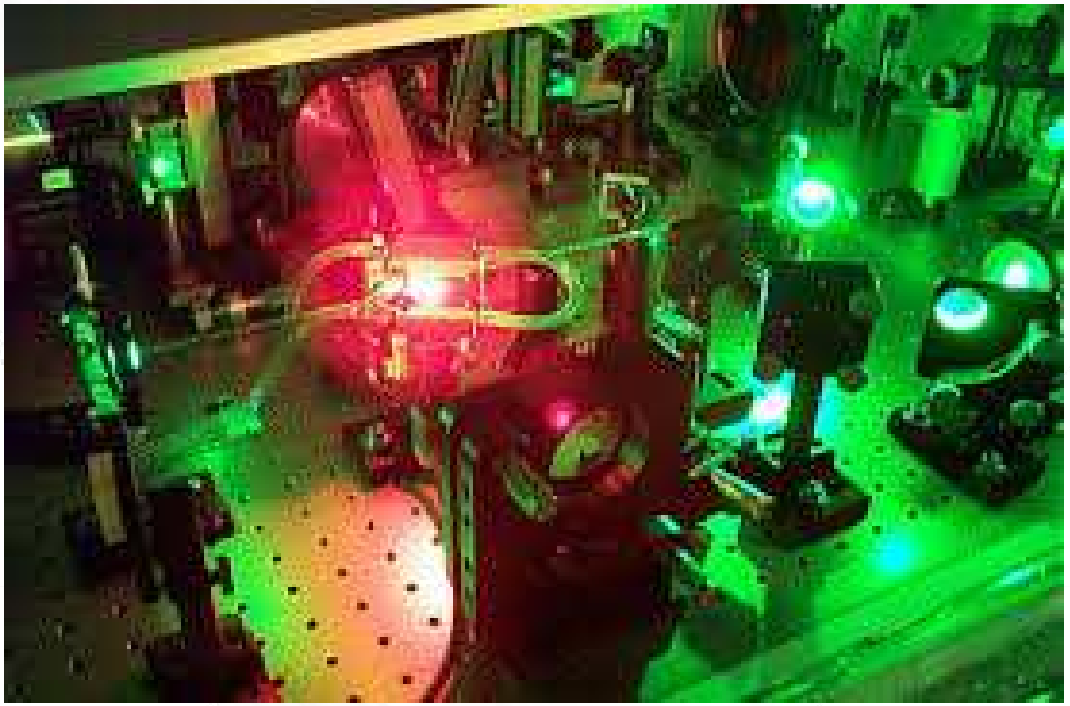
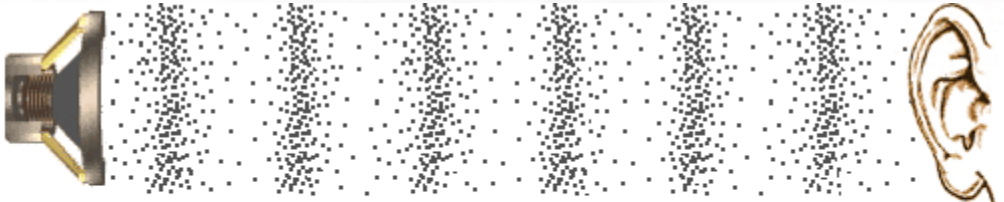
За китарата, цигулката и … фемтосекундните лазери



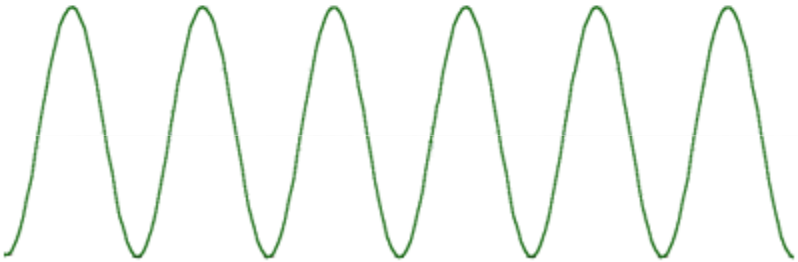
Асен Пашов,
Физически факултет

Какво е това звук?

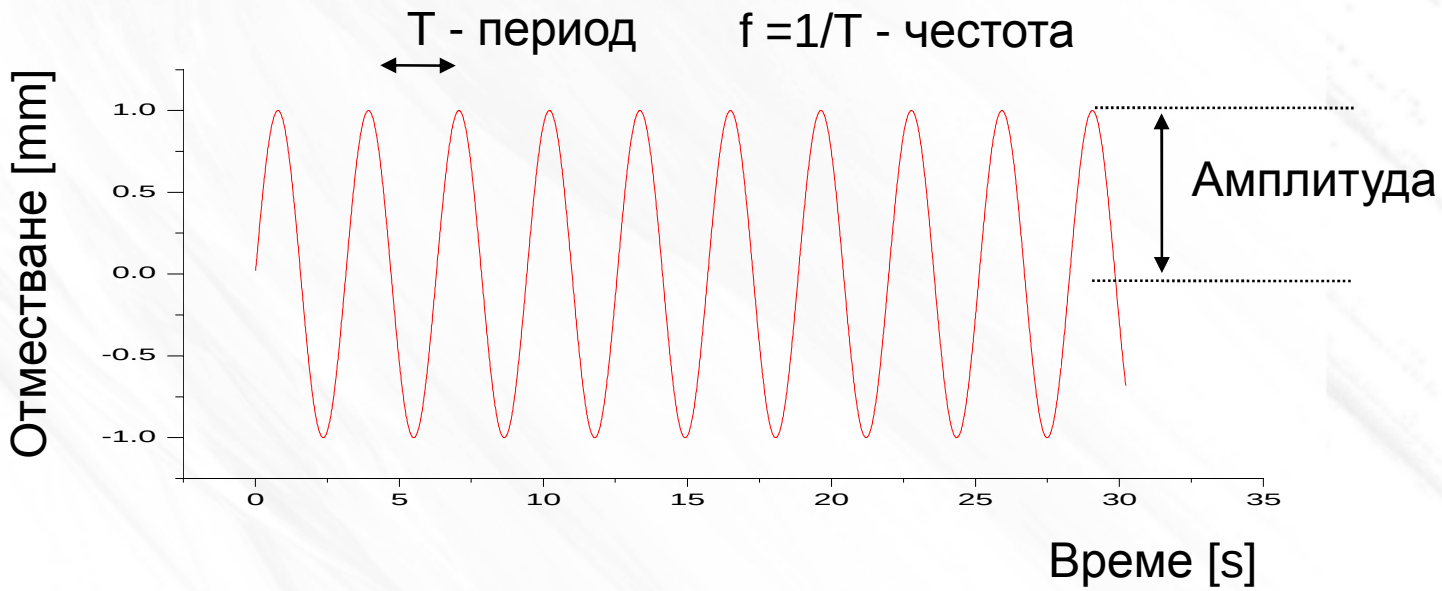


Приемник

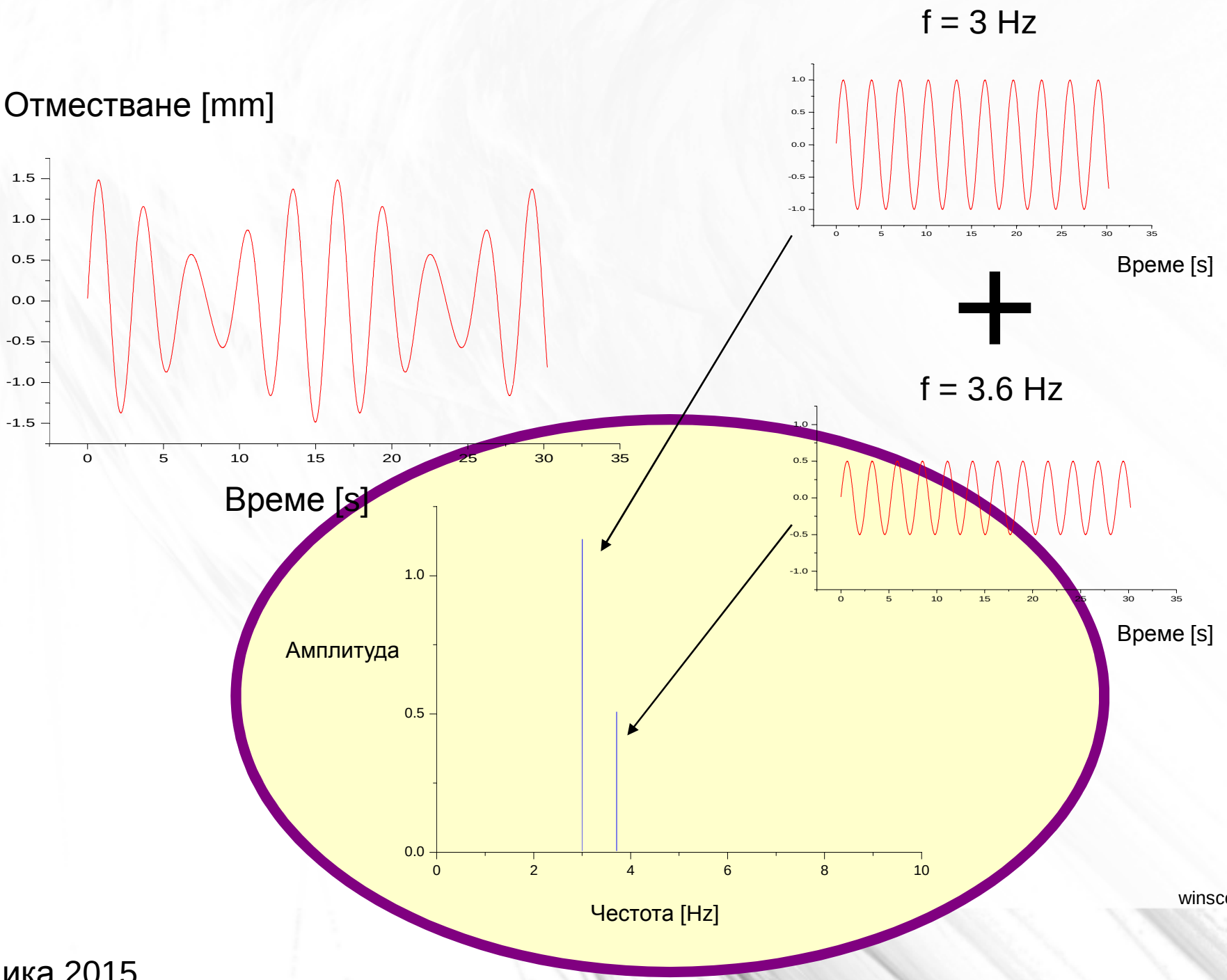
Високоговорител



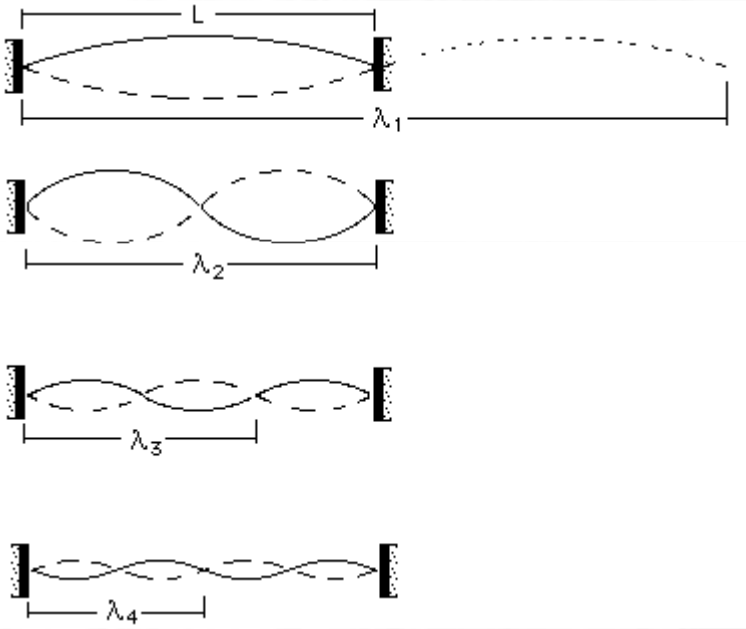
Налягане на въздуха



Какво е това спектър?



Как може да трепти една струна?



