Theoretical background of the Direct Laser Interference Patterning method

M. Perzanowski*, Y. Zabila, M. Krupiński, A. Polit, M. Marszałek

The Henryk Niewodniczański Institute of Nuclear Physics
Polish Academy of Sciences, Department of Materials Science
Radzikowskiego 152, 31-342 Kraków, Poland

Abstract

The Direct Laser Interference Patterning is a new, fast and economic method of fabrication the periodic nanostructures with size down to few nanometers. Using 2, 3 or 4 laser beams it is possible to obtain various interference patterns — from parallel periodical stripes to separated nanoislands. It can be used for obtaining new type of magnetic storage devices with separated magnetic domains.

The shape, size and period of interference image depends (apart from the number of laser beams) on optical setup geometry and used laser wavelength. On this poster there are presented theoretical calculations and simulations of interference intensity distributions for different geometrical parameters and wavelengths. There will be also shown calculation of interference image periods depended on geometry and wavelength.

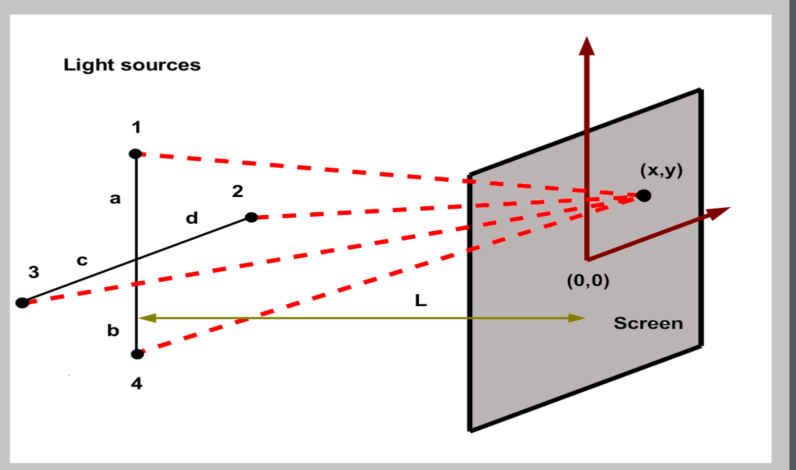
I. Scheme of the experiment geometry

- **Light beam**

$$E_i = E_0 e^{-ik\nu_i}$$

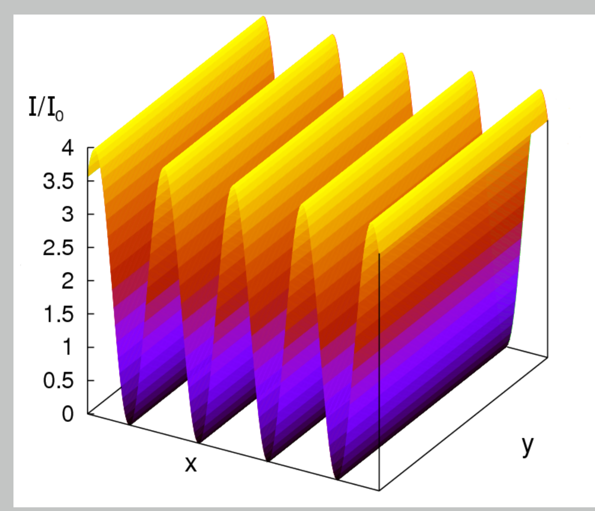
- $k = \frac{2\pi}{\lambda}$, λ — wavelenght
  ν_i — distance beetween i^{th} light source and screen
- **Interference intensity distribution for N beams**

