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
www.halo-project.eu

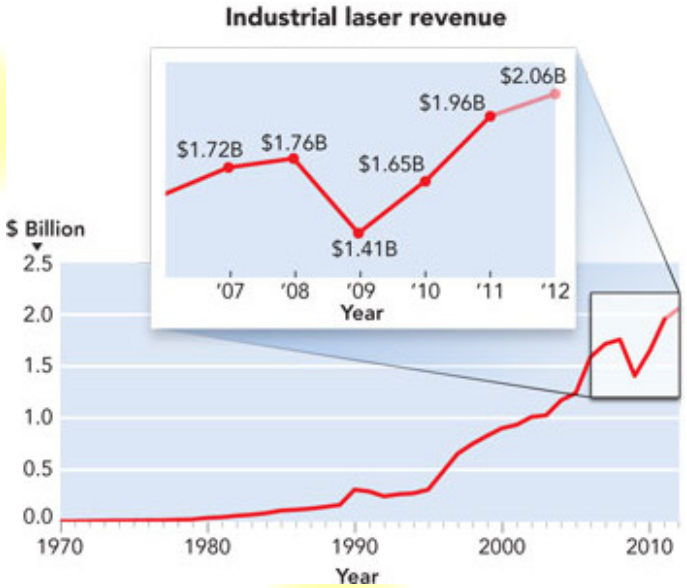
Materials processing with lasers

- 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)

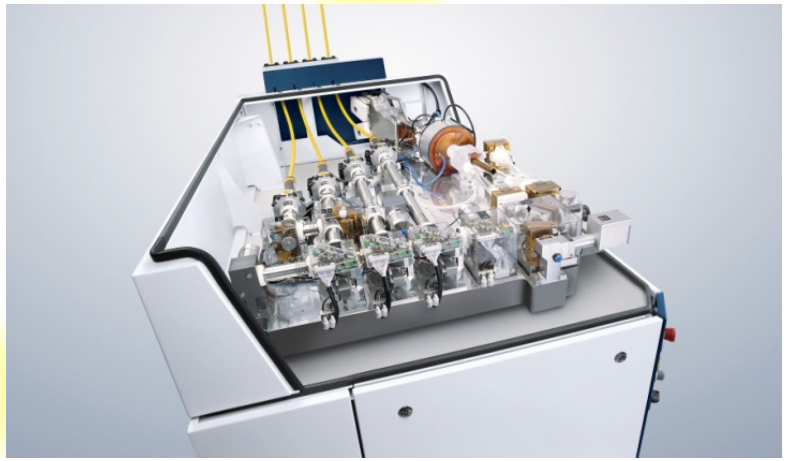
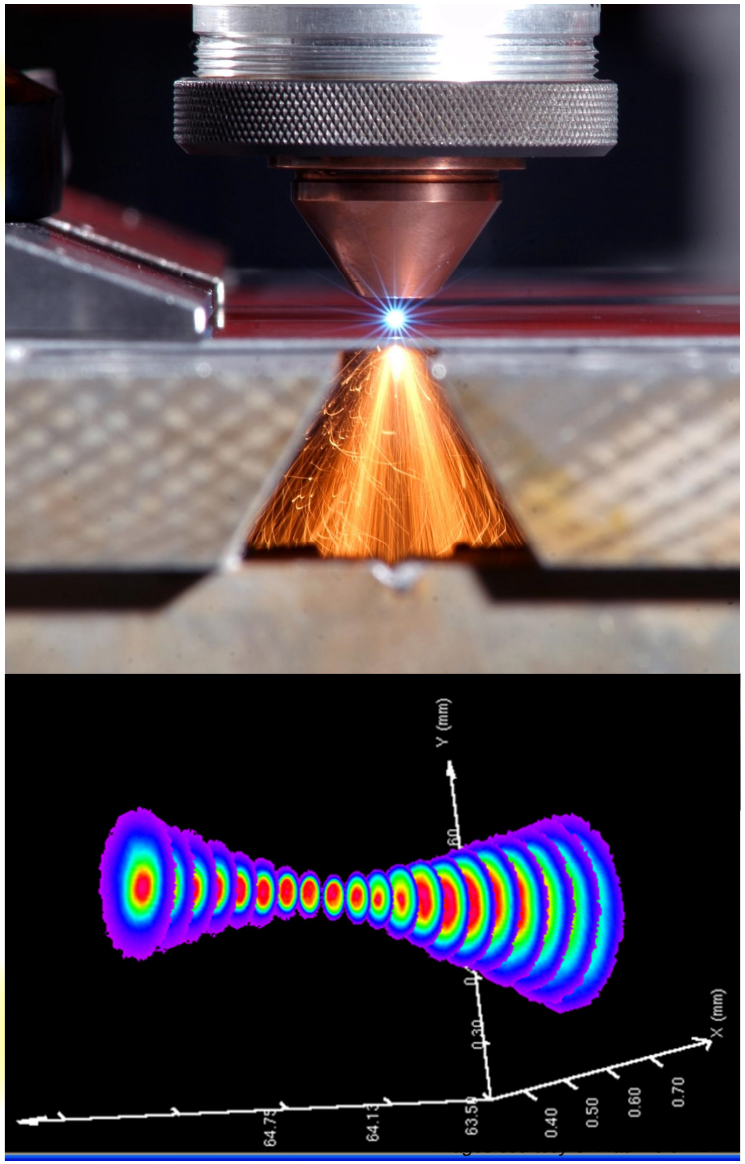