Честота f

Честота 2f

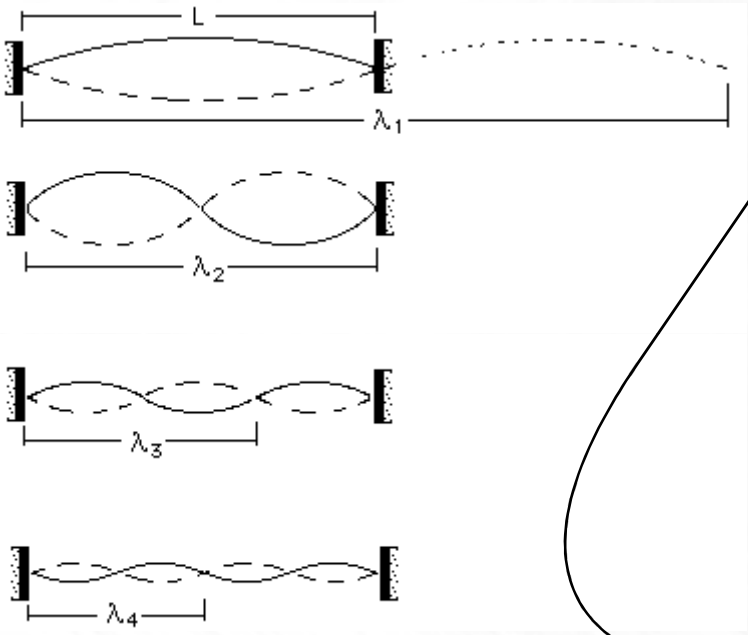
Честота 3f

Честота 4f

Мод – определен начин на трептене

Хармоници – кратни на основната честота f

Тонове и обертонове



Честота f — основен тон

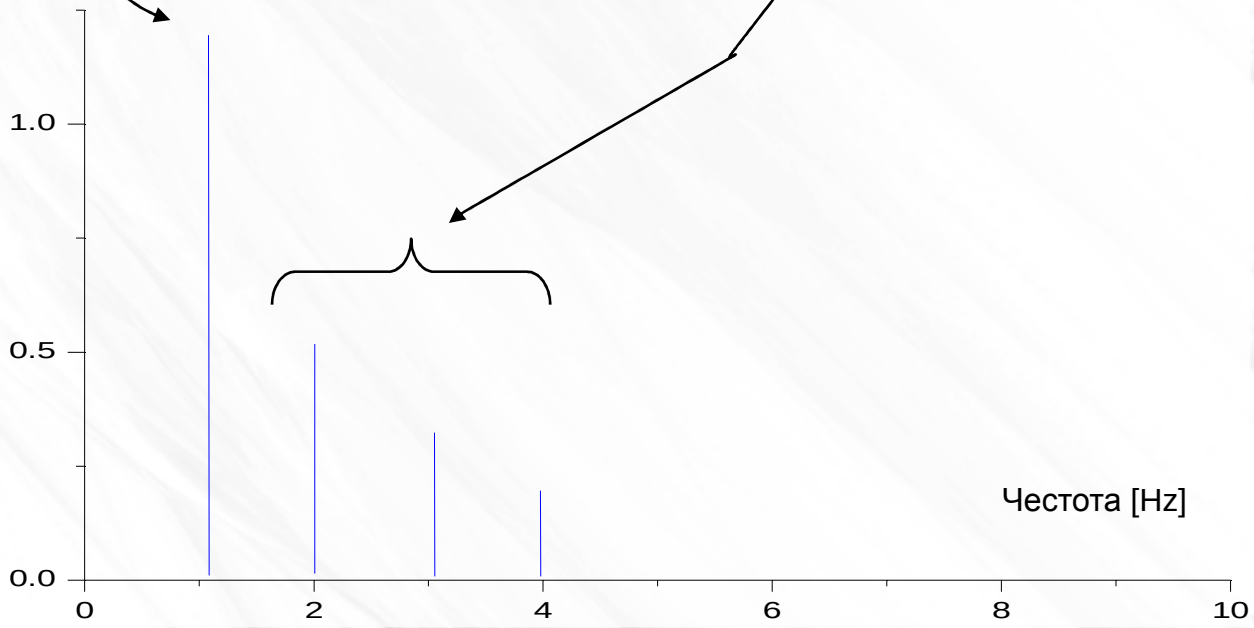
Честота 2f

Честота 3f

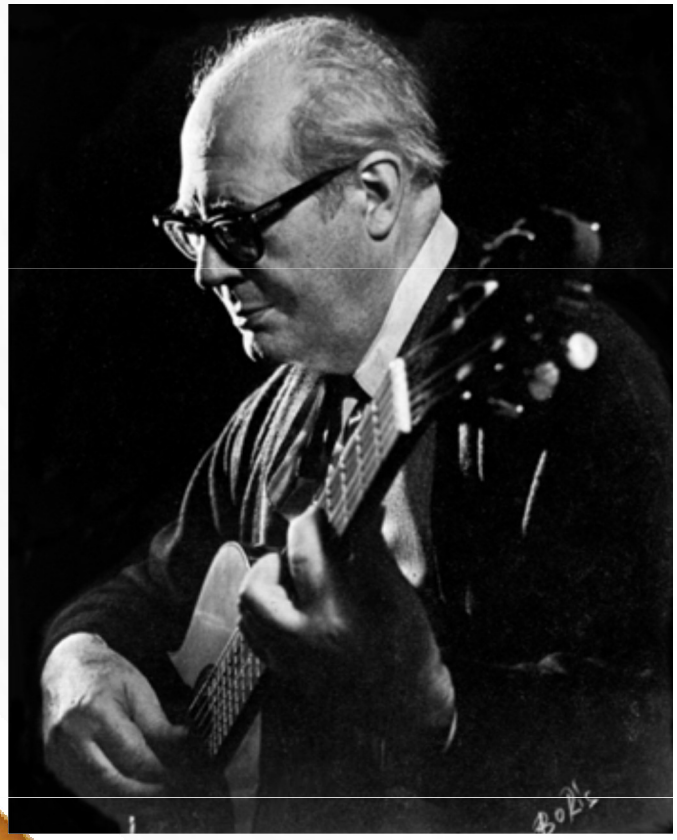
Честота 4f

обертонове

Спектър

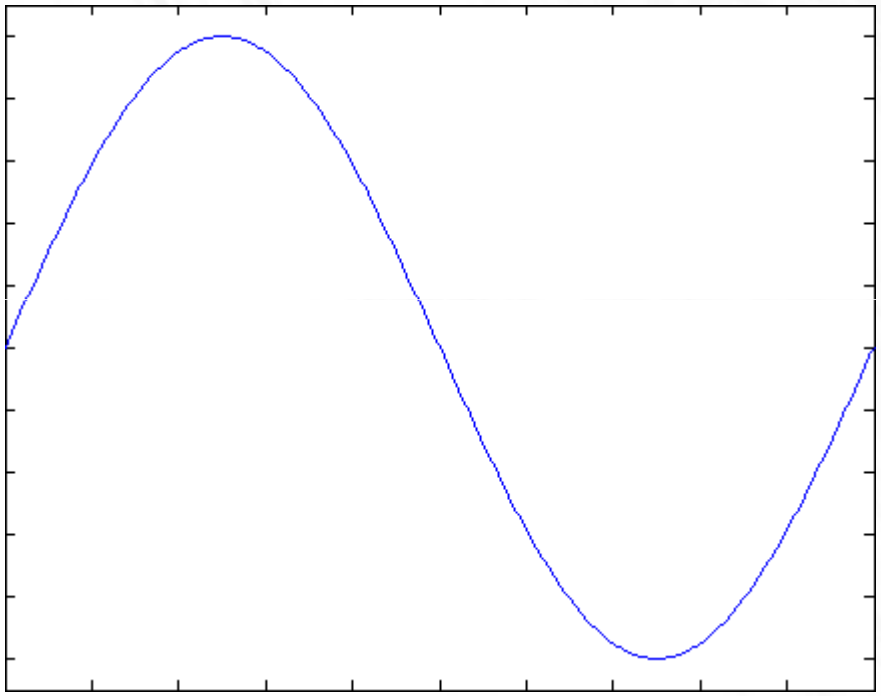


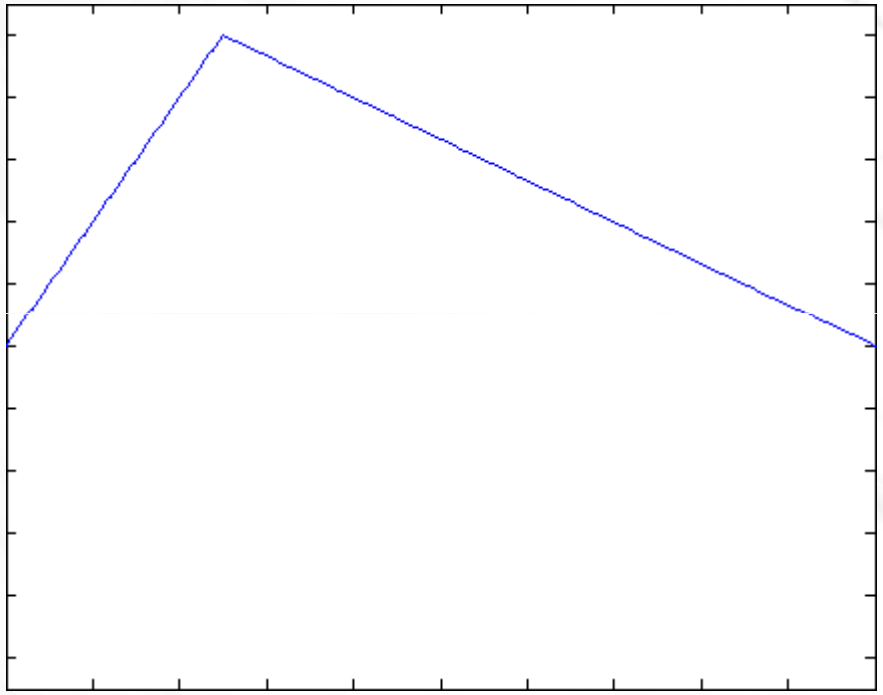
... за китарата



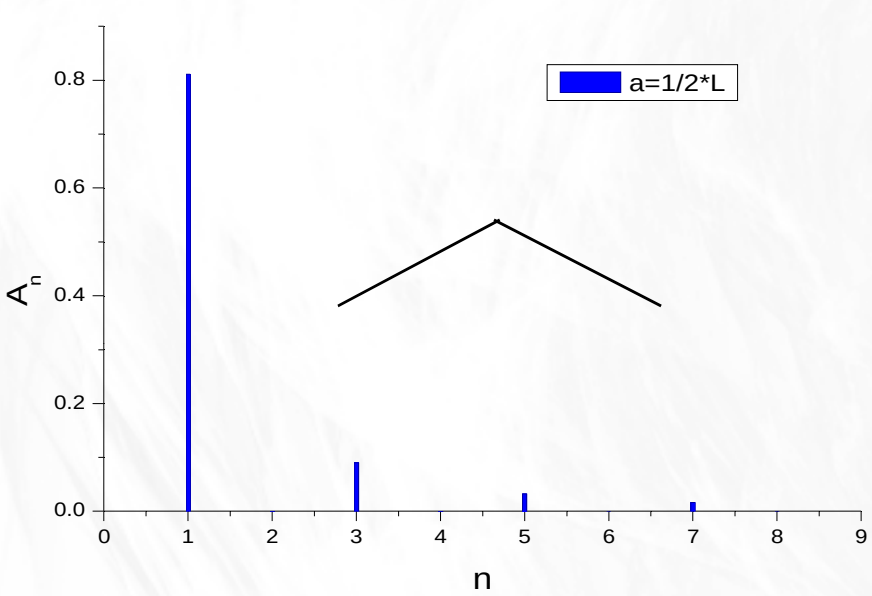
А как наистина трепти една струна?