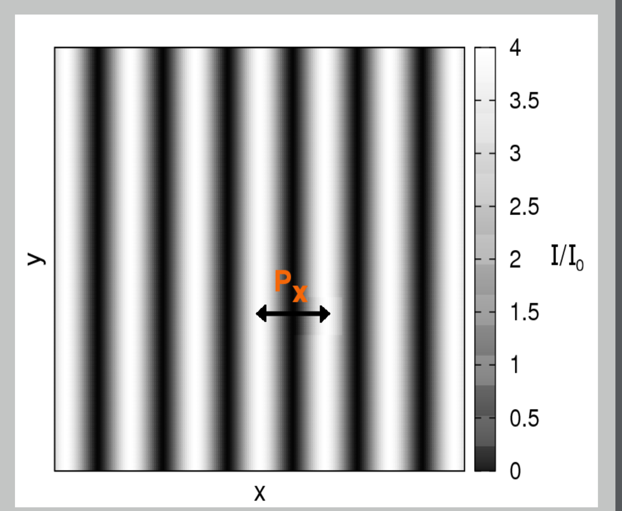
$$I = I_0\left[\left(\Sigma_{i=1}^{N}\cos(k\nu_i)\right)^2 + \left(\Sigma_{i=1}^{N}\sin(k\nu_i)\right)^2\right]$$



II. Two laser beams

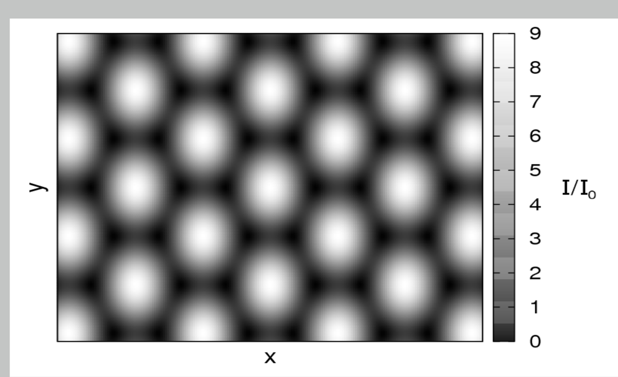
- **Distances between sources and screen:**
  $\nu_1 = \sqrt{L^2 + (a-x)^2 + y^2}$
  $\nu_2 = \sqrt{L^2 + (b+x)^2 + y^2}$
- **periodical stripes,**
- **maximum intensity ratio**
  $I/I_0 = 4$



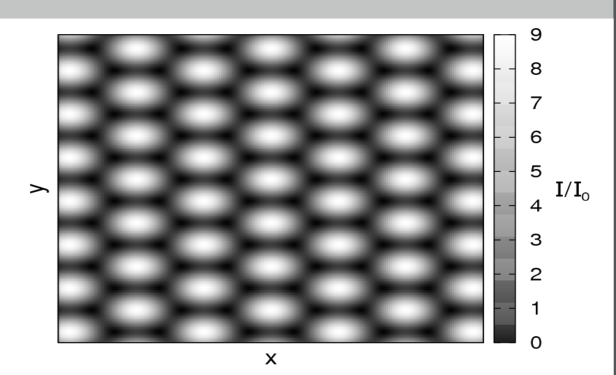


III. Three laser beams

- **Distances between sources and screen:**
  $\nu_1 = \sqrt{L^2 + (a-x)^2 + y^2}$
  $\nu_2 = \sqrt{L^2 + (b+x)^2 + y^2}$
  $\nu_3 = \sqrt{L^2 + (c-y)^2 + x^2}$
- **periodical/aperiodcal pattern of dots,**
- **maximum intensity ratio**
  $I/I_0 = 9$
- **symmetrical configuration**
  $a = b = c$

