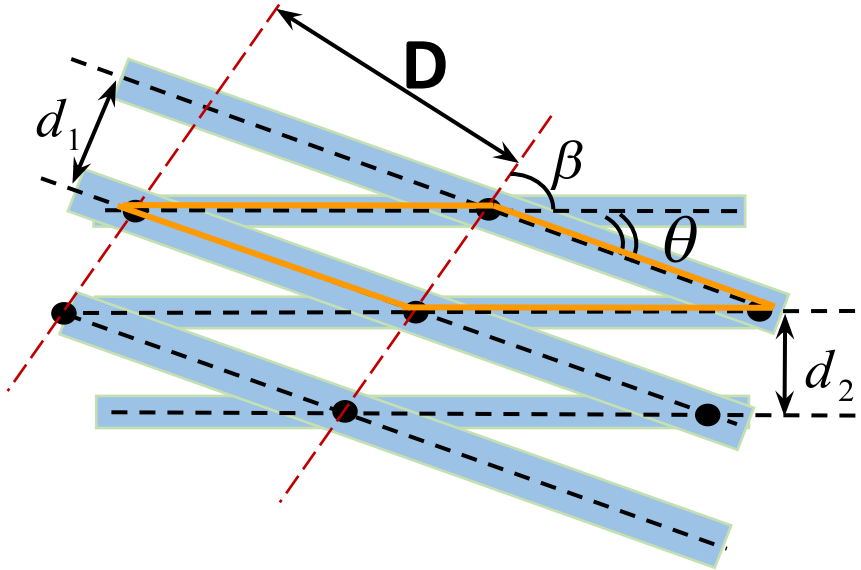


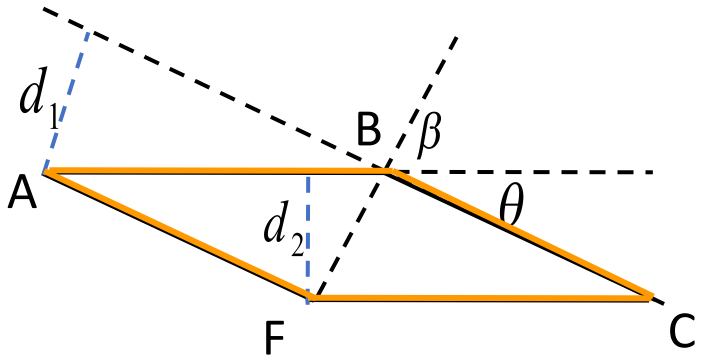
Quality explanation



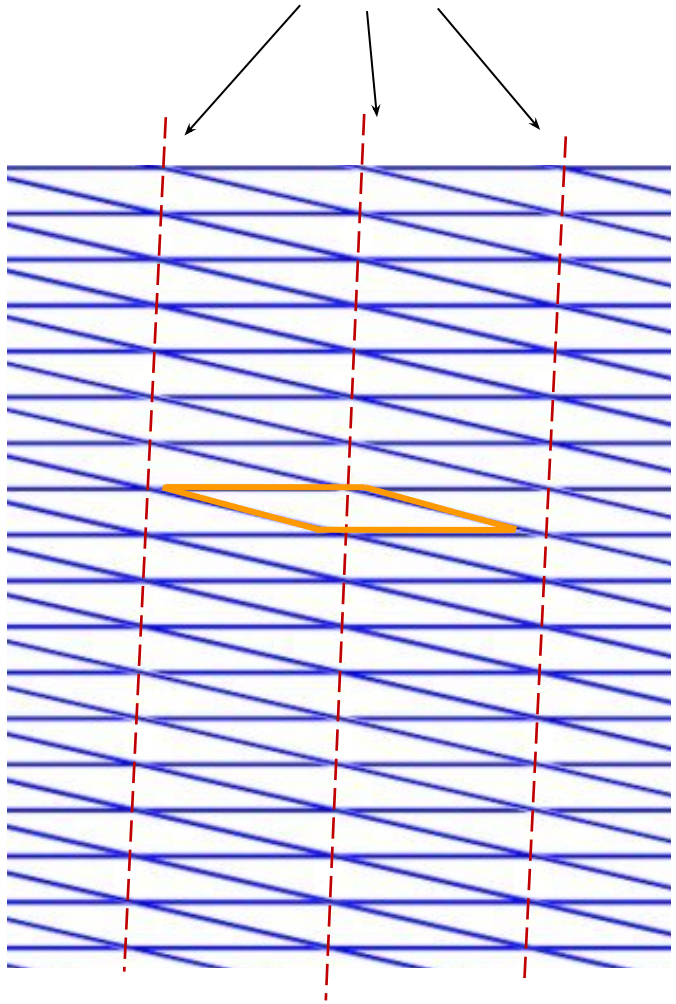


Geometric Moiré



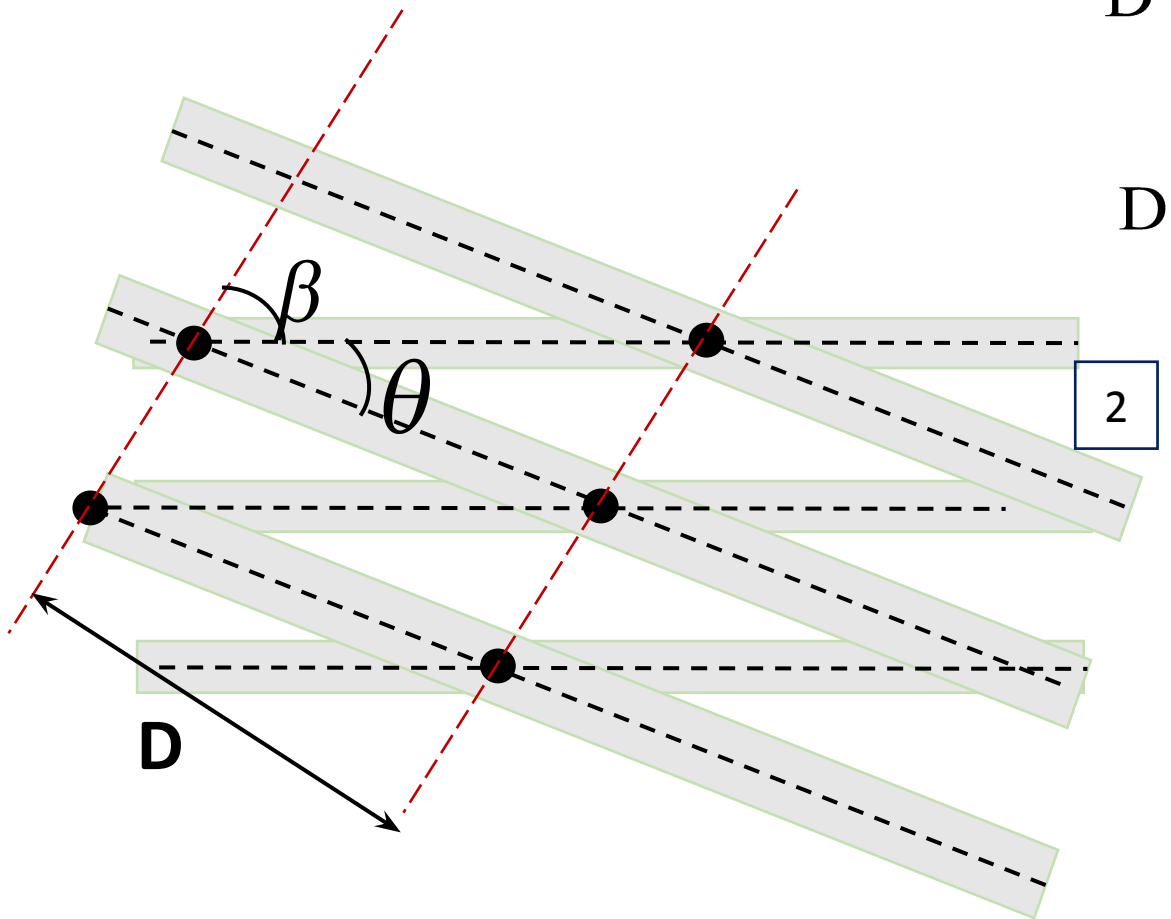


Transparent lines



$$D = \frac{d_1 \cdot d_2}{\sqrt{d_1^2 + d_2^2 - 2 \cdot d_1 \cdot d_2 \cdot \cos\theta}}$$

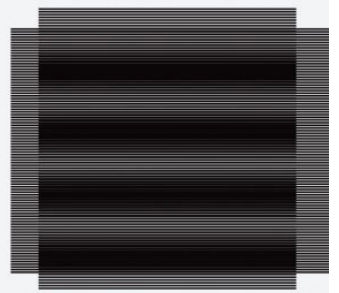
Special case



1 $\theta = 0$

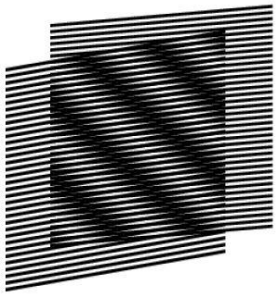
$$D = \frac{d_1 d_2}{\sqrt{d_1^{\,2} + d_2^{\,2} - 2 d_1 d_2 \cos 0°}}$$

$$D = \frac{d_1 d_2}{|d_1 - d_2|}$$



2 $d_2 = d_1$

$$\cos\beta = -2 \cdot \sin^2 \frac{\beta}{2} + 1$$



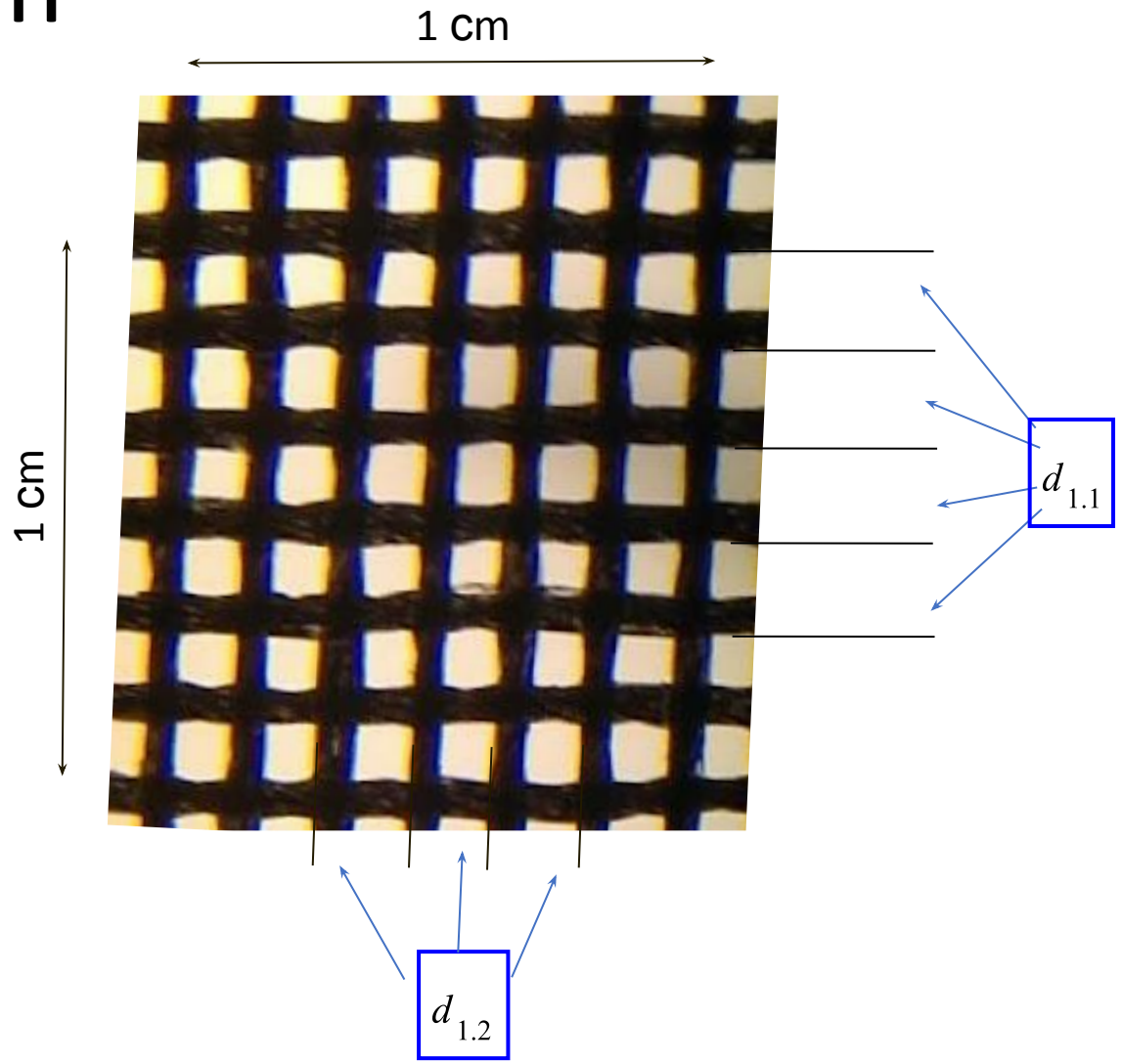
$$D = \frac{d}{\left|2 \sin \frac{\beta}{2}\right|} \qquad n = \frac{1}{2D \cdot \left|\sin \frac{\beta}{2}\right|}$$

Number of threads per 1 cm

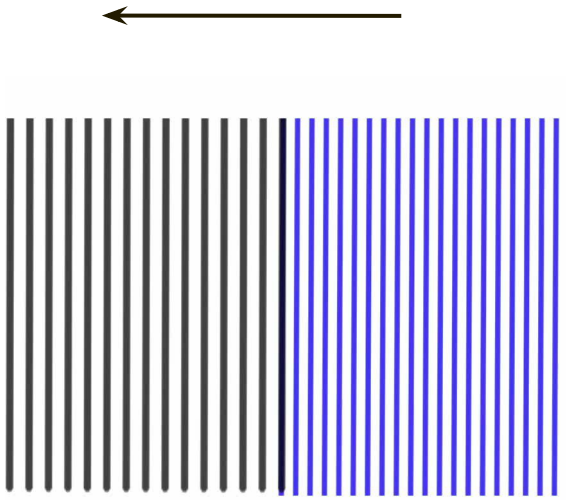
$$n_1 = \frac{1}{d_1} \cdot cm^{-1}$$

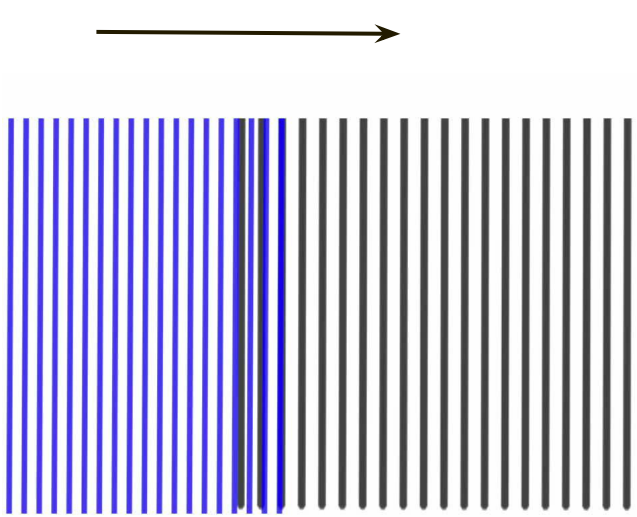
$$D = \frac{\frac{1}{n_1} \cdot d_2}{\sqrt{\frac{1}{n_1^{\,2}} + d_2^2 - \frac{2 \cdot d_2 \cdot \cos\theta}{n_1}}}$$

$$n_1(\theta, D, d_2) = \frac{D\cos\theta \pm \sqrt{d_2^2 - D^2 \sin^2\theta}}{d_2 D}$$

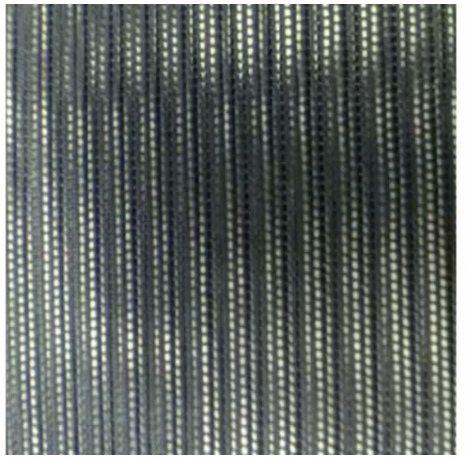


Fabric with less period



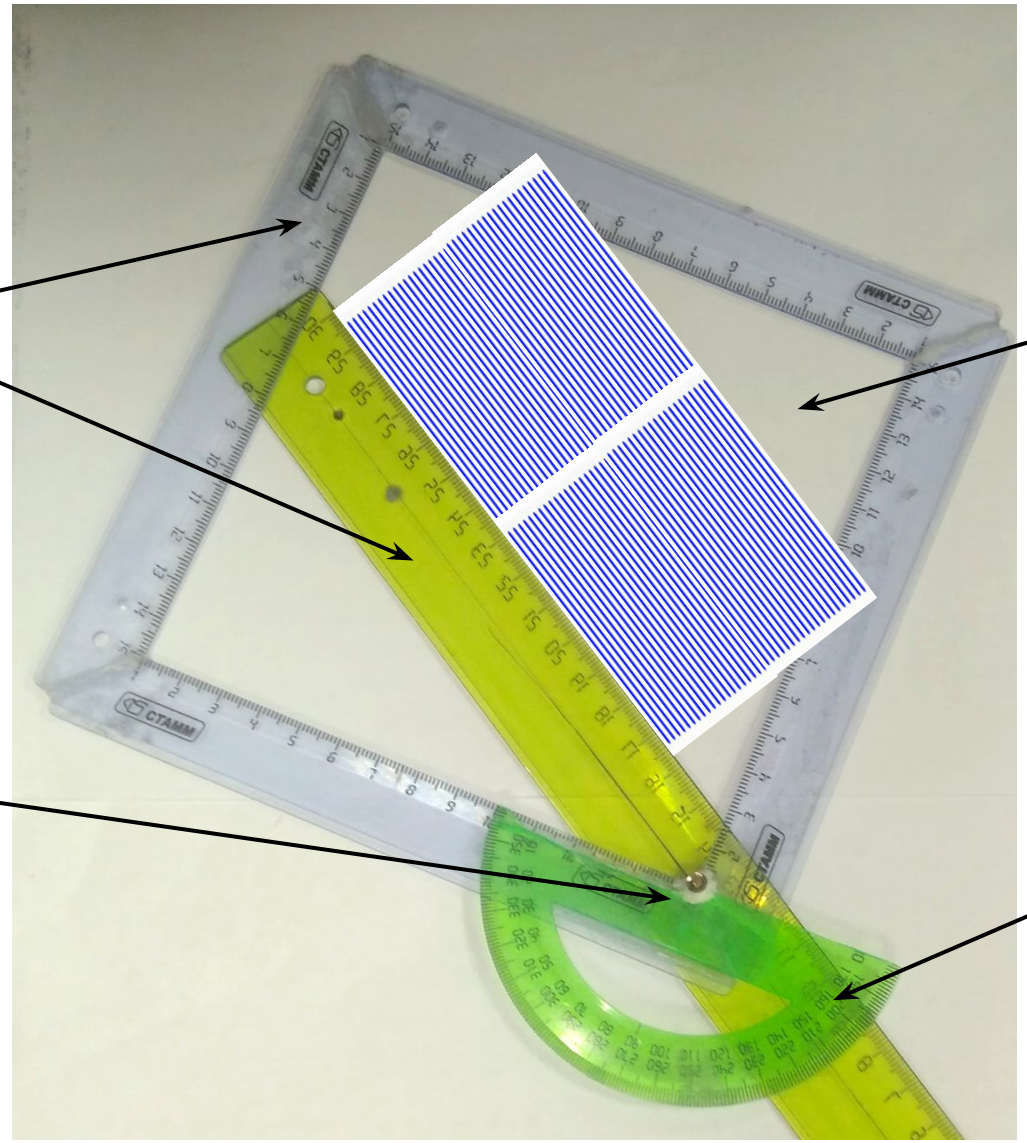


Fabric with bigger period



$$n_1(\theta, D, d_2) = \frac{D\cos\theta - \sqrt{d_2^2 - D^2\sin^2\theta}}{d_2 D}$$

