Beselio pluoštai

Skaliarinės bangų lygties sprendinys

Beselio-Gauso pluoštų formavimo būdai:

- holografinis
- Fabri ir Pero interferometras
- Žiedinė diafragma
- Eksikonas (axicone)

Beselio pluoštai

$$\left(\Delta - \frac{1}{c^2}\frac{\partial^2}{\partial t^2}\right)E(r,t) = 0$$

$$E(\rho,t) = \exp\left[i(\beta z - \omega t)\right]J_0(\alpha\rho)$$

$$\beta^2 + \alpha^2 = (\omega/c)^2$$

$$\rho^2 = x^2 + y^2$$

$$\omega = c\sqrt{(k_{II}^2 + k_\perp^2)}$$

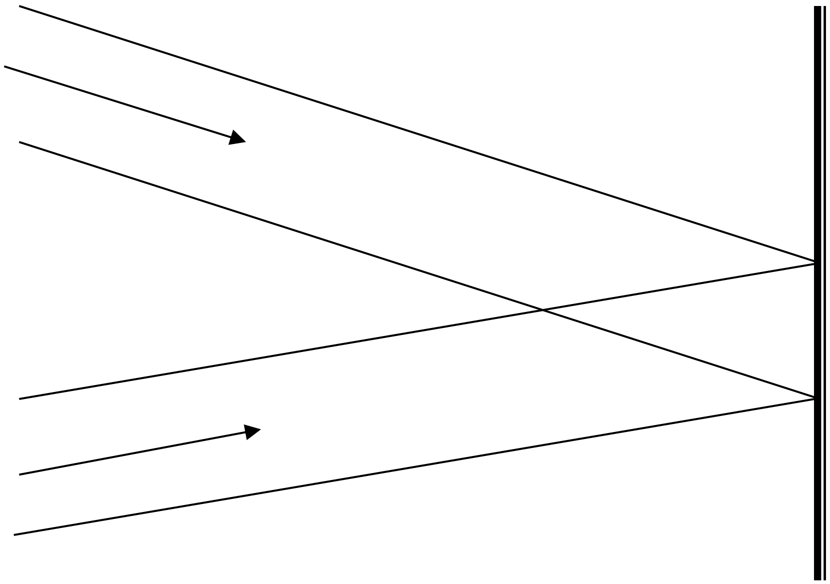
$$\lambda = \frac{2\pi}{\sqrt{k_\parallel^2 + k_\perp^2}}$$

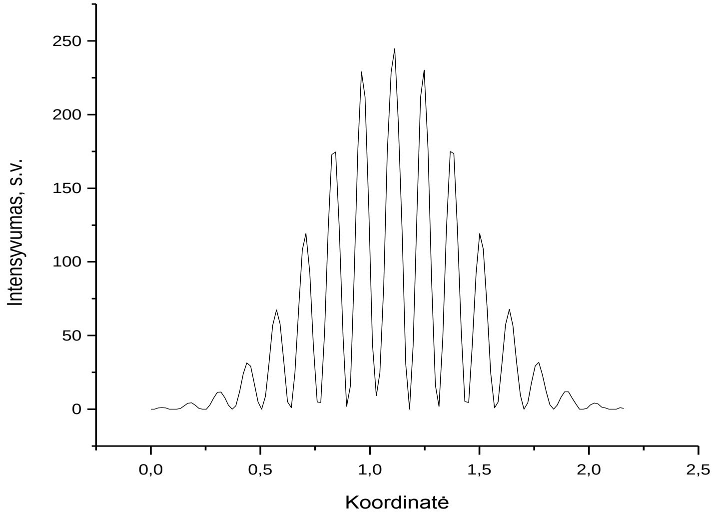
$$E(\rho,t) = \exp\left[i(\beta z - \omega t)\right]\sum_n E_n \exp(in\varphi) J_n(\alpha\rho)$$

$$A_n(\rho,\varphi) = a_n J_n(\alpha_0\rho)\exp(in\varphi - \rho^2/d^2)$$

J. Durnin, “Exact solutions for nondiffracting beams. I. The scalar theory”, J. Opt. Soc. Am. A, vol. 4, p.651-654 (1987).

Beselio pluoštai





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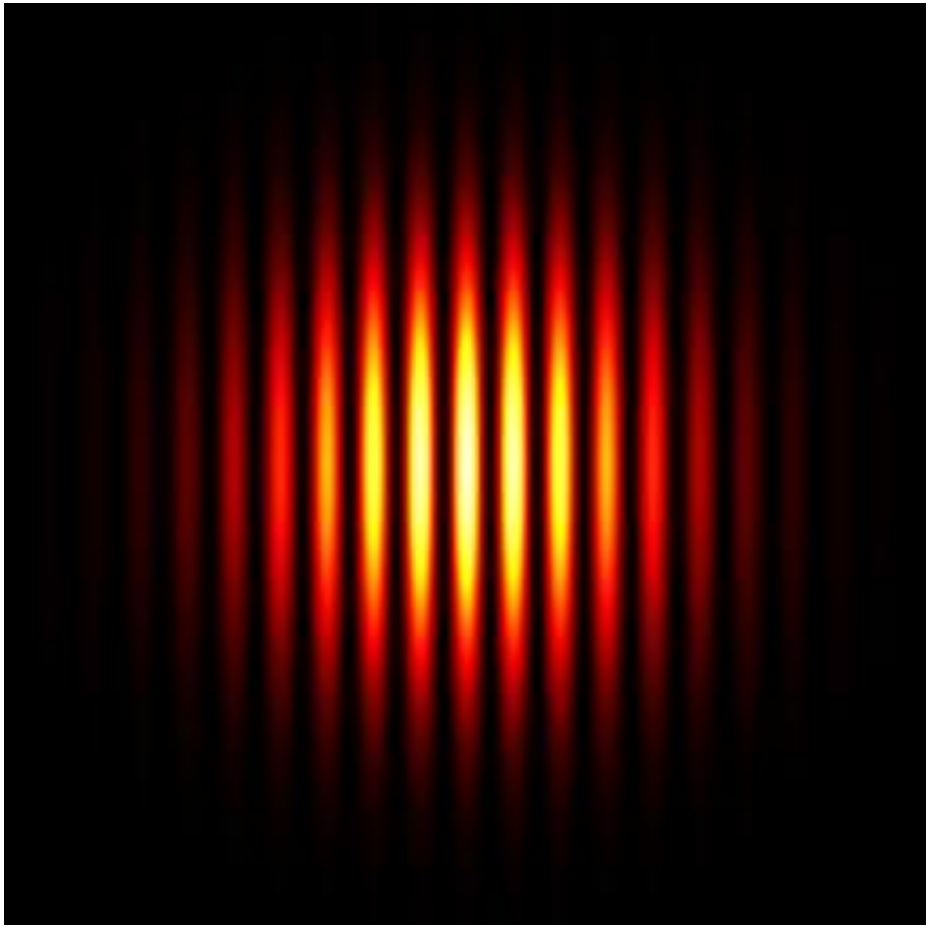
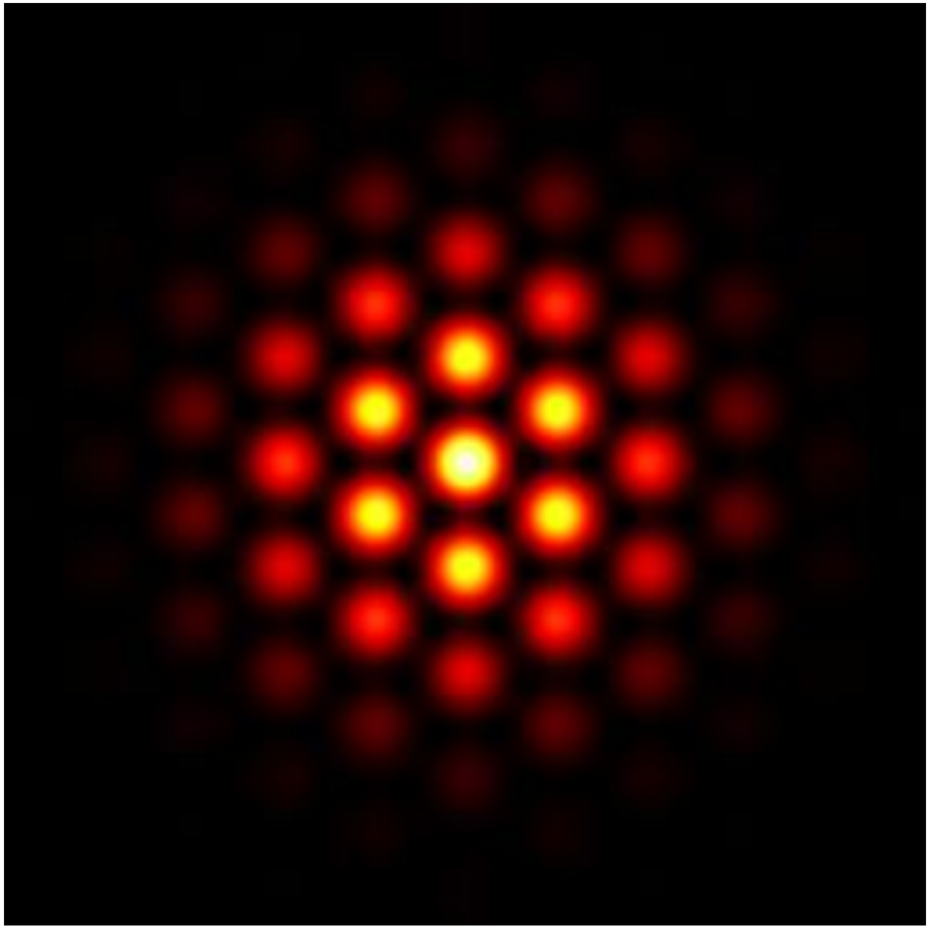
Beselio pluoštai



