Advanced beam delivery for mobile laser peening

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Presentation outline

- Brief introduction to MIC Laser Peening capability
- Performance characteristics of the MIC laser design
- Laser peening system mobility
- Methods of beam delivery
  - Fixed beam, moving part
  - Moving beam for stationary components
  - Scanning beam for large panels
  - Dual gimbal stinger for on-aircraft applications
- Optical laser peening pattern alignment using the dual gimbal stinger

Metal Improvement Company

- Wholly owned subsidiary of Curtiss-Wright Corporation
- Operates over 60 service divisions in North America and Europe offering conventional special processes
  - Shot Peening and Peen Forming
  - Heat Treatment
  - Coatings
  - Finishing
- Three Laser Peening plants
  - Livermore, CA
  - Frederickson, WA
  - Earby, UK
- New Laser Peening plant in Palmdale, CA in 2010

Three laser peening plants are in full commercial production

MIC Earby, UK

- 3 laser systems
- 4 fixed beam cells
- 1 moving beam cell

MIC Livermore, CA

- 5 laser systems (2 transportable)
- 3 fixed beam cells
- 2 moving beam cells
- 1 hybrid cell (fixed or moving beam)

Laser peen-forming for Boeing in Frederickson, WA

Boeing Skin and Spar Plant, Frederickson, WA

Boeing wing forming

- Transportable laser system
- 2-sided peen forming cell with hydraulic pre-stress
- 150' remote beam delivery sub-floor

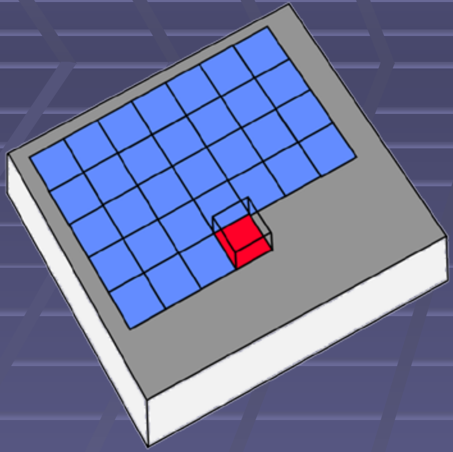
MIC uses class-leading laser designs

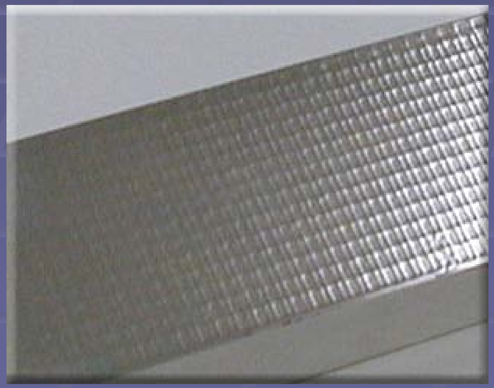
Available "up time" readily exceeds 97%; unprecedented for this class of laser system*

*Based on detailed production shutdown reports 1/1-10/31/04

- High energy peening pulses can be delivered up to 5Hz with very high beam quality
- High pulse energies are generated by a single laser amplifier
- Optical phase conjugation maintains *constant size, position, and pulse energy* for each peened spot, regardless of repetition frequency or run time
- Reliability has been demonstrated by continuous 3-shift operation with up to 500k processing shots per week from each system

