Advanced beam delivery for mobile laser peening

C. Brent Dane, Fritz Harris, Edward Lao, Jon Rankin, Randy Hurd
Metal Improvement Company

2nd International Conference on Laser Peening
San Francisco, CA
April 19, 2010

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

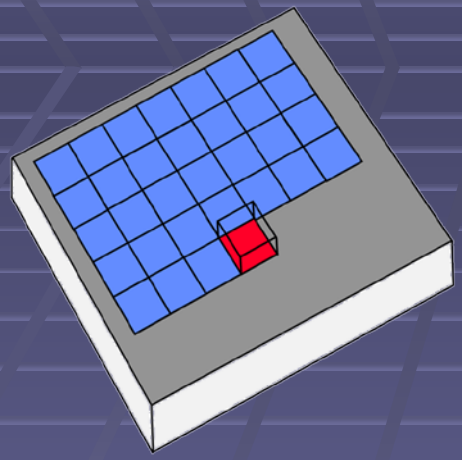
MIC uses class-leading laser designs

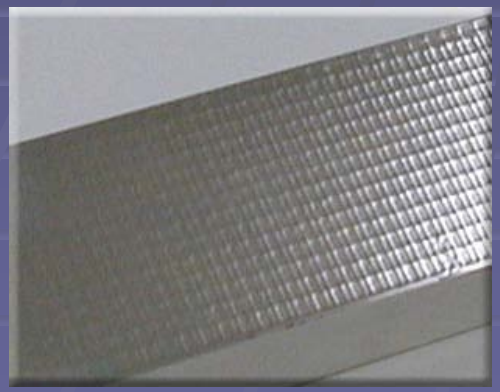
Available "up time" readily exceeds 97%; unprecedented for this class of laser system*