Image courtesy of Trumpf Laser GmbH

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)**

Industrial end users

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

Laser technology development

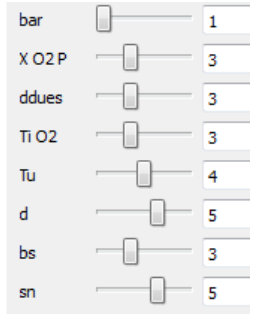
- **ORC Southampton**
- **Fraunhofer ILT**
- **Lulea University**

Admin & management

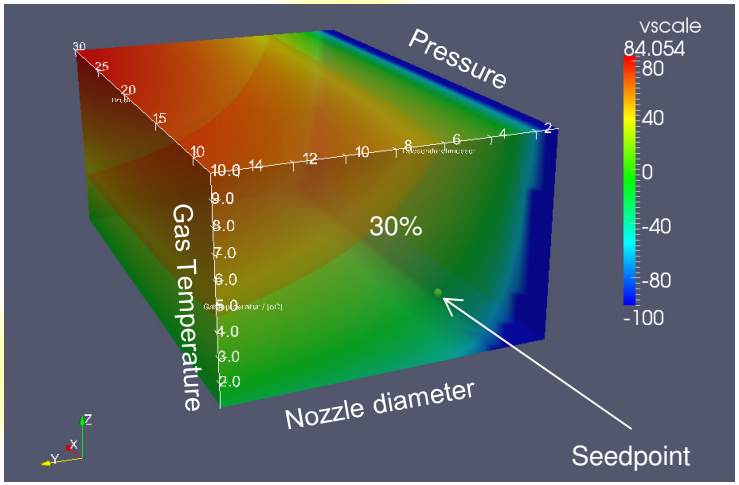
- **Vivid Components**

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



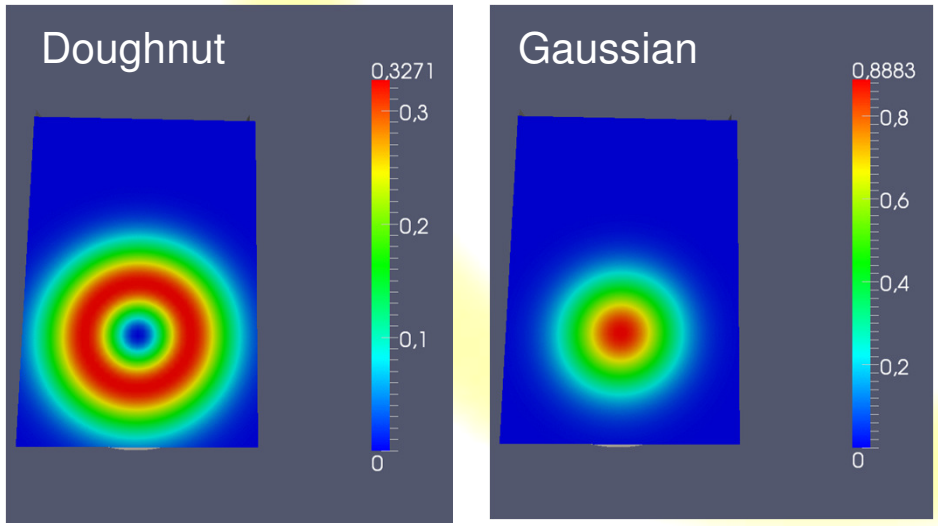
→Parameters = Model Input

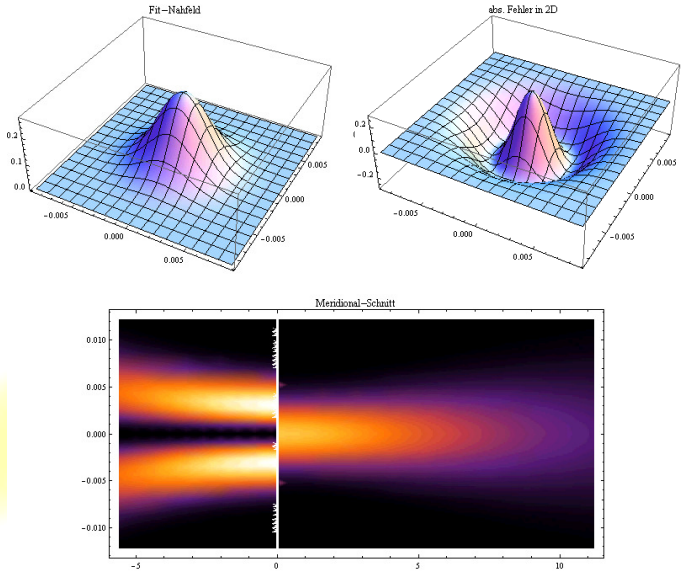
→Explorable quantitative 8-dimensional Cutting Process Map

→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.

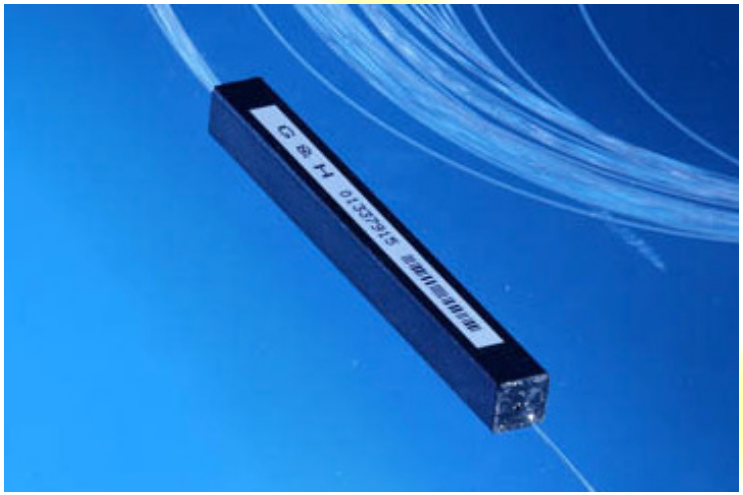




Images courtesy of Fraunhofer ILT

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.

