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Development of a Solid-state Laser for Metal Marking Equipment

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Abstract: Laser radiation has many unique properties, such as highly focused, beam profile and selectable monochromatic wavelength, that suitable for many application in industry, biology technology as well as environmental processing. National Center for Laser Technology have developed the laser devices with application-oriented in the Industry is one of the key directions of us. With the active support of National Center for Technological Progress, we have successfully studied and mastered the technology to manufacture the laser equipments for industrial applications. In this report, we will introduce the technologies in the industrial laser equipments and the customers are trusting.

Keywords: Industrial laser, Nd:YAG laser.

1. Introduction

Material processing effectiveness depends on the ability to absorb laser energy and interaction time of laser radiation. Therefore, the possibility of engraving on the different metal materials mainly depends on the optical-thermal properties of metallic materials. Using high-power laser pulses can reduce the reflectivity of surface of metal parts and can choose the suitable power of the laser radiation to resolve technology issues. Technology of engraving on metal material selected from the optical-thermal changing process of the material is shown in Figure 1 diagrams.

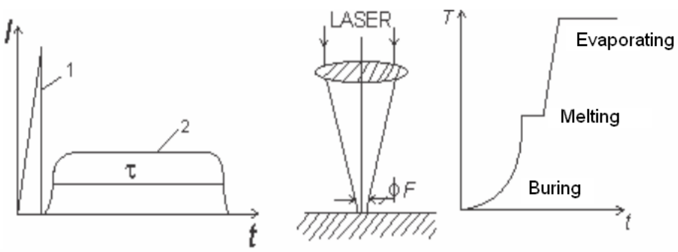

Fig 1. The changing of temperature of focused laser beam: 1 – start pulse, 2 – processing pulse.

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The intensity and the width of laser pulse specify processing technology: burning, melting and evaporating. Size of heat affected zone on the surface is defined by the dimensions of focused laser beam. Comparing with conventional machining methods, main advantage of the laser processing is capability of burning locally material in a few microns size to a high temperature in a very short time.

The spatial distribution of radiation flux density in the focused point depends on the convergence angle distribution of laser radiation intensity at different distances. Hence the other parameter of the laser radiation that affects material marking technology is the size and depth of the laser beam convergence point. To focus laser beam, it often use the lenses having the objects focal of 200-300 mm and diameter of 10-20 mm. The diameter of the laser beam at the focus point is calculated as following:

$$1/W_f^2 = (1/W_0^2).(1-d_0/f)^2 + 1/(f.\theta)^2 \quad (1)$$

If angle θ is very small:

$$W_f = f.\theta \quad (2)$$

W_0: radius at the waist of laser beam,

W_f: radius at the focus point,

d_0: size of laser beam,

f: focal length,

θ: beam divergence angle.

It is found that when increasing d_0 or decreasing f will also reduce the focus spot size. Typically, it requests spot size of about 10μm - 0.1mm will meet the metal materials engraving technology.

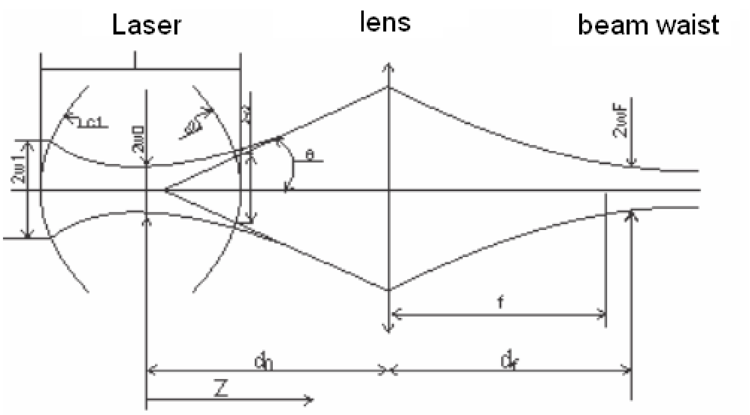

Fig 2. The focusing of laser beam TEM00.