*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

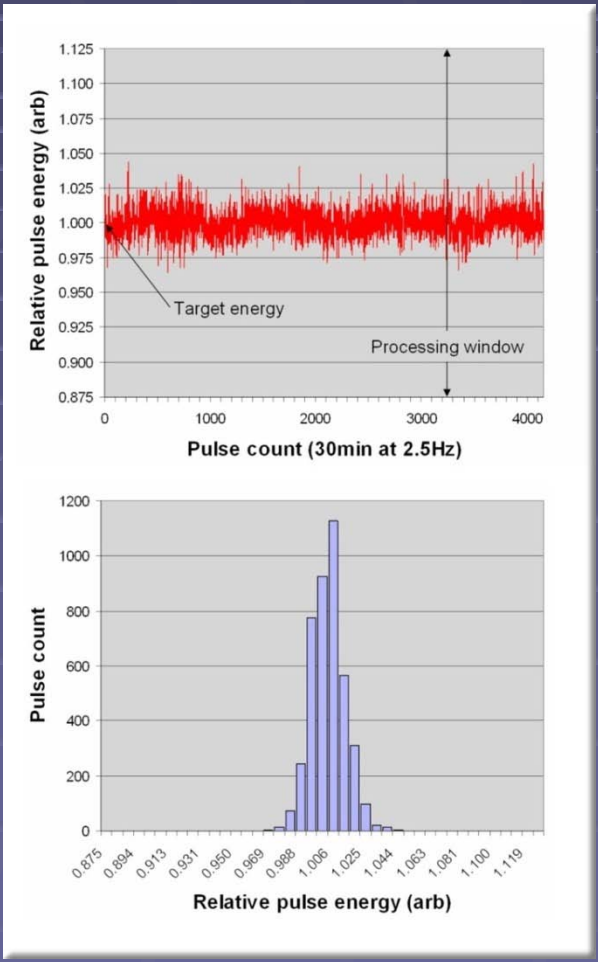
Square spots provide uniform coverage

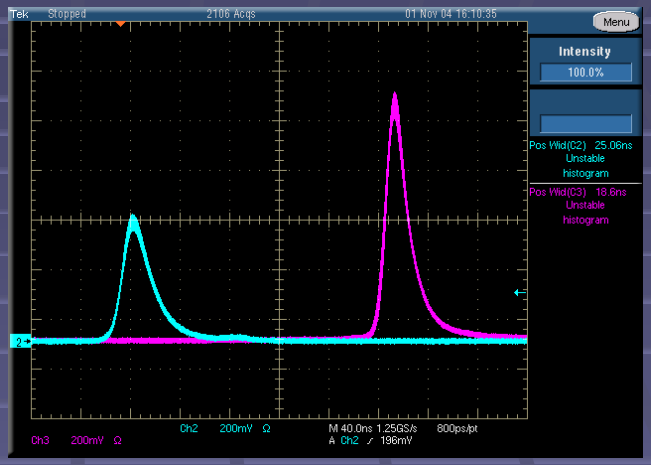




- Square spots provide efficient coverage in a single treatment layer
- Constant irradiance (flat-top) beam profile provides highly uniform stress
- Polarized beam provides efficient peening at up to 70˚ incidence angle
- Competitive approaches have reduced performance:
  - Round beam profile results 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

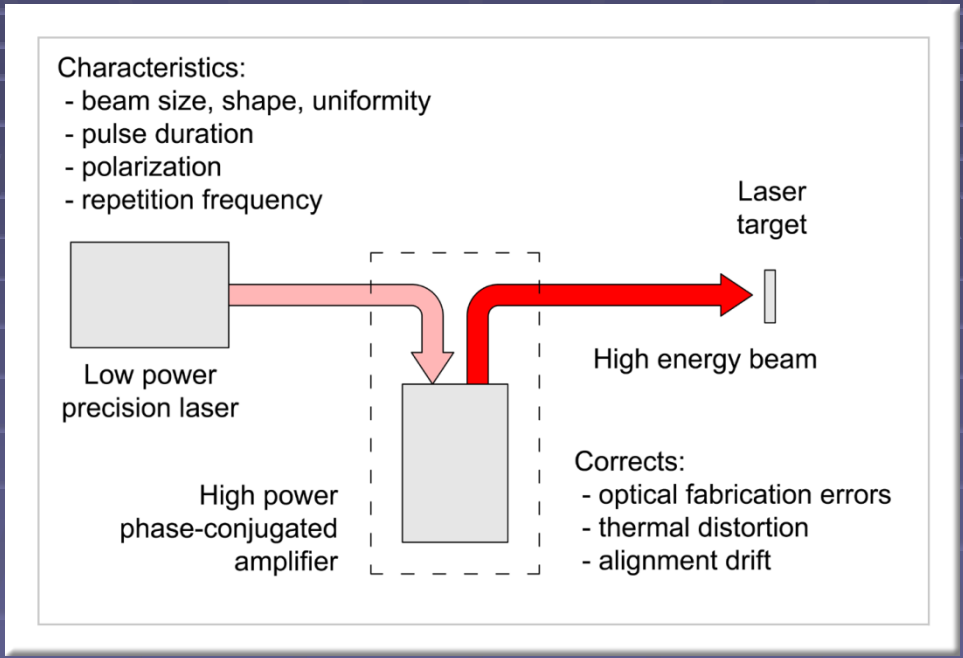




Overlay of 1000 pulses

- 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

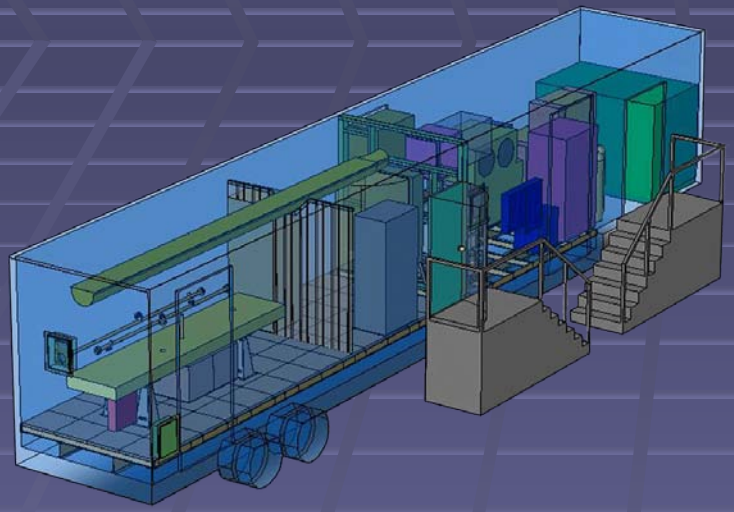


- Nonlinear phase conjugation works automatically without sensors, computers, or other actively controlled optical components
- Spot patterns tested at low energies are exactly replicated in actual processing at high average power

Beam quality – why does it matter?

