

APL0040 – Experimental Results – UV vs. CO₂ Laser Fume (HDPE, PP, ST, Al)

REVISION SHEET

Issue	Reason for Revision
01	FIRST ISSUE
02	Correction in section 5.1
03	Including second set of results from PP, Steel and Aluminium

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1 Introduction

Laser marking and cutting are widely used in various industries, with CO₂ and UV lasers being common choices for different applications. Recently, there have been claims in the market that UV lasers do not require extraction systems due to lower emissions. This experiment aims to investigate and compare the emissions from CO₂ and UV lasers when marking high-density polyethylene (HDPE), Polypropylene (PP), Steel and Aluminium samples.

The primary focus is to measure volatile organic compounds (VOCs) and particulate matter emitted during the marking process. By using specialized measurement equipment, this test will determine whether UV laser emissions are significantly lower than those of CO₂ lasers, thereby assessing the validity of the claim that UV lasers do not require extraction.

2 Materials and Equipment

The following equipment was used in the experiment:

Lasers (Linx):

- UV Laser 355nm wavelength – interact with materials through photolytic degradation, where the high-energy photons break molecular bonds. Often referred to as cold marking since there is minimal surface damage or material removal. The wavelength Customers choose UV laser for delicate marking to obtain a colour change contrast.
- CO₂ Laser 10600nm wavelength – generally plastic material is engraved so usually material is removed and fume produced. Therefore an established need for extraction. Used as a comparison in this study

Measurement Instruments:

- Tiger VOC meter (set to detect Propene for HDPE and acetaldehyde for all other materials)
- P200 Particle meter
- AD PVC iQ extraction system

Other Equipment:

- Custom sampling point
- Flexible hose with associated cuffs and boots
- HDPE, PP, Steel and Aluminium samples
- Digital scales (for pre- and post-test weighing)
- Timer
- Printed results table
- Pen/pencil

3 TEST SETUP

The experiment was conducted in a controlled environment to minimize external influences on the results. The setup included:

- Placement of the material sample at the laser marking position.
- Connection of the Tiger VOC meter and P200 Particle meter to a custom sampling point (TP1), see Figure 1 Test Set Up Diagram.
- The AD PVC iQ extraction system was connected to the laser area and set to 180m³/hr,.
- Background measurements of VOCs and particulate matter were taken before the laser was activated.
- The laser was set to generate the mark shown in Figure 10 programmed laser mark.

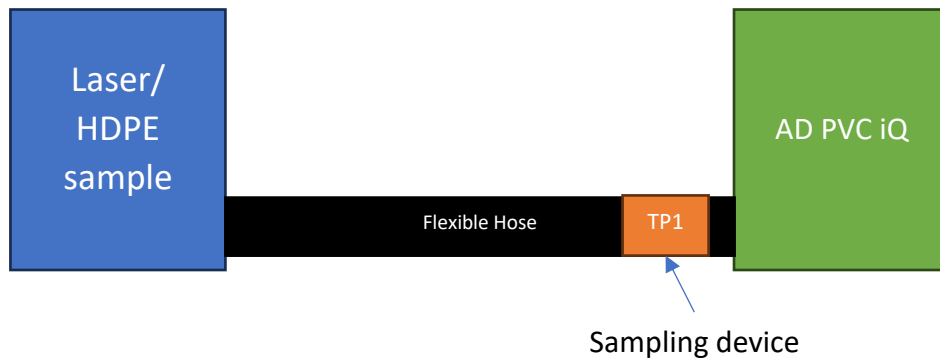


Figure 1 Test Set Up Diagram



Figure 2 test set up picture

4 TEST PROCEDURE

Full test procedure can be found in APL0038. To ensure consistency and accuracy, the following procedure was followed for both CO₂ for plastics or fibre laser for metals and UV lasers:

1. Set up the laser to mark the text specified in Figure 10 programmed laser mark with a marking speed of 500mm/sec at 80% power.
2. Configure the Tiger VOC meter to detect Propene for HDPE samples and acetaldehyde for all other materials).
3. Weigh the material sample before the test and record the value.
4. Set up the extraction system and connect it to the laser marking area.
5. Start the extraction system at the lowest flow rate and record this value.
6. Take background VOC and particle readings in the room and at TP1.
7. Connect the particle meter and VOC sensor to TP1 for simultaneous readings.
8. Start the laser and begin recording emissions data at the same time.
9. Turn off the laser and extraction system after completing the marking process.
10. Weigh the material sample again and record the final weight.
11. Repeat steps 1-10 so that 4 test runs are complete and then do that same using the second laser and other samples.