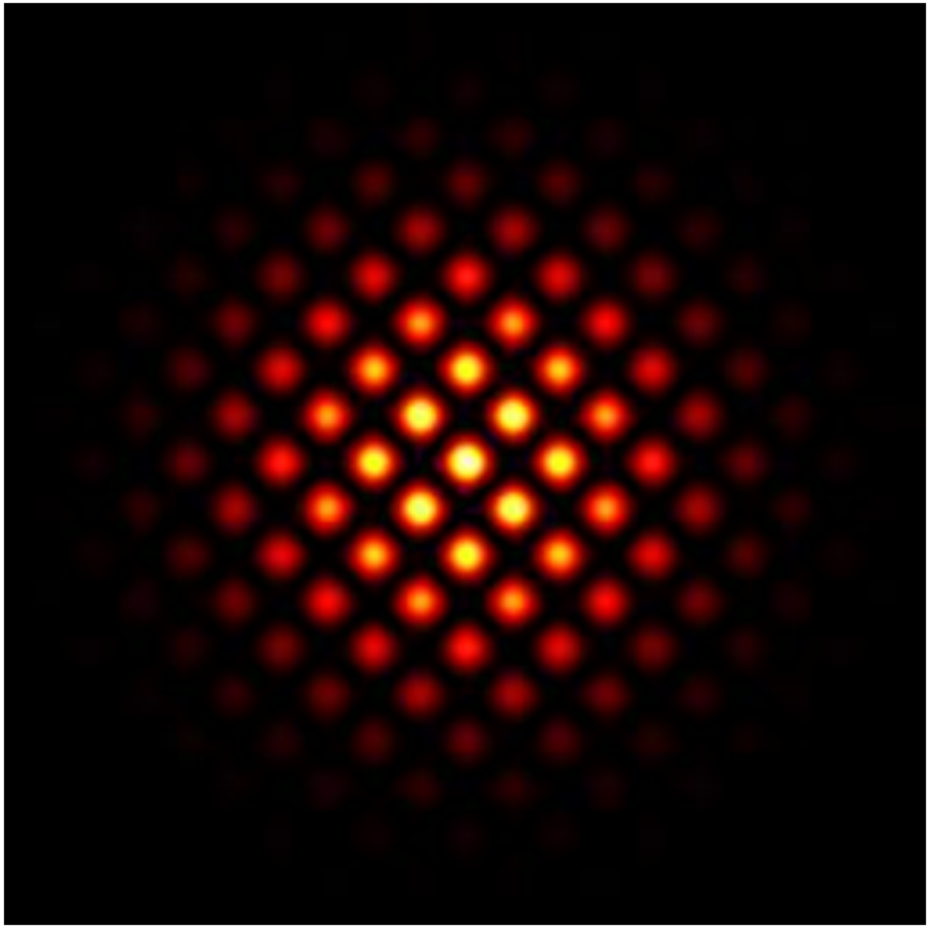
Du pluoštai: $\vartheta = \pm 0.03^o$, $\varphi = 180$

