INVESTIGATION OF IMPROVED LABEL CUTTING BY CO_2 LASERS WITH WAVELENGTH OPTIMIZATION

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Abstract

The digital printing revolution has changed the landscape of label creation significantly. With the flexibility of printed design, the need to easily change the cut shape to match has become very important. Traditionally, cutting has been done with mechanical die-presses where the user is locked into one design for a production shift and the cost and hassle of storing multiple dies makes it unfeasible to have many cut shapes available. Laser cutting with high-speed scan heads has changed this to a dynamic and easily flexible process where cut design changes can be done on the fly via software without stopping the production line. This paper presents capabilities of sealed-off CO_2 lasers for cutting a variety of labels and the impact of laser wavelength on cut quality and throughput. We investigated multiple CO_2 laser wavelengths such as 9.3µm, 10.2µm and 10.6µm on a number of common plastic and paper labels. These results were measured for overall cut speed, heat effect on the cut edge, and unwanted scoring of the paper liner underneath. We concluded that for many common polypropylene based labels, the 10.2µm wavelength was the best choice, while the 9.3µm wavelength was the best for many PET based labels. For most plain paper labels, we observed similar cut speeds and quality for all three wavelengths.

Introduction

Dynamic and creative label printing can now be done very easily with the newer digital printing technologies available. [1] With this gained flexibility on the print end of the process, the need to easily change the cut shape as well has become more important. Conventionally, cutting has been done with mechanical die-presses with a fixed label design over a production run. Usually, the cost and hassle of storing multiple dies makes it unfeasible to have many cut shapes available and tool changes take time. Over the last few years, laser cutting with high-speed scan heads has solved many of these issues with the ability to rapidly change label designs via simple program changes in the scan head software.

Laser cut labels do have a slightly different looking cut edge compared to die-cut labels, with slight melt lip being a common feature especially if the laser parameters are not optimized. To minimize this, correct and efficient absorption of the specific laser wavelength is very important for particular label materials and is the main focus of this paper.

Generally the long wavelength of the CO_2 laser (10.6 µm) is well suited for cutting labels because of its excellent absorption in plastic films and paper sheets--the most common materials used for labels. For best optimization on some film labels, the 9.3 µm or 10.2 µm variations may be used instead.

Paper based labels account for a majority of the overall label market. However, there is high growth in plastic based film labels. There are typically four common film types encountered: [2]

- Polypropylene (PP) is the primary plastic label material. It is used for many standard in-mold and glue-applied labels.

- PET films are used primarily for sleeve labels. Sleeve labels are increasing in usage so there is also growth in PET films. PET films have the advantage of being very thin while still maintaining good strength and durability.

- PVC is also used for sleeve labels. PVC generally should not be laser cut due to charring and hazardous out-gassing. [3] Also PVC labels are being phased out in some markets due to environmental concerns.

- Polyethylene (PE) film is usually used for self-adhesive (pressure sensitive) labels. PE film is problematic for laser cutting because of its high transmission across a wide range of laser wavelengths. It was not focused on in this study.

In addition to the base label material, there will often be a top laminate (commonly PP) or varnish for extra protection and/or enhanced visual appearance. Many paper based labels will often still have a plastic laminated top layer. This will change the laser cutting behaviour in many cases.

Successfully laser cutting labels requires cleanly penetrating through the top coatings, laminate, and label base, but at the same time doing minimal damage to the liner underneath. Thus a careful balance between the laser energy and the cut velocity must be chosen. In addition, the laser wavelength must ideally be absorbed at the very top surface of the label and have minimal transmission. Otherwise there will be extra heat affect zone (HAZ) and increased scoring of the liner.

This problem was investigated in two steps. First an IR spectrometer was used to measure absorption curves on a variety of different label materials. Based on these measurements, absorption peaks were identified at the easily accessible standard CO_2 laser wavelengths of 9.3 µm, 10.2 µm, and 10.6 µm. In the second step, the labels were laser cut at each of the wavelengths to determine how much of an improvement was seen for maximum cut speeds and overall cut quality near the best absorption peaks. The improved absorption at those peaks should theoretically lead to more pure vaporization of the polymer and less excess wasted energy going to heating the edge.

Experimental Setup

A Bruker Alpha Diamond ATR Spectrometer was used to measure various FT-IR absorbance spectra curves of the label surfaces. In addition, the measured absorption spectra curves were also searched against a spectra reference library to verify the label material. This was also useful for identifying if there were any top laminate or varnish top layers.

