Laser:
Propeties, Basics &Principle: B.Sc. Part-2, Hons. & Sub.

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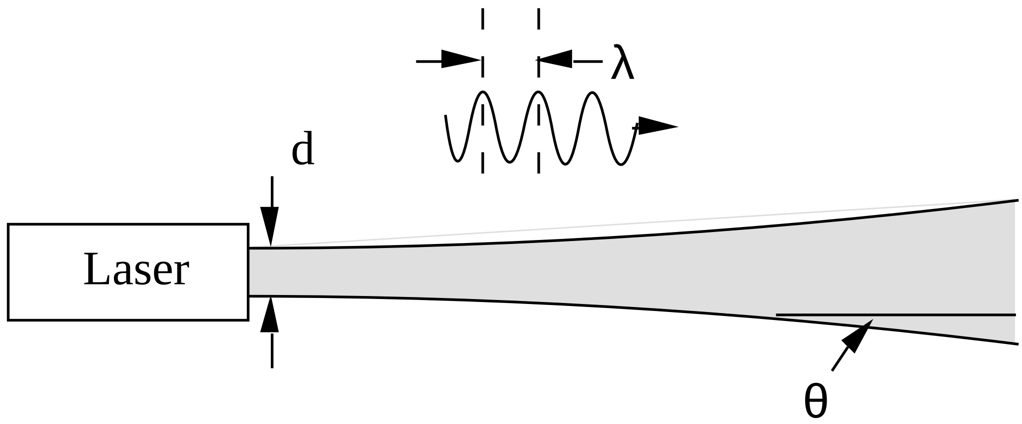
Properties of laser light

Collimation

We observe from a laboratory He-Ne, the output from a laser is well collimated



The far-field diffraction angle is $\theta \approx \frac{\lambda}{d}$ [1]