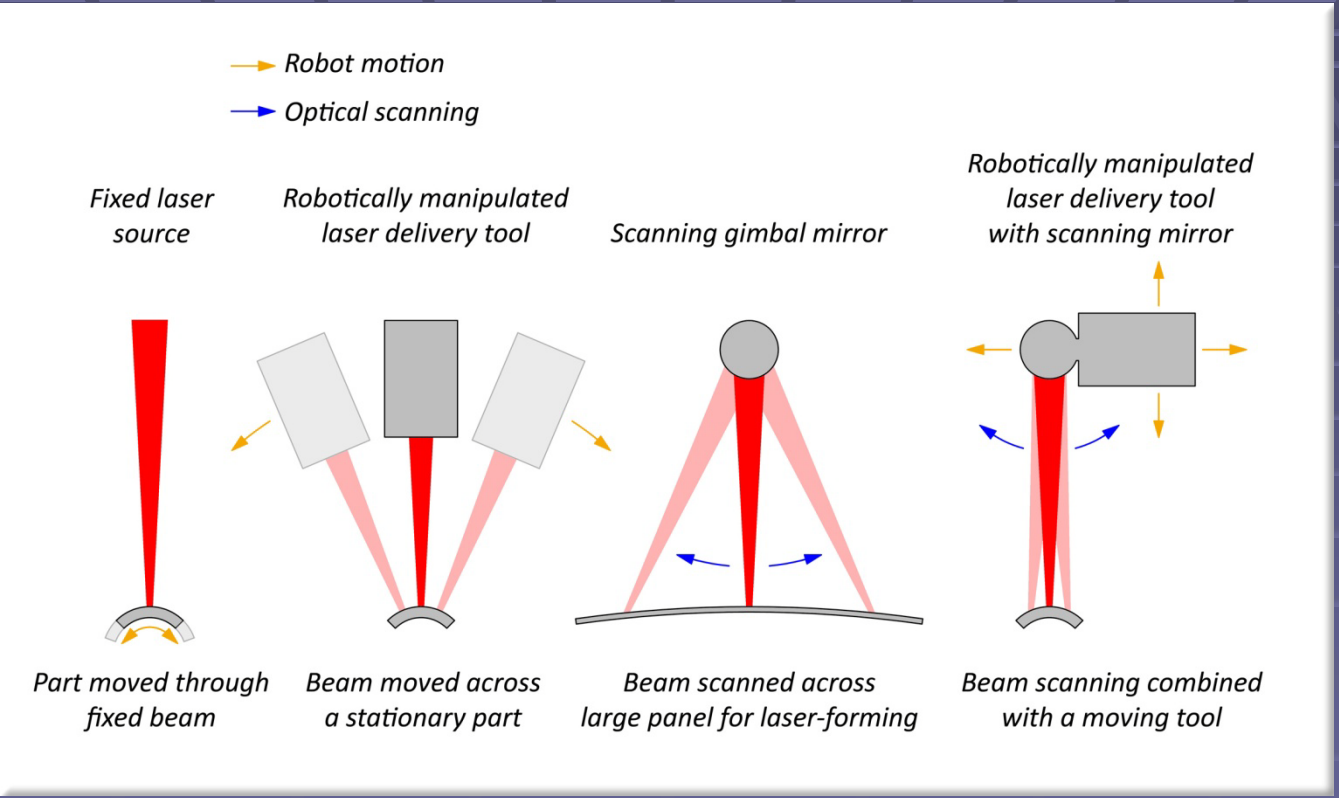
- Each laser spot has a repeatable shape on target, regardless of repetition frequency or shot count
- The quality of laser peening does not depend on thermalization (warm up) of the laser system
- A variable pulse repetition frequency allows the laser firing to adapt to the automation system for best 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



