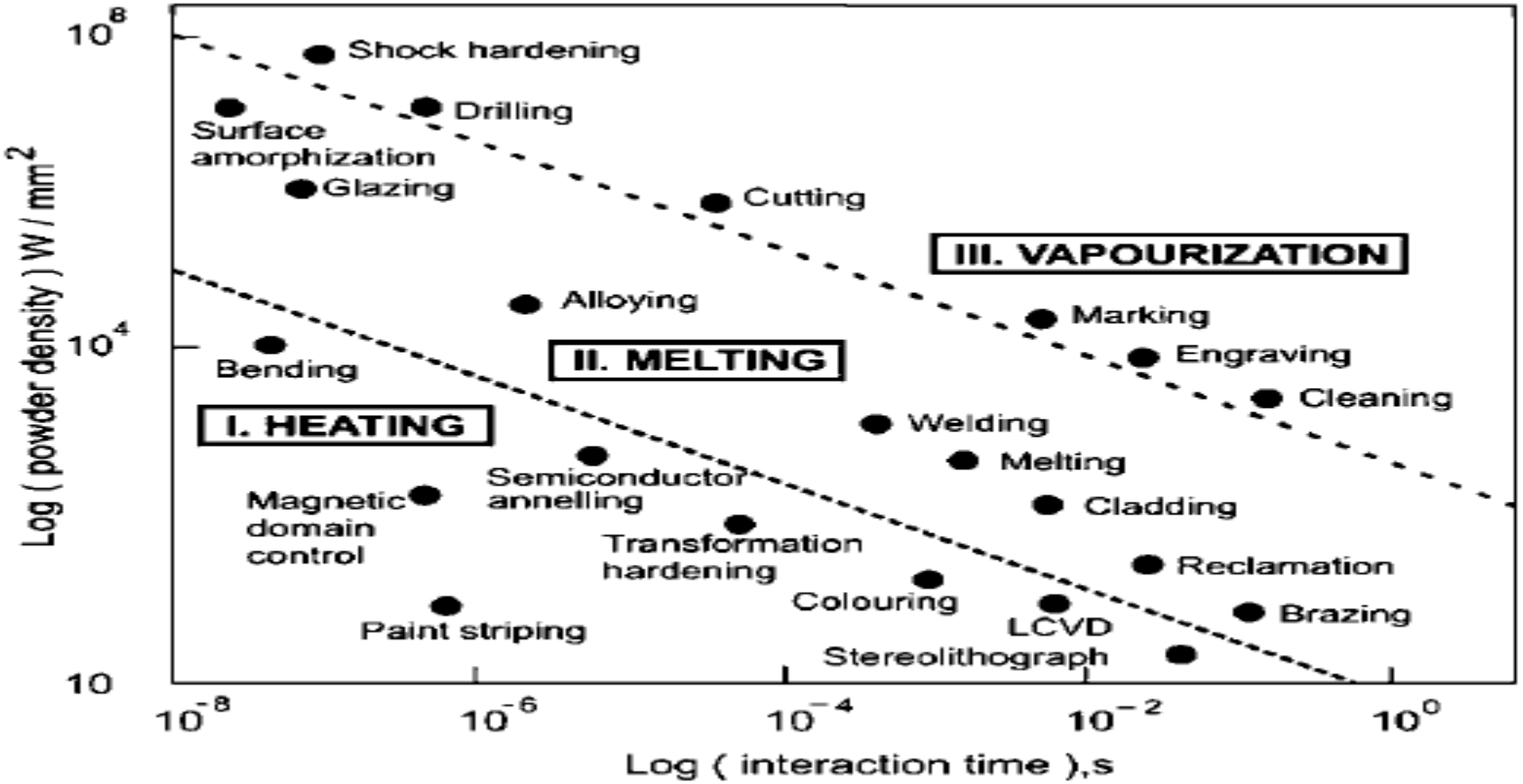
Laser Material Processing(LMP)

Lecture 4

Conclusions Remarks

-From pervious lecture we can conclude that:

Combination of laser power density and interaction time can produce different types of laser material processing involving either no (only heating) or change of state (melting or vaporization).