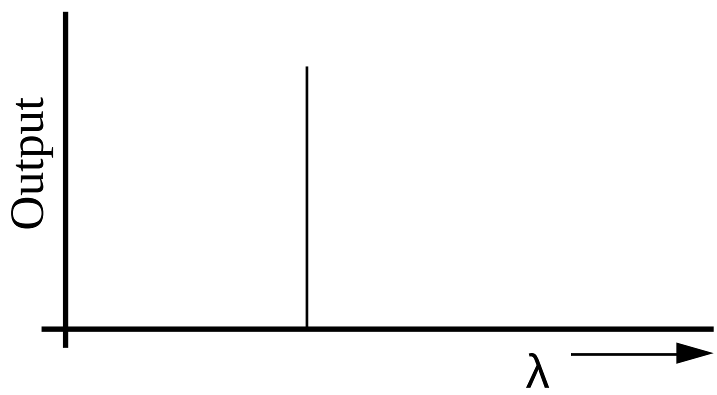
where

d = diameter of output beam

λ = wavelength of laser light

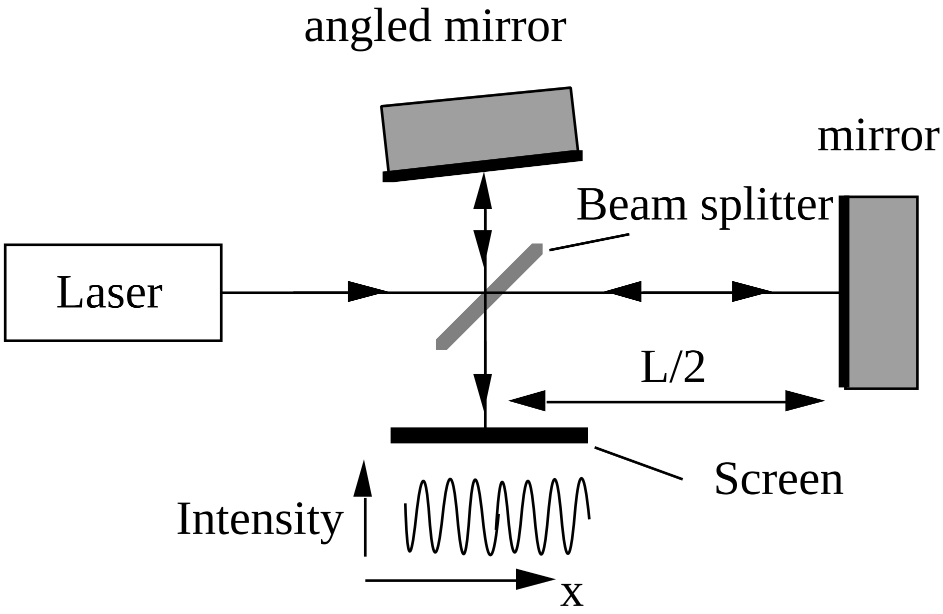
Monochromaticity

If a spectrally pure beam of laser light is examined using a monochromator it is found to comprise narrow range of optical frequencies.



Temporal Coherence

By splitting and subsequently recombining a laser beam after varying path differences, the coherence can be assessed.



Even when L is large, interference fringes are still observed. This tells us the present phase of the light is strongly related to the past phase.

We define length over which fringes are still visible as the **coherence length.** We also define a **coherence time,** where:

Coherence length = Coherence time x c [2]

Coherence time - Optical bandwidth

We know that over the coherence time, the phase of the electric field vector must not 'slip' by more than 2π

By writing the electric field vector as:

$$E = E_0 \sin((\omega_0 + \Delta\omega)t)$$

we can state that the spread of optical frequency (i.e. the bandwidth) $\Delta\omega$

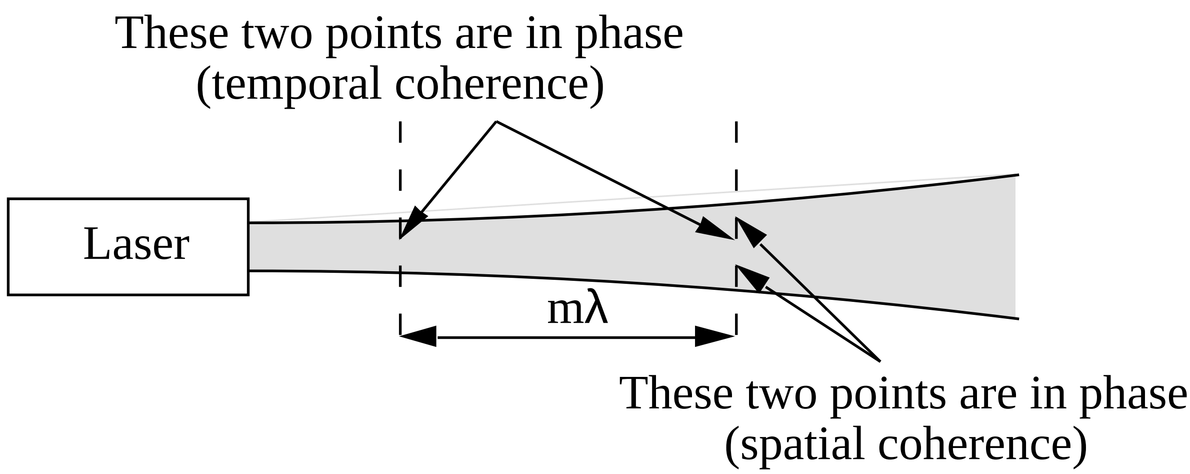
$$\Delta\omega\, t_{coherence} \approx 2\pi$$

i.e. the spread of optical frequencies in the laser beam ($\Delta\nu$) is related to the coherence time by:

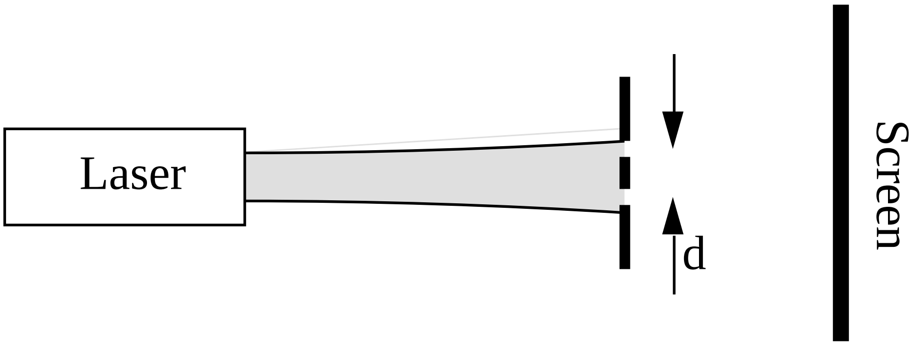
$$\Delta\nu = \frac{1}{t_{coherence}} \qquad [3]$$

Spatial coherence

As well as being temporally coherent, a typical laser beam can be spatially coherent as well.