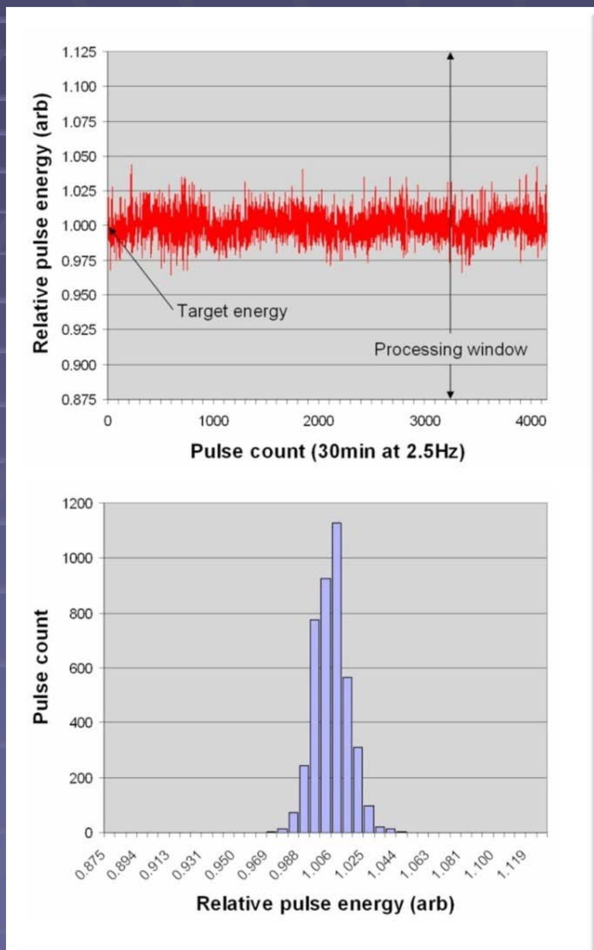
Square spots provide uniform coverage

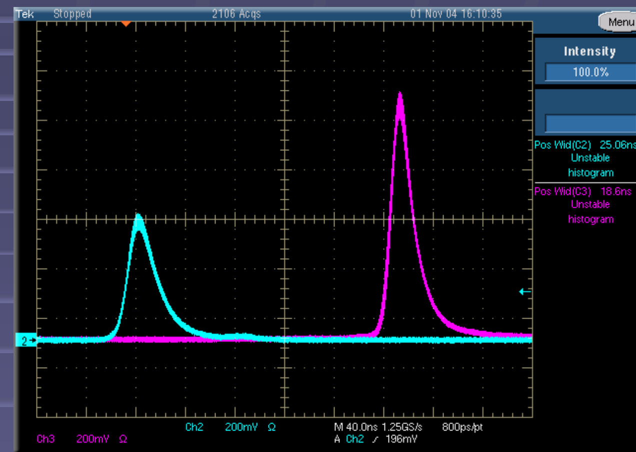




- Square spots provide efficient coverage in a single treatment layer
- Constant irradiance (flat-top) beam profile provides highly uniform stress
- Polarized beam provides efficient peening at up to 70° incidence angle
- Competitive approaches have reduced performance:
  - Round beam profile results in non-uniform coverage
  - Lower pulse energy in a small spot results in shallower stress, requiring more treatment layers
  - Smaller spot size reduces surface quality

Laser pulse energy stability provides consistent treatment from shot-to-shot

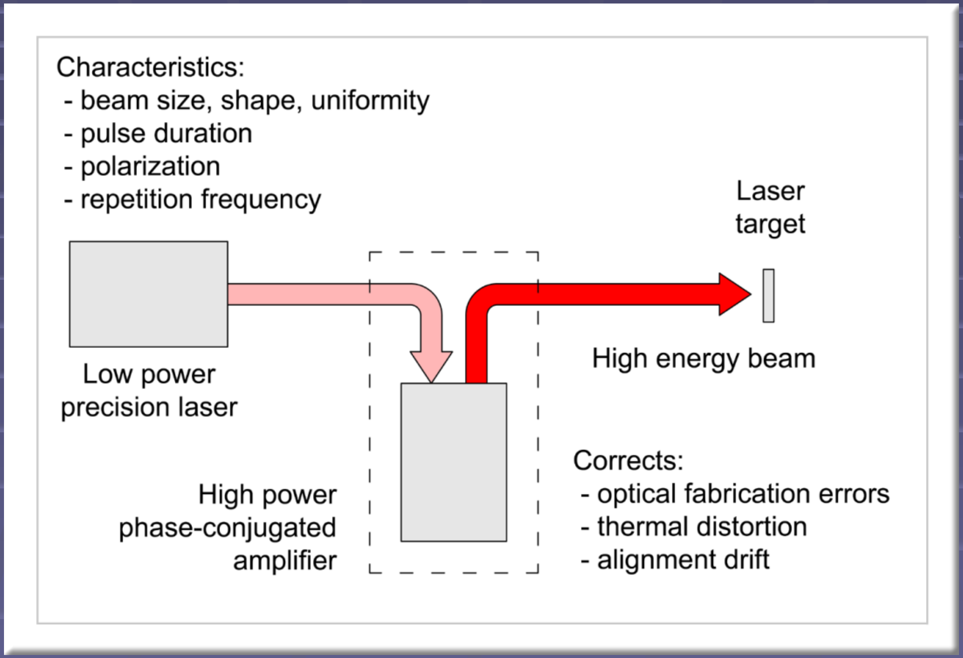




Overlay of 1000 pulses

- Shot-to-shot energy distribution typically exhibits a 1% RMS variation over each processing run
- The pulse width can be adjusted between 9 and 27ns FWHM