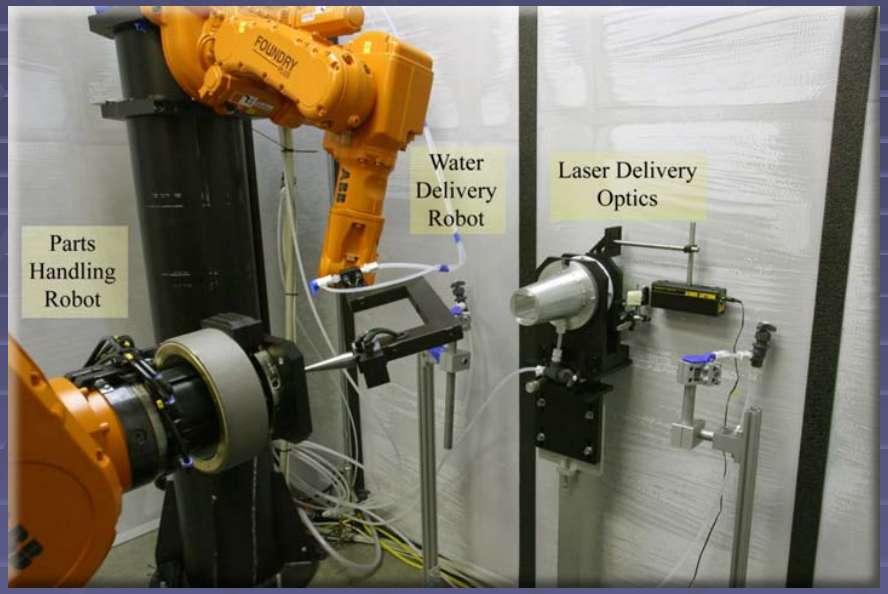
- Allows deployment anywhere in the world
- Completely self-contained, system needs only one electrical and one water connection
- System can be located remote from processing area with beam piped in to delivery robot for application

The beam delivery strategy must match the laser peening application



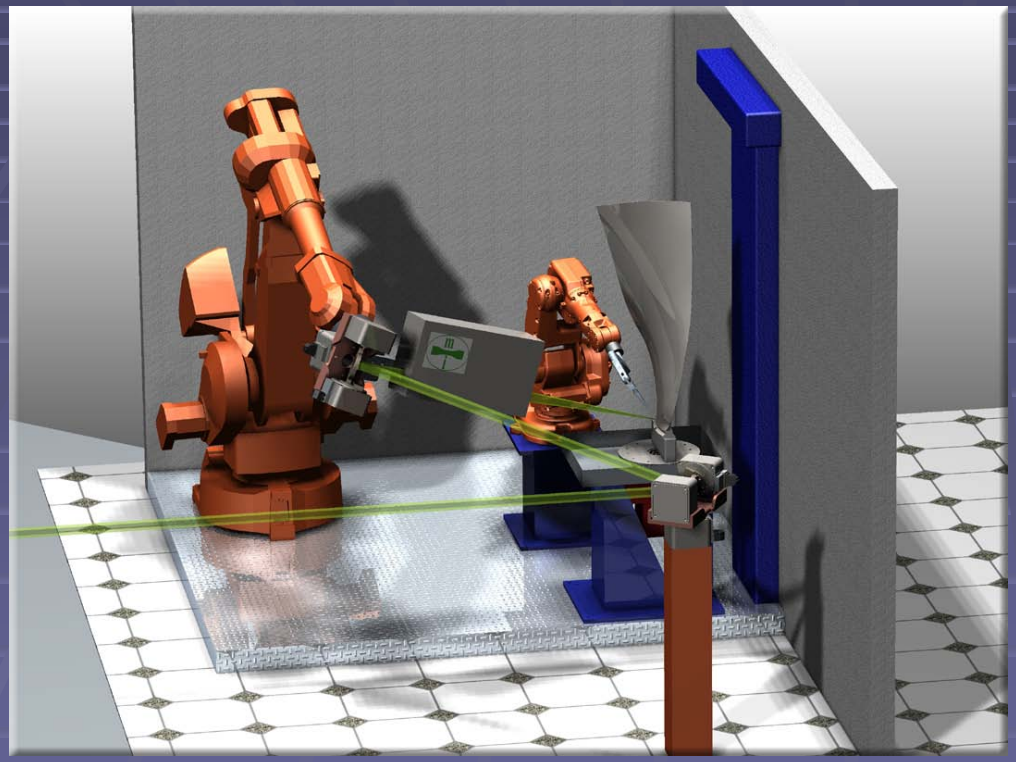
- MIC presently has 11 fully operational robotic laser peening cells in 3 plants

