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SOME CONSIDERATIONS ABOUT LASER WELDING

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Abstract: *This article is intended to show the basic principles and the actual status of metal welding with the help of laser beam technology.*
Key words: *Nd: YAG, CO2, pulsed laser, beam, laser welding, stimulated emission*

1. INTRODUCTION

In 1917 well known scientist Albert Einstein stated the theory that the "stimulated emission" is possible. Following this theory, and explaining the photoelectric effect, he won the Nobel Prize. Although, we cannot said that Einstein was the inventor of the laser, by his researches he was the one who was the pioneer in discovering the laser. Laser means Light Amplification by Stimulated Emission of Radiation. [4]

First laser ever built by Theodore Maiman in 1960, based on an older study made by Charles H. Townes, it was using a ruby bar. Light produced by a flash light with a particular wave length, has excited the ruby atoms, reaching high energy levels. Excited atoms returned quickly to lower energies (by means of photons reactions) and then slowly to fundamental state, emitting light with particular wave length. Light was reflecting back and forth between the bar ends, stimulating the emission. 1964 will be the reference for the laser development, being the year when the scientists Townes, Basov and Prokhorov won the Nobel Prize for researches regarding microwave and optical laser. [4]

2. GENERAL CONSIDERATIONS

2.1 Description of the process

The laser process consists of light amplification by stimulated emission of radiation. The laser beam is obtained with the help of a substance called active environment, which was first brought to a superior energy state, by means of energy transfer from outer substance, in a process, of so called, energy pumping.

On the thermal stability atomic systems, light stimulated absorption is dominant, because there are a greater number of atoms on lower energy state than atoms on higher energy state. In order to have predominant stimulated emission of radiation, it is mandatory to change the thermal equilibrium in such a manner that we will have more atoms on higher energy state then on lower ones. [4].

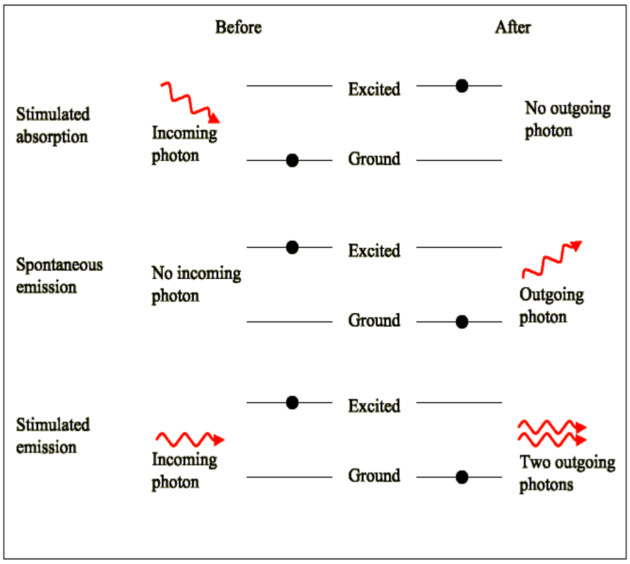

Fig. 1 Light – matter interaction [1]

Laser is a complex device which uses a laser active environment, which can be solid, liquid or gaseous, and a resonant optical cavity. The active environment, with a well determined composition and parameters, receives outside energy by pumping. Pumping is realized optical or electrical, by using a source of light (flash, another laser, etc.) and leads to atoms exciting from the active environment, i.e. bringing of some atoms, from the active environment, on higher energy levels. As against an environment in thermal stability, this pumped environment will have more electrons on higher energy levels, phenomenon called population inversion. A beam of light which passes this activated environment will be amplified by stimulated atoms unexciting. In this process one photon which interacts with one excited atom results in emitting a new photon, on the same direction, same wave length, phase and polarization. So it is possible by starting from a single photon, generated by spontaneous emission, to obtain a beam with a huge number of photons, all of them having same characteristics with the initial one. [4]