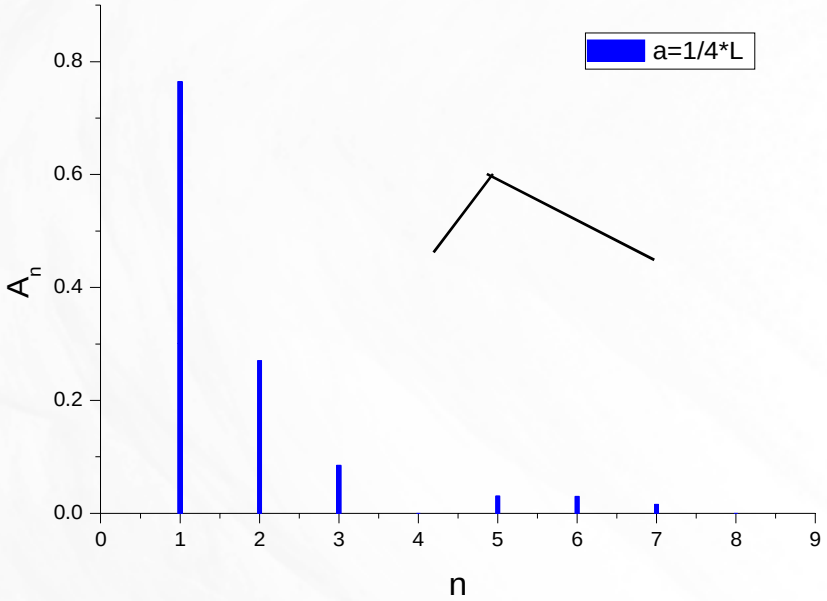
Начални условия:

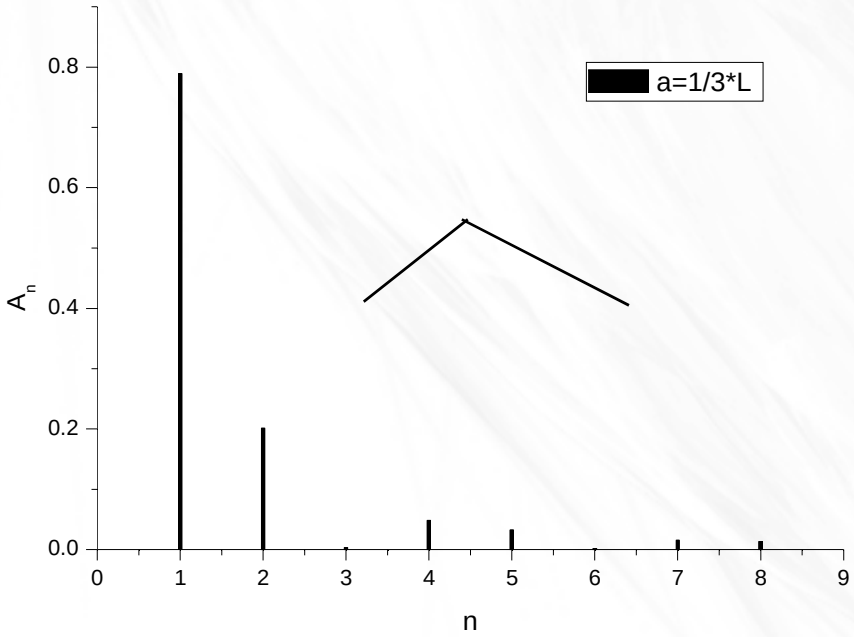


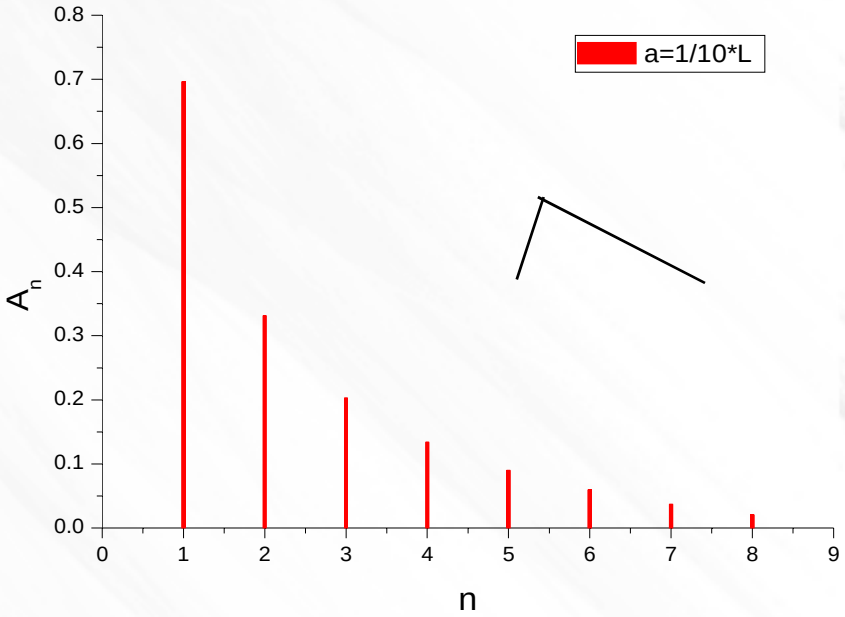


Отново: А как наистина трепти една струна?









winscope

От какво зависи височината на тона?

$$f = c / 2L \qquad c = \sqrt{\frac{F}{\rho}}$$

$$f_n = n\, c / 2L$$

- сила на опън F
- линейна плътност ρ
- дължина на струната L

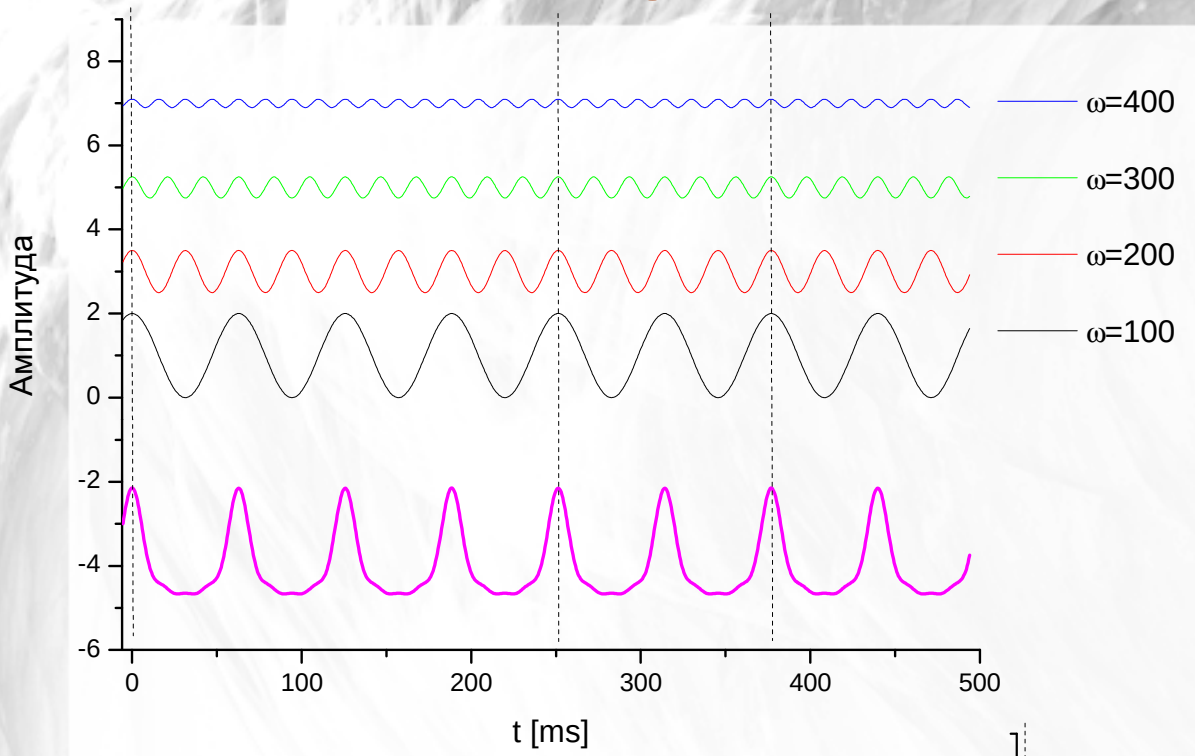
Тънкости:

Притискането на струната променя F и L

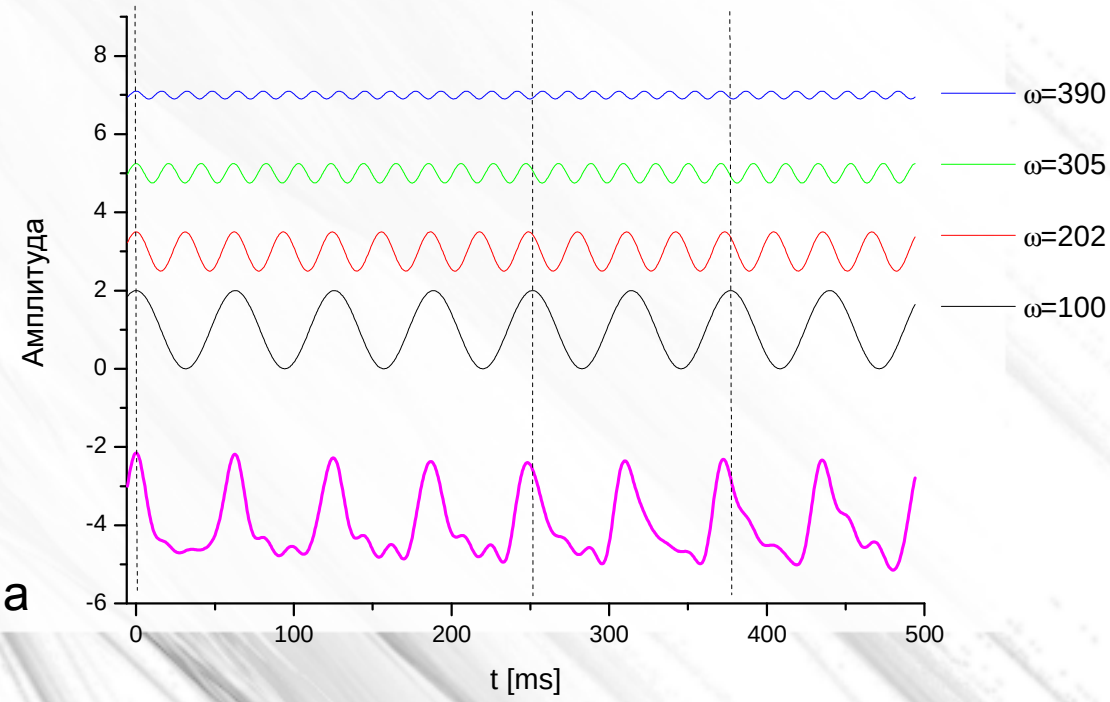
Износването и зацапването на струната променя плътността