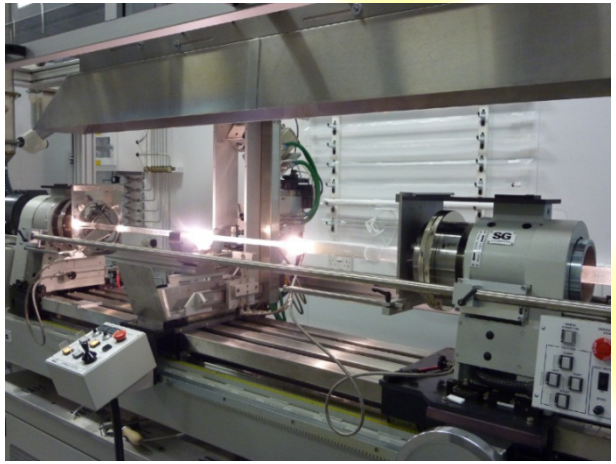
Novel acousto-optic components

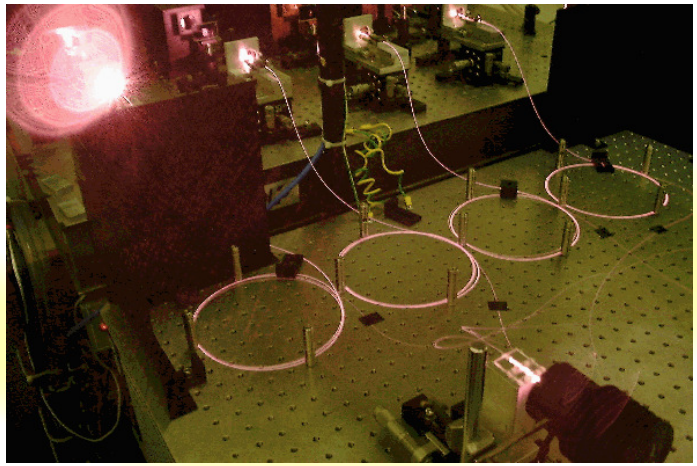
- Acousto-optic Q-switches
  - Exceptionally low insertion loss
  - Very good power handling
- RF signal ON
  - Induces a temporary diffraction grating
  - Deflects a proportion of the laser beam
  - Increased cavity losses prevents lasing
- RF signal OFF
  - Cavity losses decrease rapidly
  - Intense 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.”

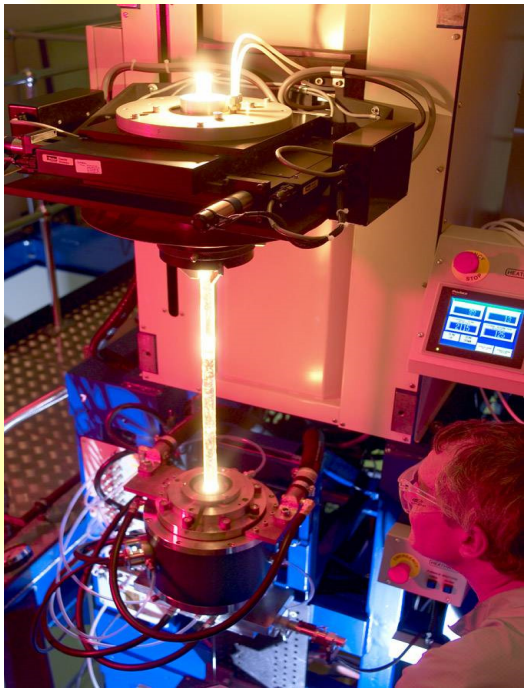
Image courtesy of Gooch and Housego (Torquay) Ltd.

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.