The experimental setup can be seen in Figure 1. A trio of Synrad P150 CO_2 lasers (at 9.3 µm, 10.2 µm, and 10.6 µm wavelengths) were used in conjunction with high speed galvo scanners. The P150 laser has a rated average output power of 150 W and a peak power of 600 W. The optical rise time of the tube is 50 µsec. The beam diameters exiting these lasers were 8 – 9 mm depending on wavelength.

The lasers output powers were measured and the duty cycles were calibrated so that the average output power was 150 W on each of the three lasers. The lasers were run at a high repetition rate of 100 kHz to get a flat optical output. This occurs in a pulsed CO_2 laser when the commanded pulse signal is much shorter than the optical rise/fall response of the tube. This provides a very smooth cut edge at high cut speeds.

The scan heads used were the Synrad FH Flyer model. The scan heads were equipped with 125 mm focal length F-Theta lenses, which gave a focused spot size of approximately 230 µm on the label surfaces.

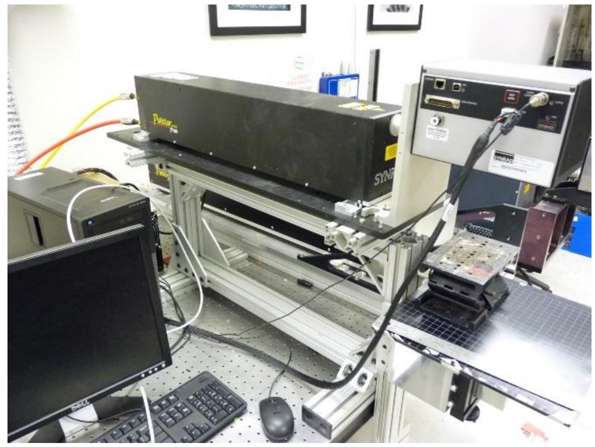

Figure 1: The experimental setup: a P150 aligned to a Flyer head.

Plastic Label Optimization Findings

The first film material examined was PP due to its usage in many common labels. Standard polypropylene plastic has an absorption peak near the 10.2 µm – 10.3 µm range. This was also seen on the uncoated polypropylene labels that were tested. See Figure 2. Previous studies [4] have noted improved speeds and quality when using the 10.2 µm wavelength to process PP films. However, the complex nature of many labels with the potential of extra varnish and/or lamination layers complicates the issue in some cases with regards to label cutting specifically.

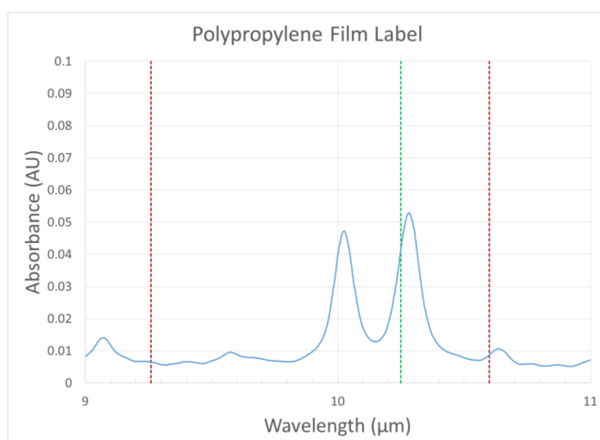

Figure 2: A measured FT-IR absorbance curve of a polypropylene label. From left to right, the 3 vertical lines

indicate the 9.3 µm, 10.2 µm, and 10.6 µm wavelengths. Green color code indicates the best absorption.

Clear and opaque polypropylene films were examined, as well as ones that had additional lamination and varnish on top. The cut speed differences between the tested laser wavelengths were the most notable on the thinner labels with around 80% increases being typical on 80 µm thickness while only 22% increases were seen on thicknesses of 140 µm. It was also observed that if there was a top varnish coating the speed differences were greatly minimized or eliminated. See Table 1.