5 HDPE RESULTS

Results tables can be found in APPENDIX A: RESULTS TABLES

5.1 Sample Mass

The change in mass of the HDPE samples is shown in Table 1 and Table 2. This indicates that the UV laser is removing 90% less material to achieve the same mark.

Table 1 HDPE sample mass before and after lasering with CO2 laser

Sample weight Before (g)	116.80
Sample weight After (g)	116.60
Sample weight difference (g)	0.20

Table 2 HDPE sample mass before and after lasering with UV laser

Sample weight Before (g)	116.80
Sample weight After (g)	116.78
Sample weight difference (g)	0.02

5.2 Average Particle Meter Readings

Figure 3 average particle meter readings shows the average particle meter readings for each particle size taken with the P200 particle meter. It shows that the UV laser generates more finer particles but fewer larger particles. The average particle size (by number) was 1.25 microns for the CO₂ laser and 0.65 microns for the UV laser.

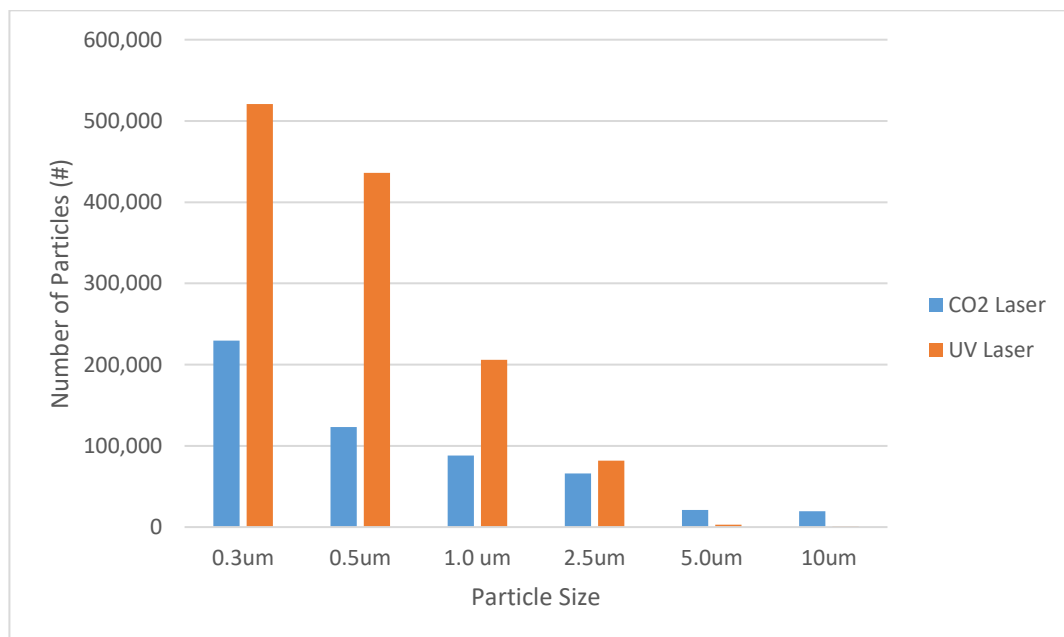


Figure 3 average particle meter readings

5.3 Average VOC Meter Readings

Figure 4 shows the average VOC meter readings taken with the Tiger Phocheck VOC meter. It shows the CO₂ laser generating 8-9 times as much VOC as the UV laser.