One other important parameter characterizing the size of laser spot is depth of focusing. It is defined as the distance from the waist of the focused beam to the plane in which the intensity was reduced by half the maximum gain at the converging point. For the laser beam TEM_{00}:

$$Z_f = \pm \lambda^2 /(\pi W_f^2) \quad (3)$$

The larger beam mode, the smaller the depth of convergence; so, to have a greater focusing depth, we must adjust the laser resonator to achieve TEM_{00} mode.

2. The Nd:YAG laser making system

The Nd: YAG laser system must have the specifications suitable with metal engraving technology: pulsing operation, high laser power, small focus size. To meet these requirements, we proposed the laser design parameters as shown in Table 1.

Table 1. The specifications of Nd:YAG laser making system

Laser type	Nd:YAG
Optical pumping source	Diode lasers
Laser wavelength	1064 nm
Output laser power	75 W
Laser pulse width	150 ns – 100 μs
Pulse repetition	200 Hz – 10 kHz
Mode laser	TEM00

The design of laser resonator including (Figure 3):

- Diode pump solid state laser (DPSSL) module.
- Acousto-optic Q-switch
- The mirrors of resonator: rear mirror and output coupler
- Optical rail and mirror mounts.

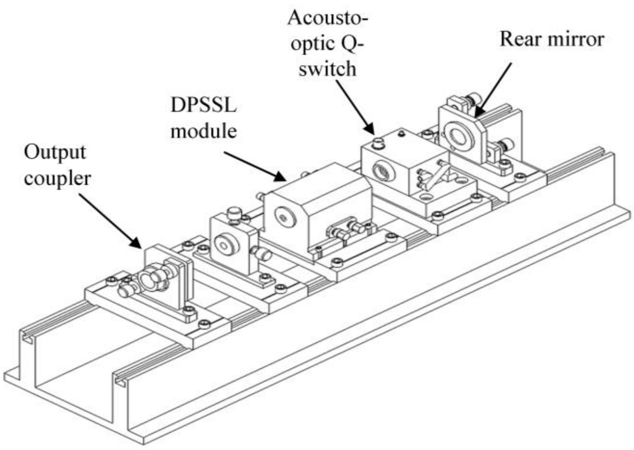

Fig 3. The design of laser resonator.

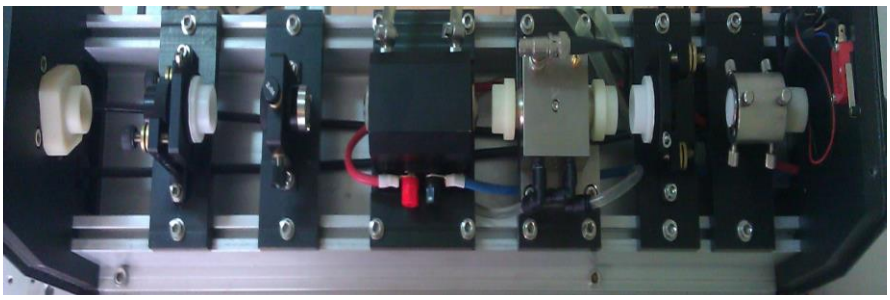

Fig 4. Aligning laser resonator.

After manufacturing the Nd:YAG laser system, we assembled the laser making machine from 4 parts: laser head, control cabinet, laser stage and chiller.

Nd:YAG laser head

Laser stage

Control cabinet

chiller

Fig 5. The parts of laser making machine.

3. Laser making technology

The Nd:YAG laser machine are designed to handle marking, etching and engraving on a wide-range of applications in several industries. It can be used for materials: metal, alloy, metal oxide and some non-metal material such as epoxy resin, ABS materials (electrical casing)…

Advantages of laser marking:

- Deep marking, engraving, etching into the surface which is anti-counterfeiting and not receptive to unauthorized removal.
- Clear, precise, and accurate marks.
- No additional materials required – Just the laser beam and the product.

- Cost efficient, low maintenance, superior quality, high reliability.
- Non-contact with the surface enables high-speed marking.
- Large variety of information/graphics/codes can be printed.

Fig 6. Some typical products processed by our laser marking equipment.

4. Conclusion

We have designed and manufactured a Nd:YAG solid state laser system pumped by diode laser's bars to obtain the output power of up to 75W. This laser system has been applied in the industrial laser machine to engrave on the metal surface of the material. We have also improved laser marking technology to enhance efficiency of laser equipment.

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