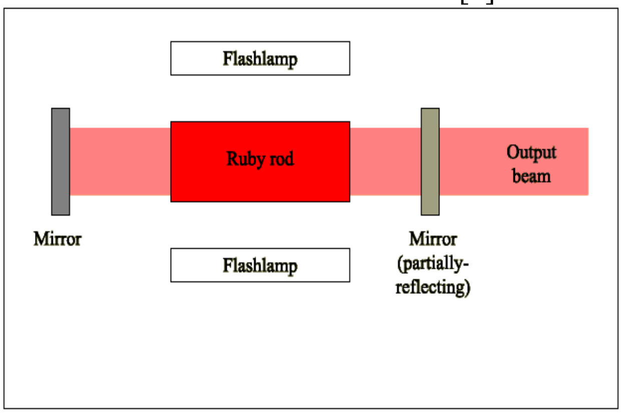

Fig. 2 Laser constructive principle [1]

2.2 Type of lasers

There are several classifications of the lasers, as follows:

a) By the state of aggregate of active environment. First laser classification criteria refer to the active environment where the pumping and stimulated emission occurs. So lasers can be:
   - Solid state lasers: ruby laser, Nd:YAG laser, semi-conductor lasers.
   - Liquid lasers: dye lasers.
   - Gas lasers: CO2 lasers, Ar lasers, N2 lasers.

b) By the radiation wave length, lasers can be:
   - Infrared emitting lasers: CO2 lasers.
   - Visible spectrum lasers: Ar lasers.
   - Ultraviolet emitting lasers: excimer lasers.
   - X-ray emitting lasers.

c) By radiation emitting time:
   - Continuous lasers.
   - Pulsed lasers: emitting radiation pulsed, with periods which can reach very low values. [4]

3. PROCESS PRINCIPLES

Generally, there are two types of lasers that are being used for welding operation: CO2 and Nd:YAG. Within the scope of this article, we will not delve into the actual laser theory since our real interest is in using the output laser light for welding.

Both CO2 and Nd:YAG lasers operate in the infrared region of the electromagnetic radiation spectrum, invisible to the human eye. The Nd:YAG provides its primary light output in the near-infrared, at a wavelength of 1.06 microns. This wavelength is absorbed quite well by conductive materials, with a typical reflectance of about 20 to 30 percent for most metals. The near-infrared radiation permits the use of standard optics to achieve focused spot sizes as small as .001" in diameter.

On the other hand, the far infrared (10.6 micron) output wavelength of the CO2 laser has an initial reflectance of about 80 percent to 90 percent for most metals and requires special optics to focus the beam to a minimum spot size of .003" to .004" diam. However, whereas Nd:YAG lasers might produce power outputs up to 500 watts, CO2 systems can easily supply 10,000 watts and greater. [2]

3.1 Laser calculation

Knowing the size of the focused spot is helpful in calculating energy density at the work surface. [2]

For a fundamental mode (TEM00) beam:

$S = (4\lambda /) \times (F / D)$ (2)

where: In performing a laser weld, optics to focus the laser beam to the desired size are necessary.

S = Focused Spot Diameter; λ = Laser Wavelength; F = Focal Length of Objective Lens; D = Diameter of Laser Beam.

For a multimode beam: S = F · Φ
where: F = Focal Length of Objective Lens
Φ = Laser Beam Divergence
If one assumes the part to be welded as a semi-infinite solid, with a constant incident heat flux, then the temperature distribution as a function of depth into the material is given by:
T(x,t) = (2E/K) × [(kt/)½× exp(-x2/4kt) - (x/2)erfc(x/2(kt)½)] (2)
where: T(x,t)=Temperature at a distance x below the work surface, at a time t after start of constant heat input; E = constant heat flux input; K = thermal conductivity; k = thermal diffusivity; x = depth below surface; t = time after start of heat flux input; erfc = complimentary error function; and at the surface (x=0), the temperature rise will be: T(x,t)x=0 = (2E/K) × (kt/)½ (2)

3.2 Laser welding factors

Thermal diffusivity, mentioned in the above calculations, is a measure of the ability of the material to conduct heat. The lower the diffusivity, the more the heat remains in the vicinity of the laser beam spot.