Beselio pluoštai



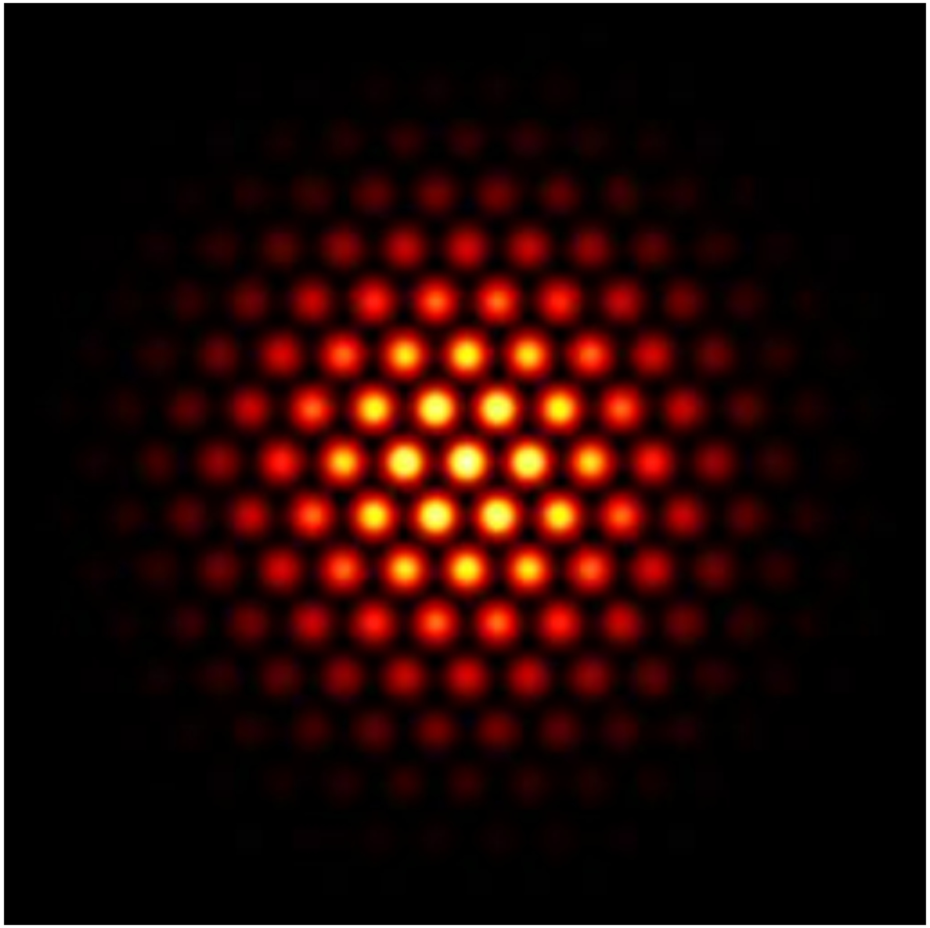
Trys pluoštai: $\vartheta = \pm 0.03^{o}$, $\Delta\varphi = 120$

Beselio pluoštai



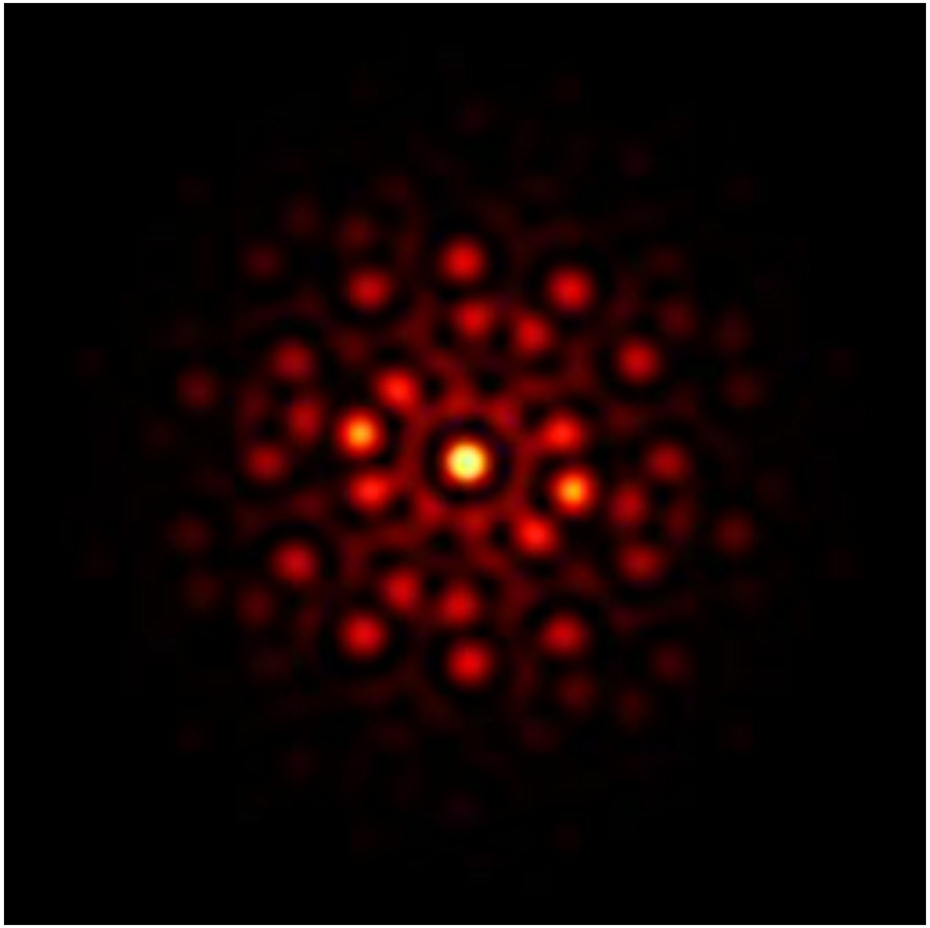
Keturi pluoštai: $\vartheta = \pm 0.03^{o}$, $\Delta\varphi = 90^{o}$

Beselio pluoštai



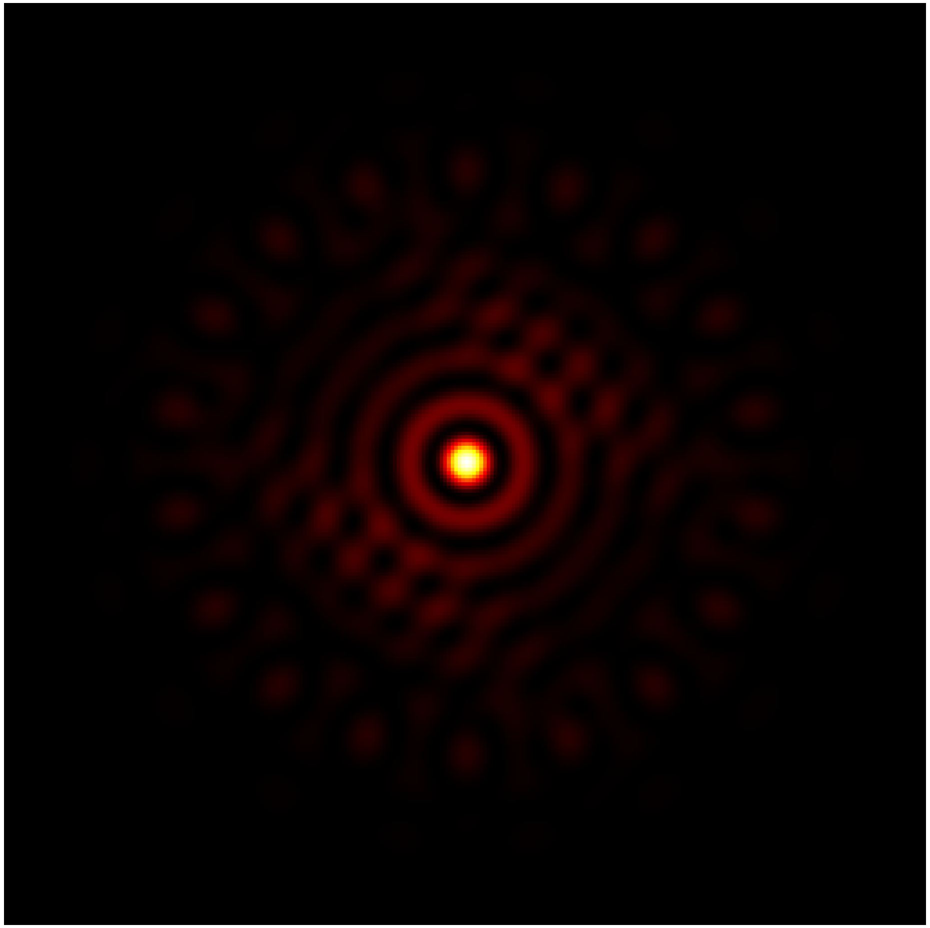
Šeši pluoštai: $\vartheta = \pm 0.03^o$, $\Delta\varphi = 60^o$

