High power Adaptable Laser beams for materials prOcessing
HALO

Project overview presentation

HALO is supported by the European Commission through the Seventh Framework Programme (FP7)
Project number 314410

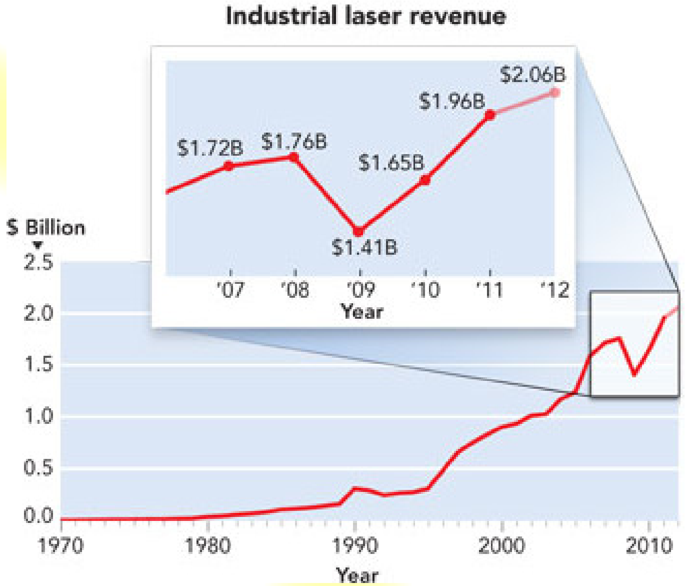
Materials processing with lasers

- Laser technology is already well established in manufacturing
- Materials processing with lasers covers many techniques
  - Cutting and bending
  - Welding and joining
  - Marking and engraving
  - Surface patterning and processing
- The next generation of lasers offers key manufacturing technology for the "Factory of the Future"
  - Faster, cheaper, better processes!
- HALO will improve
  - Efficiency, adaptability and sustainability of manufacturing systems
  - Integration into business processes.

Images courtesy of Trumpf Laser GmbH and Fraunhofer ILT

Market size

- Industrial laser market has shown robust growth for thirty years
  - Double-digit annual growth
  - Strong rebound from global crash in 2008/9
- Europe
  - Makes up almost one third of the world market (2012)
    - Industrial lasers ~1.5 M€*
    - Industrial laser systems (integrated tools based on lasers) ~5.5 M€*
  - Is a power base for laser system manufacture and development
- HALO will help to maintain Europe's leading role in industrial laser technology.

