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Multiple Wavelength Laser Processing Technology for Flexible Manufacturing

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Abstract

Multiple wavelength laser processing technology allows laser beams of several different wavelengths to be combined to form a single, coaxial beam. This hybrid laser beam is capable of cutting composite materials, which are composed of matrix and reinforcing materials that have different optical and physical characteristics. For example, carbon fiber reinforced polymer can be cut using a combination of a 1.06 micron laser beam, which cuts thought the carbon fibers, and a 10.6 micron laser beam, which simultaneously vaporizes the polymer matrix material. This technology not only allows two or more wavelengths to be combined, but also allows for seamless switching from one laser wavelength to another. This capability enables flexible manufacturing processes for many applications.

Keywords: macro processing; laser cutting; composites; multiple wavelength; multiwave

1. Introduction

Conventional laser cutting utilizes a laser beam with a single wavelength to efficiently cut through a homogeneous material. By their nature, composite materials are not homogeneous. They are comprised of a matrix material and a reinforcing material. These two components usually have different physical and optical properties. For example, Carbon Fiber Reinforced Polymer (CFRP) is comprised of a polymer matrix material reinforced with carbon fiber fabric. The polymer has a relatively low vaporization temperature and a low thermal conductivity. The carbon fiber has a vaporization temperature that is nearly an order of magnitude higher than the polymer matrix, and it has very high thermal conductivity along the length direction. The carbon fiber absorbs well across the visible and IR spectra, while the polymer absorbs in the mid-IR regime but is transmissive in the near-IR and visible regimes. This difference in both physical and optical properties suggest that a single laser wavelength will not be optimal for cutting composite materials, and that a system that allows cutting using multiple laser wavelengths simultaneously would be beneficial.

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2. Experimental Methods

All laser processing was performed using an XLS10MultiWave Hybrid™ (XLS10MWH™) system from Universal Laser Systems. The system was equipped with MultiWave Hybrid optics, which combine up to three different laser beam wavelengths into a single, coaxial laser beam as shown in Figure 1. The optics are designed so that all wavelengths converge to the same focal plane with nearly identical spot sizes.

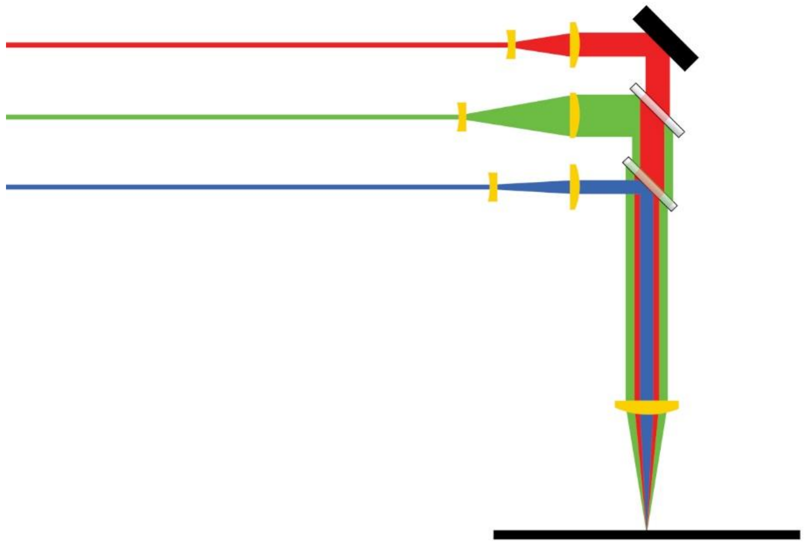


Fig. 1. Schematic view of the MultiWave Hybrid optics system, which combines laser beams of different wavelengths (indicated by colors) into a single, coaxial beam.

The system was equiped with two different CO_2 lasers; one 75 watt laser with a wavelength of 10.6µm, and one 50 watt laser with a wavelength of 9.3µm. A 40 watt Yb-doped fiber laser with a wavelength of 1.06µm was also utilized.

3. Results and Discussion

The MultiWave Hybrid technology described above can be used in two different ways. The individual wavelengths can be turned on simultaneously for a single step process that leverages multiple wavelengths, or they can be turned on individually for a multiple step process where each step requires a different laser wavelength. The former process is termed MultiWave Hybrid processing, and the latter is termed Sequential Processing.

3.1. MultiWave Hybrid Processing

Figure 2 shows a comparison of three different laser cutting processes for a 1.0 mm thick CFRP sheet. The circle at the left is an attempt to cut the sheet with only the 75 watt CO_2 laser. The polymer matrix material absorbs the mid-IR laser energy, but there is insufficient power density to cut through the carbon fibers. The middle cut was made using only the 40 watt Yb-doped fiber laser. The carbon fiber reinforcement absorbs the near-IR laser energy and vaporizes, but heat is conducted along the length of the fibers leading to substantial degradation of the polymer matrix near the cut edge. The cut at the right is the MultiWave Hybrid result. Here the beam from the 75 watt CO_2 laser was combined with the beam from the 40 watt Yb-doped fiber laser.