Experimental set-up



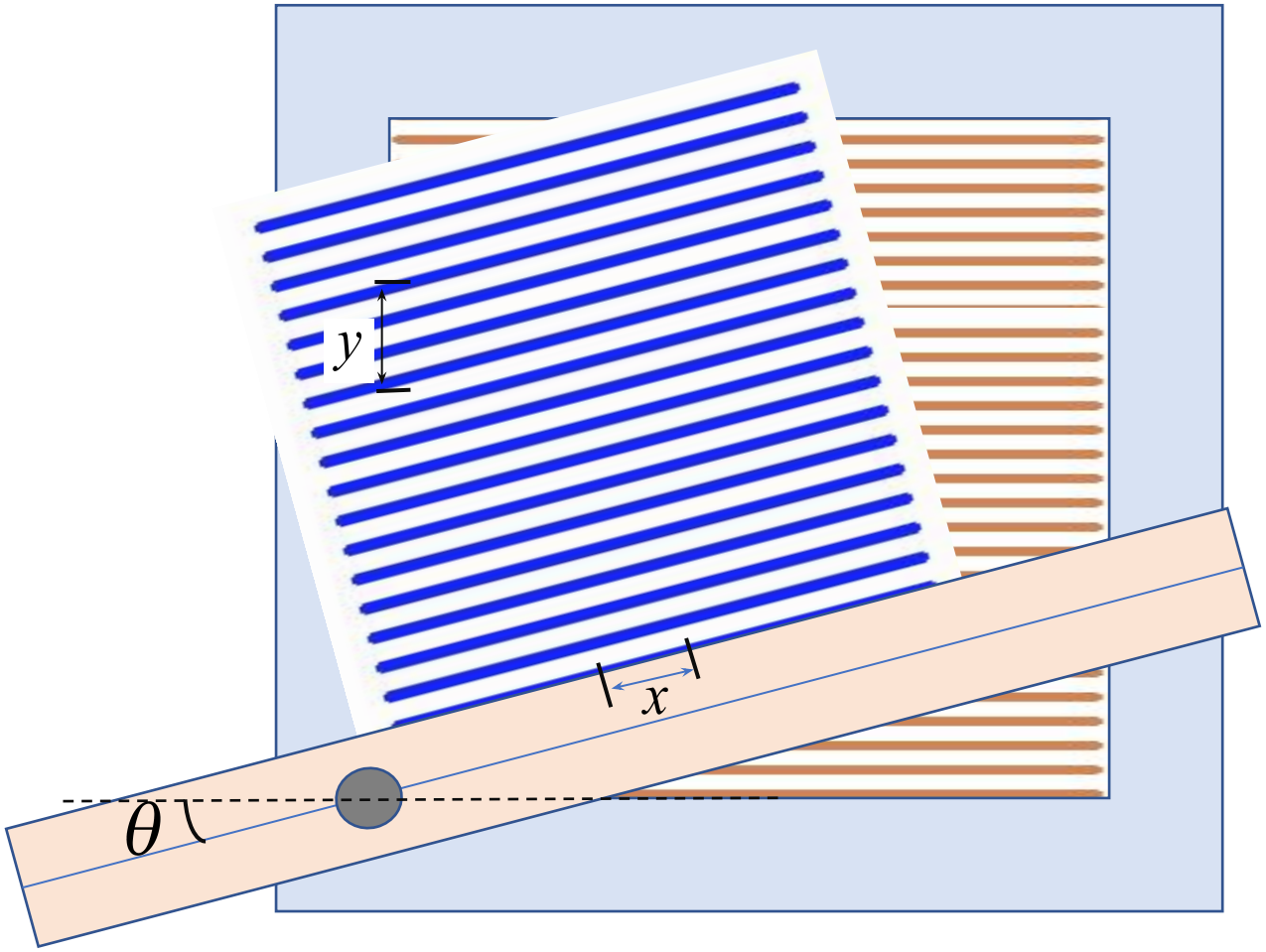
rulers

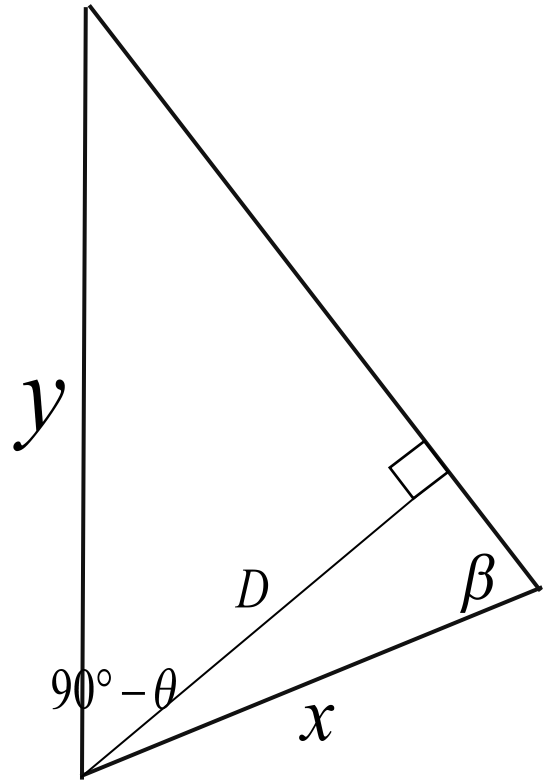
overlay
0,5мм
0,2мм
0,1мм

Screw with nut

protractor

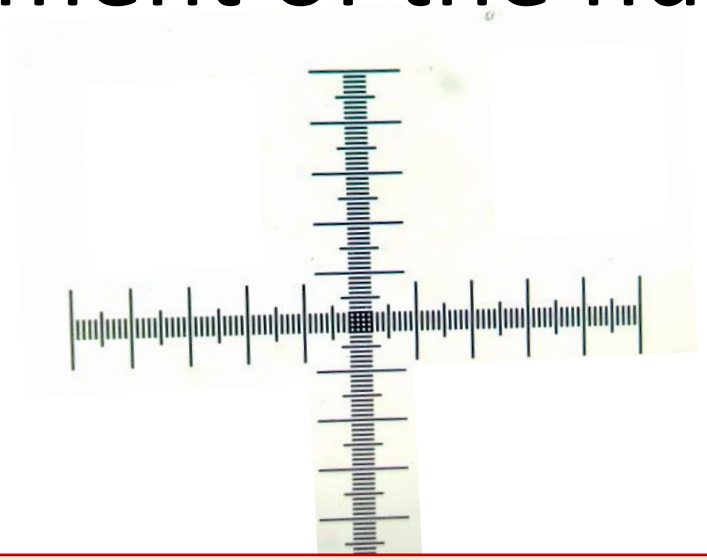
The calculation of the period of moiré





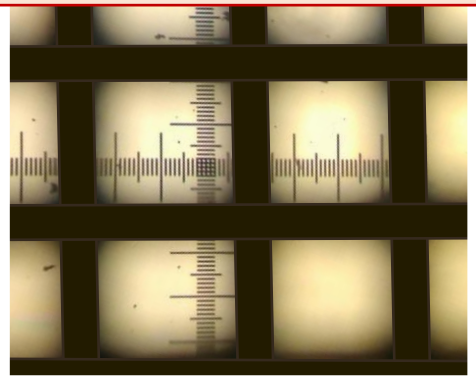
$$D = \frac{x \cdot y \cdot \cos\theta}{\sqrt{x^2 + y^2 - 2xy \cdot \sin\theta}}$$

Direct measurement of the number of threads



Errors of the number of threads of direct method:

We take around 20 measurements and average them.



Error of set up

$$n_1(\theta, D, d_2) = \frac{D\cos\theta - \sqrt{d_2^2 - D^2\sin^2\theta}}{d_2 D}$$

$$\Delta D = \sqrt{\left(\frac{\partial D}{\partial x}\Delta x\right)^2 + \left(\frac{\partial D}{\partial y}\Delta y\right)^2 + \left(\frac{\partial D}{\partial \theta}\Delta\theta\right)^2}$$

$$\Delta n_1 = \sqrt{\left(\frac{\partial n_1}{\partial d_2}\Delta d_2\right)^2 + \left(\frac{\partial n_1}{\partial \theta}\Delta\theta\right)^2 + \left(\frac{\partial n_1}{\partial D}\Delta D\right)^2}$$

$$T = \frac{1}{\Delta n_{отн}} = \frac{n}{\Delta n_{абс}}$$

$$\Delta d_2 = \pm 0{,}01 мм$$

$$\Delta\theta = \pm 1°$$

$$D = \frac{x \cdot y \cdot \cos\theta}{\sqrt{x^2 + y^2 - 2xy \cdot \sin\theta}}$$

Table values at 15°

X,мм / y,мм	**0,1**	**0,15**	**0,2**	**…**	**6**
0,1	0,079 0,03	0,87 0,031	0,105 0,031		0,174 0,045
0,15	0,87 0,031	0,119 0,032	0,13 0,034		0,186 0, 063
0,2	0,105 0,031	0,13 0,034	0,1586 0,0356		0,195 0.65
…					
8	0,096 0,1	0,01 0,11	0,012 0,11		5,347 1,54

The period of moiré,мм / overlay, мм	**0,079**	**0,87**	**…**
0,42	14,9 2,14	12,3 1,5	…
0,82	14,6 2,1	12,26 1,7	…
1,15	14,2 1,96	12,1 1,94	…

The period of moiré

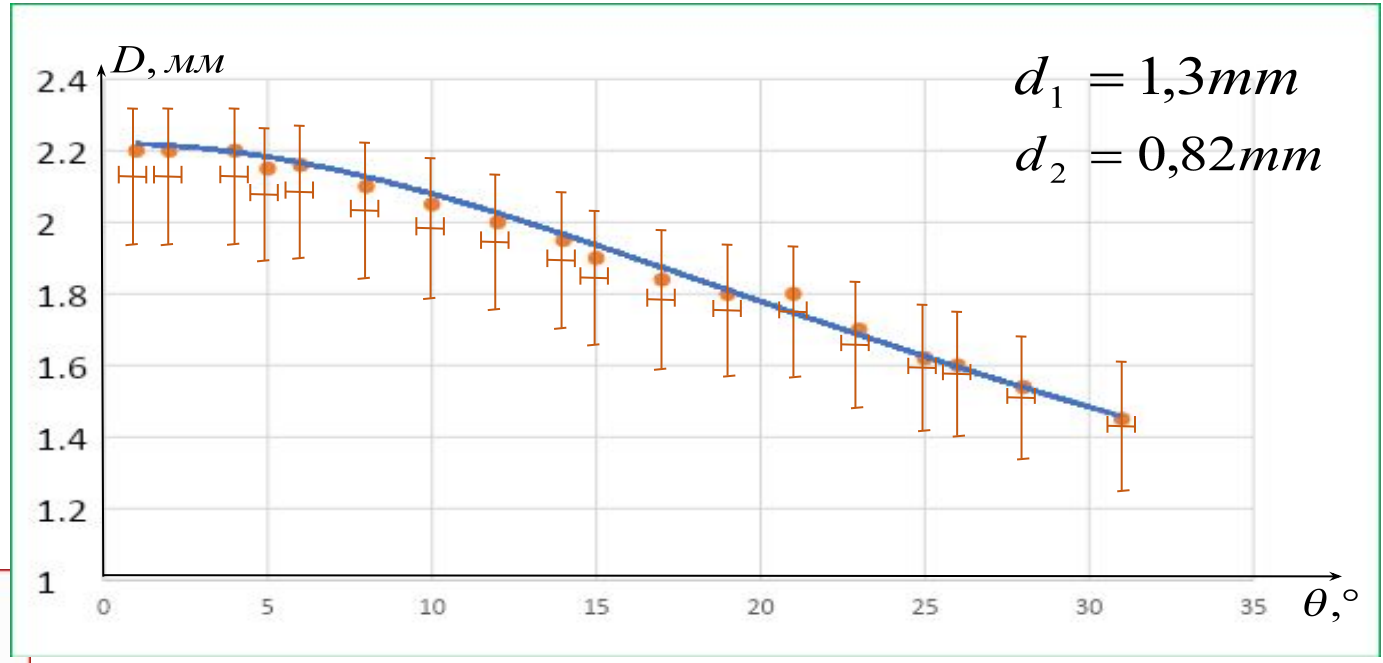
error of moire period

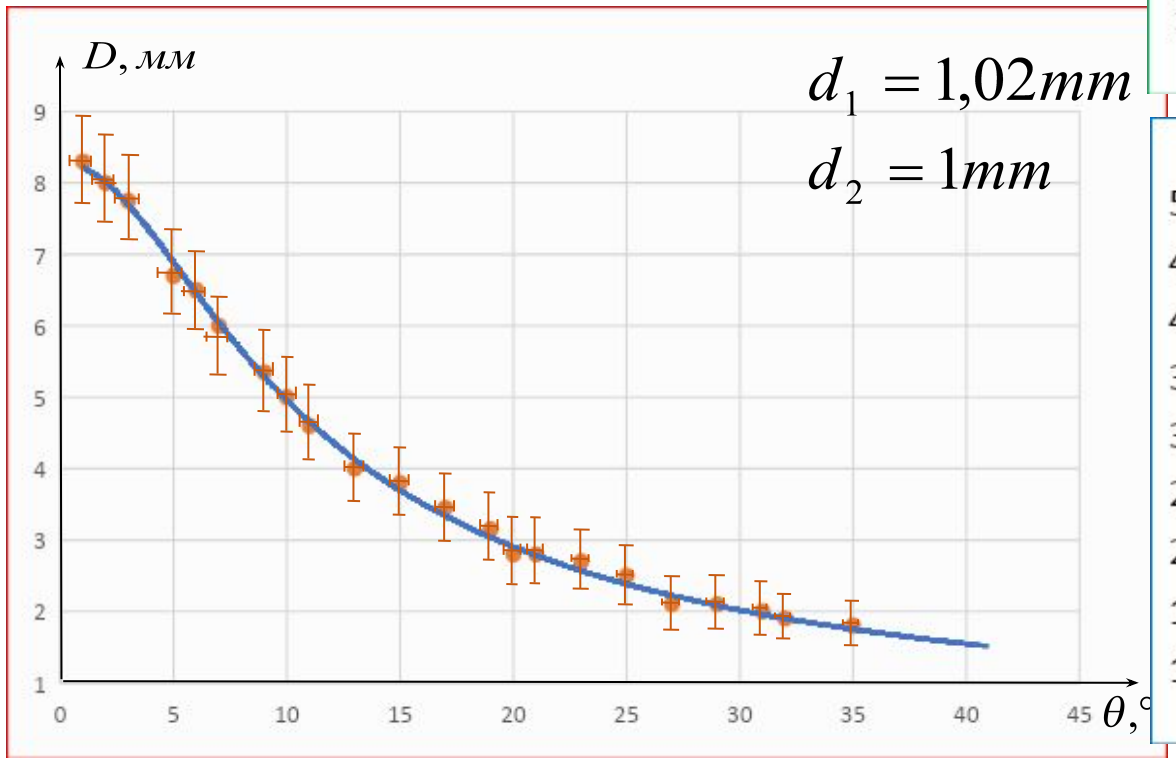
Number of threads per cm

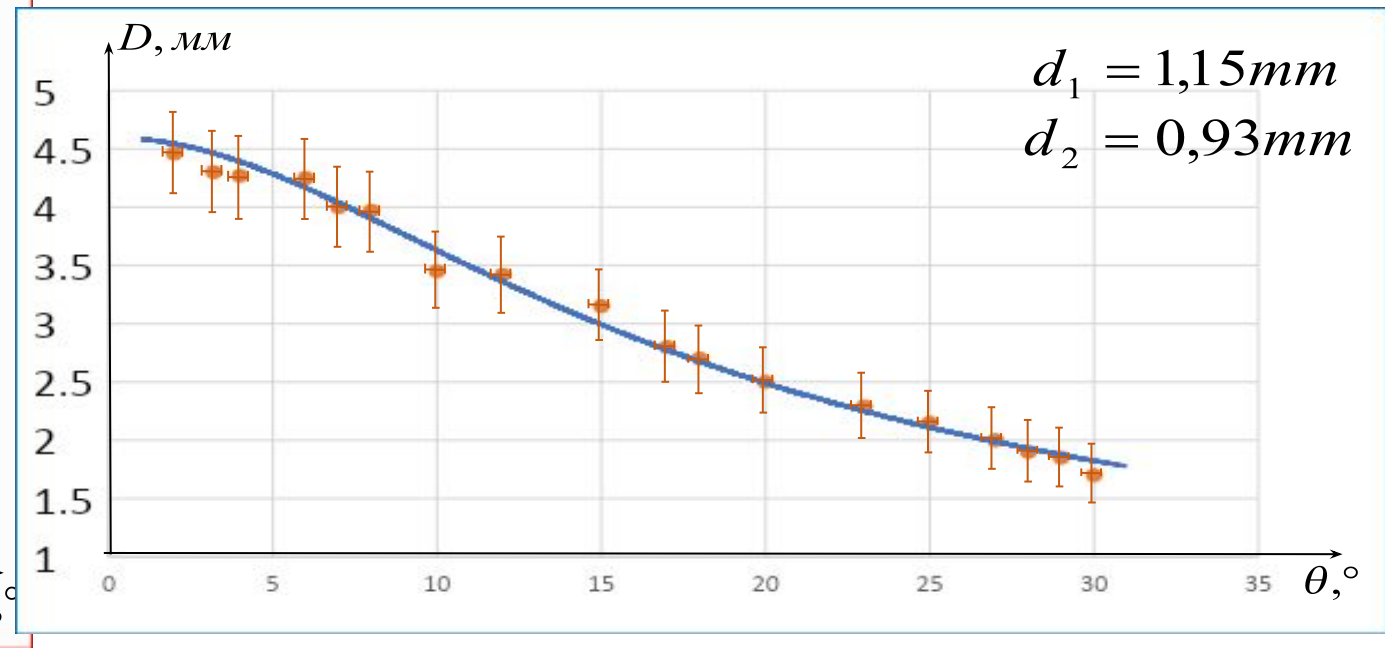
Error of set up

Dependence of the moiré pattern period on the rotation angle

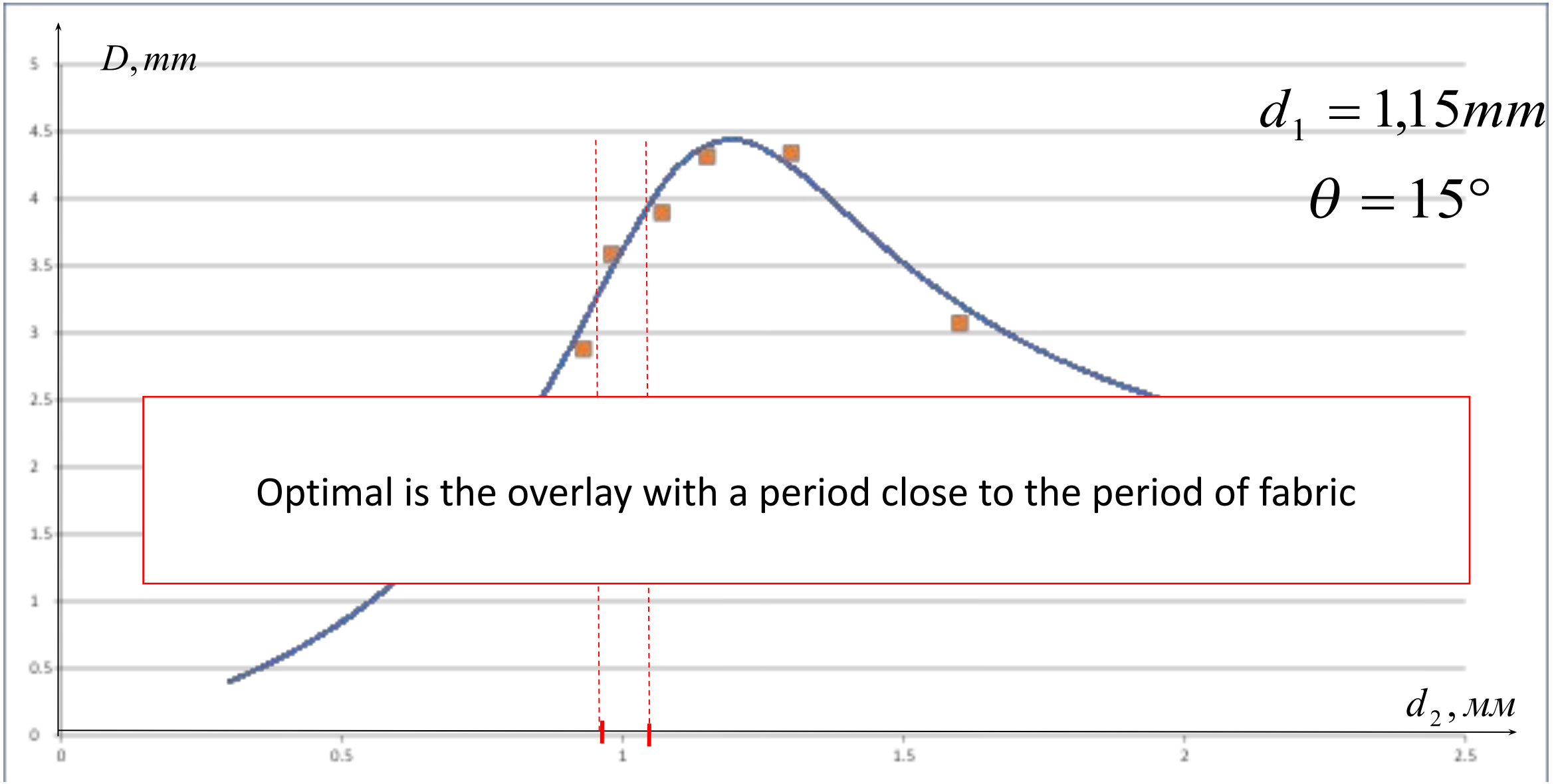
$$D = \frac{d_1 \cdot d_2}{\sqrt{d_1^2 + d_2^2 - 2 \cdot d_1 \cdot d_2 \cdot \cos\theta}}$$







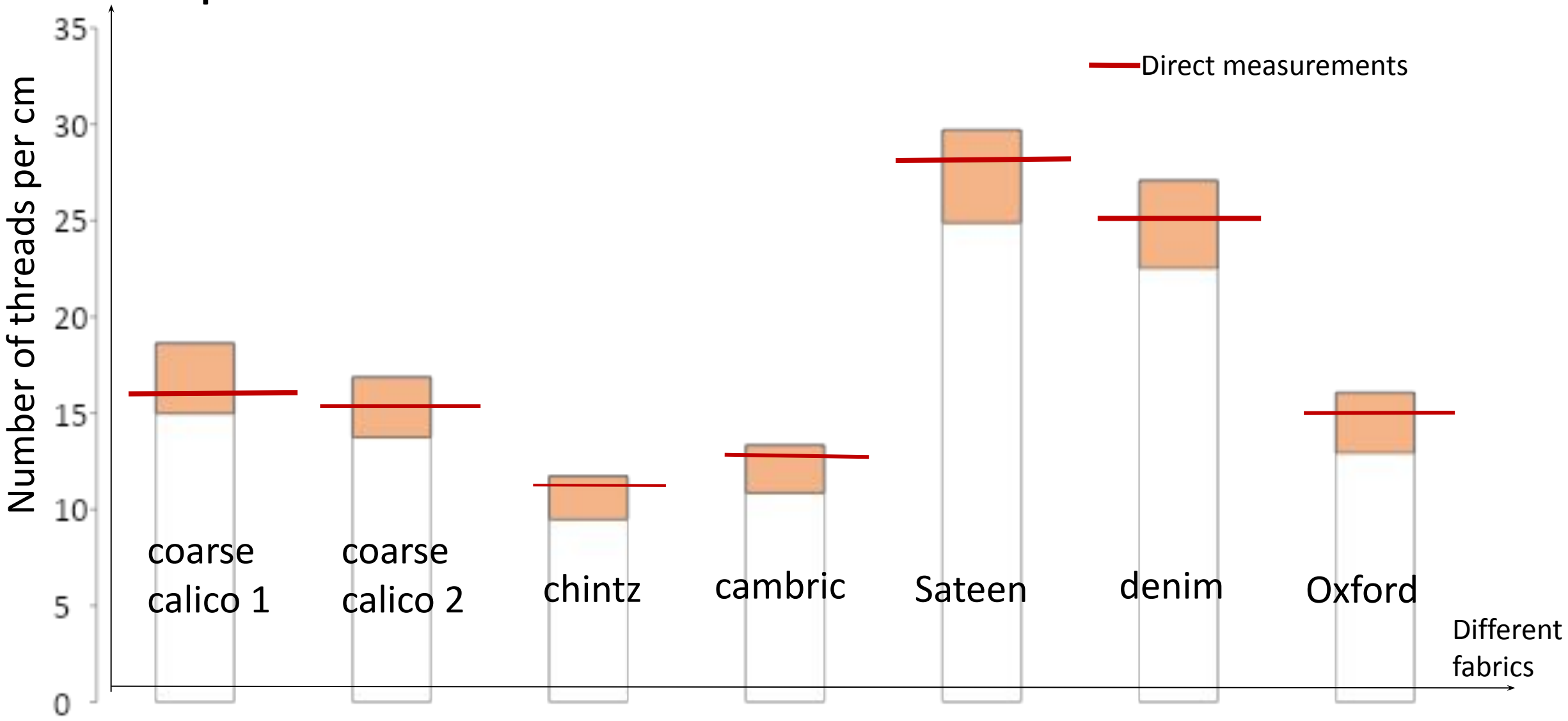
Dependence of the moire period on the overlay



