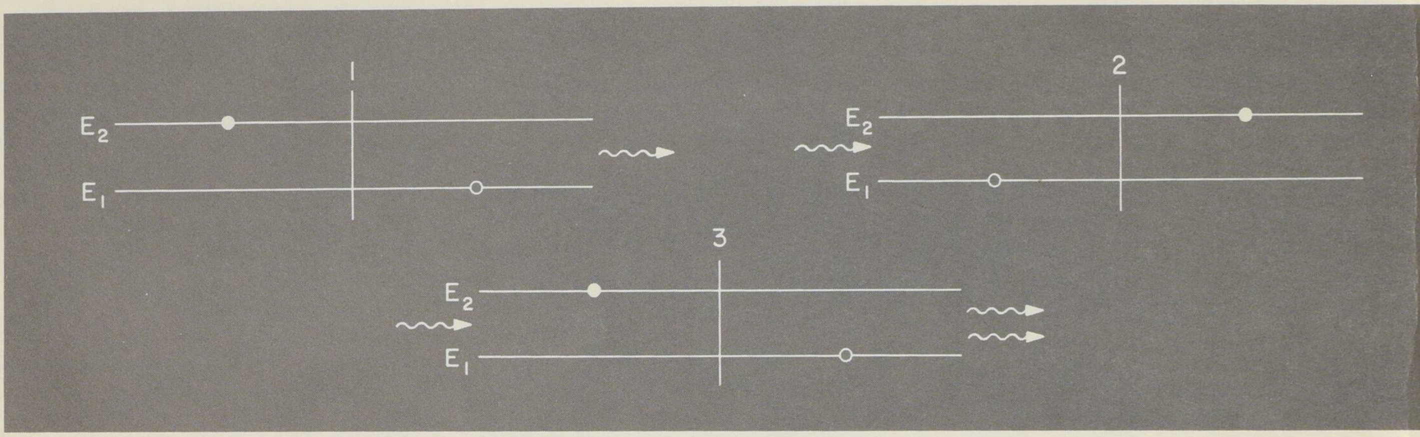

Graphic representation of (1) spontaneous emission (2) absorption and (3) stimulated emission of photons. In the first case, an atom (or molecule) raised by some means to a higher energy state (dot, top left) can emit a photon spontaneously (wavy arrow) and revert to its ground state (circle at right). On the other hand (2) an atom in its normal state (left) may absorb a photon and be raised to a higher state (right). Lastly (3) an atom excited by some means (left), if struck by a photon, can be stimulated to emit a similar photon (right); it then returns to a lower energy state. This process is at the heart of the laser.

Graphique de (1) l'émission spontanée (2) l'absorption et (3) l'émission stimulée des photons. Dans le premier cas, l'atome (ou molécule) excité d'une façon ou d'une autre à un état d'énergie supérieure (point, en haut à gauche) peut émettre spontanément un photon (flêche ondulée) et passer à un état inférieur (petit cercle, à droite). D'autre part (2) un atome non excité (à gauche) peut absorber un photon et passer à un niveau d'énergie supérieure (à droite). Enfin (3), un atome excité d'une manière ou d'une autre (à gauche) si stimulé par un photon, émettra un photon semblable au premier (à droite); ensuite, il revient à un état d'énergie inférieure. Voilà le procédé-clé du laser.

"h" is Planck's constant and "n" is the frequency of the associated radiation.

The next part of this puzzle was unravelled by Einstein in 1917. He was impressed with the breakthroughs of Planck and Bohr, and aside from his work on relativity, he took up the cudgels to extend their ideas regarding the emission and absorption of quanta as electrons jumped from one energy level to another. Einstein pointed out that three possible changes could occur. Two of these were already well known. The third was to give science the laser:

1) Spontaneous Emission

Since there is always a tendency for electrons to be at their lowest energy levels (the atom is then said to be in its "ground state") an electron excited to a high level by any means (the atom being then in an excited state) will jump down spontaneously to a lower level and in so doing will emit a photon.

2) Absorption

An electron at a low level will absorb a photon and, with this extra energy, jump to a higher level.

The third possibility was advanced theoretically by Einstein himself.

3) Stimulated Emission

An electron at a higher-than-normal energy level will, if struck by a photon, be stimulated to emit its own photon and fall to a lower level. The photon emitted, Einstein predicted, would be similar to the incident photon, travelling in the same direction, being in phase with it, and having the same frequency associated with it. In short, the photon would have multiplied.

Such was Einstein's contribution; as often was the case, however, his theories were a leap into the unknown. Although Einstein clearly established the theoretical basis for stimulated emission, physicists were incapable of demonstrating it experimentally for almost three decades. Competition from the spontaneous emission of photons and from the absorption of photons was too keen and thwarted attempts to detect this phenomenon in the laboratory.

In 1954, a physicist at Columbia University discovered how to demonstrate Einstein's idea and thereby catapulted science into the laser era. For three years Charles Townes had painstakingly examined Einstein's theory and the barriers to its confirmation. By careful planning and experimentation he was able to weed out these hindrances. In fact he succeeded in the improbable task of singling out excited molecules of ammonia and segregating them. This was the key step. His experiments to produce stimulated emission from these excited molecules were successful. The emission was triggered not by radiation from an outside source but by the first photons to be emitted spontaneously from the excited ammonia molecules; it was encouraged and built up by the clever use of the tube containing the ammonia as a kind of "echo chamber" for the increasing number of quanta, reflecting them back and forth to strike the diminishing population of already excited molecules and thereby inducing emission until a very high intensity was reached in a fraction of a second. The resulting radiation was in the microwave region of the electromagnetic spectrum. Hence Townes had effected microwave amplification by the stimulated emission of radiation – he had produced the "maser".

And in particular when this radiation can be made to fall in the visible spectrum, as Townes and his brother-in-law Shawlow predicted in 1958, when it emerges as a colored light, as Maimon witnessed for the first time in 1960, then the instrument producing it is called an optical maser. Since it produced Light Amplification by the Stimulated Emission of Radiation, the optical maser has another more common name, the laser. Four Nobel prizewinners and 60 years later and the puzzle was solved.