

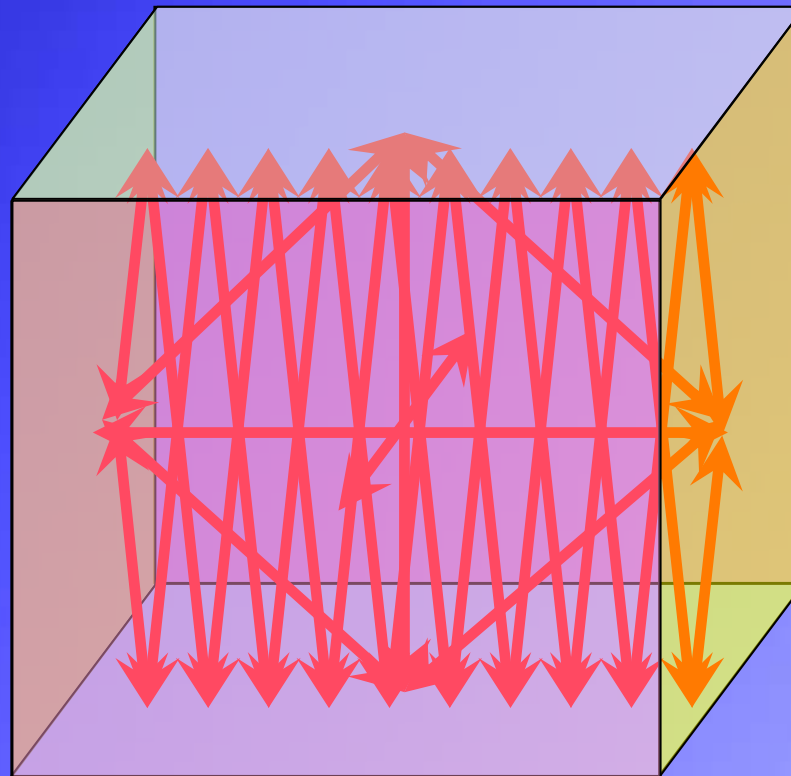


Optiniai Rezonatoriai

Andrius Melninkaitis

2004 02 11

Rezonatorius

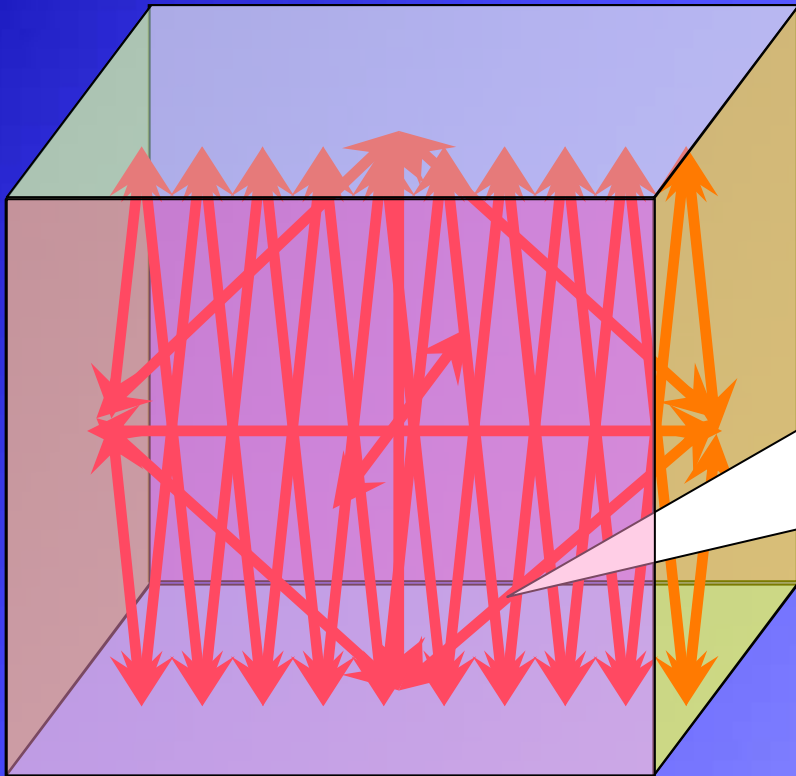




**Dvi pagrindinės rezonatorių
savybės:**

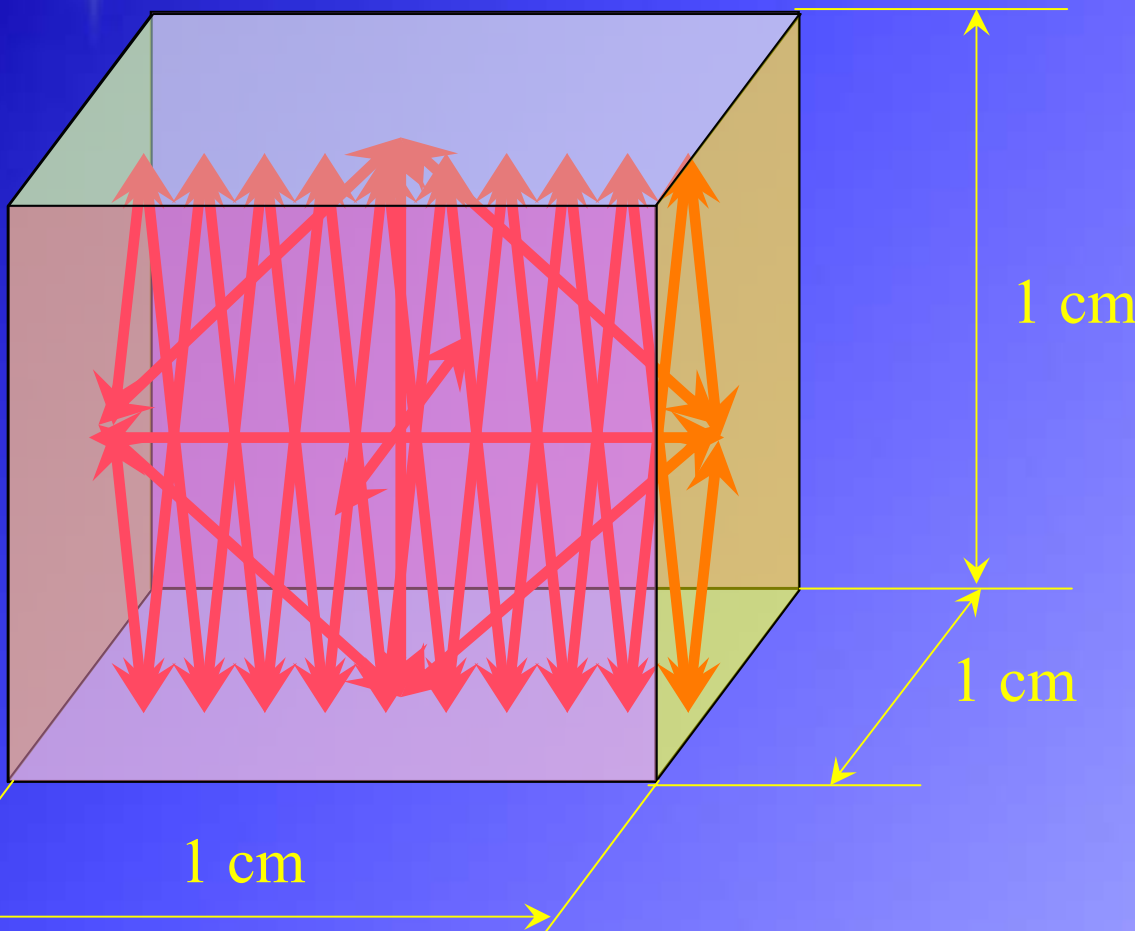
Grižtamasis ryšys

1



Galime “sukaupti”
šviesą ir pasiekti
didelę galią

Rezonatoriaus modų skaičius



$$N \approx 8\pi\nu^2 n^3 d\nu / c^3$$

Kai $V = 1 \text{ cm}^3$

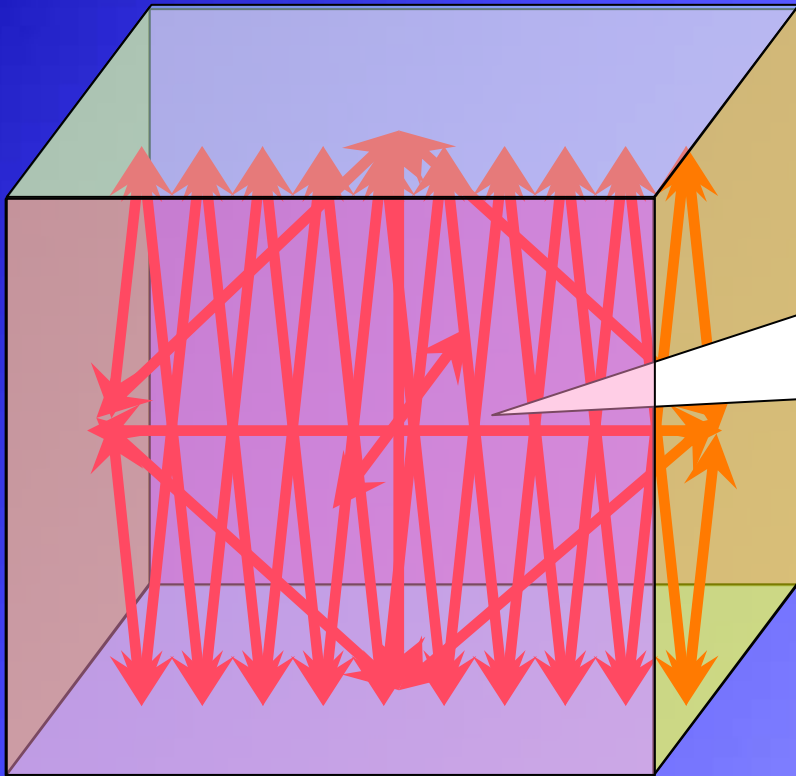
$$\nu = 3 \cdot 10^{14} \text{ Hz}$$

$$d\nu = 3 \cdot 10^{10} \text{ Hz}$$

$$N \approx 2 \cdot 10^9$$

Erdvinė ir spektrinė atranka (selektyvumas)

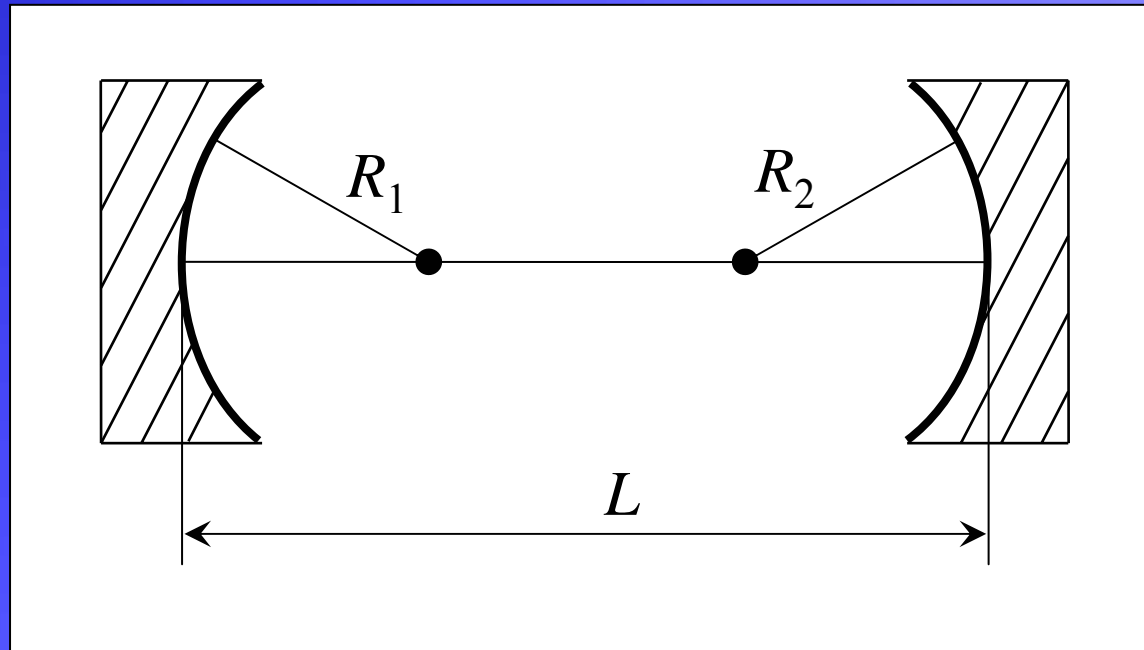
2



$$\cancel{N \approx 2 \cdot 10^9}$$

N : mažas

Atvirasis rezonatorius



Rezonatoriaus g parametrai

$$g_1 = 1 - \frac{L}{R_1}$$

$$g_2 = 1 - \frac{L}{R_2}$$

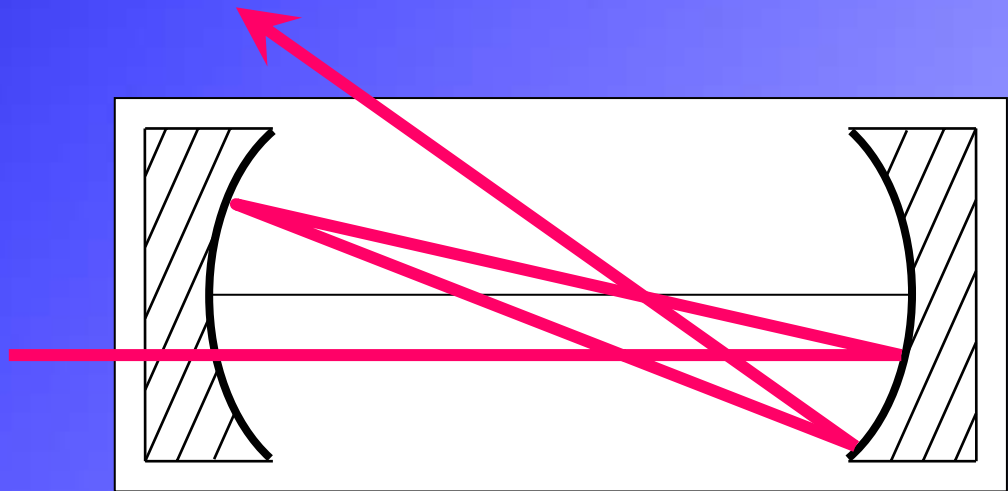
Rezonatoriaus pastovumas

Rezonatorius vadinamas **optiškai PASTOVIU**, jeigu paraksialus šviesos pluoštas net ir po daugelio atspindžių nuo rezonatoriaus veidrodžių lieka rezonatoriuje