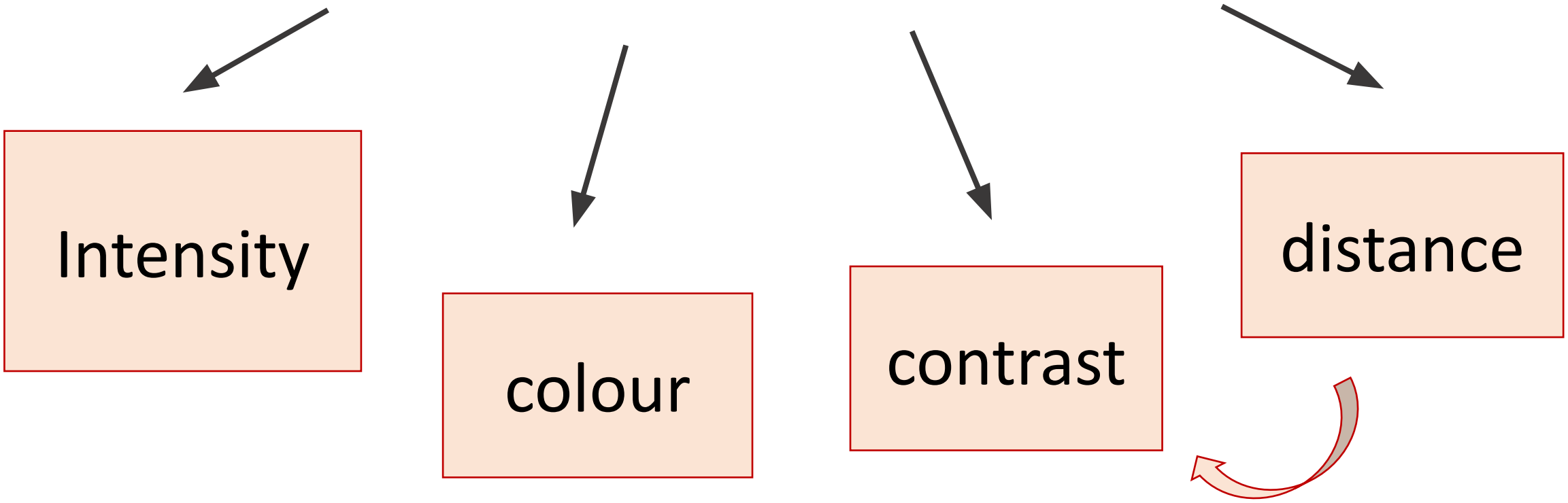
Comparison between direct and undirect measurement

Fabric	Moiré pattern(undirect)	Microscope(direct)
coarse calico 1	14,97<16,80<18,63	15,87<15,90<15,93
coarse calico 2	13,73<15,30<16,87	15,58<15,60<15,62
chintz	9,48<10,60<11,72	10,79<10,80<10,81
cambric	10,86<12,10<13,34	12,78<12,80<12,82
Sateen	24,89<27,30<29,71	28,62<28,70<28,78
Denim	22,52<24,80<27,08	24,98<25,05<25,11
Oxford	12,93<14,50<16,07	14,68<14,70<14,72

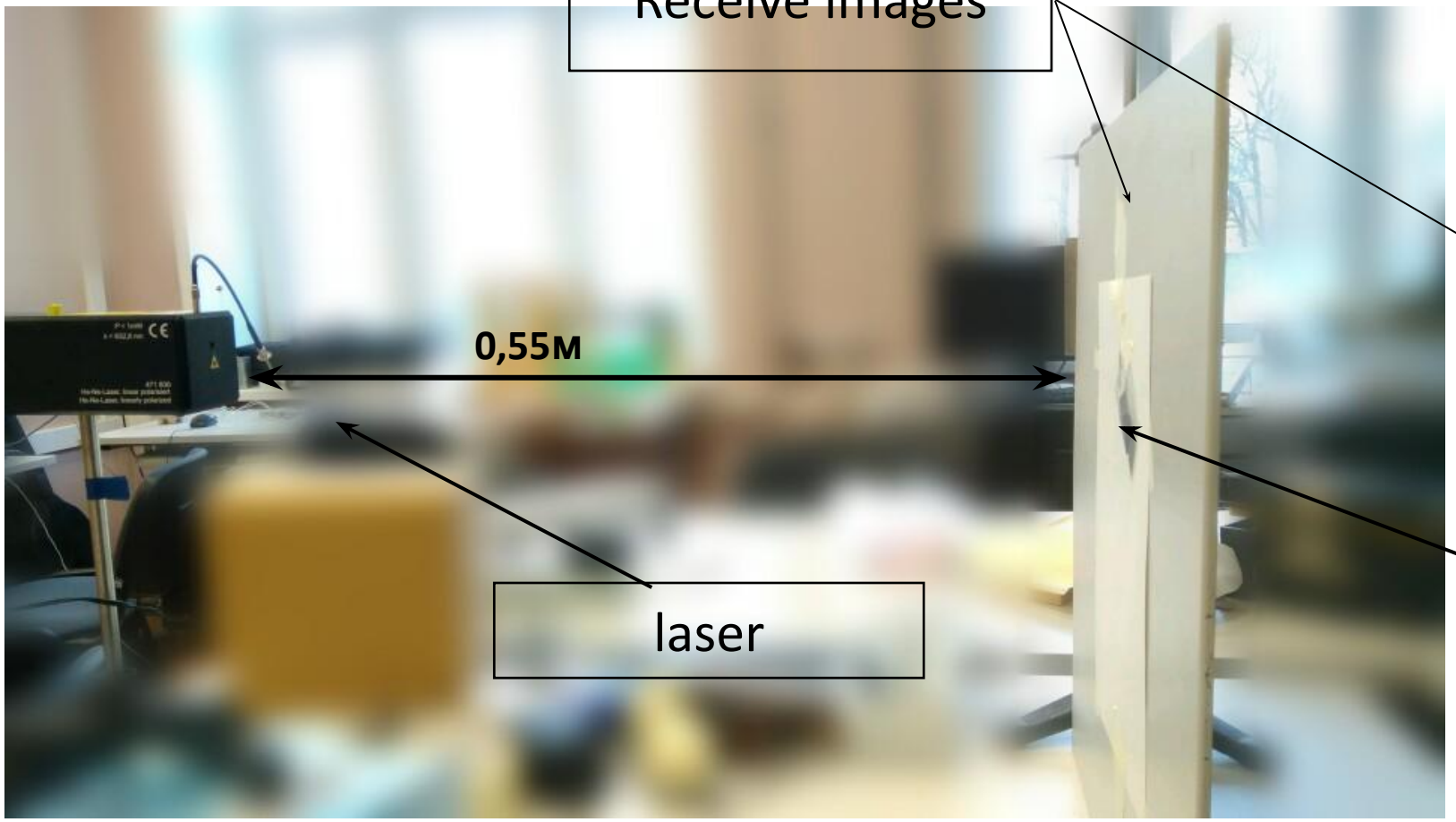
Comparison between direct and indirect measurement



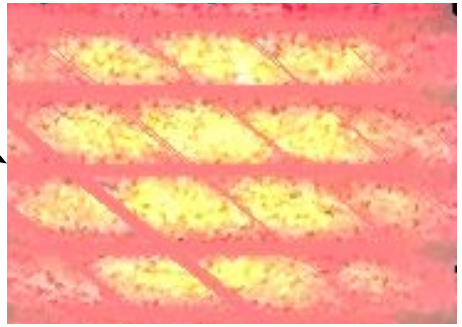
Applicability of designed overlay



Set up with improved resolution



800 kilo lux-sensor of (order of 1000 lux-sensor)

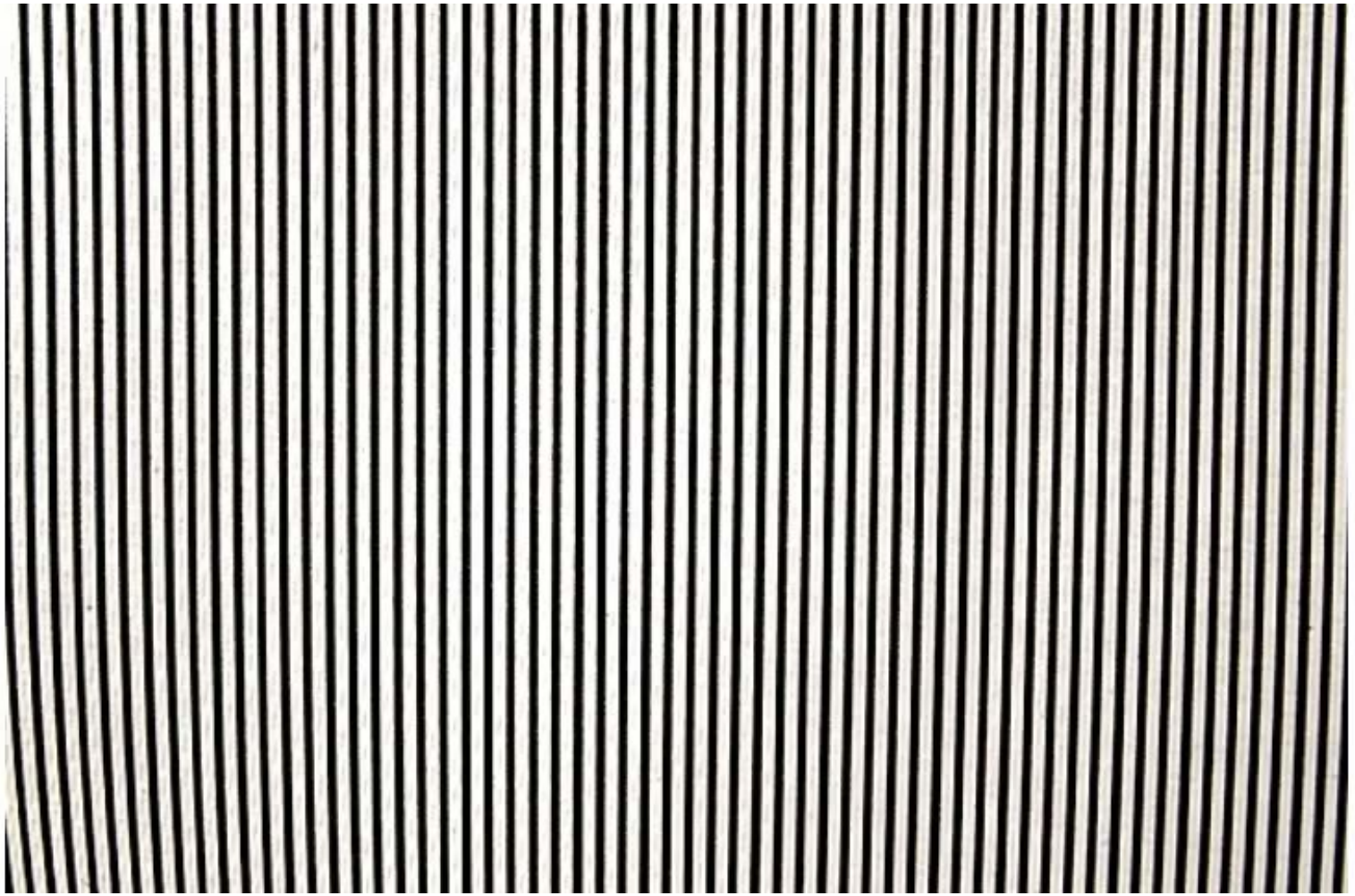


60 **kilo lux-sensor**

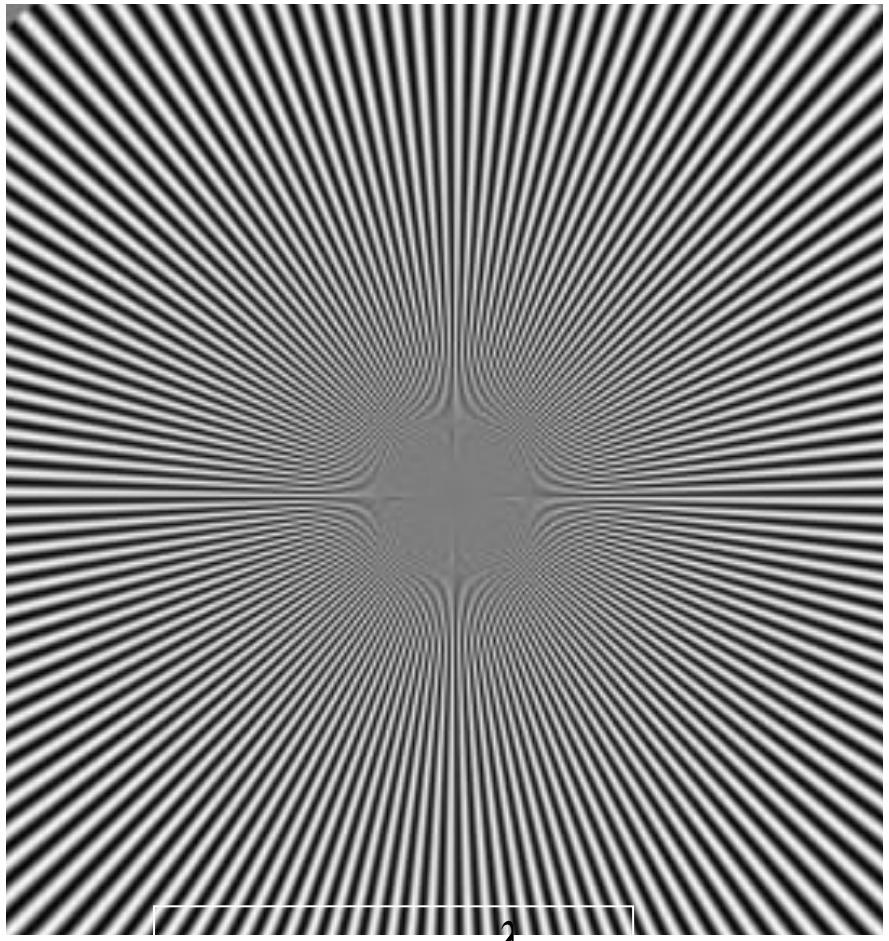
overlay

Limitations of the visibility of a moiré pattern

Critical angle

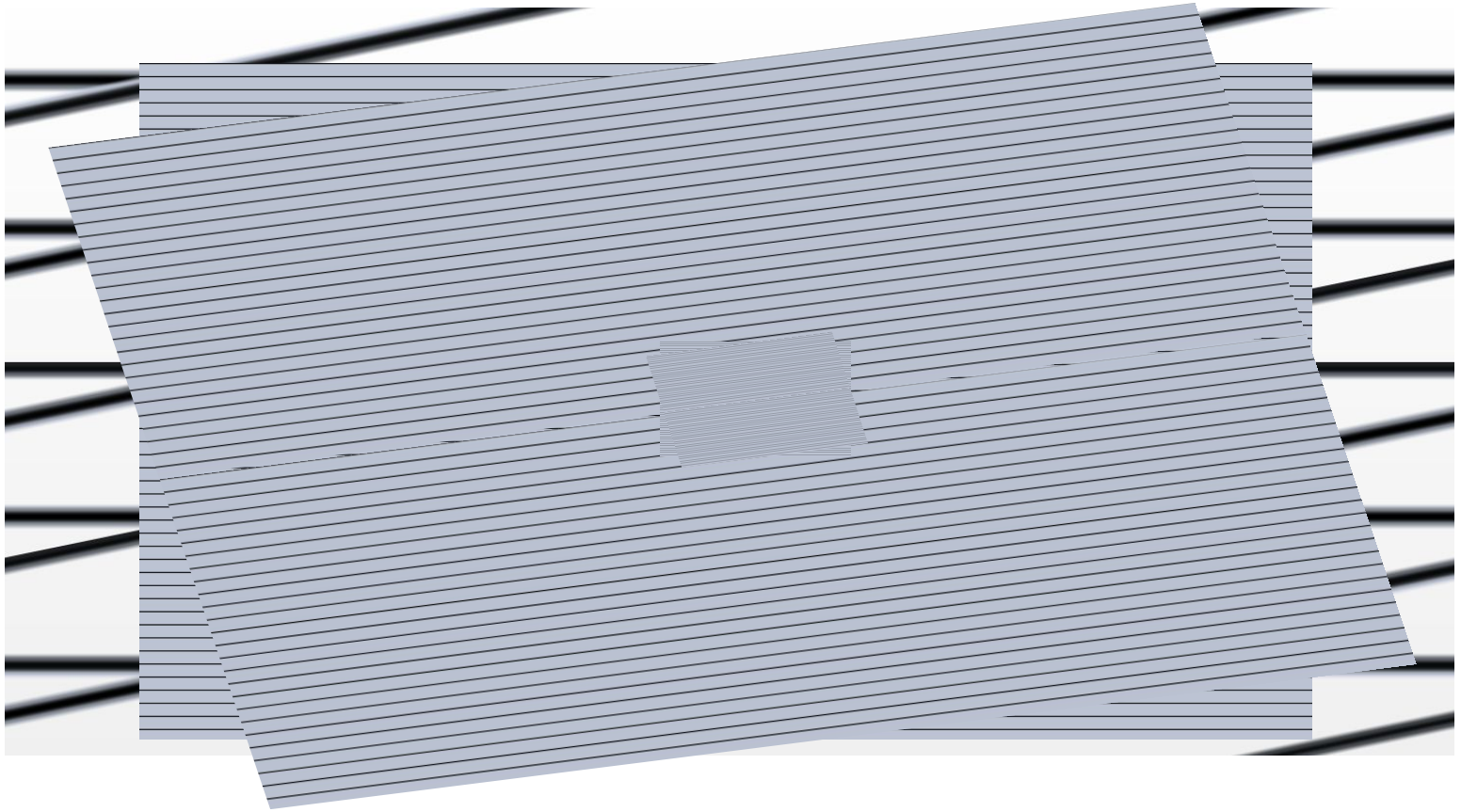


Angular resolution



$$Q = 1.220 \frac{\lambda}{D_{\text{апертуры}}}$$

Applicability of designed overlay

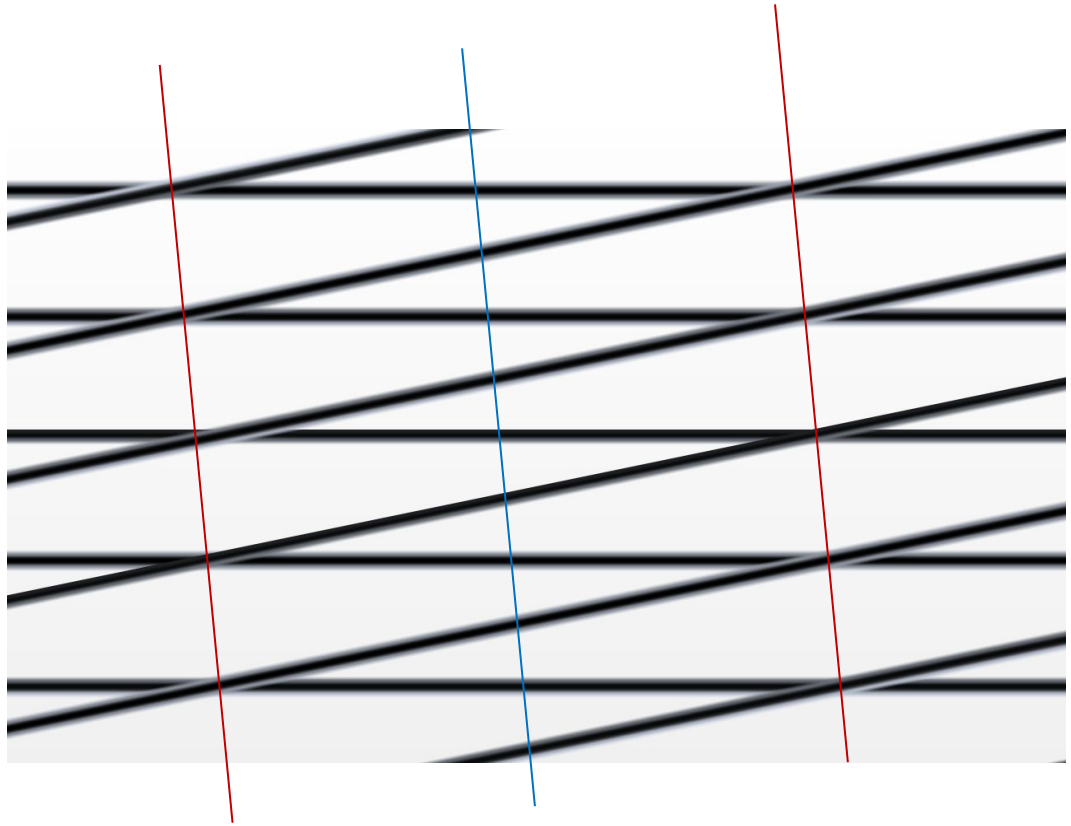


We don’t see the moiré pattern(the distance between our eyes or camera and overlay with the fabric is too small)

We see the moiré pattern

We don’t see the moiré pattern(the distance between our eyes or camera and overlay with the fabric is too big)

