

CO2 Laser Basic Knowledge

Materials & Possibilities of Processing



CO2-Laser TA020
mit Linsenteleskop

Taufenbach Laser · developed and produced in Germany
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White Paper: Lambert-Beer's Law in the CO₂ Laser Material Processing

Lambert-Beer's law describes the exponential decrease in the intensity of radiation as it passes through an absorbing medium. It is a central principle for material processing with CO₂ lasers, as it explains why the energy in organic and polymer materials is so effectively absorbed at the surface.

1. Basics

The equation in its general form is:

$$I(z) = I_0 \cdot e^{(-\alpha \cdot z)}$$

The following applies: $I(z)$ = intensity after a material layer of thickness z , I_0 = Initial intensity, α = absorption coefficient [1/length], z = layer thickness.

Physical significance

The law describes that for each additional layer thickness, the same fraction of the intensity is absorbed. This results in an exponential drop. For CO₂ laser radiation ($\lambda = 10.6 \mu\text{m}$) means that many organic materials such as wood, Plastics or glass absorb the energy even in very thin Surface layers.

2. Example calculation with 20 W CO₂ laser

A CO₂ laser with an output power of 20 W hits a polymer with Absorption coefficient $\alpha = 1000 \text{ cm}^{-1}$. The layer thickness is $z = 50 \mu\text{m} = 0.005 \text{ cm}$.

Calculation:

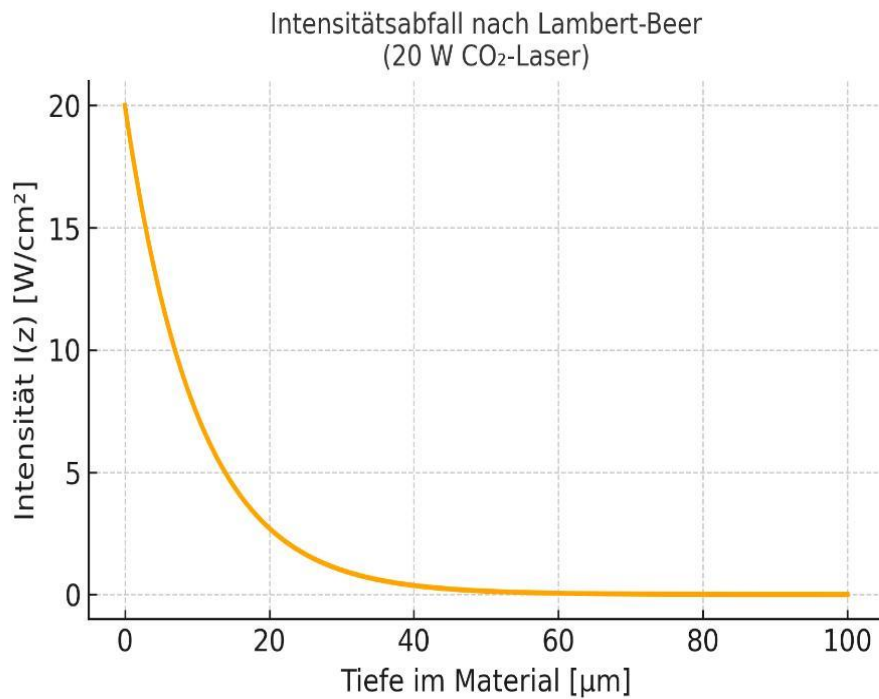
$$I(z) = 20 \cdot e^{(-1000 \cdot 0.005)}$$

$$I(z) = 20 \cdot e^{(-5)}$$

$$I(z) \approx 0.13 \text{ W/cm}^2$$

The result shows: After only 50 μm , only 0.7 % of the original Laser intensity. Almost all of the energy is absorbed on the surface – ideal for precise cutting, engraving and marking.

Visualization of the drop in intensity



3 . Practical relevance for CO₂ laser processing

Lambert-Beer 's law provides the physical basis for many Applications in material processing:

Material	Absorption behavior at 10.6 μm	Practical consequence
Wood / Paper	Very high absorption due to OH and clean CH bindings	cutting & Engrave
Plastics (e.g. PMMA)	Strong absorption by C=O groups	Precise removal, clear Edges
Glass	Absorption by Si–O–Si oscillations	Targeted scribing or Marking possible
Metals	Very low absorption, strong Reflection	CO ₂ lasers mostly unsuitable without Pretreatment

4 . Result

Lambert-Beer's Law impressively shows why CO₂ lasers are the method of choice for processing organic and polymer materials: The energy is concentrated in a thin surface layer, which enables precise, efficient and material-friendly processes . This makes the CO₂ laser an indispensable tool in modern industrial material processing.

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