Integrated disruptive componentS for 2 µm fibre LAsers

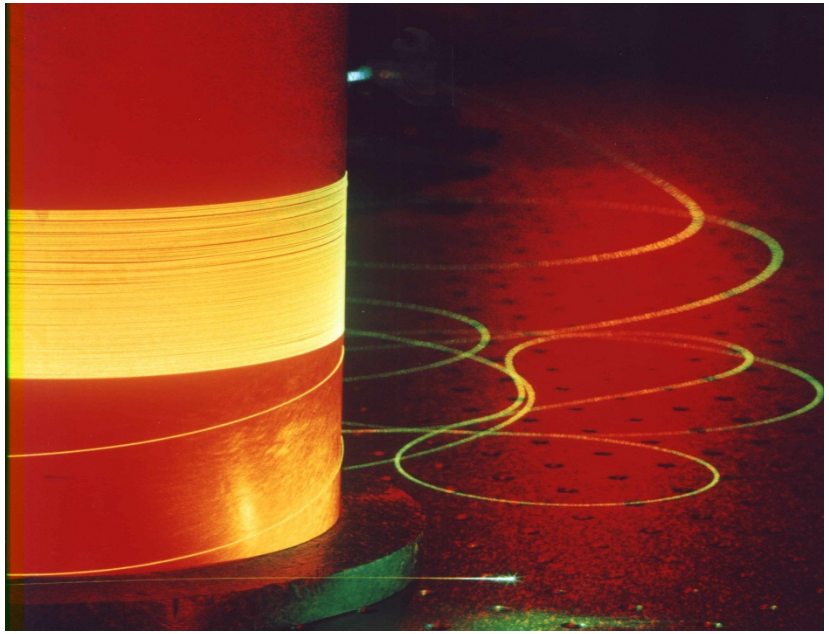
ISLA Project Presentation

ISLA is supported by the European Commission through the Seventh Framework Programme (FP7)
Project number 287732

www.isla-project.eu

Overview: why 2 µm?

- 2µm fibre laser technology has the potential to open whole new areas of ICT & industrial applications
- Power scaling
  - Increased core size
  - Higher non-linear thresholds
  - Tenfold increase in “raw power” compared with current technology
- Wavelength-specific advantages
  - Eye-safe
  - Almost unexplored spectral region
- Many potential applications
  - Industrial processing
  - Free-space communications
  - Medical procedures
  - Spectroscopy.



Overview: disruptive technology developments

- To date the lack of suitable components has blocked R&D in this field

- Several recent disruptive component developments have changed the landscape:
  - Ho-doped silica fibre technology has advanced, providing a solid base for development
  - All-fibre component technology offers integrated functionality
  - Better isolator materials and new designs offer realistic potential for effective 2 µm devices
  - New modulator materials & designs allow Q-switches, filters & switches
  - Carbon nanotube composites offer effective sub-ps modelockers
  - 790 nm diode technology is ripe for development, for optimum direct pumping of Tm.

Overview: ISLA objectives

- Develop a set of “building block” components
  - Define an integrated modular common platform for 2 µm Ho-doped fibre lasers
  - Compatible and self-consistent fibre, components and laser diodes
- Laser types under development
  - CW
  - Pulsed
  - Short pulse lasers
- Industrial demonstration applications
  - Transparent plastic cutting
  - PV cell scribing
- Industrial user group
  - Identify new applications
  - Aid exploitation routes
  - Results promoted within recognised standards bodies.

