POWERLASE
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Low environmental impact laser removal of paints and coatings at high speed

AVT-302 Workshop
Paint Removal Technologies for Military Vehicles
Amsterdam, Netherlands, 9-13 October 2017

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ANDRITZ Powerlase

Contents

Company Highlights

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Year	Event
2000	Company founded using advanced technology developed with Imperial College London
2009	Powerlase Ltd Acquired by **EO Technics Co, Ltd** – Renamed as **Powerlase Photonics Ltd**
2011	Released Short Pulse AO10SP (1.2kW), and AO16 (1.6kW) Laser system Production shipments of AO series to LCD production line in China
2012	Released modular scalable control system – UCS
2013	New CI, website and corporate rebranding Releases: Victory Polaris i200, Procyon g1600, Rigel u80
2014	Releases Polaris i100, Rigel u180 New Generation of high power IR lasers, Rigel i800, i1200 & i1600
2015	Moving to new premises with larger production and application development facility Production shipments of Rigel i800/i1200/i1600 lasers for tailored blank manufacturing plants **Establish Powerlase Photonics Inc.** in Novi, MI to support US and Canadian customers
2016	**Powerlase Holdings** Acquires **Powerlase Photonics Ltd.** and **Powerlase Photonics Inc.** Powerlase opens R&D office in Florida, USA
2017	**ANDRITZ** signed the Investment Agreement to **Powerlase Holdings (April)** Multiple installations of the new Integrated Enclosure lasers.

ANDRITZ Powerlase - locations

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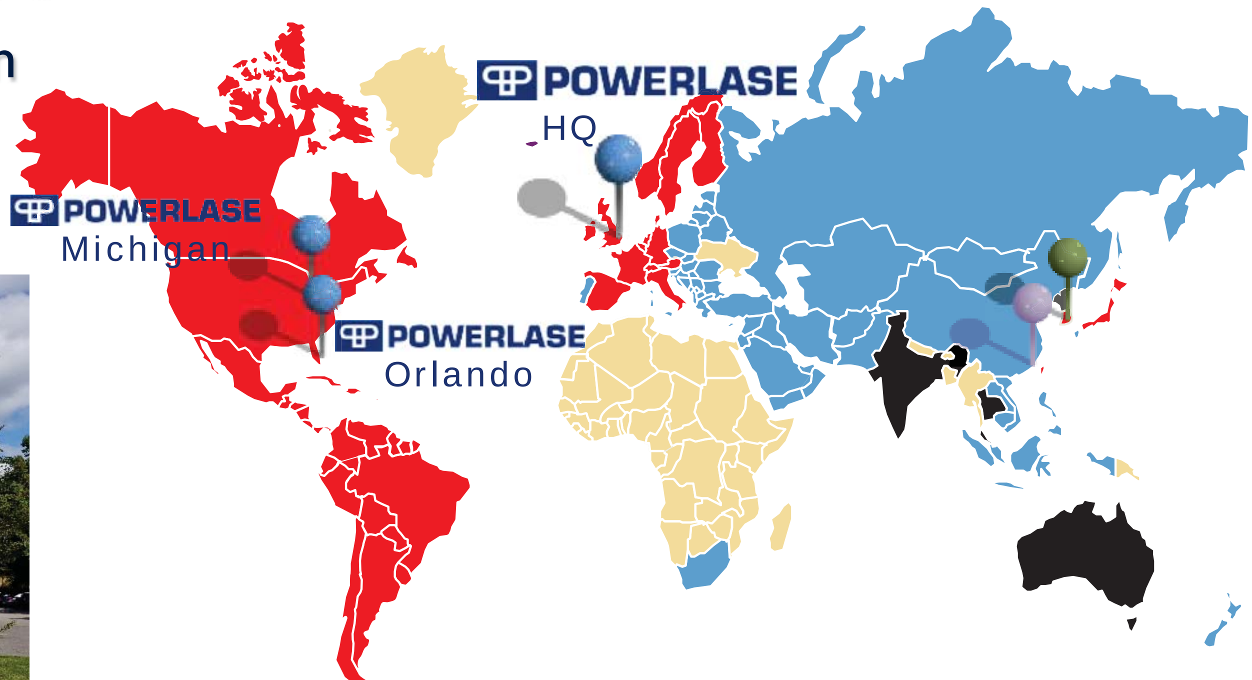
High Power, High Energy, Q-Switched DPSS lasers for industrial applications

Crawley UK, HQ & Production
Orlando USA, R&D
Novi USA, Service Support



Comparison of de-painting methods

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Favorable | Moderate | Unfavorable

Approach → ↓ Characteristics	Diode Pumped YAG Laser	Xenon flashlamp with CO_2 Pellet blasting	High pressure water jet 32,000 psi	Plastic media or sponge blasting	Methylene Chloride
Special Facility Environmental Constraints	Eyewear protection	Eyewear / Ventilation	Yes	Yes	Hazardous chemical
Multi-Coating Layer Sensitivity	High	Low	Very Poor	Poor	Limited
Adaptable to Variety of Substrates	Excellent	Good	Moderate	Poor	Moderate
Paint Stripping Rate	Moderate	Moderate	High	High	Moderate
Substrate Intrusion Potential	Controllable	Moderate	High	High	Low
Total Waste Volume	Very Low	Low	Very High	Very High	High

De-Paint Challenges for Military Vehicles

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- **Paints resistant to chemical corrosion.**
  - Typical paint strippers may be ineffective.

Laser	Pellet	Waterjet	Polymer	Chemical

- **Paints resistant to mechanical wear.**
  - Abrasive media require more time to remove paint.

Laser	Pellet	Waterjet	Polymer	Chemical

- **Undocumented deposits**
  - Metallic or other deposits collected during field operation may not be possible to selectively remove with conventional methods.

Laser	Pellet	Waterjet	Polymer	Chemical

- **Repairs in the field**
  - Urgent repairs may introduce extra layers of paint and undocumented layers applied in the field to patch problematic areas.

Laser	Pellet	Waterjet	Polymer	Chemical

- **Hazardous deposits**
  - Operation in fields of nuclear or chemical warfare, or even within settlements using non-standard building materials, may deposit hazardous substances on the vehicles.

Laser	Pellet	Waterjet	Polymer	Chemical

Typical Laser De-painting
Thick coated - pulse to pulse ablation

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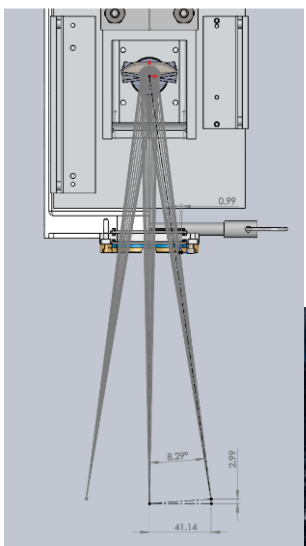
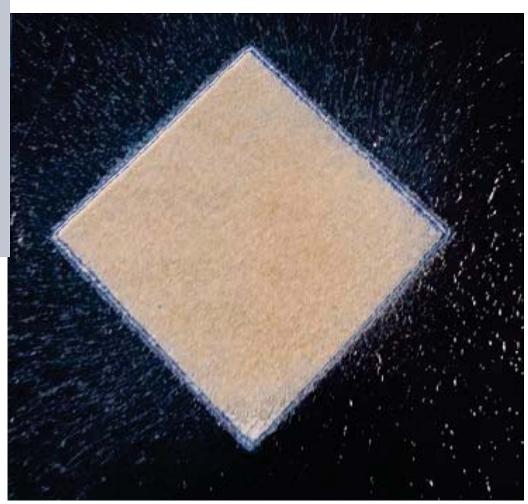
Beam scanned over sample
350 µm thick paint
Ablated by scanned
1064 nm beam, 950 W
De-paint rate 9min/m²





Comparison of laser sources

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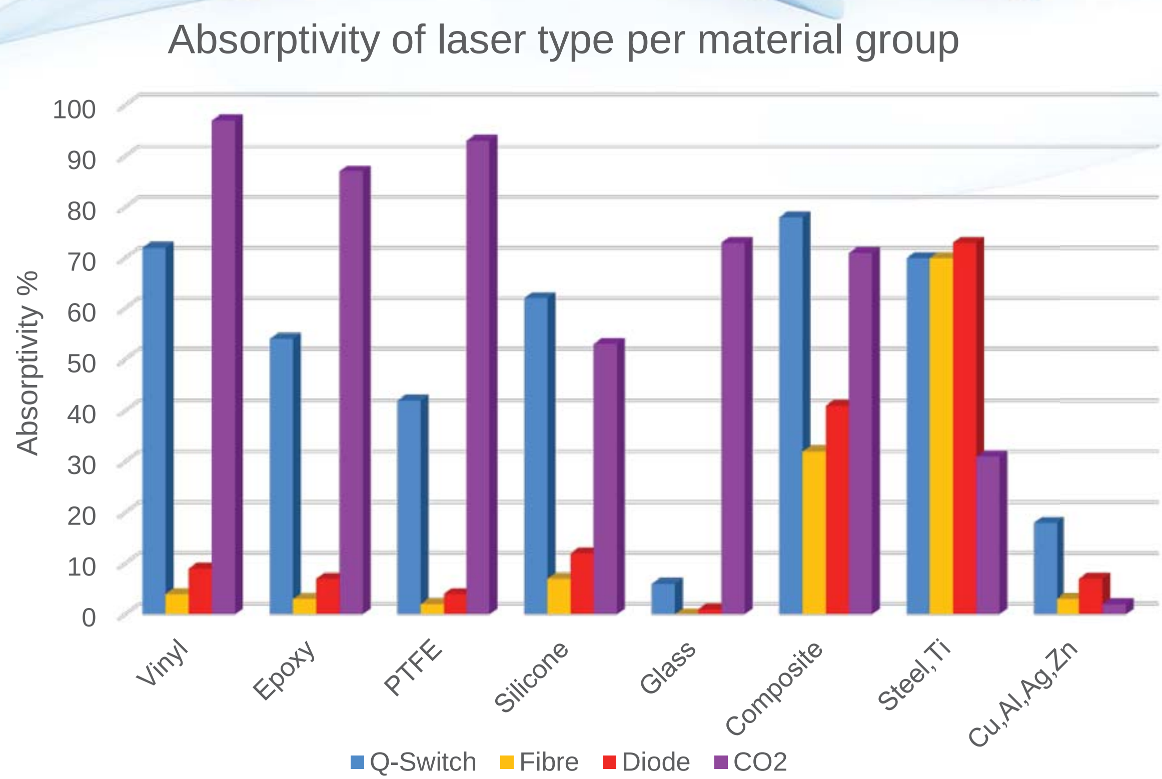