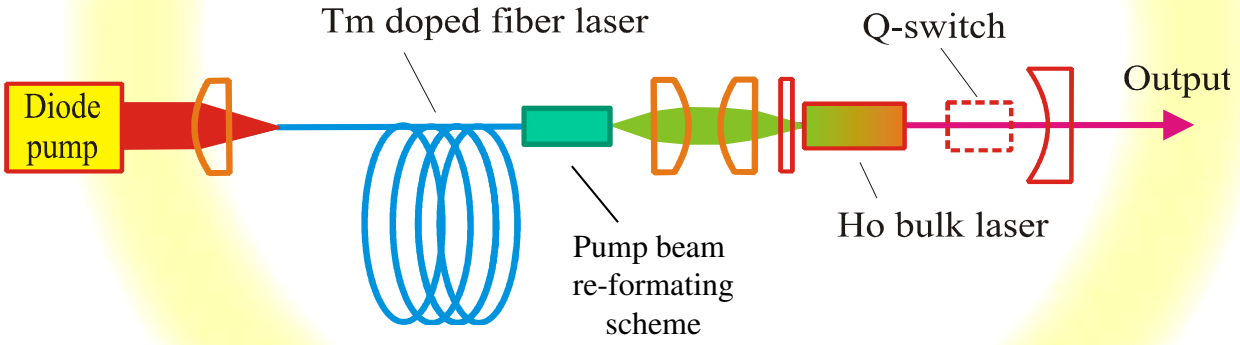


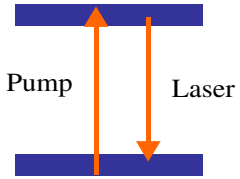


Images courtesy of ORC, University of Southampton

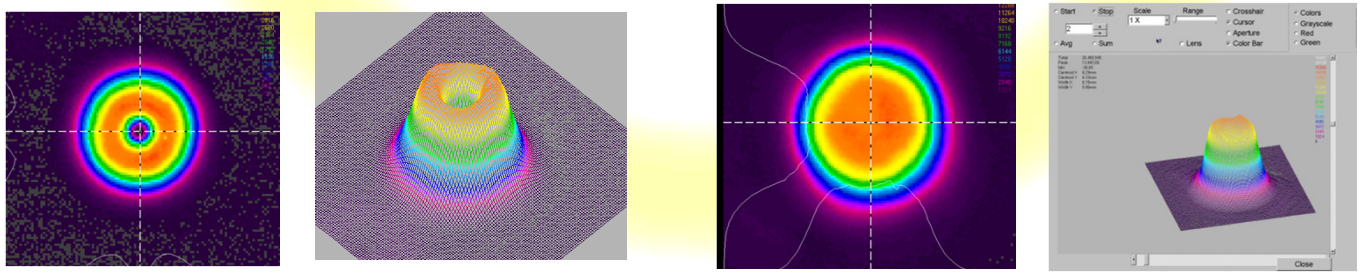
Adaptable beam 2 µm laser-2

- 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.





Ho^{3+}



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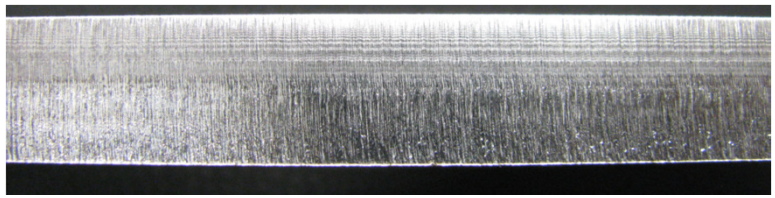
Demo-sheet metal cutting