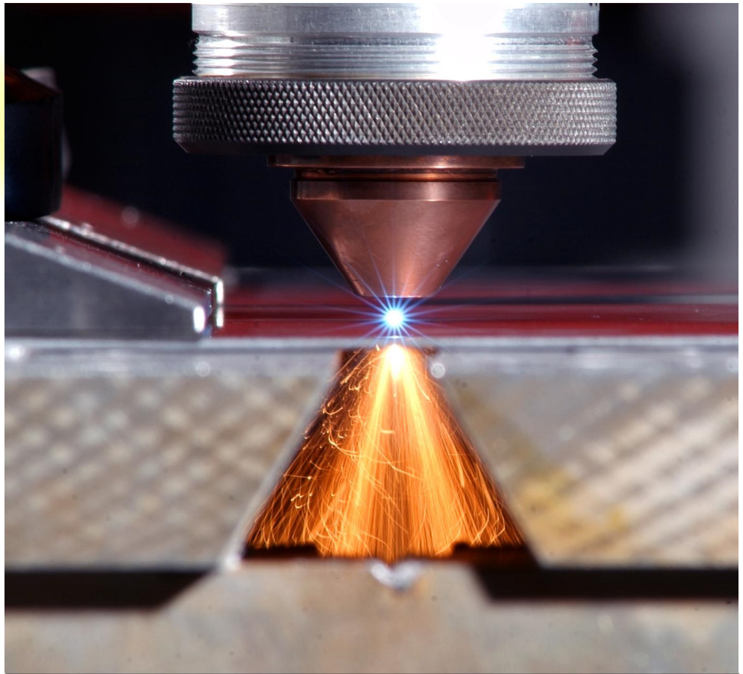


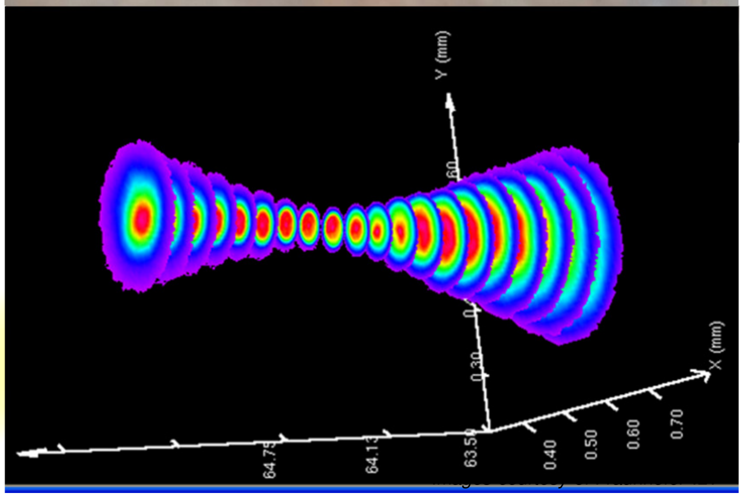
Graph and figures from David Belforte; Industrial Laser Systems (Jan-2012)

Image courtesy of Trumpf Laser GmbH

Technology advances

- The next generation of materials processing lasers will have adaptable beams to optimise efficiency
- HALO will investigate:
  - Adaptable beam profiles
    - Gaussian
    - Top hat
    - Ring modes
  - Modelling of laser cutting processes
    - Beam & pulse propagation
    - Absorption
    - Ablation
  - Novel cutting processes
    - Brittle materials
    - Sheet metal cutting
    - Liquid jet cutting.





Consortium

Components

Coordinator

- **G&H (Torquay)**

Gooch & Housego

Laser technology development

- **ORC Southampton**
- **Fraunhofer ILT**
- **Lulea University**

UNIVERSITY OF Southampton Optoelectronics Research Centre

Fraunhofer ILT

LULEÅ UNIVERSITY OF TECHNOLOGY
WORLD-CLASS RESEARCH AND EDUCATION

Industrial end users

- **Synova**
- **Laser Expertise**
- **Trumpf Laser**
- **Trumpf Werkzeugmaschinen**

TRUMPF

Laser Expertise Ltd.

SYNOVA

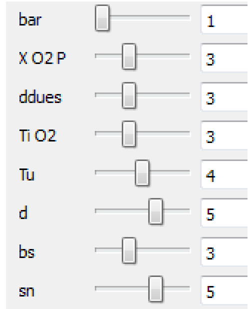
Admin & management

- **Vivid Components**

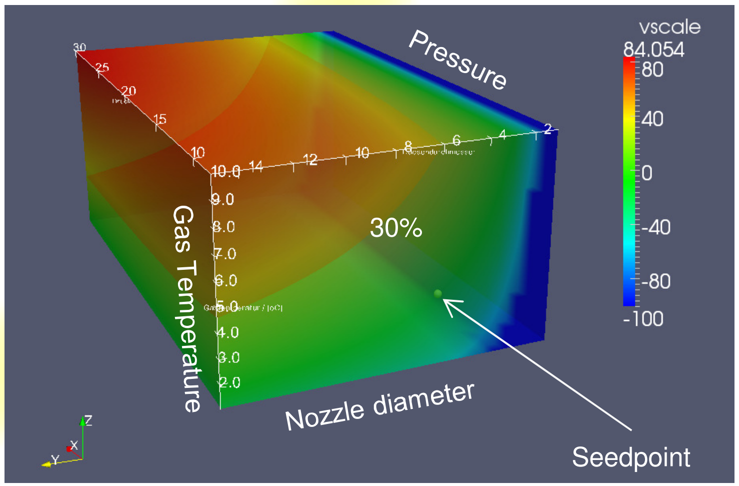
VIVID COMPONENTS

Meta-modelling

- Mathematical model of complex multi-dimension relationships
  - “Pure“ mathematical functions
  - Often without any physical meaning
- Links many parameters and criteria quickly and efficiently
  - Fast visual exploration
  - Multi-criterion optimisation
  - Sensitivity analysis
  - Machine integration/ control/ set-up
  - Direct comparison with experimental data.