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

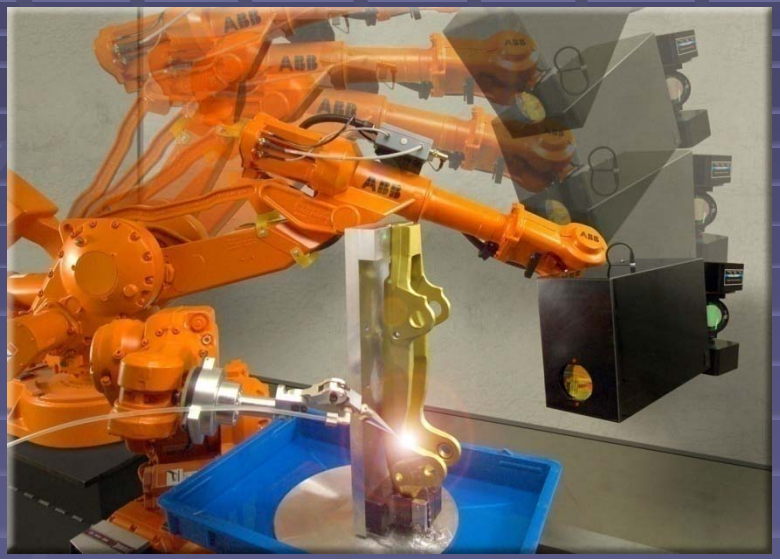


Mechanical design of the active beam delivery system
(beam distances reduced for purpose of illustration)

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

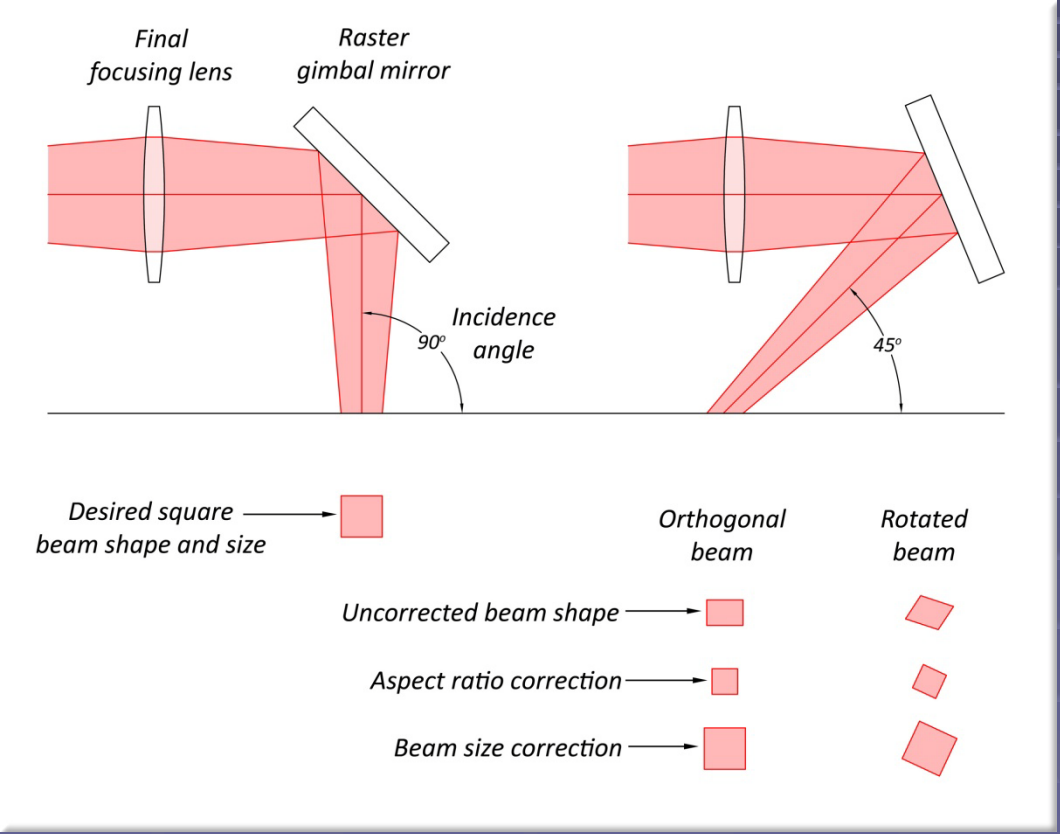


- The robot holds a laser delivery tool instead of the component
- High speed gimbals keep the high power beam aligned to the scanning delivery tool
- Palletized robot system allows straightforward transport and setup at the processing site

