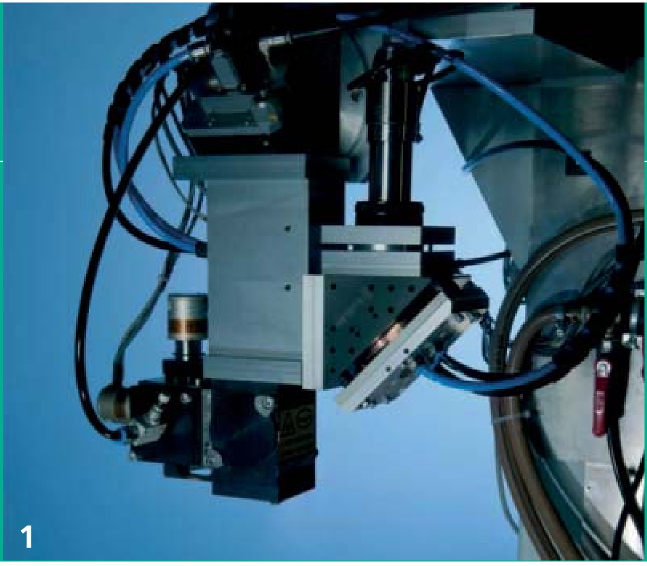

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EFFICIENT PROCESSING OF FIBER REINFORCED POLYMER COMPOSITE MATERIALS

THE TASK

High performance materials based on fiber reinforced polymers (FRP) are currently finding many applications in industry. In addition to applications in aerospace and automotive industries, FRPs are increasingly being used in general mechanical engineering applications. The focus here is to develop functionally integrated components.

One of the largest challenges in the area of FRP is the improvement and optimization of the manufacturing process. The carbon fiber is highly abrasive, which causes extreme tool wear during milling as well as water jet cutting operations. There is also the mechanically damaging impact to consider that the tools have on the component, in particular when the tools or the used abrasives approach the end of service life. Based on this situation the laser as a contactless tool with a high automation potential appears to be an excellent choice to efficiently process FRP without tool wear.

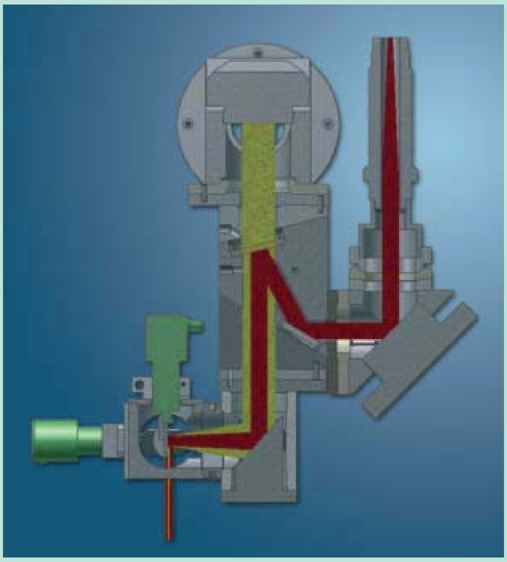
OUR SOLUTION

FRP usually consist of a fiber material embedded in a thermosetting- or thermoplastic matrix. Both base materials have vastly different thermal conductivities, evaporation temperatures and absorption properties. The differing properties of the individual material have to be considered during laser material processing in order to efficiently process the material with high quality results.

Remote laser cutting processes with continuously operating beam sources were already qualified for the treatment of FRP. The high speeds of the laser spot significantly reduce the interaction time between laser and material. This minimizes the influence of the thermal conductivity of the fiber component.

The Fraunhofer IWS joined forces with TU Dresden in a collaborative research program 639 and developed a laser beam combination module (Fig. 1 and Fig. 2). The module was developed so that the specific properties of the individual material in the FRC could be considered. The concept is to coaxially superimpose laser radiation from two beam sources with the emission wavelengths λ =10.6 µm and λ=1.07 µm. The process makes use of the optimal absorption of the CO_2 (10.6 µm) laser radiation by the polymer matrix to evaporate the same. Simultaneously the solid state laser (SSL, 1.05 µm) has good focusing capability to achieve intensities that sublimate the reinforcing fiber component. The laser power for each wavelength can be independently selected, which provides novel possibilities for parameter variations.