Струната никога не е идеално тънка и еластична

Еднократно възбуждане, свободни трептения

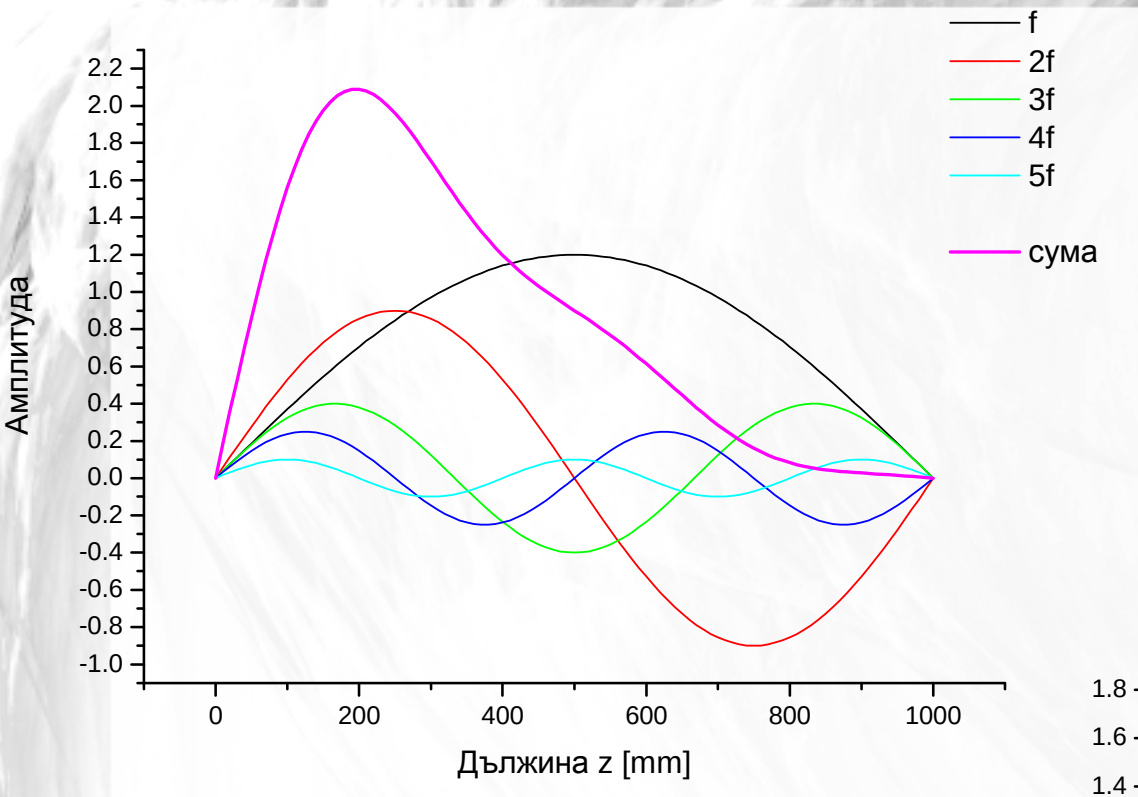


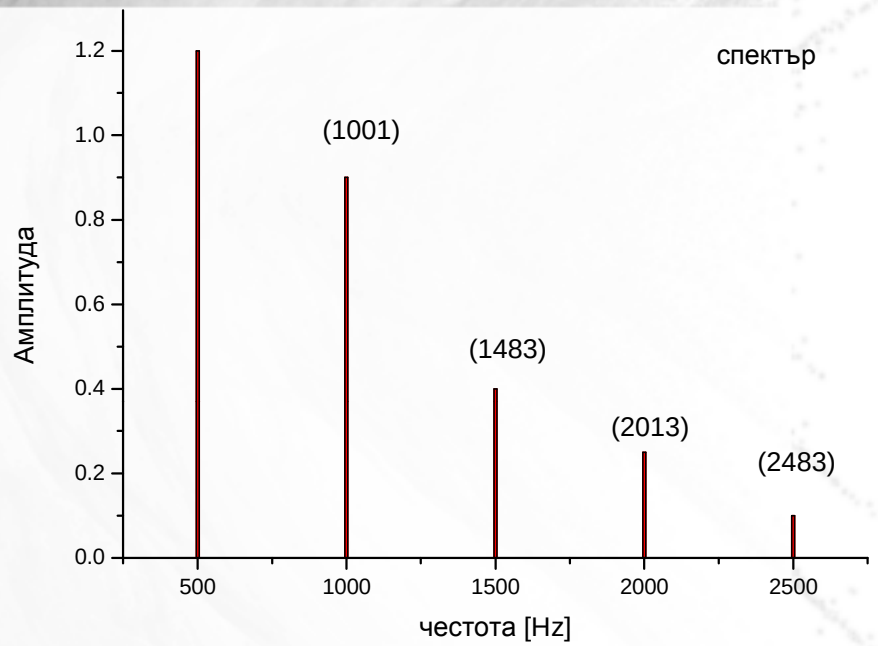
Идеална струна

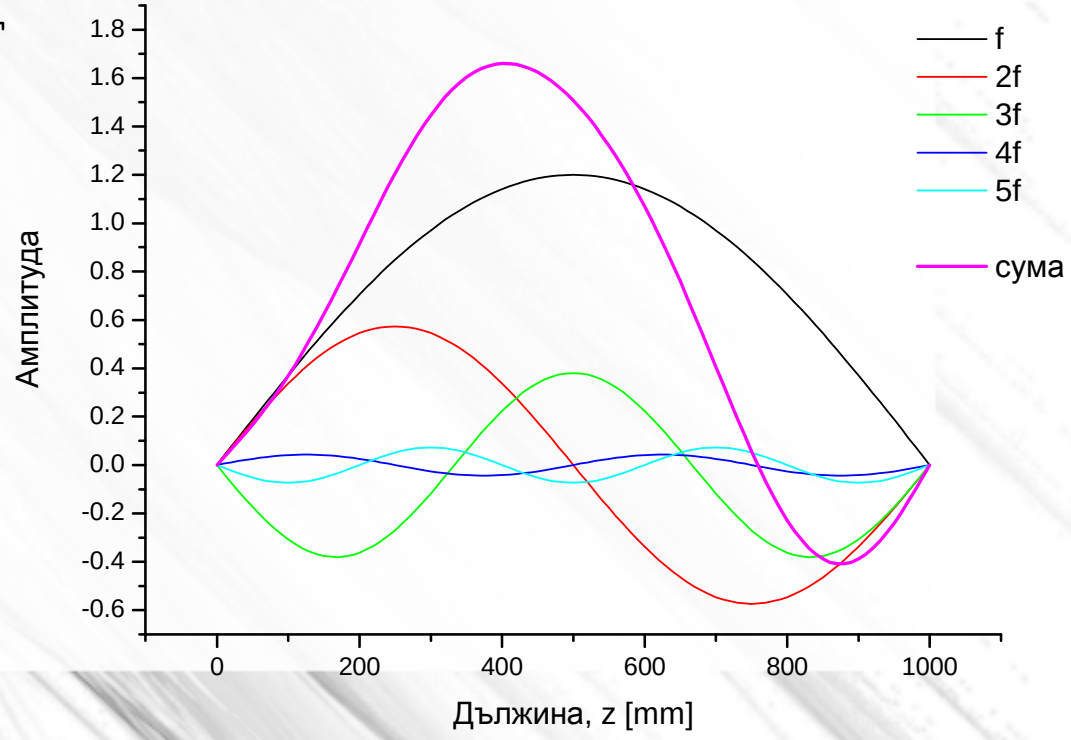


Реална струна

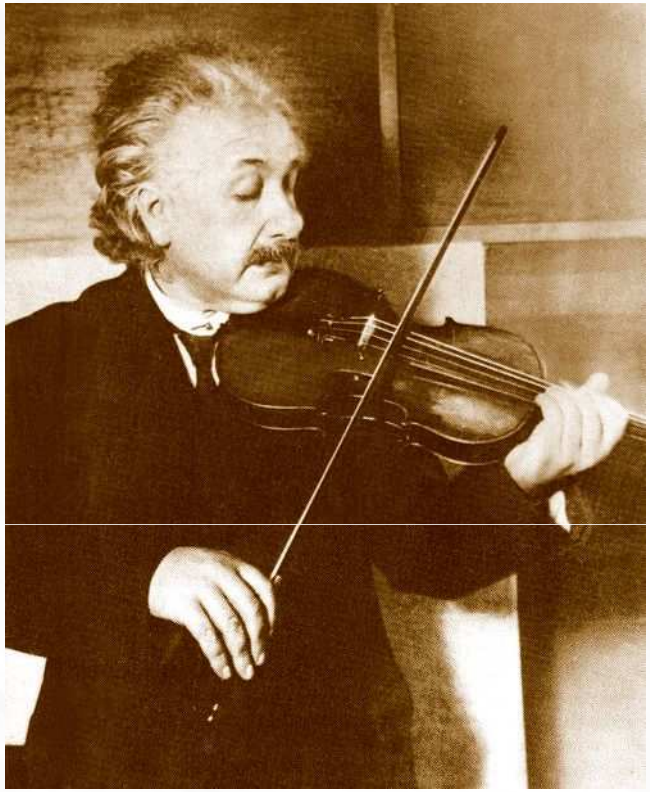
Еднократно възбуждане, свободни трептения



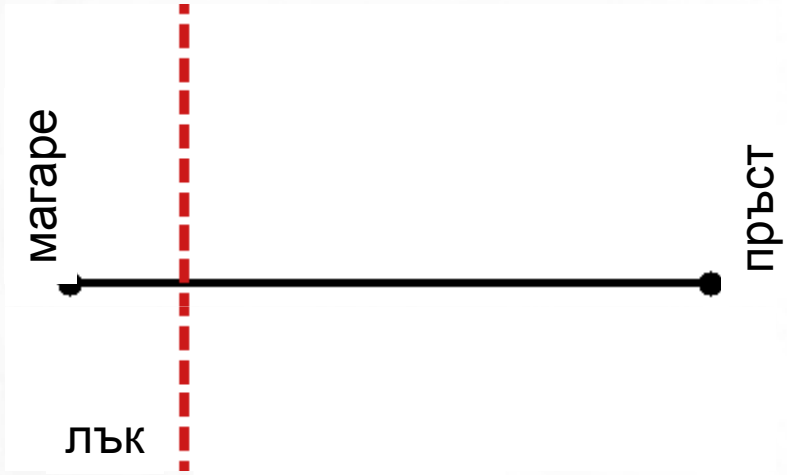




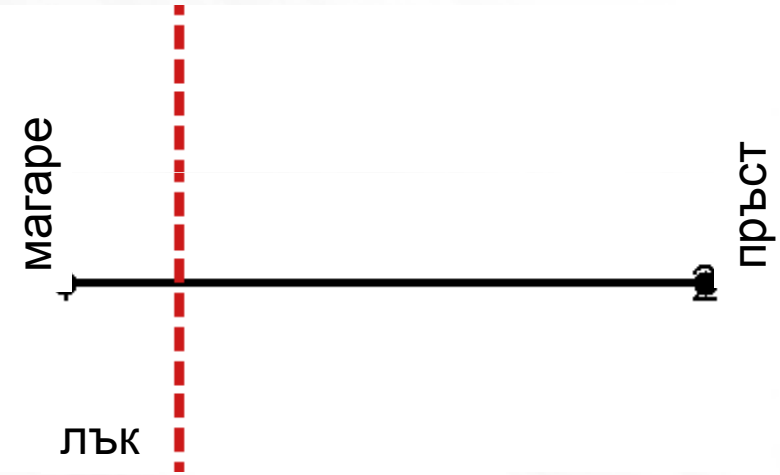
... за цигулката



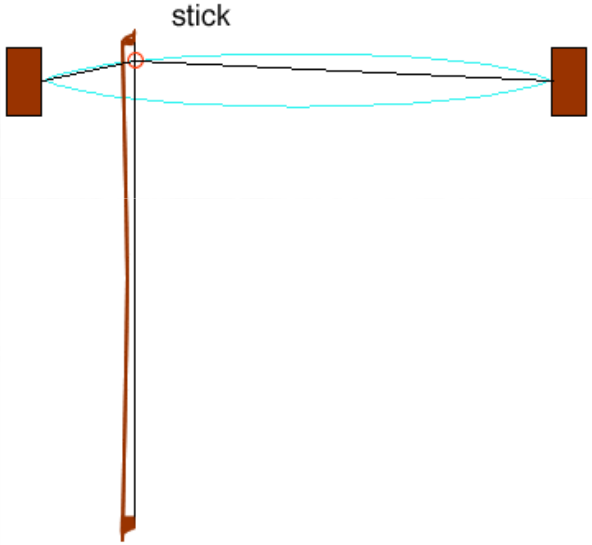
Как трепти струната на цигулката?

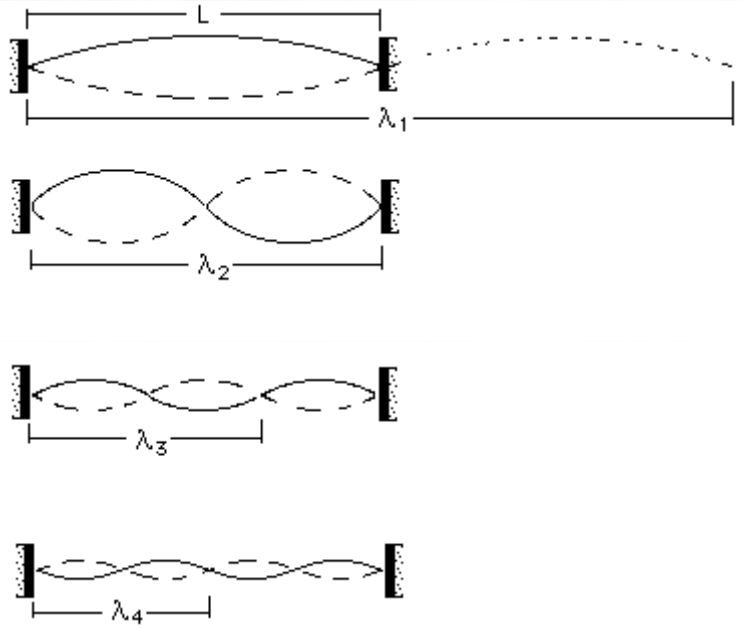


Зацепване - приплъзване



Всички модове трептят синхронно!