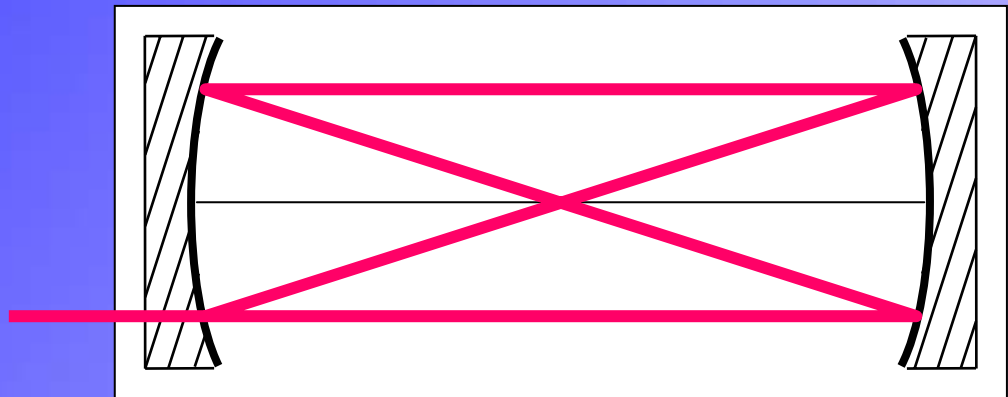
$$0 \leq g_1 g_2 \leq 1$$

Rezonatoriaus pastovumas

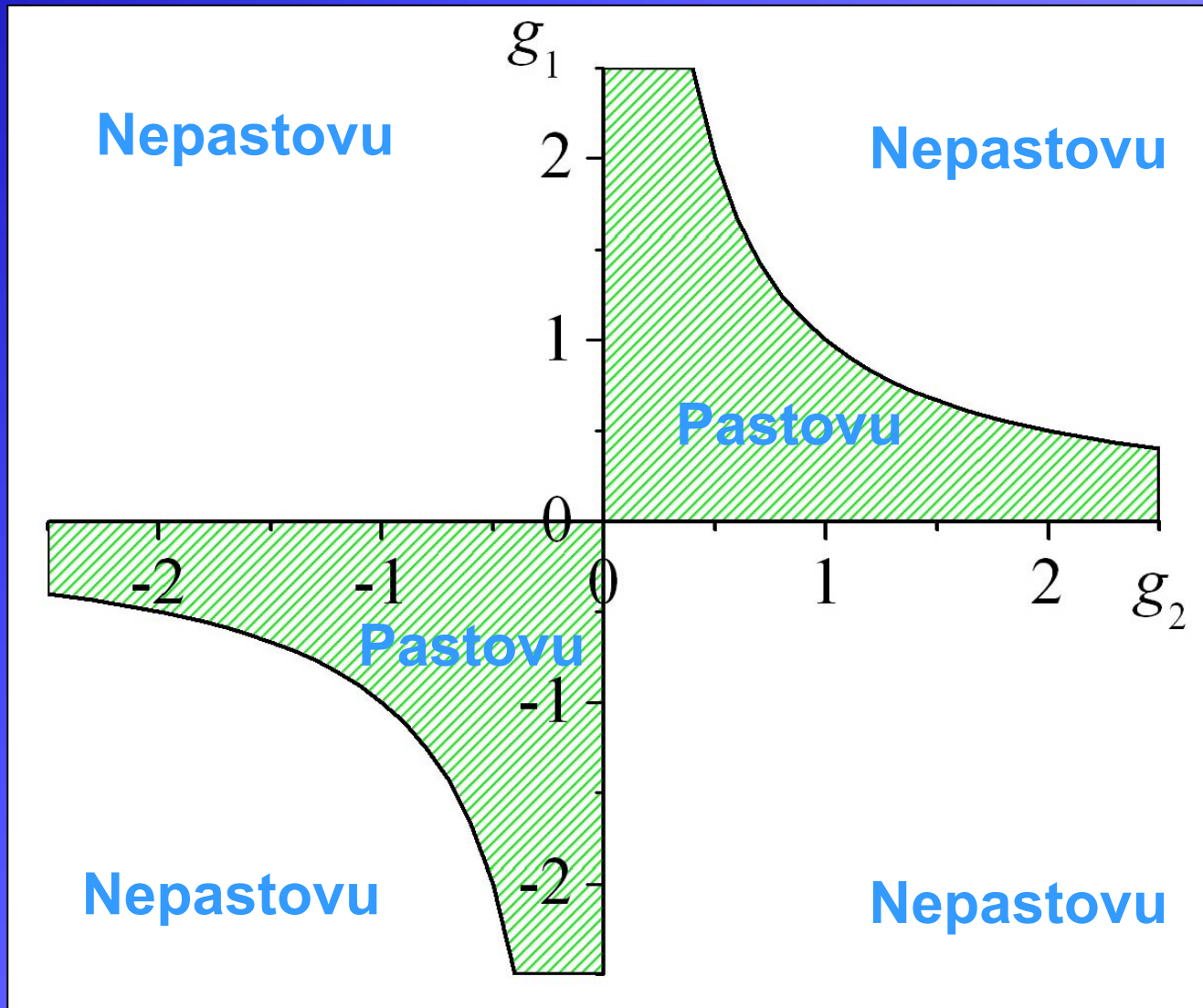
Nepastovus:



pastovus:



Pastovumo diagrama





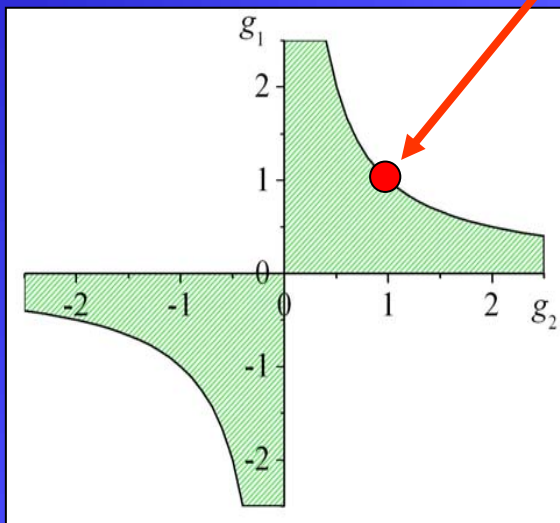
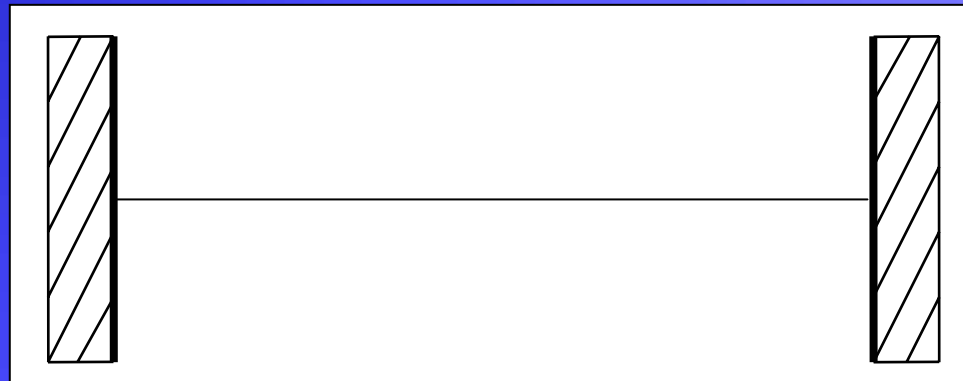
Rezonatorių tipai



Tiesiniai rezonatoriai (pastovieji)

Plokščias - plokščias

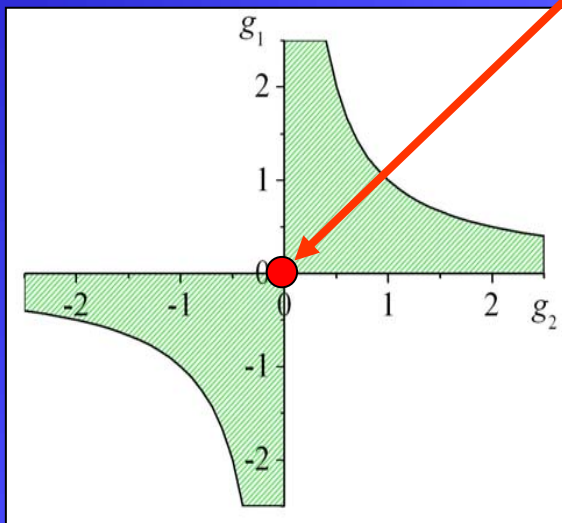
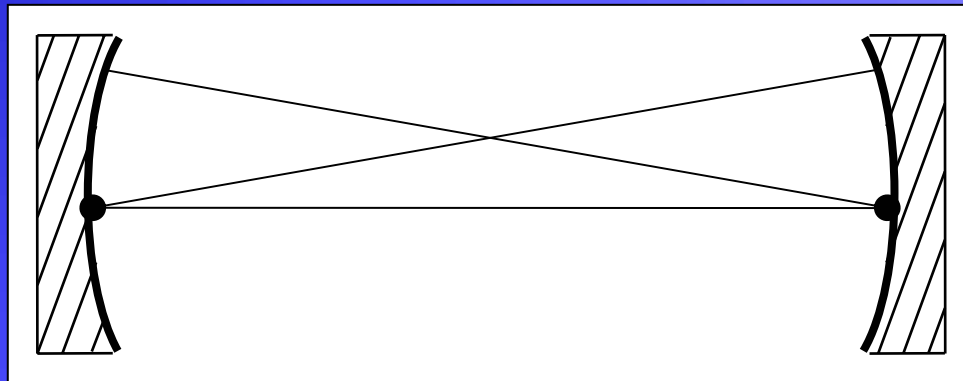
(Fabry-Perot etalonas)



- Justiravimas sunkus (pasukimo kampas vos kelios sekundės)

- Dideli difrakciniai nuostoliai

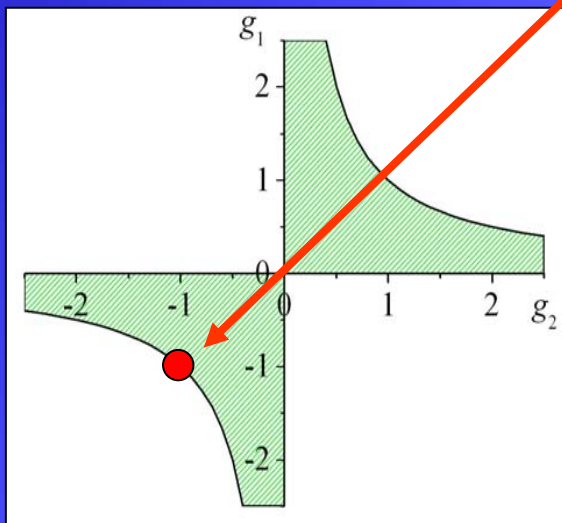
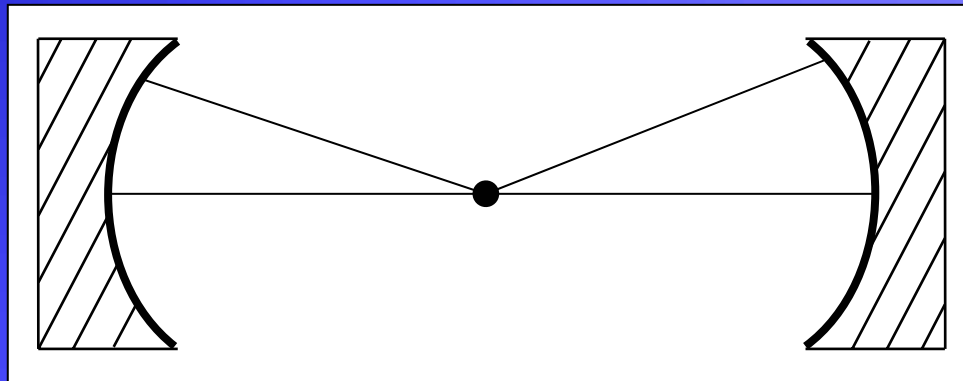
Simetrinis - konfokalusis



Abiejų veidrodžių židiniai yra viename taške

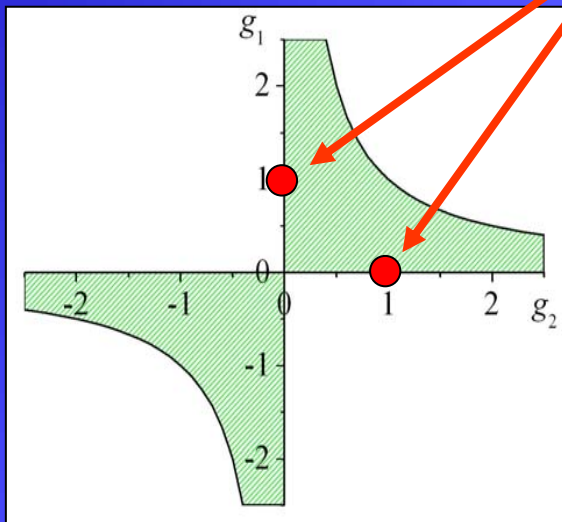
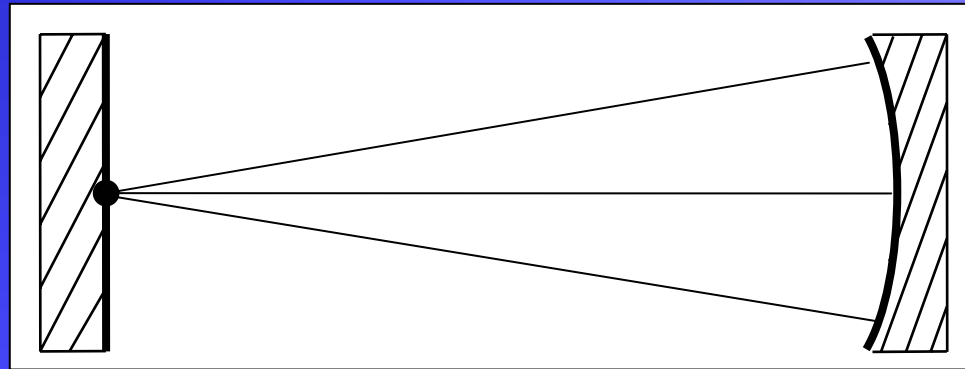
Pasižymi mažais difrakciniais nuostoliais