Applicability of designed overlay



Thickness of the overlay's line

Thickness of the thread

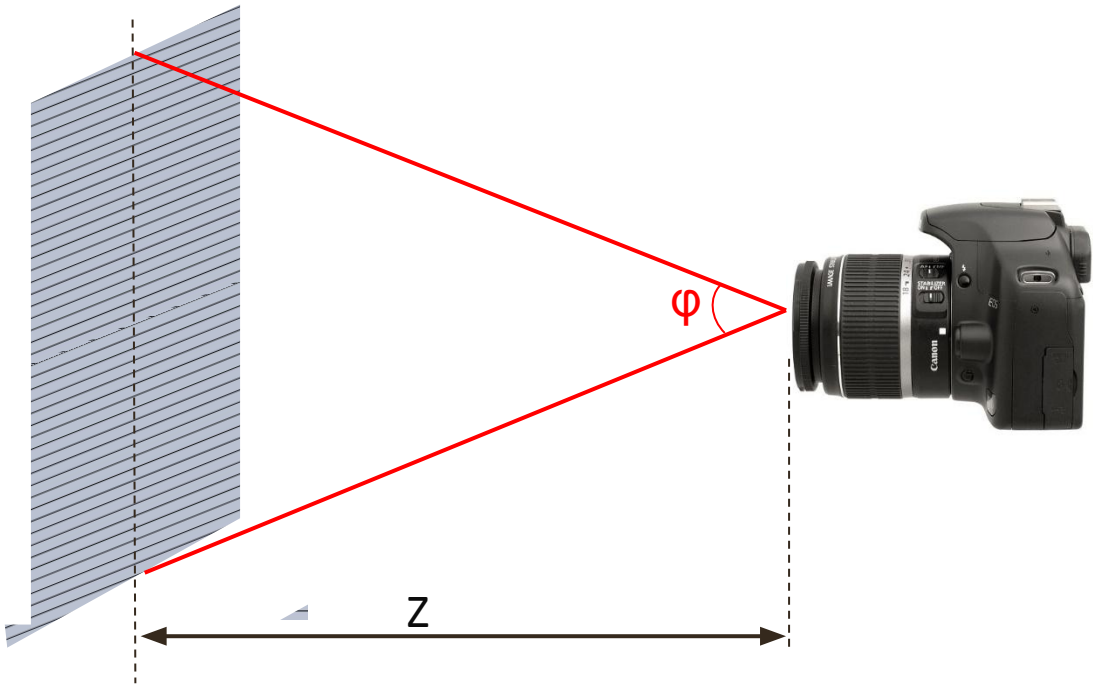
$$C = \frac{1 - \frac{t_{overlay}}{d_{overlay}}}{1 - \frac{t_{overlay}}{d_{overlay}} - \frac{t_{thread}}{d_{thread}}}$$

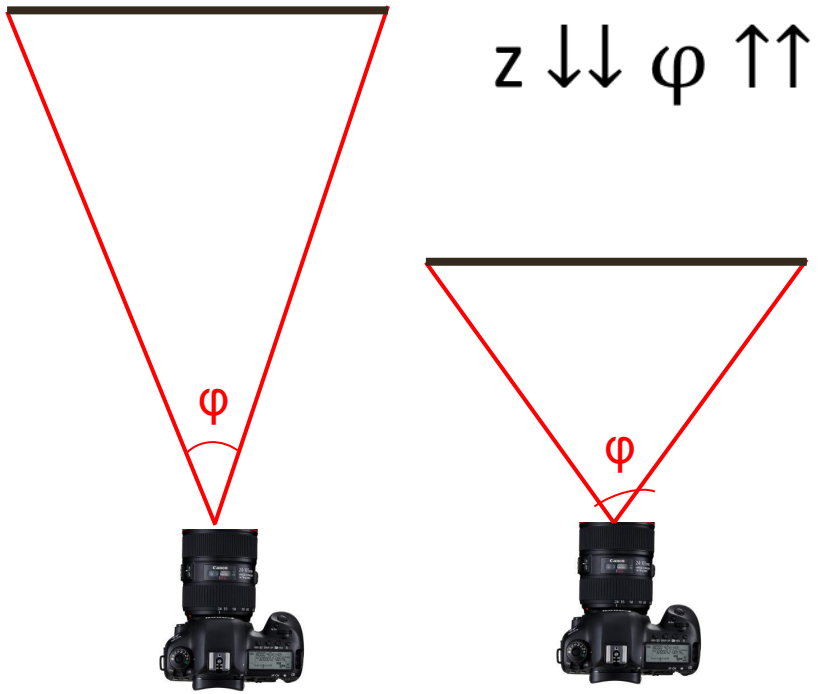
Period of the overlay

Period of the fabric

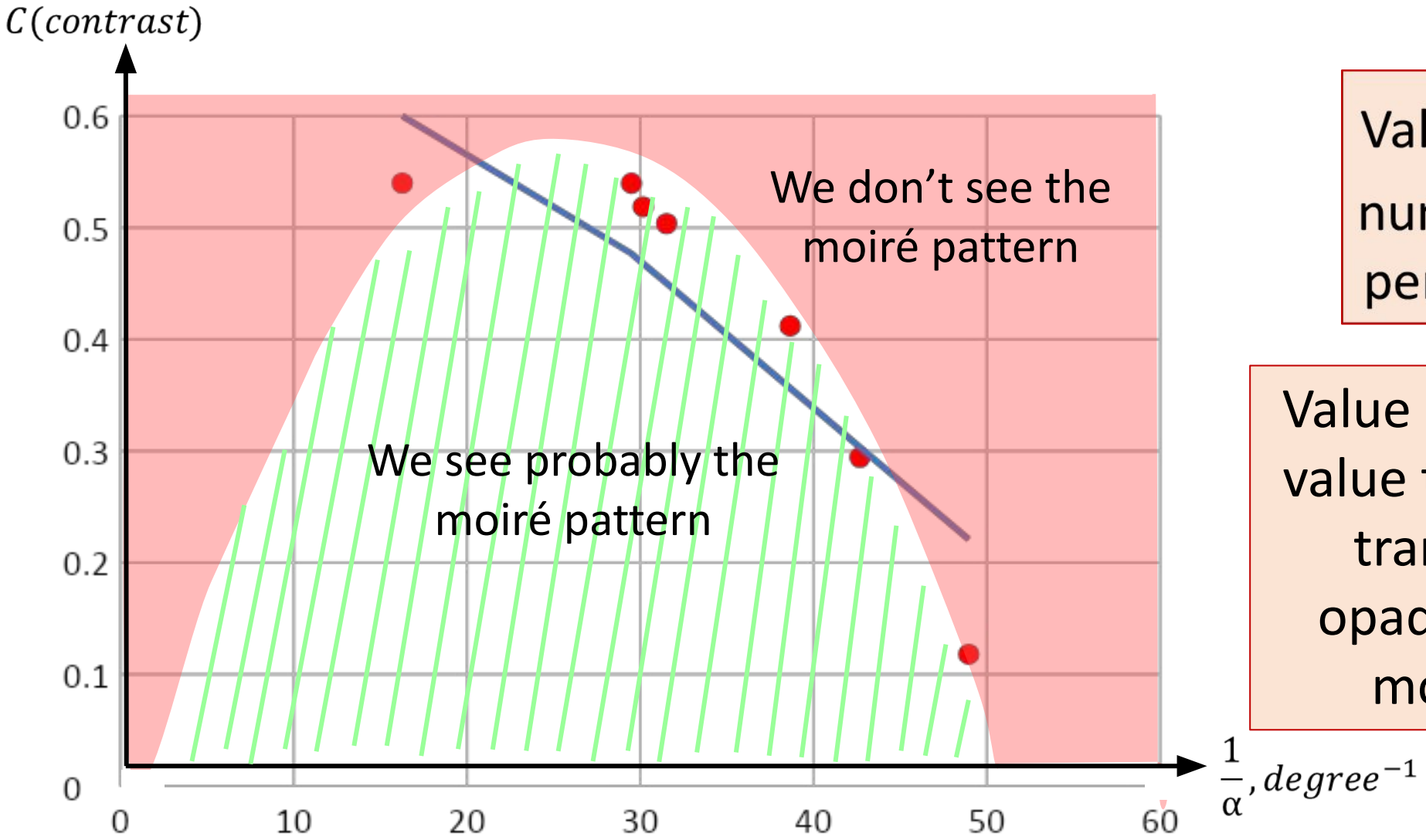
The influence of the distance

The angle, which our eyes(or camera) see the overlay at, decreases if the distance increases





The applicability of our method



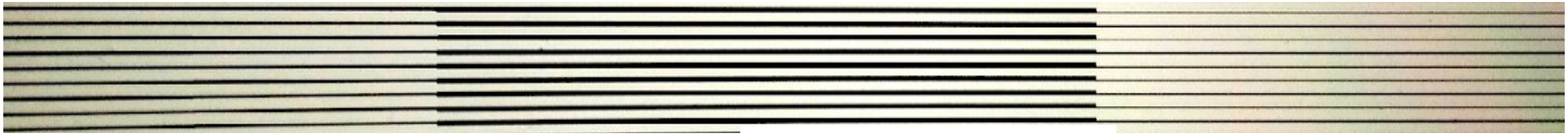
Value $\frac{1}{\alpha}$ is the number of lines per one degree

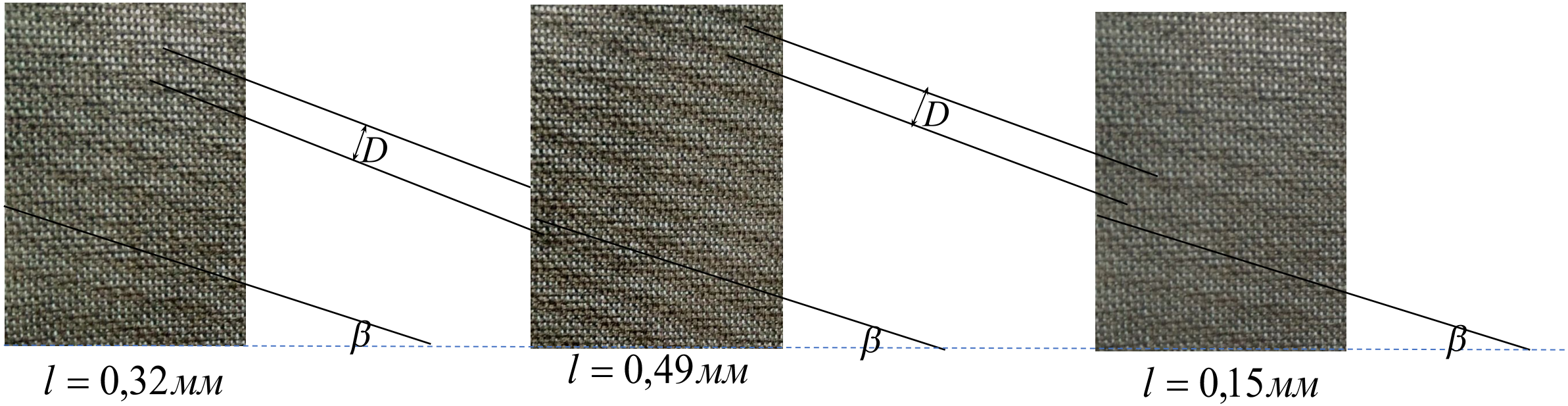
Value contrast C is the value that provide the transparent and opaque lines in the moiré pattern.

Dependence of the moire period on the thickness of the overlay`s line

$d = 1{,}45 мм$ – Period of the overlay

$$d_2 = f + l = const$$

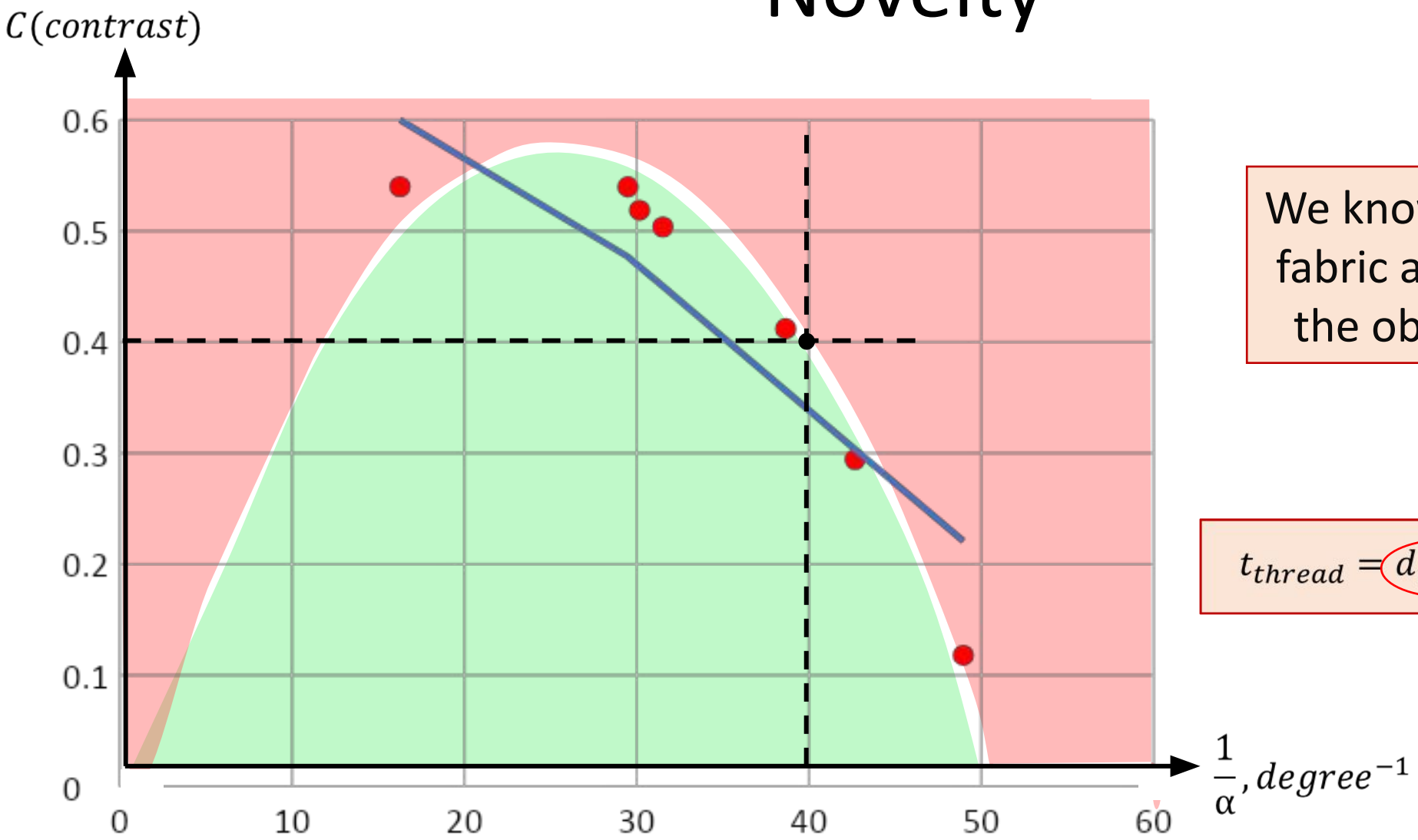




$l = 0{,}32 мм$ $l = 0{,}49 мм$ $l = 0{,}15 мм$

The thickness affects the contrast of the pattern

Novelty

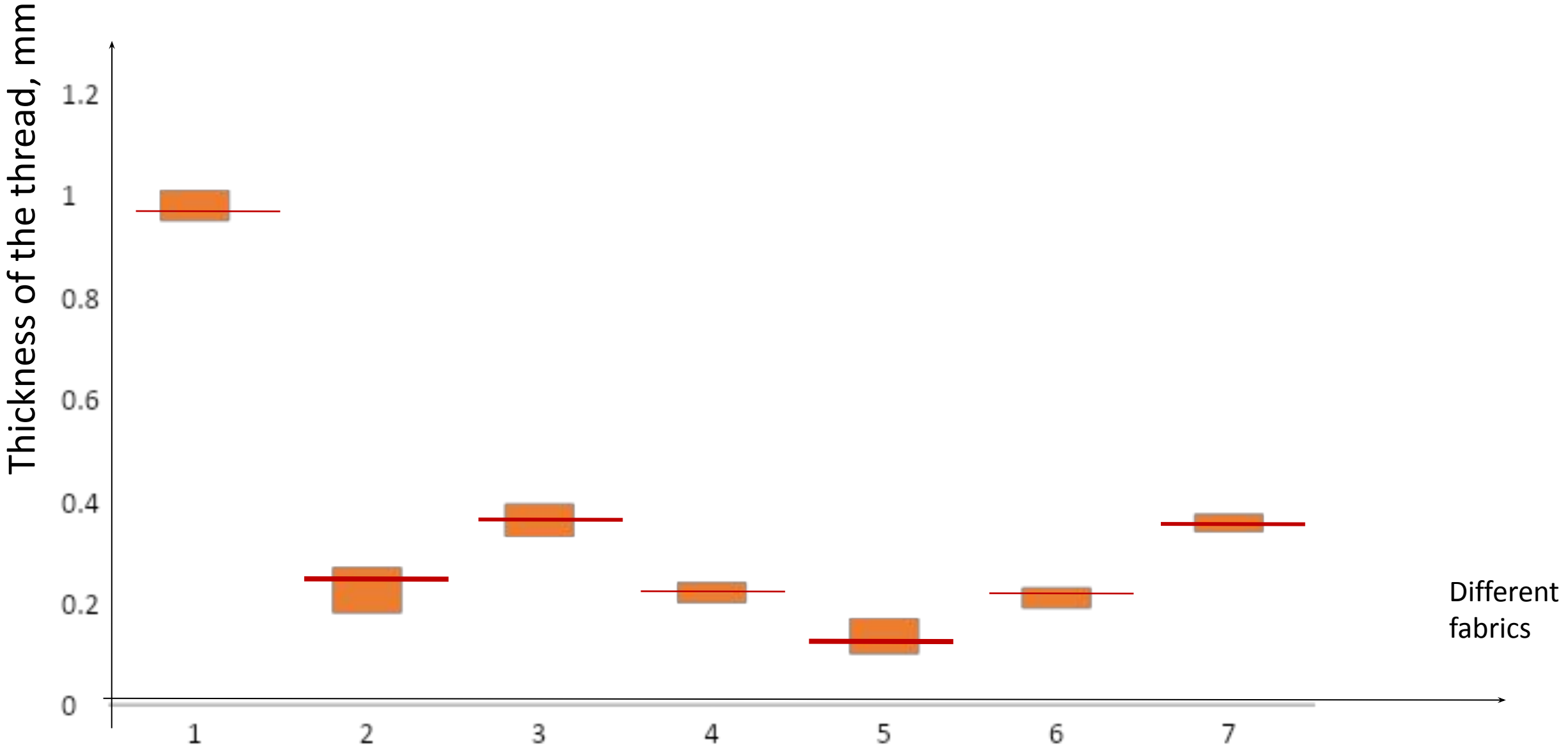


We know the period of the fabric and the moiré from the obtained equations.

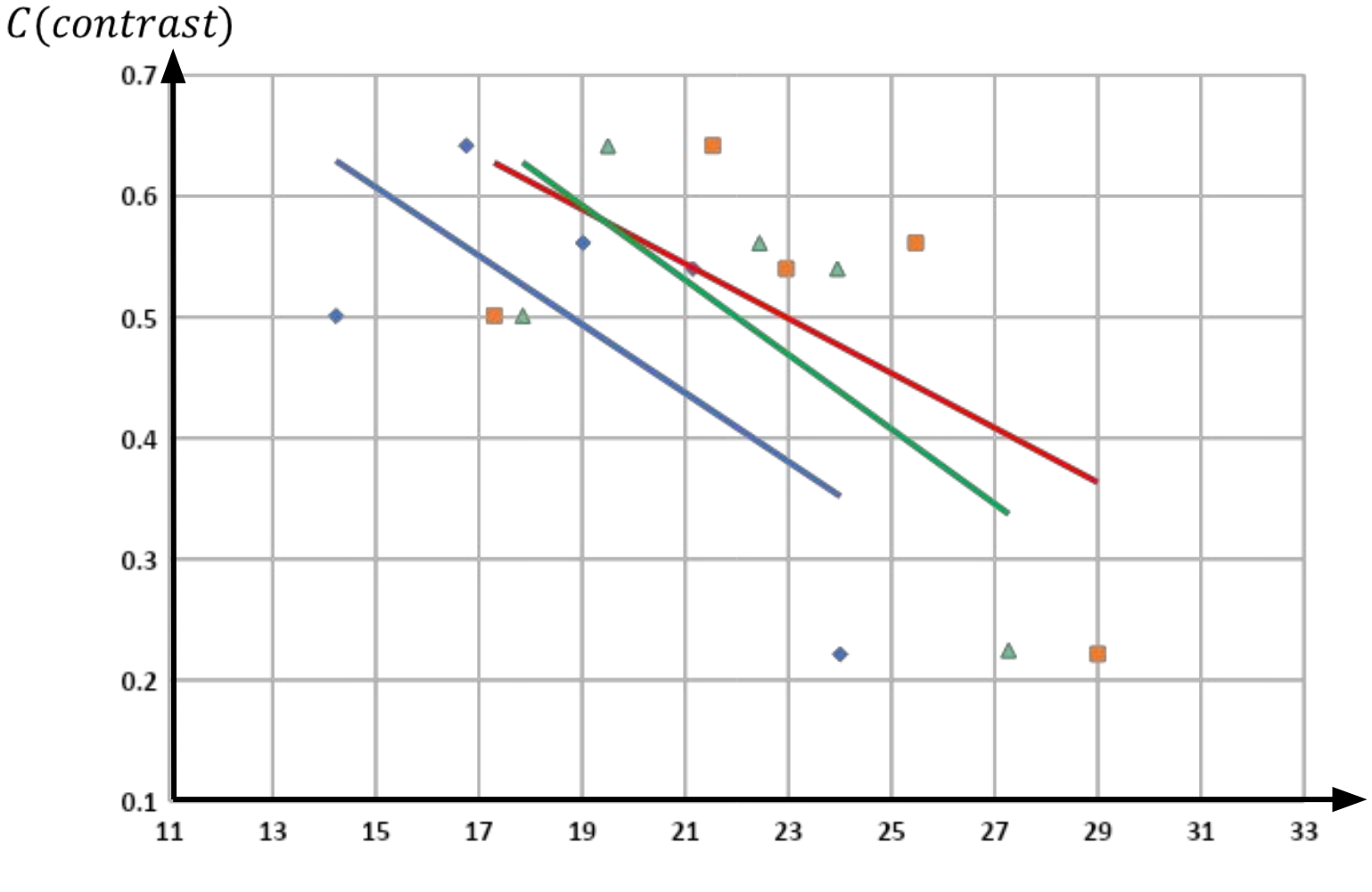
$$t_{thread} = d_{thread}(1 - c)(1 - \frac{t_{overlay}}{d_{overlay}})$$

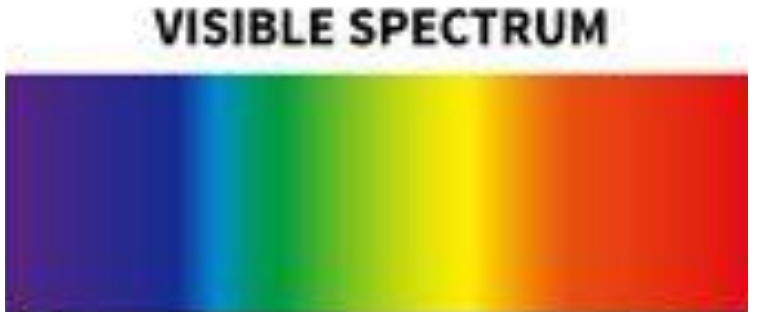
KNOWN!!!

