Coatings Trends & Technologies SUMMIT

LASER SOLUTIONS

Enabling New Generations of Coatings & Line Operations

Laser Applications for Coatings

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Cleaning

Fast
- >1,000 m^2/hr demonstrated

Selective
- Non-contact, cleans where needed

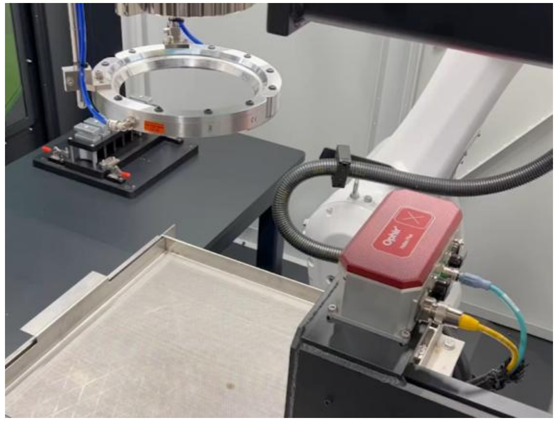
Sustainable
- No byproducts, low energy consumption

Curing and Drying

Fast
- Cure powder coat in a few minutes
- Reduce curing oven size/expense

Sustainable
- Heat the Coating, not the Part
- Simple, “Cold” Oven
- Low energy consumption

Stripping



Fast
- >50 cm^2/sec paint stripping

Selective
- Strips only where needed

Sustainable
- No byproducts, low energy consumption

Laser Solutions I 15 Minute Powder Line Concept

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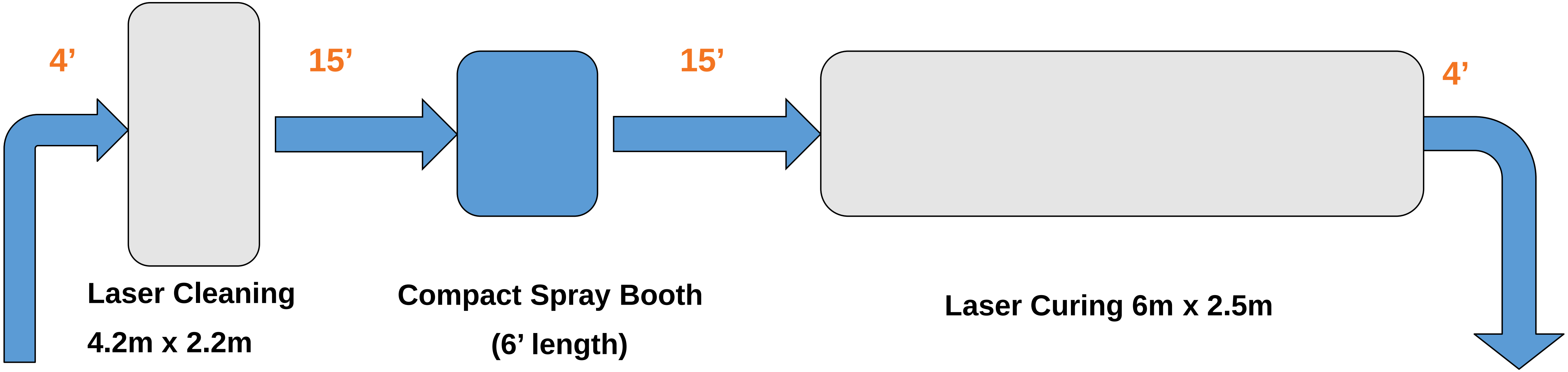
Total travel time end-tend 14:50

6.0 FPM travel Speed= 9:30 to entry of Laser Curing



LASER CLEANING/ABLAGION

Cleaning I Surface Cleaning Technologies

Abrasives: grit blasting, abrasive water jet, wire brush

- Labor-intensive, personal safety concerns
- Uneven material removal, inconsistent performance
- Eventually destroys components by reducing wall thickness
- Abrasive water jet – high maintenance cost, 50% downtime

Chemical washing/cleaning/stripping/pickling

- Slow
- Environmentally unsafe, personal safety concerns
- Masking required
- Depends heavily on PM