Optical phase conjugation provides unmatched stability and control

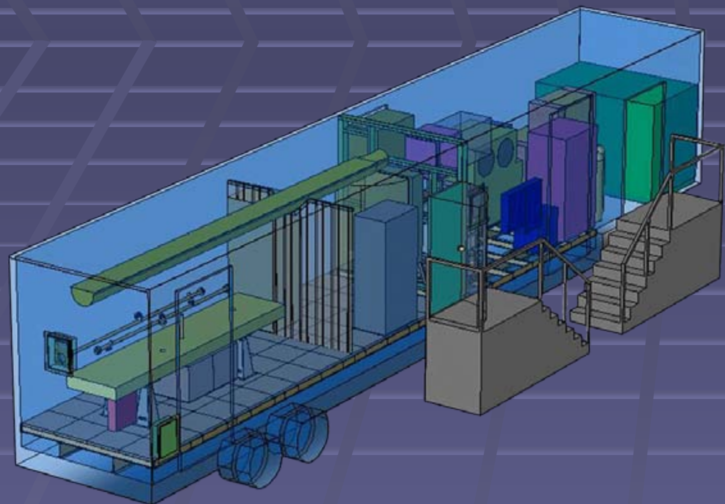


- Nonlinear phase conjugation works automatically without sensors, computers, or other actively controlled optical components
- Spot patterns tested at low energies are exactly replicated in actual processing at high average power

Beam quality – why does it matter?

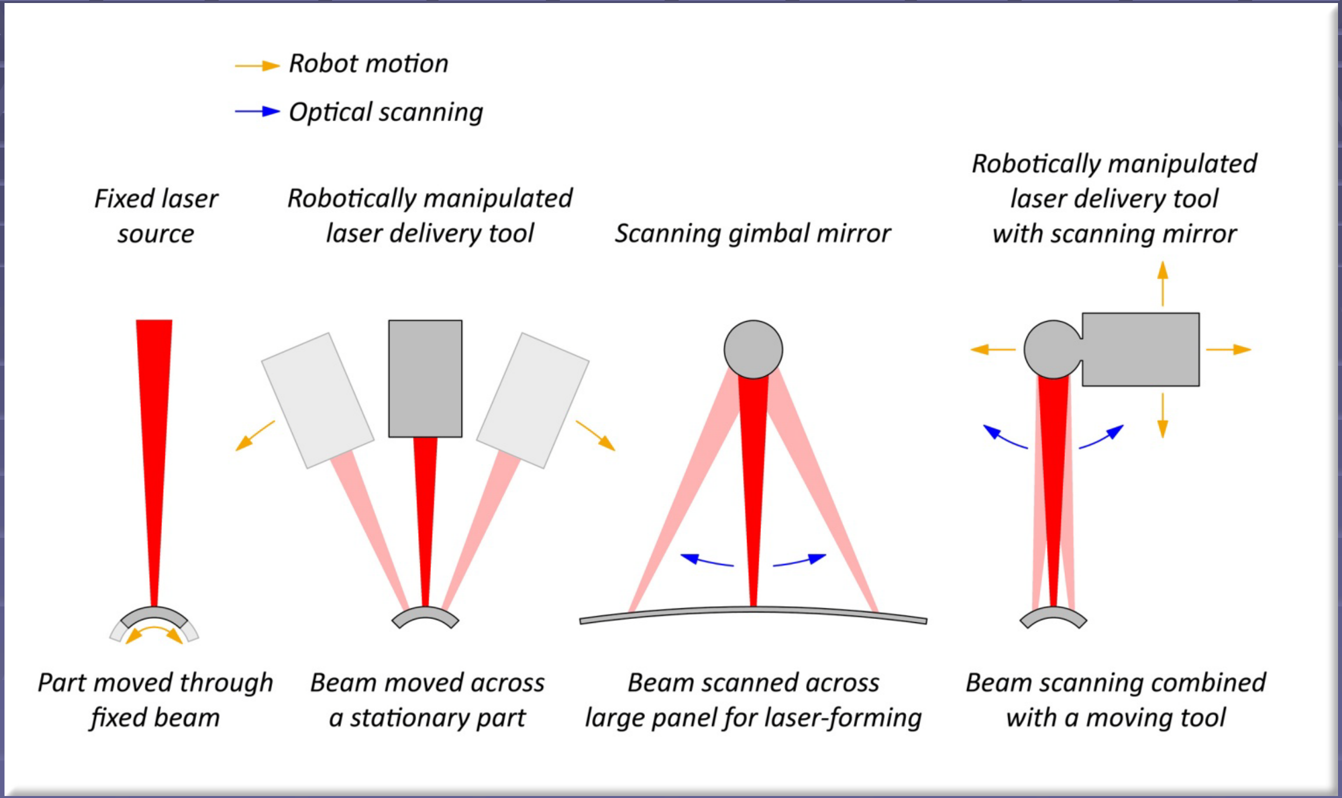
- Each laser spot has a repeatable shape on target, regardless of repetition frequency or shot count
- The quality of laser peening does not depend on thermalization (warm up) of the laser system
- A variable pulse repetition frequency allows the laser firing to adapt to the automation system for best throughput
- A pure polarization state enables efficient off-axis laser peening
- The high energy beam can be delivered over long distances without degradation

