Advancements in Automated Fiber Placement Technology: The Critical Role of the Laser-Based System

Current State of Composite Material Manufacturing

Developing strong, durable and lightweight materials is essential for improving efficiency and reducing costs in automotive, aerospace, high-performance sports and many other applications. Composite materials—carbon fiber-based in particular—are often the ideal solution as their shape can be customized while meeting strength and weight requirements. These materials can be found in a range of markets and applications such as:

- **Automotive –** safety tubes, interior and exterior parts and structural members to reduce weight and allow for enhanced fuel efficiency
- **Sports equipment –** bicycle parts, racquets and skis
- **Civil infrastructure –** lightweight, easy-to-transport concrete reinforcement members
- **Oil and gas –** lighter pipeline material which greatly reduces installation effort, maintenance costs and transportation costs

Automated Fiber Placement (AFP) is one of the manufacturing processes used to produce products with composite materials. AFP layers tapes of materials (tows), such as thermoset fiber, thermoplastic fiber or dry fiber, on top of each other to create the desired product. To create a strong bond between the layers, AFP systems heat one or both constituent layers to the appropriate working temperature and then sandwich adjacent layers under some type of press or roller for adhesion.

To achieve the desired result, the AFP process requires heat to be delivered uniformly and consistently to the workpiece. Traditional approaches, which have been in use in the aerospace industry for over 30 years, use heat lamps and hot gases as heat sources. While the industry has learned how to use these methods, they come with inherent drawbacks in terms of manufacturing downtime, lengthy setup processes, inefficient energy usage and limited flexibility, and therefore low throughput. Less common but increasingly popular approaches utilize diode lasers as the heat source (Figure 1).

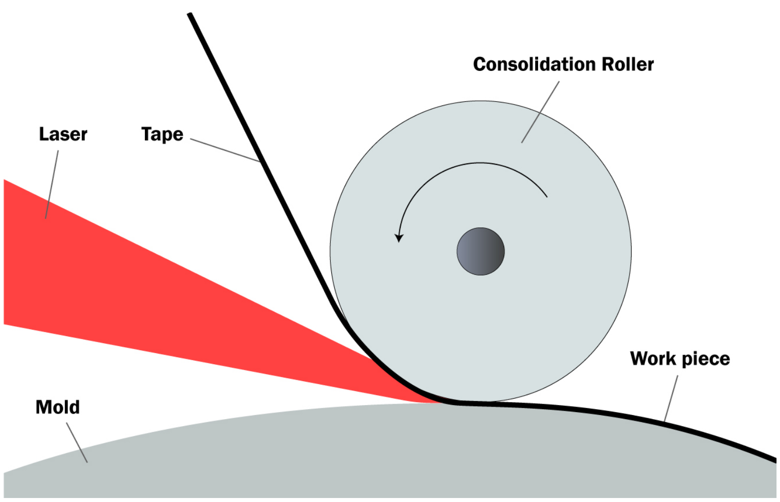

Figure 1: Diagram of diode laser based AFP system

Diode Laser Based AFP Systems

Laser-based approaches address the drawbacks of traditional heating methods because diode lasers are inherently stable, reliable and efficient and have extremely short reaction times. The energy delivered by a diode laser can be adjusted nearly instantaneously, on a microsecond scale, resulting in a simplified startup sequence and rapid in-situ process adjustments. While lasers are capable of delivering more energy to the target, they heat the environment far less, thus increasing speed and efficiency and decreasing parasitic heating.

As laser technology for AFP continues to evolve, its significant advantages enable emerging applications to meet key industry demands for efficiency, accuracy, homogeneous heating and compactness. Compact components can be placed directly on the processing head without adding much mass, allowing for a lightweight manufacturing system. Tool manufacturers are currently exploring laser-based AFP approaches to enable the creation of more custom, complex shapes by building more nimble machines.