Beselio pluoštai



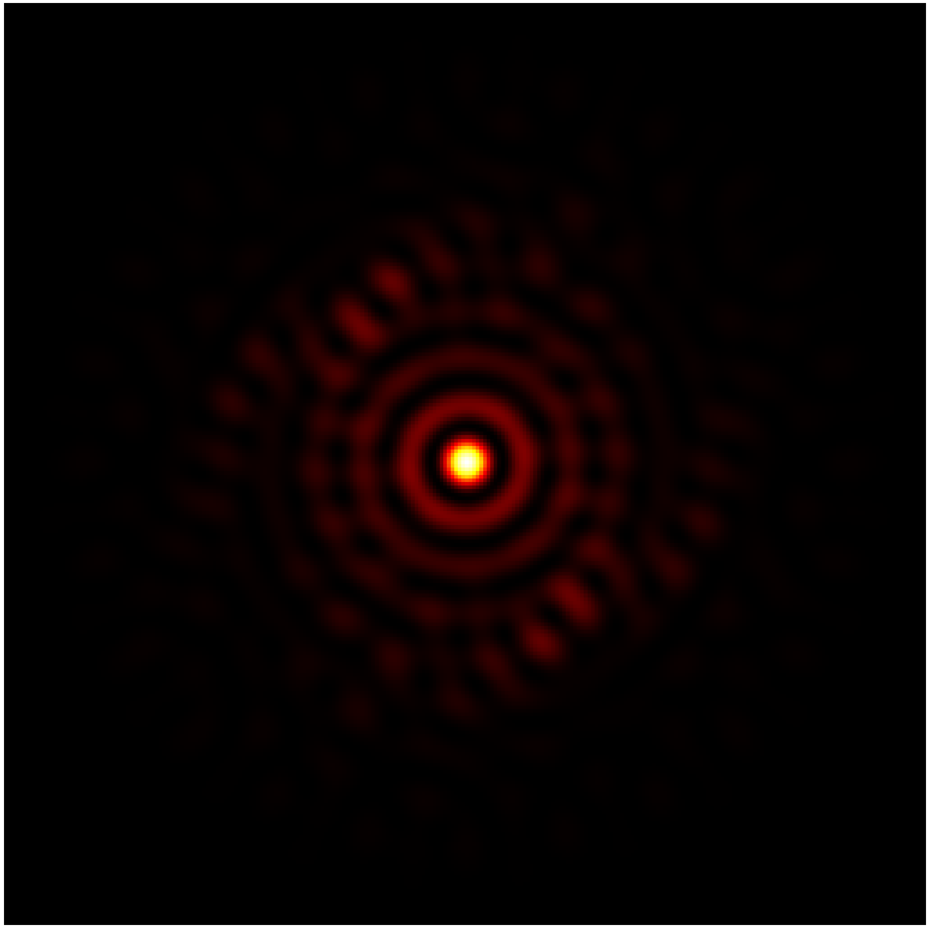
Dvylika pluoštų: $\vartheta = \pm 0.03^{o}$, $\Delta\varphi = 30^{o}$

Beselio pluoštai



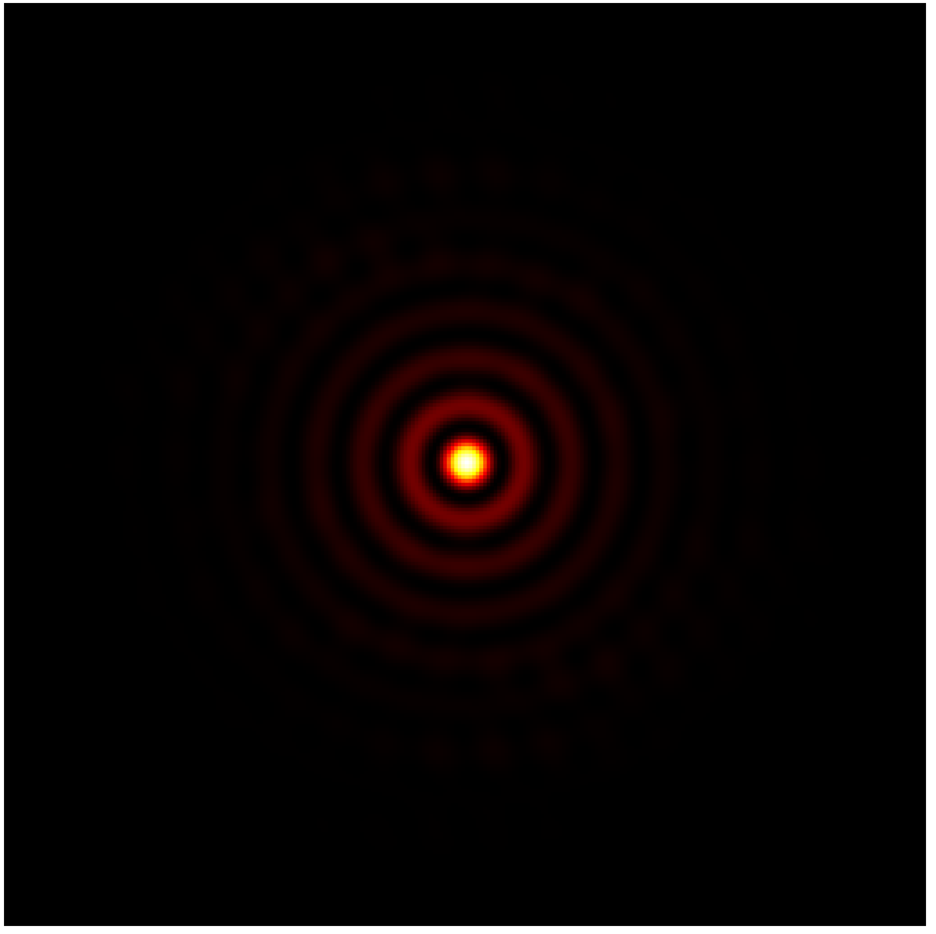
Aštuoniolika pluoštų: $\vartheta = \pm 0.03^{o}$, $\Delta\varphi = 20^{o}$