Laser	Wave- length	Fibre Delivery	Energy Efficiency
Q-Switched	1064	100m	12%
Direct Diode	768-980	60m	42%
Fibre	1074	100m	33%
CO_2	10620	0	8%

Faster paint removal
Coating thickness reduction on a pulse to pulse basis

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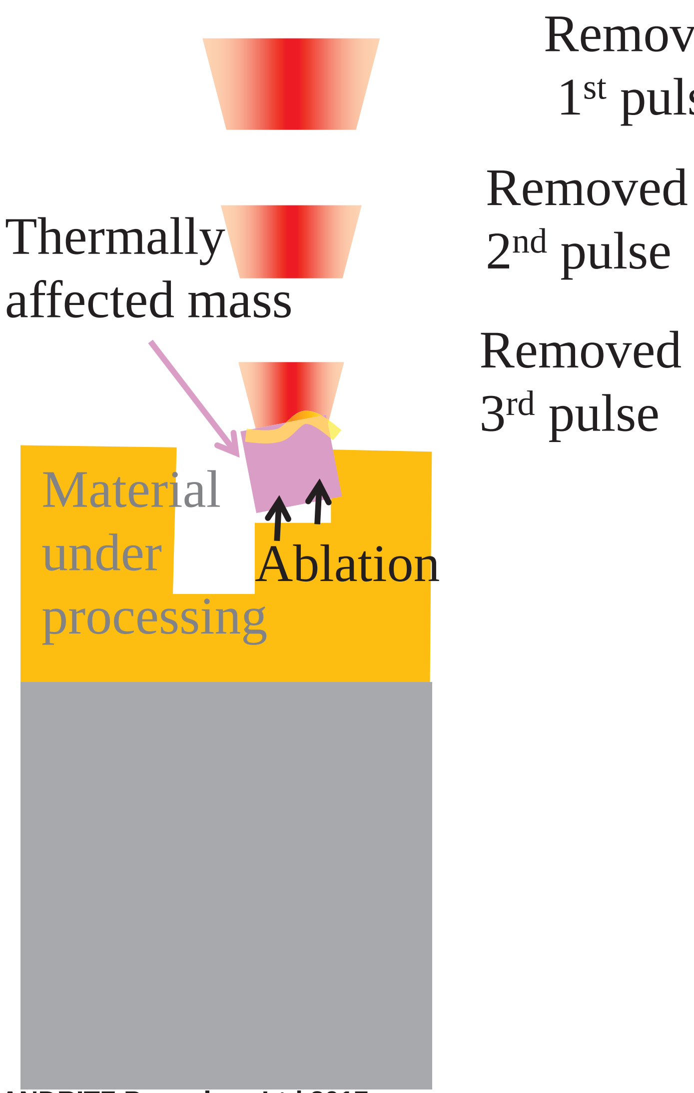
{patent pending GB1710188.2}



Faster paint removal Advantage of higher pulse energy - Detachment

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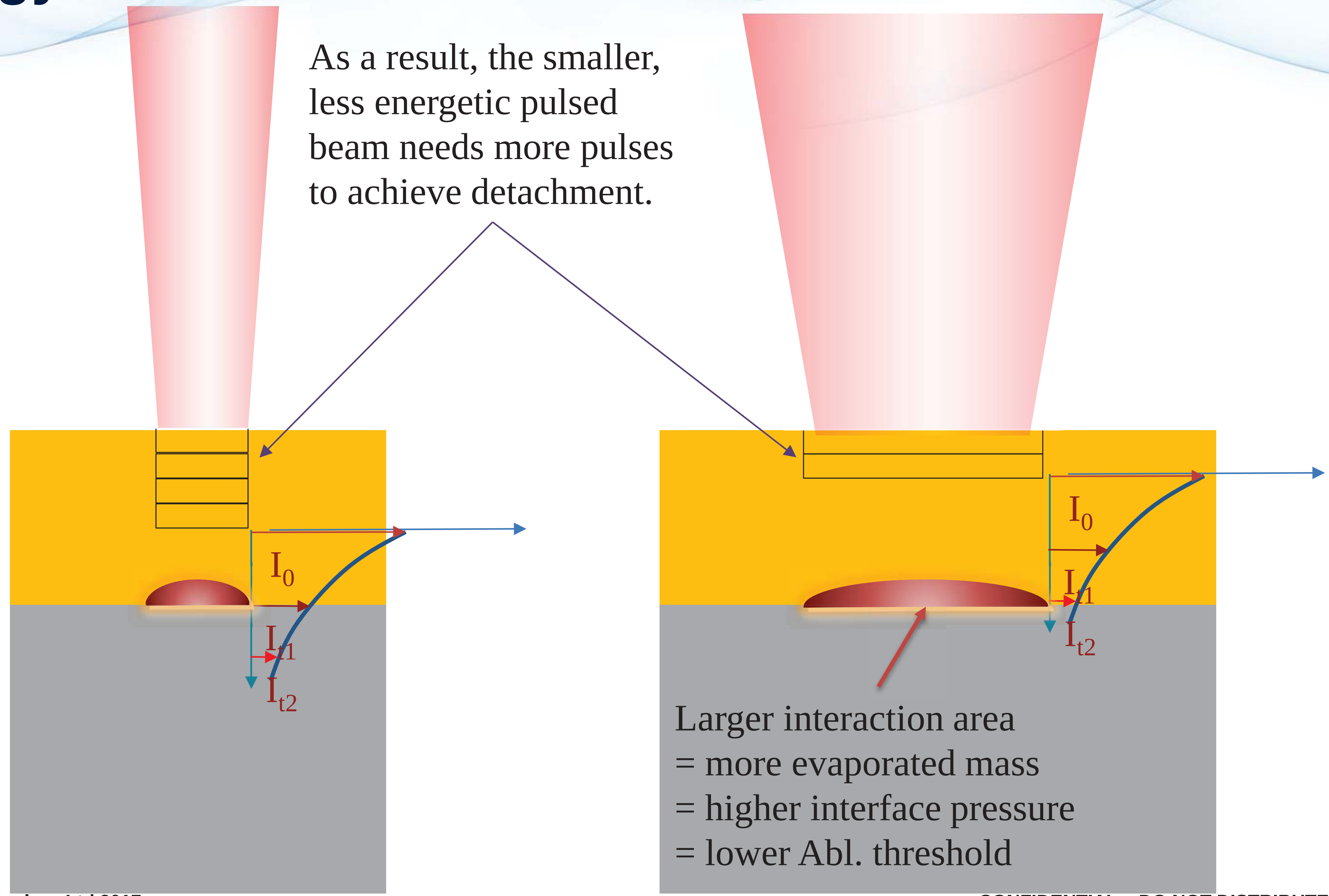
{patent pending GB1710188.2}



Area removal rate, Rigel i1600

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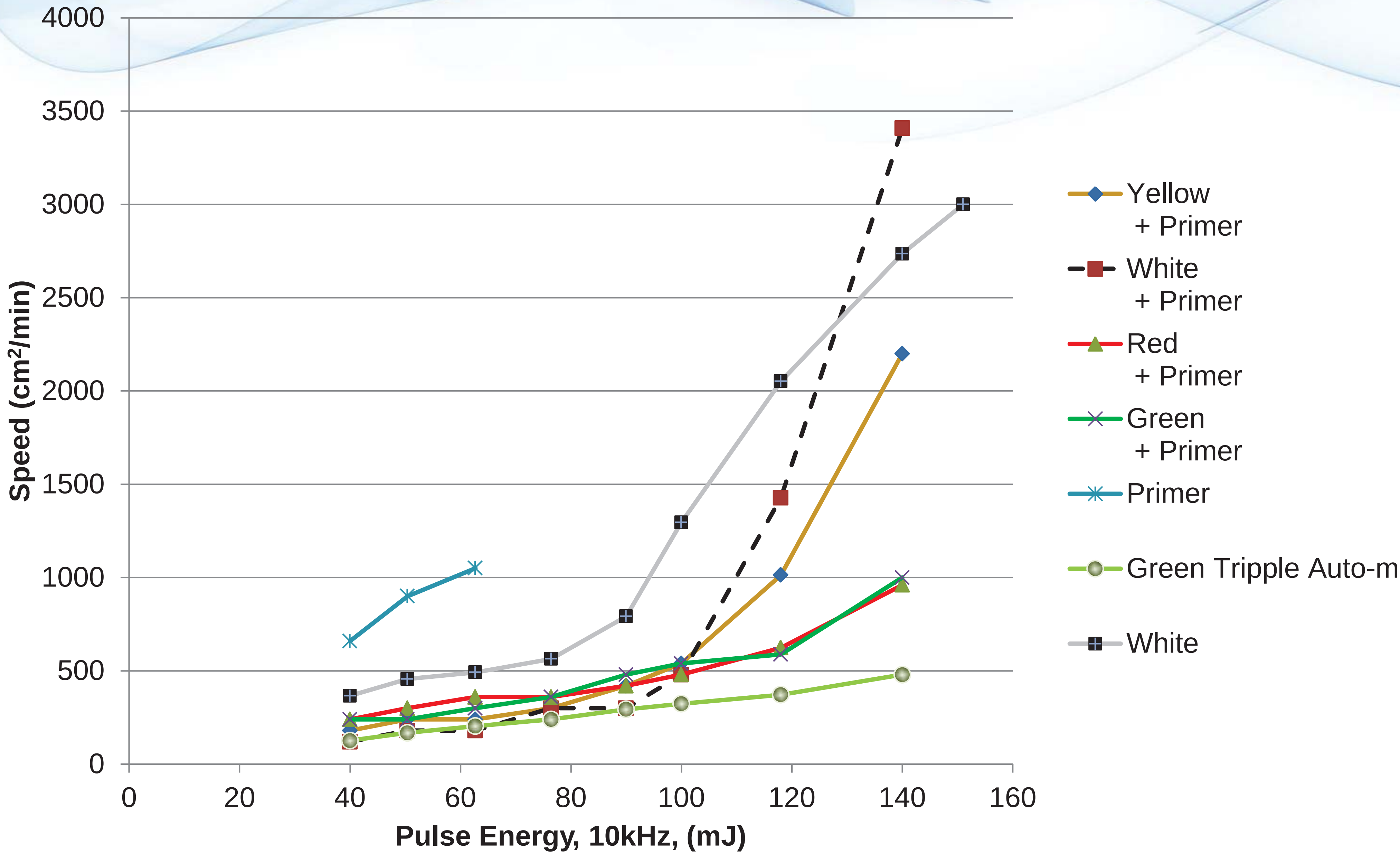

