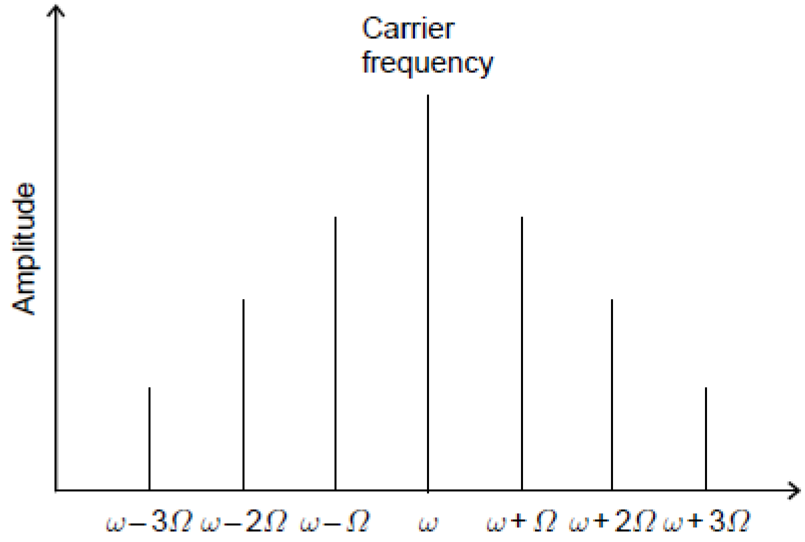


The longer the optical path, l, in the material, the greater are the amplitudes of the sidebands at the frequencies $\omega \pm n\Omega$
.

The sidebands' amplification is reached at the expense of the amplitude of the fundamental beam at the carrier frequency, ω.

The optical pathlength, l, is the parameter defining when the Debye–Sears effect can occur.

We can distinguish two limiting cases,

$$l \ll \frac{\Lambda^2}{2\pi\lambda}$$

and,

$$l \gg \frac{\Lambda^2}{2\pi\lambda},$$

where λ is the optical wavelength, and Λ is the length of an acoustic wave.

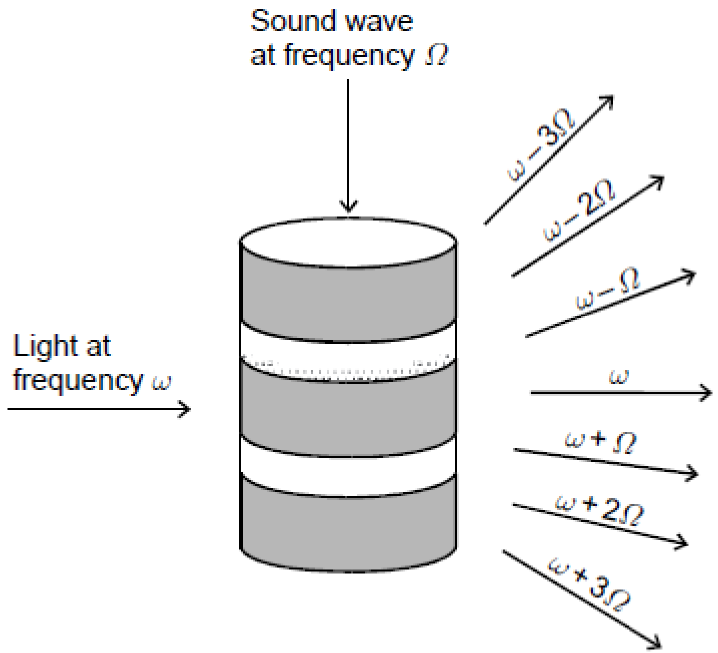
Pulse selection in cavity dumper

This relationship defines the critical length of the optical path for which the Debye–Sears effect can be observed. This relationship characterises the conditions required for modelocking with *acousto-optic devices*. This is ***Raman–Nath*** regime.

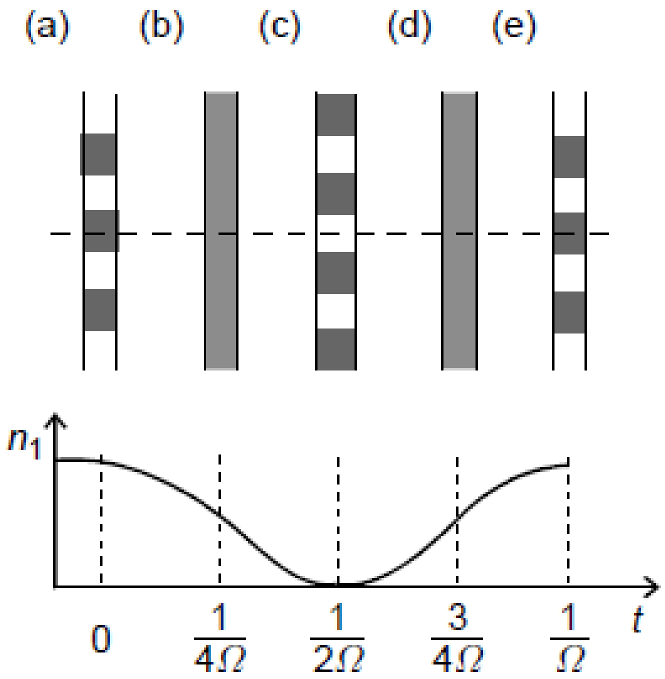
The simplest way to modulate the refractive index n_1 is to make a periodic change of a medium's density, which can be achieved by passing the acoustic wave through the medium.