Beselio pluoštai



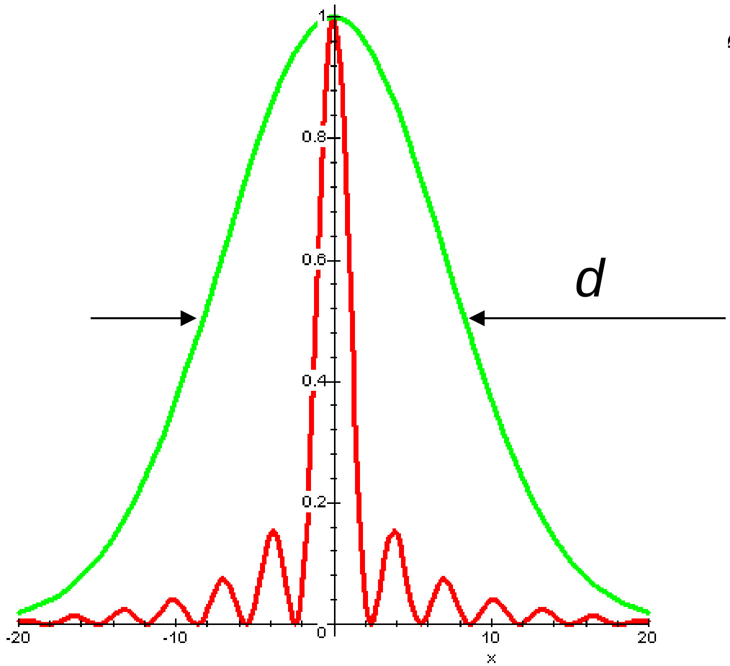
Dvidešimt keturi pluoštai: $\vartheta = \pm 0.03^{o}$, $\Delta\varphi = 15^{o}$