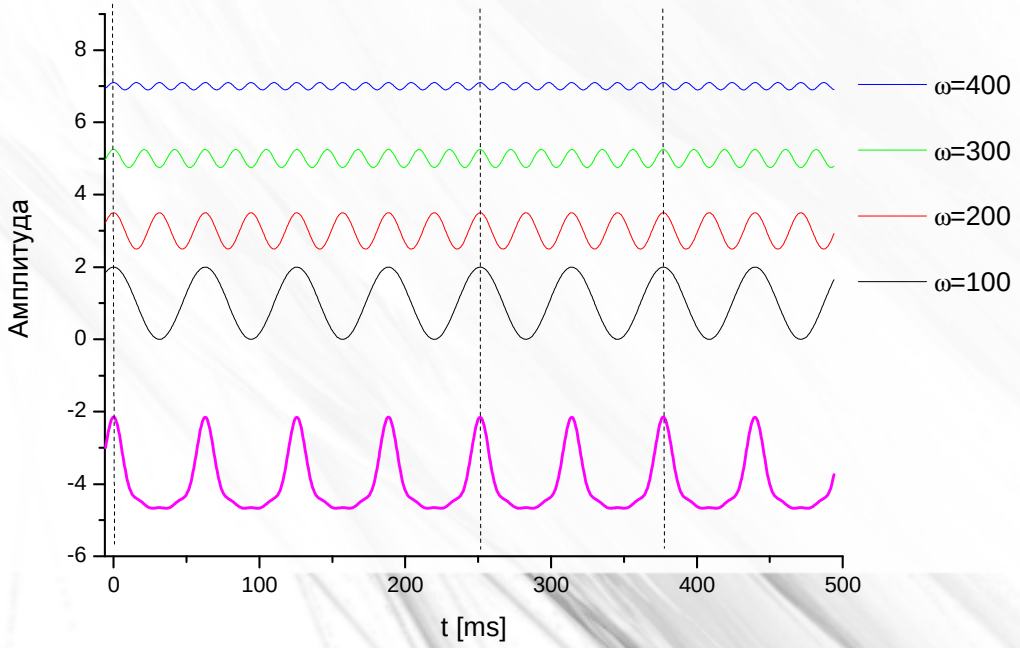


Честота f

Честота 2f

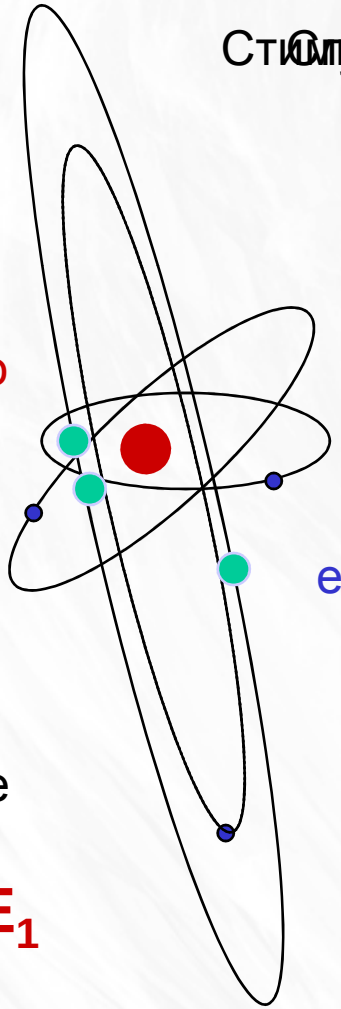
Честота 3f

Честота 4f



... за лазерите

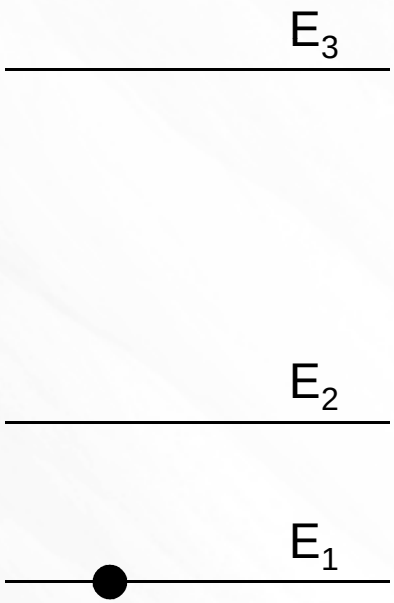
Взаимодействие фотон – атом



Стимулирано излъчване

Спонтанно излъчване

$h\nu = E_2 - E_1$

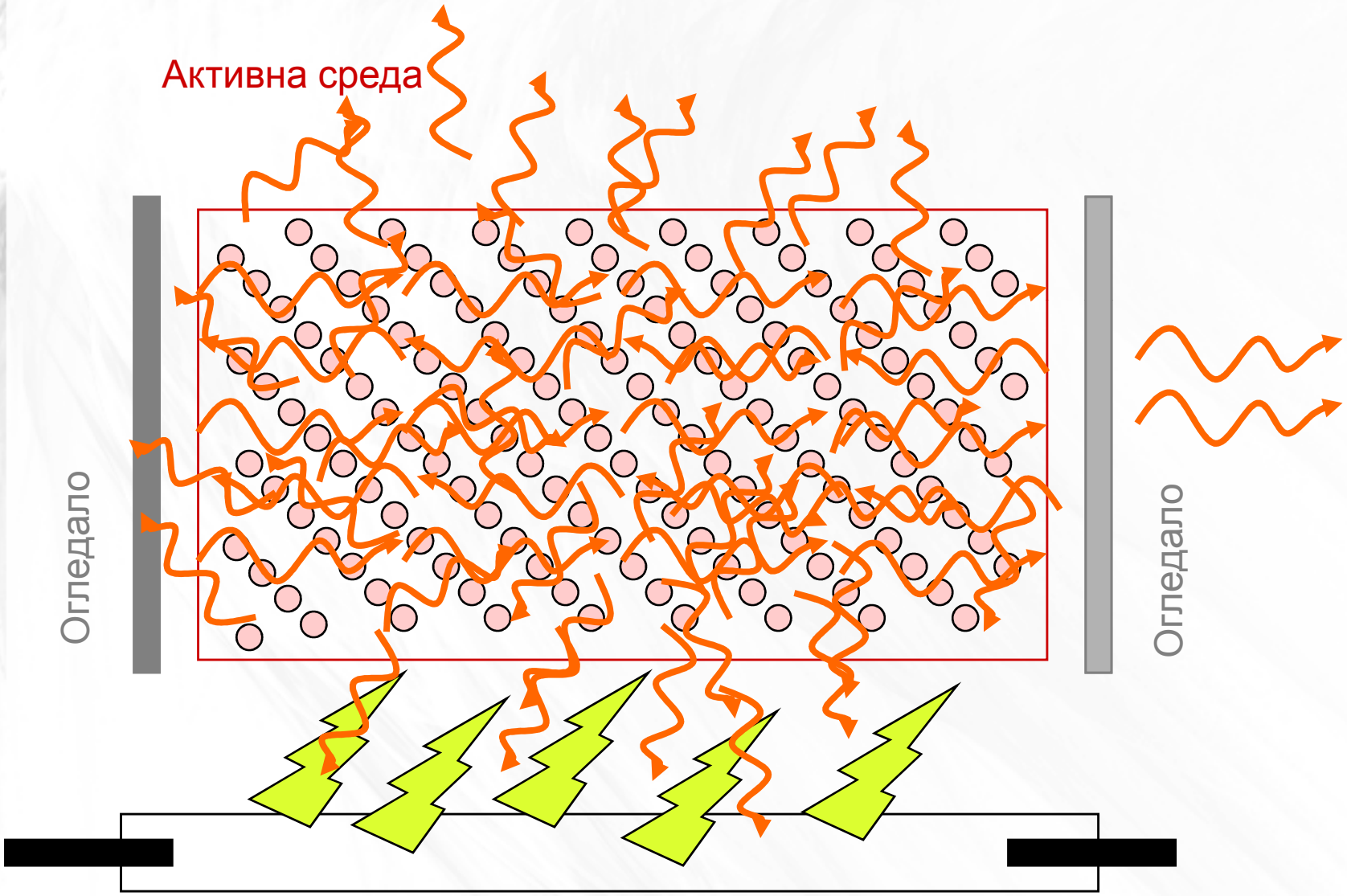


Енергетични нива на атома

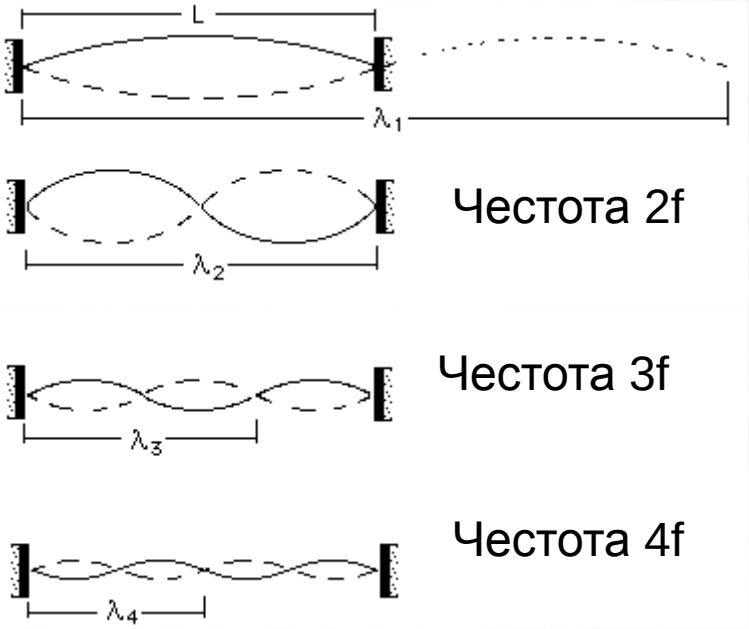
Поглъщане

$h\nu = E_2 - E_1$

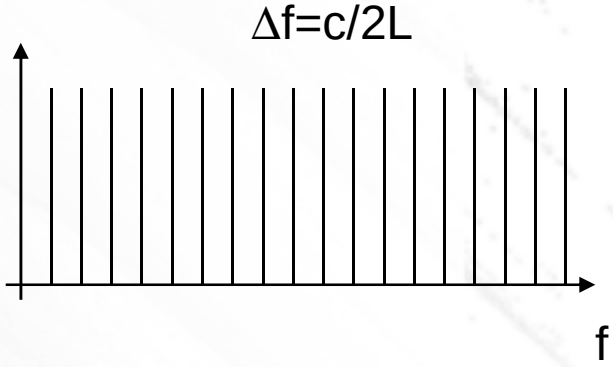
Основи на лазера

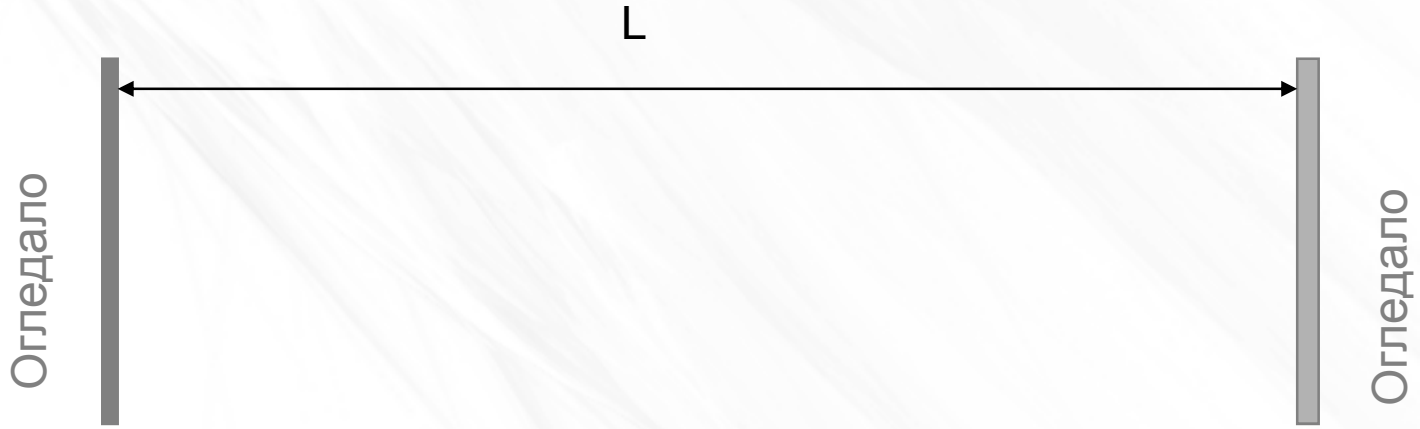


Лазерни модове

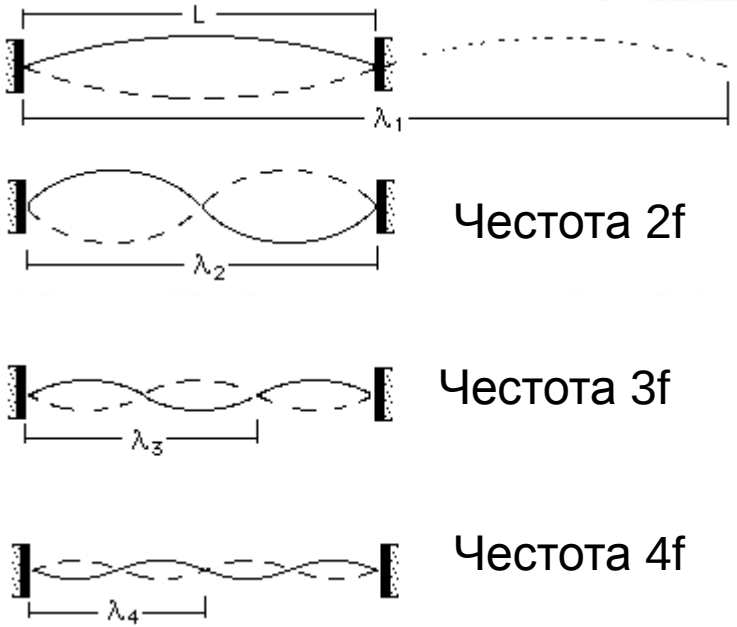


Резонатор = гранични условия!