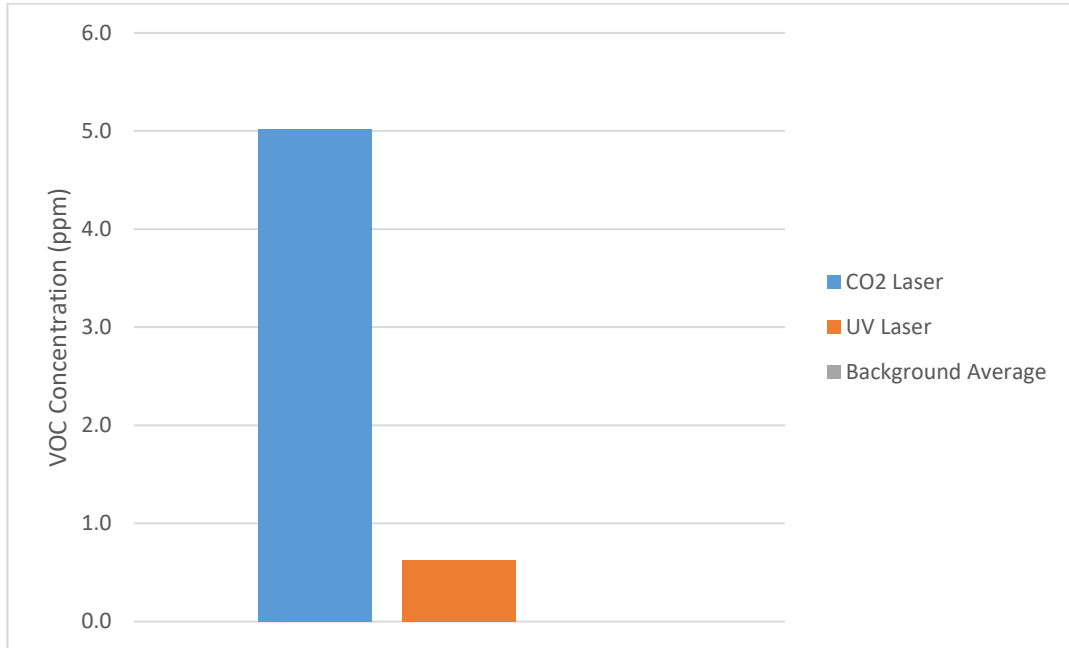


Figure 4 average VOC meter readings

6 PP RESULTS

Results tables can be found in APPENDIX A: RESULTS TABLES

6.1 Sample Mass

The change in mass of the PP samples is shown in Table 3 and Table 4. This indicates that the UV laser is removing 17% less material to achieve the same mark.

Table 3 PP sample mass before and after lasering with CO2 laser

	Sheet 1 (test 1-2)	Sheet 2 (test 3-4)	Average
Weight Before (g)	13.31	13.53	
Weight After (g)	13.26	13.47	
Weight difference (g)	0.05	0.06	0.06

Table 4 PP sample mass before and after lasering with UV laser

	Sheet 1 (test 1-2)	Sheet 2 (test 3-4)	Sheet3 (test 5-6)	Average
Weight Before (g)	13.27	13.492	13.96	
Weight After (g)	13.214	13.45	13.894	
Weight difference (g)	0.06	0.04	0.07	0.05

6.2 Average Particle Meter Readings

Figure 5 shows the average particle meter readings for each particle size taken with the P200 particle meter. It shows that the UV laser generates fewer particles across all particle size ranges. The average particle size (by number) was 0.74 microns for the CO₂ laser and 0.47 microns for the UV laser.

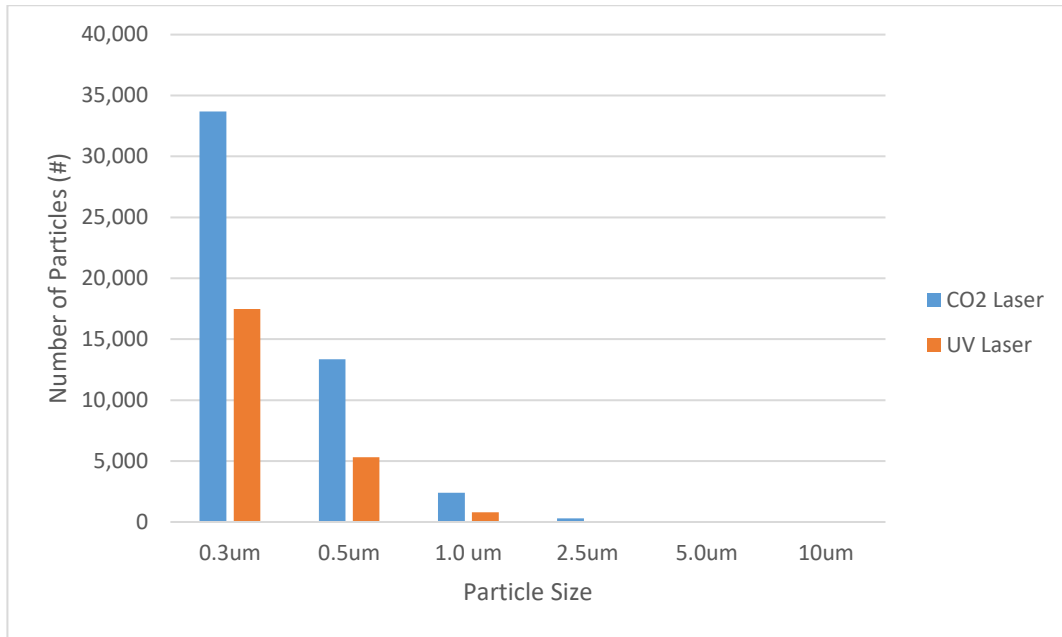


Figure 5 average particle meter readings for PP

6.3 Average VOC Meter Readings

Figure 6 shows the average VOC meter readings taken with the Tiger Phocheck VOC meter. It shows the CO₂ laser generating around 3 times as much VOC as the UV laser. Both are significantly higher than the background readings.