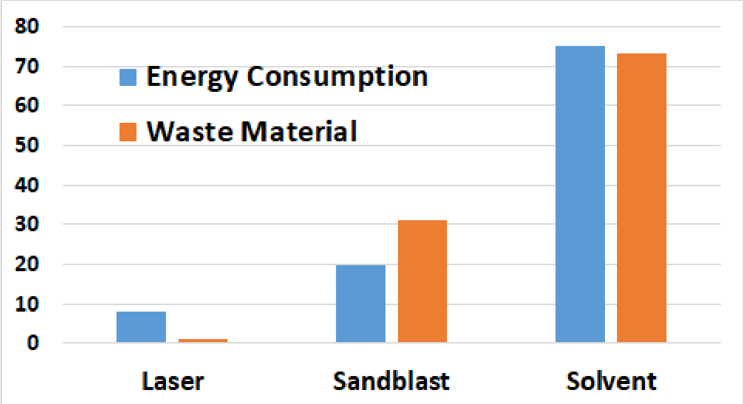
Burn-off ovens

- High energy consumption

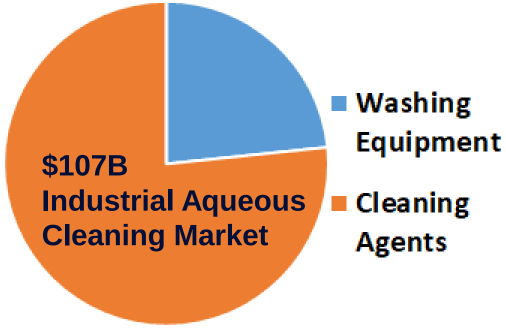
Green Technology I Laser Ablation/Cleaning/Stripping

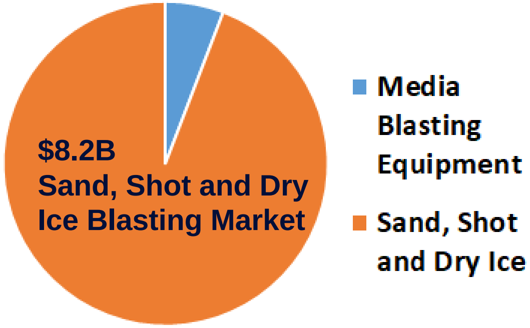
Laser Slashes Energy Consumption and Waste

Case Study – Paint Stripping



Aqueous & Abrasive Cleaning Spend Dominated by Consumables



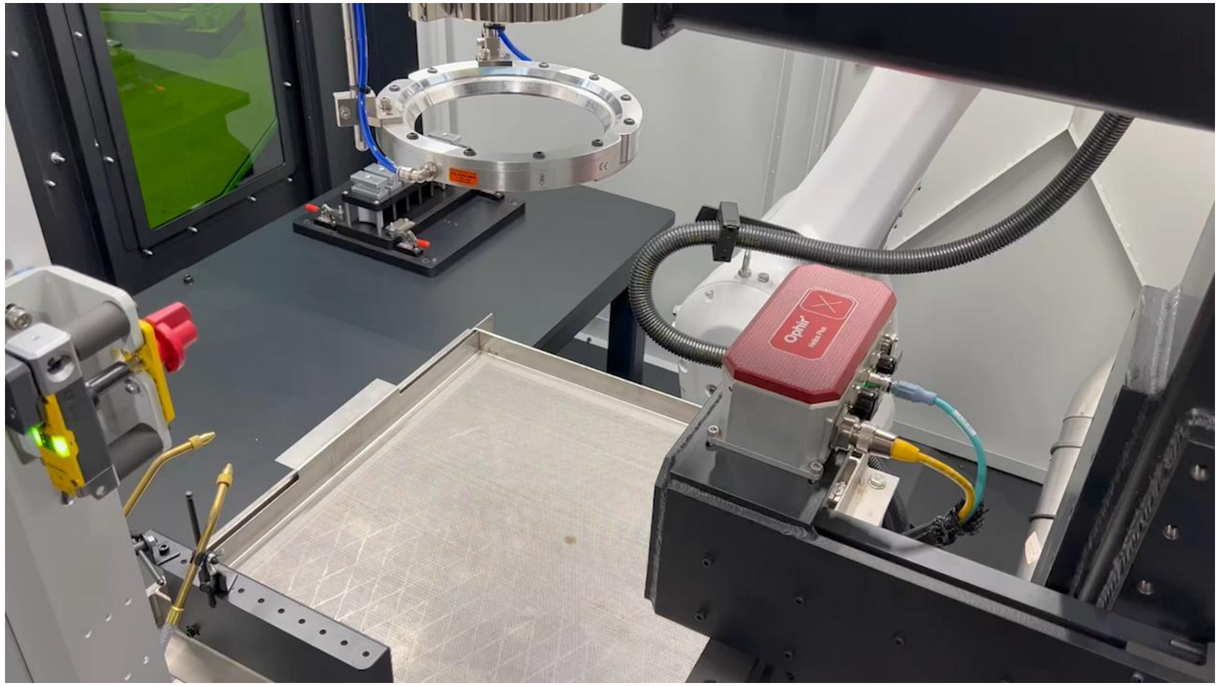


Laser Cleaning Attributes

Productive	Cleans quickly
Sustainable	Consumable-free, saves energy
Selective	Cleans only where needed
Low OpEx	Maintenance-free, eliminates consumables
Safe	Easy-to-operate, non-toxic, quiet
Touchless	Damage-free surface, extends part lifetime