Consortium

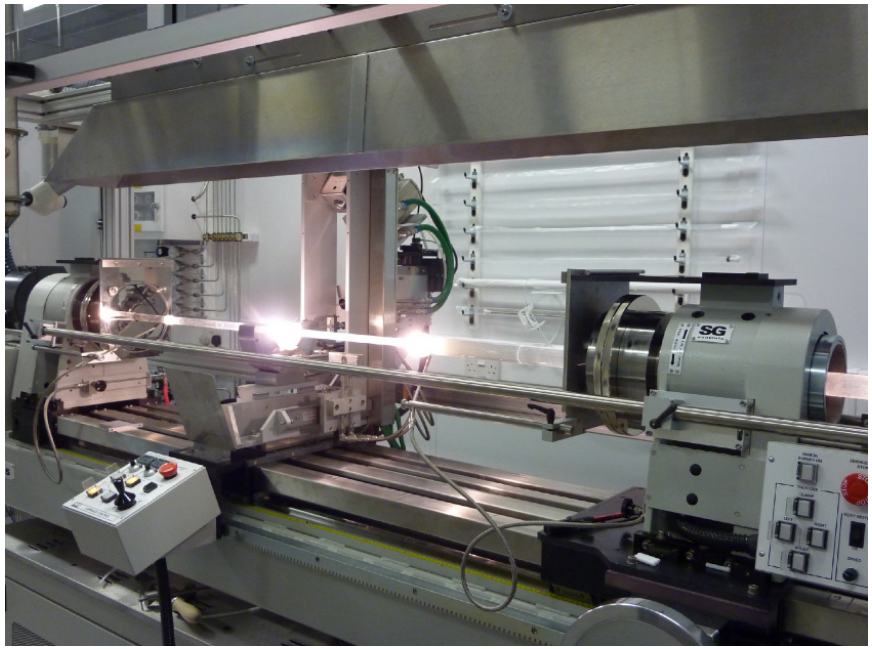
- **Seven partners from four nations**

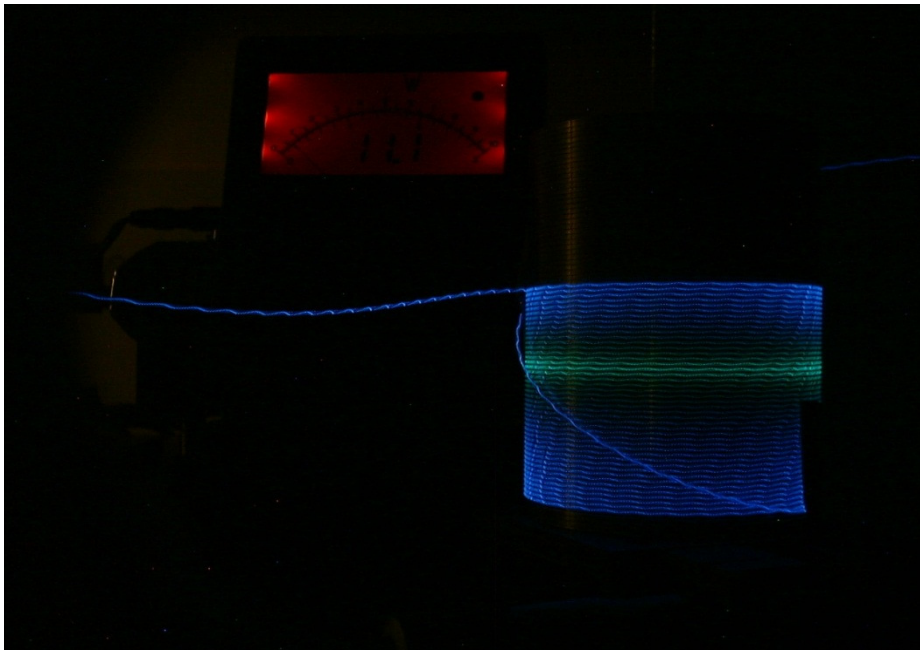
- Gooch and Housego (Torquay) [Coordinator]
  - UK component and sub-system manufacturer
  - Fused fibre couplers, photonic packaging, isolators, modulators
- ORC Southampton
  - UK university group
  - Active and passive fibre development
- Trinity College Dublin
  - Irish university group
  - Carbon nanotube component development
- Oclaro Switzerland AG
  - Swiss laser diode manufacturer
  - 79x pump diode development
- ROFIN
  - German fibre laser system integrator
  - CW and pulsed laser development
- Time-Bandwidth Products
  - Swiss SME fibre laser system integrator
  - Oscillator and modelocker development
- Vivid Components
  - German SME project managers
  - Project administration & dissemination