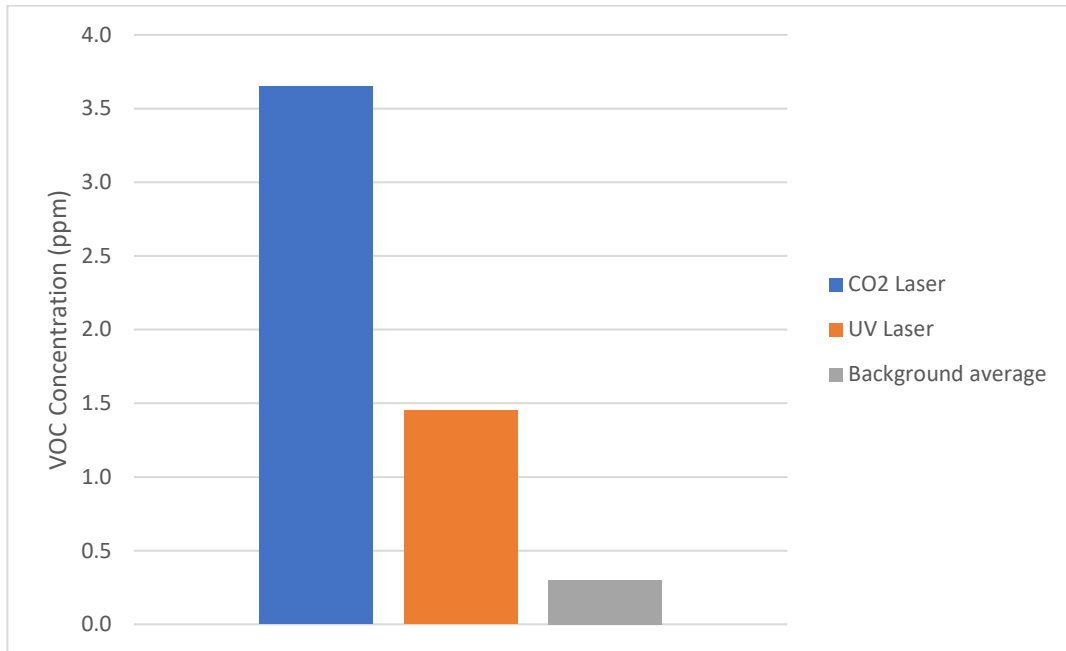


Figure 6 Average VOC meter readings for PP

7 ALUMINIUM AND STEEL RESULTS

Results tables can be found in APPENDIX A: RESULTS TABLES

It was not possible to use a fibre laser on the day of the test so the results for aluminium and steel are just from the UV Laser.

7.1 Sample Mass

The change in mass of the Aluminium and Steel samples is shown in Table 5 and Table 6 respectively. The aluminium results suggest that more material was removed than for any of the other materials (for any laser). The results for steel suggest that there was actually a slight increase in the mass of the material. As this is unlikely it is probably that the difference in material was smaller than the error margin of the scales used.

Table 5 Aluminium sample mass before and after lasering with UV laser

	Sheet 1 (test 1)	Sheet 2 (test 2)	Average
Weight Before (g)	179.22	179.21	
Weight After (g)	179	179	
Weight difference (g)	0.22	0.21	0.22

	Sheet 1 (test 1)	Sheet 2 (test 2)	Sheet3 (test 3)	Average
Weight Before (g)	79.236	78.710	78.218	
Weight After (g)	79.240	78.765	78.211	
Weight difference (g)	-0.004	-0.055	0.007	-0.02

Table 6 Steel sample mass before and after lasering with UV laser

7.2 Average Particle Meter Readings

Figure 7 average particle meter readings for Aluminium and Steel shows the average particle meter readings for each particle size taken with the P200 particle meter for Aluminium and Steel when marked with a UV Laser. The average particle size (by number) was 0.4 microns for Aluminium and 0.38 microns for Steel.

