

Concept of Coherence

- When an excited atom, depending on its lifetime at the higher energy level, comes down to lower energy level, a photon is emitted, corresponding to the equation, $h\nu = E_2 - E_1$
- where h is the Planck's constant, ν is the frequency of the emitted photon and E_2 and E_1 correspond to higher and lower energy levels respectively. This type of natural emission occurs in different directions and is called spontaneous emissions. It is characterized by the lifetime of the upper excited state after which it spontaneously returns to lower state and radiates away the energy by emission. Interestingly, apart from spontaneous emission, an excited atom can be induced to emit a photon by another photon of same frequency - i.e. a passing photon can stimulate a transition from a higher level to the lower level, thus resulting in the emission of two photons, which is gain.

The two emitted photons are said to be in phase, which means that the crest or the trough of the wave associated with one photon will occur at the same time as on the wave associated with the other photon. An avalanche of similar photons is created and these photons have a fixed phase relationship with each other. This fixed phase relationship between the photons from various atoms in the active medium results in the laser beam generated having the property of coherence. Since the radiation emitted is by the stimulation process, it is referred to as the stimulated emission and the generation of laser is by stimulated emission.

In the case of spontaneous emission, the emission is natural where as in the case of stimulated emission, it is induced or stimulated. Further there is no amplification in the case of spontaneous emission as well as no phase relationship between emitted photons, as it happens in the case of stimulated emission. But one has to remember that under normal conditions, there is far more atoms in the lower level than in the upper level and as such absorption dominates stimulated emission. In order to reverse this trend, there must be much more atoms in the upper level than in the lower level. This specific condition is called population inversion and is essential for stimulated emission to be in a predominant position for generation of laser. In the case of laser, the stimulated emission process is responsible for the emission of photons and amplification.

Since the emitted photons have a definite phase relationship with each other, coherent output is produced. i.e. the atoms emit photons in phase with the incoming stimulating photons and emitted waves adds to the incoming waves, generating brighter output. Addition is due to the relative phase relationship. Photons of ordinary light also come from atoms without any phase relationship with each other and are not coherent. Therefore, laser is called a coherent light source where as an ordinary light is called an incoherent light source.

There are two types of coherence -
spatial and **temporal**.

Correlation between the waves at one place at different times, or along the path of a beam at a single instant, are effectively the same thing, and are called "**temporal coherence**".

Correlation between different places (but not along the path) is called "**spatial coherence**".