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

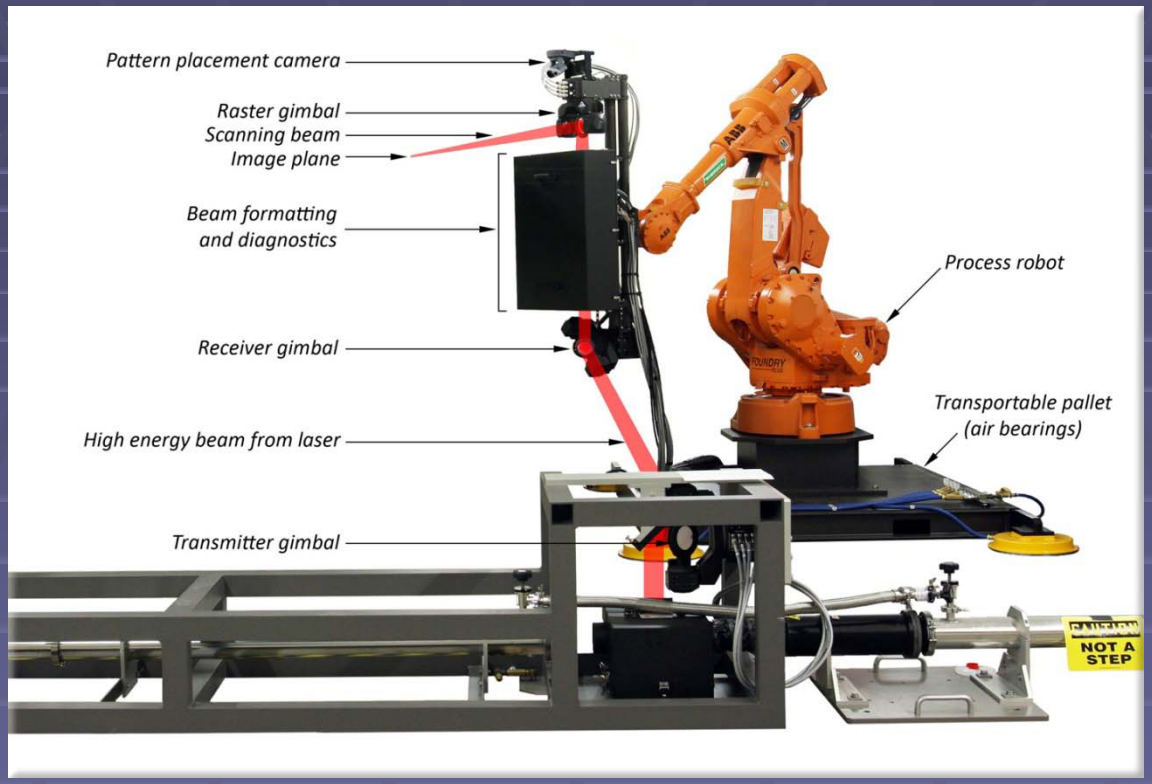


- Each pulse is individually corrected for size, rotation, and aspect ratio

Decoupling beam scanning from robot motions can improve process efficiency

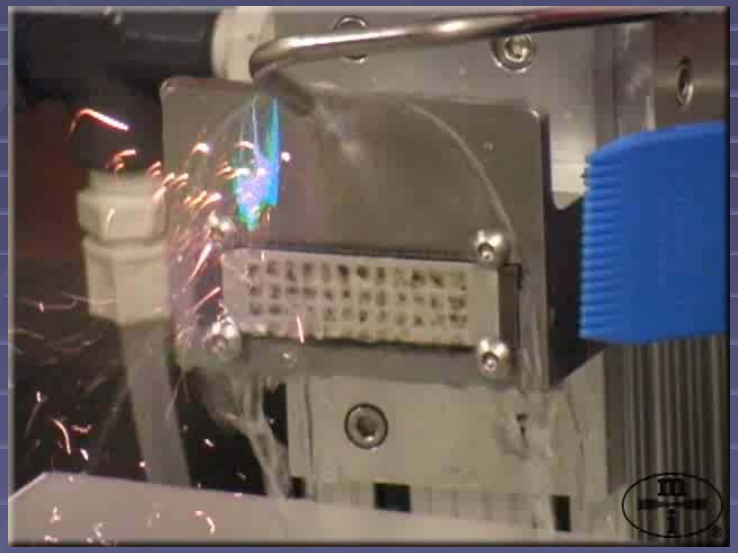
A typical wing panel is 32m long, up to 25mm thick, and requires >250k laser shots