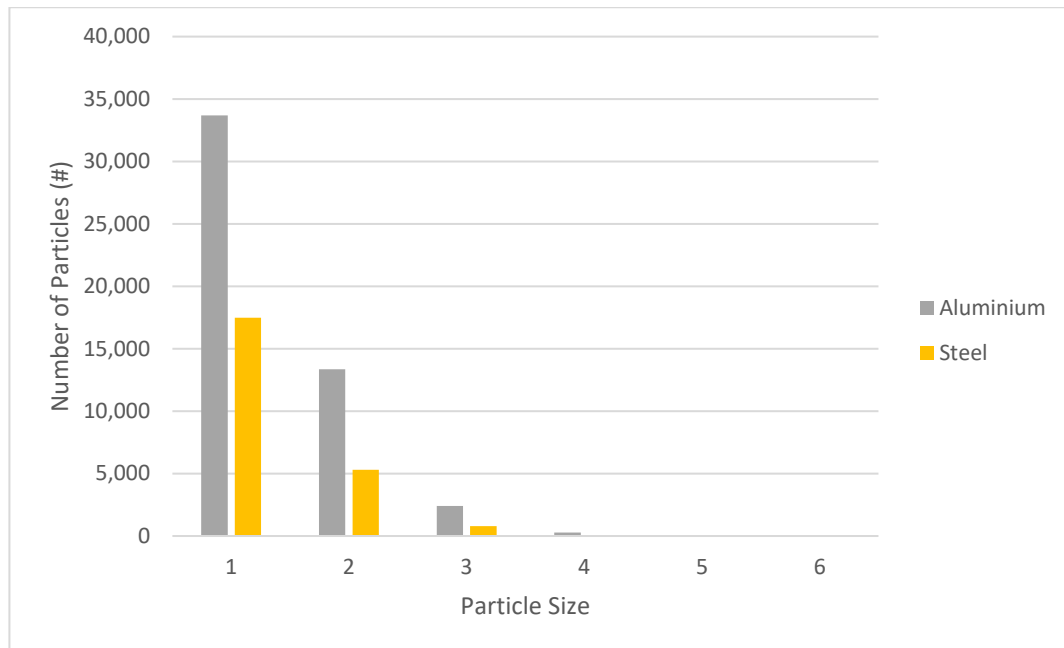


Figure 7 average particle meter readings for Aluminium and Steel

7.3 Average VOC Meter Readings

Figure 8 shows the average VOC meter readings taken with the Tiger Phocheck VOC meter. It shows that the VOC meter readings were the same as the background readings taken before the test. This is to be expected as metals won't decompose into VOCs (but into solid metal oxides). There may be some VOCs generated by lacquers/coatings on the metals however these appear to be negligible compared to background levels.

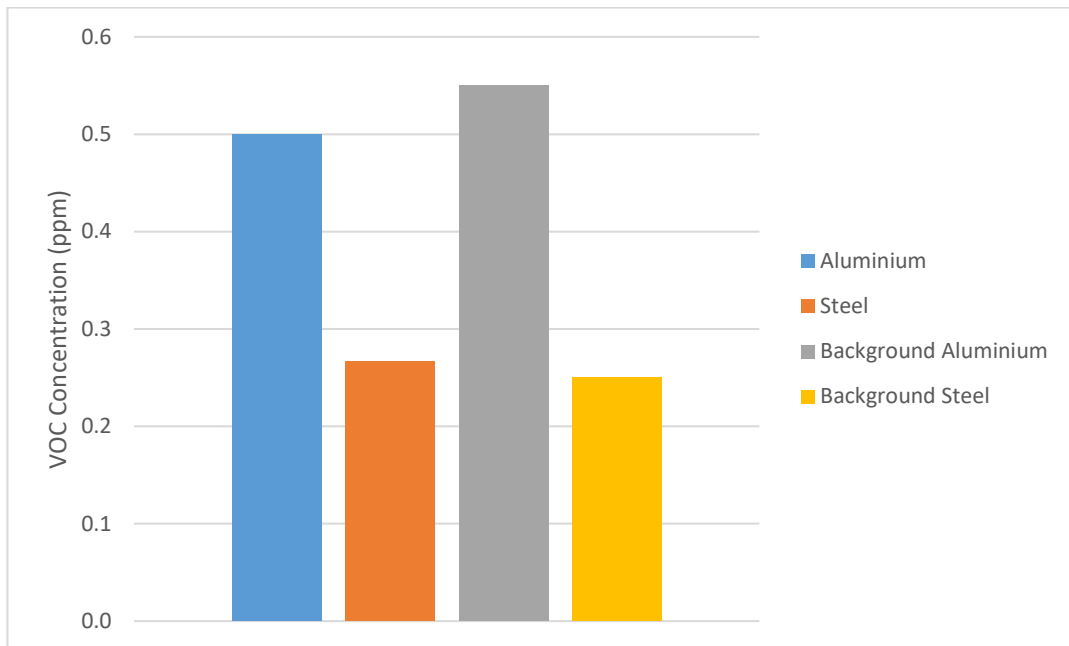


Figure 8 average VOC meter readings for Aluminium and Steel as well as the background readings taken before each test

8 DISCUSSION

Figure 9 shows that all materials generate significantly more particles than the background levels across all particles sizes measured. This is also shown by the results in Table 7. Table 7 shows that the minimum particle readings (steel) from the UV laser were 17 times higher than the background readings at the smallest particle size (0.3 microns) and 5 times higher at the largest particle sizes (10 microns). The maximum particle readings (HDPE) were 511 times higher than the background readings at the smallest particle size and 3381 times higher at the largest particle sizes.