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Vulcan In Action

Example of the high pulse energy Vulcan:

Same paint, same substrate, same distance:

1.6kW / **100mJ**

- Simulating 1kW at Maximum pulse energy

1.3kW / **260mJ** Vulcan

Vulcan In Action

Example of the high pulse energy Vulcan:

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Vulcan In Action

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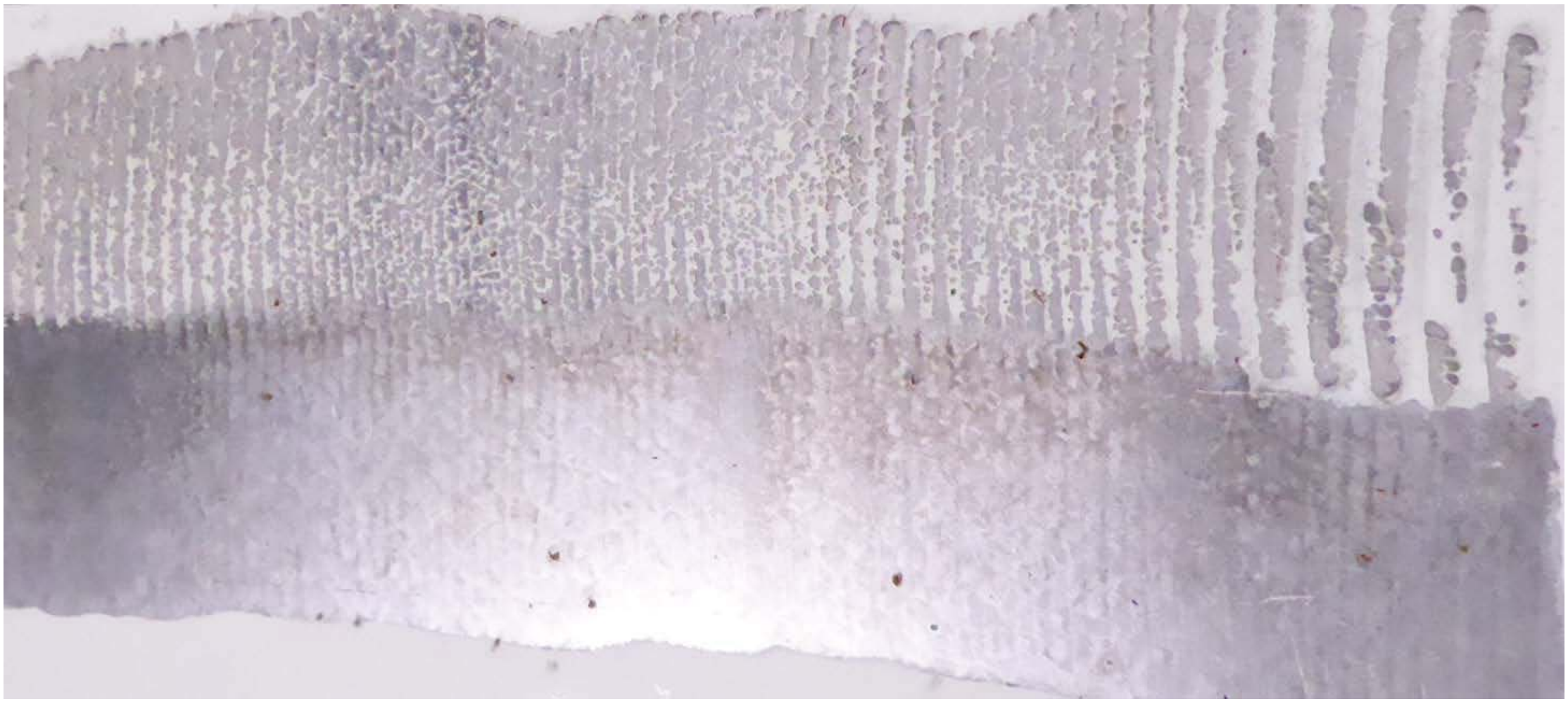

1.3kW / **260mJ** Vulcan

Performance with functional layers

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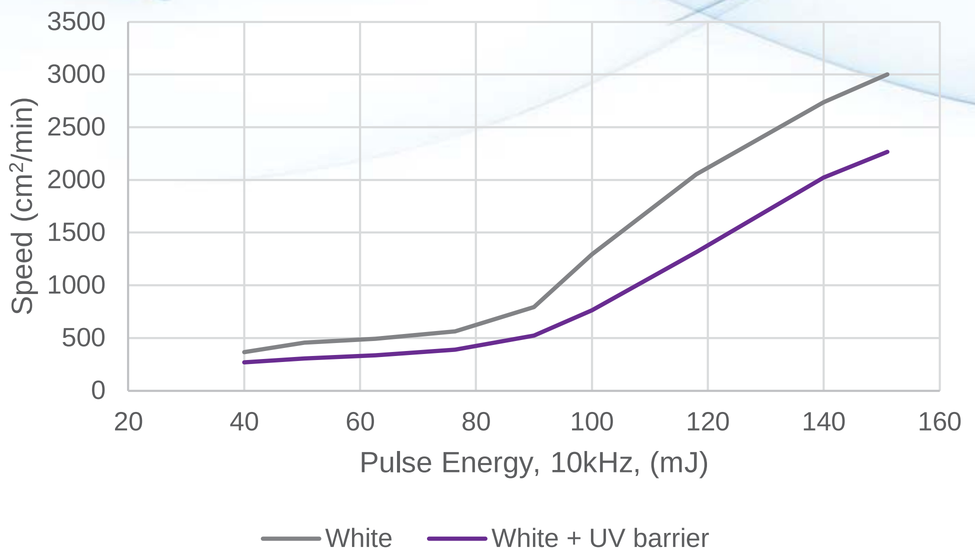
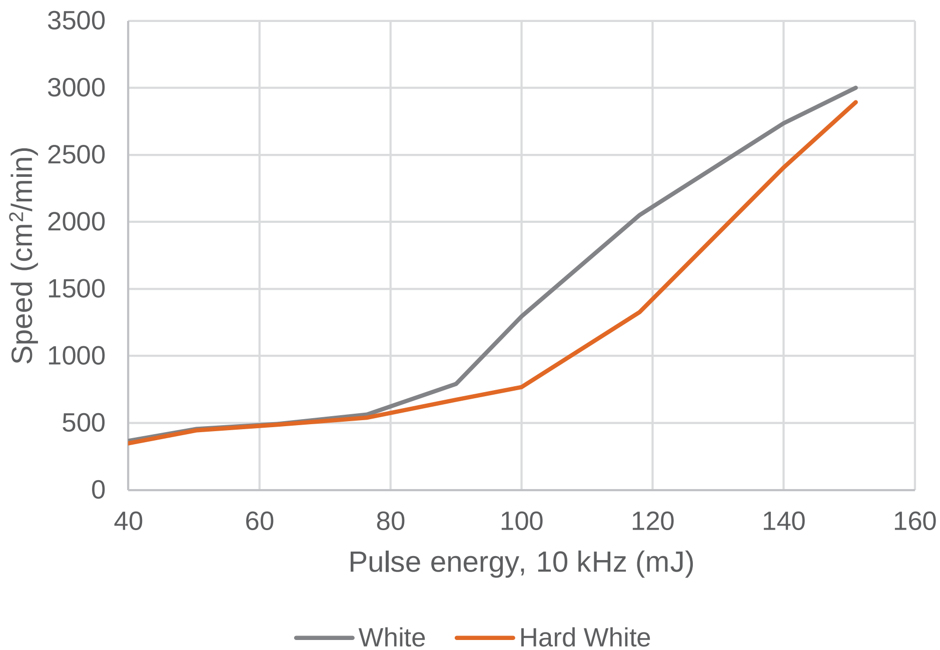


UV Barriers

Detachment based paint removal is compatible with UV protection coating systems.

Latex and 2 part linear polyurethane coatings are also semi- transparent to NIR radiation.



Hardeners such as cyclo-aliphatic amines and phenols maintain or improve NIR translucency.

Hardened coatings, feature a slightly higher detachment threshold but much steeper detachment rates due to higher pressure.

Higher pulse energies are recommended.