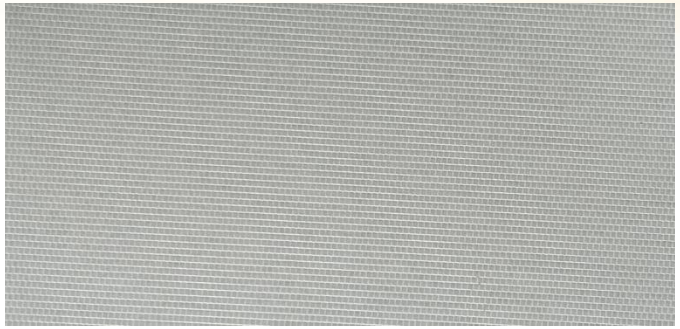
Green Technology I Laser Ablation/Cleaning/Stripping

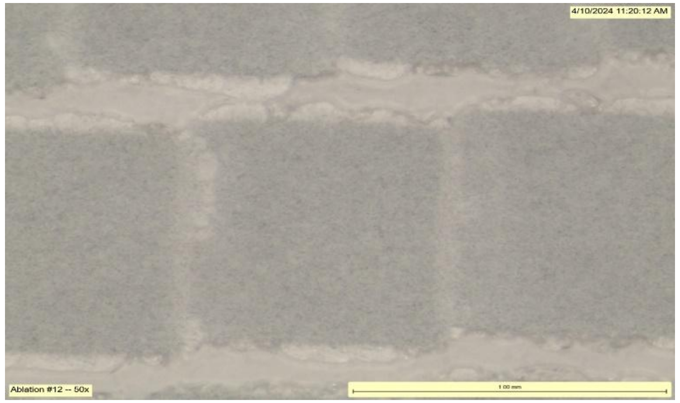
- Laser cleaning is a process of removing material from a surface by using a scanned laser beam
- The laser thermal shock peels off, vaporizes, sublimates, or burns away (paints, coatings) waste material
- Laser parameters are optimized to not damage substrate
- Laser is non-contact and repeatable, minimizes toxic waste, and has a controllable effect on the surface



Case Study I Primer Structuring

- Roughen primer surface prior to adhesion application
- Required peel strength 3.6 N/mm
- Achieved peel strength 3.8-5.3 N/mm





Case Study I Surface modification

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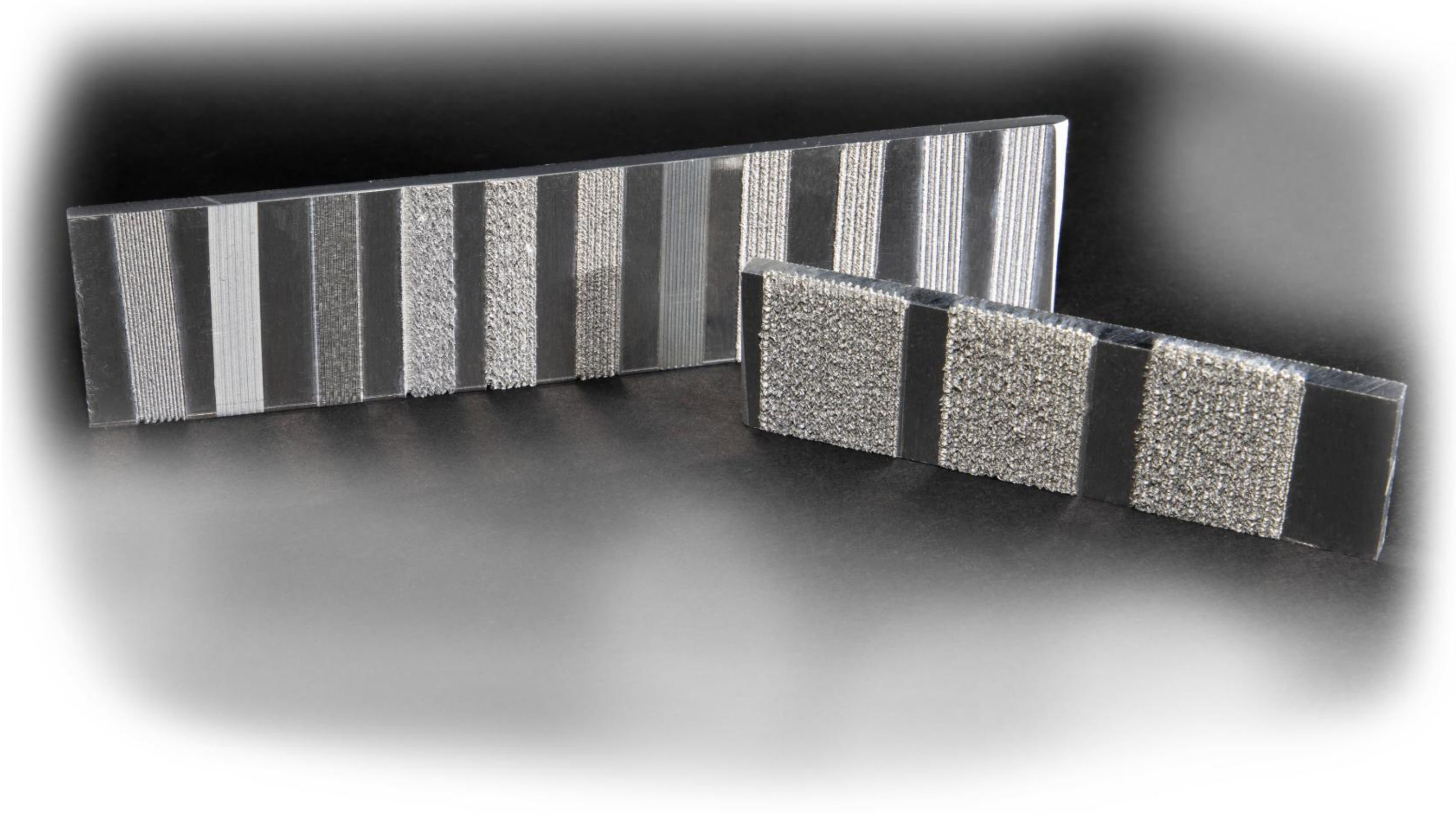
- Increase adherence prior to applying coatings or adhesives
- Increase the lifetime of paint and coatings
- Increase wettability
- Increase/reduce electrical and thermal conductivity
- Increase/reduce friction