Base Material	T (um)	Coating	10.6 Vel (mm/s)	10.2 Vel (mm/s)	% Increase
PP - Opaque	120	Varnish	4064	4064	0.00%
PP - Opaque	140	PP Laminate	2794	3429	22.73%
PP - Clear	80	None	4318	7620	76.47%
PP - Opaque	80	None	4572	8255	80.56%
Base Material	**T (um)**	**Coating**	**10.6 Vel (mm/s)**	**9.3 Vel (mm/s)**	**% Increase**
PET - Clear	80	None	4445	4445	0.00%

Table 1: The measured cut speed differences depending on wavelength for the film label materials at 150 W average power.

The cut edge quality differences were the most obvious on clear PP labels in the unprinted regions. At 10.6 µm, yellowing of the film was commonly seen and heat affect zones were evident between the liner and base label materials where residue and hot vapour was trapped. The high transmission at 10.6 µm also meant that scoring of the bottom liner material was very noticeable. These issues were completely eliminated when the 10.2 µm wavelength was used instead. See Figure 3 for example cut edge quality example.

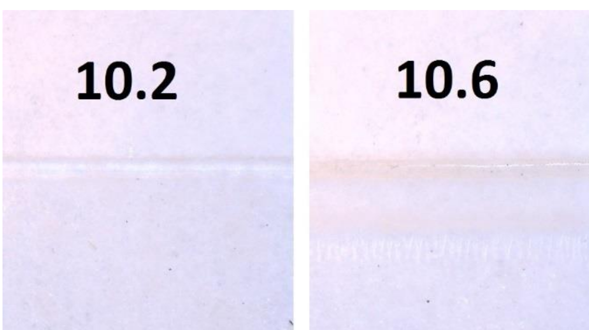

Figure 3: Clear PP cut edges are compared at 10.2 and 10.6 µm wavelengths at 40X magnification. The yellow discoloration seen at 10.6 µm was clearly visible even with the naked eye. The secondary line in the image on the right is vapour residue trapped between the label and liner.

For opaque PP labels, the quality differences were more subtle, but still apparent especially for cut edges near the darker print regions. The 10.6 µm cut edges had some slight thermal damage to the dark ink, while at 10.2 µm there was none. See Figure 4.

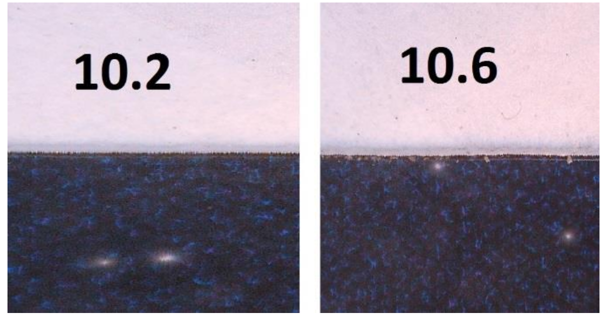

Figure 4: Opaque PP cut edges are compared at 10.2 and 10.6 µm wavelengths at 40X magnification. Slight damage to the dark ink is seen in the image on the right.

For PP labels with a varnish coating, the speed and quality differences by going to the 10.2 µm wavelength were eliminated. The varnish had similar absorption at either wavelength and this resulted in similar cutting behaviour.

The second film type examined was PET. For these films there is typically better absorption around 9.3 µm. See Figure 5. There was no speed benefit noted on the label films tested in this study. See Chart 1. This is likely due to the absorption depth being very short even at 10.6 µm, so there is little energy wasted exiting the bottom of the label cut.

However, there were still significant quality differences between 10.6 µm and 9.3 µm. The 10.6 µm cuts had inconsistent edge roughness and melt micro-bubbling. On the other hand, the 9.3 µm cuts were very smooth and consistent with a polished look. See Figure 6.

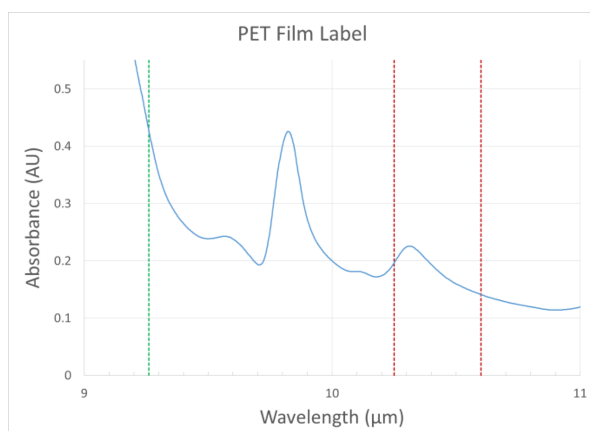

Figure 5: A measured FT-IR absorbance curve of a PET label. From left to right, the 3 vertical lines indicate the 9.3 µm, 10.2 µm, and 10.6 µm wavelengths. Green color code indicates the best absorption.