Images courtesy of Fraunhofer ILT



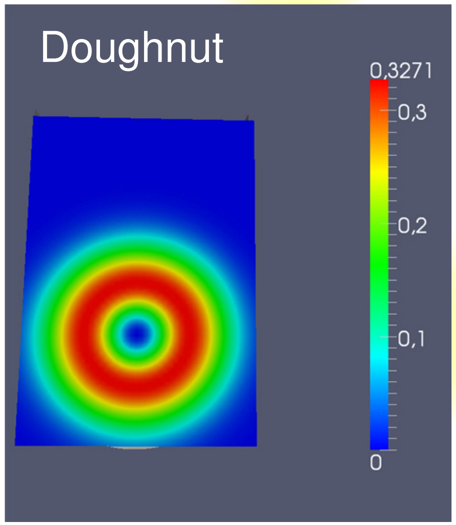
→Parameters = Model Input

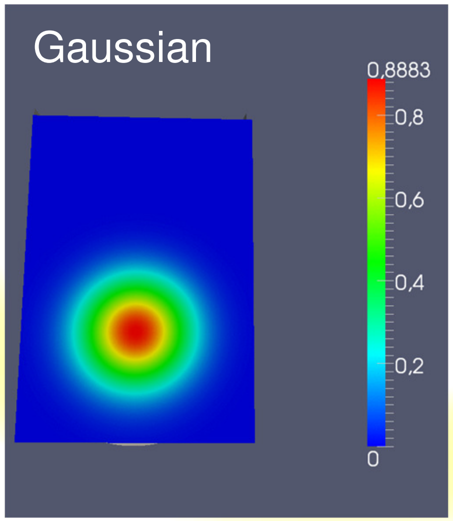
→Explorable quantitative 8-dimensional Cutting Process Map

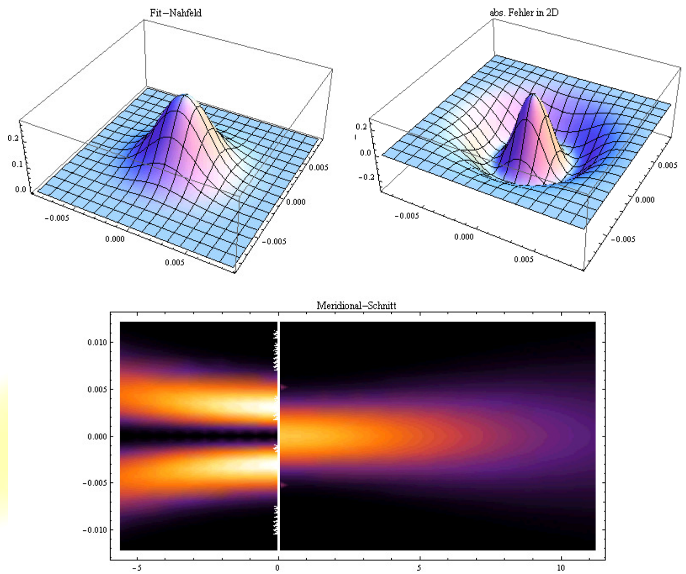
→Design Tool Metamodel → Solution in Design Space.

Beam forming

- Beam shape has a large influence on cutting efficiency
- Optimum shape depends on precise process details
  - Dozens of variables
  - Highly sensitive optimisation
  - Non-intuitive!
- HALO will
  - Develop adaptable lasers to optimise beam shape to the process
  - Identify ideal beam parameters for real processes through meta-models.



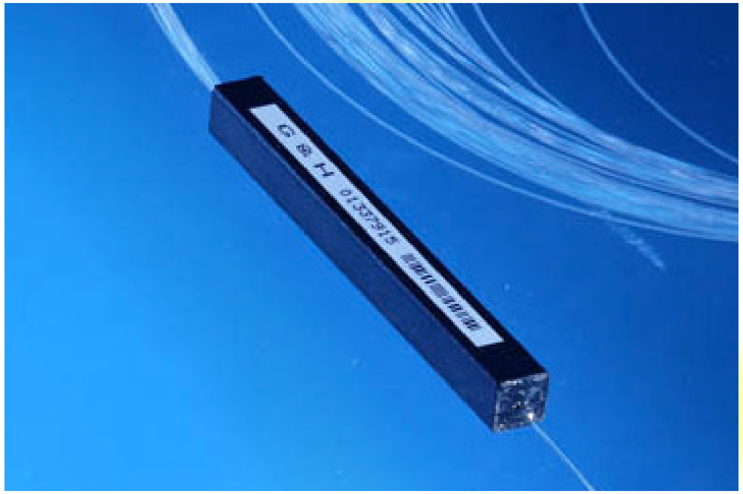




Images courtesy of Fraunhofer ILT

Novel passive components

- Optical isolators
  - Novel designs to permit the unusual beam polarisations used in HALO
  - Comprehensive modelling to understand thermal and optical effects resulting from novel beam shapes
  - Materials for use in high power operation will be investigated



- Fused fibre devices
  - Novel hollow core fibre tapers will provide ring-shaped pump beam for selecting desired LG mode
  - Customised MM pump combiners will be built for high power thulium pump sources.

Images courtesy of Gooch and Housego (Torquay) Ltd.