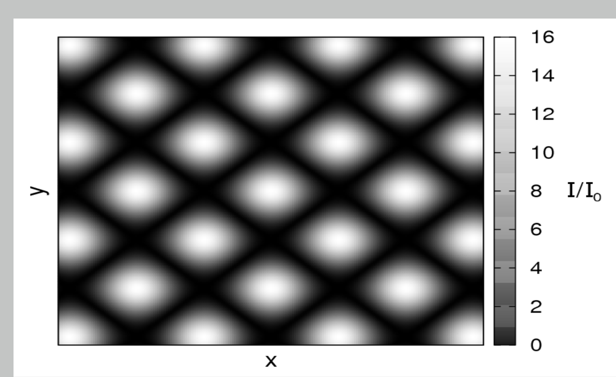


- **asymmetrical configuration**
  $a = b \neq c$

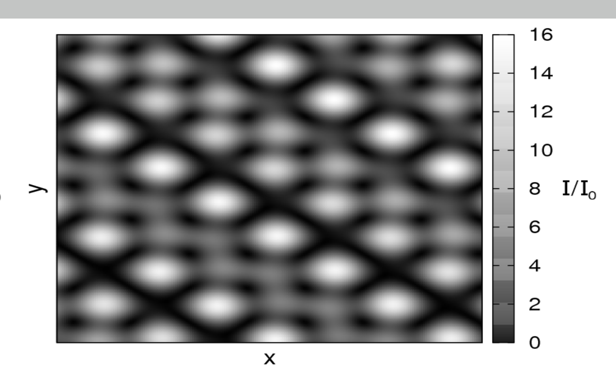


IV. Four laser beams

- **Distances between sources and screen:**
  $\nu_1 = \sqrt{L^2 + (a-x)^2 + y^2}$
  $\nu_2 = \sqrt{L^2 + (b+x)^2 + y^2}$
  $\nu_3 = \sqrt{L^2 + (c-y)^2 + x^2}$
  $\nu_4 = \sqrt{L^2 + (d+y)^2 + x^2}$
- **periodical/aperiodical pattern of dots,**
- **maximum intensity ratio**
  $I/I_0 = 16$
- **symmetrical configuration**
  $a = b = c = d$



- **asymmetrical configuration**
  $a \neq b \neq c \neq d$



V. Period calculations for 2-beams system

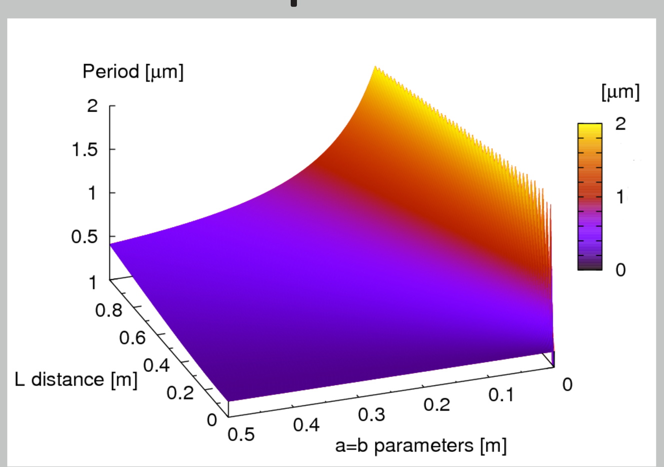
- **Period between two stripes (n and $n+1$) for symmetrical case $a = b$:**

$$P(a,L,\lambda) = \left(\sqrt{\frac{4L^2\eta_{n+1} + 4a^2\eta_{n+1} - \eta_{n+1}^2}{16a^2 - 4\eta_{n+1}}}\right)_{n+1} - \left(\sqrt{\frac{4L^2\eta_n + 4a^2\eta_n - \eta_n^2}{16a^2 - 4\eta_n}}\right)_n$$