Case study – layer by layer removal from GRP using 532nm

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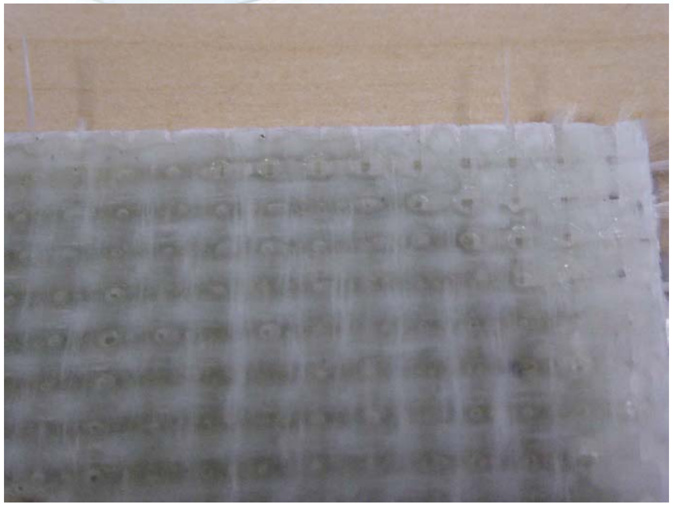
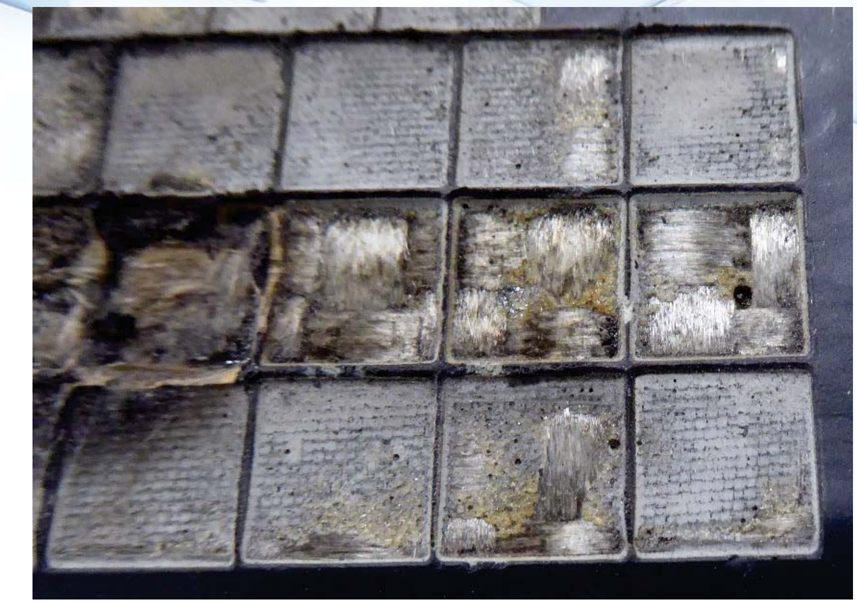
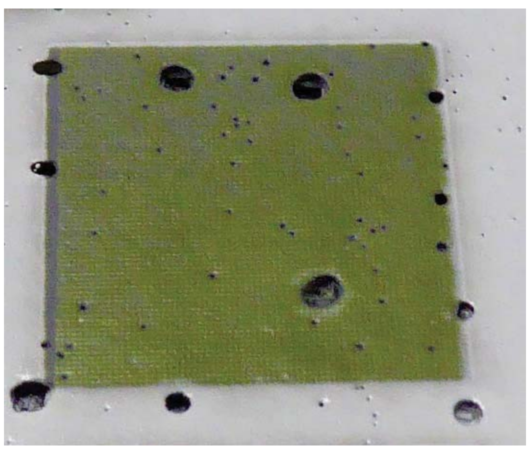
Bare GRP, before coating

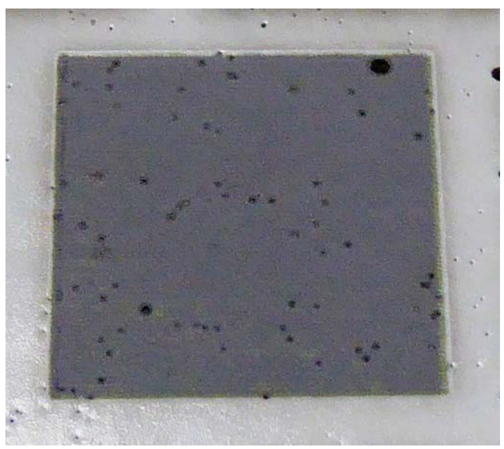


Depth selectivity

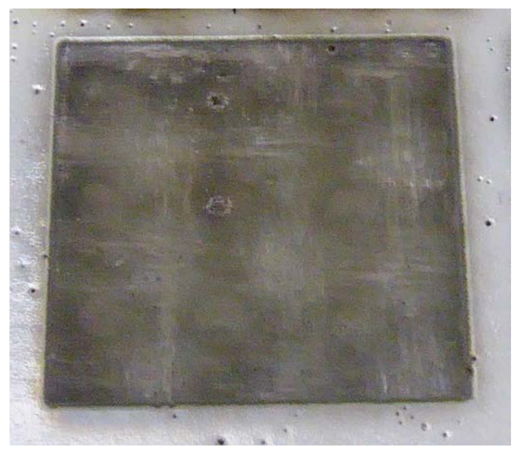




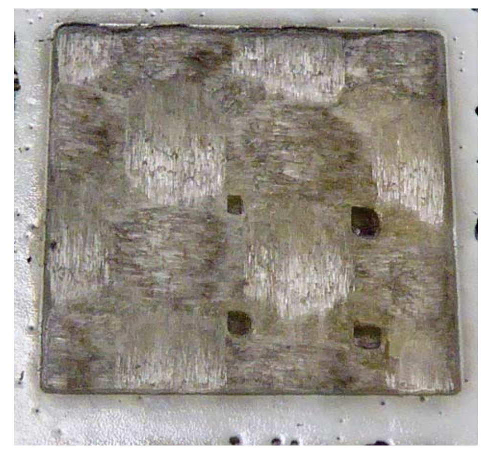
Reveal 2nd sealer
350 mJ/mm^2
0.4 m^2/min



Reveal corrosion protector
500mJ/mm^2
0.28 m^2/min



Reveal GRP sealer
820mJ/mm^2
0.17 m^2/min



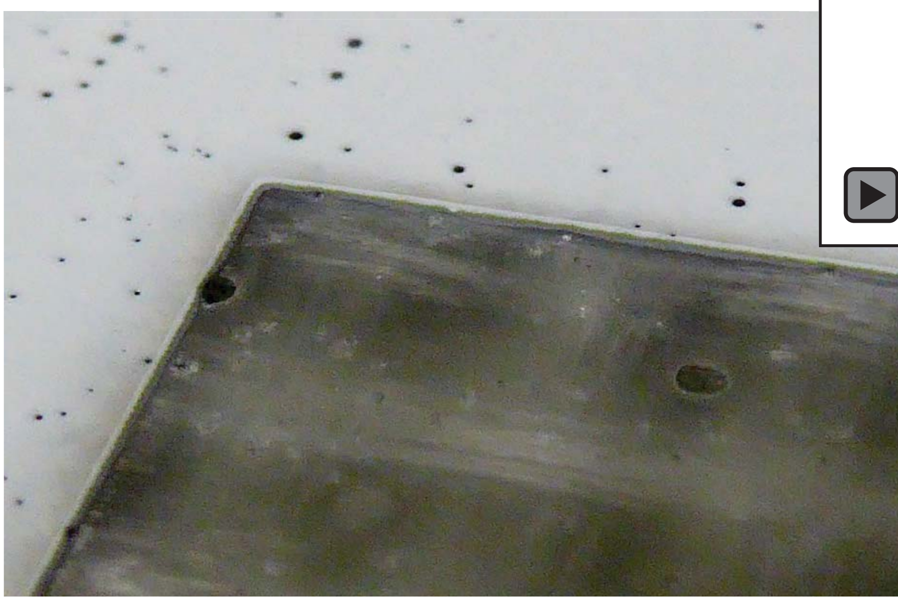
Expose fibres
1.23 J/mm^2
0.11 m^2/min

Revealing GRP sealer at 355nm

355nm (UV) offers best control of removal thickness to 3 µm steps.

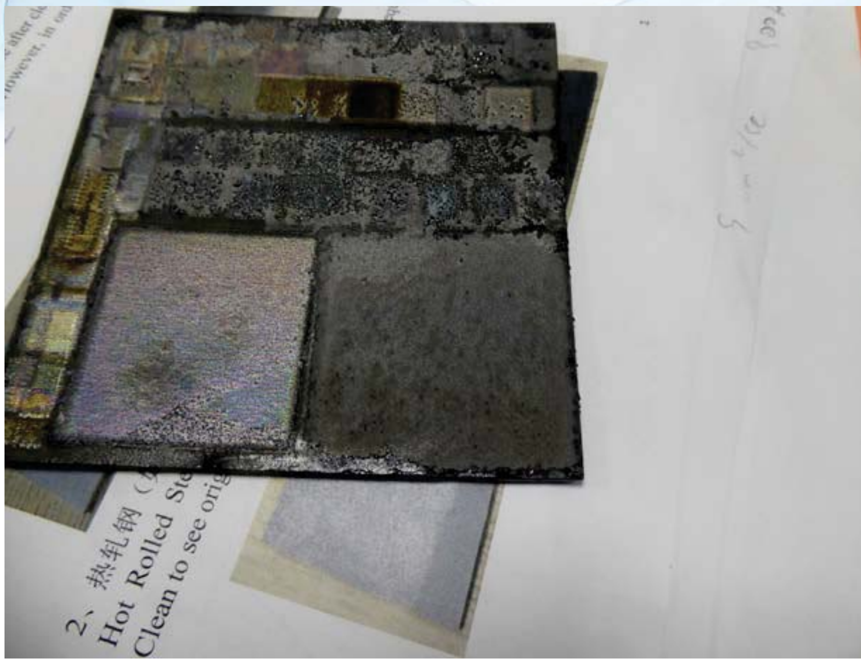
No fraying of fibres

Independence to materials and metal particle loading of paints



Cost of ownership is 4x higher than 532nm.