Comparison for the thickness of the threads



For different colours





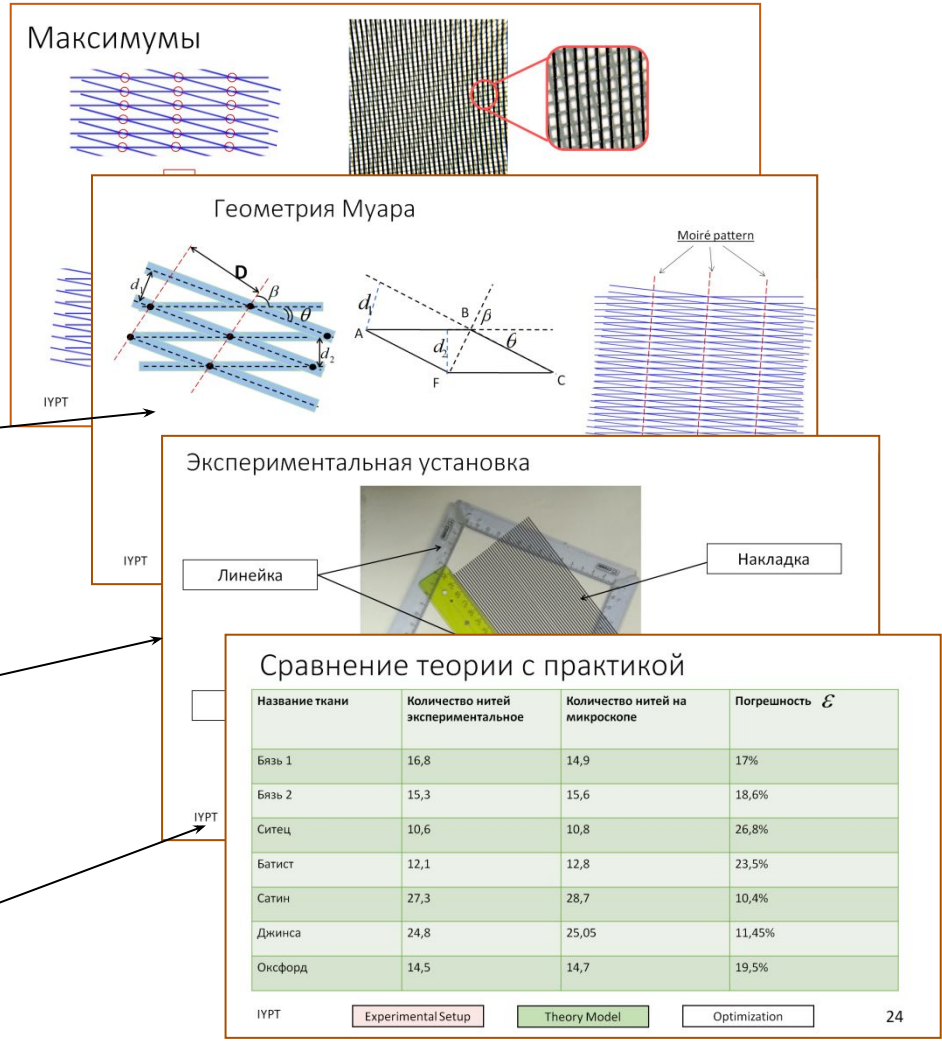
Conclusions

1) Qualitative explanation of the appearance of the moiré pattern (geometry)

2) Mathematical description based on geometrical neglect

3) An experimental setup was created to determine the number of fabric threads with a minimum accuracy of 62 and a maximum of 202

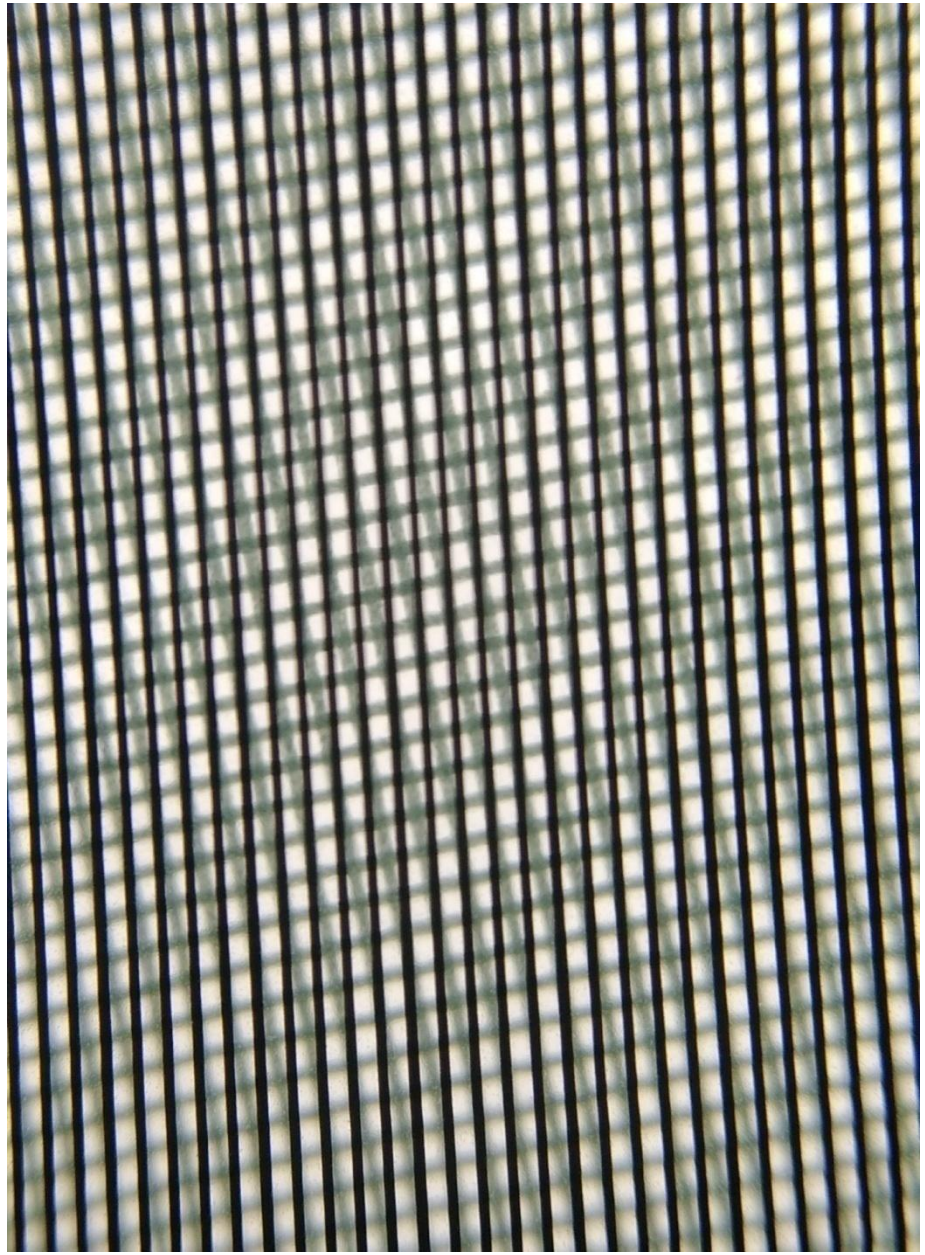
4) Experimentally studied different types of fabric, the set-up allows you to determine the number of threads in all fabrics



Thank you for your attention!

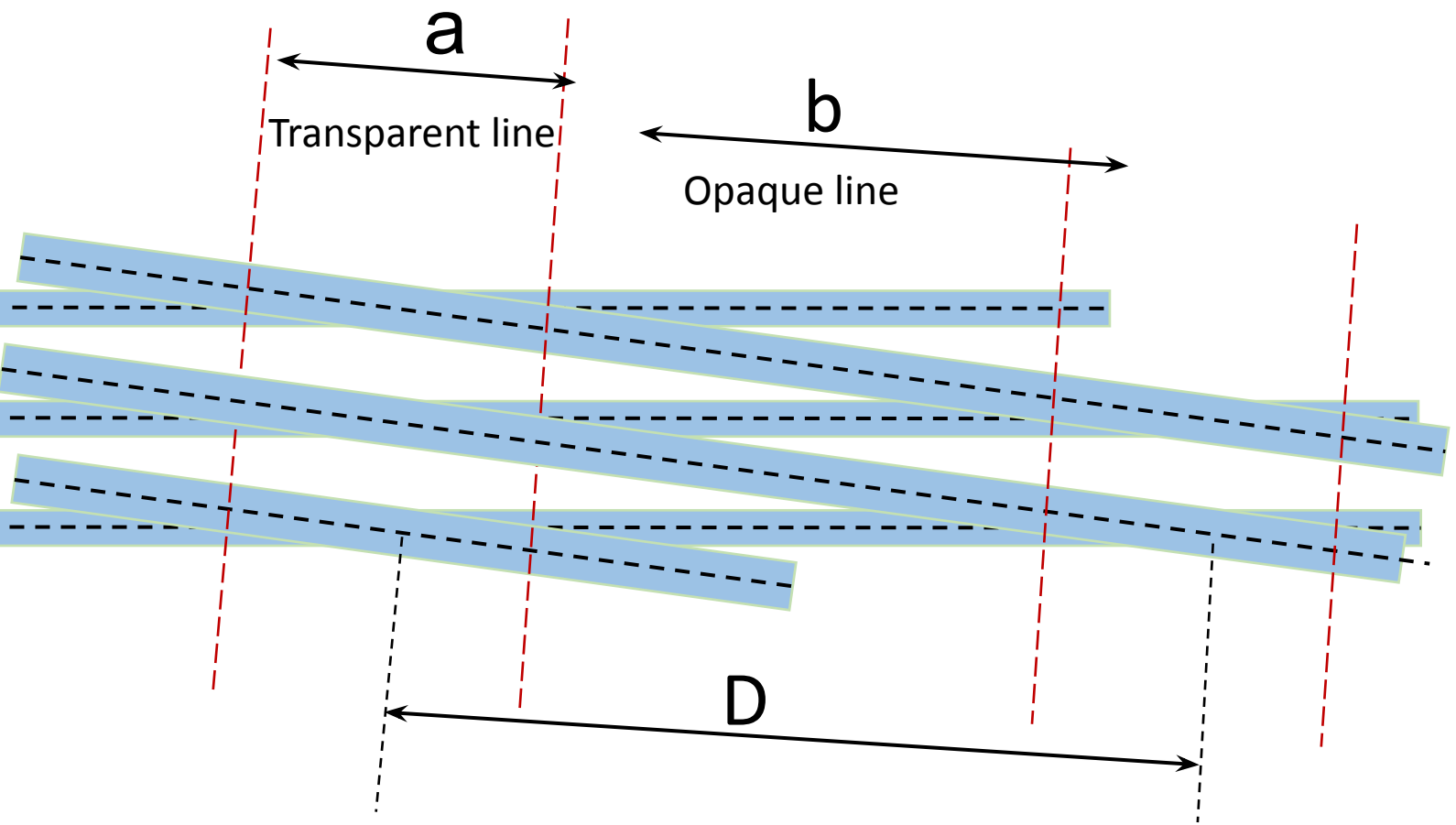
Bibliography:

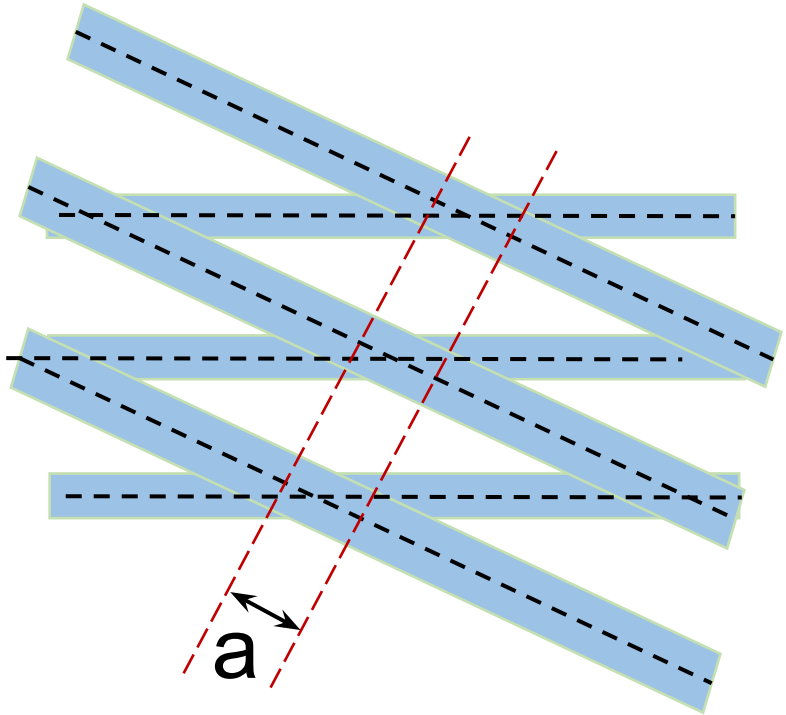
- A Moiré Pattern-Based Thread Counter (Gary Reich)
- Isaac Amidror_The_theory_of_the_moire_769_phenomen_Volume_I
- The Effects of a Visual Fidelity Criterion on the Encoding of Images JAMES L. MANNOS, MEMBER, IEEE, AND DAVID J. SAKRISON (IEEE TRANSACTIONS ON INFORMATION THEORY, VOL. IT-20, NO. 4, JULY 1974)



Limitations of the visibility of a moiré pattern

$$D = a + b$$

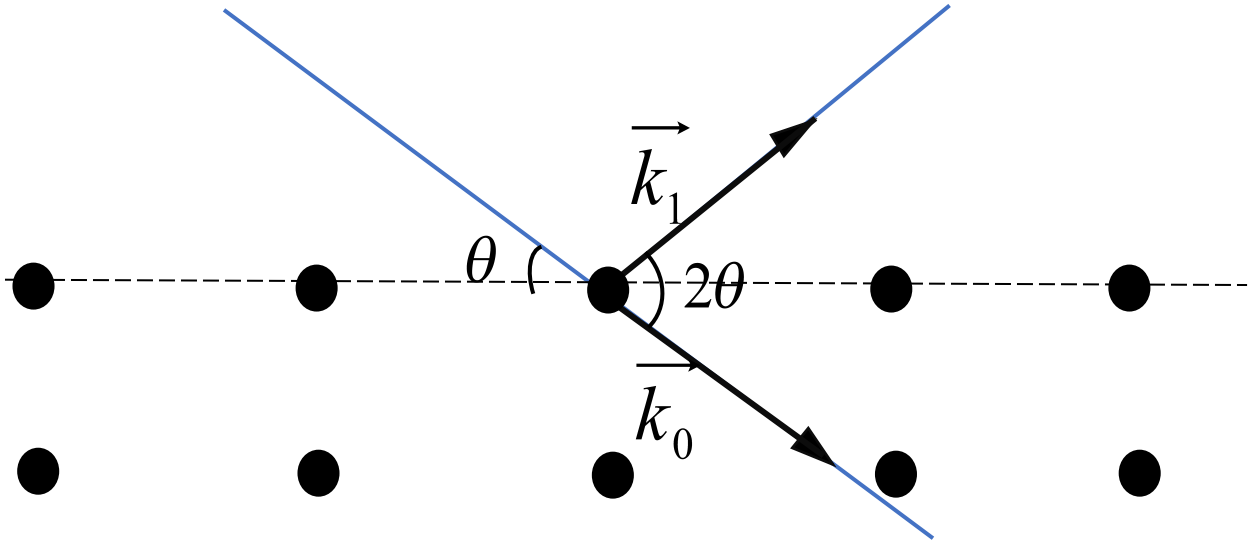




Дифракция рентгеновского излучения

Формула Вульфа-Бреггов:

$$2d \cdot \sin\theta = n * \lambda, n \in N$$



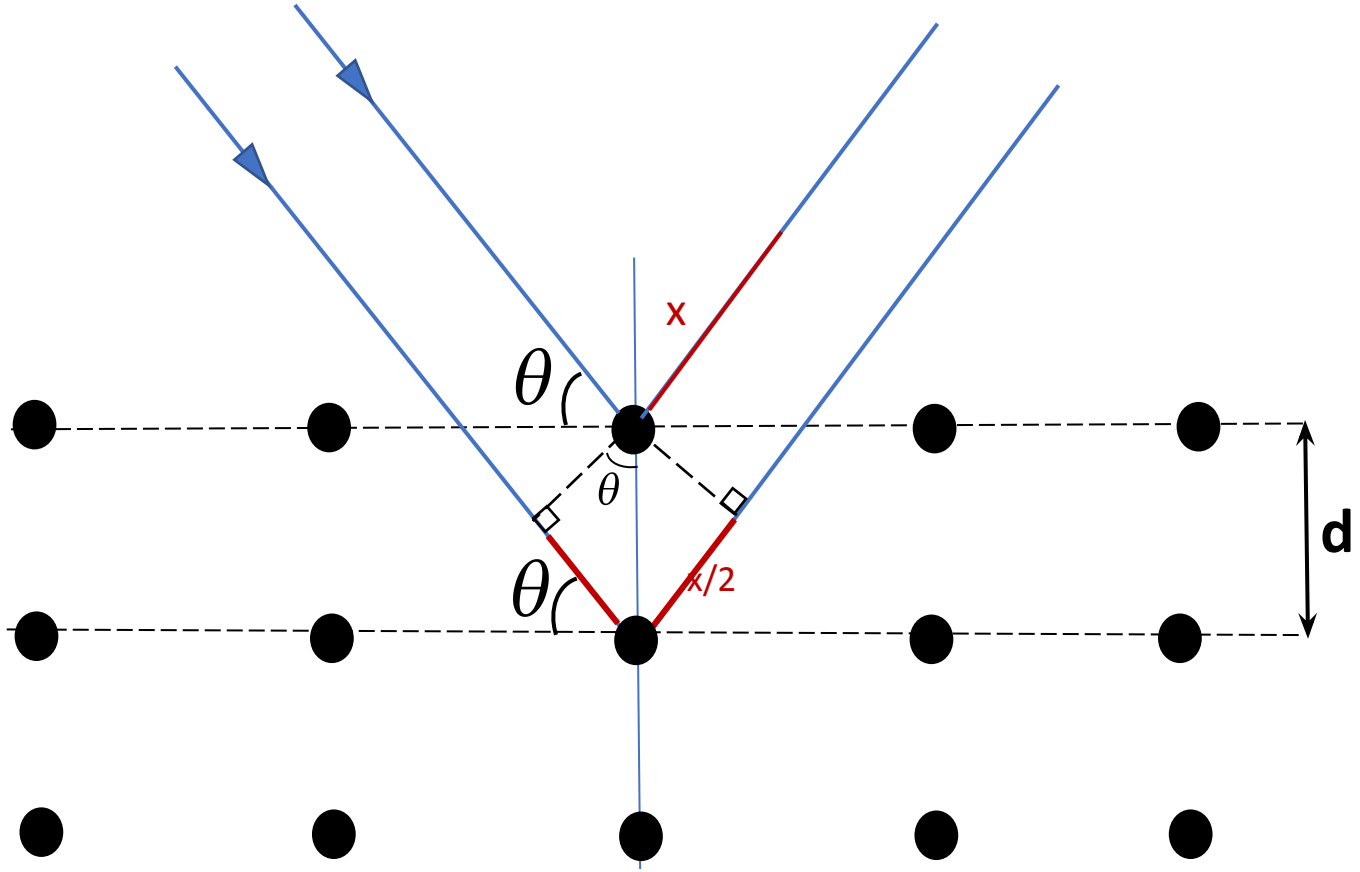
$$V = \frac{\lambda}{2\pi}\omega = \frac{\omega}{k}$$