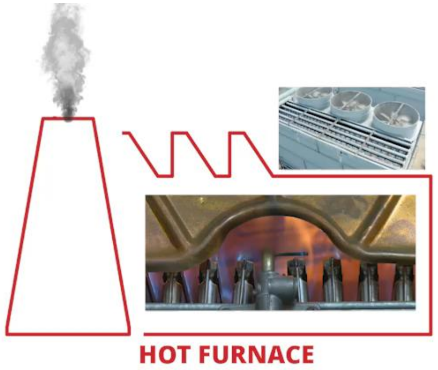


Supplier Opportunities

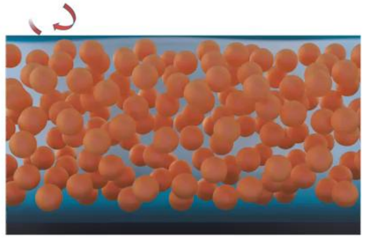
- High value direct to metal coating line
- Custom surface modifications to enhance performance
- Performance benefits from enhanced wetting
- Anticorrosion performance over laser cleaned surface
- More sustainable solution to chemical pretreatments

LASER CURING/DRYING

Precise Laser Drying & Curing



HOT AIR
only dries the surface
which reduces throughput
and wastes energy



Sub-surface moisture requires time to be
drawn to the surface before it can be removed