Enamel tile



ILE4, 100 mJ @10 kHz (1000 W):
ΔZ=30 mm, 0.04 mm line spacing,
0.6 m/s scan speed, twice
Ablation speed= 3.33 cm^2/sec.

I1600(b), 150 mJ @10 kHz (1510 W):
ΔZ= 40 mm, 1.20 mm line spacing,
0.60 m/s 1^{st} scan speed,
1.20 m/s 2^{nd} scan at 90 deg,
Ablation speed= 11 cm^2/sec.

I1600(b), 250 mJ @5 kHz (1260 W):
ΔZ= 40 mm, 1.60 mm line spacing,
1.0 m/s scan speed,
Ablation speed= 32 cm^2/sec.

Enamel tile Observations

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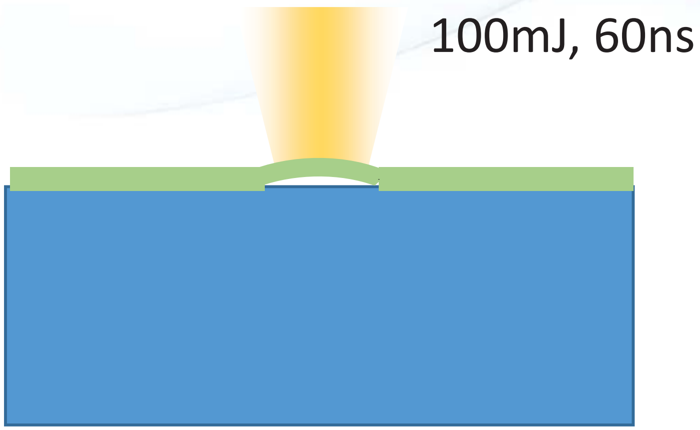
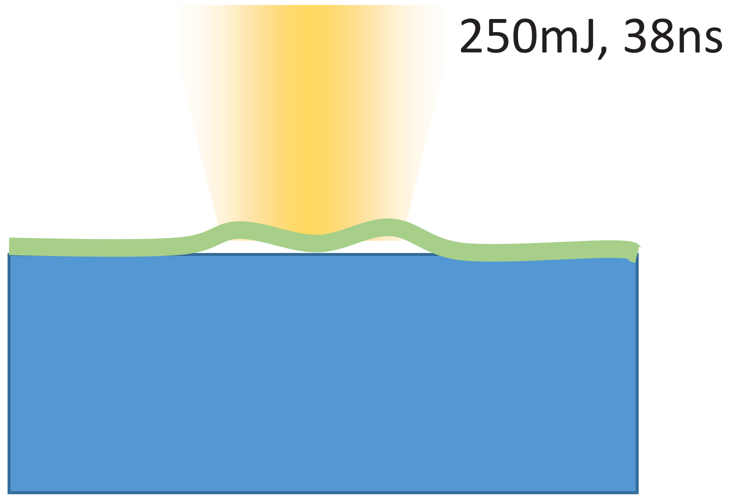
- The coating transforms under radiation if not ablated with first pass.
- High pulse energy needs less irradiance for removing coating material.
- The coating seems to be subject to acoustic shockwave ripple of the substrate due to high pulse energy. Thus more effective “shake-off”.





Removal of heat resistant paint

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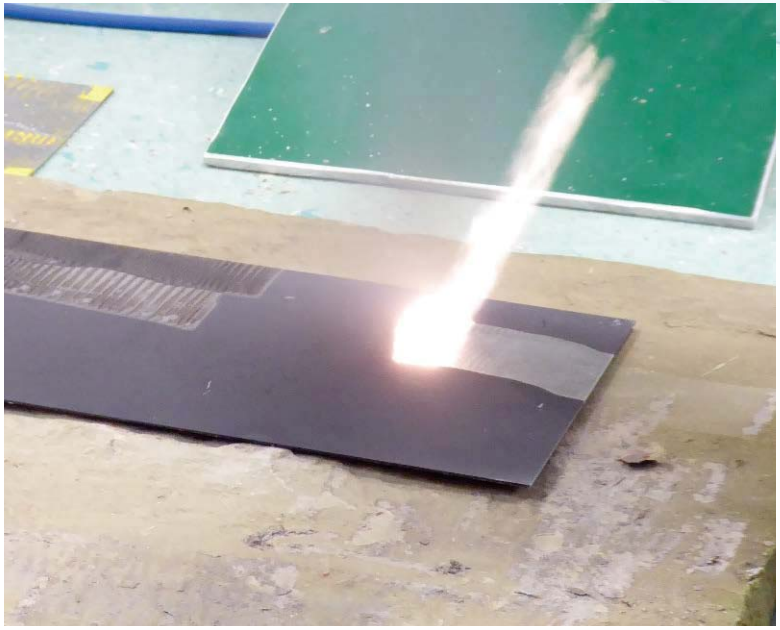
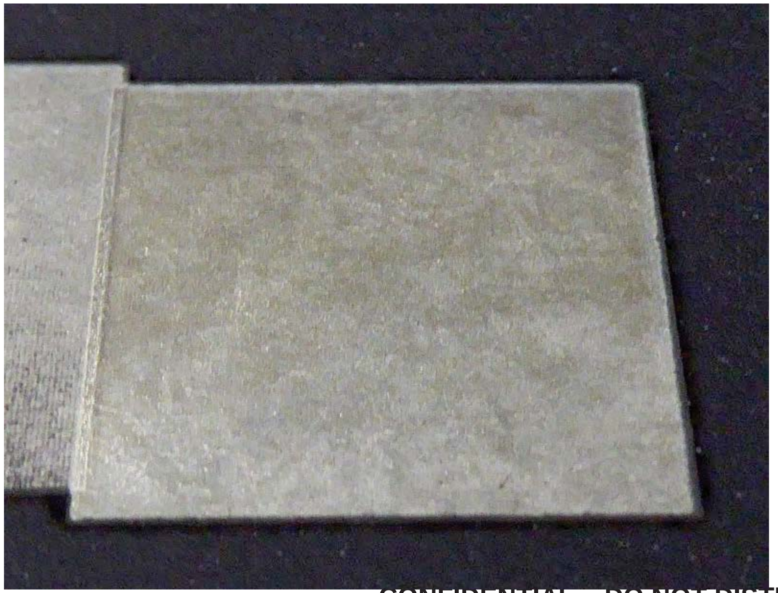
1.6kW average power has been used to remove heat resistant paint.
The paint protects up to 800 ^{o}C.

200 μm double layer removed at 0.28 m^2/min.

There is no non-linear effect with pulse energy.

The higher peak intensity is seen to boost laser interaction with the paint's additives.





Rust Removal

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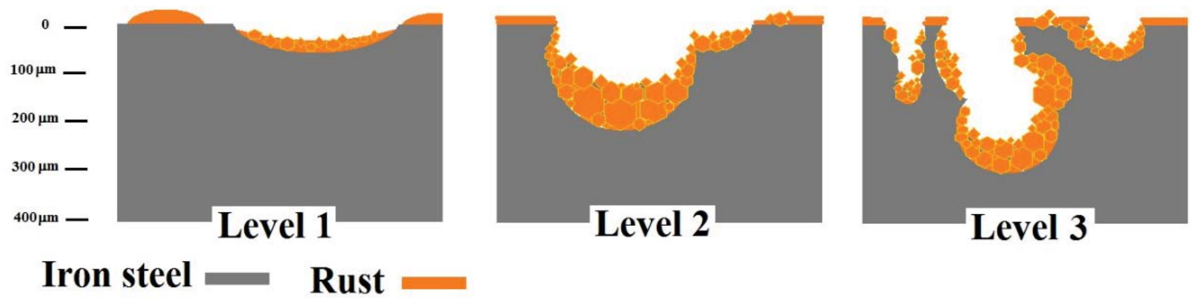
**3 levels of rust:
Surface, pitting, penetrating**



For level 3, laser needs to remove rust and substrate.

Acoustic shock removal aids Levels 1 & 2.

Removal of coated debris

1. Simulating maintenance conditions in the field.
Metal plate was covered with primer. Then metal and polymer swarf were sprinkled while the primer was still wet. An overcoat and a hardening coat followed.

Difficulty to remove contaminants with NIR is mainly dependent on the size of the particle, especially the metallic.

2. UV was used for removal of marker pen, oil, swarf and lacquer overcoat. Results were excellent.

Removal of coated debris

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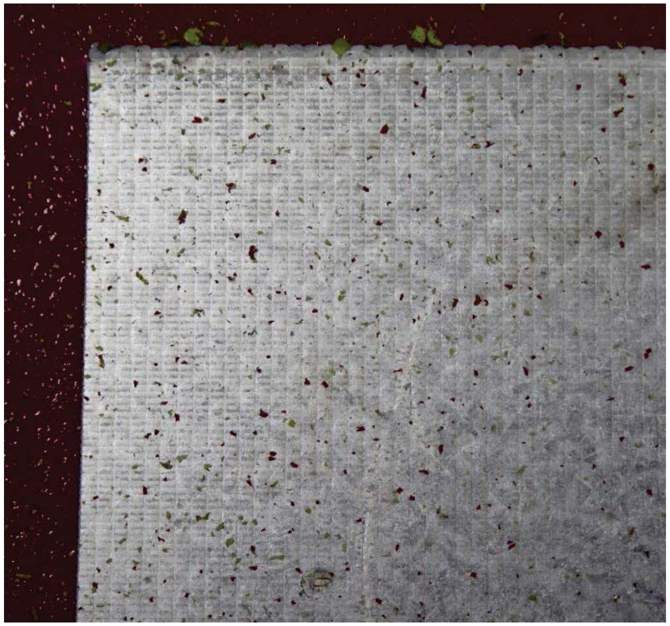
In single pass:

- **Higher pulse energy can help to shock away larger swarf particles.**
- **The difference up to 300mJ is just enough to observe.**
- **Higher pulse energies are expected to demonstrate more intense results.**