Simetrinis - koncentrinis



Labai jautrus net ir mažiems veidrodžių poslinkiams

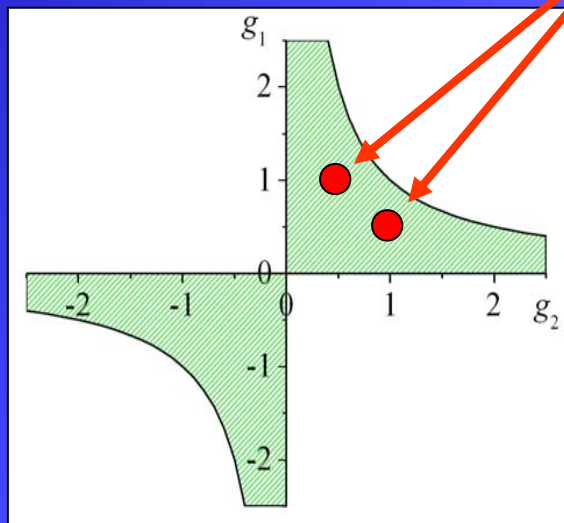
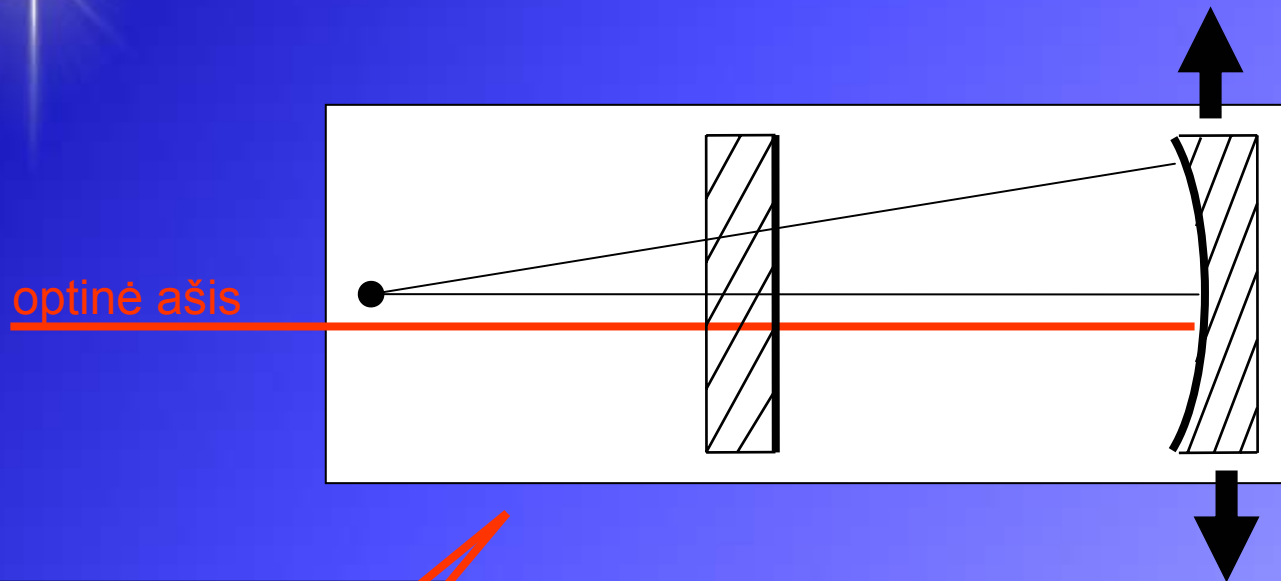
Pusiau sferinis



Mažas pluošto diametras ant plokščio vedrodžio

Didelis pluošto diametras ant plokščio vedrodžio

Pusiau konfokalusis



(Labai paplitęs)

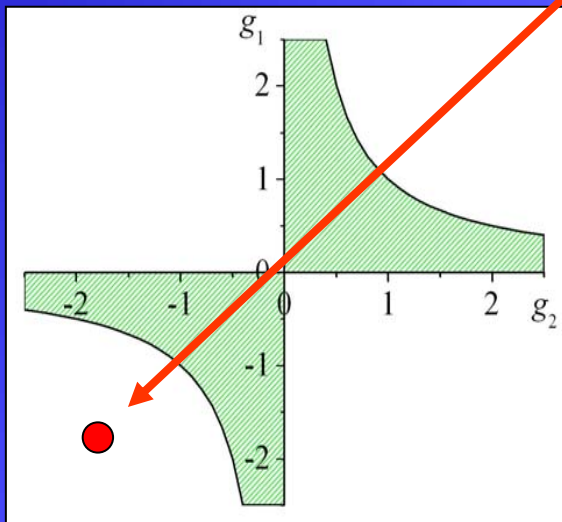
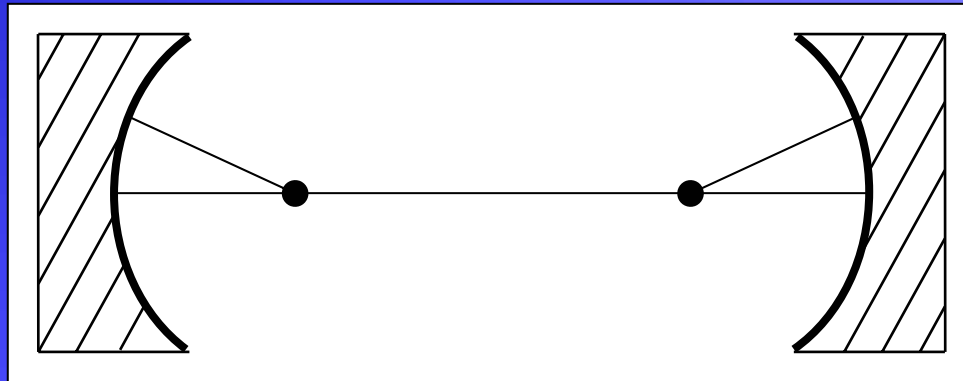
Nelabai jautrus mažiems veidrodžių postūmiams

Optinę ašį galime paslinkti slankiojant iškreivintąjį veidrodį

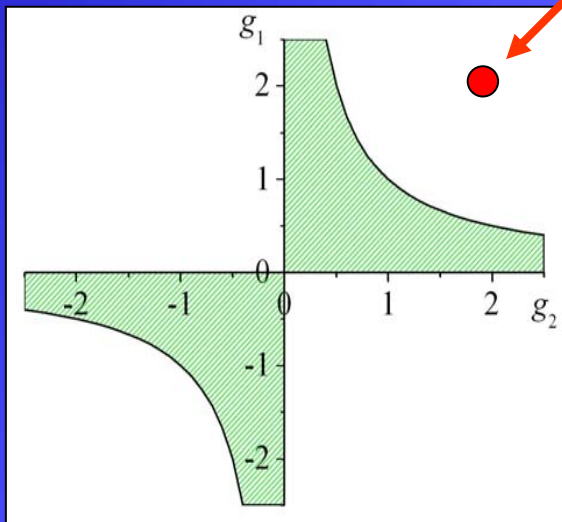
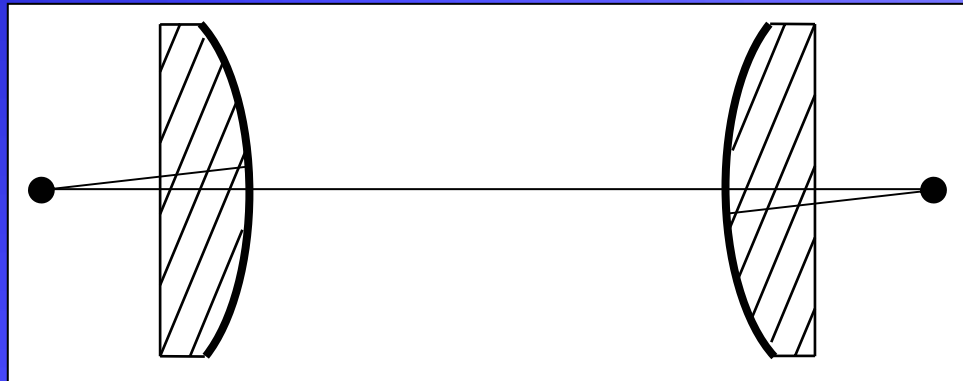


Tiesiniai Rezonatoriai (nepastovieji)

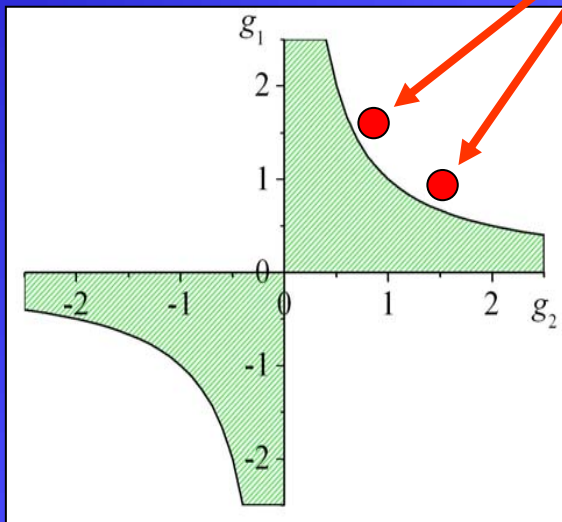
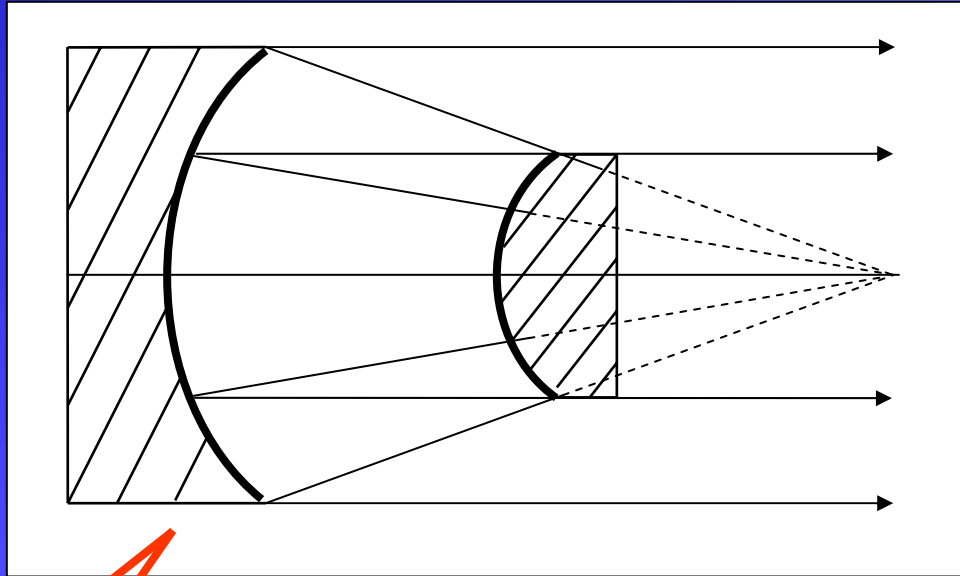
Nepastovusis - simetrinis



Simetrinis su virtualiaisiais židinio nuotoliais



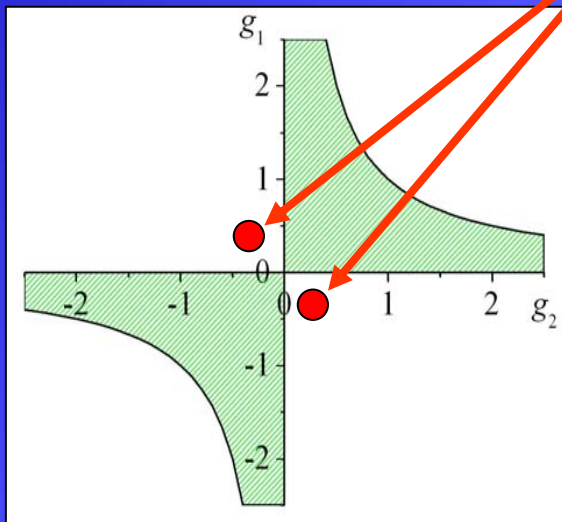
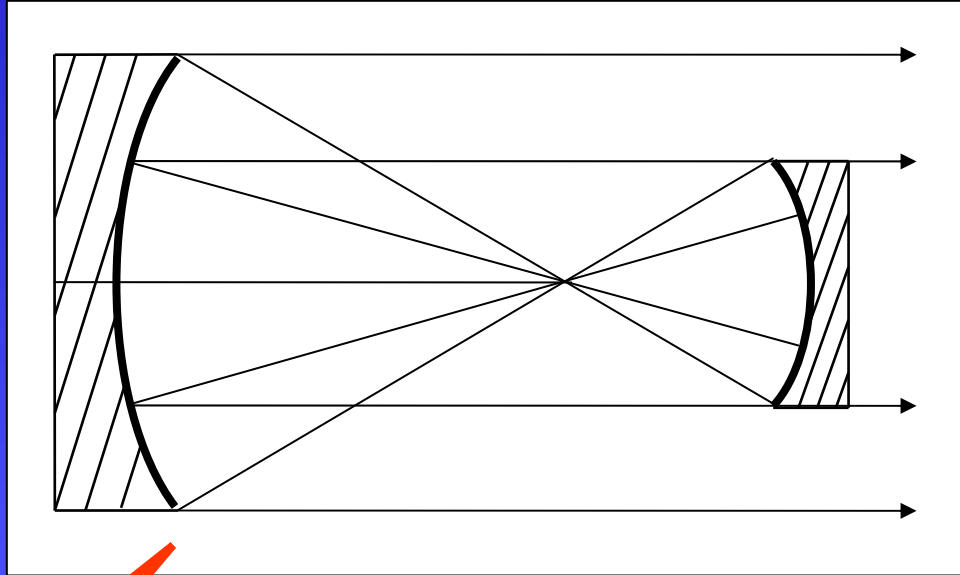
Konfokalusis - nestabilus