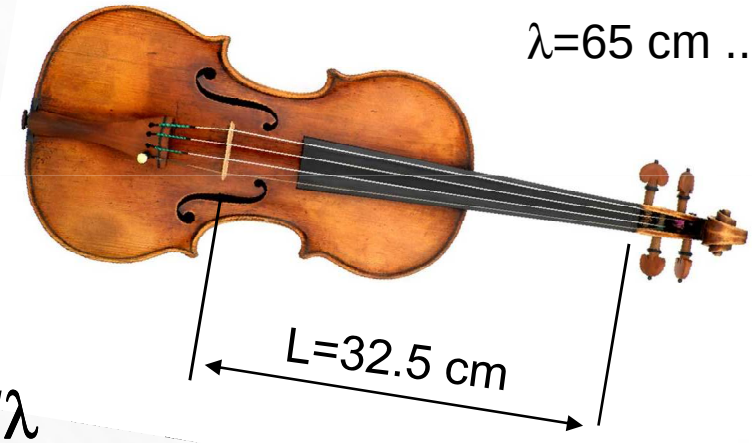


Цигулка и лазер



m=1…10

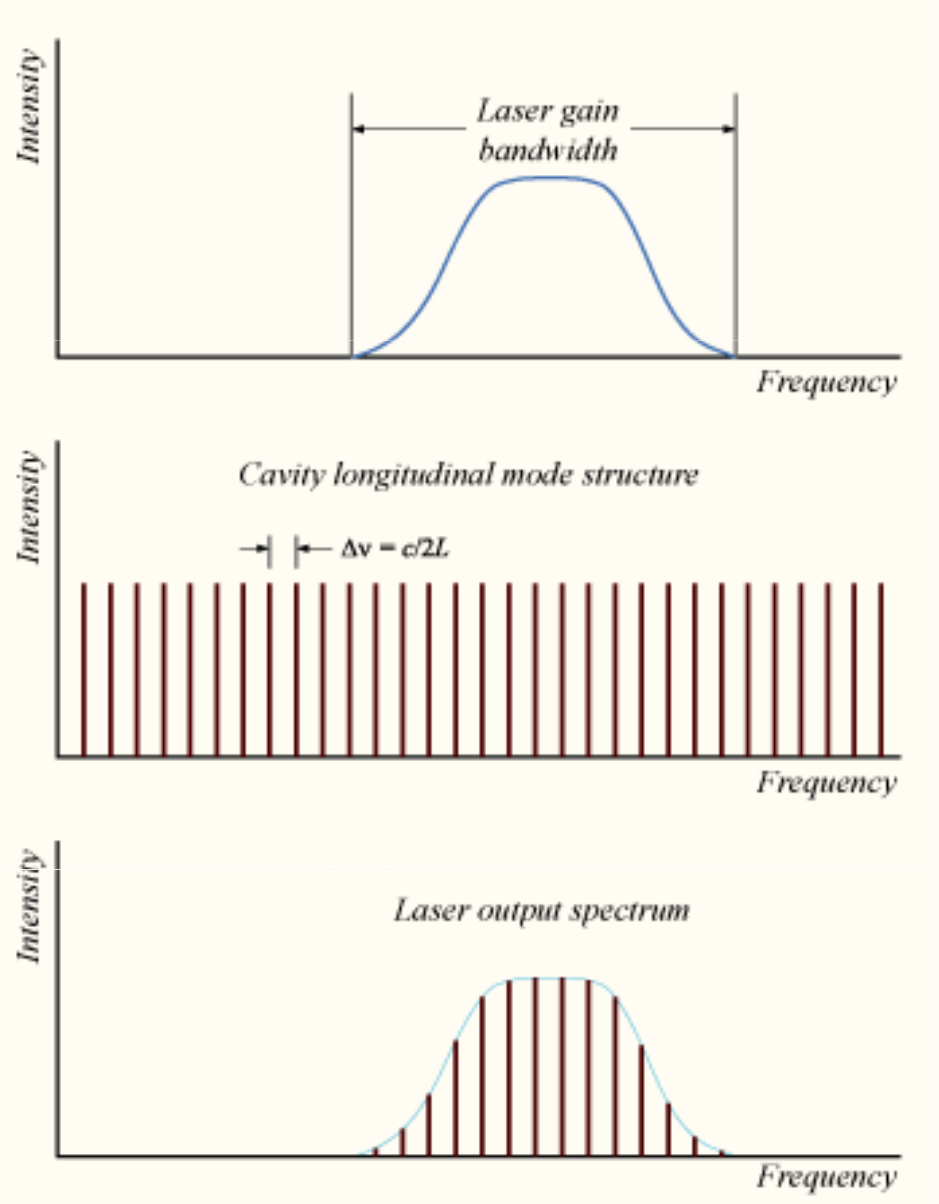
λ=65 cm .. 6.5 cm

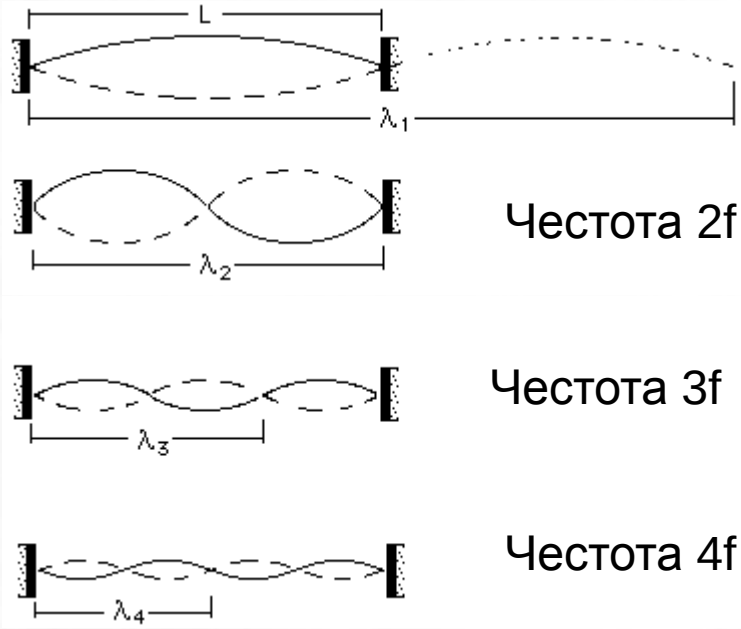


m=2L/λ

m>1 000 000..

Как може да свети един лазер





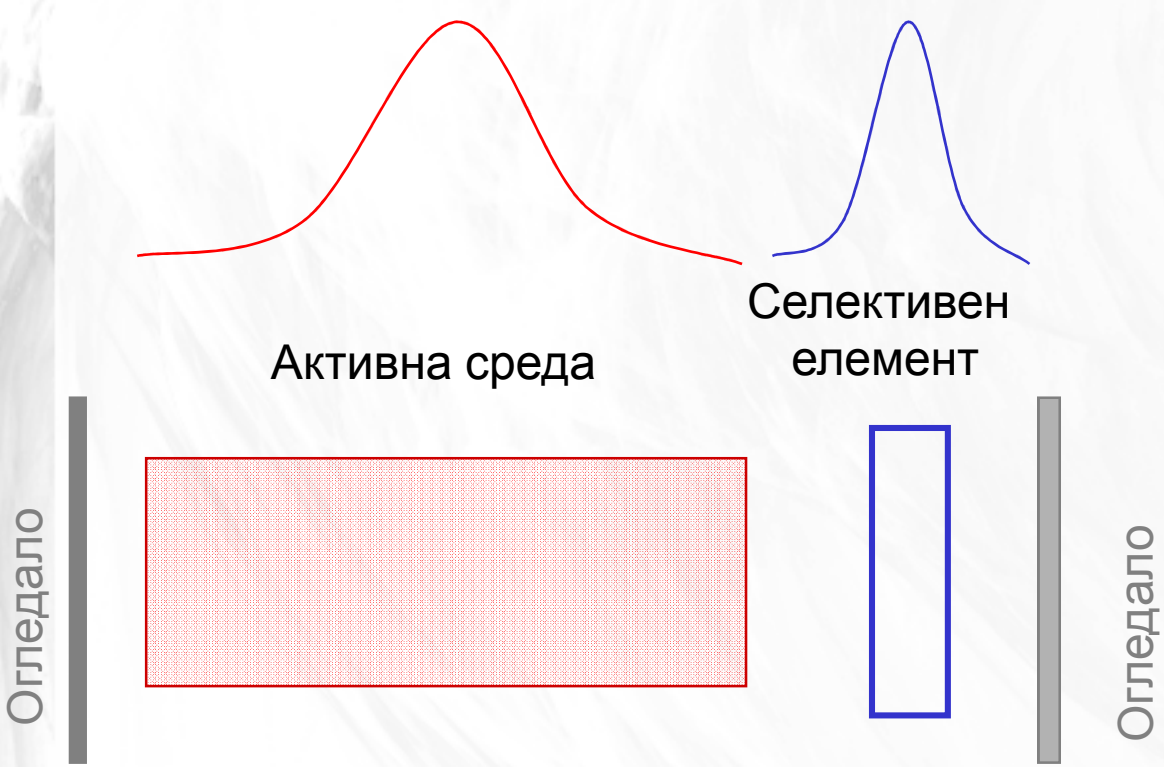
Честота 2f

Честота 3f

Честота 4f

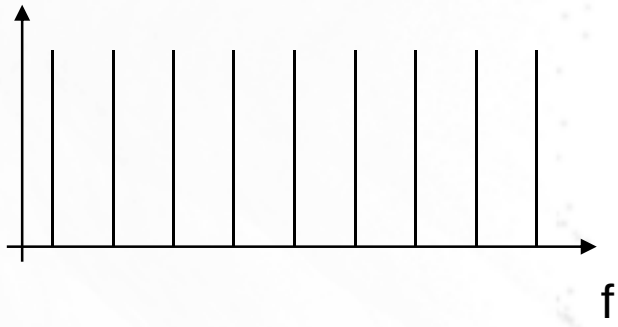
Важно!
Един лазер не е задължително едночестотен!