100mJ



150mJ

220mJ

Removal rate data
White Paint + primer with 1064 nm

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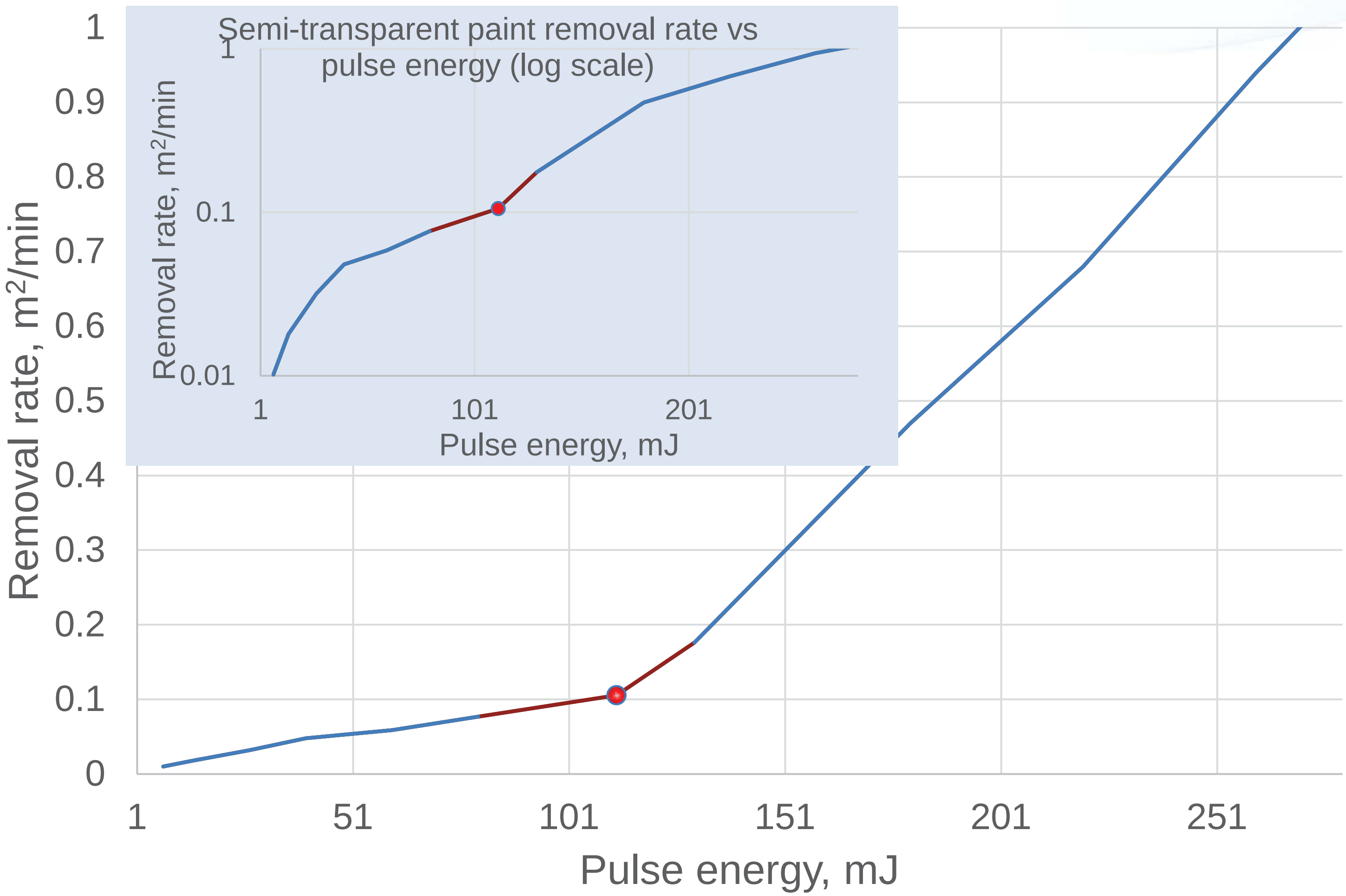
Nonlinear increase of semitransparent paint removal rate vs pulse energy, <u>stable intensity</u>



Performance with functional layers – UV barriers

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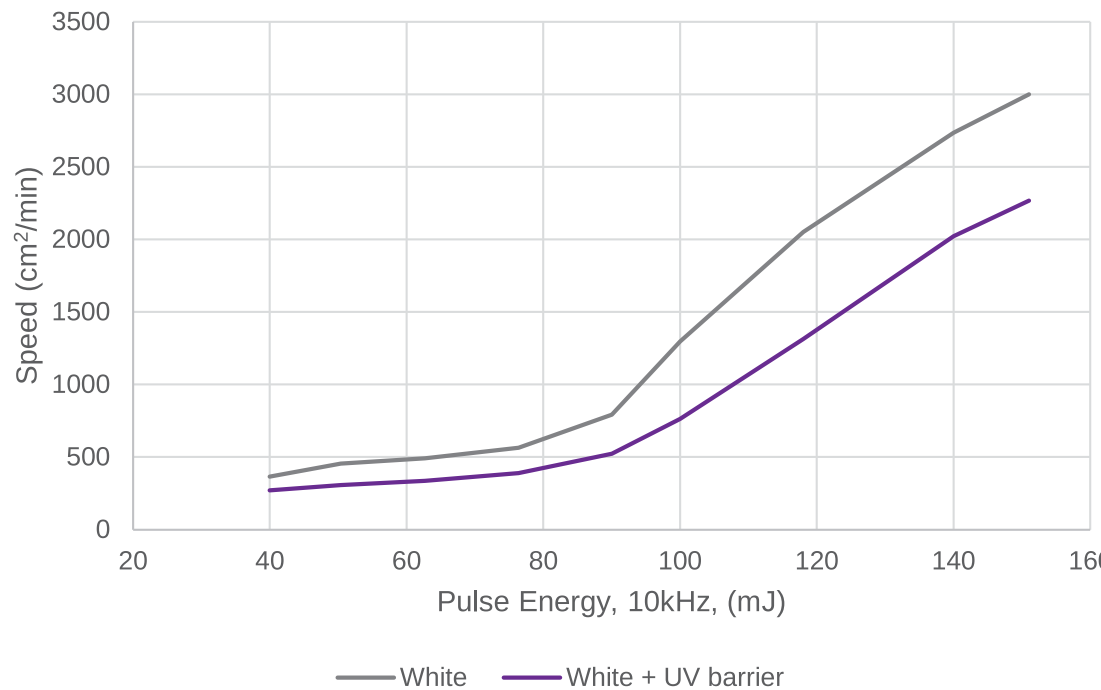

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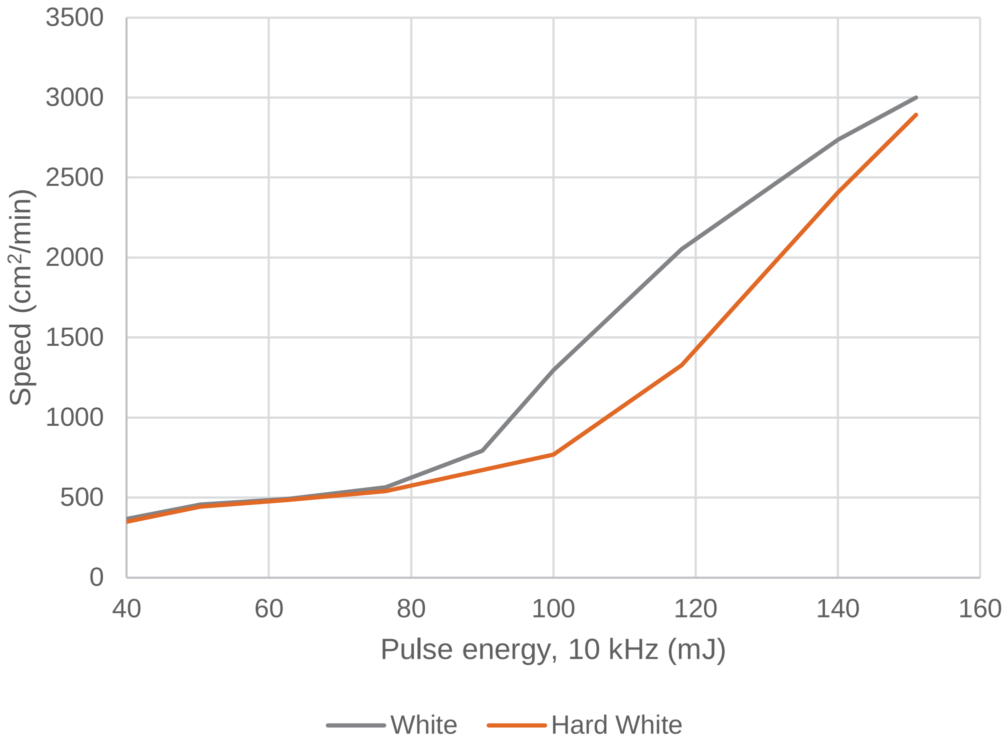

Laser De-paint limitations

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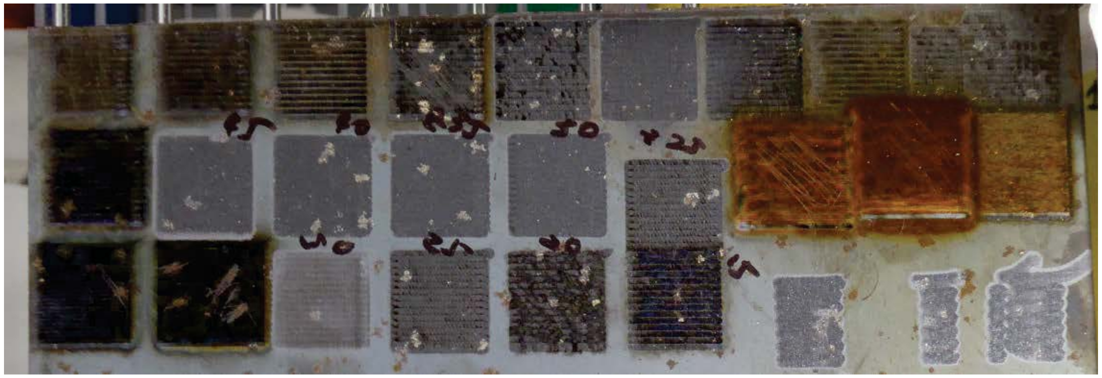
Heat input

- **Persisting on an area for several seconds can thermally load the substrate material.**



The results are:

- Fraying and melting of underlying composites and polymers.