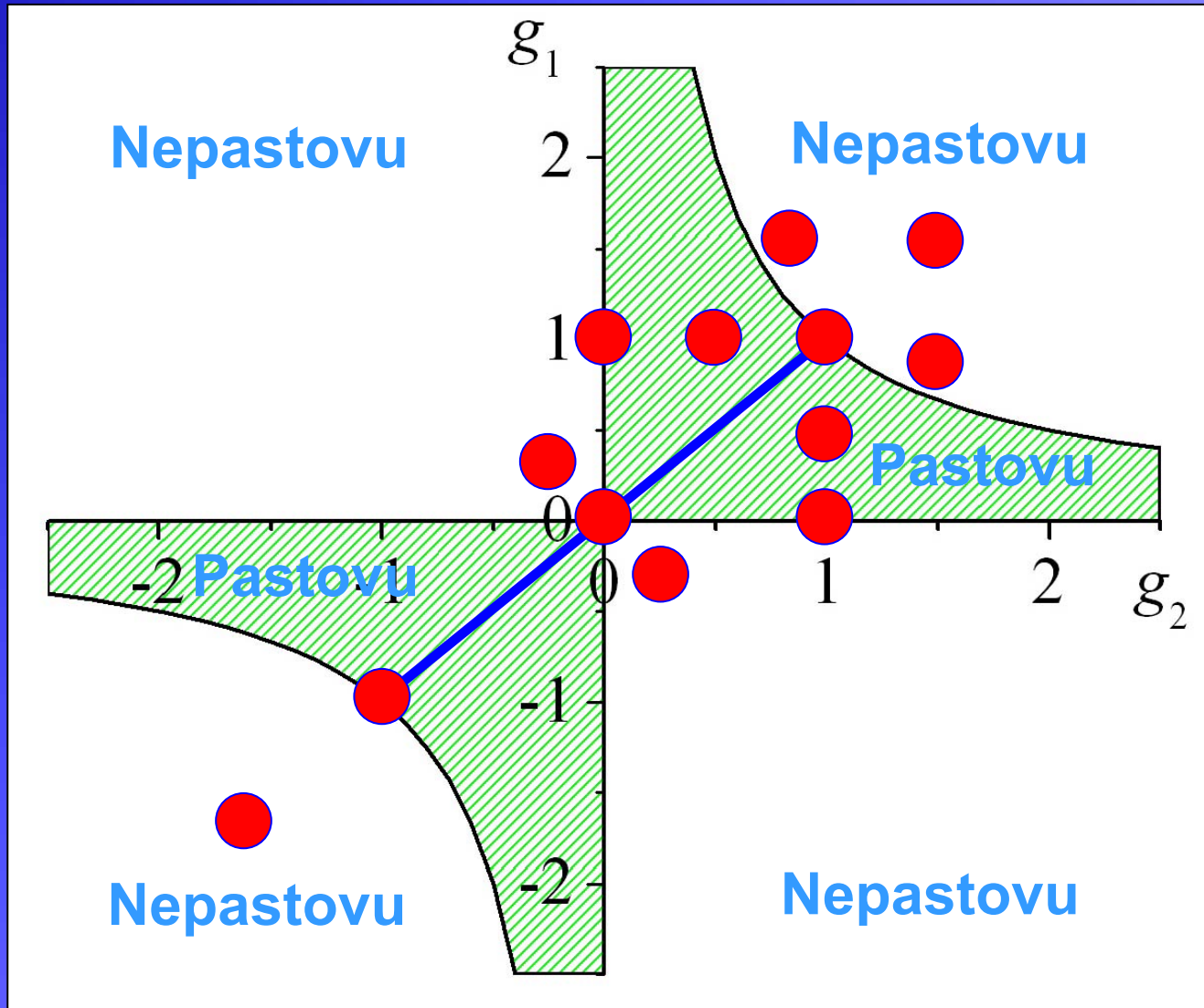
Pasižymi tiesiniu didinimu

Bandoma generuoti fraktalines modas

Konfokalusis - nestabilus 2



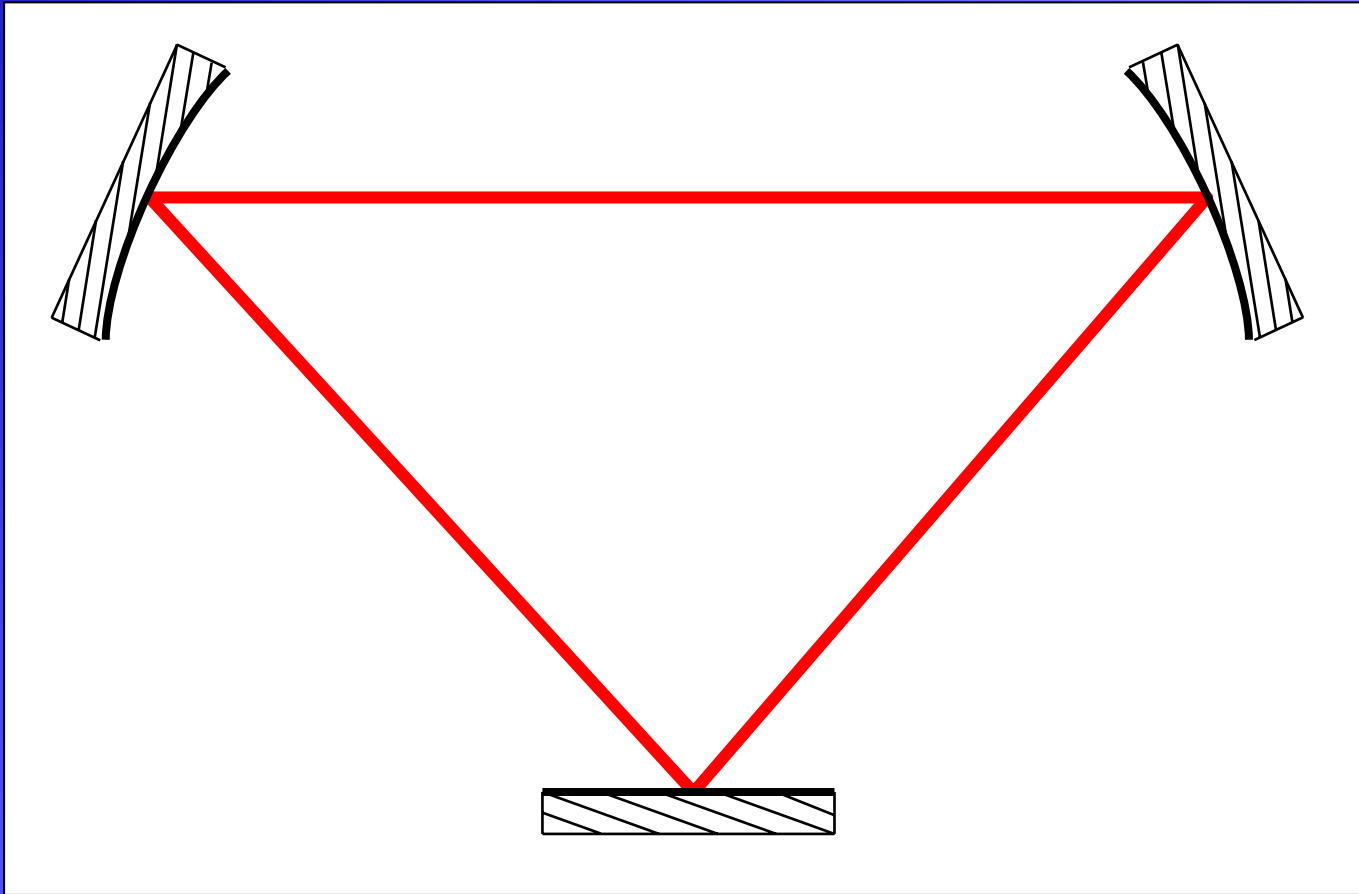
Pastovumo diagrama



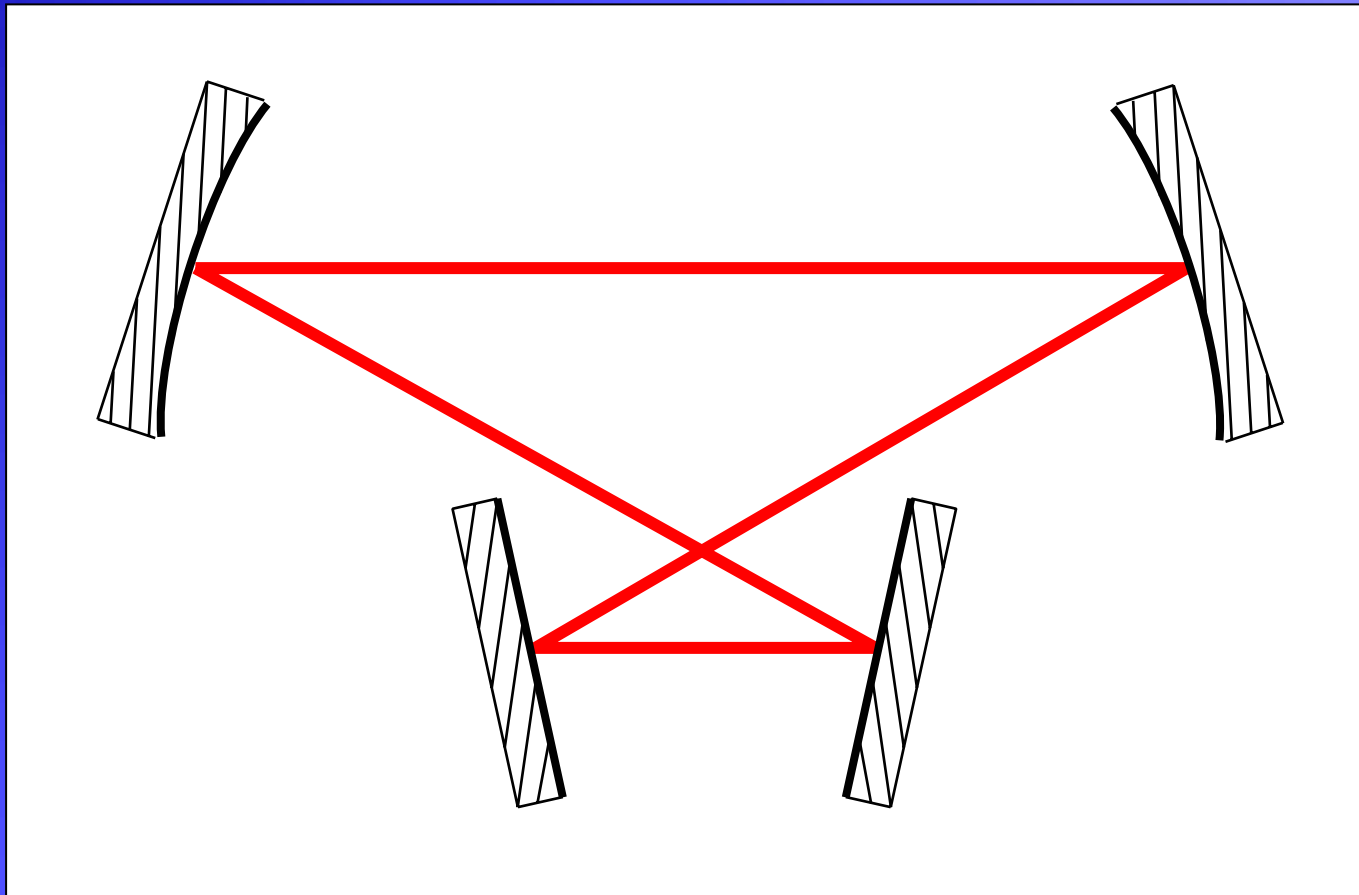


Žiediniai Rezonatoriai

Žiedinis Rezonatorius 1



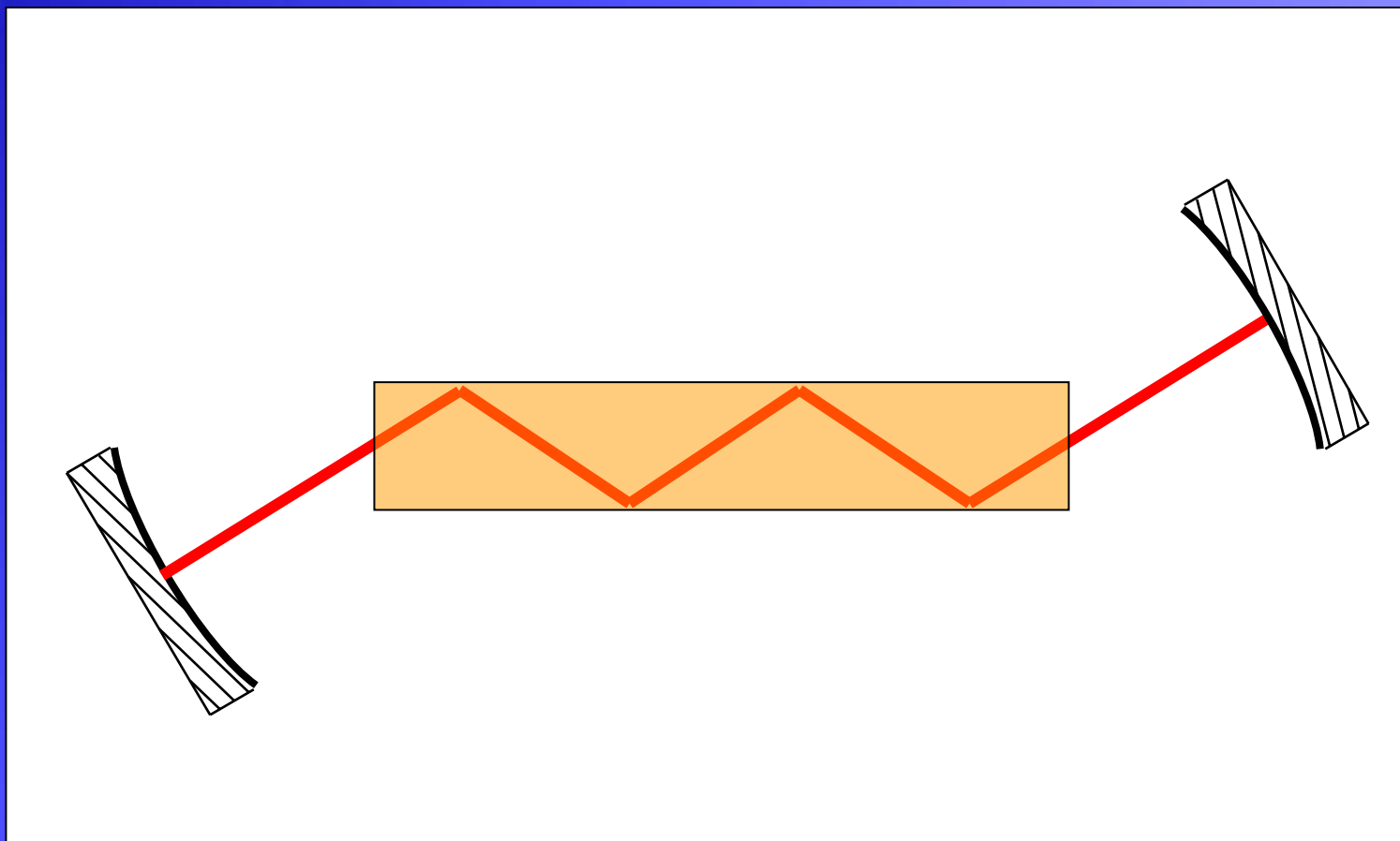
Žiedinis Rezonatorius 2



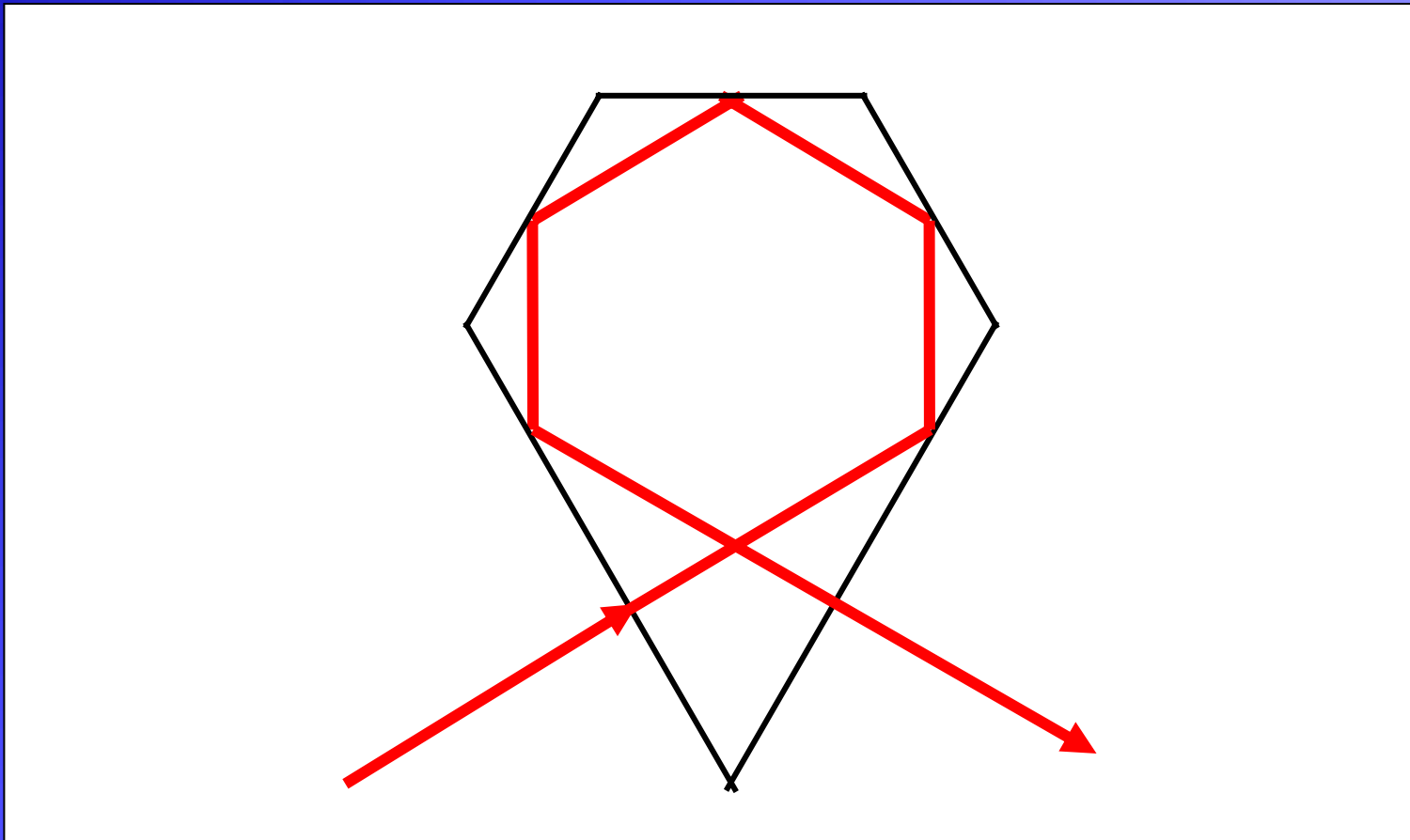


“Nestandartiniai” Rezonatoriai

“Zigzaginis” rezonatorius