Laser material interaction

-When a laser beam strikes on the target material, part of the energy is reflected R , part of the energy is transmitted T and part of it is absorbed A.

-The effective energy is the portion of energy actually absorbed by the target

-The relation for surface absorption of laser energy is:

$$A = 1 - R - T$$

- Where A is the surface absorptivity, R is reflection, and T is transmission.

-For opaque material(e.g. metals), $T = 0$, then

$$A = 1 - R$$

Laser material interaction

- The predominate phenomena A or T or R **depends on:**

-Material type,

-Its temperature,

-Surface conditions, and

-Light parameters.

Laser material interaction

-Material type

- For example, the values of thermal diffusivity for Al and Ti, are 0.91 and 0.092 cm^2/sec, respectively, thus Al will dissipate heat from the treated area at a rate approximately 10 times than that of Ti

-Its temperature,

- With temperature increase the laser-electron energy exchanges increase and thus absorptivity increases see Fig. below.
- Remember that for metals $A = 1 - R$

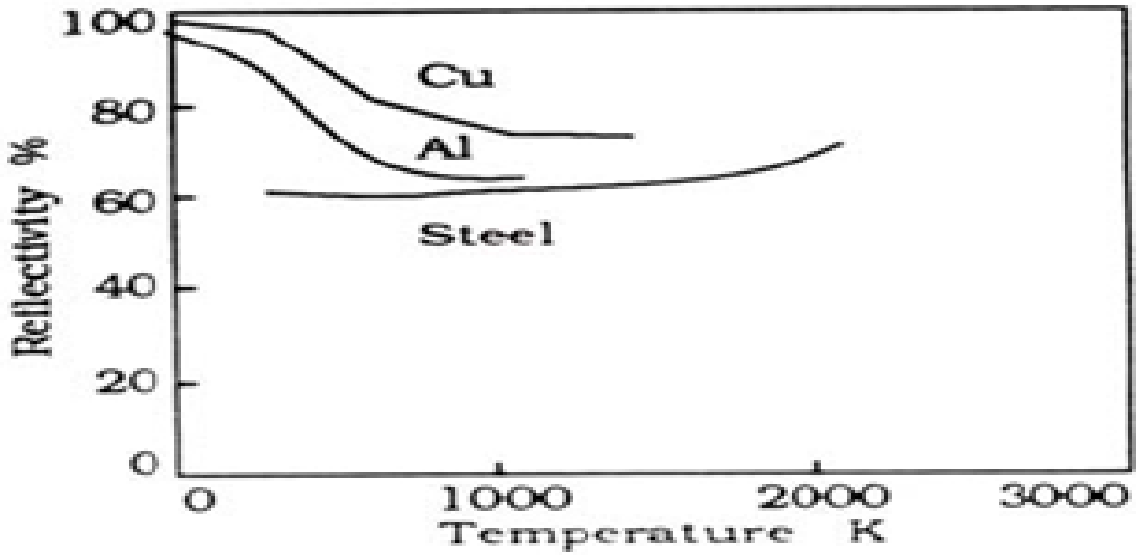


Fig. *Reflectivity vs. temperature for different metals*

Laser material interaction

-Actually absorption increases from less than 5% as a solid metal to more than 95%, with temperature increases from room temperature to boiling temperature of the material.

-Preheating the surface of material improves its absorptivity , thus enhancing laser coupling and interaction.

-Surface conditions

-Surface conditions have important role in absorption of the incident beam, thin layers of oxides increase the absorptivity,