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

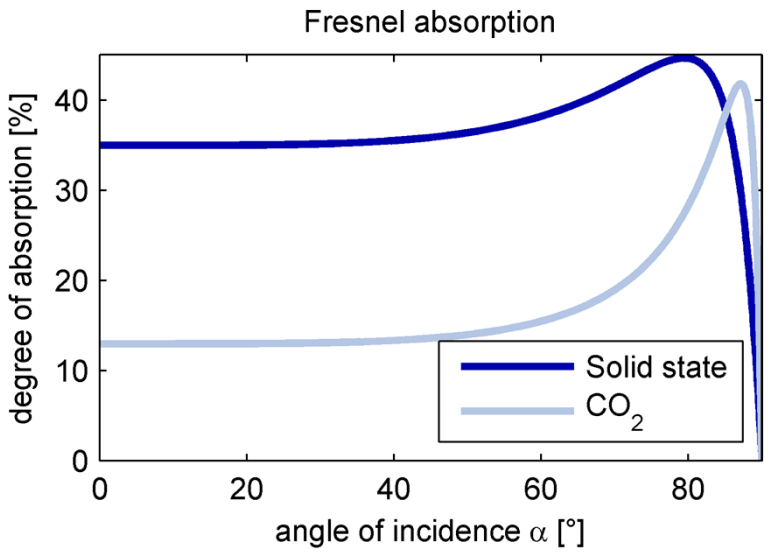


CO_2 laser, 6 kW

Solid state laser, 5 kW

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

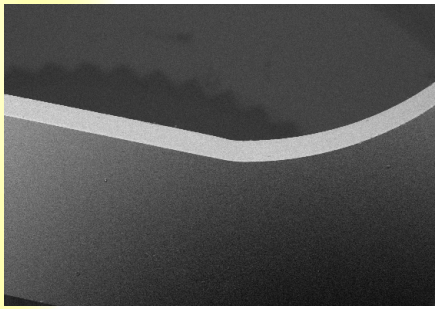
- HALO objectives
  - Improve cutting with solid state lasers
  - Increase cutting quality and productivity
  - Use of extra-cavity beam converters
  - Quality criteria
    - roughness of edges
    - dross length.

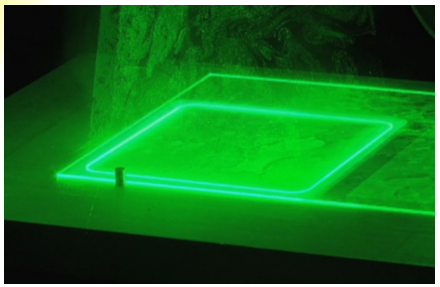


Images courtesy of Trumpf Laser GmbH

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.