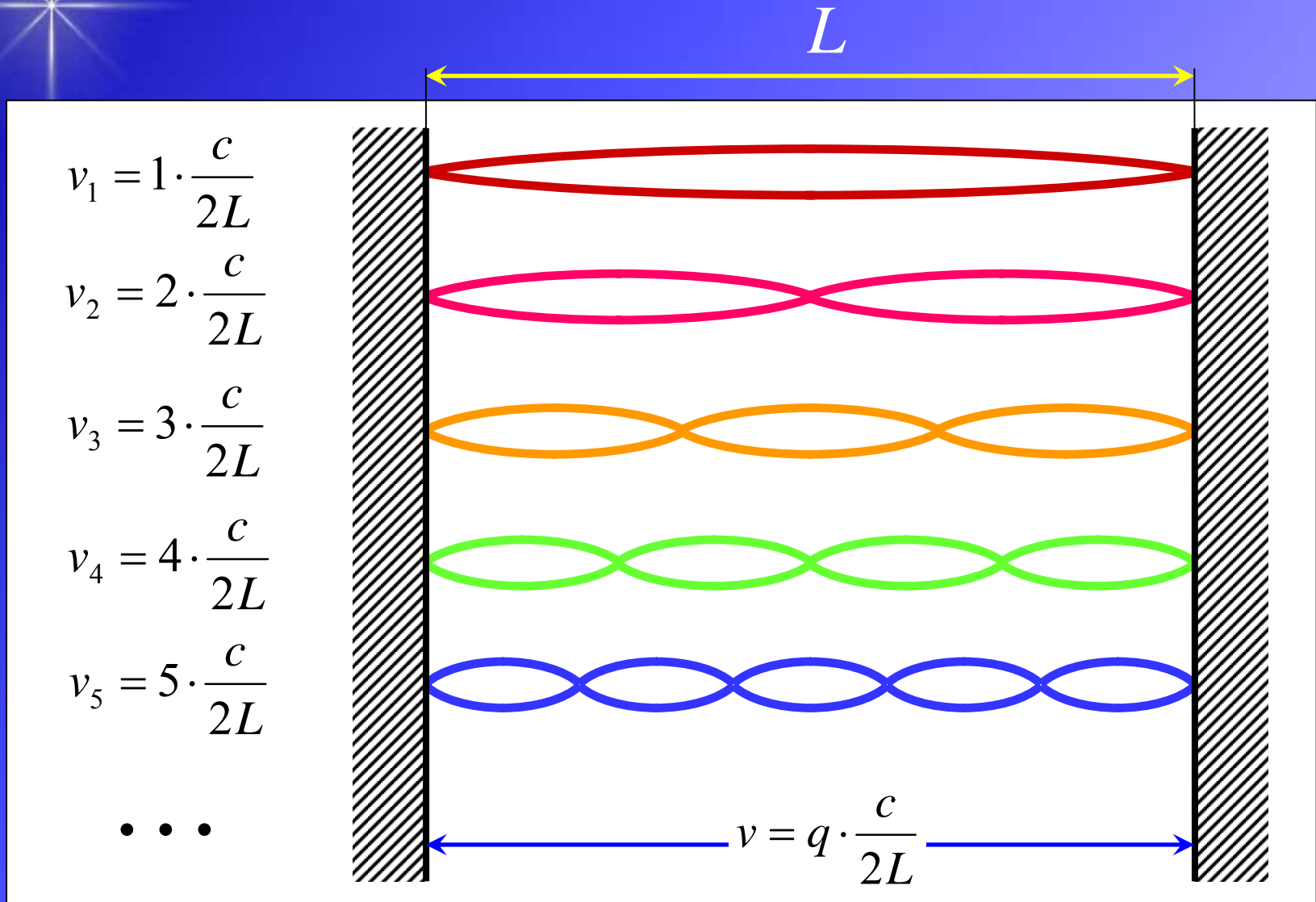
Rezonatorius aktyviojoje terpėje



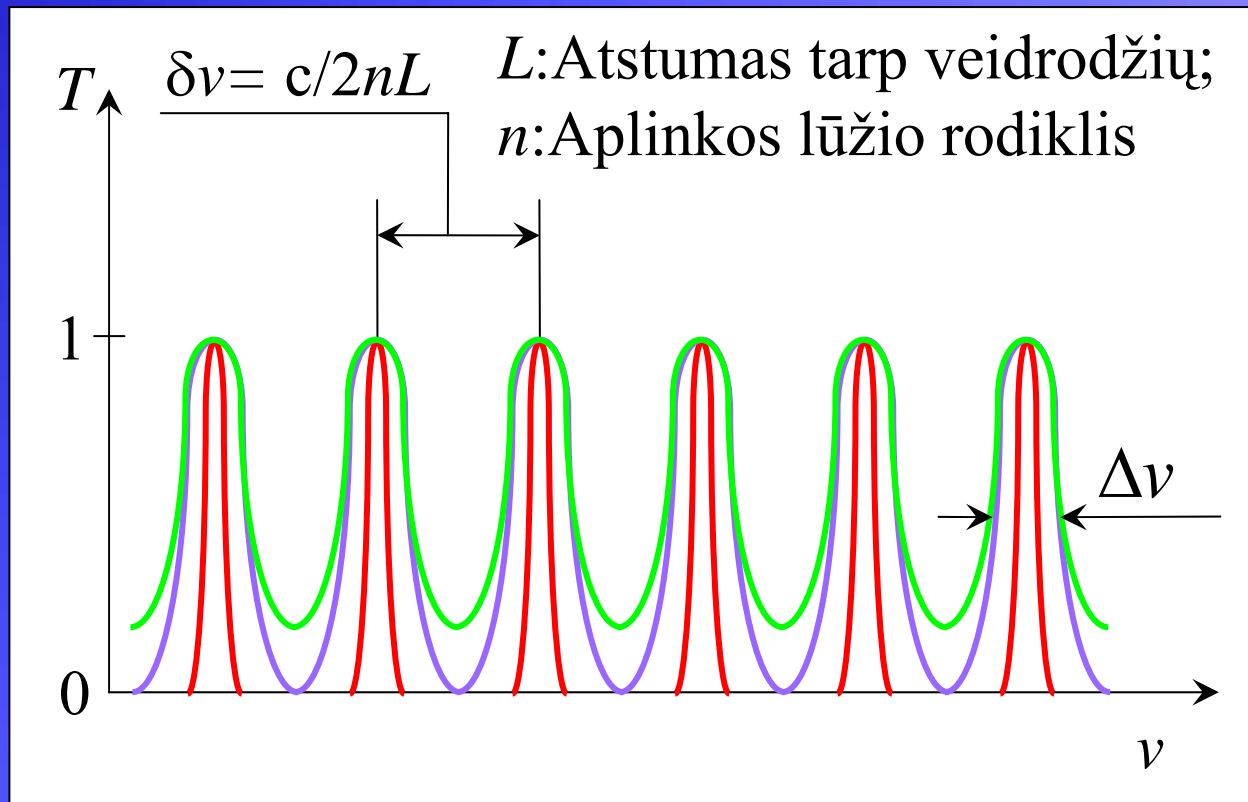


Atvirųjų rezonatorių tikriniai (nuosavieji) dažniai

Išilginės modos



Tarpas tarp išilginių modų ir spektrinis linijos plotis



Kokybė (Finesse)

$$F^* = \frac{\delta \nu}{\Delta \nu} = \frac{\text{tarpas tarp išilginių modų}}{\text{spektrinis linijos plotis}}$$

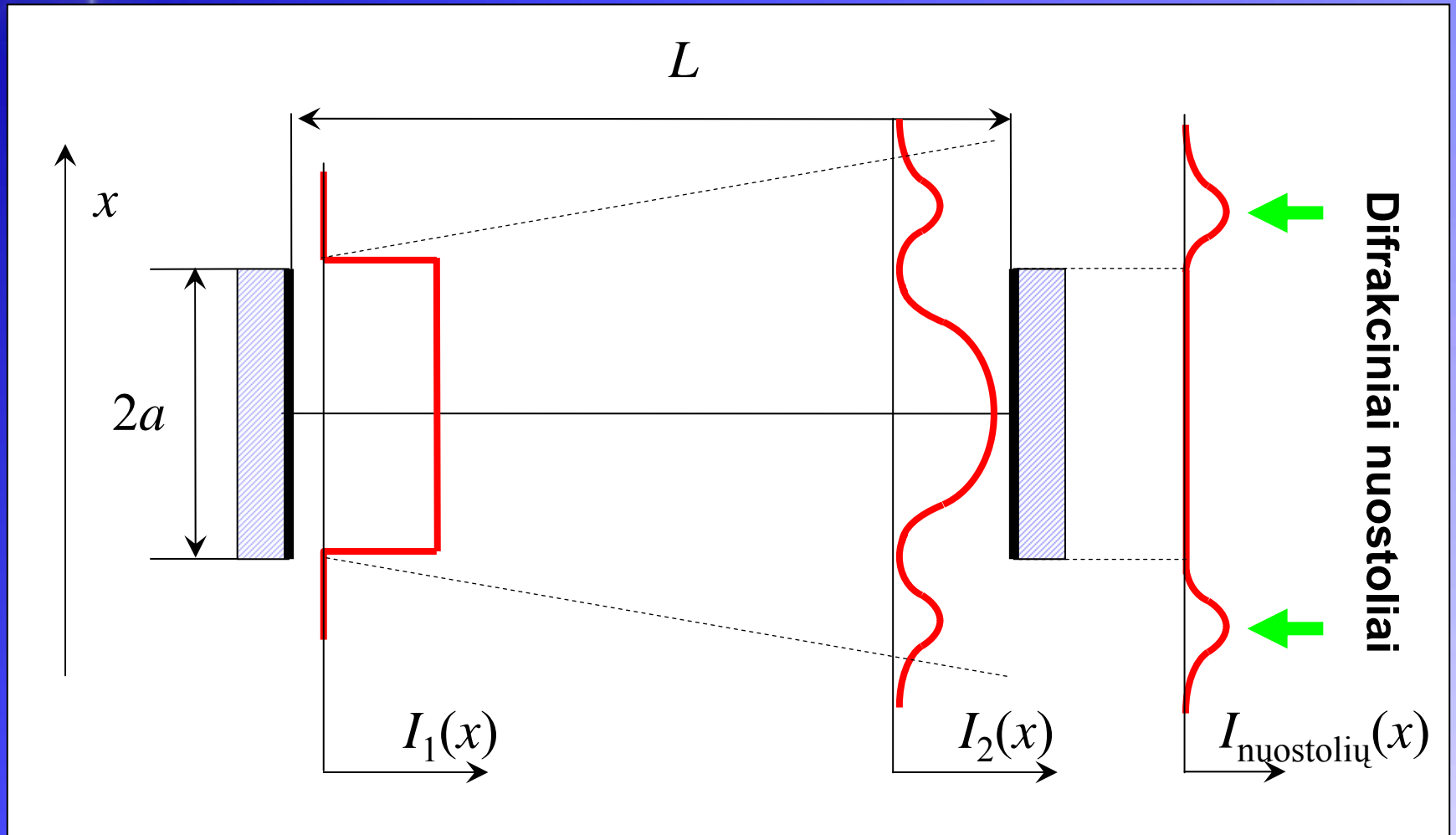
Atskiras atvejis:

Atspindžio kokybė:

$$F^* = \frac{\pi \sqrt{R}}{1 - R}$$

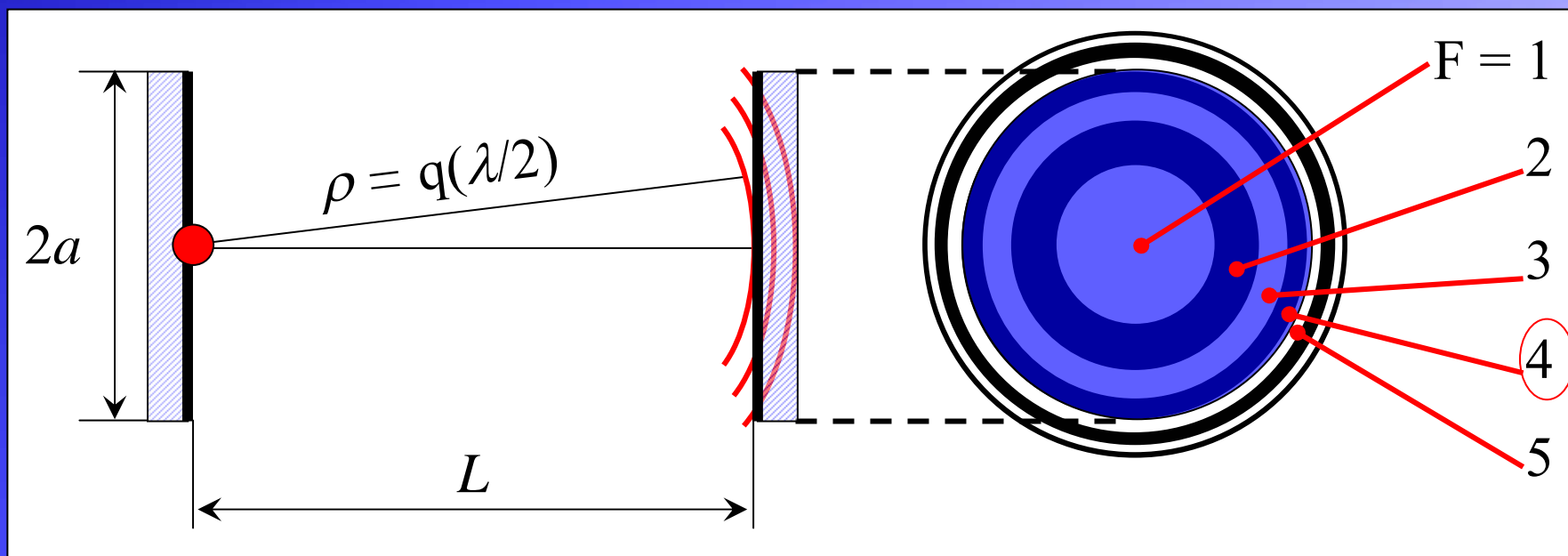
R : Bendras abiejų veidrodžių atspindžio koeficientas

Difrakciniai nuostoliai



Fresnel'io - skaičius:

$$F = \frac{a^2}{\lambda L}$$



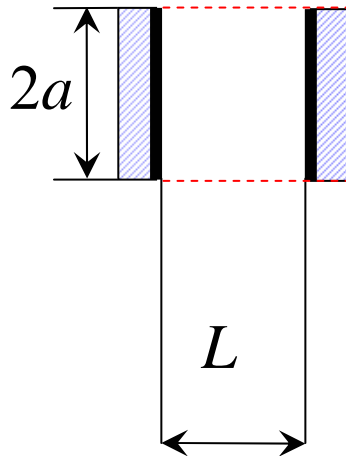


Difrakciniai nuostoliai:

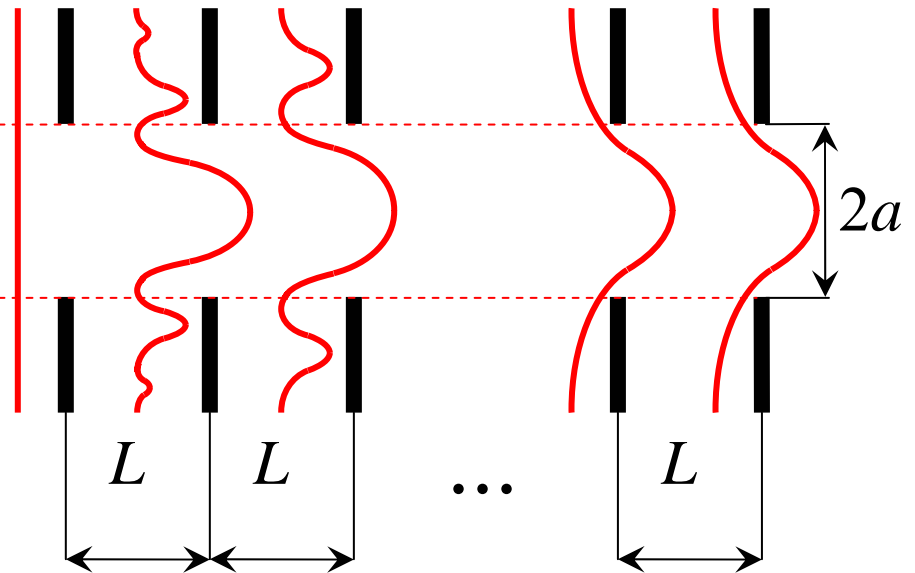
$$\gamma_B \approx \frac{1}{F} \cdot 100\%$$

Atitikmuo

Veidrodžių sistema



Ekvivalentiška diafragmų sistema



Iš Kirchhoff'o-Fresnel'io difrakcijos teorijos:

$$A_{m,n}(x, y, z) = C_{m,n} \cdot H_m(x^*) \cdot H_n(y^*) \cdot e^{-\frac{(x^{*2} + y^{*2})}{4}} e^{-i\varphi(x, y, z)}$$

$C_{m,n}$: Normavimo daugiklis

$H_m(x^*)$ ir $H_n(y^*)$: Ermito polinomai –
m ir n eilės atitinkamai

$x^* = \sqrt{2} \cdot x / w$; $y^* = \sqrt{2} \cdot y / w$: Normuotosios koordinatės

Iš Kirchhoff'o-Fresnel'io difrakcijos teorijos:

$$w^2(z) = \lambda \cdot \frac{L}{2\pi} \left[1 + \left(\frac{2z}{L} \right)^2 \right]$$

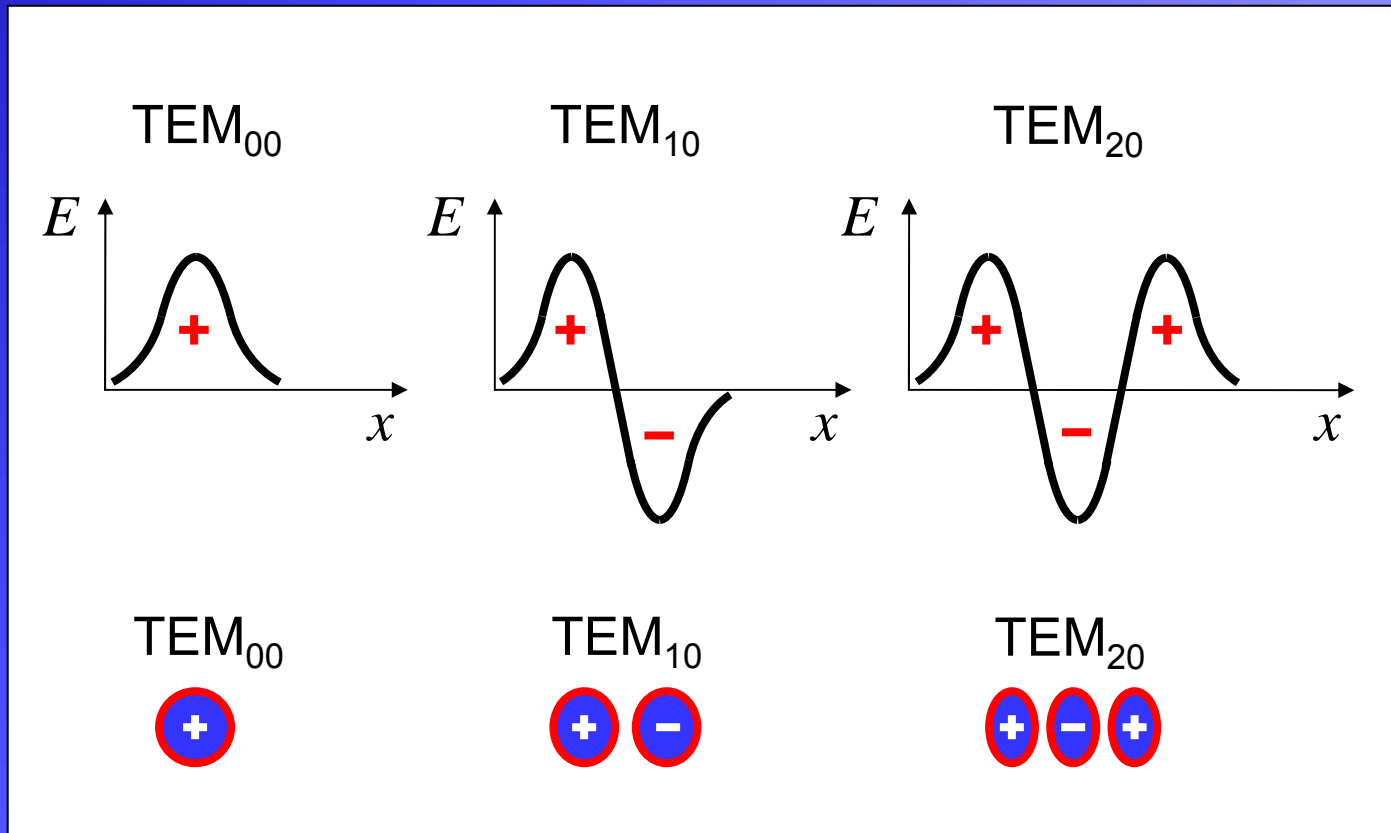
ir

$$\varphi(x, y, z) = \frac{2\pi}{\lambda} \left[\frac{L}{2} (1 + \xi^2) + \frac{(x^2 + y^2)\xi}{L(1 + \xi^2)} \right] - (1 + m + n) \left(\frac{\pi}{2} + \arctan \frac{1 - \xi}{1 + \xi} \right)$$