The Yb-doped fiber laser vaporizes the carbon fibers, while the CO_2 laser simultaneously ablates the polymer. This minimizes damage to the polymer, and allows the cutting speed to be increased by a factor of two.

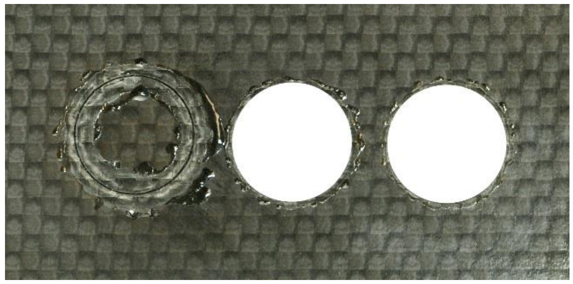


Fig. 2. CFRP sheet cut with a: (a) CO_2 laser; (b) Yb-doped fiber laser; (c) MultiWave Hybrid laser beam.

Figure 3 shows microscopic images of the cut made with only the Yb-doped fiber laser (a) and with the MultiWave Hybrid process (b). These images demonstrate that using the MultiWave Hybrid process significantly reduces the heat affected zone. It also reduces the number of exposed carbon fibers at the cut edge.

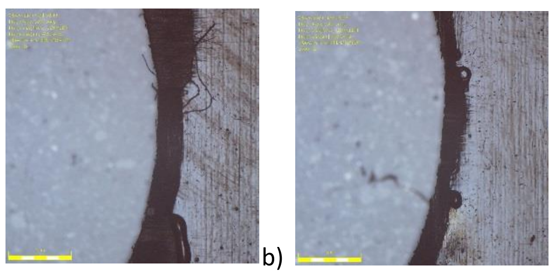
a)  b)

Fig. 3. (a) Microscopic image of the laser cut made with only the Yb-doped fiber laser; (b) the cut made with the MultiWave Hybrid laser beam.

The MultiWave Hybrid™ process is beneficial for cutting other composites such as metal filled polymers, which are commonly used for EMI shielding. In this application the CO_2 laser ablates the polymer matrix, while the Yb-doped fiber laser vaporizes the metal particles.

3.2. Sequential Processing

In addition to combining laser beams with different wavelengths, Multiwave Hybrid technology allows each laser to be used independently. This enables sequential process steps that require different laser wavelengths to be completed in a seamless workflow. An example of such a process is the formation of a flexible electronic circuit using three different laser wavelengths. Figure 4 depicts the sequential process steps. The starting material is carbon ink that has been screen printed onto a PET substrate (Figure 4a). The carbon ink absorbs strongly at 1.06µm, and the PET is transparent at this wavelength. This allows the carbon ink to be selectively ablated from the PET using the 1.06µm Yb-doped fiber laser. This process is used to define the conductive circuit elements as shown in Figure 4b. The next process step is to mark the PET substrate with a serial number using the 9.3µm CO_2 laser (Figure 4c). The 9.3µm wavelength was chosen because PET has a strong absorption peak at this wavelength, creating a sharp mark without substantial material removal. The final step is cutting the finished part from the web using the 10.6µm CO_2 laser, as shown in Figure 4d.

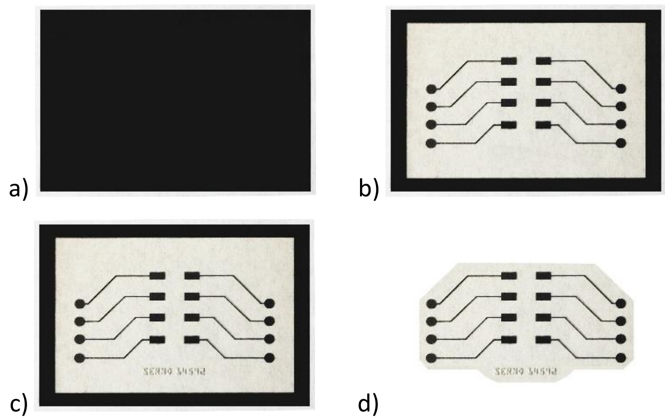


Fig. 4. Sequential process steps for flexible electronic circuit formation: (a) Carbon ink screen printed on PET substrate; (b) Laser ablation of carbon ink using 1.06μm fiber laser to form circuit elements; (c) Serial number marking using 9.3μm CO_2 laser; (d) Cutting the circuit from the PET web using a 10.6μm CO_2 laser.

Sequential processing has also been demonstrated for laminated structures such as metal clad gasket material. Here the first cutting pass through the top metal cladding layer is made using the Yb-doped fiber laser. The second pass is done using the CO_2 laser to cut through the compliant gasket material. Then the final step uses the Yb-doped fiber laser to cut through the bottom metal layer.

4. Conclusions

MultiWave Hybrid laser processing technology enables flexible manufacturing in two ways. First, it allows laser beams with different wavelengths to be combined to form a single, coaxial beam. This allows materials that are made up of constituents that have different physical and optical properties to be laser cut efficiently. Secondly, the individual lasers can be used sequentially. This allows laser processing steps that require different wavelengths to be integrated into a seamless workflow.