Principle of the coaxial beam superposition



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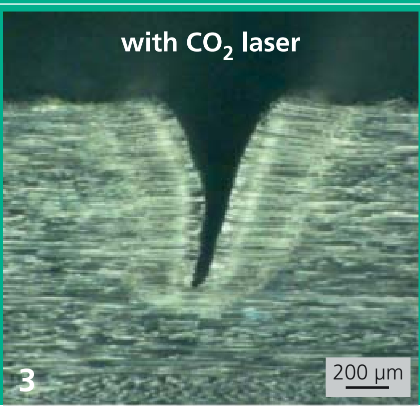
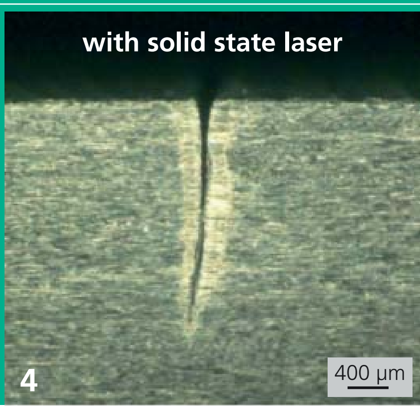
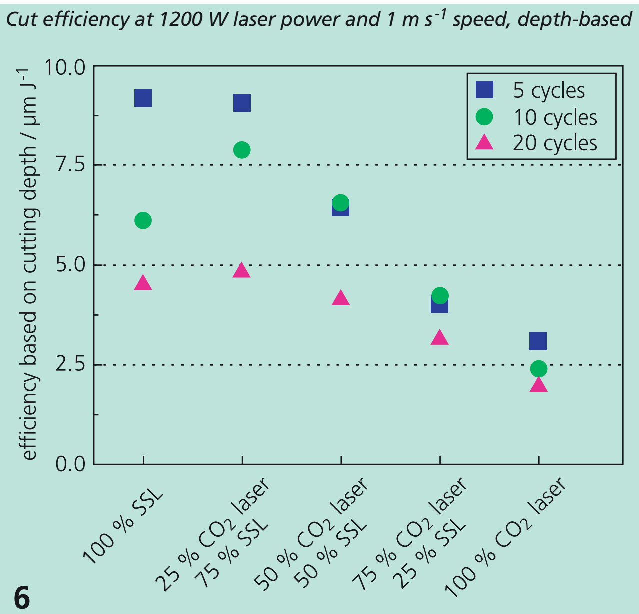




RESULTS

The radiation from the solid state laser can be focused very well, which yields a focal point diameter that is ten times smaller compared to the CO_2 laser radiation using the same optical setup. This translates to a smaller interaction zone and reduced interaction times between laser beam and material. The improved efficiency was demonstrated by cutting carbon fiber reinforced polymer with high modulus carbon fibers and a fiber volume content of 60 percent. The high intensity and short interaction time led to very high quality cuts compared to processing with CO_2 radiation only (Fig. 3 and Fig. 4).

The depth-specific cutting efficiency can be further improved by using synchronous laser radiation with about 25 percent of CO_2 laser radiation (Fig. 6). The cut widens due to the CO_2 laser radiation component, which increased the ablation of material.



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The CO_2 radiation interacts with the matrix material and disintegrates the same thermally. Thus the local fiber volume fraction increases, which in turn leads to a higher absorption of solid state laser radiation within the interaction zone. It can also be assumed that the widening cut will reduce the interaction between solid state laser radiation and the sidewalls in the cut. This leads to a more straightened cut and to increased the cutting depths (Fig. 5 and Fig. 6).

The combination of solid state and CO_2 laser radiation expands the parameter field for processing FRP. The increased effort that is necessary on the system side is justified by the improved cutting results.

1 Laser beam combination module with scanner

3-5 Polished cross sections of cuts in FRP after remote cutting with CO_2 laser (3), solid state laser (4) and a combined laser radiation with 25 percent CO_2 fraction

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