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Theoretical and experimental aspects of laser cutting with elliptically polarized laser beams

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Abstract

The strong effect that beam polarization has on the performance of industrial laser cutting is well known. The linear and circular polarization states were widely investigated for CO_2 lasers. These two states are, in fact, special cases of elliptically polarized laser beams. Theoretical models have predicted an optimal cutting performance for a specific ellipse ratio (b/a=0,75), but experimental validation was never reported. The main reason is that this characteristic is difficult to obtain in practice. With the technology shift towards solid state lasers, different optical solutions become available for polarization control of high power laser beams (e.g. transmissive beam retarders). This paper reports on the novel design of an elliptically polarized laser beam with a continuous control of the ellipse axes ratio. Starting with a full description of the concept, the equations describing the control of the optical elements are deduced using Jones calculus formalism. A motorized optical module has been built to transform the output of a linearly polarized laser beam into a given elliptic polarization characteristic. Beam analysis equipment was used to validate the experimental setup. Cutting experiments were realized for 2 *mm* thick 304 L stainless steel and compared with a simulation model. Both results show a comparable nonlinear effect on the achievable maximum cutting speed. The influence of the beam shape is also considered, revealing a strong interaction with the beam polarization. With the help of simulation tools, the applicability of such concept is investigated and, in agreement with the experimental results, the obtained output confirms that the optimal ellipse beam ratio is much closer to b/a=0 than anticipated in literature.

Keywords: Laser cutting, elliptical polarization, modeling, solid state lasers