Beselio pluoštai



Trisdešimt šeši pluoštai: $\vartheta = \pm 0.03^{o}$, $\Delta\varphi = 10^{o}$

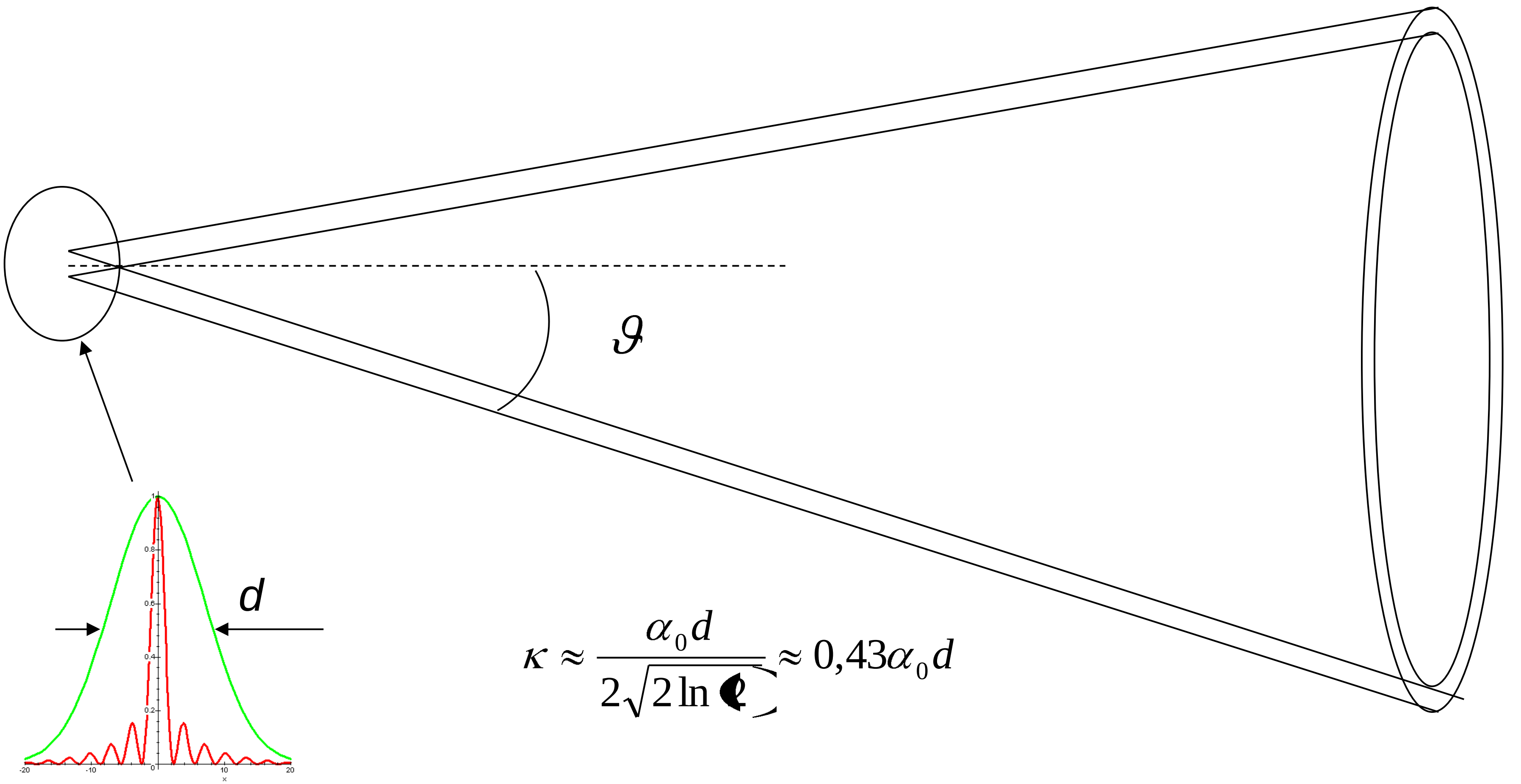
Beselio pluoštai



$$A_n(\rho,\varphi) = a_n J_n(\alpha_0 \rho)\exp(in\varphi - \rho^2/d^2)$$

$$\alpha_0 = k\sin(\vartheta) = (\omega/c)\sin(\vartheta)$$

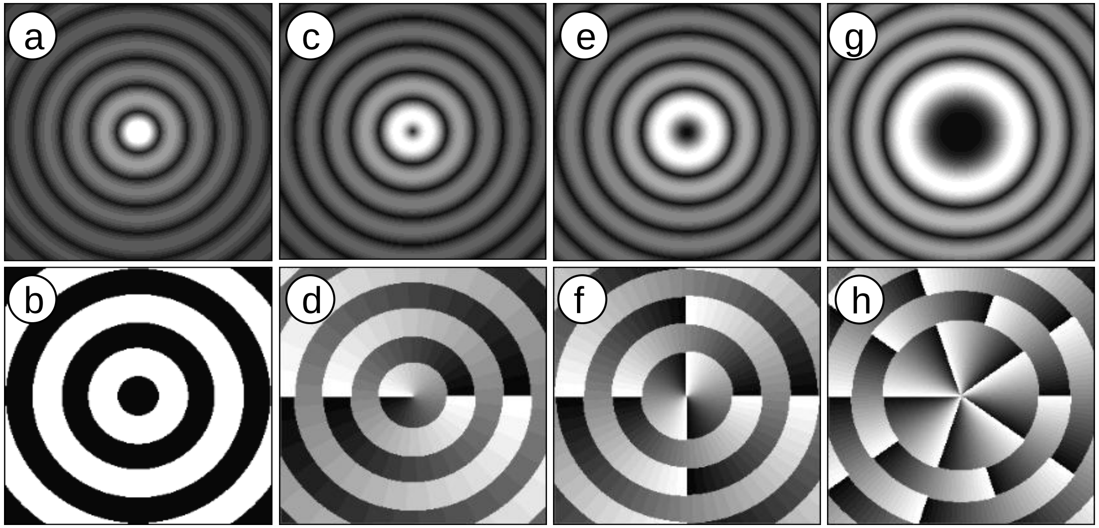
Beselio pluoštai



$$\kappa \approx \frac{\alpha_0 d}{2\sqrt{2\ln(2)}} \approx 0{,}43\alpha_0 d$$

$$\alpha_0 = k\sin(\vartheta) = (\omega/c)\sin(\vartheta)$$

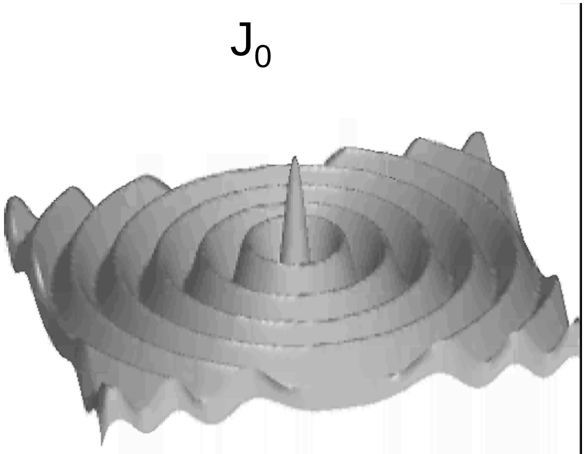
Beselio pluoštai



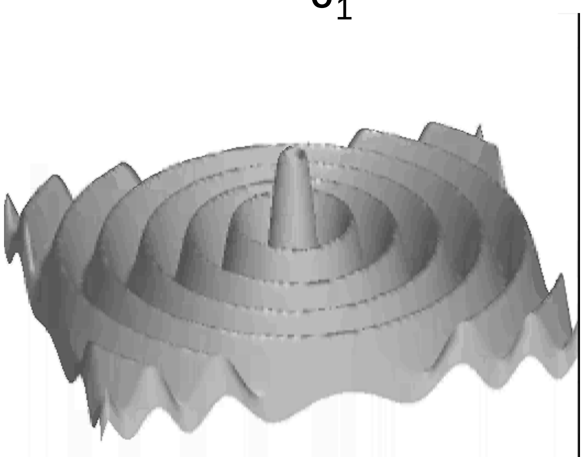
Beselio pluoštų intensyvumo skirstiniai (a, c, e, g) ir faziniai portretai (b, d, f, h). Atitinkamai paveikslėliuose pavaizduoti nulinės (a, b), pirmos (c, d), antros (e, f) ir penktos (g, h) eilės Beselio pluoštai. Fazinių portretų paveikslėliuose juoda spalva atitinka fazę lygią nuliui, o balta atitinka fazę lygia . Tarpines fazės vertes atitinka pilka spalva.

Beselio pluoštai

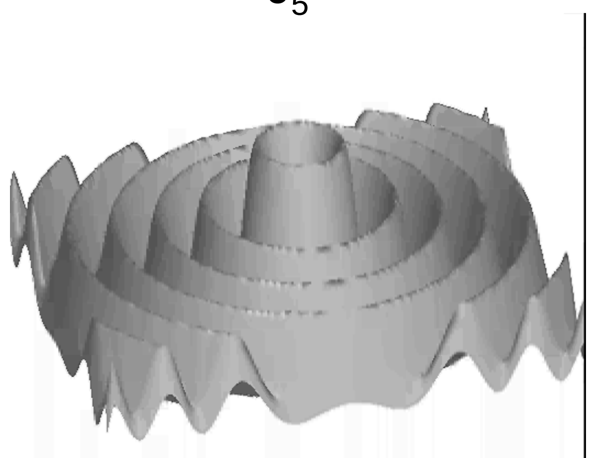
J_0



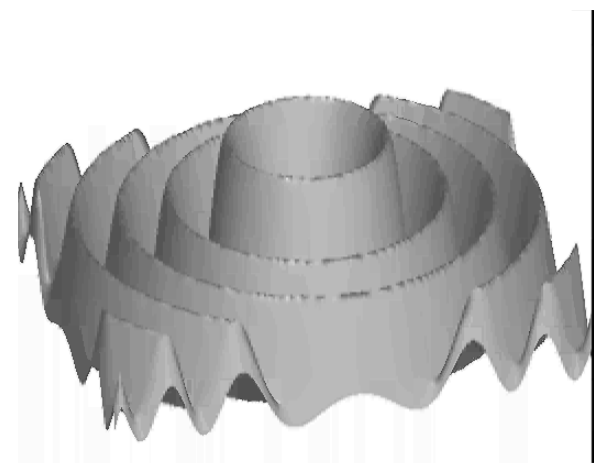
J_1



J_5

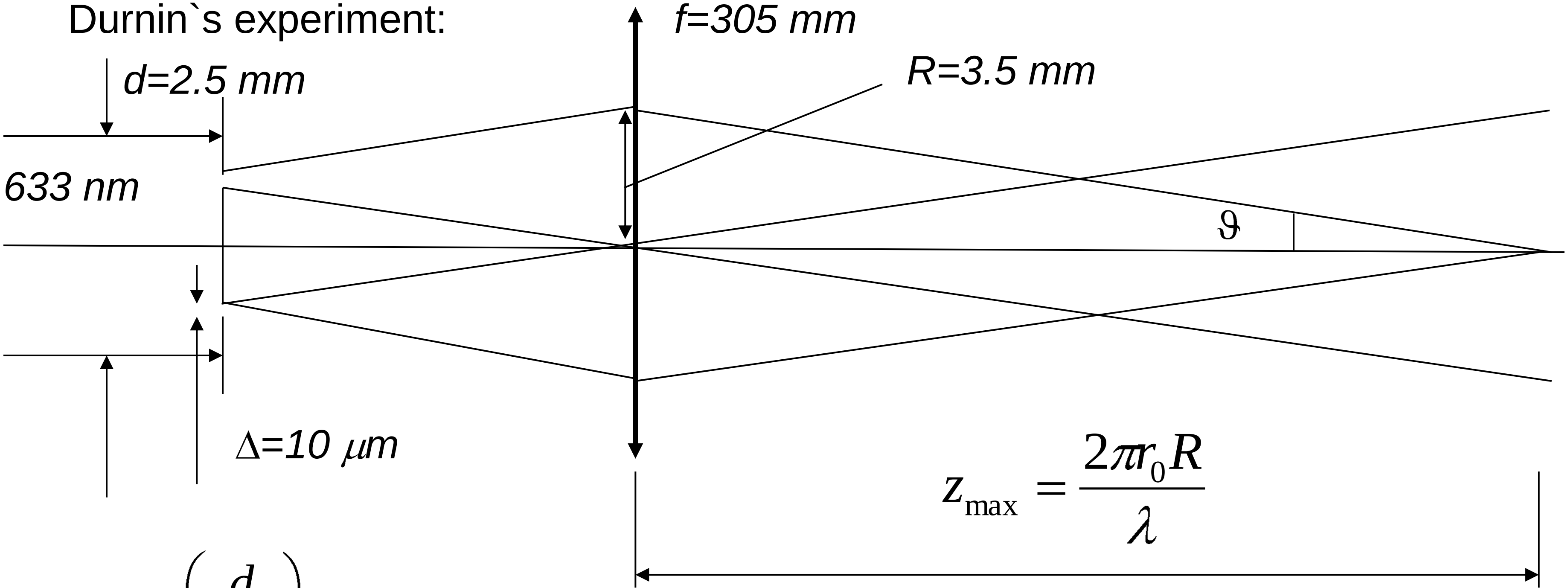


J_{10}



Beselio pluoštai

Durnin`s experiment:



$$z_{\max} = \frac{2\pi r_0 R}{\lambda}$$

$$\vartheta = arctg\left(\frac{d}{2f}\right)$$

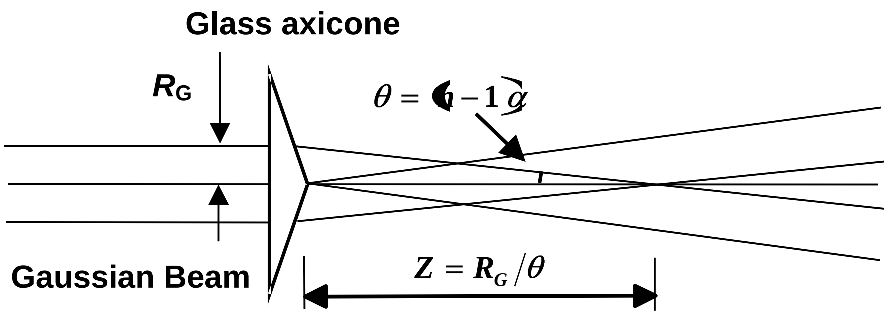
$$r_0 \approx 25\mu m \qquad z_{\max} = 85cm$$

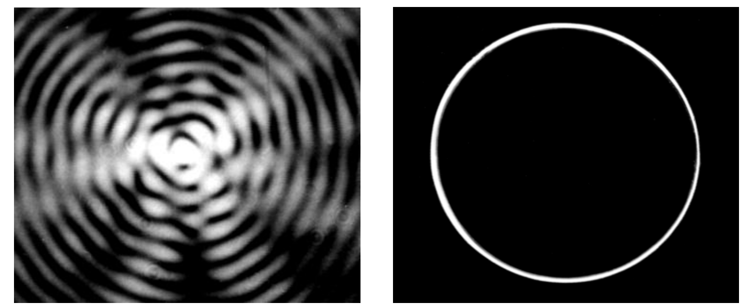
$$r_0 \approx \frac{1}{k\perp} \qquad k_{\perp} = \left(\frac{2\pi}{\lambda}\right)\sin\vartheta$$

Gauso pluoštui: $z_{\max} = 3mm$

J. Durnin, “Exact solutions for nondiffracting beams. I. The scalar theory”, J. Opt. Soc. Am. A, vol. 4, p.651-654 (1987).

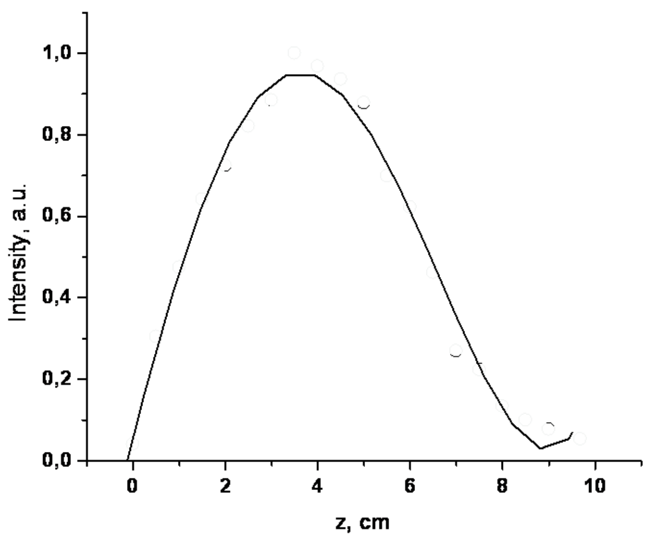
Beselio pluoštai





a b

Beselio pluošto suformuoto aksikonu intensyvumo skirstinys (a) ir jo Furje spektras (b)



$$z_{\max} = R / \vartheta$$

Beselio pluoštai

$$A_n(r,\varphi) = a\left(\frac{r}{d}\right)^n \exp\left[-(r/d)^2 + in\varphi\right], \quad n = 0, 1, 2, \ldots$$

Lagero ir Gauso pluošto kompleksinė amplitudė cilindrinėse koordinatėse

$\exp(-i\beta_0 r)$ Kūginės prizmės perdavimo funkcija $\beta_0 \cong \frac{2\pi}{\lambda}(n_a - 1)\alpha$

$$B_n(r,\varphi) = A_n(r,\varphi)\exp(-i\beta_0 r) = a\left(\frac{r}{d}\right)^n \exp\left[-(r/d)^2 + i(n\varphi - \beta_0 r)\right]$$

Lagero ir Gauso pluošto kompleksinė amplitudė už kūginės prizmės

$$B_n(\xi,\varphi,z_0) = a(\pi m/2)^{1/2} e^{i(n\varphi - n\pi/2 - \pi/4)}\left[(F_1 + F_2)J_n(m\xi) - i(F_1 - F_2)J_{n-1}(m\xi)\right]$$

$\xi = r/d$ $z_0 = \frac{mz}{2L_d}$ $L_d = \frac{kd^2}{2}$ $m = \beta_0 d$

$$F_1 = (z_0 + \xi)^{n+1/2} e^{-(z_0+\xi)^2}$$

$x > 0$ $H(x) = 1$

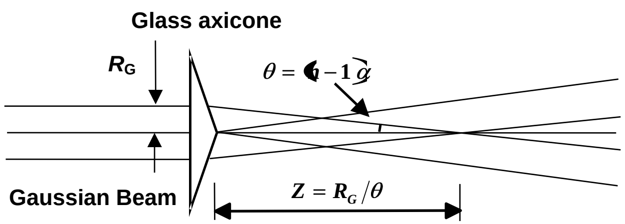
$x \le 0$ $H(x) = 0$

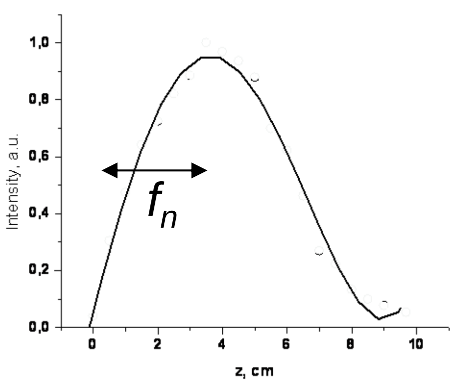
$$F_2 = (z_0 - \xi_0)^{n+1/2} e^{-(z_0-\xi)^2} H(z_0 - \xi)$$