Advantages of laser-based AFP

- **47%** reduction in rework through improved heat targeting and control
- **Long lifetime** of diode lasers
- **400%** improvement in processing speed
- Distinct **homogenized** beam
- **Fast** response time
- **2-5x** faster than traditional hot gas or IR heating systems

Six Considerations for AFP Diode Laser Specifications

Depending on an AFP tool integrator's particular needs, there are different requirements for the diode laser system. Here are six key considerations when evaluating AFP diode laser sources:

1. Power

The CW power of a diode laser, measured in watts, can be customized from just a few watts to tens or even hundreds of kilowatts (kW). In most cases, AFP applications require around 1 kW per panel.

2. Size and weight

Compactness allows for integration into a smaller and more nimble system, giving the integrator more flexibility in the design. Very small diode laser modules, that are tolerant to acceleration, can be put directly on the robotic arm of the machine. Larger, or less rugged, modules will need to be placed on a static part of the machine. The light then is routed through an optical fiber to the target.

3. Beam homogeneity

The amount of heat, and therefore light, needs to be uniform across a designated target area. With beam conditioning optics, diode laser systems can be designed to provide up to 99% uniformity.

4. Beam shape or energy distribution

A diode laser can be designed to provide a customized beam shape. These applications generally require a rectangular shape. Multiple arrays can be stacked to allow for many rectangular spots to be put next to each other to extend the target area without reducing energy and heat—expanding the number of tapes to be placed on the work piece.

5. Cooling capabilities

With significant heat requirements, systems need a mechanism to keep the laser head from overheating. Water is typically available in industrial settings, making water-cooled diode lasers a good fit for industrial heating applications.

6. Wavelength

The fixed wavelength of a diode laser can be designed around the specific wavelength needed; AFP applications generally use 800 nm – 900 nm, since this is where the efficiency of the semiconductor material is the highest. In terms of material, when carbon fiber is being used, wavelength does not play a large role as it readily absorbs any wavelength. However, diode laser wavelength customization becomes important for glass fiber and plastics to ensure absorption.

Leonardo T6 Package

Leonardo offers a compact, configurable, fluid-cooled diode laser array (see Figure 2) that provides shaped, high-power beam configurations ideal for use in AFP systems. The size of this solution is extremely impressive—nearly a factor of 200 smaller in volume than competing laser systems. The degree of optical modification of the output beam can be customized to fit the needs of almost any AFP system.

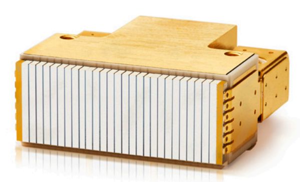

Figure 2: Leonardo's T6 diode laser module

The T6 diode laser package can be configured according to specific requirements and provide up to 2.5 kW of power per module in an extremely small space: The unhoused T6 package only measures 12 mm x 26 mm x 28 mm. A beam profile, as shown in Figure 3, can be achieved with optional homogenization optics that require only 5 mm of additional space.

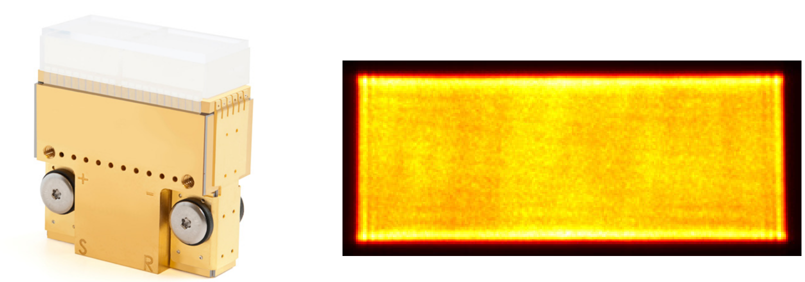

Figure 3: Leonardo's compact T6 high-power diode laser module with homogenizing optics (left). Example of a homogenized beam profile at the target (right).

The T6 offers rear access to all cooling and electrical connections, which is unique in the industry. The design enables tight side-by-side tiling of modules, maintaining the power area density for multi-module arrays, which can be scaled to hundreds of kW.
More details can be found on our website.

Are you ready to take your laser to the next level?

Contact us to discuss how our technology can address your needs.

Summary

As industry embraces AFP for the manufacturing of modern composite components, diode laser heating offers multiple benefits over traditional approaches in terms of overall throughput and efficiency. Leonardo's compact, rugged and modular T6 design is ideally suited for diode laser AFP systems.

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