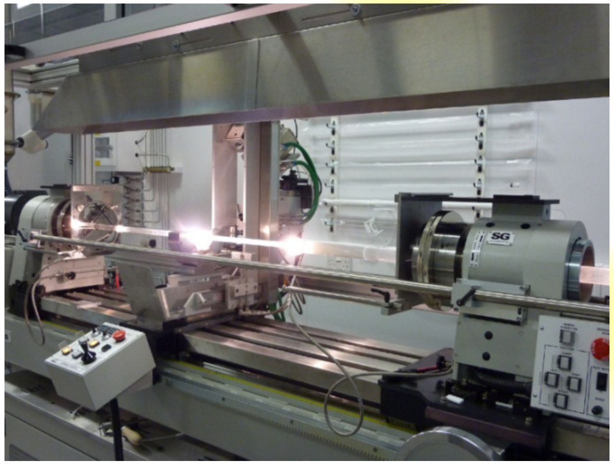
Novel acousto-optic components

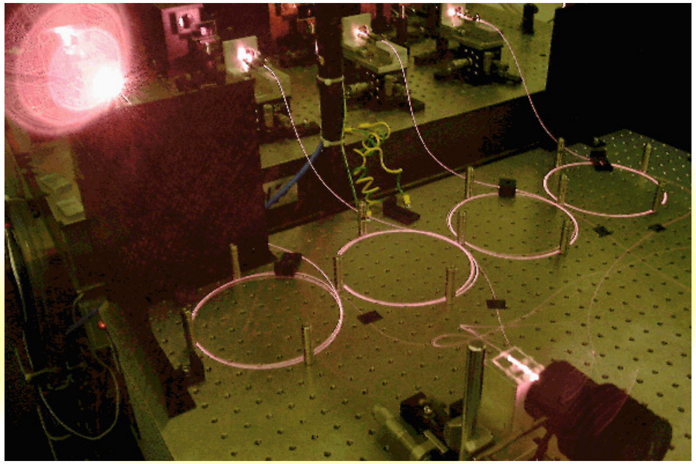
Image courtesy of Gooch and Housego (Torquay) Ltd.

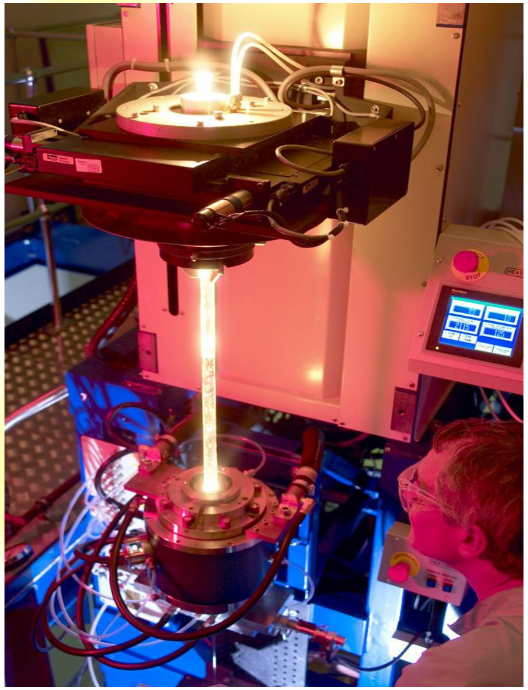
- Acousto-optic Q-switches
  - Exceptionally low insertion loss
  - Very good power handling
- RF signal ON
  - Induces a temporary diffraction grating
  - Deflects a proportion of the laser beam
  - Increased cavity losses prevents lasing
- RF signal OFF
  - Cavity losses decrease rapidly
  - Intense laser pulse evolves
- HALO advances
  - Fibre-coupled polarisation insensitive AO Q-switches
  - First of their kind polarisation selecting and control AO devices
  - Preservation of Laguerre Gaussian “doughnut modes.”

Adaptable beam 2 µm laser-1

- Holmium-doped hybrid (fibre laser-pumped) solid-state laser
  - Generation of high average power laser output at ~2 µm
  - Adaptable output beam profile (doughnut shape to a quasi-top hat)
- Novel technique for direct generation of required beam profile
  - Components located within the laser resonator
  - Architecture compatible with high power operation
    - Continuous-wave (CW)
    - High peak power pulsed modes.