kur

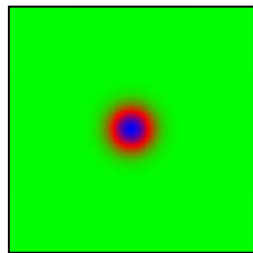
$$\xi = \frac{2z}{L}$$

Skersinės modos

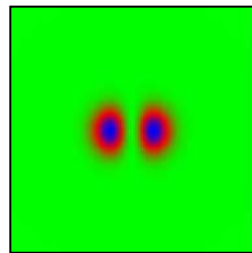


Skersinės modos

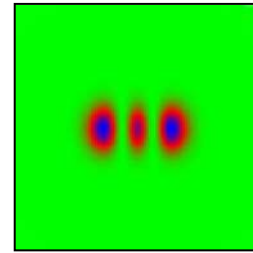
Hermite'o - Gauß'o modos



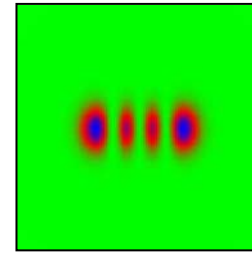
TEM₀₀



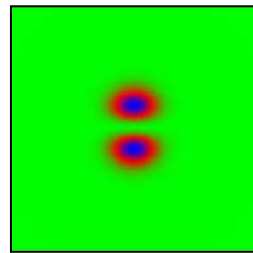
TEM₁₀



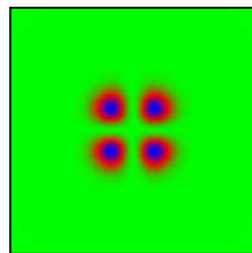
TEM₂₀



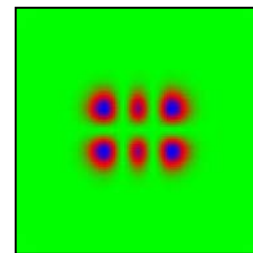
TEM₃₀



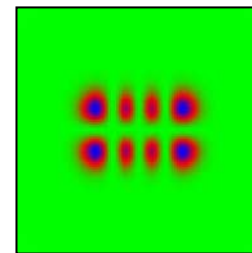
TEM₀₁



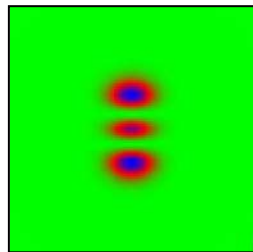
TEM₁₁



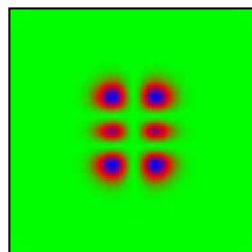
TEM₂₁



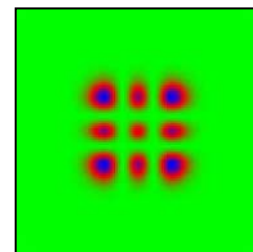
TEM₃₁



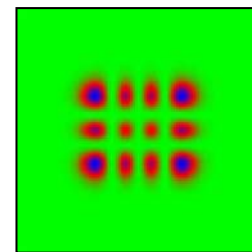
TEM₀₂



TEM₁₂



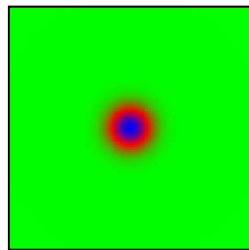
TEM₂₂



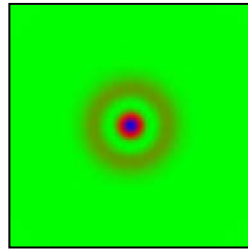
TEM₃₂

Skersinės modos

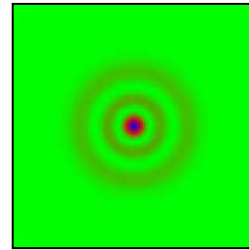
Laguerre'o - Gauß'o modos



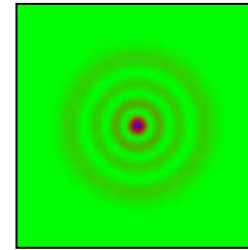
TEM₀₀



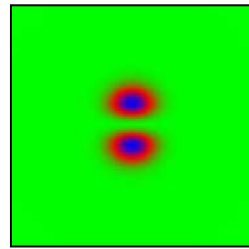
TEM₁₀



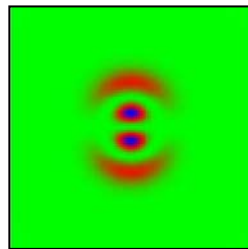
TEM₂₀



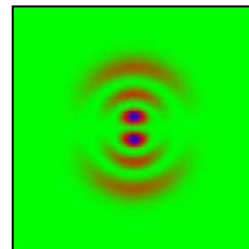
TEM₃₀



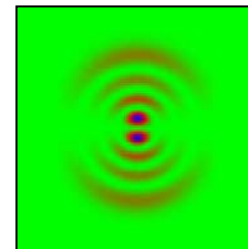
TEM₀₁



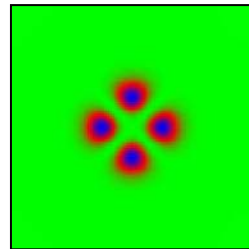
TEM₁₁



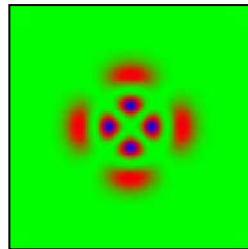
TEM₂₁



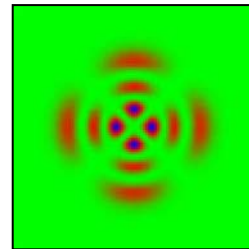
TEM₃₁



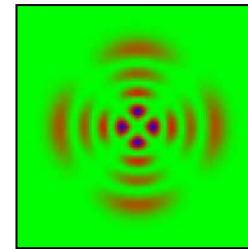
TEM₀₂



TEM₁₂



TEM₂₂



TEM₃₂

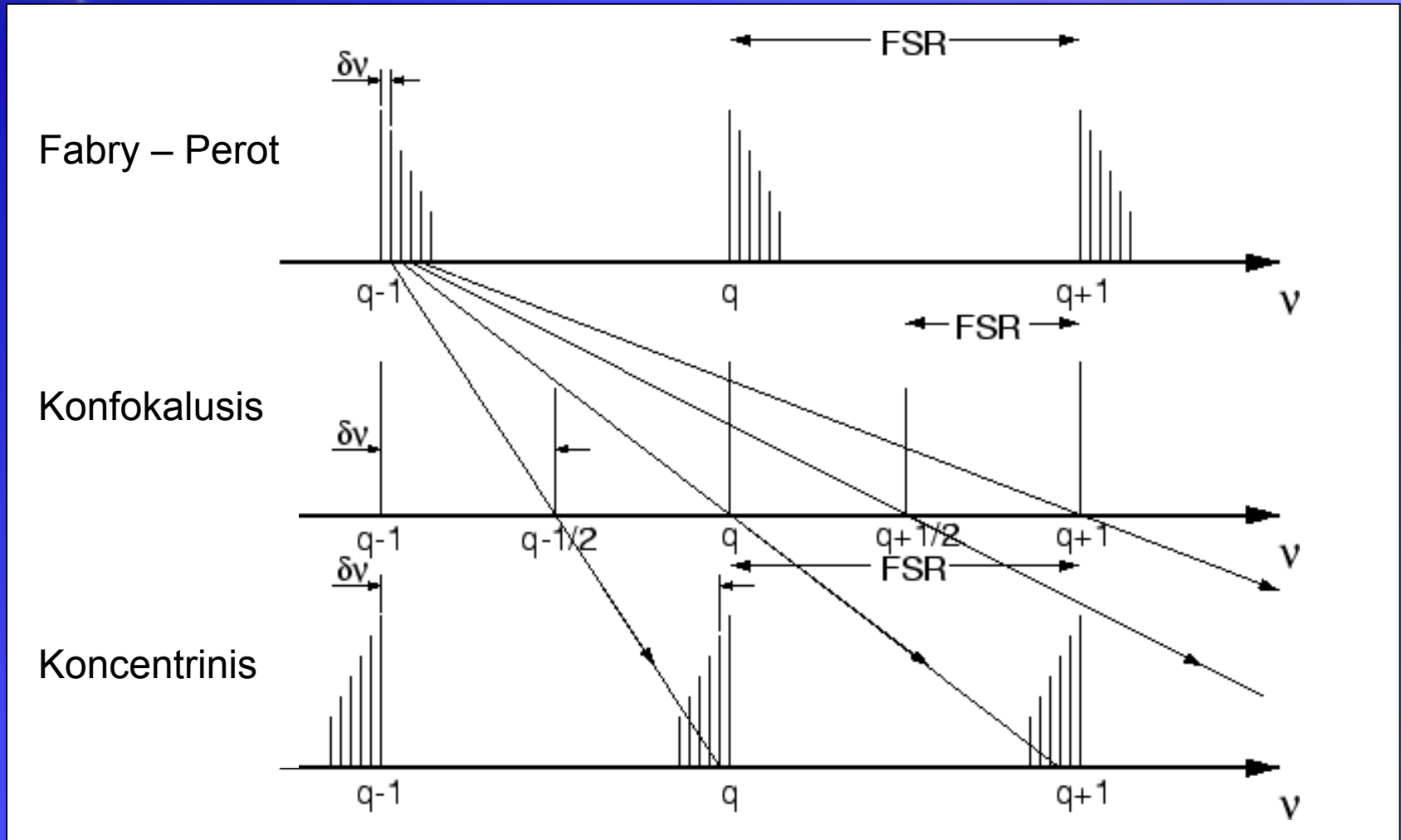
Tikriniai rezonatoriaus dažniai (modos)

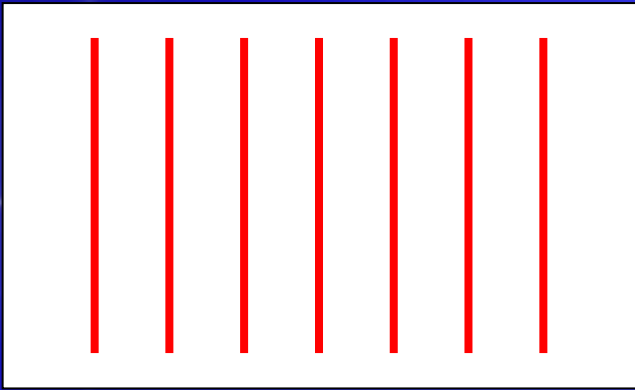
$$v = \left(\frac{c}{2L} \right) \cdot (q + (m + n + 1) \cdot f)$$

$$f = \frac{\arccos(\sqrt{g_1 \cdot g_2})}{\pi}$$

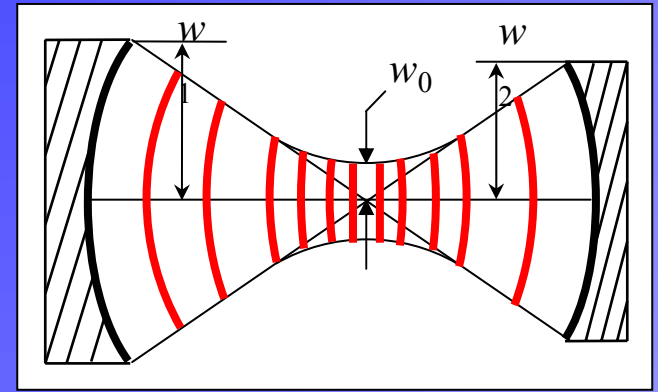
$$g_1 = 1 - \frac{L}{R_1} \quad g_2 = 1 - \frac{L}{R_2}$$

Tikriniai dažniai





$$E(z, t) = A(z)e^{-i\omega t}$$



$$E(x, y, z, t) = A(x, y, z)e^{-i\omega t}$$

$$\Delta E = \frac{1}{c^2} \frac{\partial^2 E}{\partial t^2}$$

~~$$\frac{\partial^2 A(z)}{\partial x^2} + \frac{\partial^2 A(z)}{\partial y^2} + \frac{\partial^2 A(z)}{\partial z^2} = \text{const} \cdot A(z)$$~~

$$= 0$$

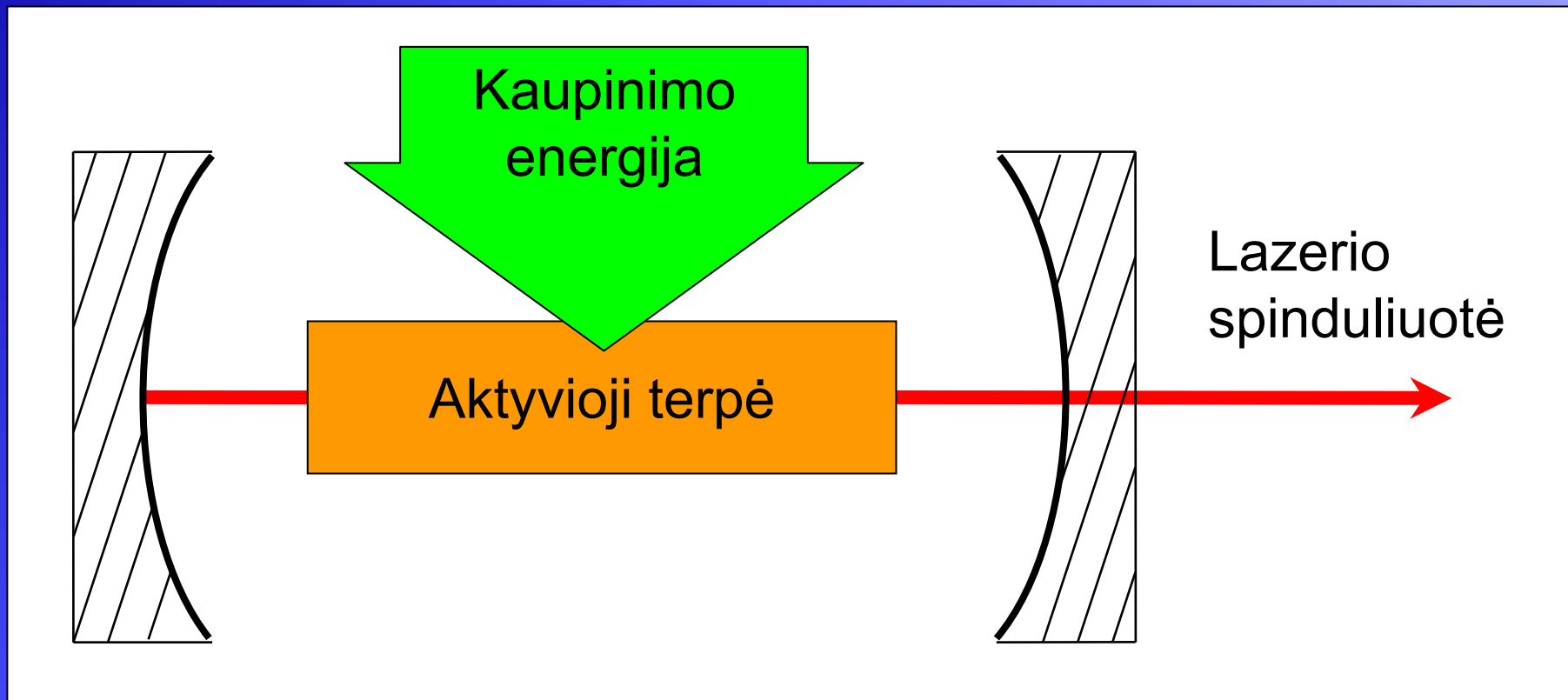
$$\frac{\partial^2 A(x, y, z)}{\partial x^2} + \frac{\partial^2 A(x, y, z)}{\partial y^2} + \frac{\partial^2 A(x, y, z)}{\partial z^2} = \text{const} \cdot A(x, y, z)$$

Guoy fazé



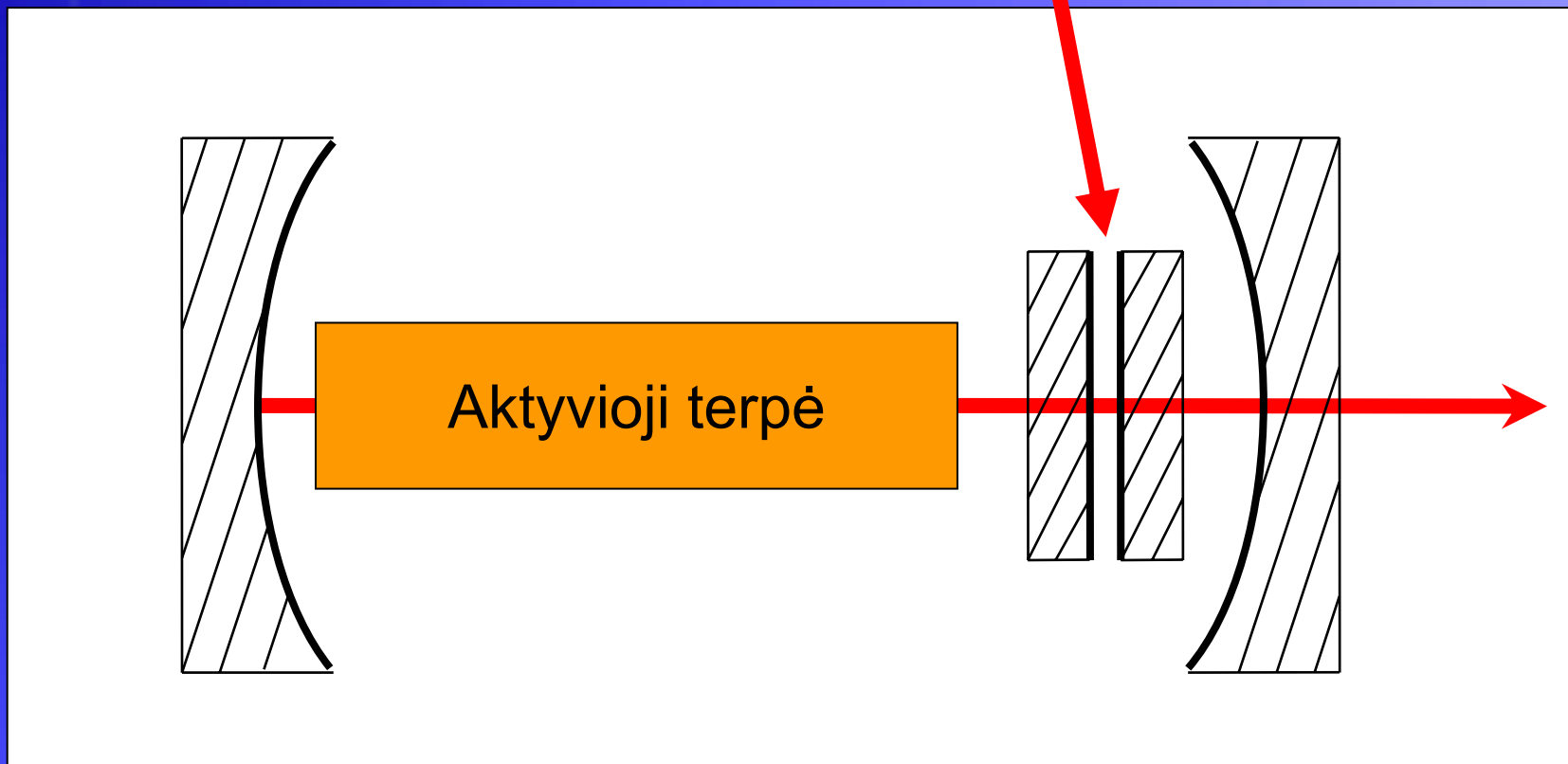
Kai kurie rezonatorių taikymai

Lazeriuose...