- Bending, hardening and oxidation on metal sheet substrates

Laser De-paint limitations

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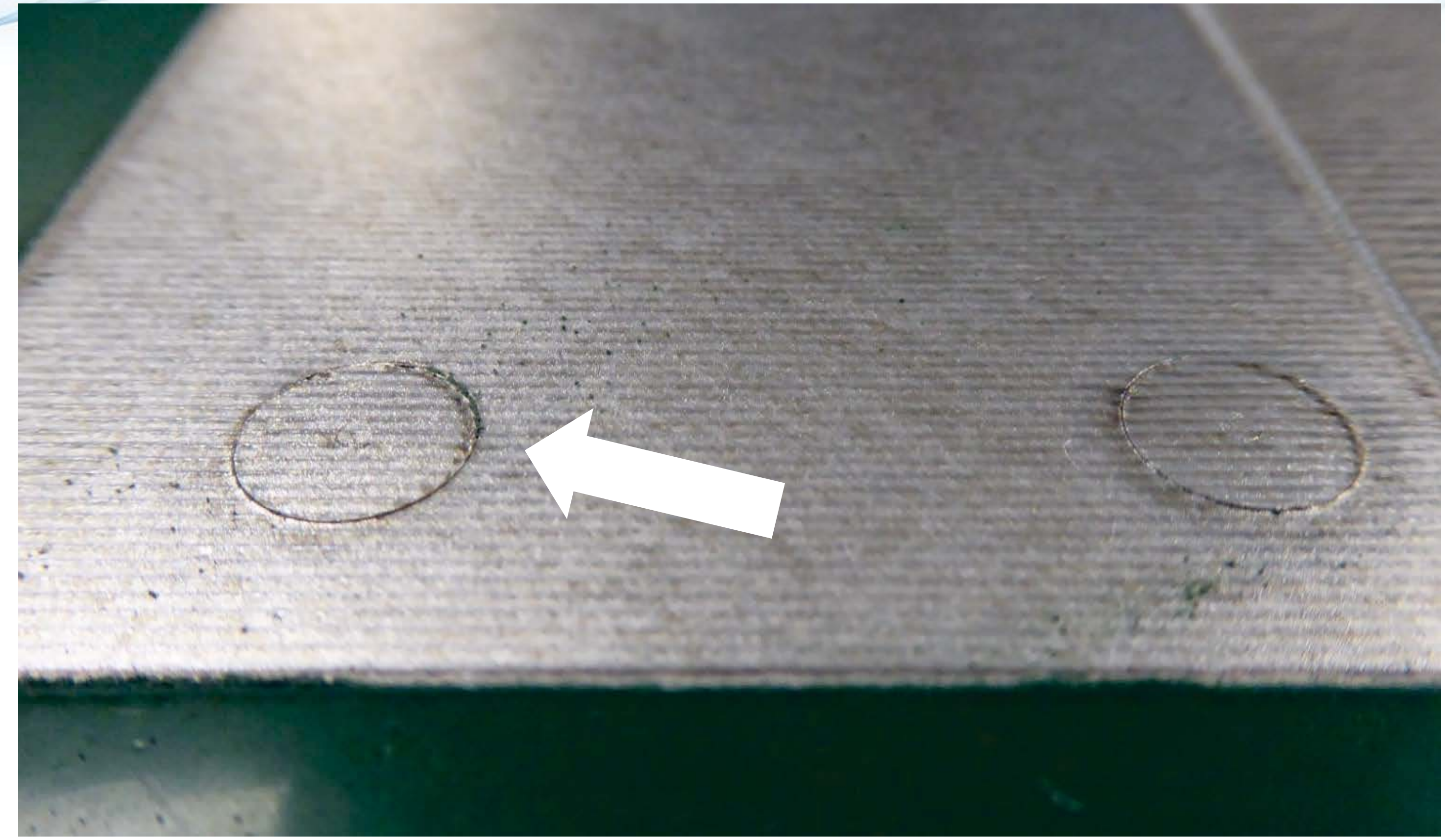
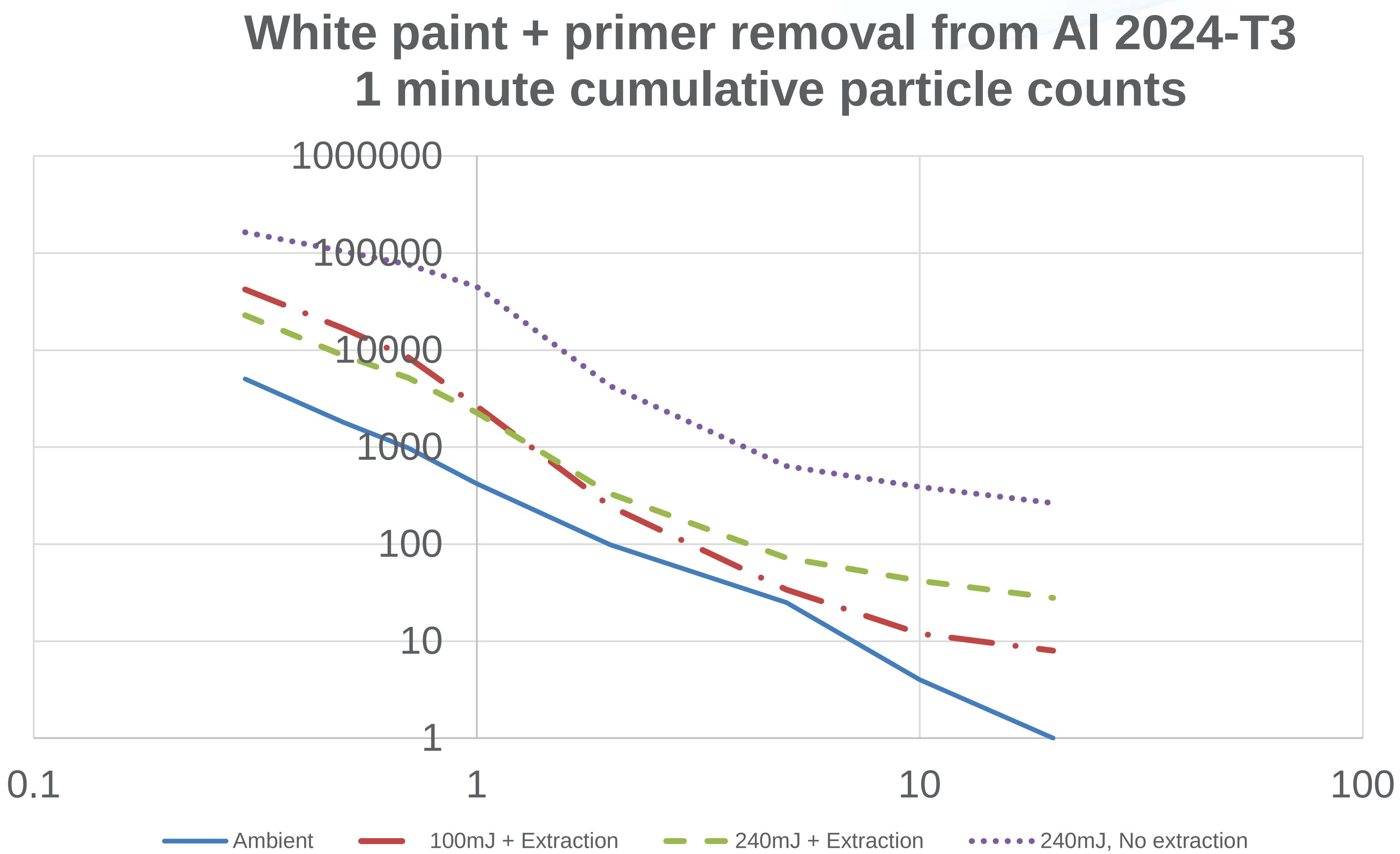
Line of sight



The laser beam will typically affect anything that can be directly exposed to the stream of photons.
If the coating is not in line of sight from the source, it typically remains attached.

Environmental considerations

Flake and particle distribution



MIL-PRF23377 Primer + MIL-PRF-85285E,Type 1, Class H, Colour #17925

Environmental considerations

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Thermochemical decomposition

The following by-products have been detected during laser <u>burning</u> (cutting) of epoxy and polyurethane polymers:

Benzene, phenol, p-cresol o-cresol, o-xylene,-m-xylene, p-xylene, phenyl acetylene, aphthaiene, 2,3-benzofuran, toluene, naphthalene, 2,3-benzofuran, styrene, 2-ethyl phenol, 4-ethyl phenol, ethyl benzene, formaldehyde, acetaldehyde, methyl methacrylate, 2-brmo phenol, acetophenone, 1,1-biphenyl, ethyl benzene, methyl furanone, benzoic acid, 2-phenyl toluene, 2-methyl benzofuran, acenaphythylene, phenanthrene, pyrene.