-Increase roughness of the surface, can enhance its absorptivity,

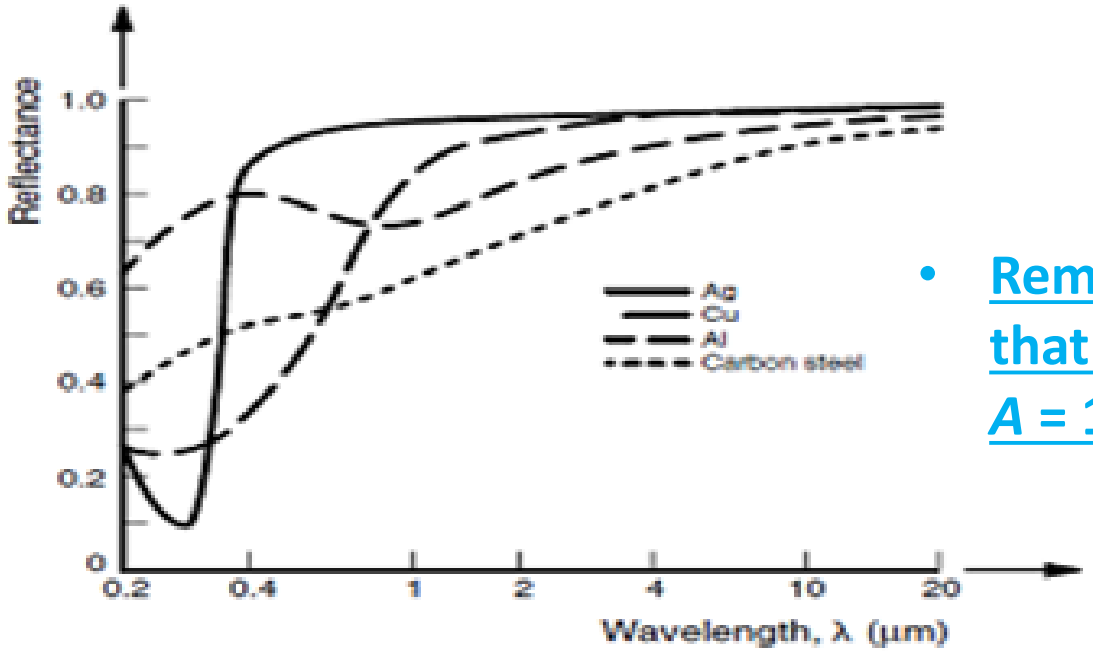
-If the roughness of the surface is less than the beam wavelength the surface is considered as flat.

Laser material interaction

-Light parameters.

-Shorter laser wavelength consider advantage, because it is absorbed more efficiently by materials(less reflected by surface), where the laser photons are more energetic and therefore can be absorbed by more electrons see Fig. below

For example, copper has an absorptivity of 2 percent for CO2 lasers (Wavelength = 10.6 um), but it has much higher absorptivity for UV lasers (Wavelength = 0.2 um) (about 60 percent)



- **Remember that for metals** ***A* = 1- *R***

Fig. *Reflectance vs. wavelength for different metals*

Laser material interaction

-In material processing, The laser energy is absorbed by free electrons first as illustrated by Fig. below

-The absorbed energy TL propagates through the electron subsystem Te , and then is transferred to the lattice ions Ti .