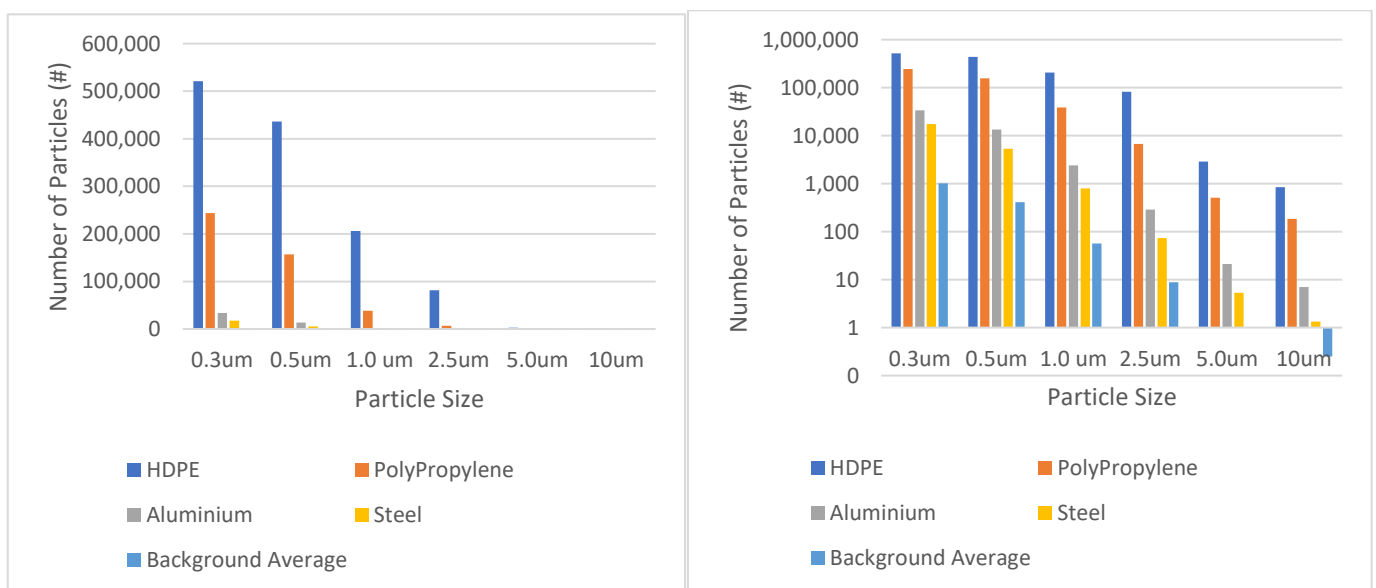


Figure 9 UV laser particle emissions for all materials compared to background readings. Shown both on an absolute scale (left) and logarithmic scale (right)

Table 7 ratio of the number of particles generated by the UV Laser (for all materials) to the number of particles taken from background readings

Particle size	0.3um	0.5um	1.0 um	2.5um	5.0um	10um
Minimum ratio	17	13	14	8	5	5
Minimum ratio	511	1070	3642	9334	2905	3381

For HDPE when looking at the results in section 5 we see that the overall mass generated by the UV laser is 10 times smaller than the CO₂ laser and the VOC emissions are 8-9 times smaller. If doing a simple parts per million or milligrams per meter cubed assessment of the exposure this may lead to less of a risk being assessed from the UV laser. However, Figure 3 average particle meter readings that, while less mass is being generated by the UV laser, far more smaller particles are generated by the UV laser. Generally smaller particles are considered more harmful as they can penetrate further into the respiratory system; for example in EH40 (<https://www.hse.gov.uk/pubns/priced/eh40.pdf>) respirable dust is given a lower workplace exposure limit than inhalable dust. Therefore it may be harder for laser users to assess whether more mass of contaminant or finer contaminant particles are of greater risk.

One unexpected result was that the amount of material removed by the UV and CO₂ lasers were similar (though slightly less for the UV) but the number of particles generated and the VOC meter readings were significantly lower for the UV. This might be explained if the particles generated by the UV laser were outside the size range detectable by the P200 meter. It's also possible that the different lasers generate different VOCs from the same material; as the VOC meter has differing responses to different chemicals it's possible that a higher concentration of one chemical may give a lower reading than a lower concentration of a different chemical.