Fibre development

- ISLA will develop rare-earth doped silica fibres for highly-efficient generation of very high-average power laser output in the 2 µm wavelength regime

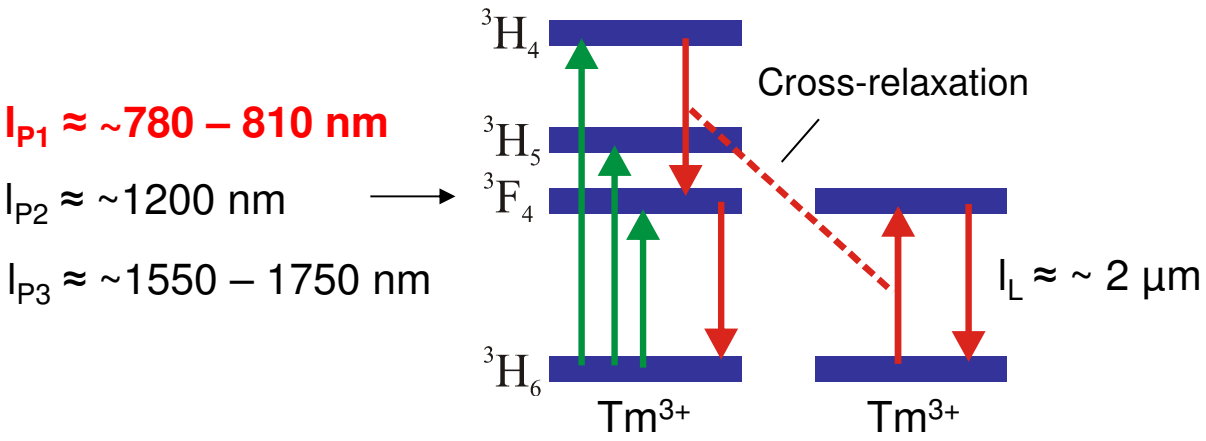
- The ISLA approach is based on a novel two-stage pumping scheme that employs thulium (Tm) doped and holmium (Ho) doped double-clad fibres.