Industrial Coating Applications

- Pre-drying
- Parts Heating
- Powder
- Liquids
- Adhesives

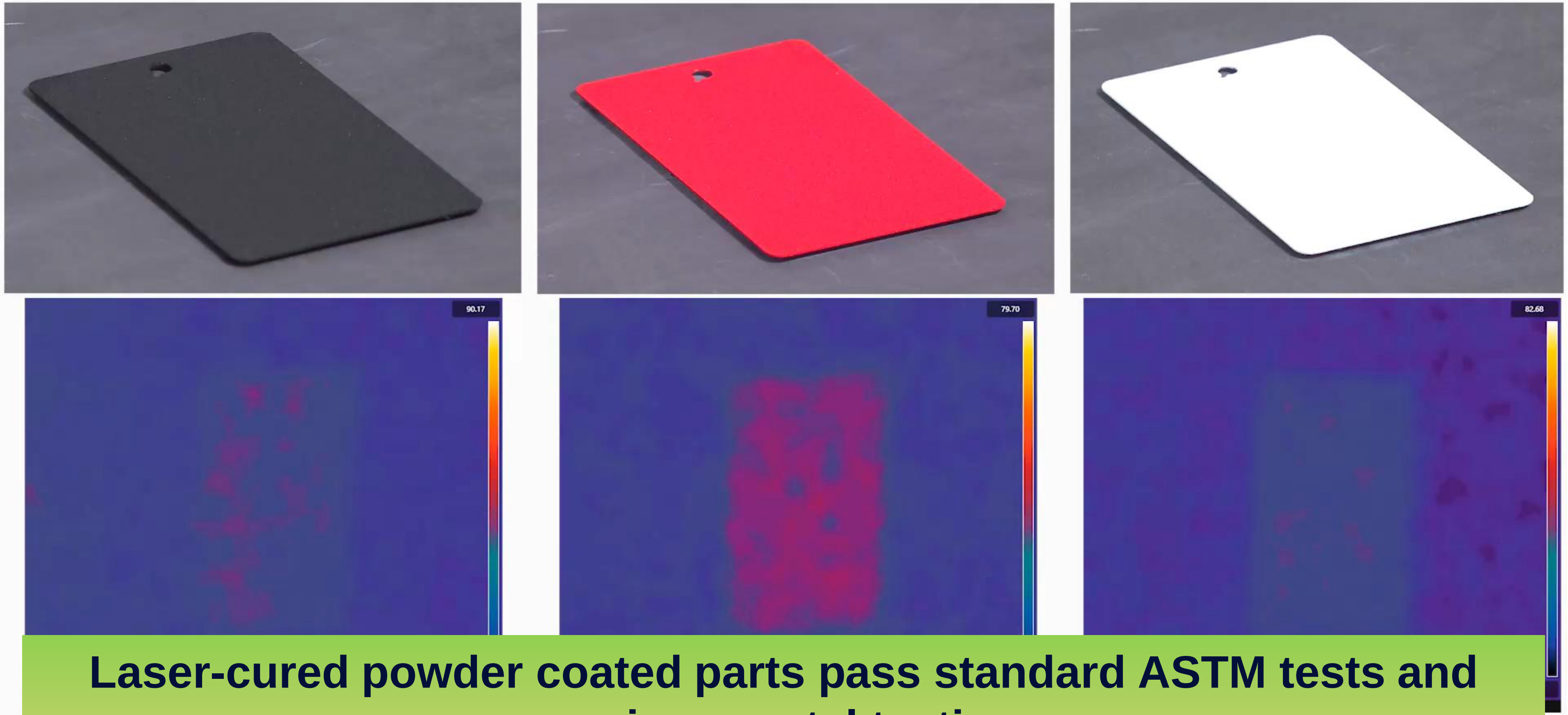
Why Use Lasers?

Speed
(4-10X)

Control
(+/- 1C)

Carbon/Physical Footprint

LASER CURING | Powder Coat on Steel



Laser-cured powder coated parts pass standard ASTM tests and environmental testing

Laser Cure in <2.5 min

- 5 - 15 sec to gel powder
- 120 - 150 sec curing

Conventional Cure

- 10 min cure at 350-400°F
- 20-30 min cycle time including pre-heating and cool down

Discussion | Is today's curing recipe efficient?

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Energy needed to heat Powder?

- Powder is $50^{+}\%$ polyester, so model polyester
  - Density of polyester: 1.38 g/cm^3
  - Specific heat of polyester: 1.1 J/g-K
- 1 cm^2 of polyester, 2 mil (50µm) coating thickness
  - Mass of polyester coating is: 6.9 milligrams
- Energy to heat this polyester to 350°F/177°C
  - 155 Kelvin temperature increase requires: 1.18 Joules

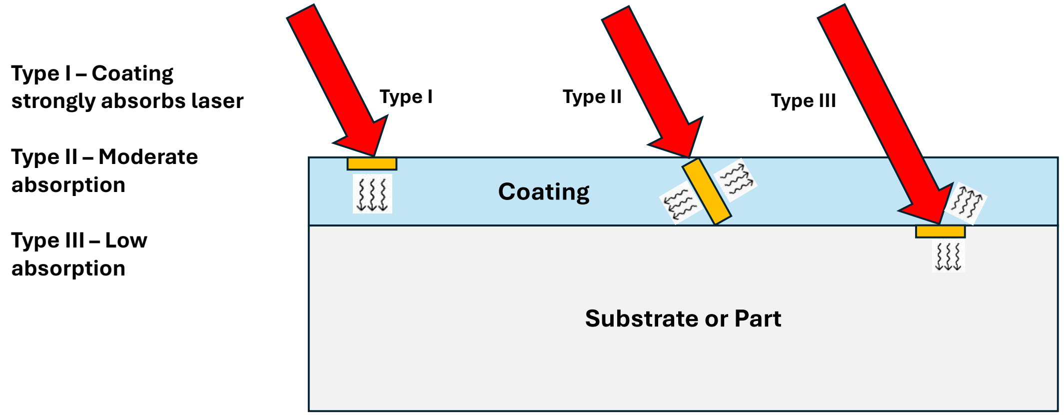
Laser curing recipe utilizes 80 J/cm^2 to heat powder coating to cure temperature → 68X more energy than required per polyester-based calorimetric estimate