$$\vec{k} = \frac{2\pi}{\lambda}\vec{n}$$

$k = \frac{2\pi}{\lambda}$ -Волновое число

$\vec{n}$ - Волновой вектор

Условия возникновения максимумов и минимумов



Разность хода: $x = 2d \cdot \sin\theta$

Условия появления максимума: $x = n * \lambda$

Условия появления минимума: $x = (2n-1)\frac{\lambda}{2}$

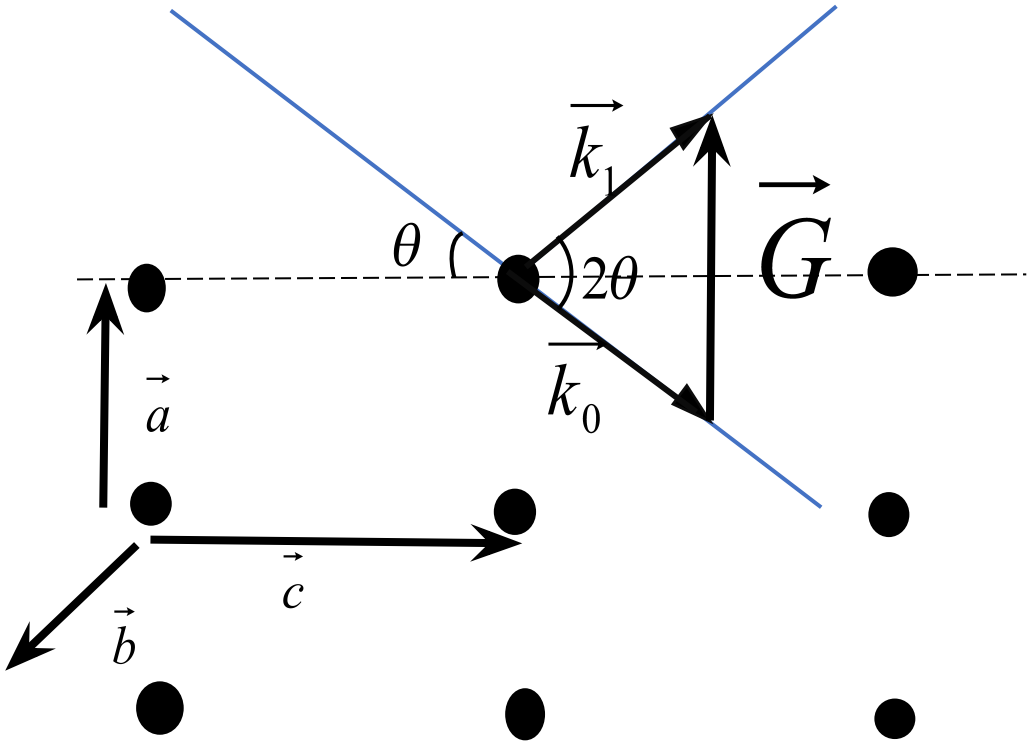
Задаём обратную решётку

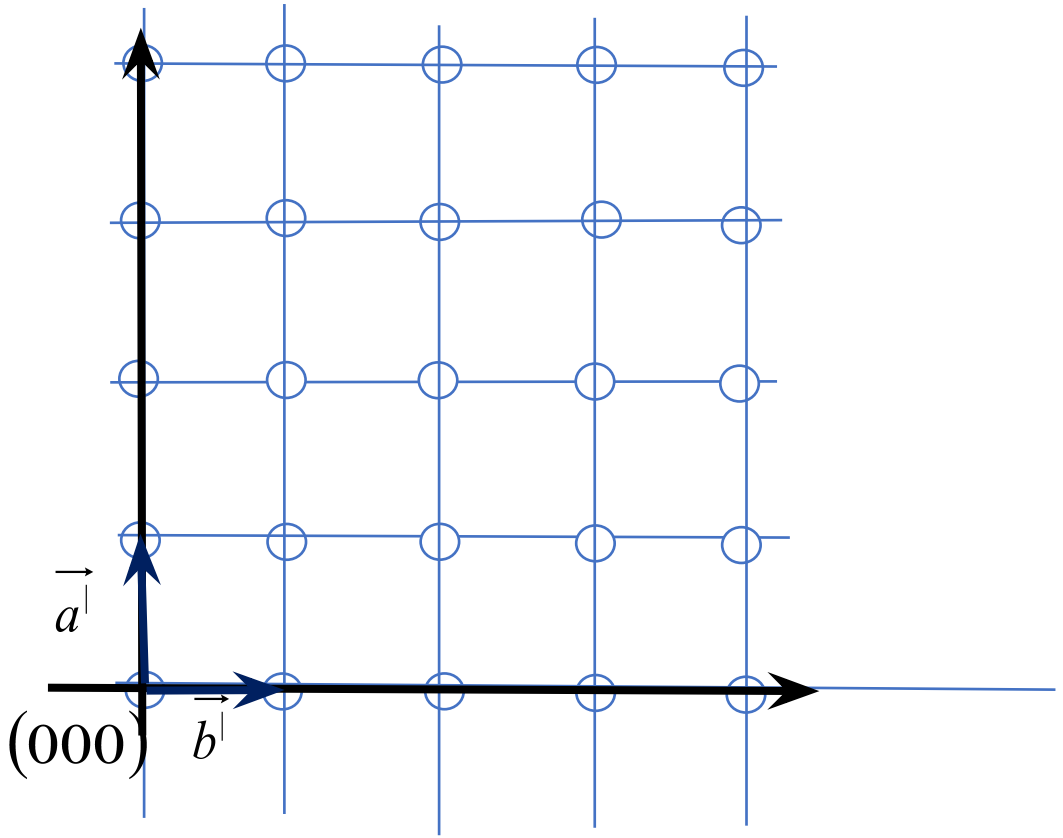
$$\vec{a} \cdot \vec{a^*} = 2\pi$$

$$\vec{a} \cdot \vec{b^*} = 0$$

$$\vec{a^*} \uparrow\uparrow \vec{b} \times \vec{c}$$

$$\left|\vec{a^*}\right| = \frac{2\pi}{a}$$

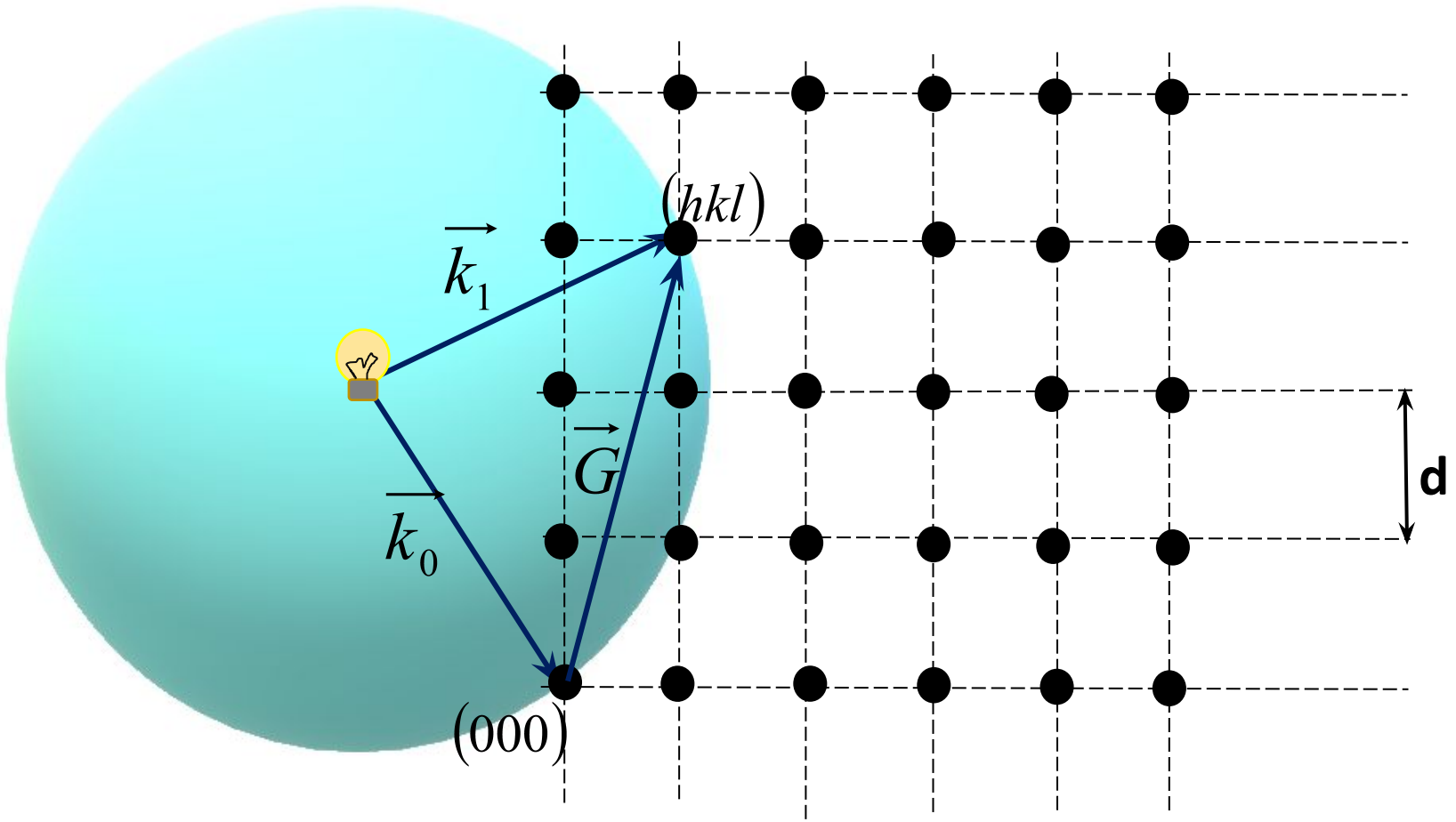




Слайд про точность,

Здесь надо рассказать про накладку и ткань, перескок с периода на период 45 градусов. Всегда две решётки()часть ткани и накладка

Задаём обратную решётку

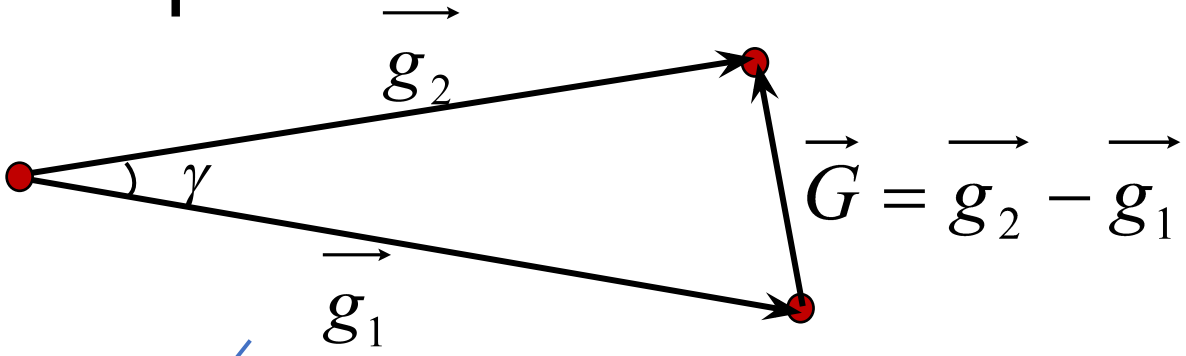


$$\left|\vec{k}_0\right| = \left|\vec{k}_1\right|$$

$$\vec{G} = \vec{k}_1 - \vec{k}_0$$

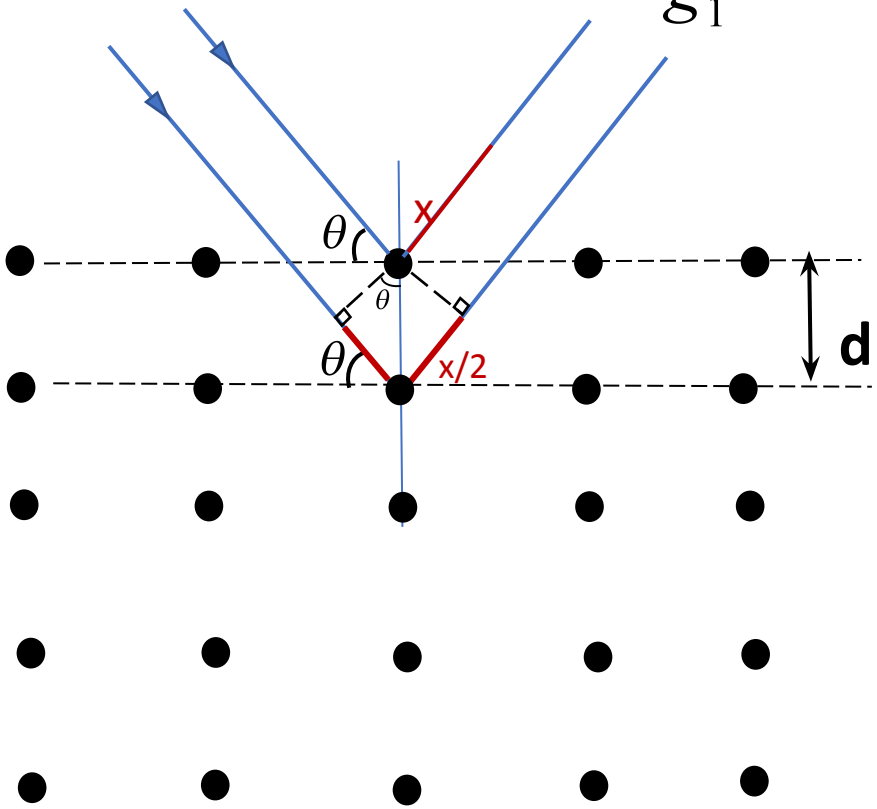
$\vec{G}$ -рассеивающий вектор

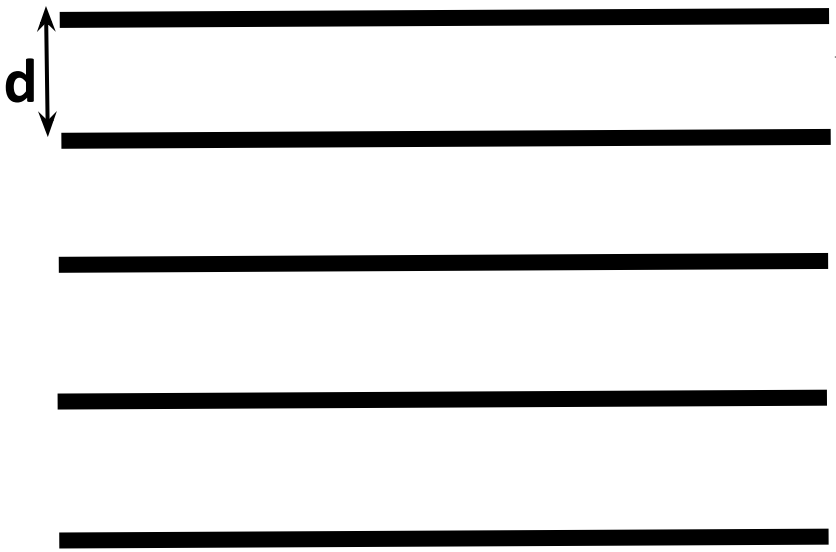
Обратная решётка



$$\left|\vec{g}_1\right| = \frac{2 \cdot \pi}{d_1} \qquad \left|\vec{g}_2\right| = \frac{2 \cdot \pi}{d_2}$$

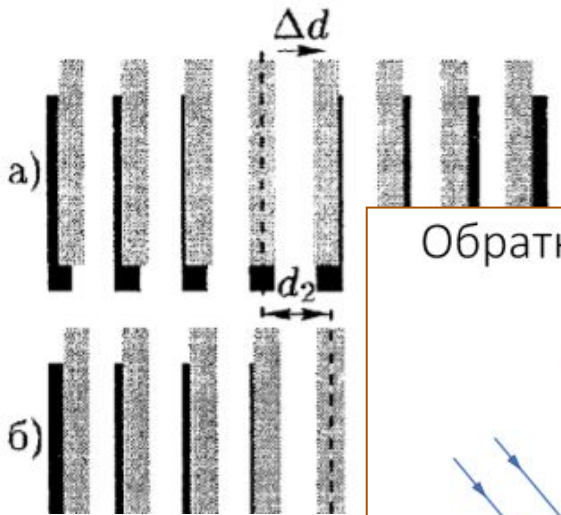
$$\left|\vec{G}\right| = \left|\vec{g}_2 - \vec{g}_1\right| = \frac{2 \cdot \pi}{D}$$





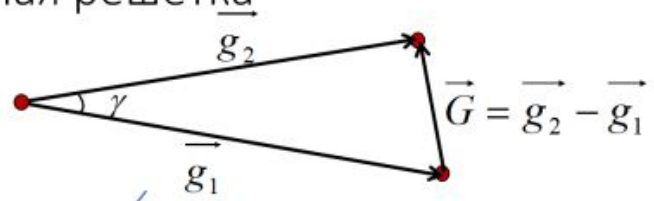
$$D = \frac{2\pi}{\sqrt{\frac{4\pi^2}{d_1^2} + \frac{4\pi^2}{d_1^2} + \frac{2\pi}{d_1} \cdot \frac{2\pi}{d_2} \cdot \cos\gamma}}$$

$$D = \frac{d_1 \cdot d_2}{\sqrt{d_1^2 + d_2^2 - 2 \cdot d_1 \cdot d_2 \cdot \cos\gamma}}$$



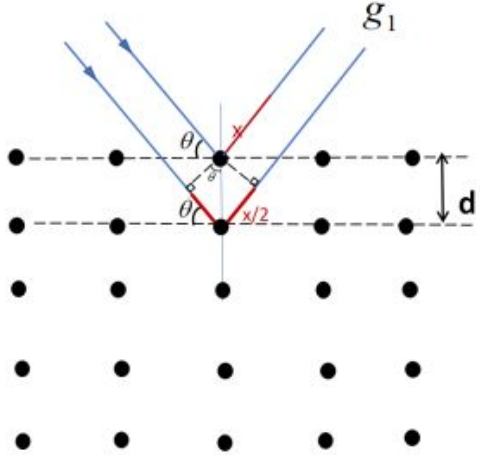
3. Если внимательно рассмотреть рисунок 11, то можно увидеть, что при смещении более частой решётки (на рисунке серой) вправо на расстояние Δd, совпадающие полосы (середи-

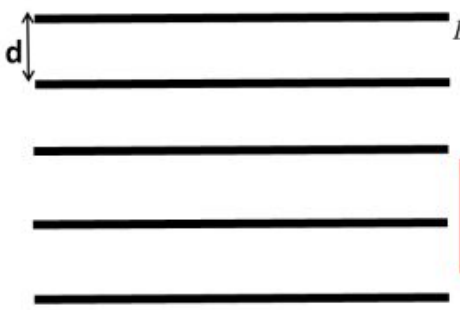
Обратная решётка



$$|\vec{g}_1| = \frac{2\cdot\pi}{d_1} \qquad |\vec{g}_2| = \frac{2\cdot\pi}{d_2}$$

$$|\vec{G}| = |\vec{g}_2 - \vec{g}_1| = \frac{2\cdot\pi}{D}$$





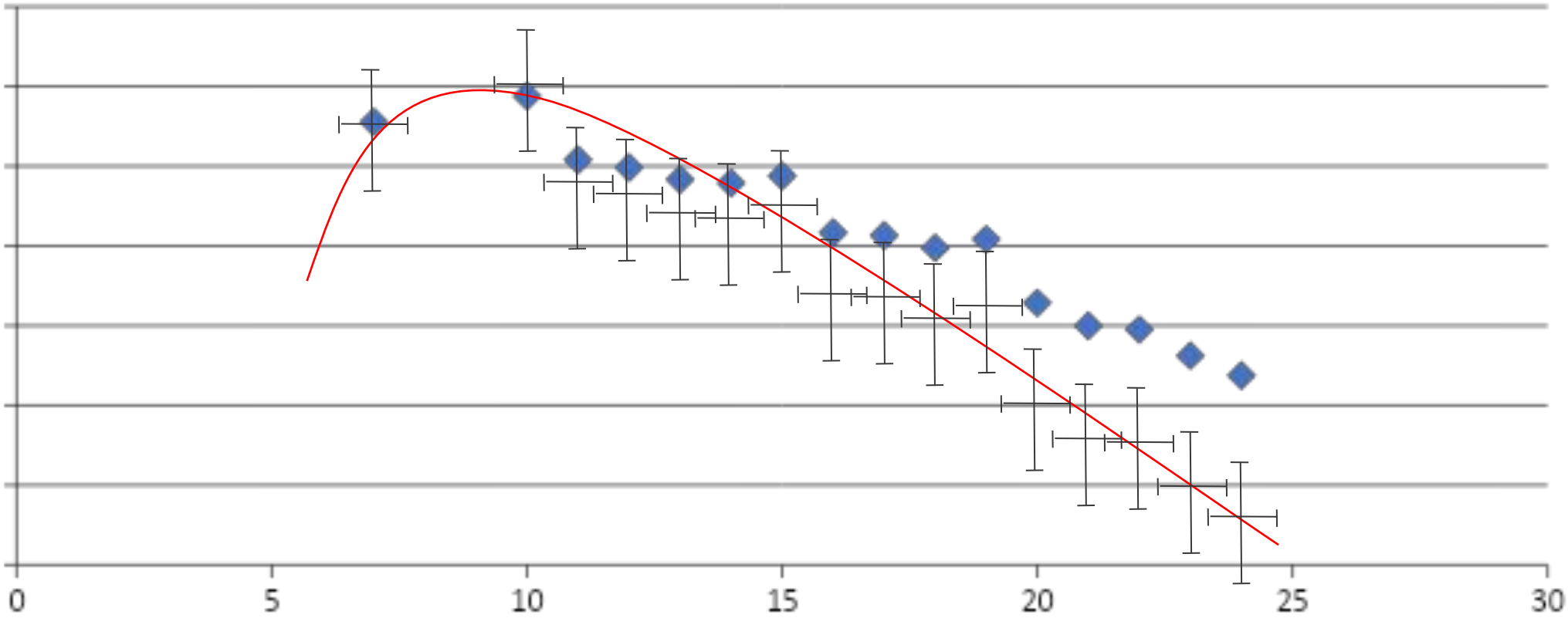
$$D = \frac{2\pi}{\sqrt{\frac{4\pi^2}{d_1^2} + \frac{4\pi^2}{d_1^2} + \frac{2\pi}{d_1}\cdot\frac{2\pi}{d_2}\cdot\cos\gamma}}$$

$$D = \frac{d_1\cdot d_2}{\sqrt{d_1^2 + d_2^2 - 2\cdot d_1\cdot d_2\cdot\cos\gamma}}$$

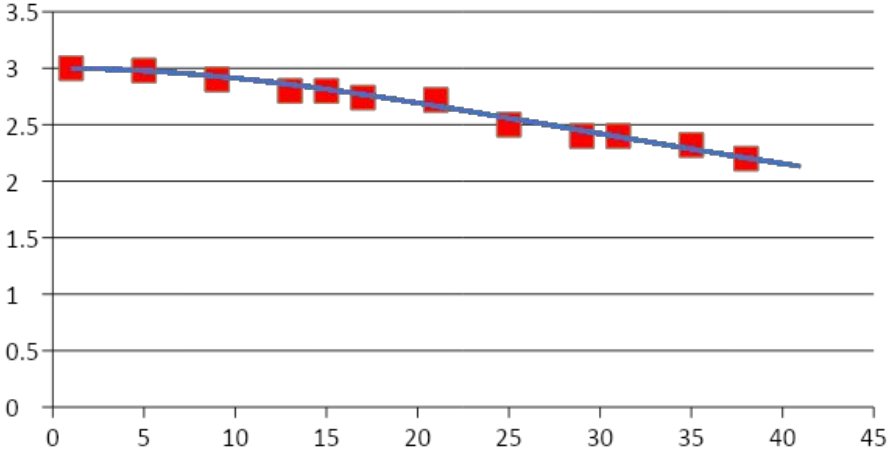
Зависимость β от θ

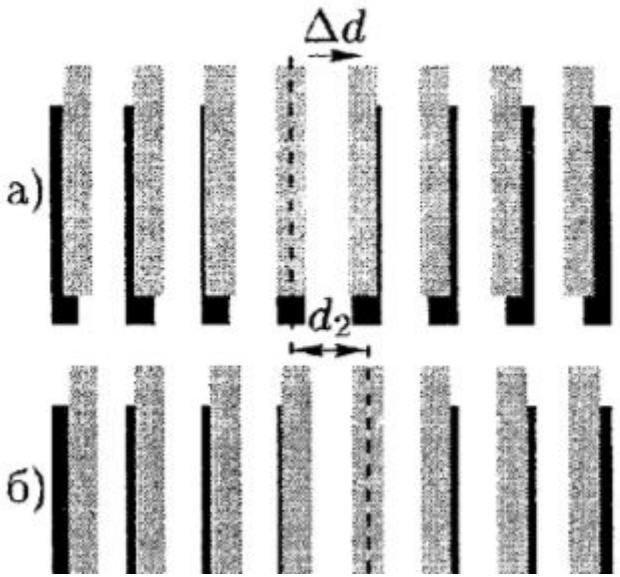
$$\beta = \arcsin\left(\frac{\sin\theta \cdot d_2}{\sqrt{d_1^2 + d_2^2 - 2 \cdot d_1 \cdot d_2 \cdot \cos\theta}}\right) = \arcsin\left(\frac{\sin\theta \cdot D}{d_1}\right)$$

$$\sin\beta = \frac{D \cdot \sin\theta}{d_1}$$



Оксфорд и джинсовая ткань





3. Если внимательно рассмотреть рисунок 11, то можно увидеть, что при смещении более частой решётки (на рисунке серой) вправо на расстояние Δd, совпадающие полосы (середина светлой полосы) переместятся на расстояние d_2 в ту же сторону. Поэтому, если мы будем сдвигать решётку A относительно B и полосы будут «бежать» в том же направлении, то это будет значить, что $d_A < d_B$; если же полосы будут «бежать» в обратном направлении, то $d_A > d_B$.