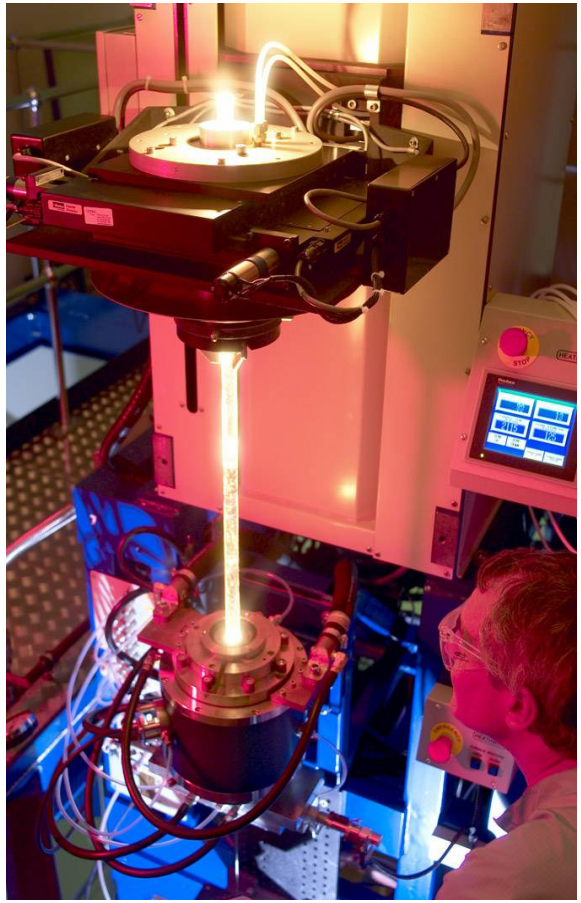




Tm-doped silica fibres

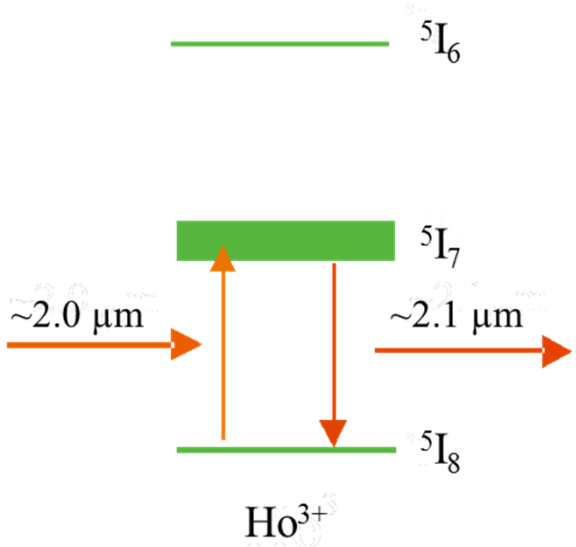
- Tm-doped double-clad fibres will be required for the first pump stage
- The fibre design will be tailored for high efficiency at moderate power levels
- Core composition optimised for high efficiency pumping by 790 nm diode lasers exploiting the two-for-one cross-relaxation process
- Multimode core design to give flexibility in composition
- Target output power ~100 W at 1.95 - 2.00 µm.

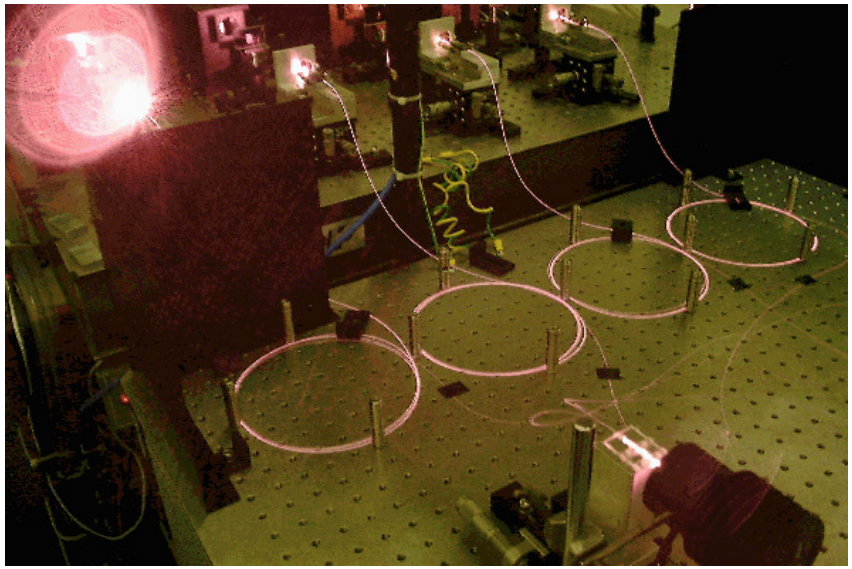




Ho-doped silica fibres

- Ho-doped double-clad fibres will be required for the second pump stage
- In-band pumped by multiple (fibre-combined) Tm fibre lasers
  - Core composition optimised for high efficiency in-band pumping by Tm fibre lasers at 1.95 – 2.00 µm
- Fibre design will be tailored for high efficiency at very high power levels
  - Small cladding-to-core area ratio for high-brightness pumping
  - Large-mode-area core design
  - Target output power >500 W at 2.1 µm.