Heating - ~ 8 W/cm^2
High peak power shortens time to gel and cure
Typical 5 - 15 sec to gel → used 10sec

Curing - ~ 1 W/cm^2
Maintains ~ 350-400°F (part and color dependent)
Typical 90 - 180 sec to cure (coating and color dependent)
→ used 90sec (assume dark powder, about 2mil thickness)

Total Energy Input of Heating is 80 J/cm^2
Total Energy Input of Curing is 90 J/cm^2

Laser Energy Transfer Mechanisms



Powder Coat Curing I Calorimetric View

Thick (6mm) part case study

Example – 50µm coating on 6mm steel motorcycle handlebar

Recipe to cure powder on handlebar at 170ºC/350ºF

- $8 W/cm^2$ for 15 sec — 120 Joules
- $1 W/cm^2$ for 180 sec — 180 Joules

→Total Laser Energy Input is $300 J/cm^2$

6mm steel sheet maximum temperature increase is 125 Kelvin assuming worst case that all energy input enters the metal

Some laser energy is reflected, some absorbed by coating, so motorcycle handlebar temperature rise << 125 Kelvin

<u>Take-aways</u>

- If bulky metal part is not fully heated during curing, energy savings can be high
- A goal of sustainable laser curing is the heat the coating, not the part

ECONOMICS I Laser-optimized Powder

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Part #1	3x1 Rectangular Tube	Laser Curing Cell	Gas-Fired Convection Oven
Throughput	Part/shift	256.92	220.40
Conveyor Speed	meters/minute	1.02	1.10
Hot Zone Length	meters	3.06	16.76
Hot Zone Width	meters	3.00	5.49
Oven Size	normalized	1.00	10.02
Exhaust	scfm	<50	984.00
Cost	per Part	$1.15	0.94
Opex	per Part	$0.60	0.64
Capex	per Part	$0.55	0.30
Cost per part	normalized	1.22	1.00
Opex	normalized	0.93	1.00
Capex	normalized	1.84	1.00

Cure recipe: 10 sec @ 8W/cm2 +170 sec @ 1W/cm2

Outlook – Laser Optimized Powder Opportunity

- <3% of laser energy heats current powder formulations

Part #1	3x1 Rectangular Tube	Laser Curing Cell	Gas-Fired Convection Oven
Throughput	Part/shift	256.92	220.40
Conveyor Speed	meters/minute	1.02	1.10
Hot Zone Length	meters	2.04	16.76
Hot Zone Width	meters	3.00	5.49
Oven Size	normalized	1.00	15.03
Exhaust	scfm	<50	984.00
Cost	per Part	$0.48	0.94
Opex	per Part	$0.20	0.64
Capex	per Part	$0.28	0.30
Cost per part	normalized	0.51	1.00
Opex	normalized	0.32	1.00
Capex	normalized	0.91	1.00

Cure recipe: 7 sec @ 4W/cm2 +113 sec @ 0.5W/cm2

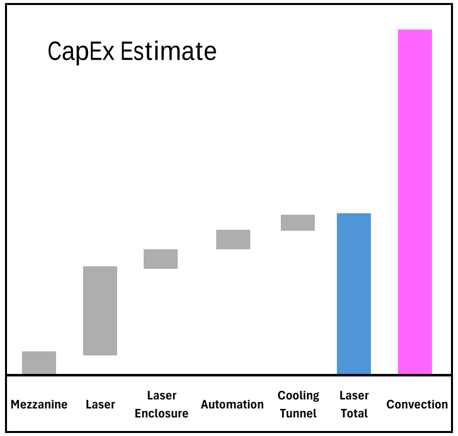
"Optimized" coatings allow laser to dominate gas

- <6% of laser energy heats the powder.