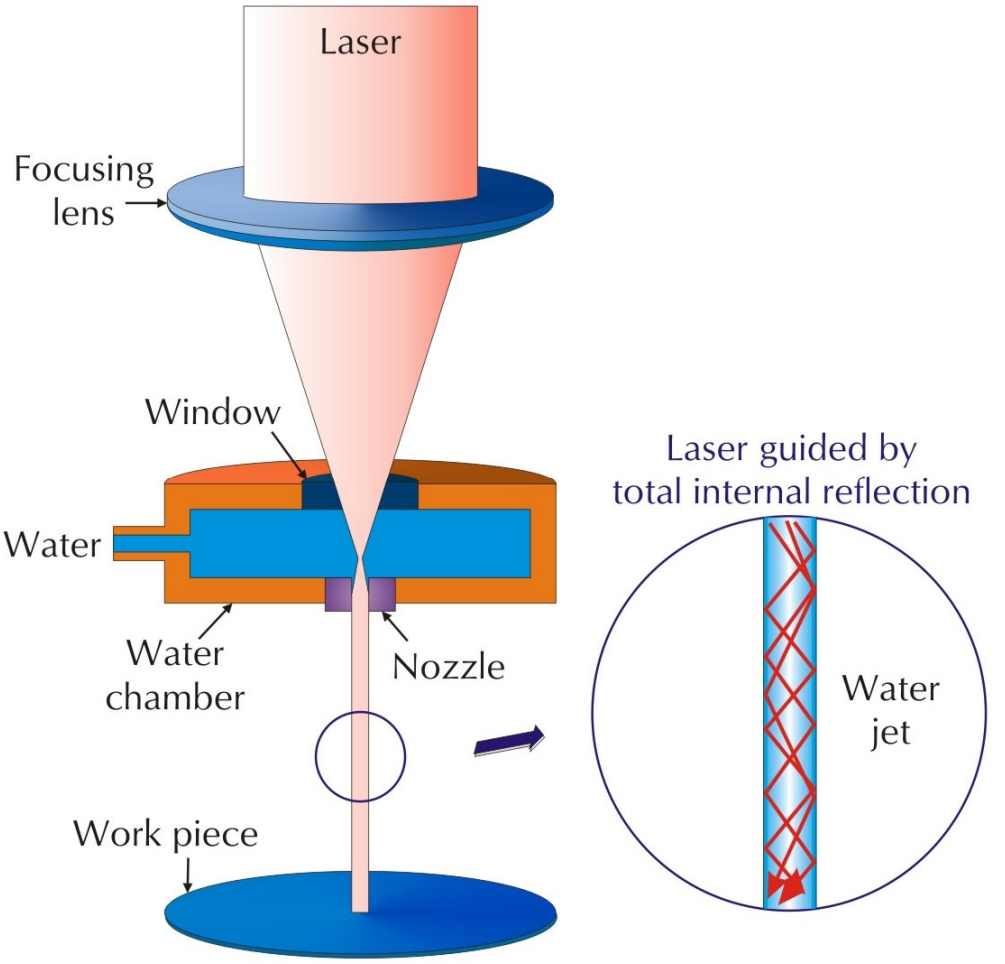


Images courtesy of Trumpf Laser GmbH

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.