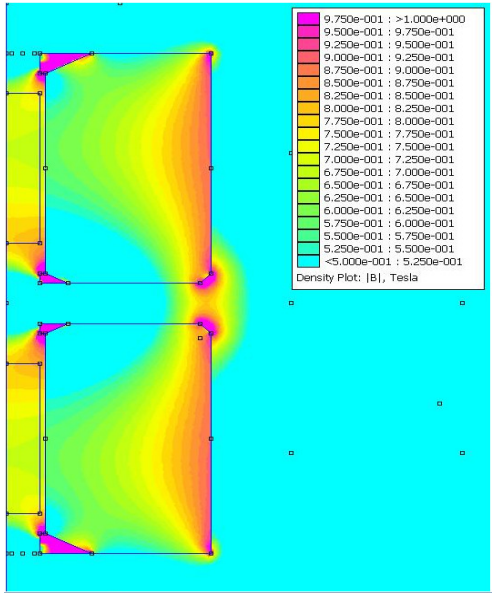


Isolators

- Materials for 2 µm Faraday rotation will be investigated and characterised

- Key properties include:
  - Absorption
  - Verdet constant
  - Thermal conductivity
  - Thermal and wavelength dispersion of Verdet constant

- Fibre-to-free space and fibre-to-fibre isolators will be designed and demonstrated as part of ISLA
  - Fibre-in/ beam out (FIBO)
  - Fibre-in/ fibre out (FIFO).

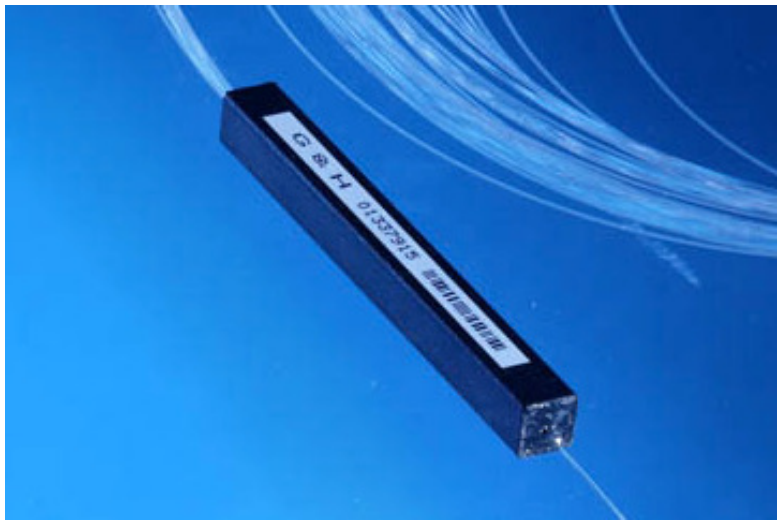


Fused fibre couplers

- Increase understanding of fused fibre couplers at 2 µm
  - Particularly buffer, adhesive and water interactions

- Develop a unique 2 µm 7x1 pump combiner required for ISLA fibre amplifier architecture
  - 7 SM Tm-pump laser fibres combined into small (~50 µm) MM output fibre for cladding pumping Ho-laser

- 2 µm fused fibre WDMs and taps will also be developed.

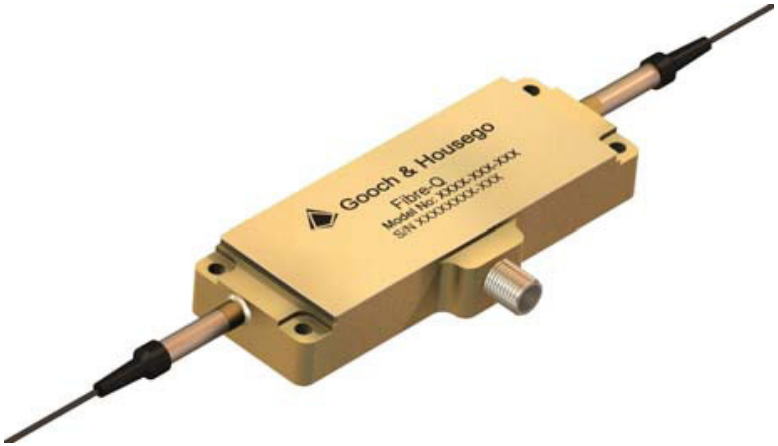


Modulators

- 2 µm Q-switches/ modulators and acousto-optic tuneable filters (AOTFs) will be developed as part of the ISLA project