Едночестотни лазери

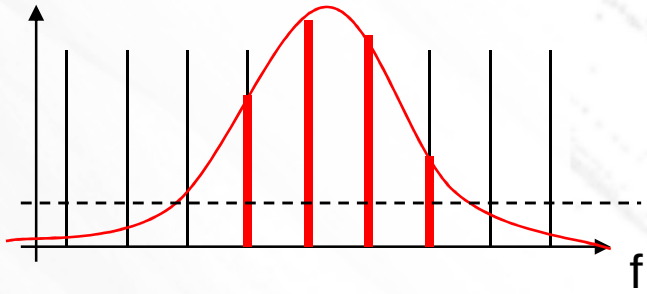


Модове на резонатора

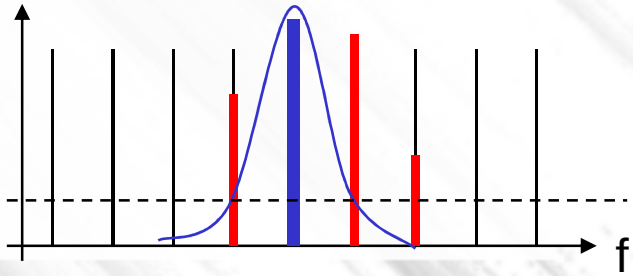
$\Delta f = c/2L$



Резонатор + активна среда



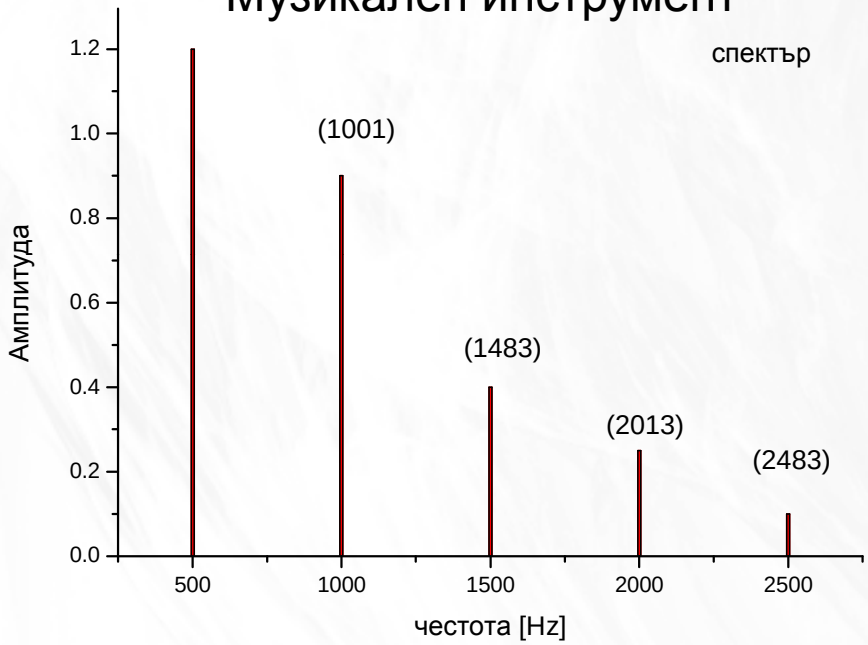
Резонатор + активна среда + селективен елемент



Генерация на един обертон!

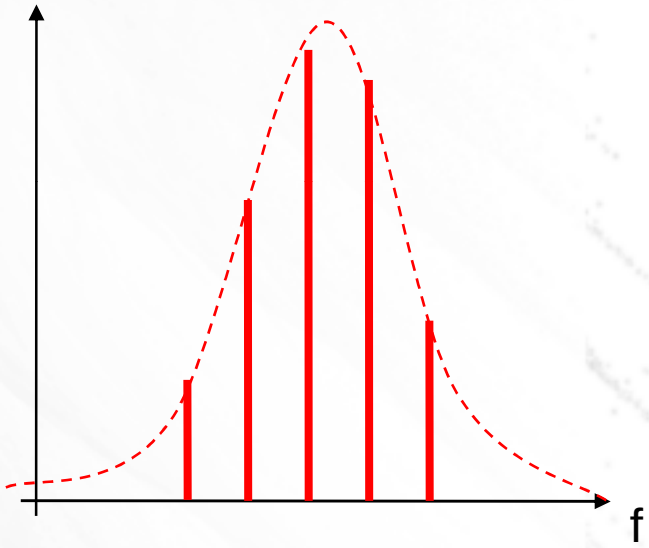
Лазер – китара, лазер – цигулка

Музикален инструмент



Несинхронно – китара
Синхронно - цигулка

Лазер

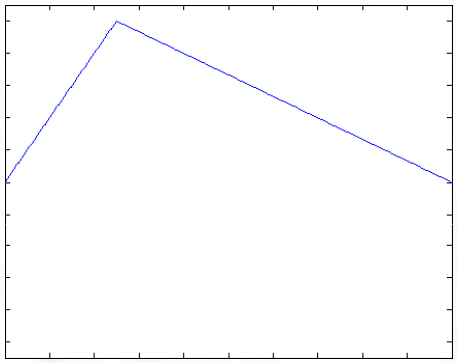


Честота [Hz]

?

Лазер – китара, лазер – цигулка

Различни начални условия!



Модовете са независими.