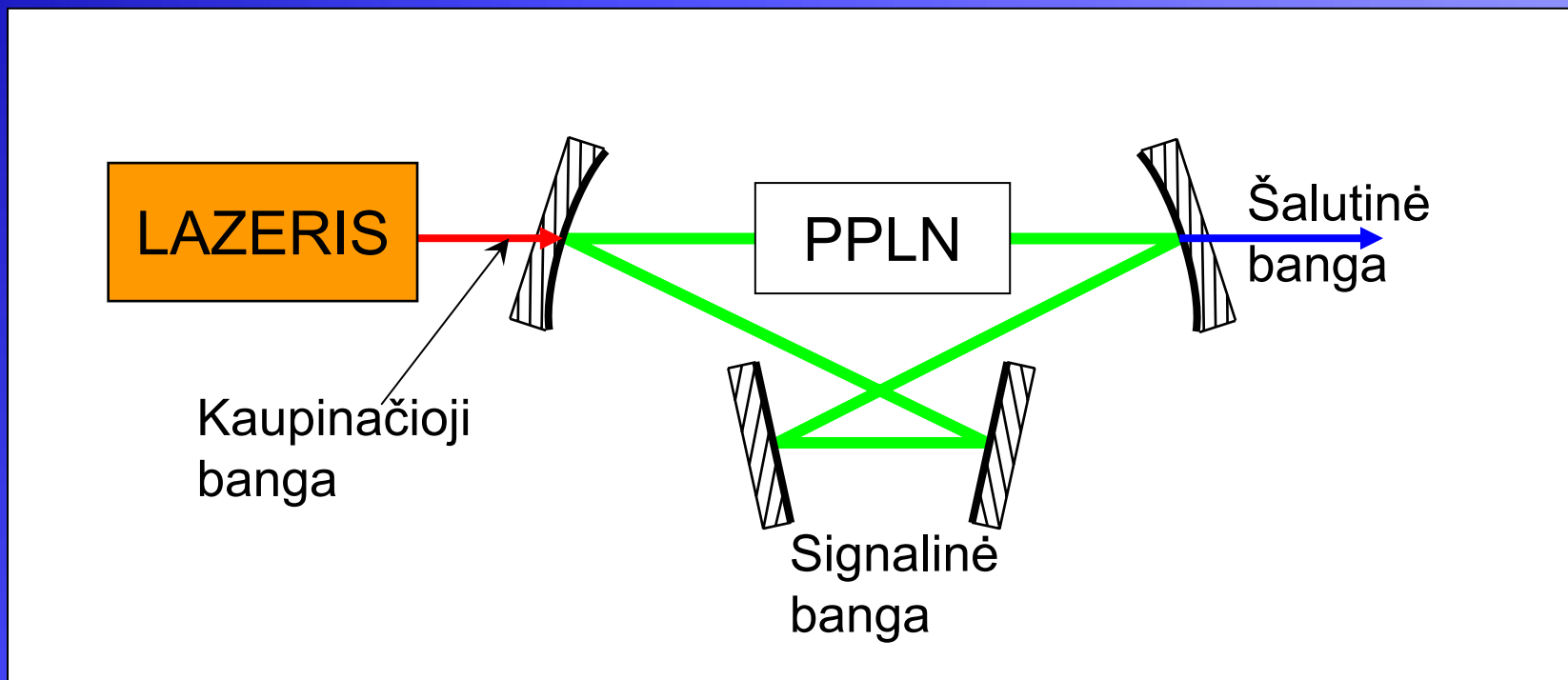


Principinė lazerio veikimo schema

Rezonatorius, kaip spektrinis filtras

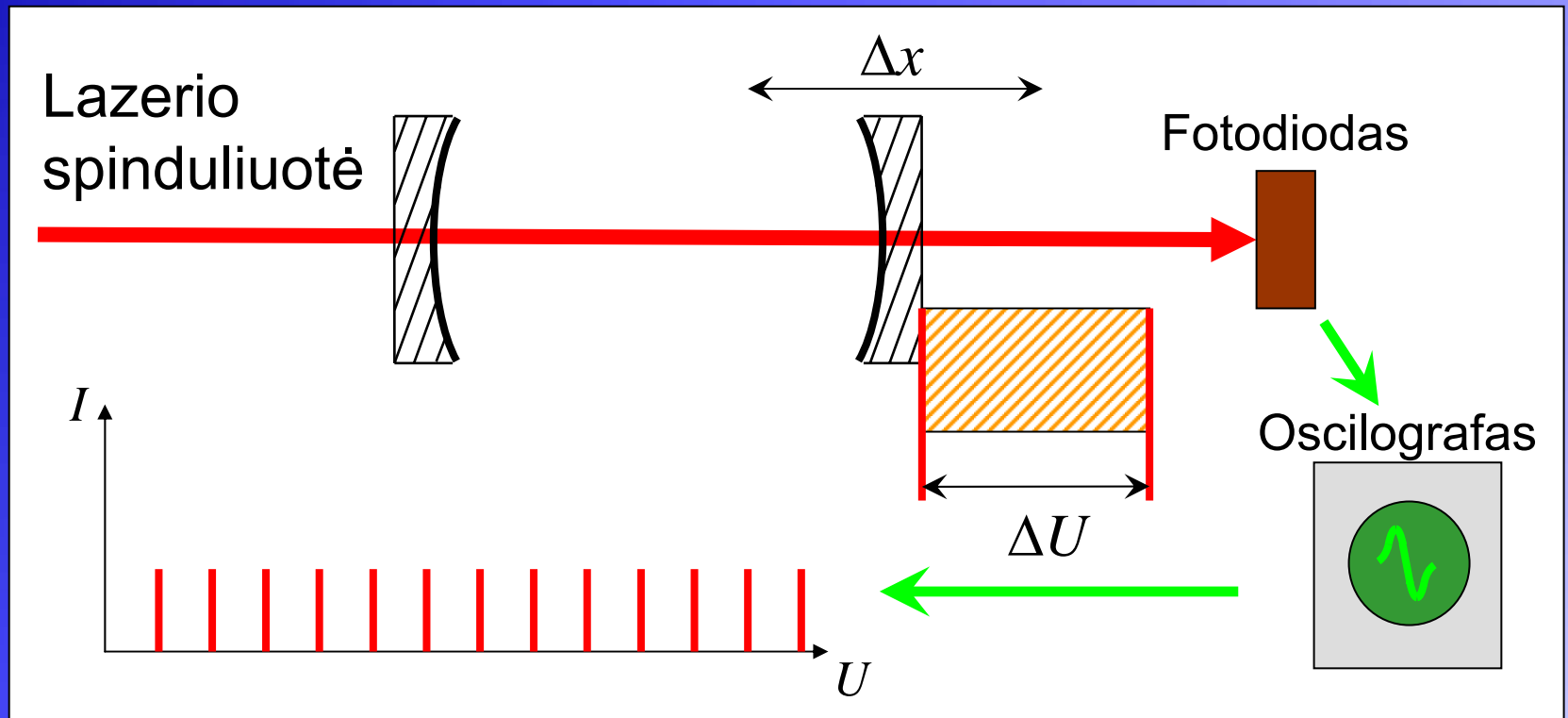


Optiniai parametriniai genetatoriai




Principinė OPG veikimo schema

Lazerio stabilizavimas



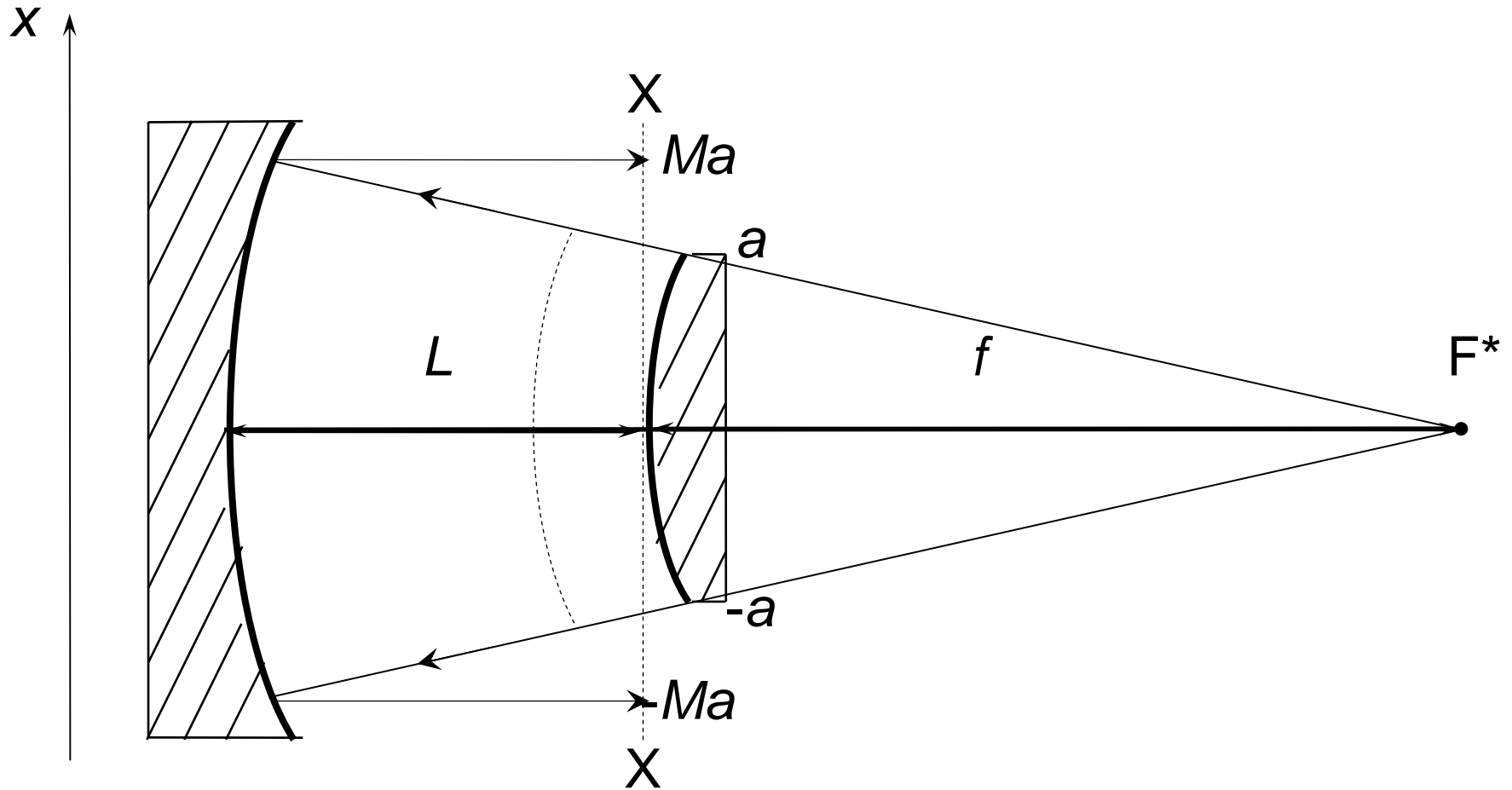


BONUS 😊



**Fraktalinės modos
nestabiliuosiuose
lazerių rezonatoriuose**

Nestabilusis konfokalinis rezonatorius

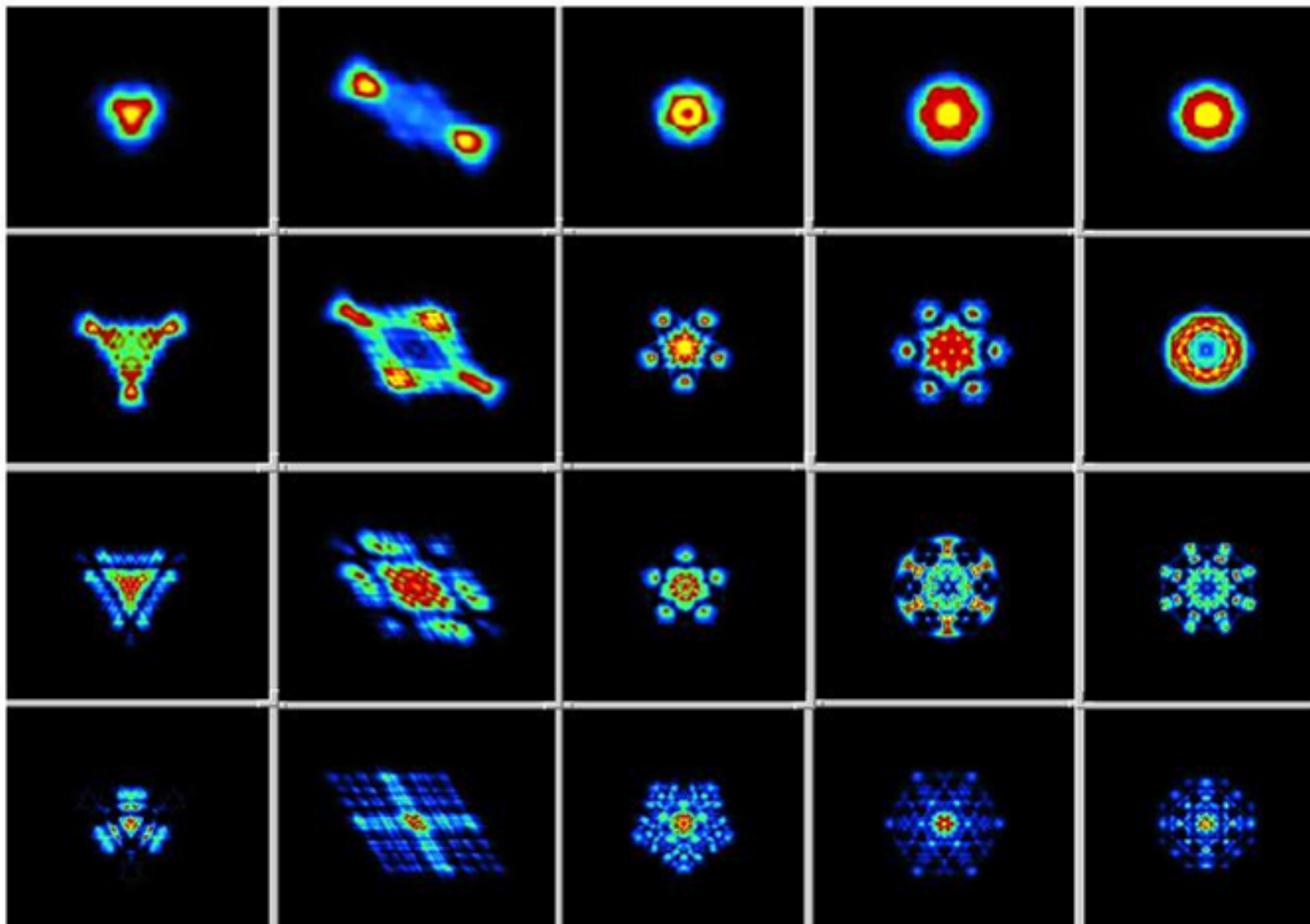




Rezonatoriaus tiesinis didinimas:

$$M = \frac{L + f}{f} = \frac{f_1}{f_2}$$

Fraktalinės modos





Ačiū už dėmesį!