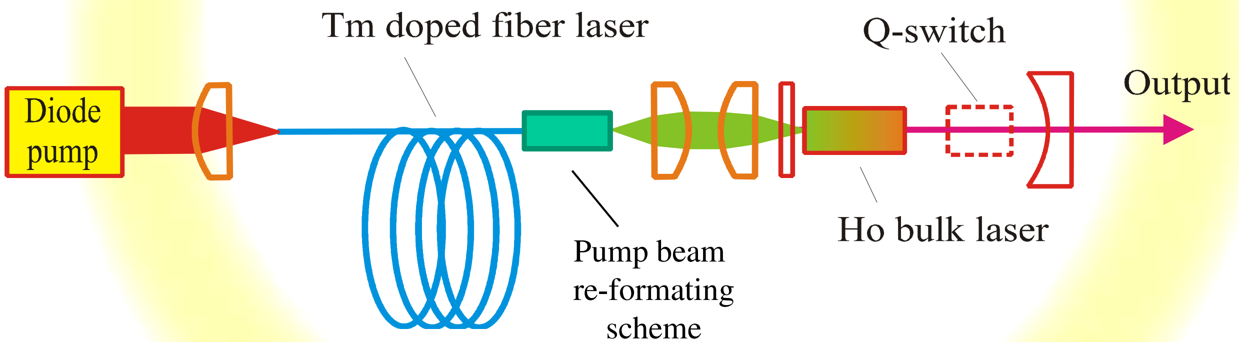


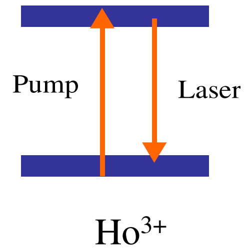


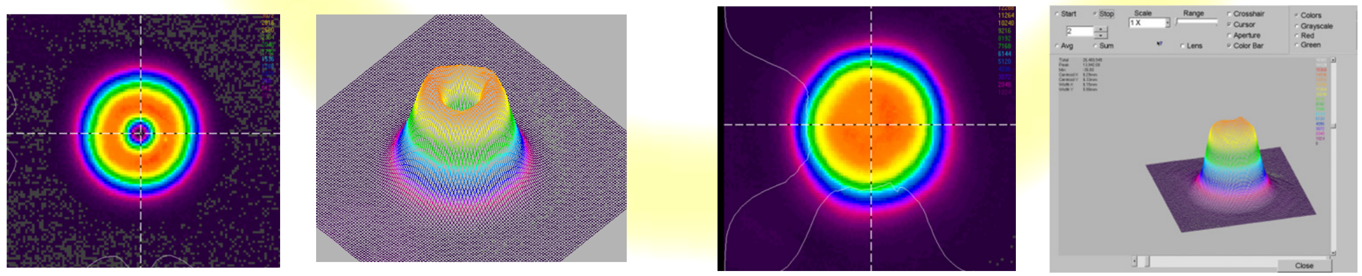
Images courtesy of ORC, University of Southampton

Adaptable beam 2 µm laser-2

- Hybrid laser development comprises three stages:
  - High-power cladding-pumped Tm fibre laser pump source
  - Low-loss fibre-based pump beam shaping and delivery scheme
  - High-power Ho:YAG laser at ~2.1 µm
    - Adjustable near-field and far-field intensity profile
    - Doughnut or top hat
- Hybrid laser will be evaluated in various laser processing trials.







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Demo-sheet metal cutting

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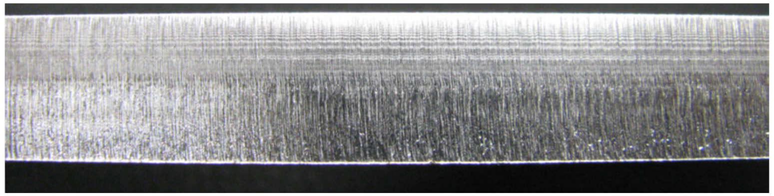
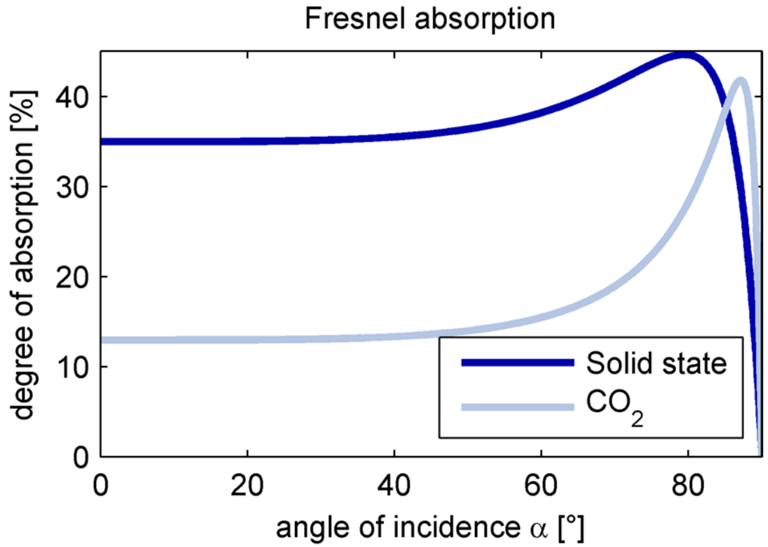
- Currently CO_2 lasers offer state-of-the-art edge quality
  - E.g. 12 mm stainless steel



CO_2 laser, 6 kW

Solid state laser, 5 kW

- In principle solid state lasers offer a much more efficient process
  - 3x higher absorption



Images courtesy of Trumpf Laser GmbH

- HALO objectives
  - Improve cutting with solid state lasers
  - Increase cutting quality and productivity
  - Use of extra-cavity beam converters
  - Quality criteria
    - roughness of edges
    - dross length.