9 CONCLUSION

The particle meter readings when lasering all materials with the UV laser were significantly higher than the background levels.

For the materials that were lasered with both the UV and CO₂ laser (HDPE and PP), the average particle size was lower for the UV laser. When all other parameters kept the same, smaller particles are considered more harmful due to the depth into the respiratory system they can penetrate. However, the UV laser removed less mass from both materials. For HDPE the UV laser gave off more smaller particles, the use of a higher grade pre-filter in fume extraction systems may extend overall filter life and therefore reduce the cost of ownership for users.

Both plastics detected VOC readings significantly higher than background readings. When lasered the VOC meter readings for the metals were indistinguishable from background readings.

The particle and VOC readings above background levels indicate that UV lasers present a health risk and therefore users would benefit from the use of fume extraction.

From a laser perspective, the reduction of fume produced by the UV laser can support using smaller extraction units. The settings used on the laser will vary between applications and the customers contrast expectations. However, this study shows the importance of extraction in all instances due to the smaller particle sizes.

10 Appendix A: Results Tables

10.1 HDPE CO₂ Laser

Sample weight Before (g)	116.80
Sample weight After (g)	116.60
Sample weight difference (g)	0.20

	VOC (ppm)	0.3um	0.5um	1.0 um	2.5um	5.0um	10um
Background Room	0	1603	723	79	20	4	1
Background TP1	0	923	335	54	4	0	0
Test 1	2.6	110,369	86,394	46,131	37,976	3,018	2,499
Test 2	3	100,045	76,874	35,594	24,836	9,272	8,814
Test 3	4.8	396,946	303,239	132,632	83,899	23,552	20,501
Test 4	9.7	311,509	25,606	138,536	116,615	47,747	46,109
Test Average	5.0	229,717	123,028	88,223	65,832	20,897	19,481

10.2 HDPE UV Laser

Sample weight Before (g)	116.80
Sample weight After (g)	116.78
Sample weight difference (g)	0.02

	VOC (ppm)	0.3um	0.5um	1.0 um	2.5um	5.0um	10um
Background Room	0	882	345	52	5	0	0
Background TP1	0	666	227	41	6	0	0
Test 1	1.1	562404	501753	279720	127830	4010	1083
Test 2	0.5	646884	575990	317998	141150	5036	1415
Test 3	0.4	481014	366182	121360	30466	1397	464
Test 4	0.5	393546	300821	103915	27247	1177	419
Test Average	0.6	520,962	436186.5	205,748	81,673	2,905	845

10.3 PP CO₂ Laser

	Sheet 1 (test 1-2)	Sheet 2 (test 3-4)	Average
Weight Before (g)	13.31	13.53	
Weight After (g)	13.26	13.47	
Weight difference (g)	0.05	0.06	0.06

	VOC (ppm)	0.3um	0.5um	1.0 um	2.5um	5.0um	10um
Background Room	0						
Background TP1	0						
Test 1	3.7	756,776	688,540	358,631	135,162	3,423	867

Test 2	3.2	270,880	247,771	150,272	88,221	3,679	1,371
Test 3	3.6	678,348	616,548	336,945	152,149	4,238	1,686
Test 4	4.1	460,899	434,213	294,328	189,767	6,934	3,234
Test Average	3.7	541,726	496,768	285,044	141,325	4,569	1,790

10.4 PP UV Laser

	Sheet 1 (test 1-2)	Sheet 2 (test 3-4)	Sheet3 (test 5-6)	Average
Weight Before (g)	13.27	13.492	13.96	
Weight After (g)	13.214	13.45	13.894	
Weight difference (g)	0.06	0.04	0.07	0.05

	VOC (ppm)	0.3um	0.5um	1.0 um	2.5um	5.0um	10um
Background Room	0.2						
Background TP1	0.4						
Test 1	1.4	362,007	237,621	58,101	10,269	865	294
Test 2	0.8	121,215	58,949	11,896	1,870	150	55
Test 3	2.2	322,374	206,733	49,790	8,472	624	219
Test 4	0.8	155,967	97,093	23,275	3,890	323	131
Test 5	1.2	342,075	236,843	61,883	10,908	706	242
Test 6	2.3	157,519	104,493	27,063	4,996	397	159
Test Average	1.5	243,526	156,955	38,668	6,734	511	183

10.5 Aluminium UV Laser

	Sheet 1 (test 1)	Sheet 2 (test 2)	Average
Weight Before (g)	179.22	179.21	
Weight After (g)	179	179	
Weight difference (g)	0.22	0.21	0.22