Environmental considerations

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Thermochemical decomposition

Monitoring concentration of phenol and xylene during white paint + primer removal for 1 minute:

	CO_2 or CW Fibre/YAG	λ=1μm, ns Pulsed <100mJ	λ=1μm, ns Pulsed >200mJ
Phenol	32 mg/m^3	26 mg/m^3	4 mg/m^3
Xylene	87 mg/m^3	63 mg/m^3	11 mg/m^3

Laser De-paint limitations

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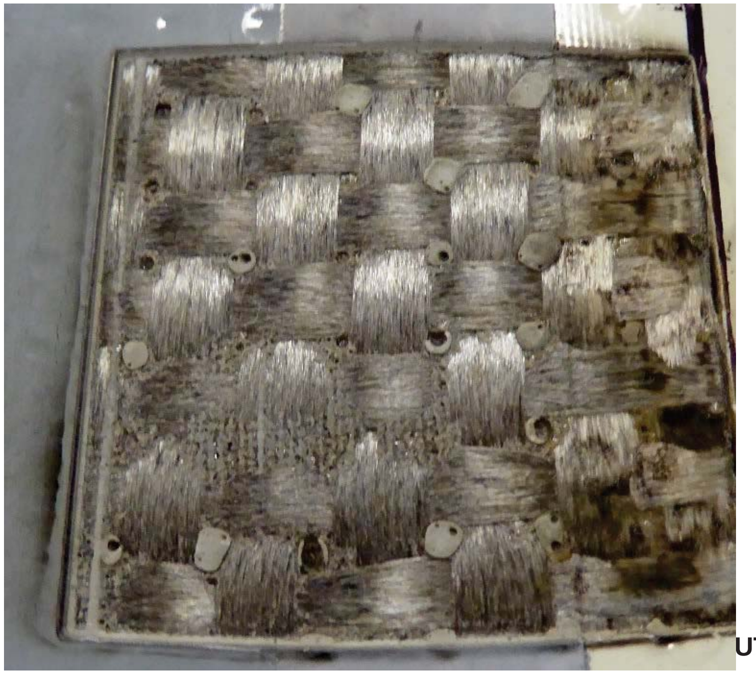
Thickness variations and Undocumented repairs and sublayers:

- Can result in uneven removal of paint
- Residue in areas of thicker paint
- Control feedback loop or human operation is necessary to deal with such.



Description of Q-Switched laser

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Characteristic	Powerlase i1600E
Average Power	Up to 1600 W
Pulse peak power	Up to 4 MW
Power scalability	400W, 800W, 1200W, 1600W
Integrated Ablation Sensor	Yes
Max Abl. Speed. 70 μm layer	0.8 m^2/min
Fibre length	up to 100 m
User replaceable fibre	Yes
Power variation	<1%

Beam direction

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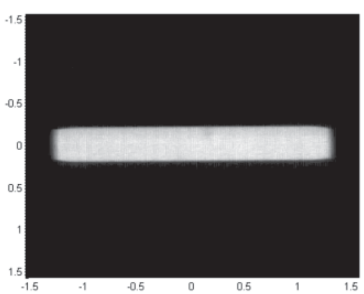
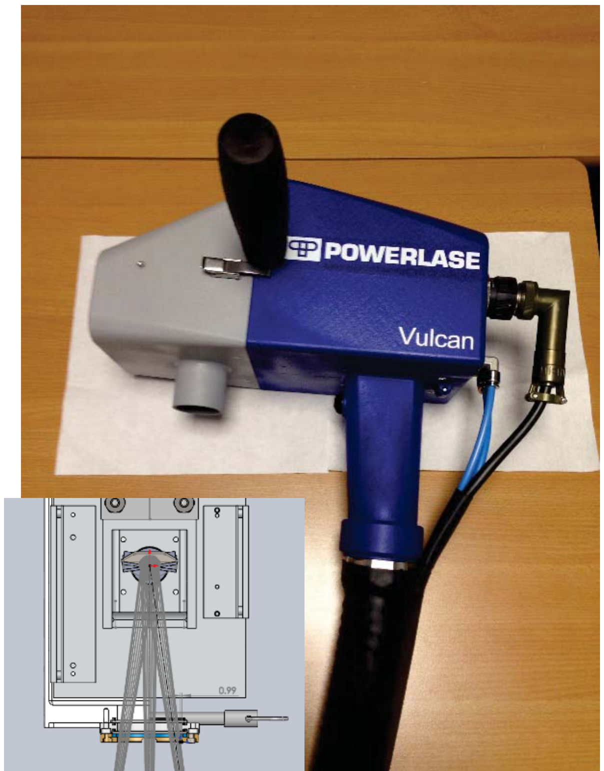
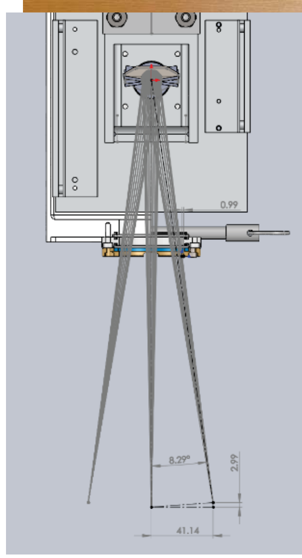
Line Focus

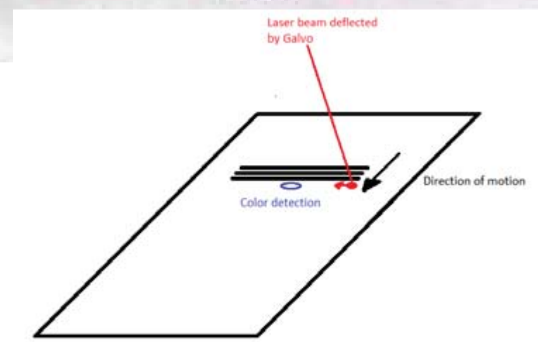


Galvanic scanner





Polygon scanner



Operation and architecture

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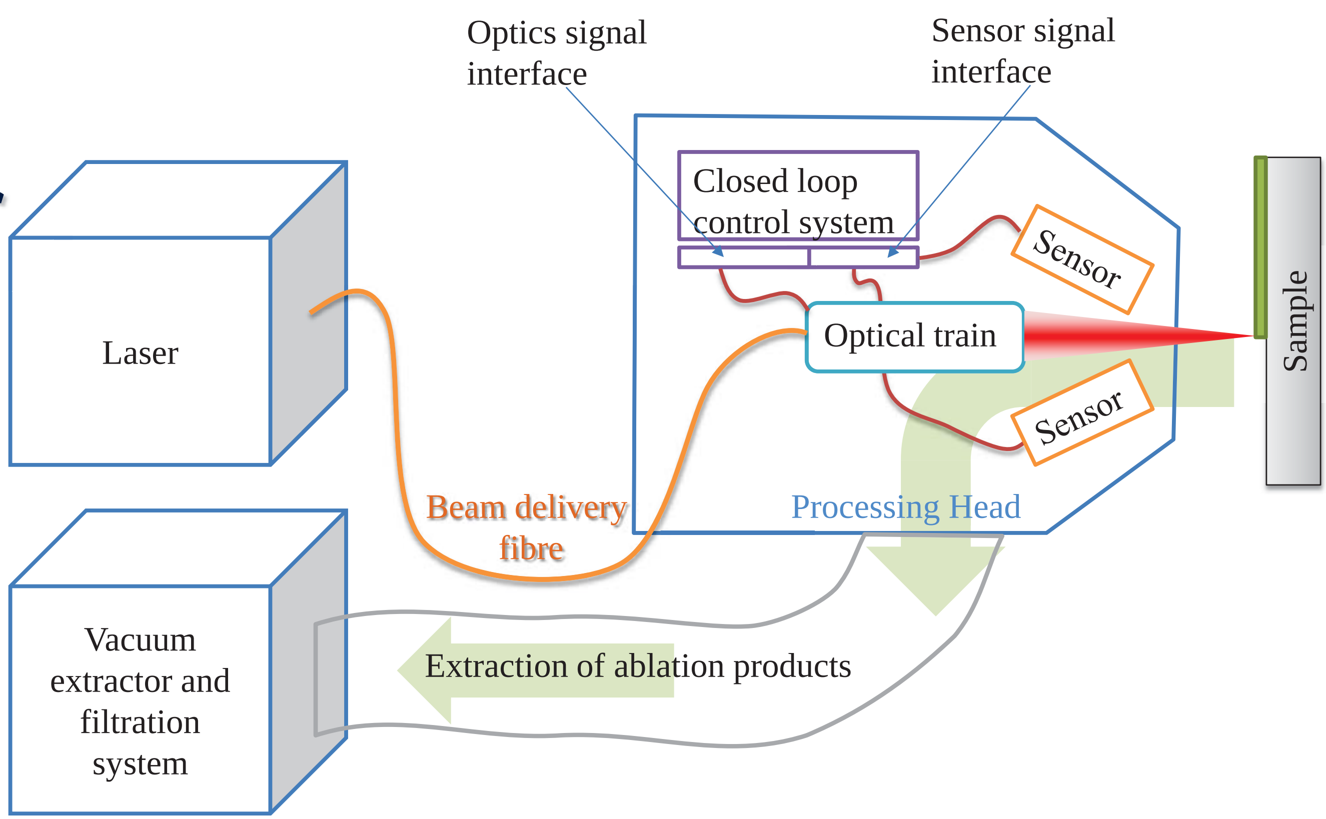
Scanning field up to 10cm
Max speed 25cm/s
Up to 2.4kW average power
500um smallest spot size
152 J/cm^2 fluence
3GW/cm^2 irradiance
Smart paint detector



Potential sensors for closed loop control

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- **LIBS**
  - Qualitative monitoring of ablatants
- **Plasma emission**
  - Monitor successful ablation of coating
- **Reflectivity**
  - Monitor reflection to assess full or partial removal
- **Camera**
  - Target coated areas only, identified by colour
- **Thermal emissivity**
  - Identify coating residue by emissivity variation
- **Acoustic**
  - Assess coating thickness prior irradiation
- **Capacitive**
  - Assess coating thickness
- **Surface profile**
  - Assess surface variations prior irradiation
- **T-Rays**
  - Assess coating thickness, impurities and density variations, prior irradiation

Conclusion

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Lasers offer a versatile solution for paint removal.
The process is mainly self limited on a metal substrate.
High pulse energy can enable a fast coating detachment process available with most polymer coatings on metal.
Process limitations can be resolved with automated control and safety aids.