Где физика, что по смещениям.

$$n_1(D,\theta,d_2)=\frac{D\cdot\cos\theta\pm\sqrt{d_2^2-D^2\cdot\sin^2\theta}}{D\cdot d_2}=\frac{\cos\theta}{d_2}\pm\frac{\sqrt{d_2^2-D^2\cdot\sin^2\theta}}{D\cdot d_2}$$

$$\frac{\delta D}{\delta n_1}=(\frac{\cos\theta}{d_2})'\pm(\frac{\sqrt{d_2^2-D^2\cdot\sin^2\theta}}{D\cdot d_2})'=\pm\frac{\left(\sqrt{d_2^2-D^2\cdot\sin^2\theta}\right)'\cdot D\cdot d_2-(D\cdot d_2)'\sqrt{d_2^2-D^2\cdot\sin^2\theta}}{D^2\cdot d_2^2}$$

$$\frac{\delta D}{\delta n_1}=\pm\frac{\frac{1}{2}\left(d_2^2-D^2\cdot\sin^2\theta\right)'\cdot D\cdot d_2-(D\cdot d_2)'(d_2^2-D^2\cdot\sin^2\theta)}{D^2\cdot d_2^2\cdot\sqrt{d_2^2-D^2\cdot\sin^2\theta}}=\pm\frac{-d_2^3}{D^2\cdot d_2^2\cdot\sqrt{d_2^2-D^2\cdot\sin^2\theta}}$$

$$\frac{\delta D}{\delta n_1}=\boxtimes\frac{d_2}{D^2\cdot\sqrt{d_2^2-D^2\cdot\sin^2\theta}}$$

$$\frac{\delta\theta}{\delta n_1}=(\frac{\cos\theta}{d_2})'\pm(\frac{\sqrt{d_2^2-D^2\cdot\sin^2\theta}}{D\cdot d_2})'=\frac{-\sin\theta}{d_2}\pm\frac{-2D^2\sin\theta\cdot\cos\theta}{2D\cdot d_2\cdot\sqrt{d_2^2-D^2\cdot\sin^2\theta}}$$

$$\frac{\delta\theta}{\delta n_1}=\frac{-\sin\theta}{d_2}\boxtimes\frac{D\sin\theta\cdot\cos\theta}{d_2\cdot\sqrt{d_2^2-D^2\cdot\sin^2\theta}}$$

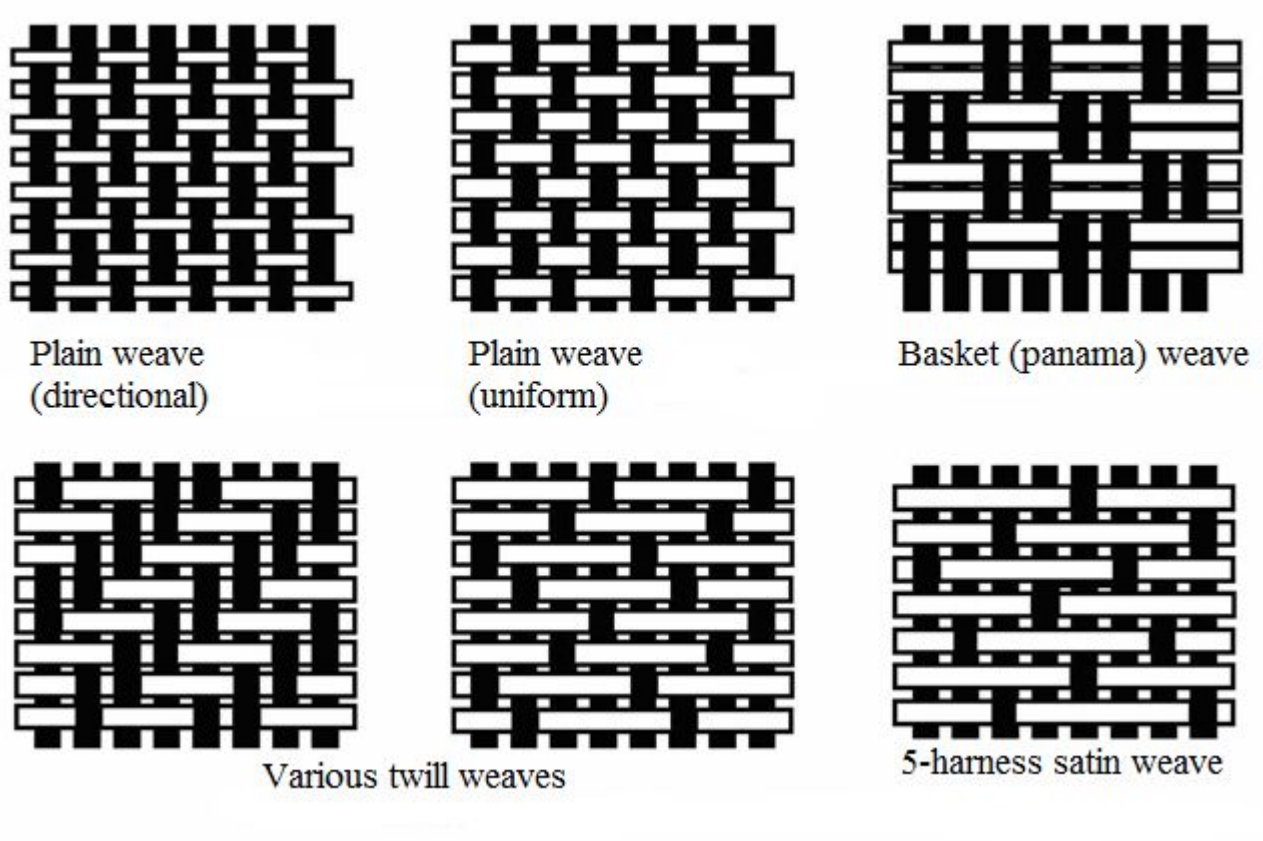
$$\frac{\delta d_2}{\delta n_1}=(\frac{\cos\theta}{d_2})'\pm(\frac{\sqrt{d_2^2-D^2\cdot\sin^2\theta}}{D\cdot d_2})'=\frac{-\sin\theta\cdot d_2-\cos\theta}{d_2^2}\pm\frac{\frac{2d_2}{2\sqrt{d_2^2-D^2\cdot\sin^2\theta}}\cdot d_2-\sqrt{d_2^2-D^2\cdot\sin^2\theta}}{D\cdot d_2^2}$$

$$\frac{\delta d_2}{\delta n_1}=\frac{-\sin\theta\cdot d_2-\cos\theta}{d_2^2}\pm\frac{d_2^2-d_2^2+D^2\cdot\sin^2\theta}{D\cdot d_2^2\sqrt{d_2^2-D^2\cdot\sin^2\theta}}=\frac{-\sin\theta\cdot d_2-\cos\theta}{d_2^2}\pm\frac{D\cdot\sin^2\theta}{d_2^2\sqrt{d_2^2-D^2\cdot\sin^2\theta}}$$

$$D=\frac{d_1\cdot d_2}{\sqrt{d_1^2+d_2^2-2\cdot d_1\cdot d_2\cdot\cos\theta}}$$

Производство счетчі
counters

Сделать счётчик с ограничением. То есть, неподвижно накладываем и смотрим по длине полосы. Будет сделана градуеровка



Что-то про маленький уголок

1. Расстояние между полосами l будет равно половине длинной диагонали ромба, образованного пересечениями центров линий (рис. 9). Поскольку из геометрии $nl = S = L/\cos(\theta/2)$, то:

$$d_A = 2\frac{L}{n}\frac{\sin(\theta/2)}{\cos(\theta/2)}, \qquad \text{или} \qquad \operatorname{tg}\frac{\theta}{2} = \frac{d_A}{2L}n.$$

Построим график зависимости $\operatorname{tg}(\theta/2)$ от n. По точкам проведём прямую и по значению углового коэффициента определим период решётки d_A по формуле $d_A = 2Lk$, где k — значение коэффициента наклона графика.

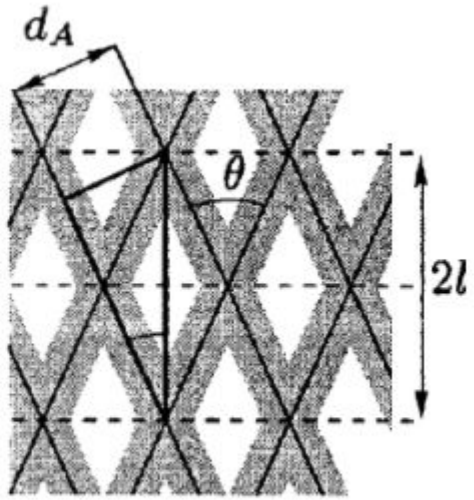


Рис. 9

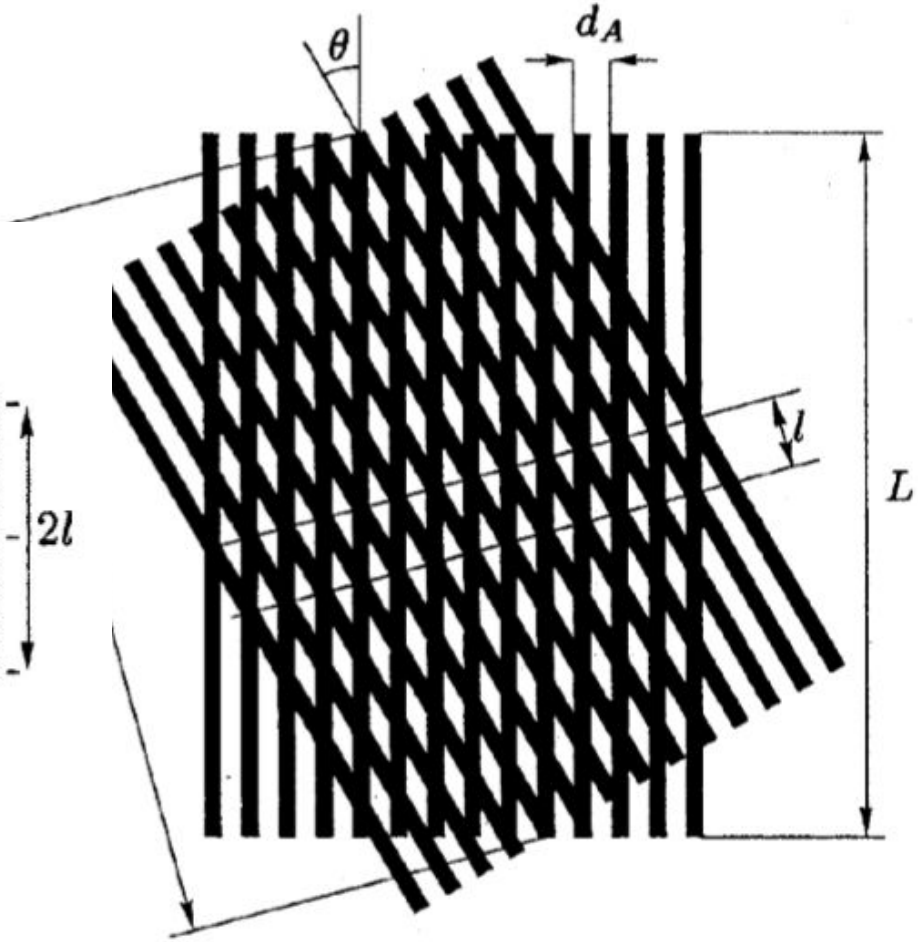
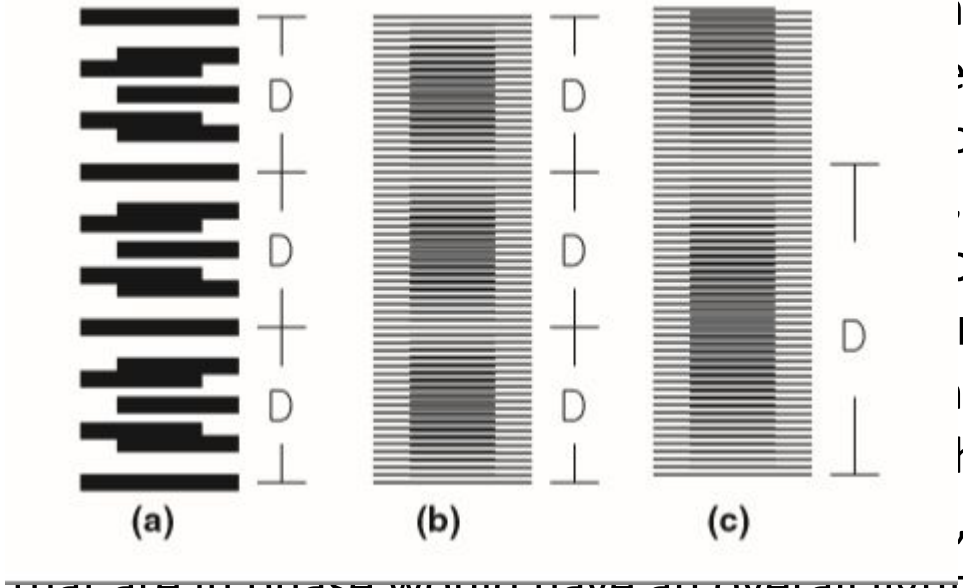


Рис. 1



omenon that occurs when patterns of lines with different
xtends from the left toward the center with a spacing of d = 1/6
oward the center with a spacing of d’= 1/8 in. In the middle
, a repeating pattern with period D = 1/2 in can be seen. At the
ов) marked D in the figure, the lines extending from left and
ностью перекрываются в средней части, они в фазе) fully
ase. The visual significance of being in phase is that in the
he underlying white paper that we are trying to look at
, if the density of the lines were greater, the regions near lines
that are in phase would have an overall lighter ton (Визуальное значение нахождения в фазе
заключается в том, что в области, близкой к перекрытию, больше частей
основной белой страницы. Если бы мы смотрели на образец, затеняющий эквивалентно
если бы плотность линий была больше, области вблизи линий, которые находятся в фазе,
имели бы общий более светлый тон. на рисунке.) In Fig. 4(b) the spacings are d = 1/40 in and
d’=1/42 in, and in 4(c) d = 1/40 in and d’= 1/41 in. The lighter toned regions in the middle sections of those
figures are places where the two sets of lines are in phase, producing light fringes(создавая светлые
полосы). Halfway between them are dark fringes where the lines do not overlap, and more of the
underlying white paper is blacked out. An important qualitative feature of the moiré patterns, seen in Fig.
4(b) and (c), is that as the two spacings d and d’ become closer to each other, the moiré fringes become
broader(станет более широкой).

A quantitative measure of the distance D between successive light fringes can be derived as follows. If two lines overlap at one location, there will be another location of overlap at a distance D, where for so

$$D = kd = (k+1)d' \qquad (d' < d).$$

giving a general formula for the fring

$$D = kd = \frac{dd'}{|d - d'|}.$$

As this formula makes clear, when th become closer, the denominator app distance D between the fringes grow overlay thread counter, d correspon the parallel threads of the fabric (d i of threads per inch) and d 9 corresp between the lines of the overlay. Sin converge, d 9 decreases from left to converge from a spacing of d1 = 1/3(fabric of Fig. 2(b) is woven with 37 th some point along the horizontal leng approaches d, and near that point, the width of the fringes increases rapidly, creating the fringe pattern seen in the Fig. 2(b).

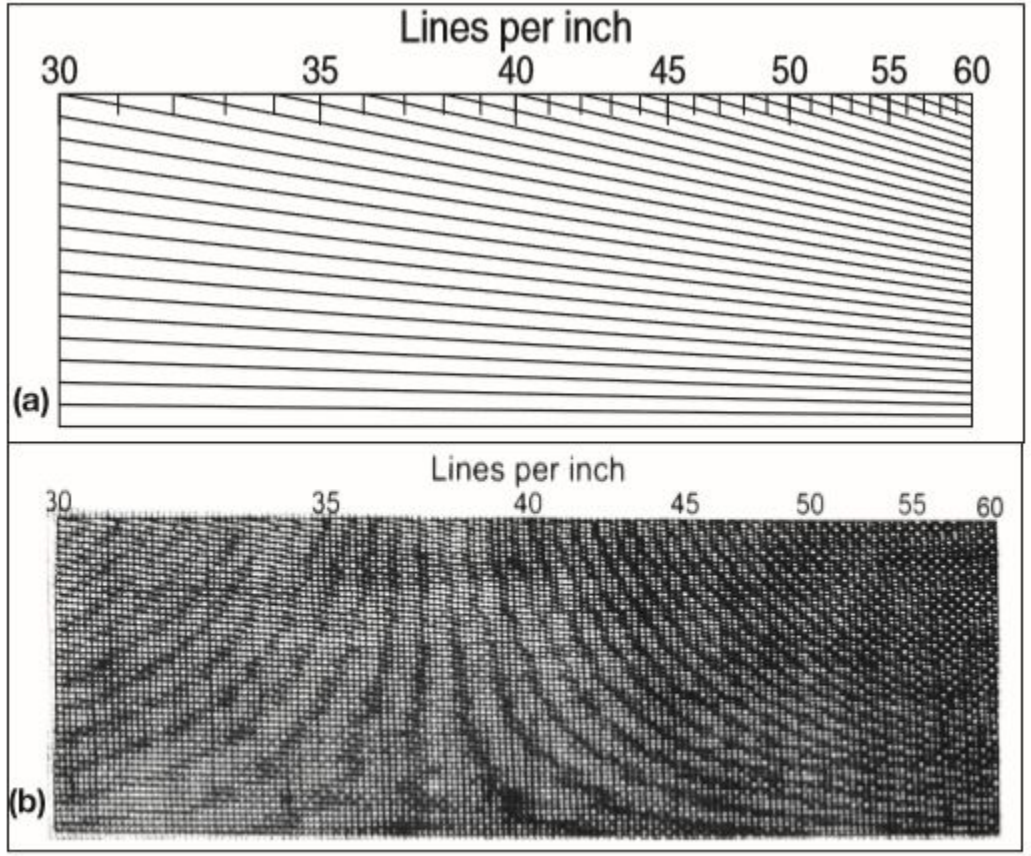
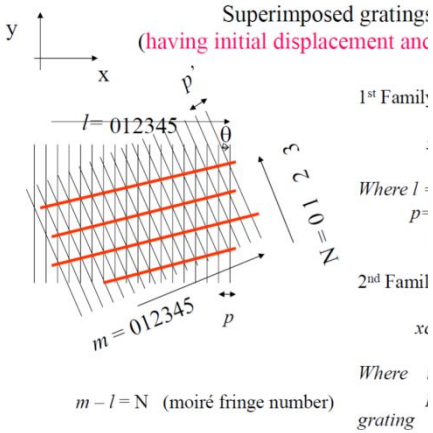


Fig. 2. (a) An overlay thread counter. (b) Transparency made from Fig. 2(a) laid on a fabric woven at 40 threads per inch.