Three completely transportable facilities are fully operational



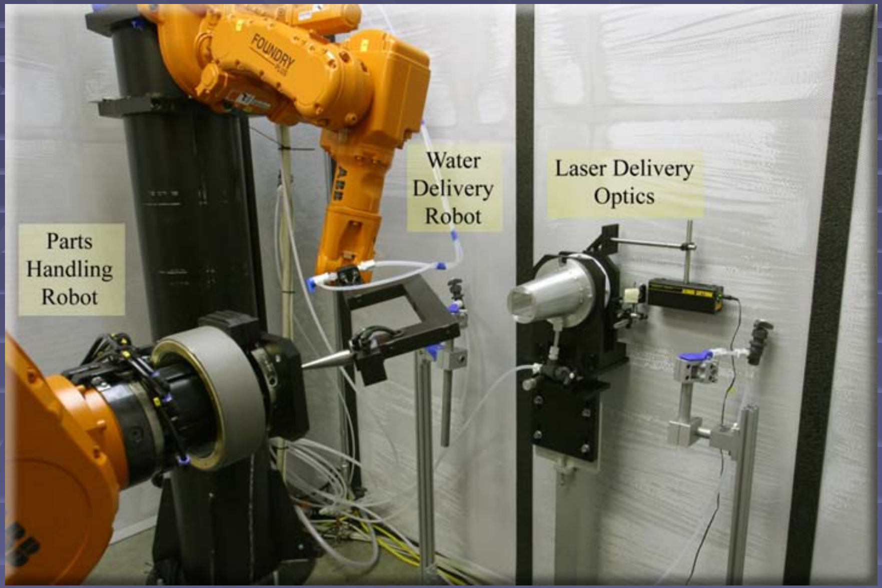
- Allows deployment anywhere in the world
- Completely self-contained, system needs only one electrical and one water connection
- System can be located remote from processing area with beam piped in to delivery robot for application