Spatial coherence can be measured using Young's slits



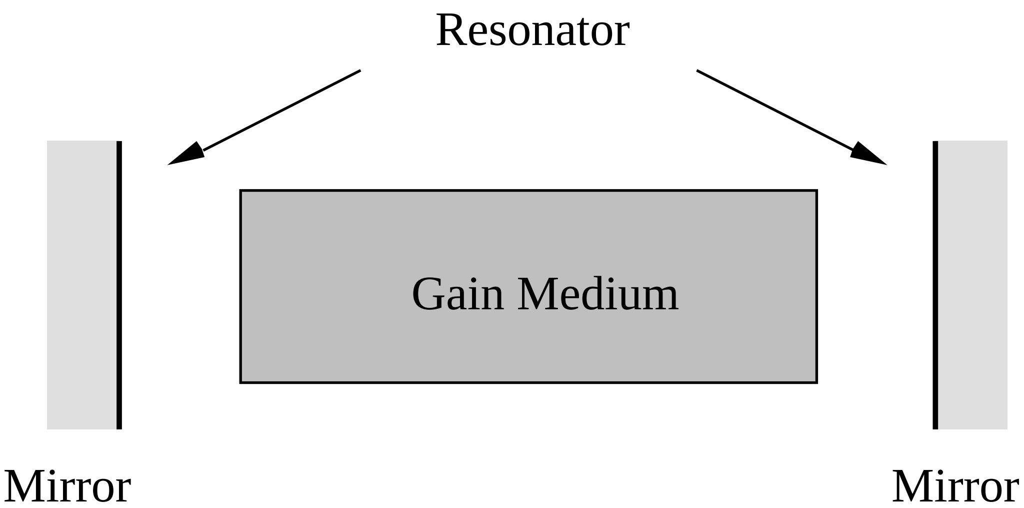
In order to see a high contrast interference pattern on the screen the phase difference between the light at the two slits must be constant. Typically, laser light is found to be spatially coherent across the whole of the beam.

laser action:

There are two components to a laser

Gain Medium (something to amplify the light)

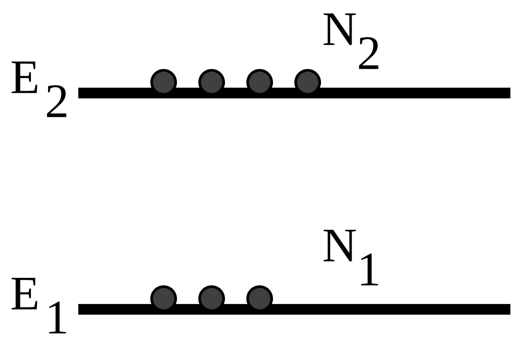
Resonator (something to provide suitable optical feedback)



Gain Medium

Consider two energy levels, E_1 and E_2, with populations N_1 and N_2.

We will use an atomic system in which the electrons occupy well defined energy states.



There are three ways in which this system can interact with light.

Spontaneous emission, Stimulated absorption and emission

An electron in the upper state can spontaneously relax to the lower state and in doing so will emit a photon.

Conservation of energy means the photon energy will equal the change in electron energy, i.e.

$$h\nu = E_2 - E_1$$

where h is Planck's constant

The average time an electron will remain in one state before relaxing is called the lifetime (τ)

The exact time at which the electron "chooses" to relax is totally random and therefore the radiation emitted will be **incoherent.**

Steps to achieve laser action

Stimulated emission will enable us to amplify an incoming stream of photons (One photon in, two photons out).

But, under normal conditions, the ratio between stimulated and spontaneous emission is very poor.