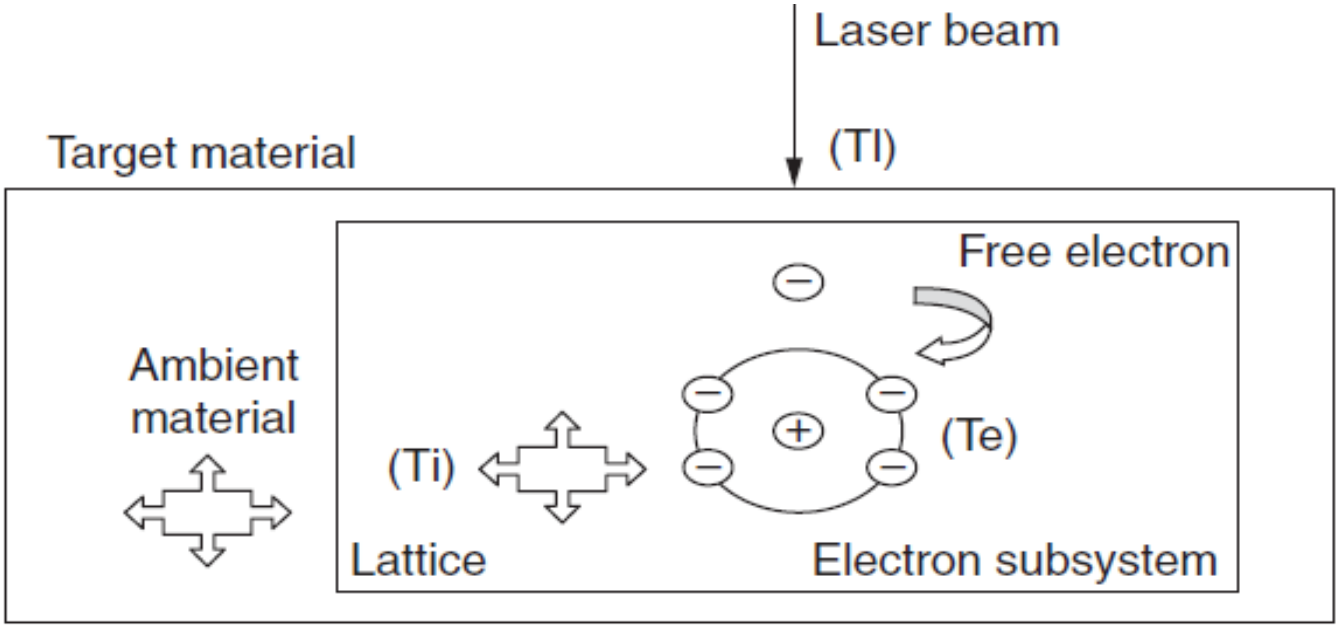


Fig. *Laser energy absorption by target material.*

-In this way laser energy is transferred to the ambient target material.

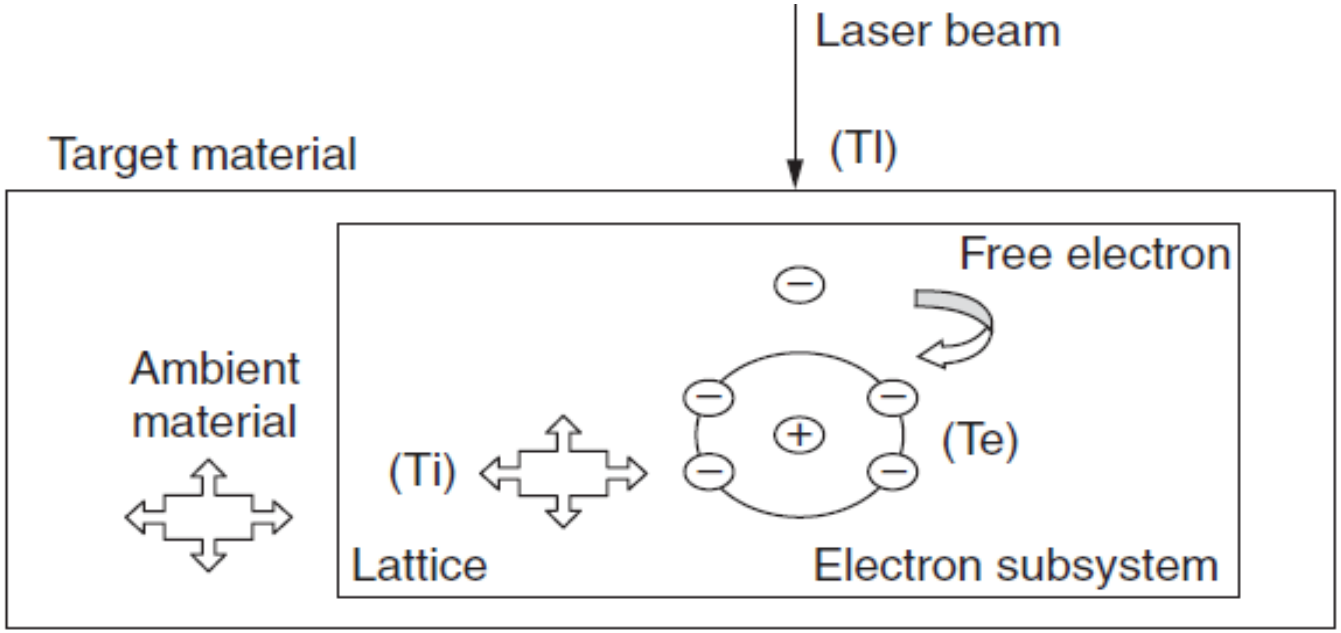
Laser material interaction

-The conversion of the absorbed energy TL to heat in metals involves:

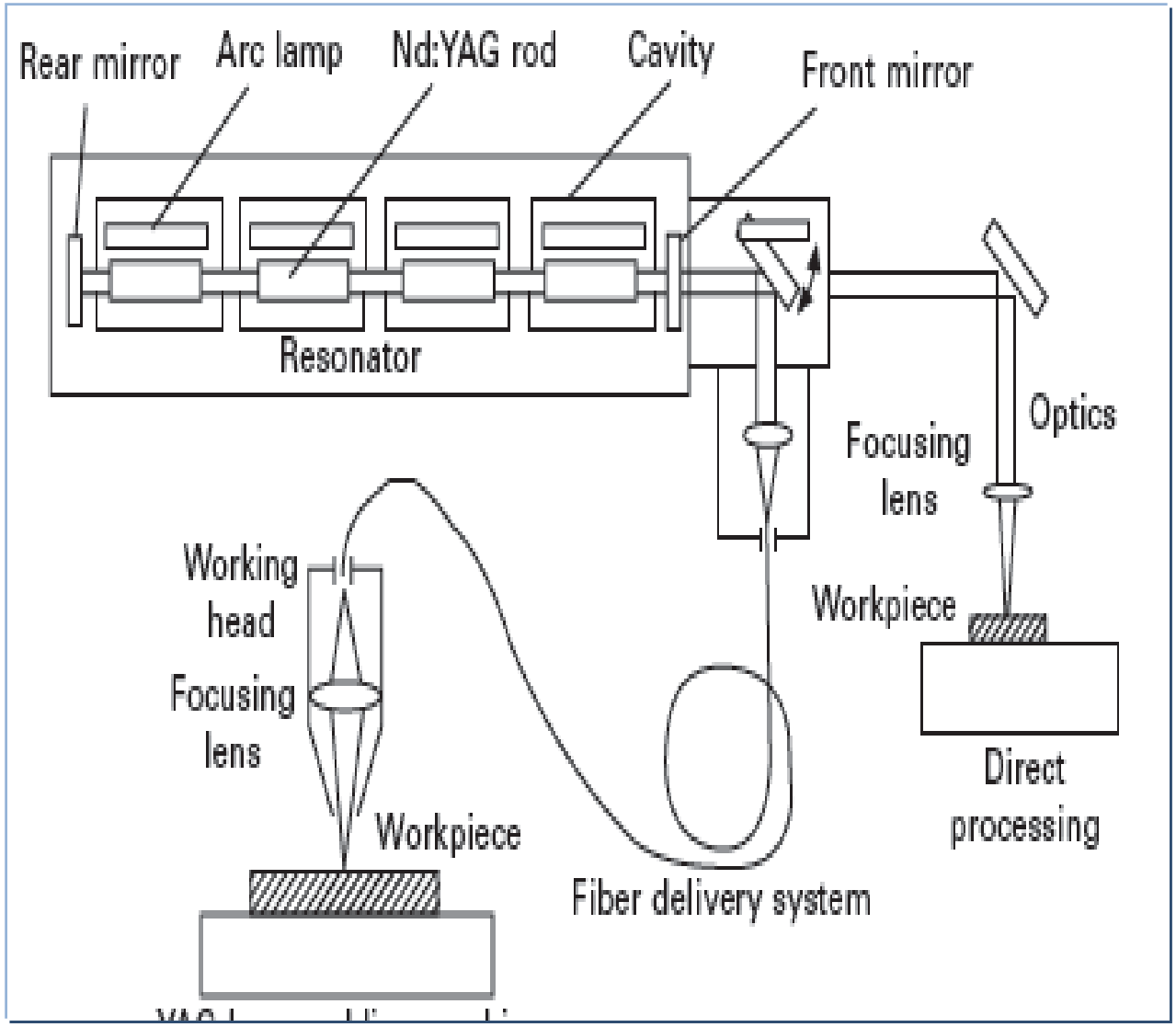
-(a) excitation of free electrons in metals (Te),

-(b) excited electron (Te) gives up this energy through collisions with metal wave lattice (phonon Ti) within a time of 10^{-11} to10^{-12} s,