Demo-brittle materials cutting

- HALO will investigate the cutting of brittle materials using ultra-short pulsed lasers
  - Glass
  - Ceramics
  - Sapphire
- Effect of spatial and temporal beam shaping
- Understanding laser-material interactions
  - Absorption and ablation mechanics
  - Thermal behaviour
- HALO objectives
  - Reduce material damage
    - Roughness, micro-cracks and chipping
    - Improved bending strength
  - Increase process efficiency, quality and throughput
    - Ablation rate and cutting speed
    - Edge sharpness kerf width.

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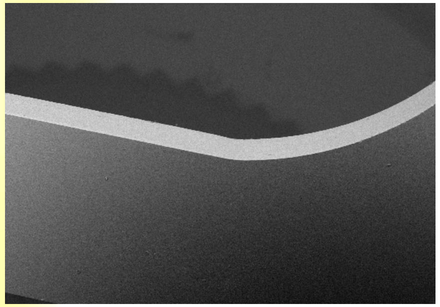
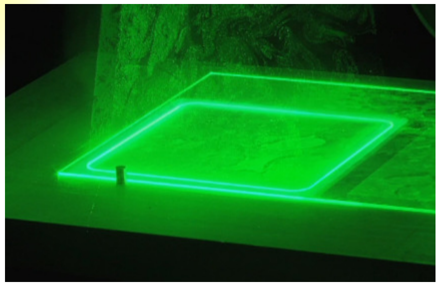