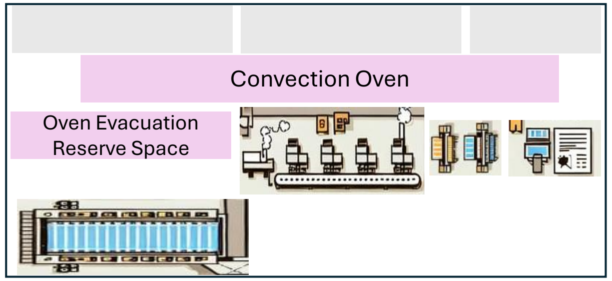
Powder Coat Curing | Customer Proof Point

- **Key Benefits**
  - Exceptionally fast powder curing
  - Operational and sustainability benefits of cold oven
    - eliminate fossil fuel consumption and waste heat
  - Cure quality matches/exceeds convection oven
- **Economic Impact**
  - Fast curing drastically reduces oven size
    - oven evacuation reserve space also eliminated
  - Short cycle time increases productivity
    - Higher throughput lowers per-part OpEx and CapEx
  - "cold" cure eliminates HVAC support infrastructure

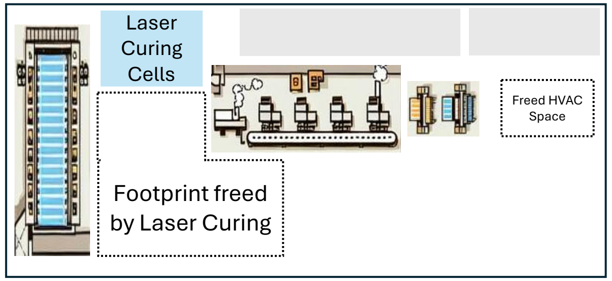
Operational Model* Example from Representative Customers



Baseline Layout



Proposed Laser Curing Layout



High Volume Manufacturing Cost Comparison

	Oven	Laser	Improvement
Unit CapEx Depreciation ($/unit)	$6.70	$2.91	56.6%
OpEx ($/unit)	$7.96	$1.43	82.1%
Labor ($/unit)	$5.34	$6.35	-18.9%
Total Cost ($/unit)	**$20.01**	**$10.68**	46.6%

*Drawings/Tables are non-confidential, for illustrative purposes only. The data are representative of what IPG's customers shared, but all drawings and numbers above are fabricated by IPG to preserve customer confidentiality.

<u>Take-aways for High-Volume Manufacturing</u>

- Smaller oven, less infrastructure reduces CapEx
- Shorter cycle time, reduced floor space and energy consumption slashes OpEx

OPPORTUNITY I The Chemists' Design Handbook

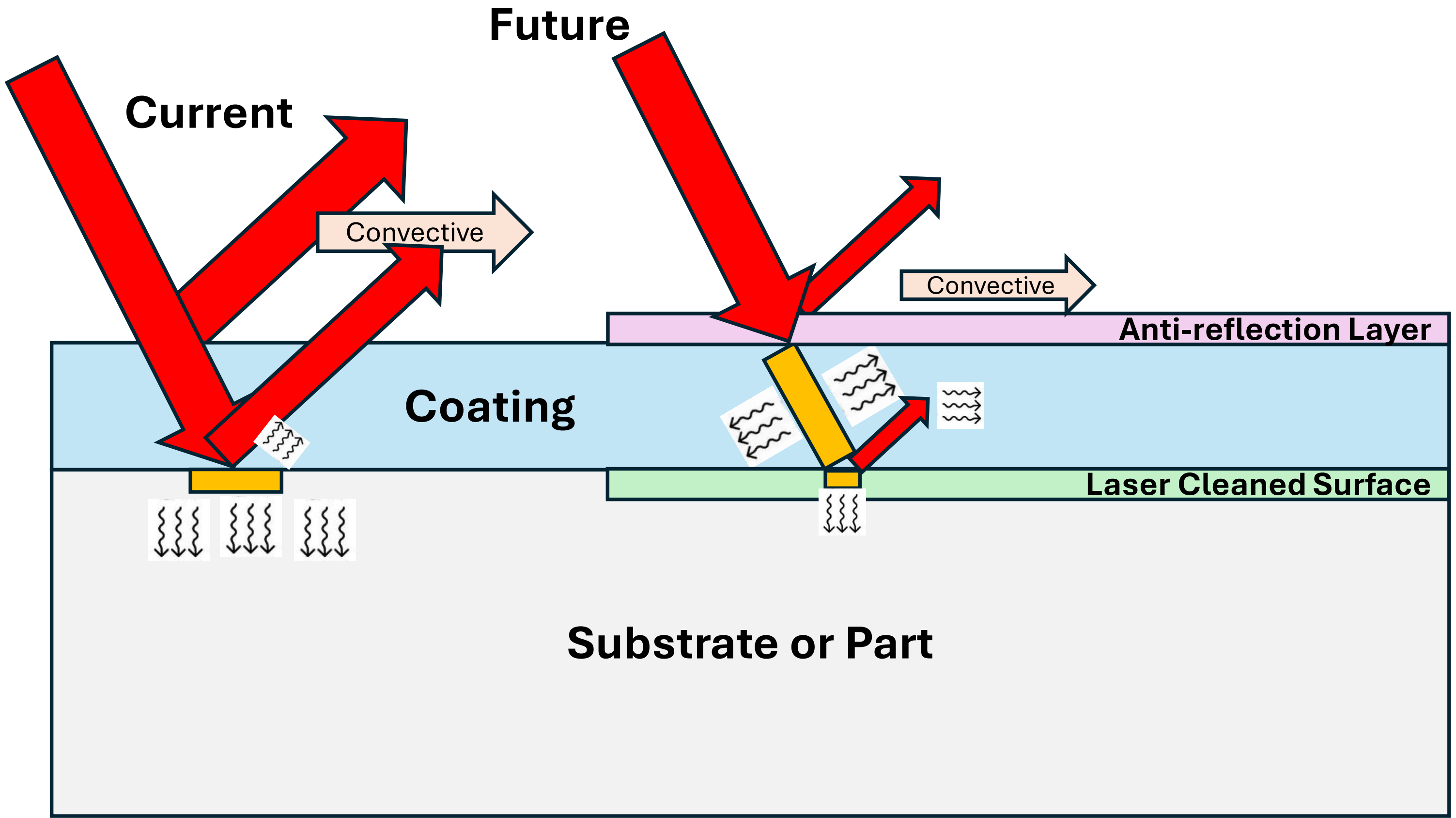
Coatings and Process engineered to take full advantage of Laser