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



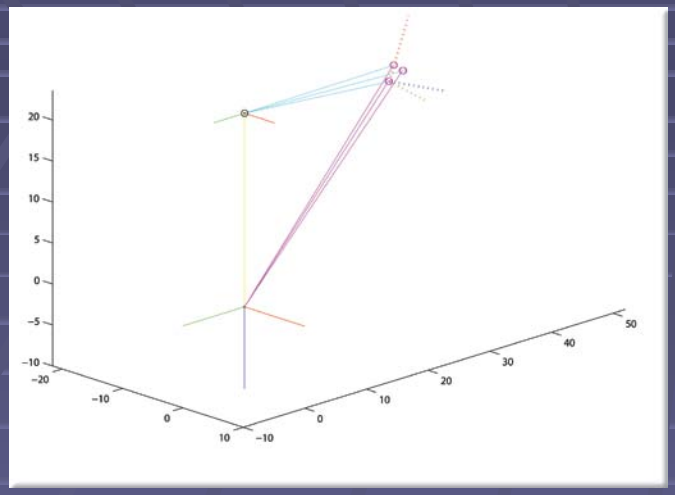
- Complex spot patterns can be delivered from a single robot position
- Each individual shot is pre-formatted to correct for changes incidence angle, rotation, and propagation distance

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

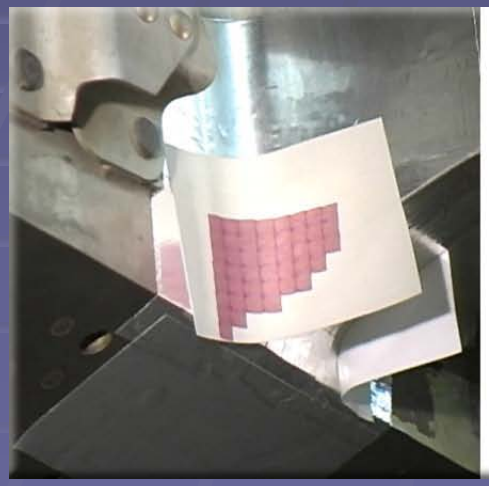


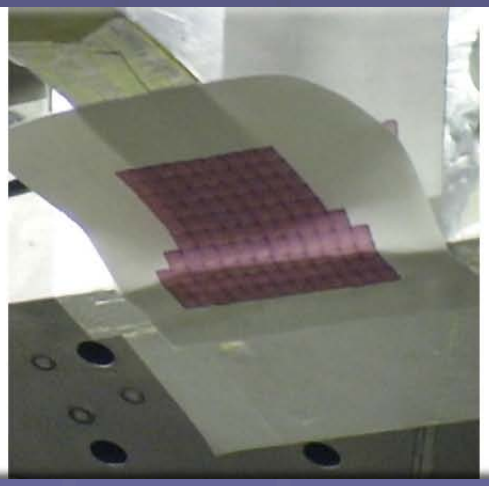
- Advanced optical metrology and precision beam formatting are provided in a single tool
- Fixed nozzles eliminate requirements for a water robot
- The system is now ready to be installed in the customer facility

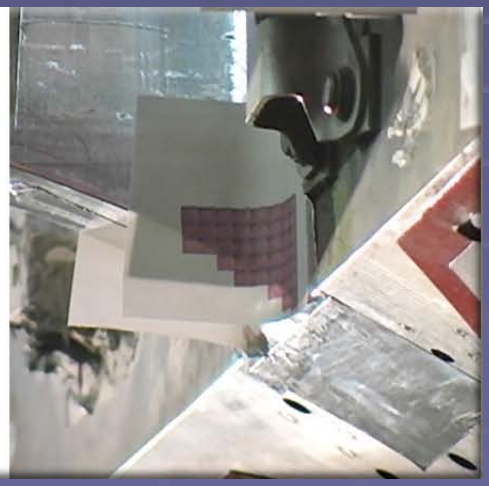
Built-in optical metrology provides quick and accurate spot pattern registration



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