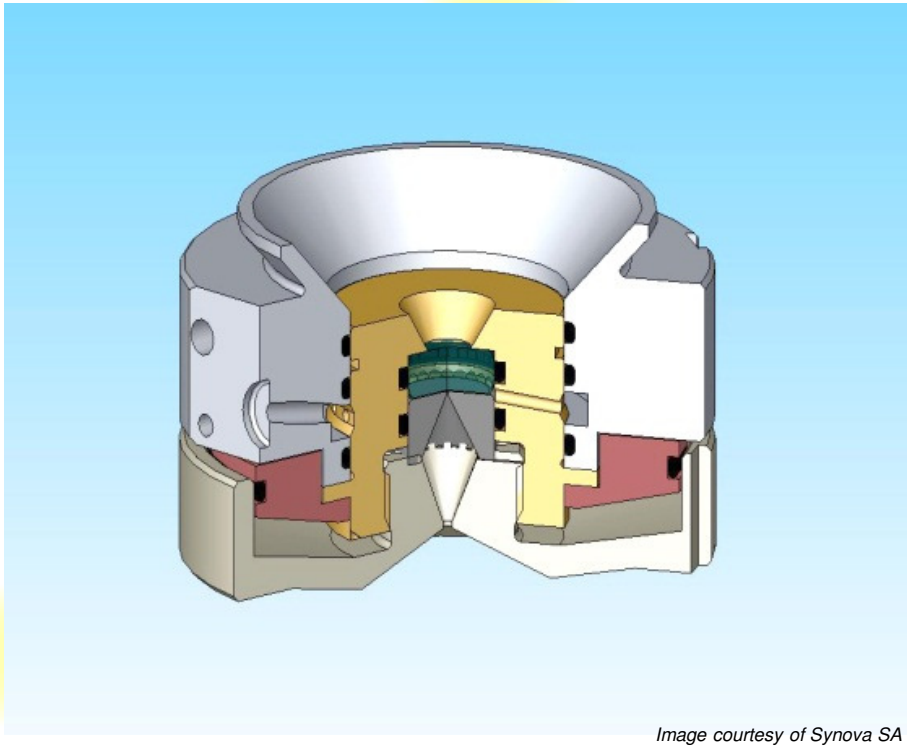
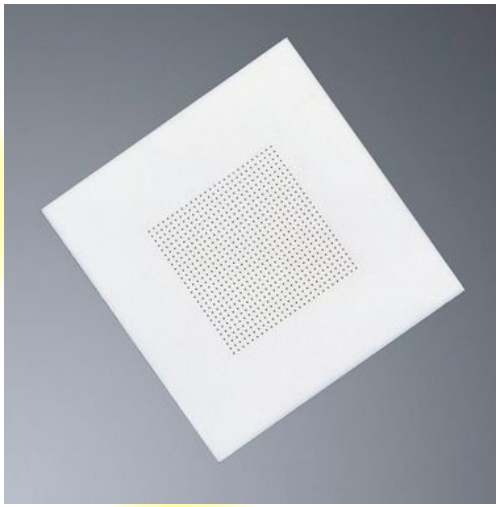
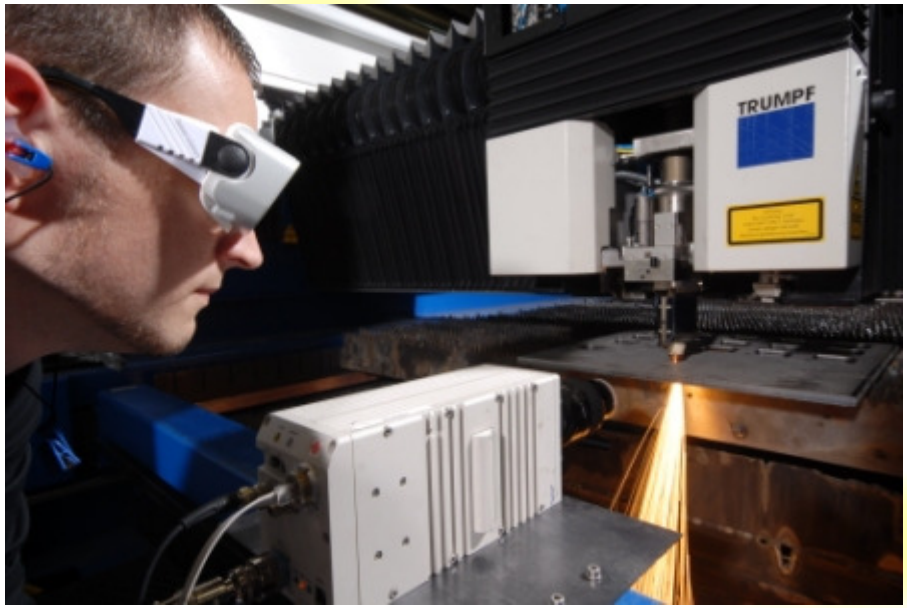