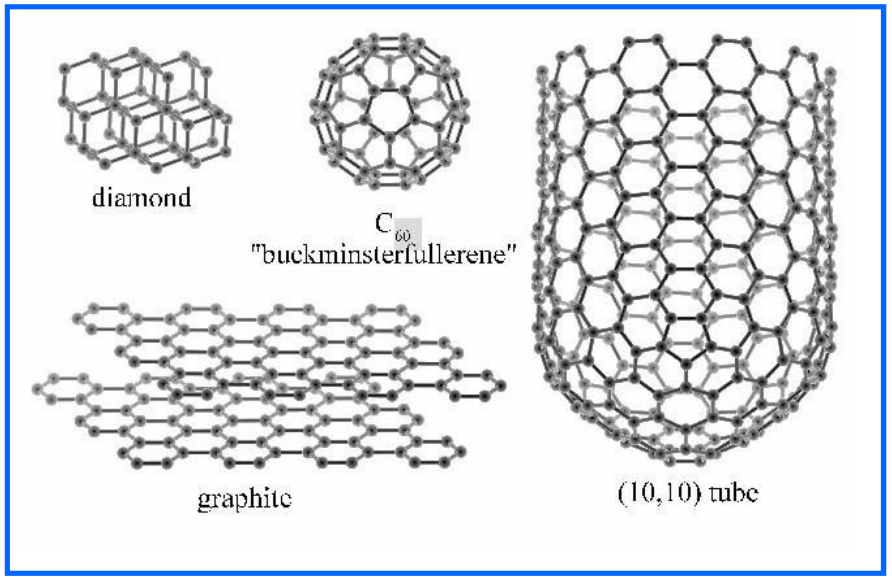
- AOTFs could be used to produce a tuneable fibre laser source to take advantage of broad holmium gain

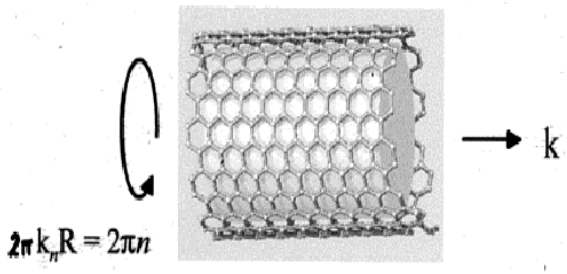
- Develop fibre-coupled 2 µm AOM Q-switch leveraging current G&H technology.



Carbon nanotube based modelockers

- CNTs are a particular form of carbon
  - Single (SWNT) and multi-walled (MWNT) versions
- Optical transitions allowed between valence and conduction bands of the same symmetry