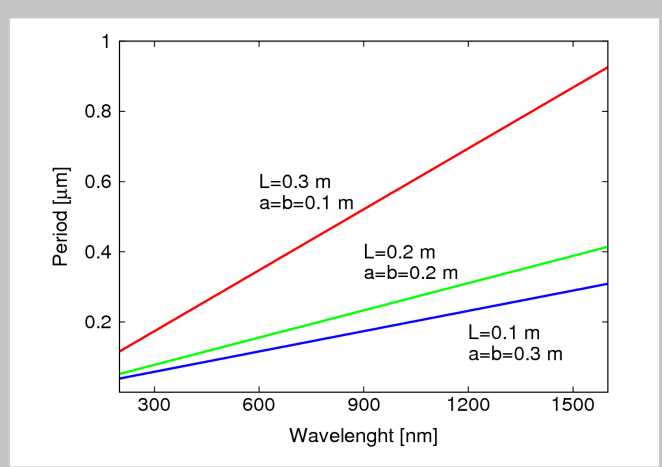
- **where:**

$$\eta_{n+1} = \frac{\lambda^2(1+2(n+1))^2}{4}\ ,\quad \eta_n = \frac{\lambda^2(1+2n)^2}{4}$$

- **Period calculated for $\lambda = 1000\ nm$ and various L and a parameters:**



- **Period dependent on wavelenght for fixed L and a values:**



VI. Period calculations for 3-beams system

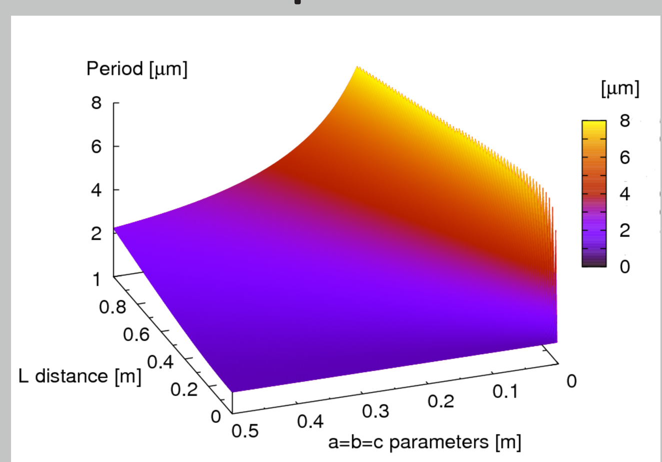
- **Period between two dots along the x or y axis for symmetrical case $a = b = c$:**

$$P(a,L,\lambda) = 2\cdot\left(\left(\sqrt{\frac{4\phi_{n+1}^2L^2 + 4\phi_{n+1}^2a^2 - \phi_{n+1}^4}{16a^2 - 4\phi_{n+1}^2}}\right)_{n+1} - \left(\sqrt{\frac{4\phi_n^2L^2 + 4\phi_n^2a^2 - \phi_n^4}{16a^2 - 4\phi_n^2}}\right)_n\right)$$