The beam delivery strategy must match the laser peening application



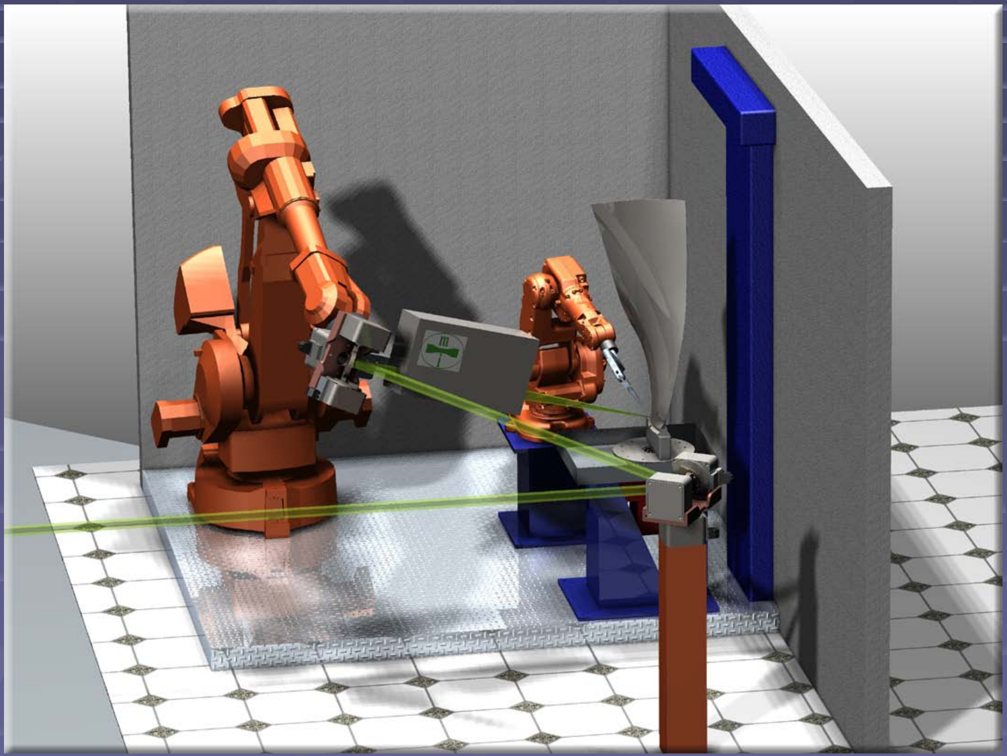
- **MIC presently has 11 fully operational robotic laser peening cells in 3 plants**

Small components can be moved through a stationary beam



- Fixed beam automation system moves the part through the laser beam
- Production robots routinely handle components with weights >100kg

A moving beam system allows larger components to be laser peened

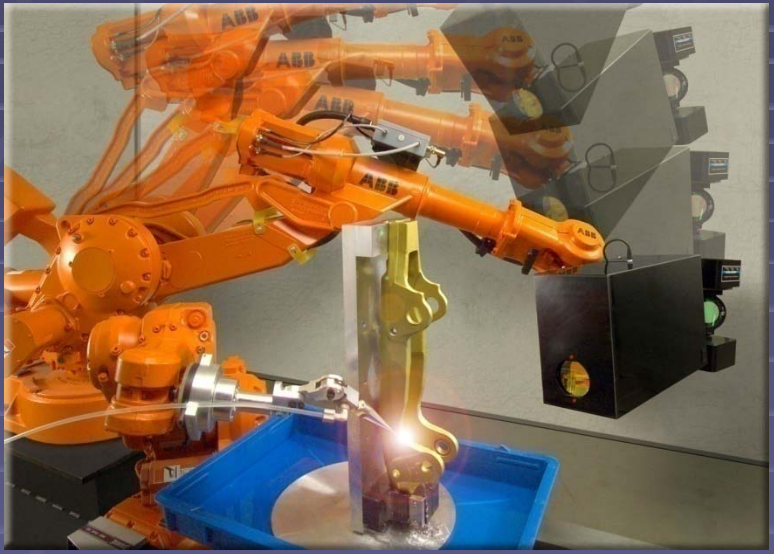


Mechanical design of the active beam delivery system (beam distances reduced for purpose of illustration)

Advantages

- Ability to treat large, stationary parts
- *In situ* treatment of aircraft structures, large pipe work, etc.
- Streamlined process development
- Reduced NRE for fixturing
- Rotary parts stage reduces required robot motion for small parts

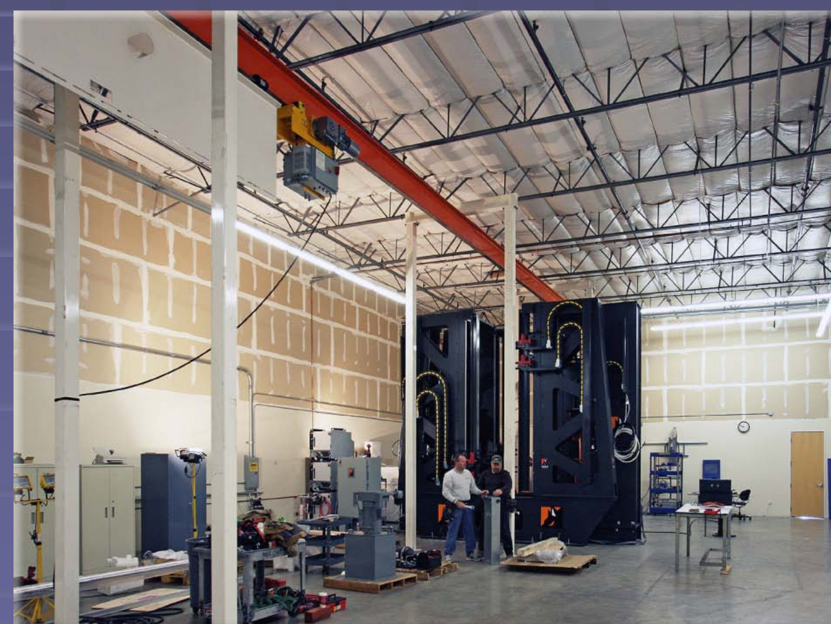
A moving beam system enables the laser peening of larger components