Китара, цигулка

Неравномерна линейна плътност ρ

↓

Различна скорост на модовете

↓

Различна честота на модовете

Лазер

Дисперсия на показателя на пречупване *n*

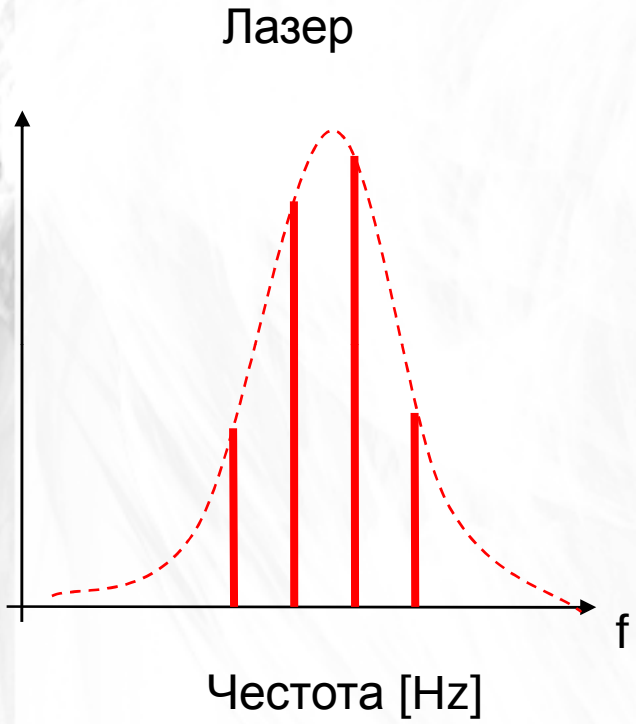
↓

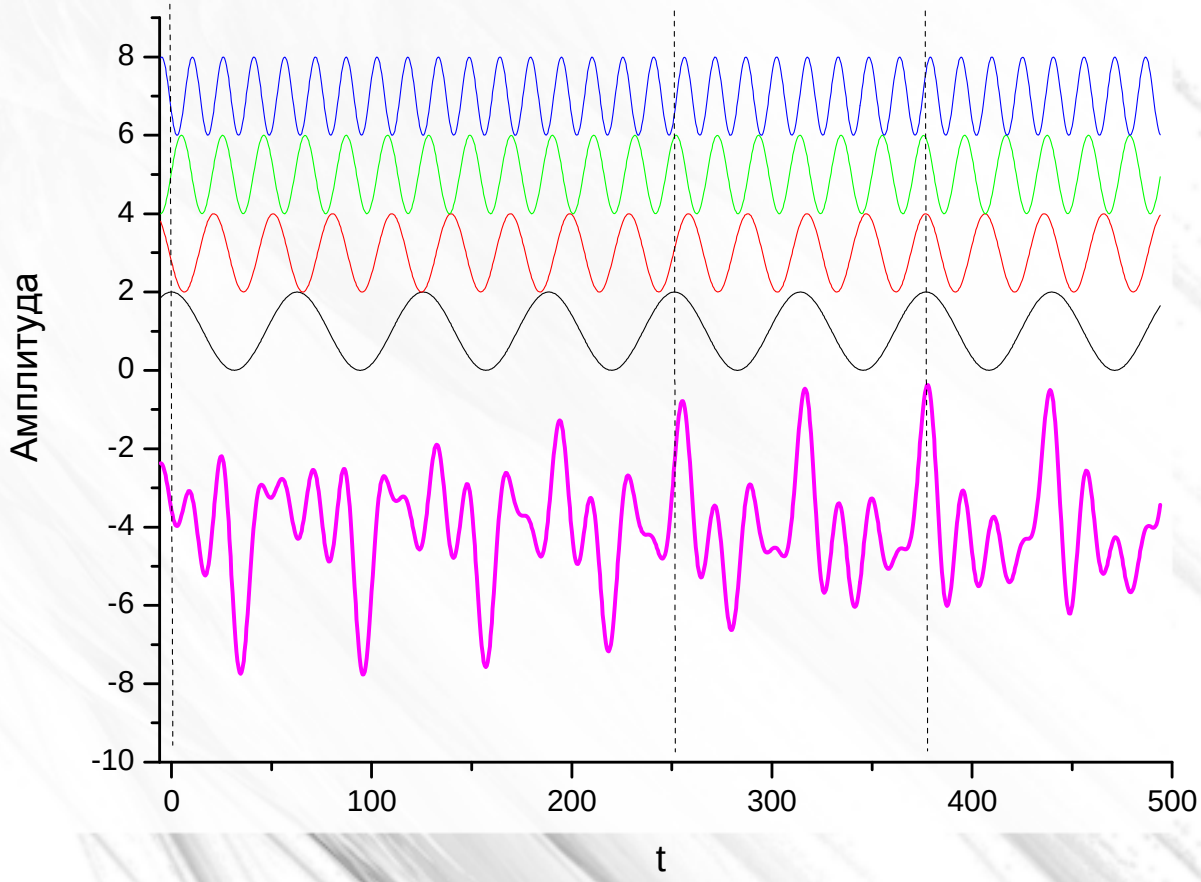
Различна скорост на модовете

↓

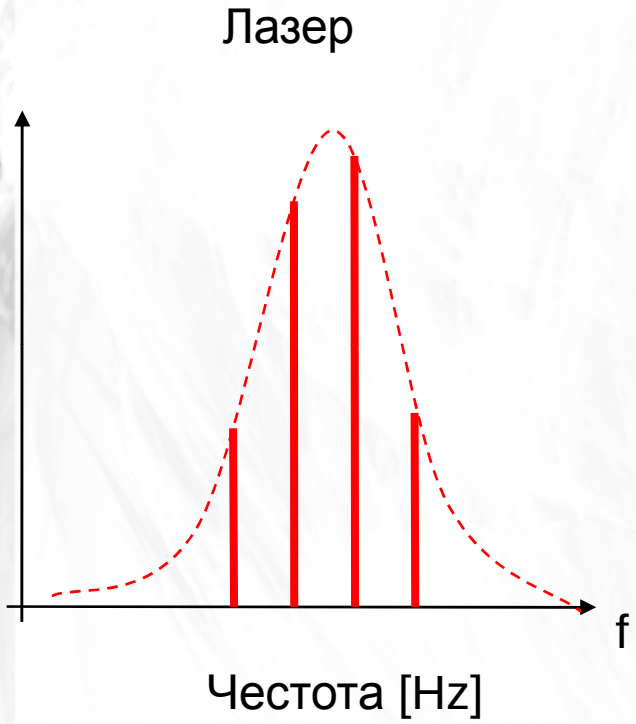
Различна честота на модовете

Лазер без синхронизация на модовете

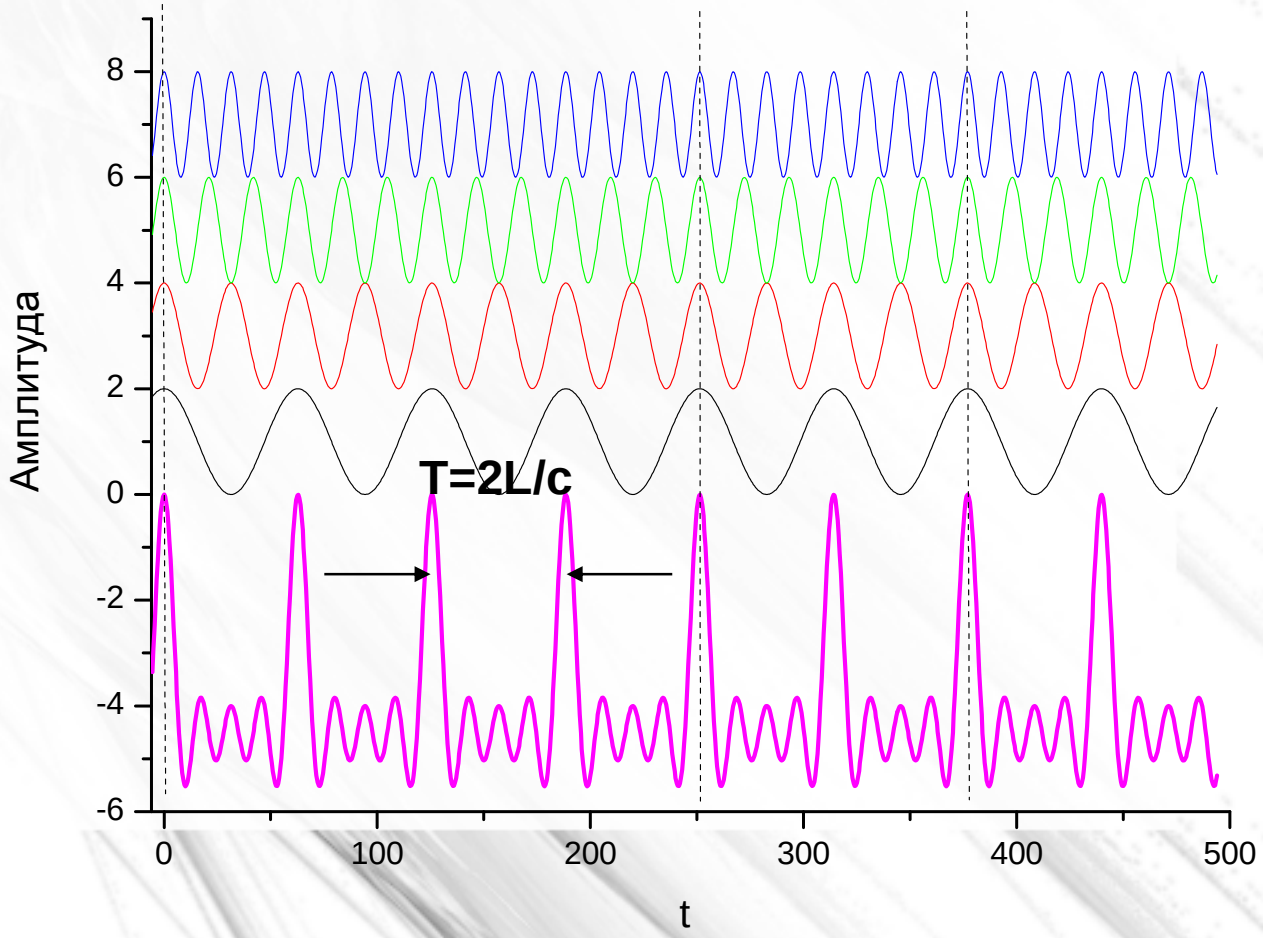




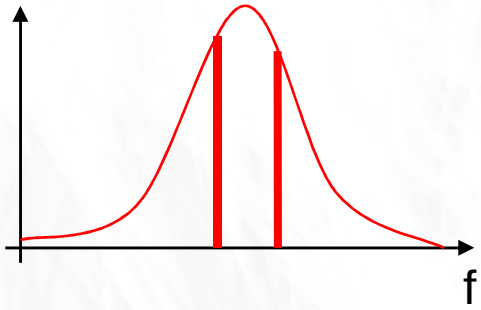
Лазер със синхронизация на модовете

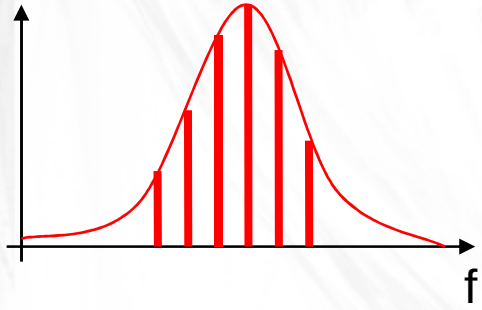


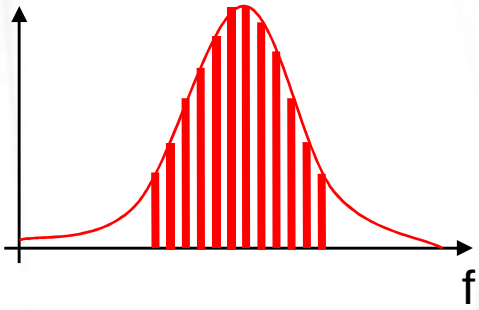
Поредица от импулси!

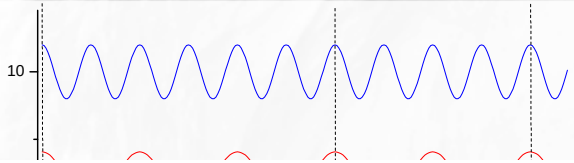


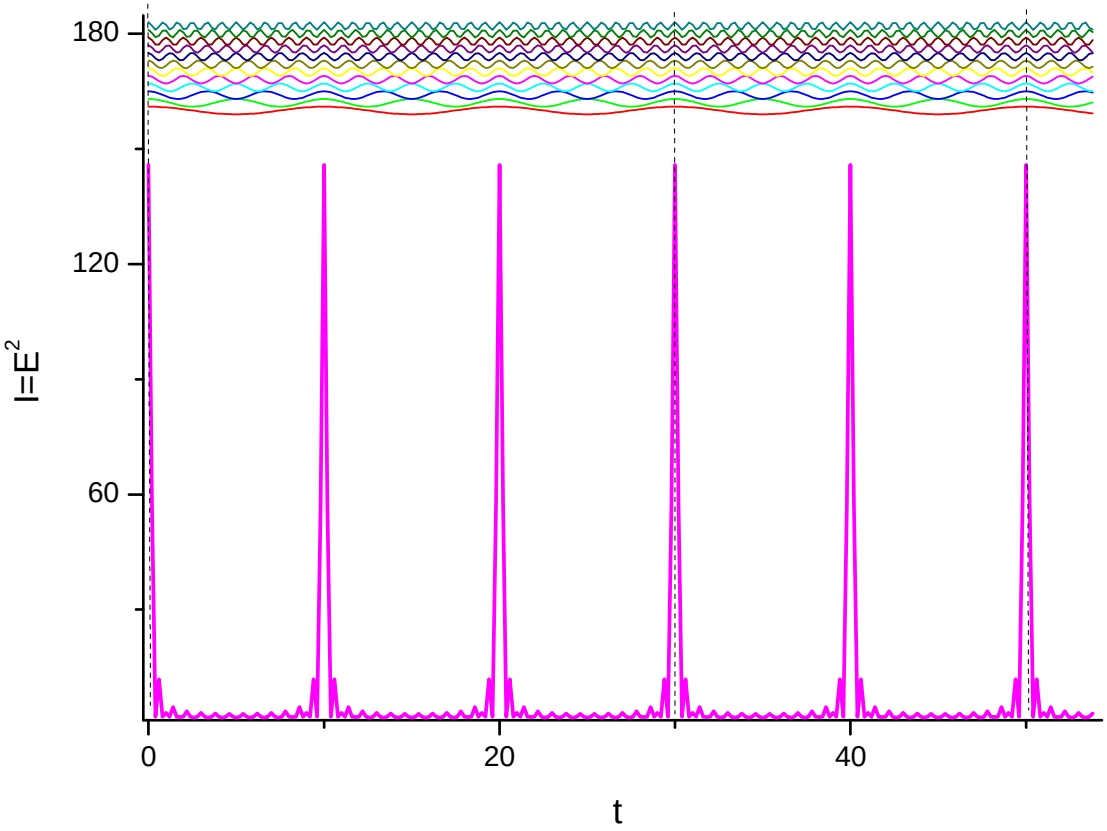
Колко е ширината на един импулс?

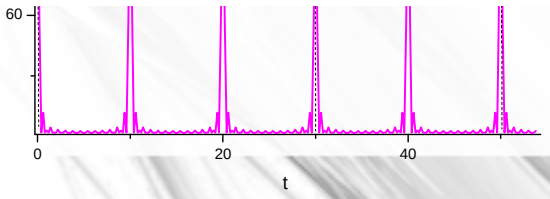








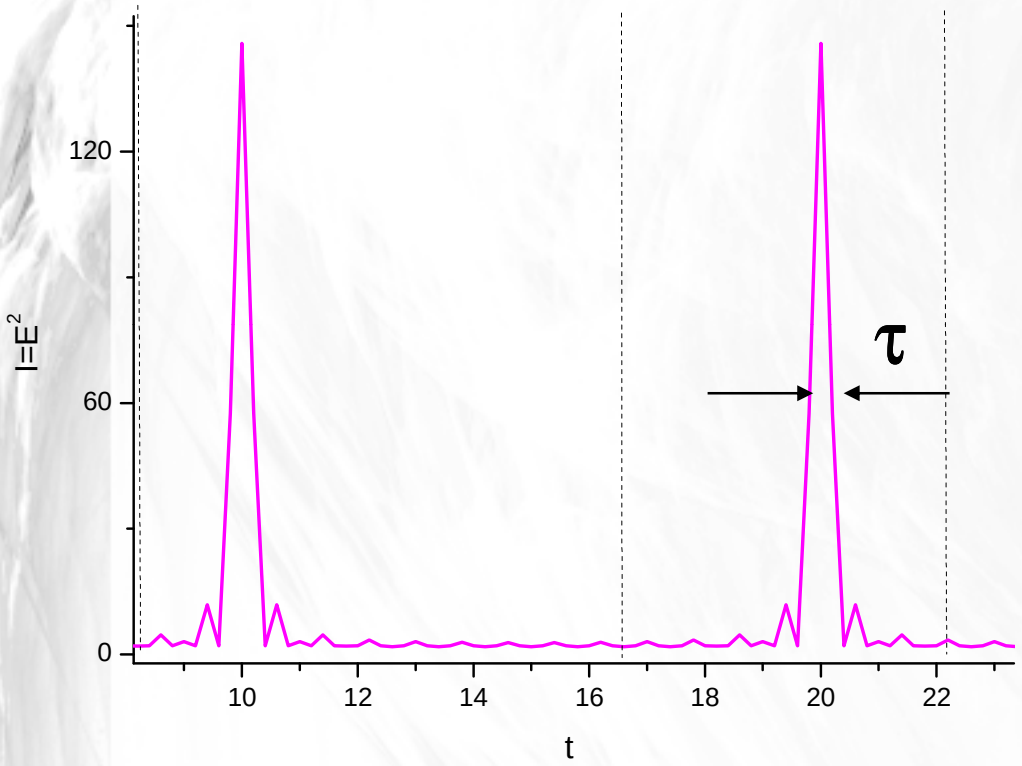




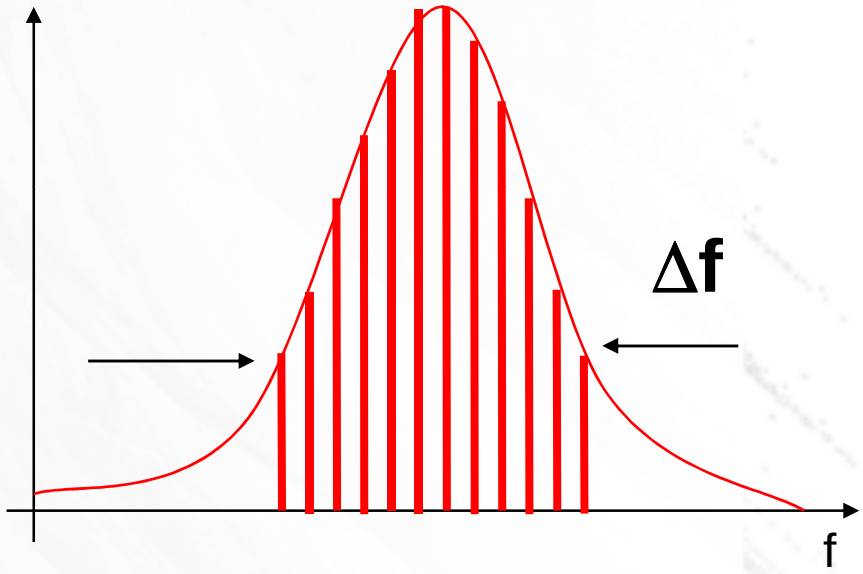
Фемтосекунден лазер

1 fs = 10^{-15} s

$$\tau \sim 1/\Delta f$$



m~2L/τc



τ =10 fs, $\Delta f=10^{14}$ Hz λ_0=800nm $\Delta\lambda$=200 nm

He-Ne: $\Delta f=1{,}5.10^9$ Hz Ti:Sapphire: $\Delta f= 1{,}3.10^{14}$ Hz

Диоден лазер: $\Delta f= 10^{12}$ Hz

L=1 m, τ =100 fs m=67 000 мода

Методи за синхронизация на модовете