Beselio pluoštai

$$I_n\left(\xi, z_0\right) = \frac{\pi m}{2} a^2 \left[\left(F_1 + F_2\right)^2 J_n^2\left(n\xi\right) + \left(F_1 - F_2\right)^2 J_{n-1}^2\left(n\xi\right)\right]$$

$$f_n = \frac{L_d}{m}\sqrt{2n+1} = \frac{d\sqrt{2n+1}}{2\alpha\left(n_a - 1\right)}$$





Beselio pluoštai

$$I = \left| R_0\, e^{i k_x x} + a\left(\frac{r}{d}\right)^n \exp\left[-(r/d)^2 + i(n\varphi - \beta_0 r)\right]\right|^2 =$$

$$= R_0^2 + a^2\left(\frac{r}{d}\right)^{2n} e^{-2r^2/d^2} + 2R_0 a\left(\frac{r}{d}\right)^n e^{-r^2/d^2}\cos(k_x x - n\varphi + \beta_0 r)$$

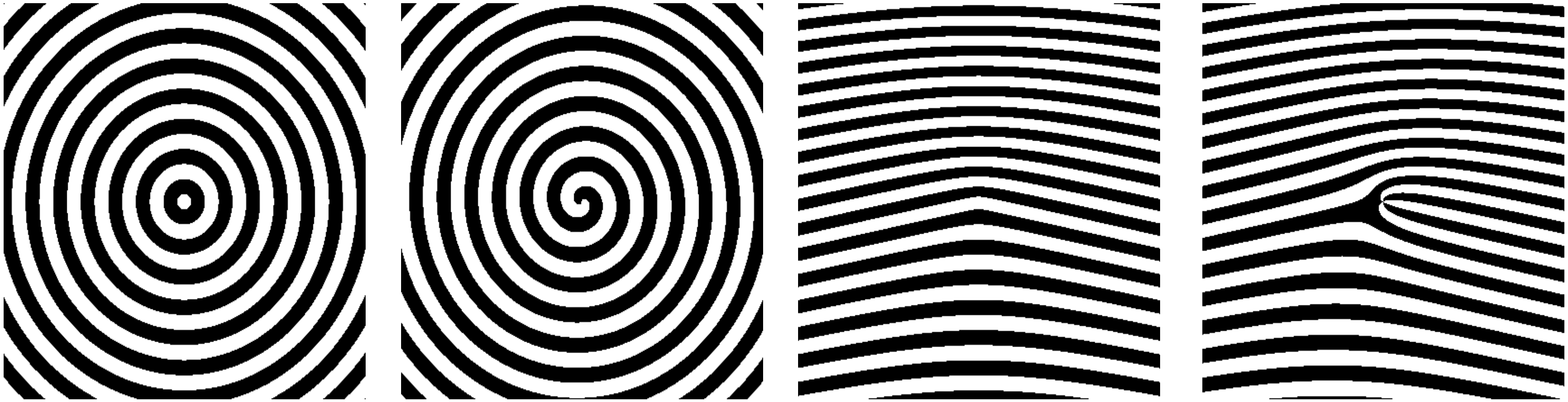
Intensyvumo skirstinys, kai interferuoja Beselio pluoštas ir atraminė banga (holograma)

$$T = \frac{1}{2}\left(1 - \cos(k_x x - n\varphi + \beta_0 r)\right)$$

Pralaidumo funkcija

$$E_T = \frac{a}{2} e^{-r^2/d^2} - \frac{a}{4} e^{-r^2/d^2} e^{i(k_x x - n\varphi + \beta_0 r)} - \frac{a}{2} e^{-r^2/d^2} e^{-i(k_x x - n\varphi + \beta_0 r)}$$

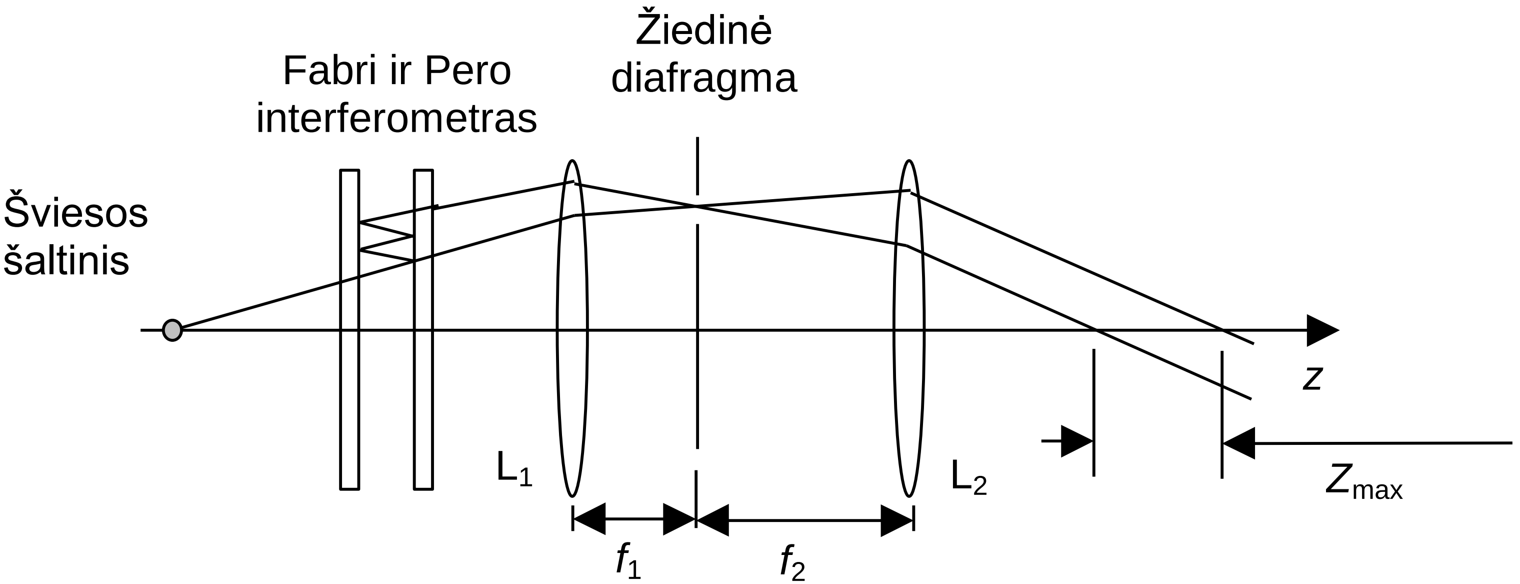
Beselio pluoštai



(a) (b) (c) (d)

Amplitudinių binarinių (juoda ir balta) hologramų, skirtų generuoti įvairios eilės Beselio pluoštams, pavyzdžiai. (a) ir (b) bendraašės hologramos atitinkamai J_0 ir J_1 Beselio pluoštų formavimui. (c) ir (d) nebendraašės hologramos skirtos J_0 ir J_3 Beselio pluoštų formavimui.

Beselio pluoštai



Beselio pluoštai

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