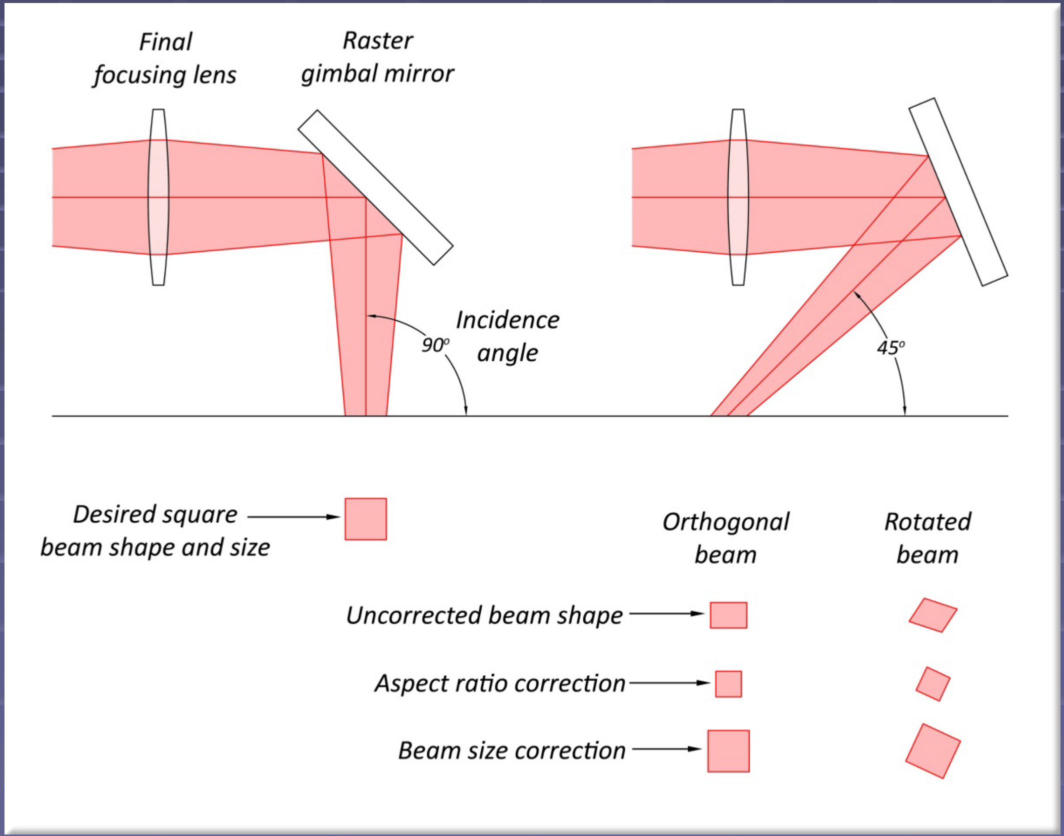
- The robot holds a laser delivery tool instead of the component
- High speed gimbals keep the high power beam aligned to the scanning delivery tool
- Palletized robot system allows straightforward transport and setup at the processing site

Beam scanning allows large panels to be laser peened

An overhead gantry transports wing skins through a fixed processing cell; the laser propagates ~150ft between the trailer and the cell.