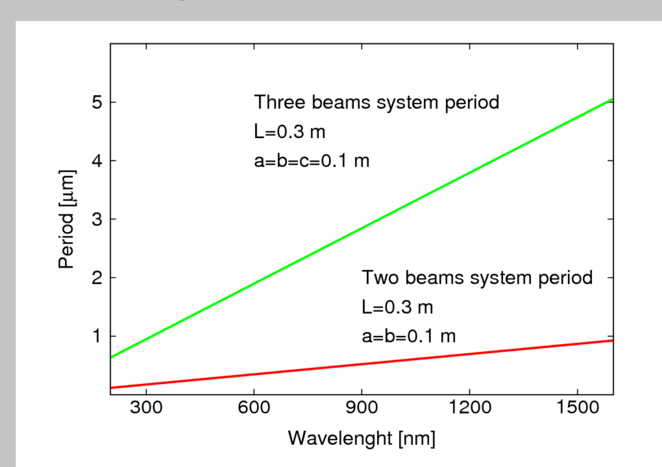
- **where:**

$$\phi_{n+1} = (n+1)\lambda\ ,\quad \phi_n = n\lambda$$

- **Period calculated for $\lambda = 1000\ nm$ and various L and a parameters:**



- **Comparison the periods for 2- and 3-beams systems:**



VII. The experimental setup and example of calculated interference pattern

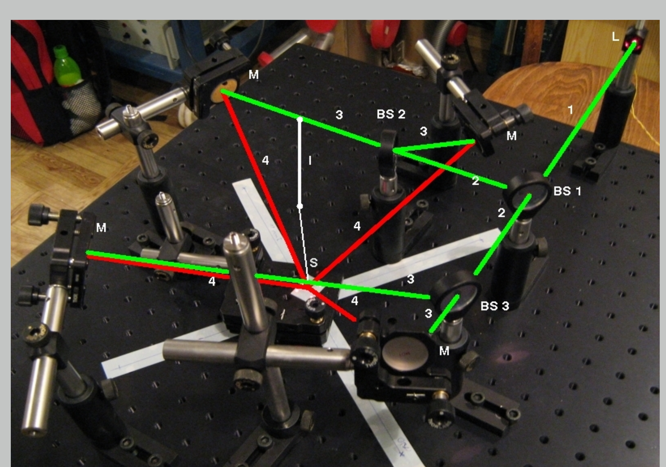
Used optical elements:

- four mirrors (M1 – M4),
- three 50% – 50% beam splitters (BS1 – BS3),
- holders for optical elements,
- laser with wavelenght 600 nm (L)

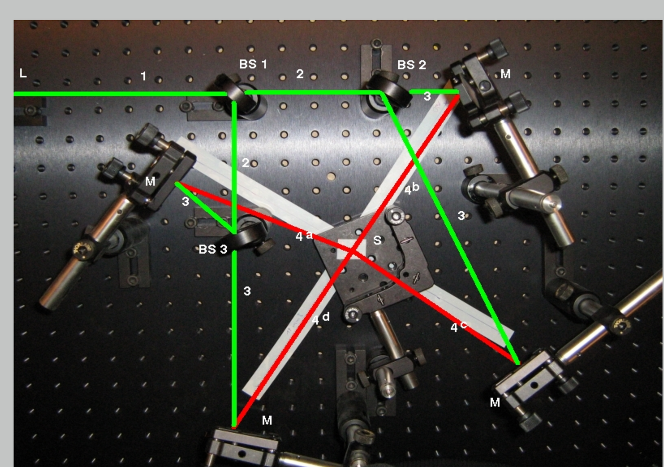
Interference geometry:

- four laser beams,
- symmetrical case $a = b = c = d = 0,31\ m$,
- the L-distance between sample (screen) and plane of light sources was $L = 0,17\ m$

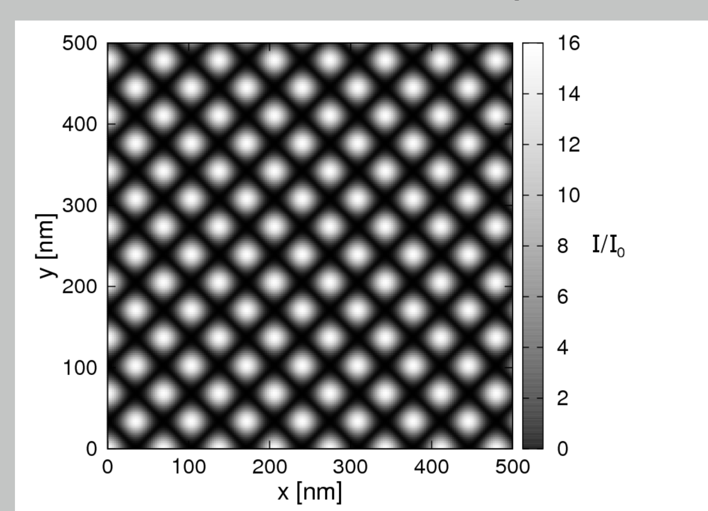
- **Experimental setup — side view**



- **Experimental setup — top view**



- **Calculated intereference pattern**



http://www.ifj.edu.pl, http://www.ifj.edu.pl/dept/no5/nz53/

*Marcin.Perzanowski@ifj.edu.pl