	VOC (ppm)	0.3um	0.5um	1.0 um	2.5um	5.0um	10um
Background Room	0.5						
Background TP1	0.6						
Test 1	0.4	31,907	12,506	2,297	267	19	5
Test 2	0.6	35,487	14,207	2,520	311	23	9
Test Average	0.5	33,697	13,357	2,409	289	21	7

10.6 Steel UV Laser

	Sheet 1 (test 1)	Sheet 2 (test 2)	Sheet3 (test 3)	Average
Weight Before (g)	79.236	78.710	78.218	
Weight After (g)	79.240	78.765	78.211	
Weight difference (g)	-0.004	-0.055	0.007	-0.02

	VOC (ppm)	0.3um	0.5um	1.0 um	2.5um	5.0um	10um
Background Room	0.2						
Background TP1	0.3						
Test 1	0.2	13,527	3,916	582	70	5	1
Test 2	0.3	20,235	6,264	990	82	7	1
Test 3	0.3	18,707	5,741	797	68	4	2
Test Average	0.3	17,490	5,307	790	73	5	1

11 APPENDIX B: LASER MARK

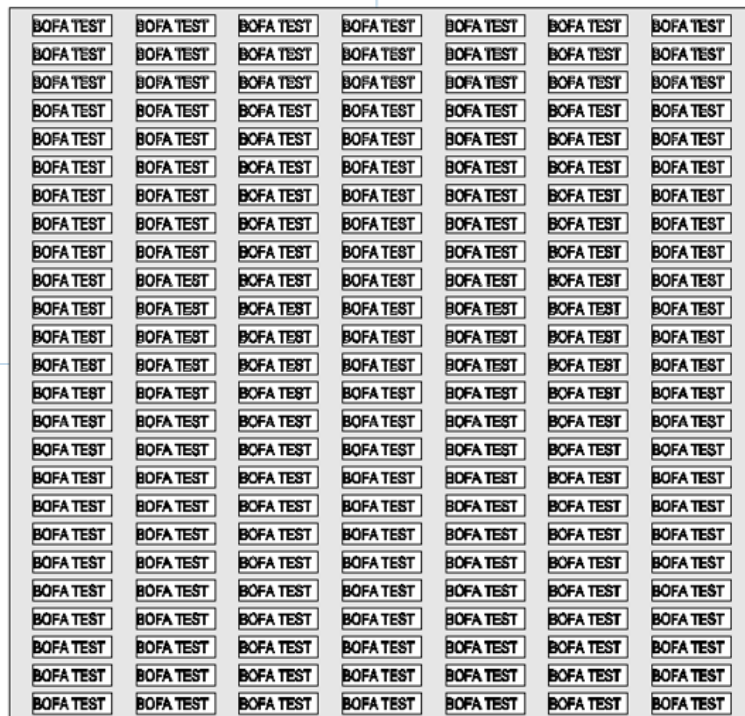


Figure 10 programmed laser mark



Figure 11 achieved laser mark HDPE



Figure 12 achieved laser mark aluminium



Figure 13 achieved mark steel



Figure 14 achieved laser mark PP (CO2)

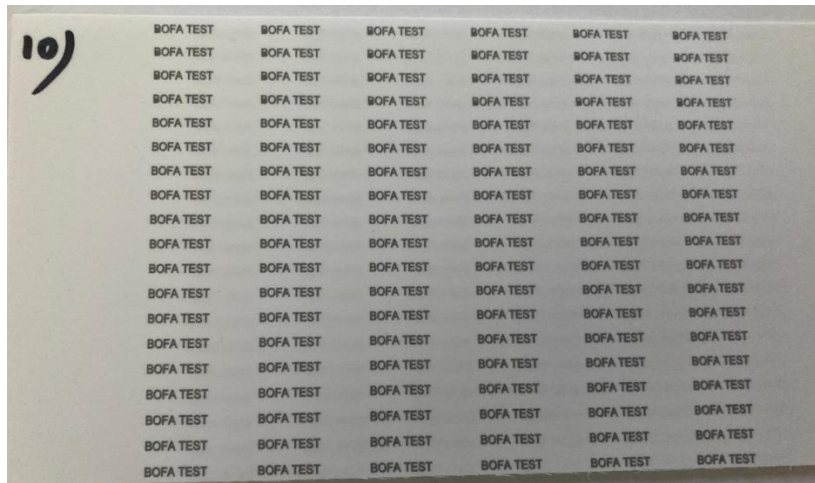


Figure 15 achieved laser mark PP (UV)