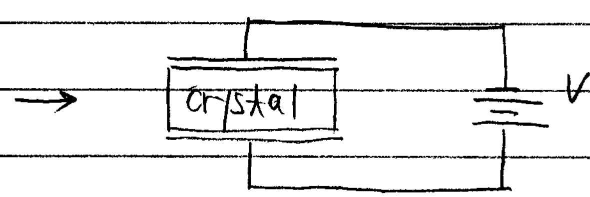
Done with lasers.
2nd half : nonlinear optics = things can be done with lasers

Start with modulation techniques
= ways to switch laser light on & off quickly

Electro-optic modulation
Acoustic-optic modulation
Applications to pulsed lasers

* Overview :

Electro-optic modulation :
In general, index of refraction of a material depends on applied electric field :



n depends on V
$n \to n + \Delta n$

Why ?
Classically ; electrons shift in response to field to new position, oscillation freq. changes
Quantum mechanics : applied field shifts energy levels (like Stark effect)

Expect effects to be small:

electric field from nucleus $\sim \frac{e}{4\pi\varepsilon_0 a_0}$ a_0 = Bohr radius

$E_{atom} \sim 5 \times 10^{11} \frac{V}{m}$

Typical applied voltage $E_{app} \sim \frac{10kV}{1mm} = 10^9 \frac{V}{m} \ll E_{atom}$

So expect applied field to cause a small perturbation to index

$$\Delta n \sim \frac{E_{app}}{E_{atom}} \sim 10^{-12} \frac{m}{V} E_{app}$$

Or, expand n as Taylor series:

$$n(E) \approx n + a_1 E + \frac{1}{2} a_2 E^2 + \cdots$$

expect linear term to dominant since E is small

But, sometimes $a_1 = 0$:

Consider medium with inversion symmetry:

medium unchanged if $\vec{r} \to -\vec{r}$

Examples: symmetric crystals

amorphous solids

liquids & gases

Now apply E in some direction

linear shift $a_1 E$

Reverse direction, expect shift $-a_1 E$

But physically same system:

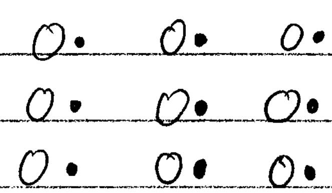
could have just flipped medium over

So, should have same shift for either case

$\rightarrow a_1 = 0$

Get linear term only in materials with some asymmetry

Crystal:



o and • : different species

$$\xrightarrow{\quad} \vec{E}$$

$$\neq \quad \xleftarrow{\quad} \vec{E}$$

* Overview of modulation:

Two kinds:

amplitude modulation = variation of intensity

- * communication
- * process control
- * time delay experiments
- * intensity stabilization

Frequency modulation = variation of ν

* spectroscopy
  - ↳ reaching desired frequency
  - ↳ FM detection techniques
* stabilization.

Methods :

Diode laser current modulation	(mostly AM)	] laser specific
pulsed laser	(AM)	
Vary laser cavity length	(FM)	] slow ~ kHz
Mechanical shutters	(AM)	
Electrooptic effect	(AM & FM)	] general
Acousto-optic effect	(AM & FM)	

Linear effect : Pockels effect → relatively strong
Quadratic effect : kerr effect → exhibited by all media

write $n(E) = n - \frac{1}{2} r n^3 E - \frac{1}{2} S n^3 E^2$

r : Pockels coefficient
S : kerr coefficient