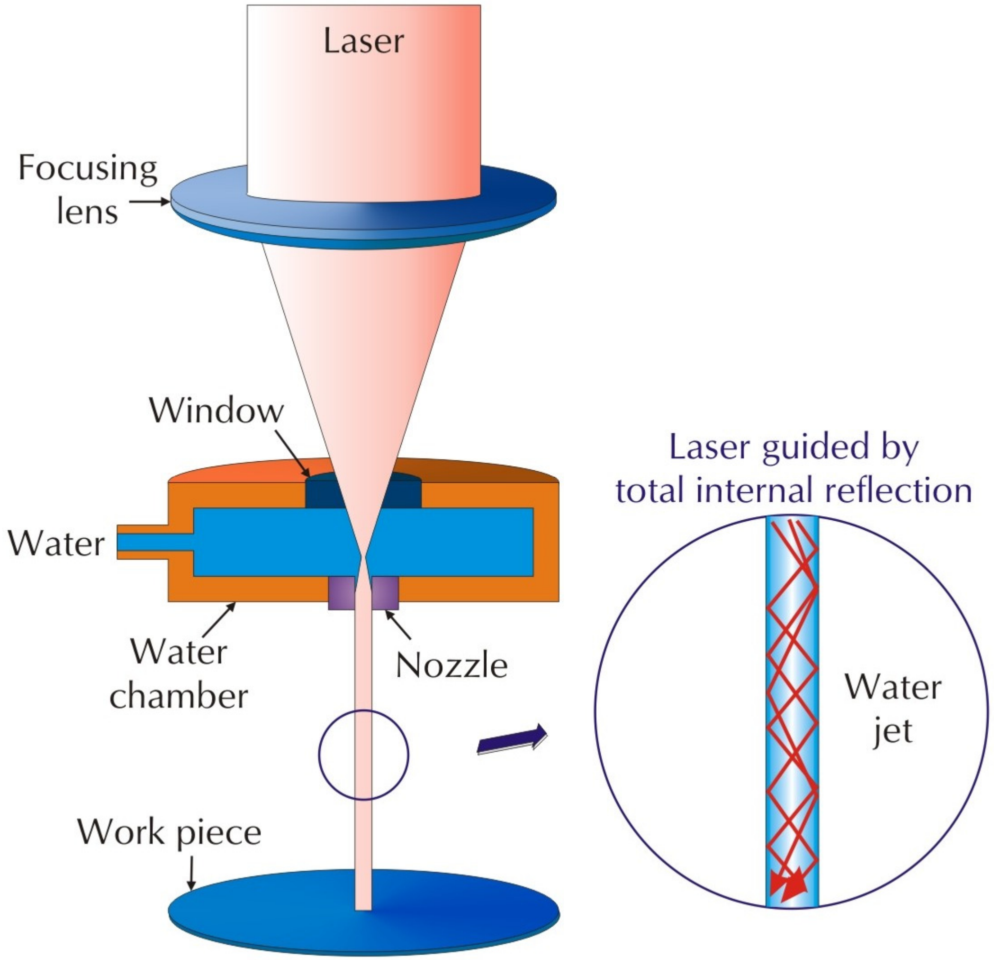


Images courtesy of Trumpf Laser GmbH

Demo-Water jet cutting 1

Laser micro-jet cutting

- Utilizing the difference in the refractive indices of air and water, the technology behind Laser MicroJet® creates a laser beam that is completely reflected at the air-water interface
- The laser beam is entirely contained within the water jet as a parallel beam, similar in principle to an optical fibre
- This allows improved cutting with reduced heat damage, contamination and deformation.



Images courtesy of Synova SA

Demo-Water jet cutting 2

- HALO will demonstrate:
  - Cutting of delicate materials including glass and sapphire
  - End user trials in an industrial environment
    - Brittle materials
    - Sheet metal

- HALO targets:
  - Cut precision <15 µm
  - 20% bending strength increase for glass cutting
  - Cut precision from reduced nozzle diameter <15 µm.

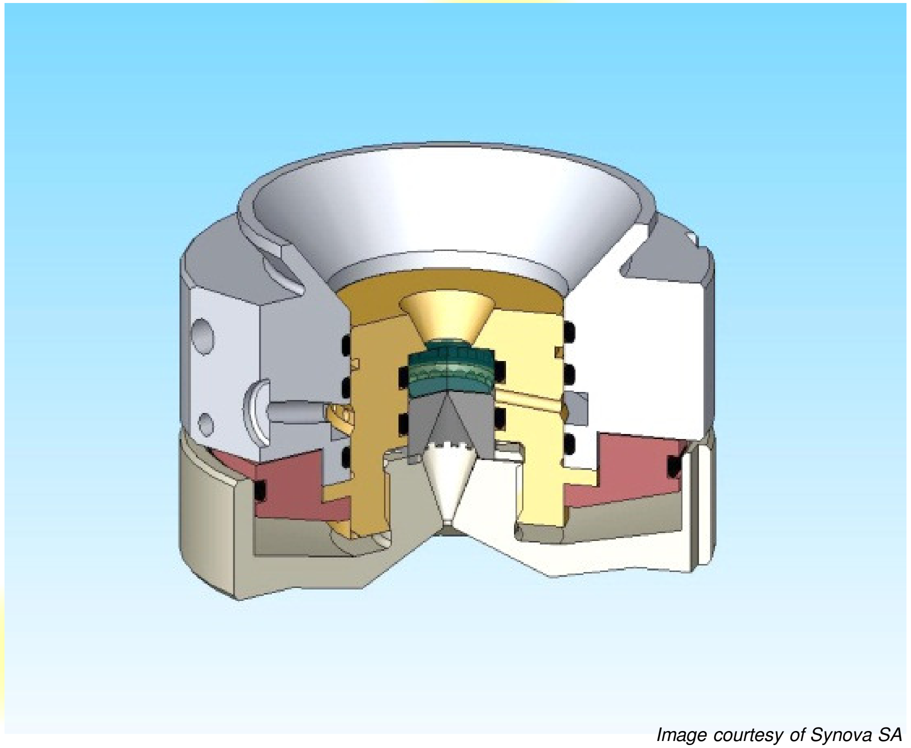
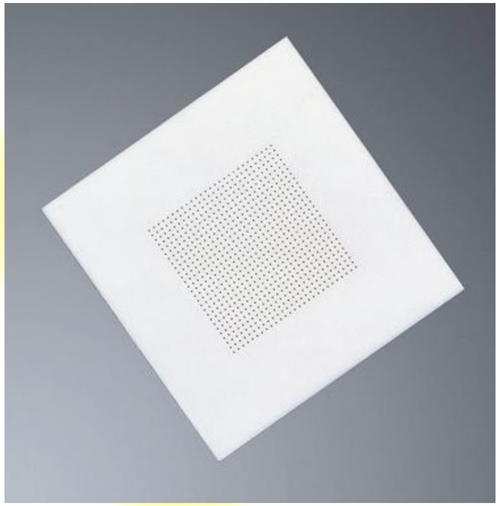
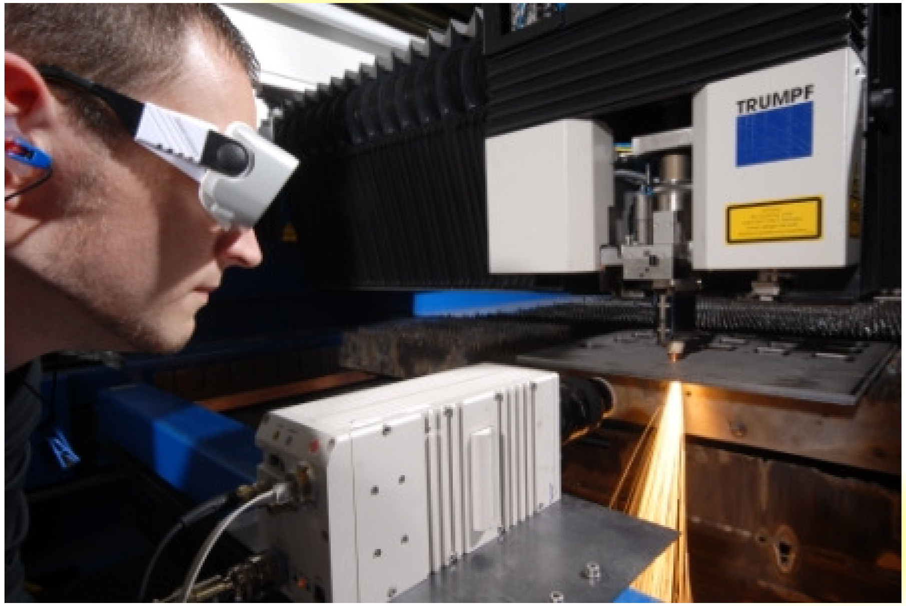