Shape correction for incidence angle and beam rotation

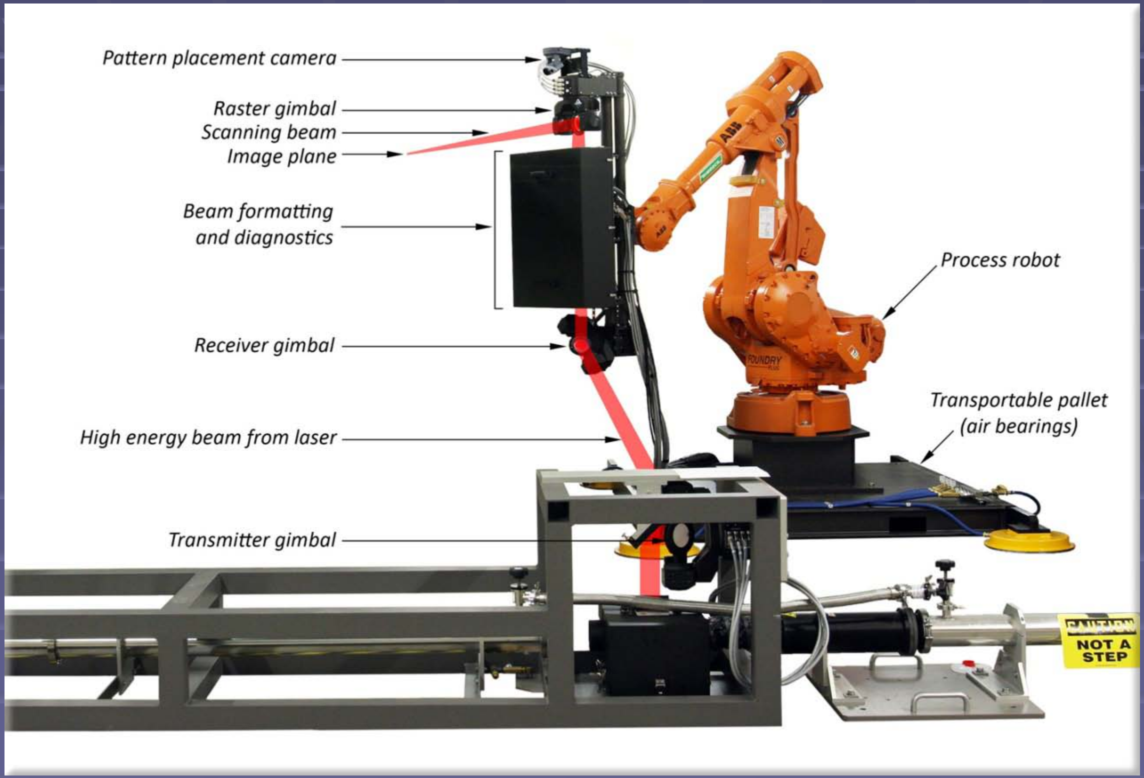


- **Each pulse is individually corrected for size, rotation, and aspect ratio**

Decoupling beam scanning from robot motions can improve process efficiency

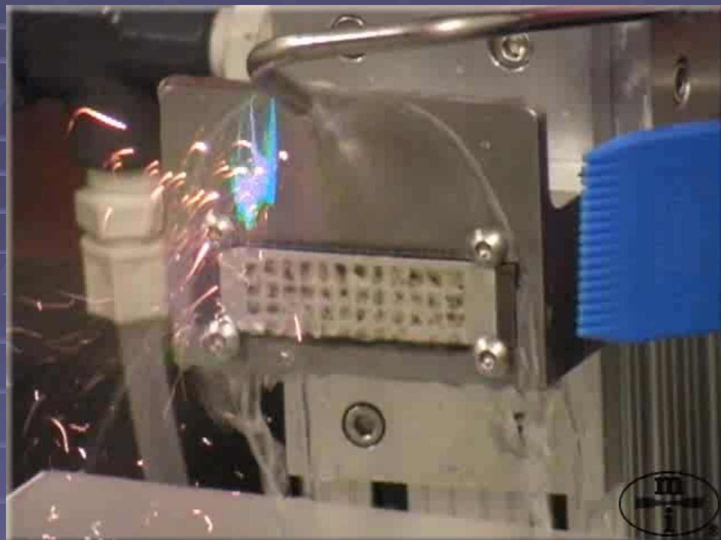
A typical wing panel is 32m long, up to 25mm thick, and requires >250k laser shots