оормулы, когда два интервала d и
ниже, знаменатель приближается
D между полосами растет без
ка наложения нитей d соответств
параллельными нитями ткани (d
ей на дюйм), а d 9 - расстоянию
ожения. Поскольку линии
я, d decreases уменьшается слева
е. 2 (a), линии сходятся с интерва
дюйма. Ткань Fig. 2 (b) сплетено с
гак, что в некоторый момент вдол
ины верхнего слоя D approaches
около этого пункта, ширина краев
о, создающ картину края увиден

угол

Small angle rotation and approximation approach



$m -$ $(p\text{-}p')/p$ = length change/ original length = ε_x (strain in x direction)

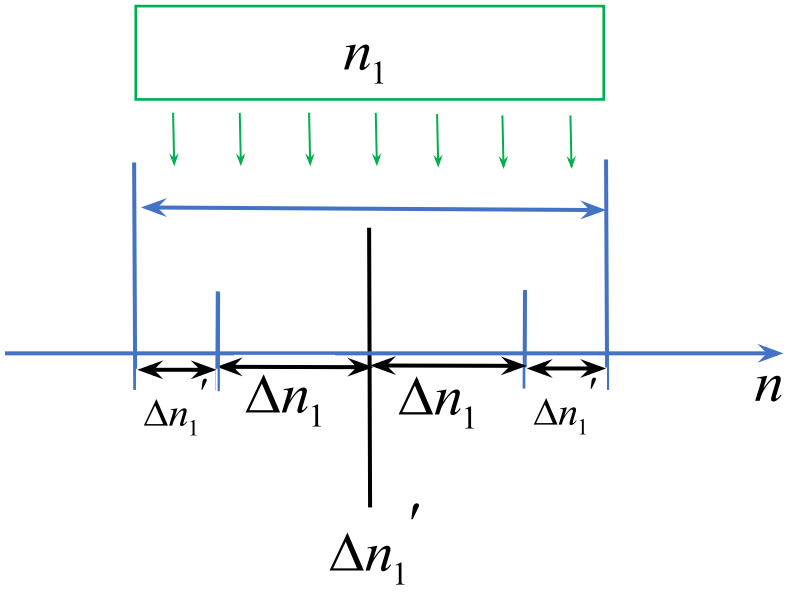
---> $\varepsilon_x x + \theta y = Np'$

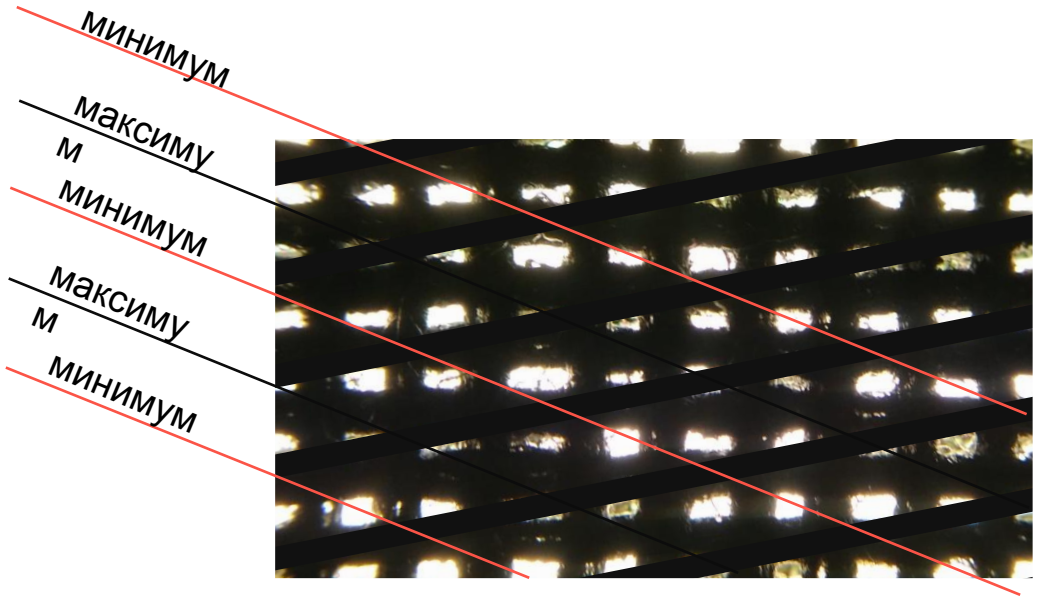
If r *Equation implies N depends on the initial pitches of the the gratings, and their initial relative position and orientation.*

Or *Fringe shift can be used to measure the change of pitch (strain), change in relative position (translation) and orientation (rotation)*

$$x(p\text{-}p')/p + \theta y = Np'$$

Conclusions





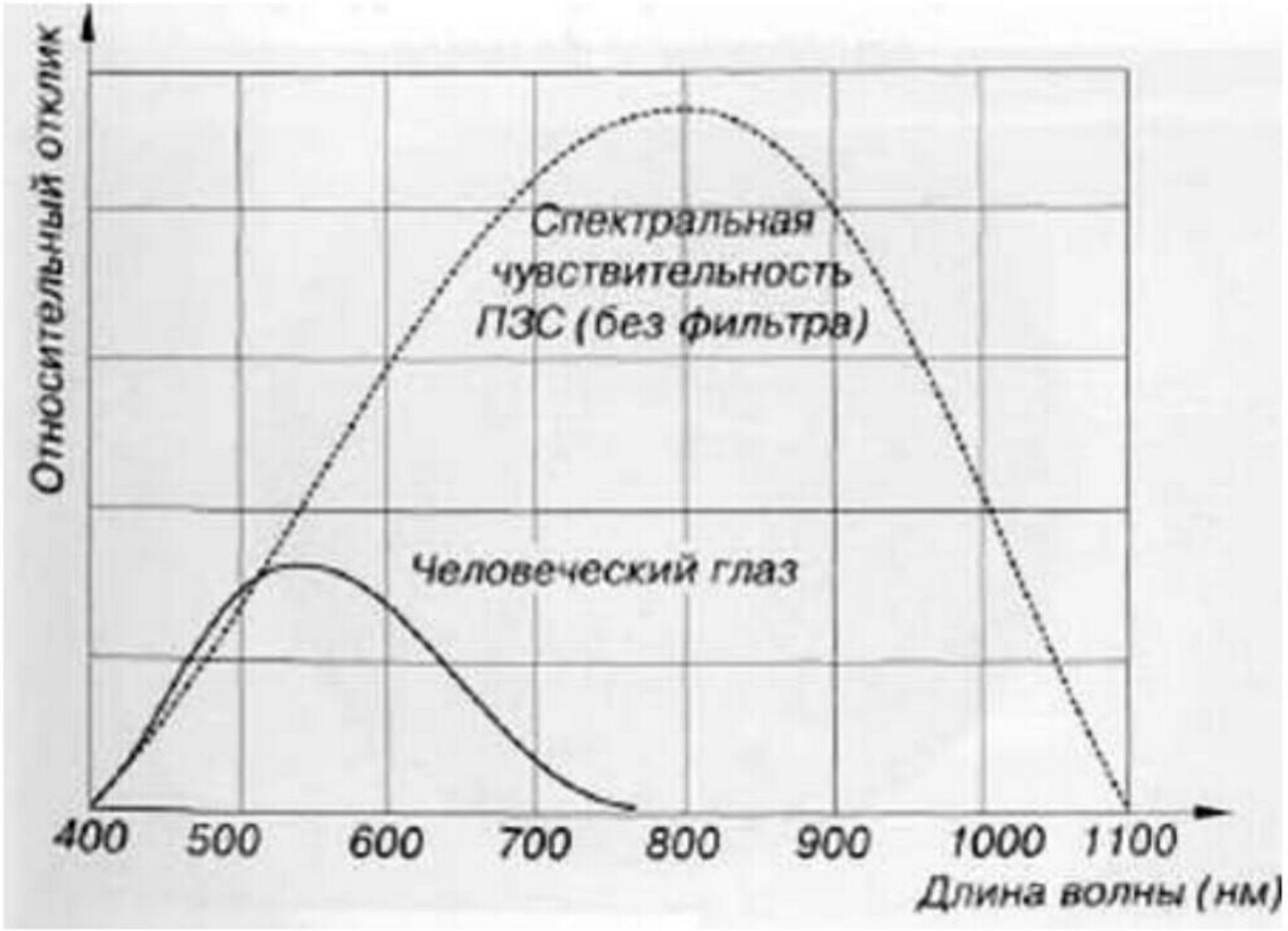
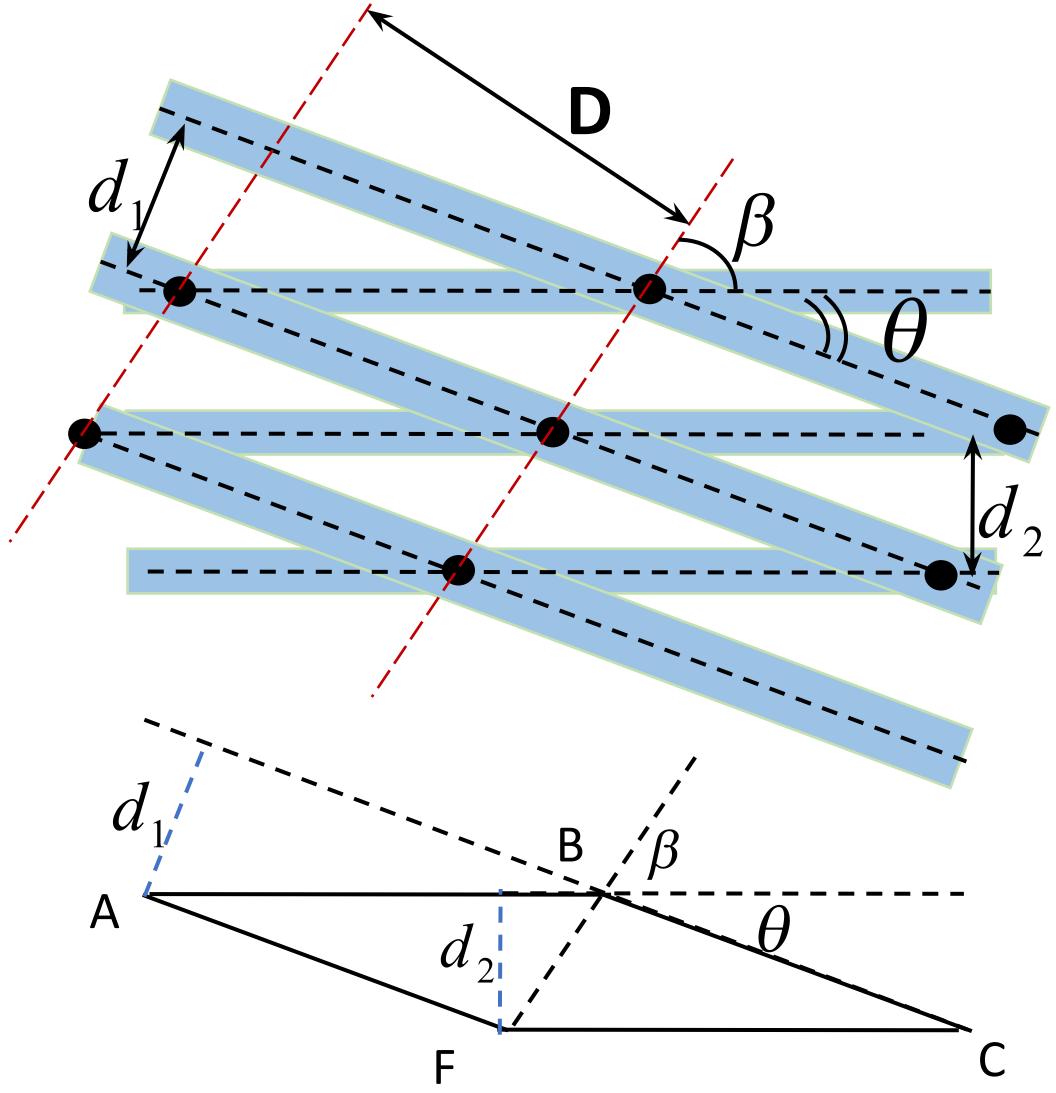


Рис. 5.15 . *Спектральная чувствительность глаза и ПЗС-матрицы*

Теперь. Будут спрашивать, что такое люкс. Люкс - это люмен на квадратный метр. Один люмен равен световому потоку, испускаемому точечным источником, с силой света, равной одной канделе, в телесный угол величиной в один стерадиан. Канделла -это единица силы света в СИ.

Geometric Moire’



$$d_1 = AB \cdot \sin\theta = FB \cdot \sin(\beta + \theta)$$

$$d_2 = AF \cdot \sin\theta = FB \cdot \sin\beta$$

$$D = FC \cdot \sin\beta = AB \cdot \sin\beta$$

$$\sin\beta = \frac{D \cdot \sin\theta}{d_1}$$

$$FB = \frac{d_1}{\sin(\beta+\theta)} = \frac{d_1}{\sin\beta \cdot \cos\theta + \cos\beta \cdot \sin\theta} =$$

$$= \frac{d_1}{\frac{D \cdot \sin\theta}{d_1} \cdot \cos\theta + \sqrt{1 - \frac{D^2 \cdot \sin^2\theta}{d_1^{\,2}}} \cdot \sin\theta}$$

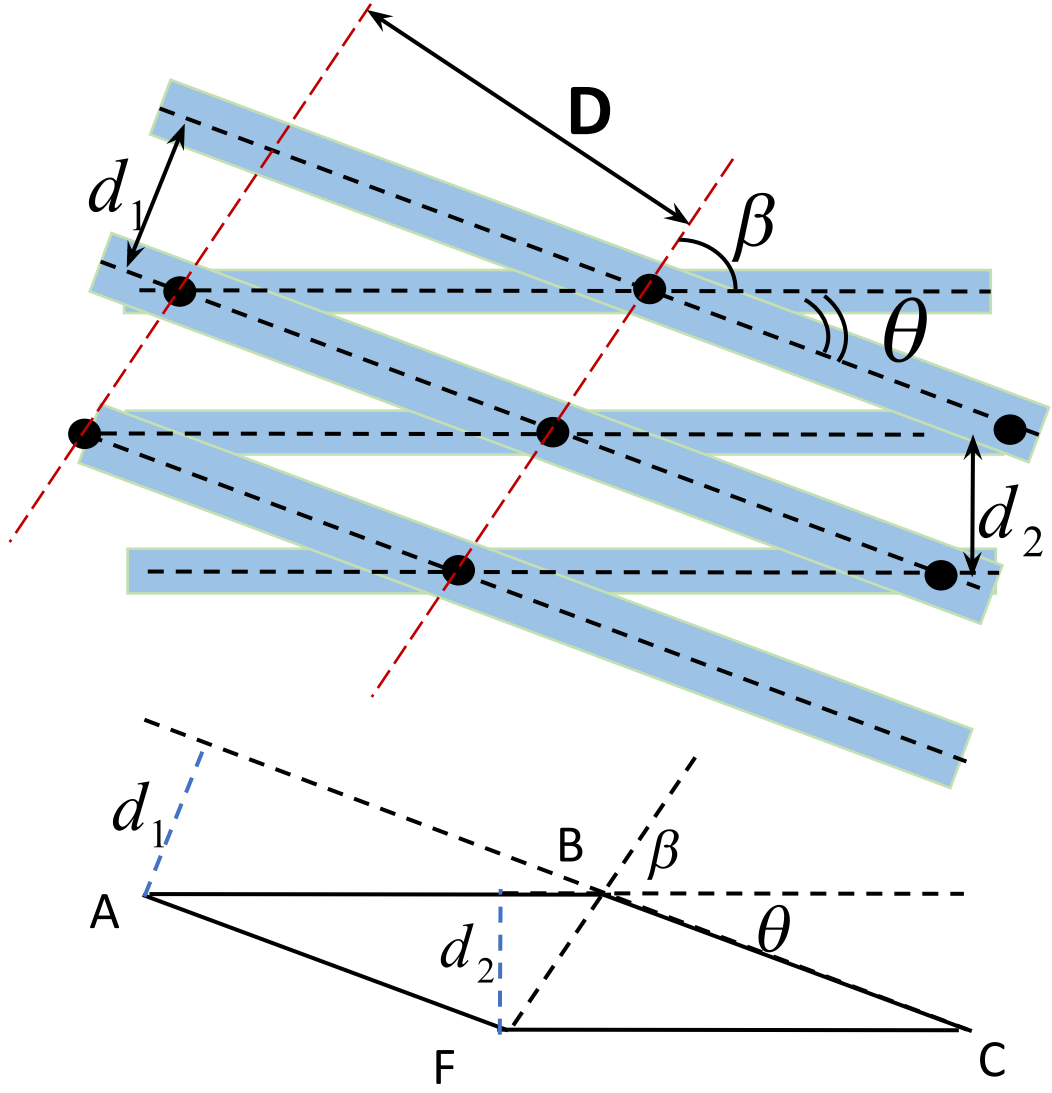
$$\cdot d_2 = \frac{d_1^{\,2} \cdot D \cdot \sin\theta}{d_1 \cdot (D \cdot \sin\theta \cdot \cos\theta + \sqrt{d_1^{\,2} - D^2 \cdot \sin^2\theta} \cdot \sin\theta)} =$$

$$= \frac{d_1 \cdot D}{D \cdot \cos\theta + \sqrt{d_1^{\,2} - D^2 \cdot \sin^2\theta}}$$

$$D \cdot \cos\theta \cdot d_2 + \sqrt{d_1^{\,2} - D^2 \cdot \sin^2\theta} \cdot d_2 = d_1 \cdot D$$

$$D^2(d_1^{\,2} - 2 \cdot d_1 d_2 \cdot \cos\theta + d_2^{\,2} \cdot \cos^2\theta) = d_2^2 \cdot d_1^2 - d_2^2 \cdot D^2 \cdot \sin^2\theta$$

Geometric Moire’



$$D^2(d_1^{\,2} - 2\cdot d_1 d_2\cdot\cos\theta + d_2^{\,2}\cdot\cos^2\theta) = d_2^2\cdot d_1^2 - d_2^2\cdot D^2\cdot\sin^2\theta$$

$$D^2\cdot d_1^{\,2} - 2\cdot D^2\cdot d_1 d_2\cdot\cos\theta + D^2\cdot d_2^{\,2}\cdot\cos^2\theta = d_2^2\cdot d_1^2 - d_2^2\cdot D^2\cdot\sin^2\theta$$

$$d_1^{\,2}(D^2 - d_2^2) - 2\cdot D^2\cdot d_1 d_2\cdot\cos\theta + D^2\cdot d_2^{\,2} = 0$$

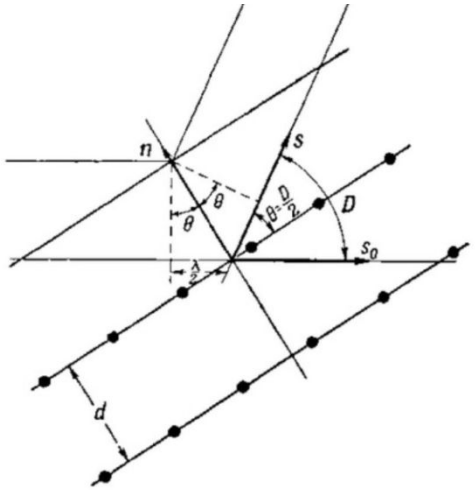
$$d_1 = \frac{D^2\cdot d_2\cdot\cos\theta \pm \sqrt{D^4\cdot d_2^{\,2}\cdot\cos^2\theta - D^2\cdot d_2^{\,2}\cdot(D^2 - d_2^2)}}{(D^2 - d_2^2)} =$$

$$= \frac{D\cdot d_2}{D^2 - d_2^2}\cdot(D\cdot\cos\theta \pm \sqrt{D^2\cdot(\cos^2\theta - 1) + d_2^2}) =$$

$$= \frac{D\cdot d_2}{D^2 - d_2^2}\cdot(D\cdot\cos\theta \pm \sqrt{d_2^2 - D^2\cdot\sin^2\theta})$$

Errors

$$d_1(D,\theta,d_2)=\frac{D^2\cdot d_2\cdot\cos\theta\pm D\cdot d_2\sqrt{d_2^2-D^2\cdot\sin^2\theta}}{D^2-d_2^2}$$



$$\Delta d_1=\sqrt{\sum_{n=1}^{i}\left(\frac{\partial d_1}{\partial x_i}\Delta x_i\right)^2}=\sqrt{\left(\frac{\partial d_1}{\partial d_2}\Delta d_2\right)^2+\left(\frac{\partial d_1}{\partial\theta}\Delta\theta\right)^2+\left(\frac{\partial d_1}{\partial D}\Delta D\right)^2}$$

$$\frac{\partial d_1}{\partial d_2}=\frac{D^4\cdot\cos\theta\pm D^2\frac{2Dd_2^2-D^3\cdot\sin^2}{\sqrt{d_2^2-D^2\cdot\sin^2\theta}}\boxtimes d_2{}^2\frac{2Dd_2^2-D^3\cdot\sin^2}{\sqrt{d_2^2-D^2\cdot\sin^2\theta}}+D^2\cdot d_2{}^2\cdot\cos\theta\pm 2D\cdot d_2{}^2\sqrt{d_2^2-D^2\cdot\sin^2\theta}}{(D^2-d_2^2)^2}$$

$$D^2=\frac{d_1^2\cdot d_2^2}{d_1^2+d_2^2-2\cdot d_1\cdot d_2\cdot\cos\theta}d$$

$$D^2=\frac{d_2^2}{n_1^2\left(\frac{1}{n_1^2}+d_2^2-\frac{2d_2\cos\theta}{n_1}\right)}$$

Good afternoon, name is N Gribova! represer team SES(And I wan tell you n vision of t problen number 1 “Moiré Thr Counter ”. address statement the proble

Here is a pla my presenta .... Then I will te the qualita explanatio this problen theoretical r Considering special case comparing t with practi will make conclusic

двумерн узор из постоян повторя ся. The perio grid is the distance between centers o nearest b of one gr Number threads p is the n=1 три боли пункта

First it is necess some concepts. I see grid. It is 2-di pattern of regula nature(two-dime with any kind o involving) . The p the distance b centers of the ne one grid. I will Small ‘l’ is the dis the bands and ‘f’ the ba In my vision of the use number of centim In the fig2 we example of the r How can we get

Let’s mo two-dime fa Moire patte by the superpose transparen the line of s Angle b horizontal l an angle be So w after some we obtain t period on t

Moire effec of light by s In this sit ef Два пл

First it is necessary to define some concepts. In a fig1 you can see grid. It is 2-dimensional line pattern of regularly repetitive nature(two-dimensional arrays with any kind of periodicity involving) . The period of grid is the distance between the centers of the nearest bands of one grid. I will denote it d.
Small ‘l’ is the distance between the bands and ‘f’ is the width of the band.
In my vision of the problem I will use number of threads per centimetre.
In the fig2 we can see the example of the moire pattern. How can we get such picture?