Image courtesy of Synova SA

HALO summary

- HALO will develop technology for adjustable lasers for materials processing
  - Active and passive components
  - Novel adaptable beam solid-state lasers
  - Adaptable beam optics
  - Simulation of adjustable beam laser cutting
  - Process optimisation





- HALO hardware and processes will offer measureable efficiency and quality improvements
- Validation and demonstration for key cutting applications
  - Brittle material
  - Sheet metal
  - Liquid-jet.

Images courtesy of Trumpf Laser GmbH

HALO Industrial Group (HIG)

- HALO will establish a group of interested parties to:
  - Guide HALO research
  - Develop new exploitation routes
  - Identify novel applications

- Target organisations:
  - End users
  - Research organisations
  - Universities
  - Industrial companies.

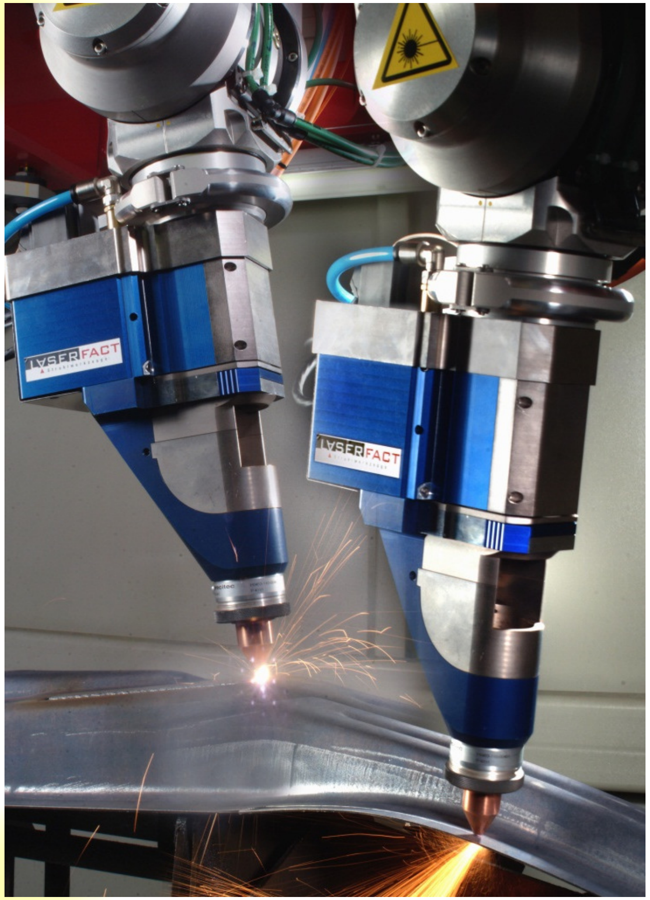


Image courtesy of Fraunhofer ILT

Project info

- HALO is funded under the European Commission's Seventh Framework Programme
  - Programme acronym FP7-ICT
  - http://cordis.europa.eu/fp7/ict/home_en.html
- Area: Smart Factories
  - Energy-aware, agile manufacturing and customisation (FoF-ICT-2011.7.1)

- Project Reference 314410

- Project cost 5.71 M€
- Project funding 3.86 M€

- Start date 01-Sep-2012
- End date 31-Aug-2015
- Duration 36 months.

Further information

Thanks for your attention!

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