B.Sc Part II (Physics Hons)
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Question: Feind the basic principle of LASER. Sketch & Describe the Construction and working of Ruby Laser with necessary diagram

Ans **LASER:→** The name Laser is an acronym of light amplification by stimulated emission of radiation. A laser is a device that produces an intense, concentrated, and highly parallel beam of Coherent light. So parallel is the beam from a visible light of laser 10cm in diameter that at the moon's surface, 384,000 Km away, the beam is no more than 5Km wide.

Principle:→ Consider a gas enclosed in a vessel containing free atoms having a number of energy levels, at least one of which is metastable. By shining white light into this gas many atoms can be raised from the ground state to excited states. As the electrons drop back many of them will be tapped in the metastable state. If the pumping light is intense enough, we may obtain population inversion.

When an electron from the metastable state can spontantaneously jumps to the ground state, it emits photon of energy $h\nu$. As the photon passes by another nearby atoms to radiate a photon of the exact same frequency and return into its ground state. This stimulated photon has the same frequency, direction and polarisation as the primary photon and exactly the same phase & speed. Both of these photons may now be considered primary waves, and upon passing close to other atoms in their metastable states, they stimulate them to emission in the same direction with the same phase. However, transis transitions from the ground state to the excited state can also be stimulated, thereby absorbing the primary wave. An excess of stimulated emission, therefore requires of population inversion. If the

Condition - is the gas are at right, a chain reaction can be developed, resulting in high intensity coherent radiation.

In order to produce laser one must be collimate the stimulated emission. This is done by introducing an appropriate solid, liquid or gas having metastable states between the two end mirrors of a Febry-Perot etalon. The two mirrors are of high reflecting power and are wide apart. By some means we excite electrons in these atoms and produce a population inversion. If som atoms in a metastable state spontaneously ~~radia~~ radiate, those photons having moving moving at an appreciable angle to the wall of the tube will escape and be lost. Those emitted parallel to the axis will reflect back and forth from end to end. Their chance of stimulating emission will now depend upon a high reflectance at the end mirrors and a high population density of metastable atoms within the tube. If both the conditions are satisfied, the build up of photons surging back and forth through the tube can be self-sustaining and the system will oscillate.

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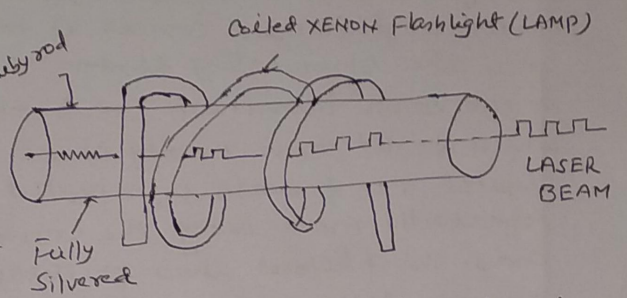
RUBY LASER:→

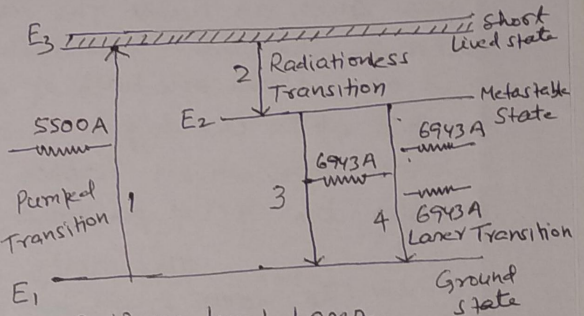
This is the first laser developed in 1960, and is solid state laser. It consists of a pink ruby cylindrical rod whose ends are optically flate & parallel.



one end is fully selvered and other is only partially selvered. upon the rod is wound a coiled flash lamp filled with ~~xn~~ xenon gas.

WORKING:→

In figure, a simplified version of the energy level diagram of Cr ion. It consists of an upper short lived energy level (rather energy band) E_3 above its ground-state energy level E_1



A three level Laser

The energy difference $E_3 - E_1$ Corresponding to a wavelength of about 5500 A°. There is an intermediate excited state level E_2 which is metastable having a life time of 3×10^{-2} sec.

Normally, most of the Cr ions are the ground state E_1, when a flash of light falls upon the ruby rod, the 5500 A° radiation photons are absobed by the Cr Cr ions which are pumped to the excited state E_3. The transition 1 is the (optical) pumping transition. The excited ions give up, by collision, part of their energy to the crystal lattice and decay of metastable state E_2. The corresponding transition 2 is thus a radiationless transetion. Since the state E_2 has a much longer life time, the number of ions in this state goes on increasing while due to pumping, the number in the ground state E_1 goes on decreasing. Thus population inversion is established between the metastable (excited) state E_2 and the ground state E_1.

when an (excited) ion passes spontaneously from the metastable state to the ground state (transition 3), it emits a photon of wavelength 6943 A°. This photon travels through the ruby rod and it is moving parallel to the axis of the crystal is reflected back and forth by the silvered ends until it Stimulates and excited ion and causes it to emit a fresh photon in phase with the stimulating photon. This stimulated transition 4 is the laser transition. The photon emitted spontaneously which do not move axially escape through the sides of the crystal. The process is repeated again and again due to photons repeatedly move along the crystal being reflected from its ends. The photons thus multiply, when the photon beam becomes sufficiently intense. Part of it emerges through the partially-silvered end of the crystal.

There is a drawback in the three levels laser such as ruby. The laser requires high pumping power because the laser transition terminates at the ground state, and more than one half of the ground state atoms must be pumped up to the higher state to acheive population inversion. Moreover, ions which happen to be in their ground state absorbs, the 6943 A° photons from the beam as it builds up.

The ruby laser is "pulsed" laser. The active medium (Cr^{+++} ions) is excited in pulses and it emits laser light in pulses.