The acoustic wave then creates regions of compression and dilation at its frequency Ω.

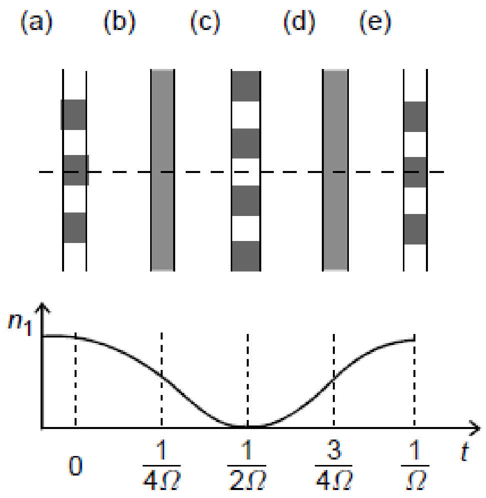
In real acousto-optic devices, a standing acoustic wave is generated instead of a travelling wave whose forefront moves downward as shown below



The standing wave shown below remains in place instead of moving down the column, and the refractive index, n_1, at each place in the column (e.g., the dashed line) changes sinusoidally with the frequency Ω.



Twice during the cycle the density is distributed uniformly along the whole column (b and d), and twice it achieves a maximum at which the refractive index, n_1, is largest (a and e), as well as once when it achieves the minimum density at which the refractive index, n_1, is the smallest (c).



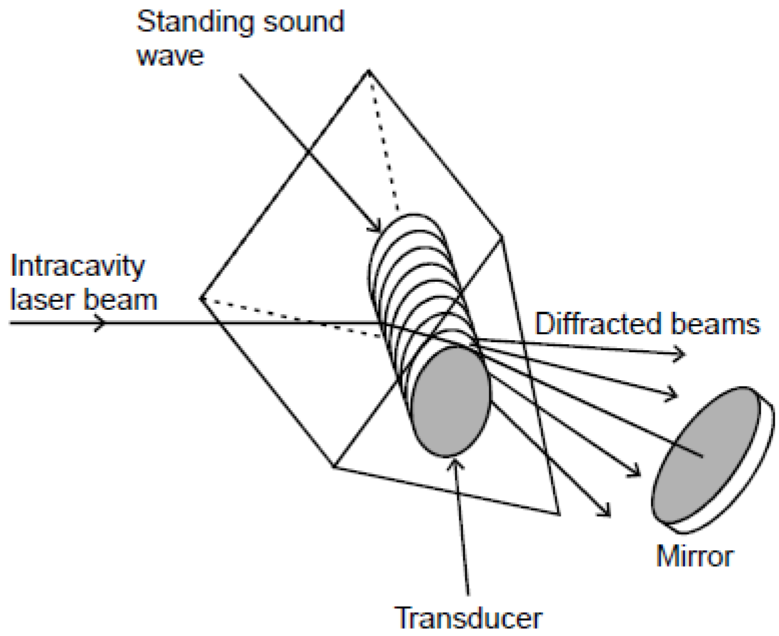
Thus, twice during the cycle $T = 1/\Omega$ when the density is distributed uniformly, the incident beam passes unaffected and the frequency of the transmitted beam is equal to ω, and the radiation amplitude is equal to the amplitude of the incident light.

At other times diffraction occurs, leading to the appearance of additional bands at $\omega \pm \Omega$, at the expense of weakening the amplitude of the carrier wave at frequency ω .

This is why an acousto-optical transducer modulates the amplitude of the light in an optical resonator

If this modulation is held at the frequency equal to the difference between the longitudinal modes, $\omega_q = c/2L$, the Debye–Sears effect leads to modelocking!!!

In practical applications an acousto-optic modulator consists of a small fused silica (SiO_2) element (prism or plate) placed close to the optical resonator mirror



Model of piezoelectric transducer

The piezoelectric transducer at one end of a prism or a plate generates an acoustic wave of frequency c /2L. The end walls of the prism are polished to permit acoustic resonance to produce the standing acoustic wave inside. A laser beam inside the optical resonator passes through the region of formation of the standing acoustic wave, interacting with it in the manner described earlier

As a consequence of this interaction, the laser beam with frequency ω is periodically modulated at the frequency Ω =c/2L by losses coming from the sidebands at frequency $\omega \pm n\Omega$.

Only the axial beam participates in the laser action: the sidebands which are deflected from the main axis will be suppressed, since the length of the optical path for the sidebands is different from L at which the condition $n\lambda$=2L fulfilled.

Traditionally, the acousto-optic modulation is used in flash-lamp pumped solid-state lasers such as Nd:YAG lasers.

A continuous-wave actively modelocked laser produces a train of pulses at a repetition rate in the range of 80–250MHz and energy of a few nJ.

If more energy is required, a pulse selected from the train can be amplified in a regenerative amplifier to reach a few mJ

If a more powerful pulse is needed, techniques that combine simultaneous modelocking and Q-switching or cavity dumping are used.