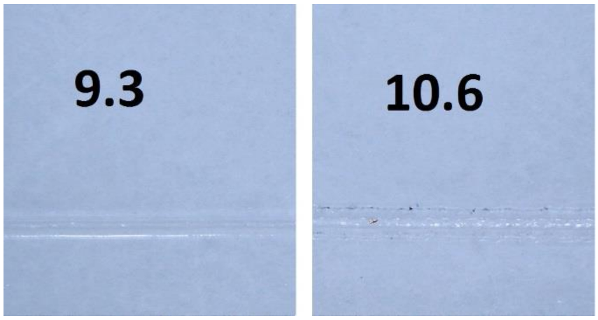

Figure 6: Clear cut edges are compared at 9.3 and 10.6 µm wavelengths at 40X magnification. The 10.6 µm cuts are rough and not as consistent.

Paper Label Optimization Findings

Bare uncoated paper labels were tested. It was found that bare paper samples had similar absorption at all of the standard CO_2 wavelengths and no noticeable speed or quality differences were seen.

Base Material	T (um)	Coating	10.6 Vel (mm/s)	10.2 Vel (mm/s)	% Increase
Paper	80	PP Laminate	3556	3810	7.14%
Paper	120	PP Laminate	3048	3429	12.50%
Paper	110	None	3429	3429	0.00%

Table 2: The cut speeds on bare and laminated paper labels was recorded for 10.6 µm and 10.2 µm at 150 W average power.

However, many paper labels were found to have a thin PP lamination. In these cases, it was found that a similar behaviour was seen as the full PP based labels from the first section of this study. Because the PP laminations were thinner than a full PP based label, the speed increases were not as significant, but still notable. See Table 2.

The quality differences were also noticeable. The 10.6 µm cuts had more edge discoloration in the paper compared to the 10.2 µm cuts. See Figure 7.

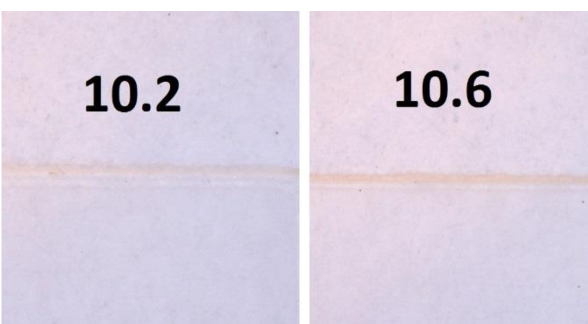

Figure 7: Paper with laminated PP cut edges are compared at 10.2 and 10.6 µm wavelengths at 40X magnification

Discussion

More investigation needs to be done into the kinds of varnish used on plastic film labels. In most instances, a thick varnish appeared to minimize any wavelength optimization on the film underneath. However, there appeared to a wide variety of different varnishes used--even for the small sample size analysed here--so it is possible that certain varnishes may have some wavelength dependence as well.

It was also noted that biaxially-oriented plastic film labels had very different cut quality depending on the orientation of the film, with one axis having significantly worse quality than the other. The test results shown in this paper are for films which did not fall in this category, but this could be a topic of future research.

Conclusion

There was a clear speed and quality difference on polypropylene based film labels when the 10.2 µm wavelength was used. For the PET based labels, there were clear edge quality improvements when the 9.3 µm wavelength was used, but no speed benefit was seen.

For paper labels, no speed or quality differences were seen over any of the standard CO_2 laser wavelengths. However, it was found that many paper labels actually have a thin PP lamination. These PP laminated labels were found to typically cut with better speed and quality at 10.2 µm, although the differences were not as large as those seen on the purely plastic labels.

Acknowledgements

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Meet the Author

Justin Conroy has spent the last nine years with Synrad as a Laser Applications Engineer. In addition to optimizing and perfecting current CO_2 laser processes, his work includes exploring cutting edge applications in industries and fields of study that could benefit from processing materials with CO_2 lasers. Justin holds a Bachelor's of Science Degree in Physics with Minors in Astronomy and Math from Western Washington University.