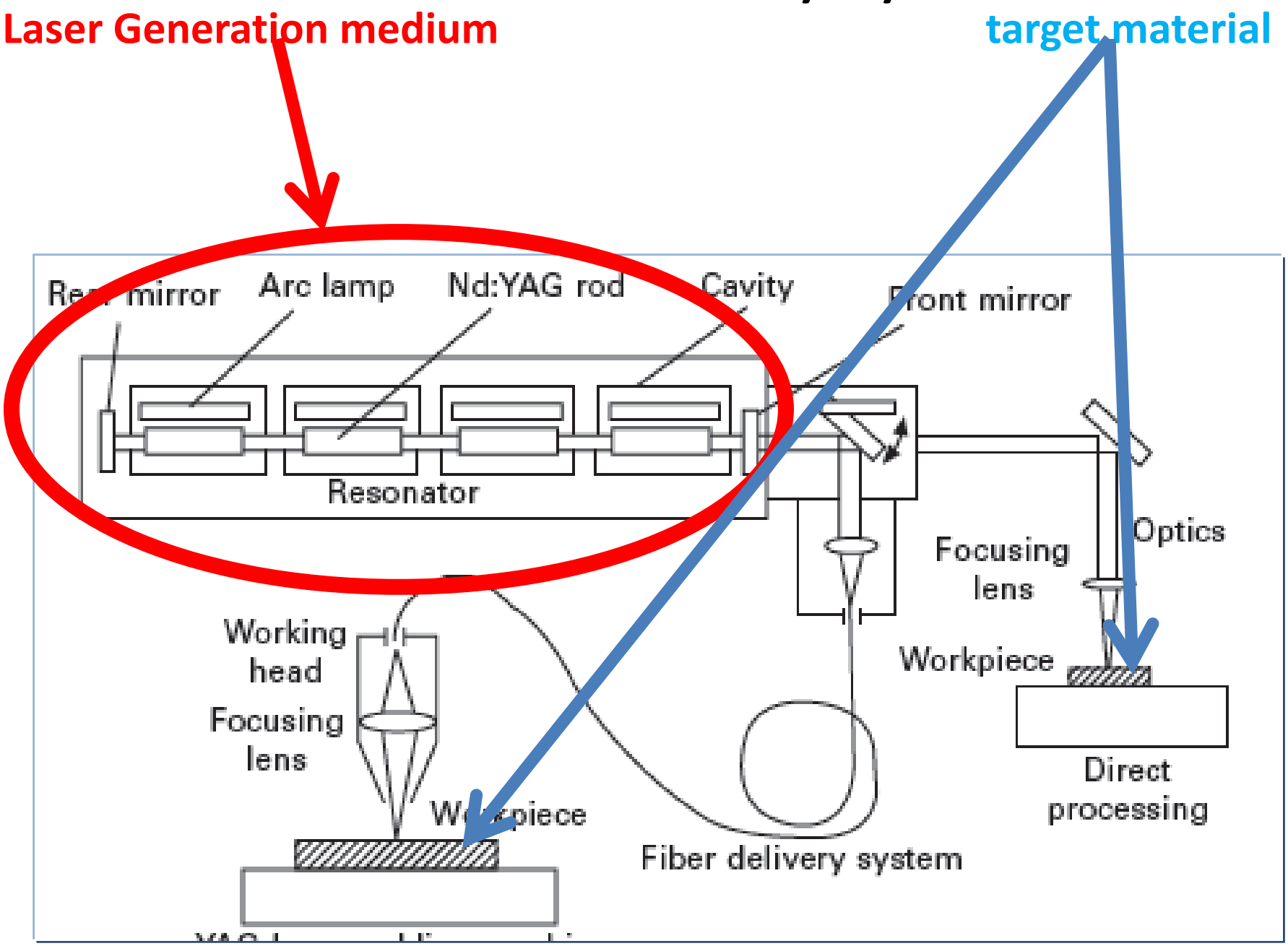
(c) electron (Te) collides with other electrons (Te of another close atom) .