Future - optimized

- Minimize reflection/scattering losses
- Absorptive additives ensure laser energy preferentially heats coating, not the part
- Some laser energy reaches the part interface to promote adhesion
- Optimize convective air-flow losses
- Benefit from sustainable laser surface prep

Current – non-optimal

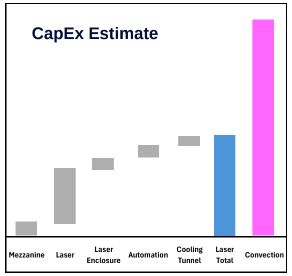
- High reflective losses, >50% for bright colors
- Too much energy absorbed at metal interface; nearly all heat conducts into part
- Conventional surface prep consumes too much water, chemicals, time and energy

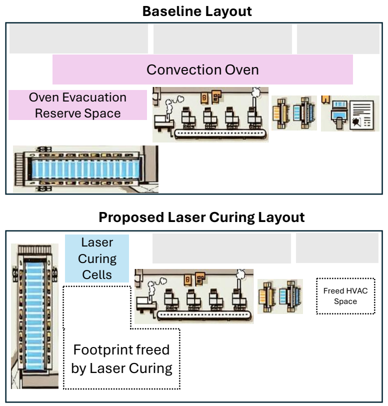


Discussion | The Laser Curing Opportunity

Value-added, laser compatible coatings and processes

- **The Company that Optimizes Laser Absorption Wins**
  - More efficient coatings will save customer CapEx and provide an instant value add.
  - Allow for retention of highly sought after customers as the industry giants will see the most benefit from laser curing
- **Cost and Sustainability Proof Points Established**
  - Exceptionally fast powder curing and thermal control
  - Operational and sustainability benefits of cold oven
    - eliminate fossil fuel consumption and waste heat
  - Cure quality and consistency matches or exceeds convection oven
- **Current Coatings are not optimized for Laser**
  - Fast moving coatings companies can develop valuable IP
  - Laser curable coatings will require less energy and less time to cure





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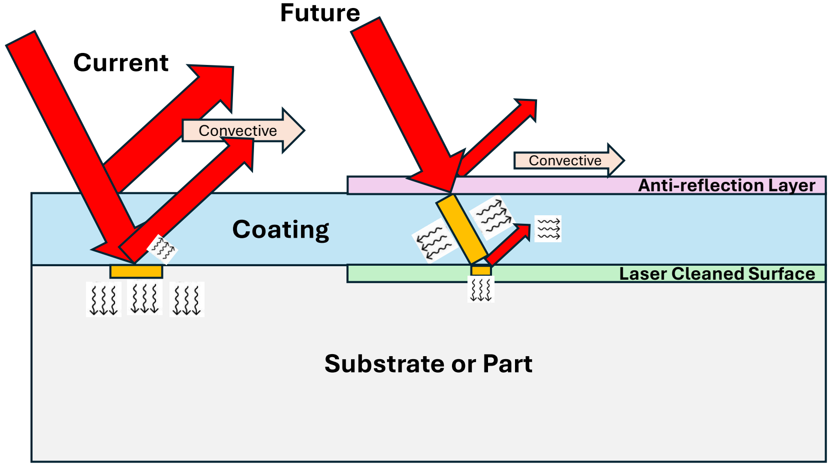

QUESTIONS?