Image courtesy of Synova SA

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





Images courtesy of Trumpf Laser GmbH

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

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.

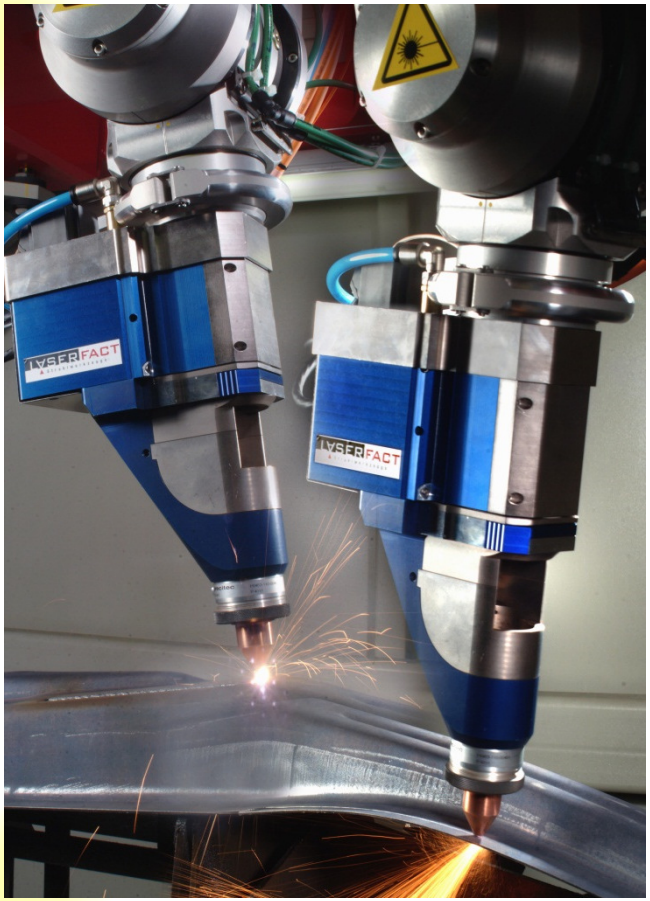


Image courtesy of Fraunhofer ILT

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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