Metals with low boiling points produce a large amount of metal vapor which could initiate gas breakdown and plasma generation in the region of high beam intensity just above the metal surface. This plasma, which readily absorbs the laser energy, can block the beam passes, and bubbles tend to form at the root of the weld. If the viscosity is high, these bubbles do not escape before the molten metal solidifies. [2]

4. APPLICATIONS OF LASER WELDING

4.1 Automotive

Typical applications are the welding of side walls, doors and door steps, roof joints, floor groups, the front of the vehicle and hood parts.
Designs assuming laser fabrication can reduce flanges, enlarge window openings, increase rigidity and save material. The material savings don't just help reduce costs; they also improve mileage and the CO2 efficiency of the vehicle.
Laser welding is faster than conventional welding technology and especially interesting for large series. Galvanized sheet metal in an overlap configuration can be welded reliably with laser dimpling. Remote scanner optics combined with laser pulses make small craters near the weld zones forming a gap that allows the vapor to escape resulting in excellent weld quality. [3]

Fig. 3 Laser welding of a vehicle [3]

4.2 Electronics

In the production of mobile phones, the laser is used in many ways. Pulsed lasers trim the deep-drawn housing on a 3D laser processing system and cut keypad holes and penetrations. Housing parts in the interior and lithium ion batteries are precision-welded by pulsed lasers. Nearly all keypads are marked with lasers. Frequently, the plastic cover that protects the display is fastened to the shell of the phone by a laser.

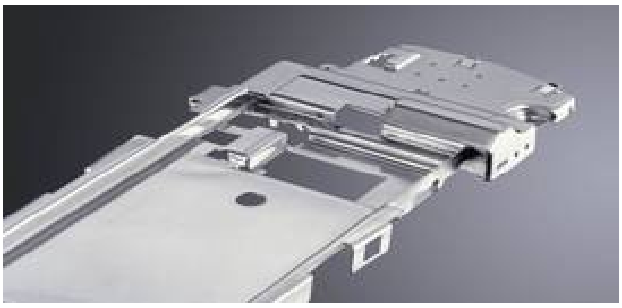

Fig. 4 Mobile phone housing [3]

4.3 Medical technology

Whatever the application - the production of endoscopes, medical instruments or implants -

lasers work with speed, precision and repeatability. The result is the highest quality. Some products could not be made without lasers, such as pacemakers. The laser welds the titanium housing air tight, with no porosity and without the need for refinishing.

Fig. 5 Spot welding of a laser marked heart pacemaker [3]

4.4 Photovoltaic's

Hair-thin conductors, thin film layers and drill holes accurate to the micrometer: The success of solar power rests on tiny features
Dosing of the circumference in production automatically yields short circuits on the front and back sides. In laser edge insulation, the laser makes a separation line at speeds of over 700 millimeters per second, which eliminates the short circuit.

5. CONCLUSION

Despite laser welding is an expensive manufacturing process; we can't neglect the main advantages which are:

- accurate welding with high precision in placing of the energy spot
- welding of complicated joint geometry
- low heat applied, therefore minor changes in microstructure
- low thermal distortion
- no cavity welds
- possibility of welding from big distances, and on hard to reach points.

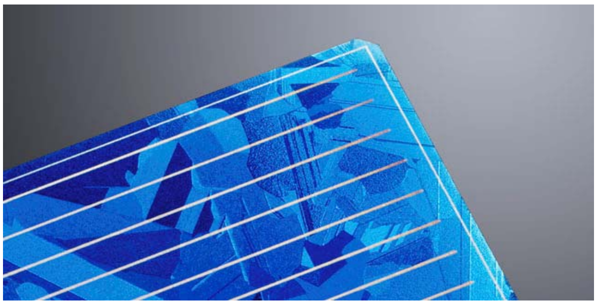

Fig. 6 Laser edge insulation on a polycrystalline solar cell. [3]

6. REFERENCES

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Cateva consideratii referitoare la sudura laser

Rezumat : Lucrarea prezinta principiile de baza si stadiul actual de aplicare a sudurii metalelor cu ajutorul tehnologiei cu fascicul laser.

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