Transferring of the laser Beam



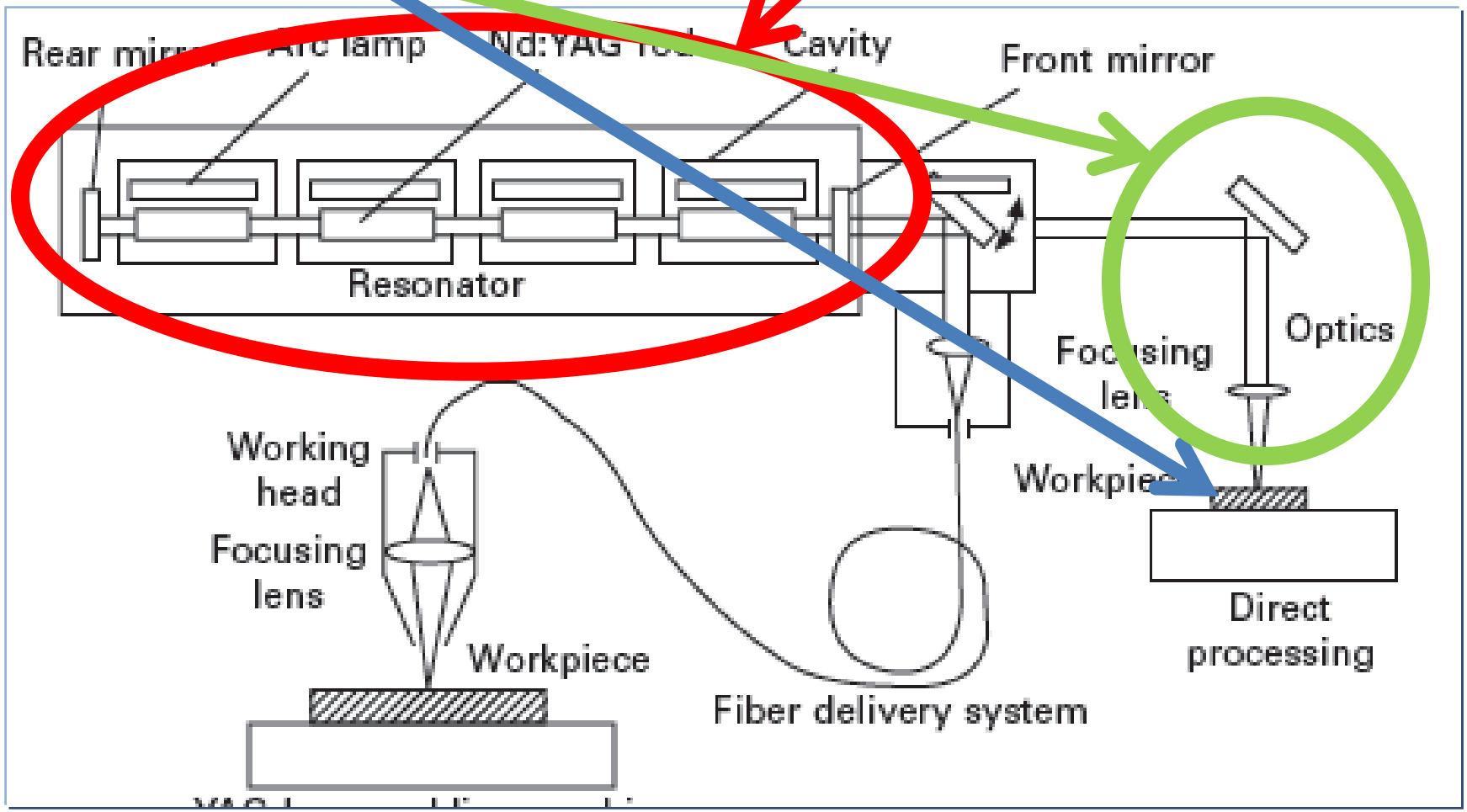
Laser beam delivery systems



Laser beam delivery systems

-Laser beam can be transferred from the **generation medium** to the **target material** by tow ways:

1- **Optics**, such as driven mirrors reflect/deflect the laser beam onto the desired location on the target



Laser beam delivery systems

-Laser beam can be transferred from the **generation medium** to the **target material** by tow ways:

2- Fiber waveguide: Laser beam is coupled into the fiber or the flexible waveguide,

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