A new dual gimbal stinger has been developed for on aircraft laser peening



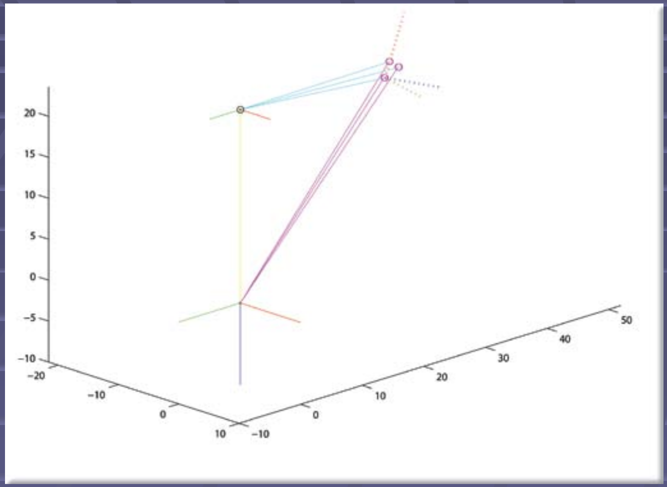
- Complex spot patterns can be delivered from a single robot position
- Each individual shot is pre-formatted to correct for changes incidence angle, rotation, and propagation distance

The dual gimbal head has been fully demonstrated on an aircraft in Livermore

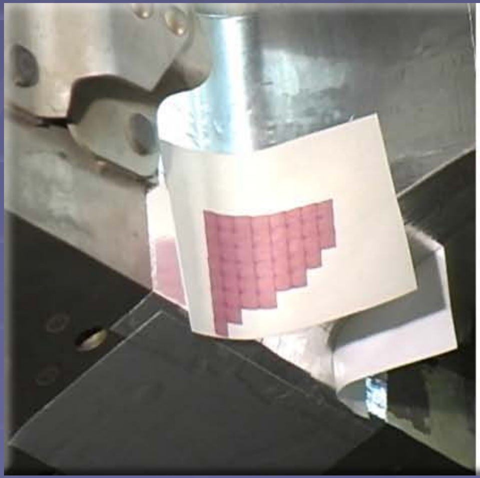


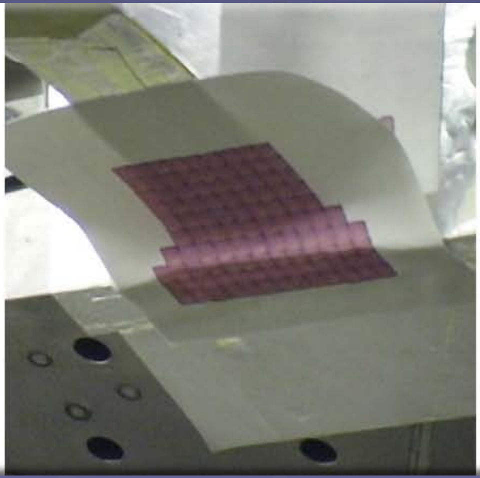
- Advanced optical metrology and precision beam formatting are provided in a single tool
- Fixed nozzles eliminate requirements for a water robot
- The system is now ready to be installed in the customer facility

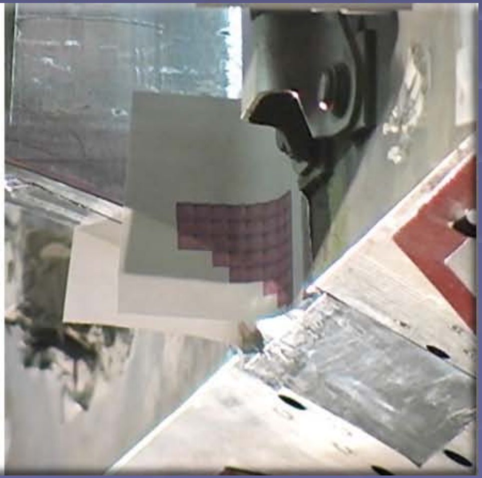
Built-in optical metrology provides quick and accurate spot pattern registration



Optical metrology quickly and accurately adapts to variations in work piece location







Summary

- MIC has developed advanced beam delivery which adapts laser peening to a wide range of customer products ranging in size from a small diesel fuel injector to a 100' long wing panel
- Recent development of a dual gimbal stinger specifically addresses the challenges of large component, on-site laser peening such as required for in-service aircraft