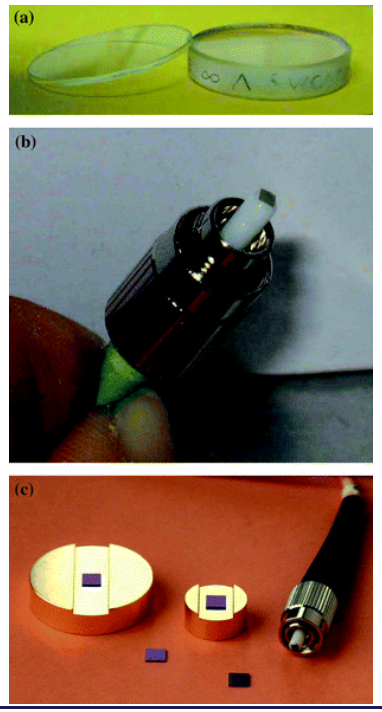


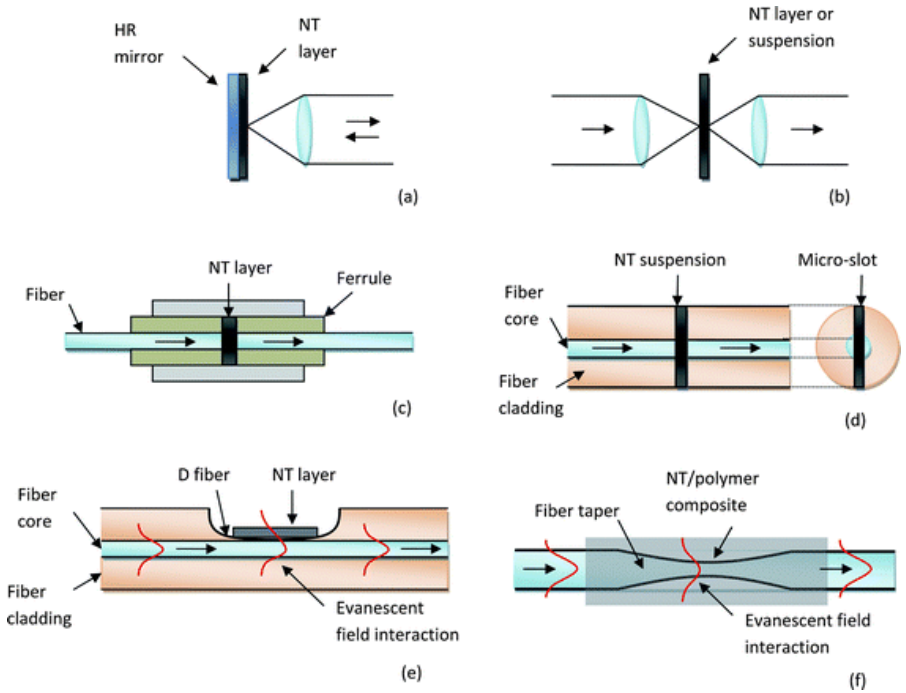


- Optical absorption
  - Energy is a function of diameter and chirality
  - Different tubes have a different energy spacings.

SWNTs as optical materials

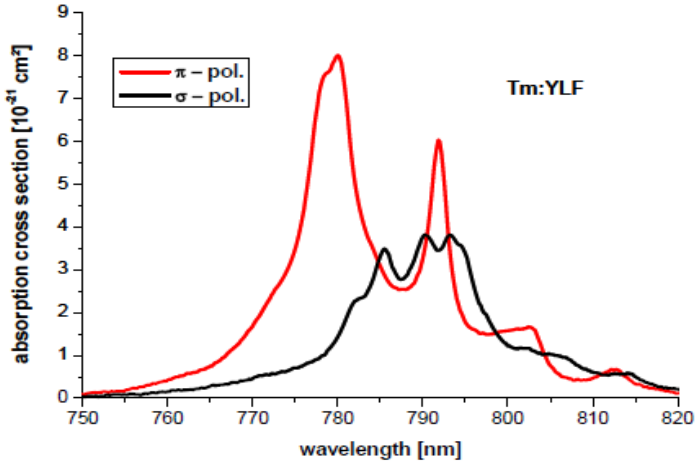
- Extremely tuneable, covering the near infrared and visible
- Intrinsically fast non-linear optical response
  - 1-D confinement implies a short lifetime & large oscillator strength in a narrow resonance
  - Lifetime can be accelerated by bundling
- Polymer composites offer a natural way towards miniaturisation
- Extremely good transport properties
- Suitable for integration with both organic and inorganic substrates.



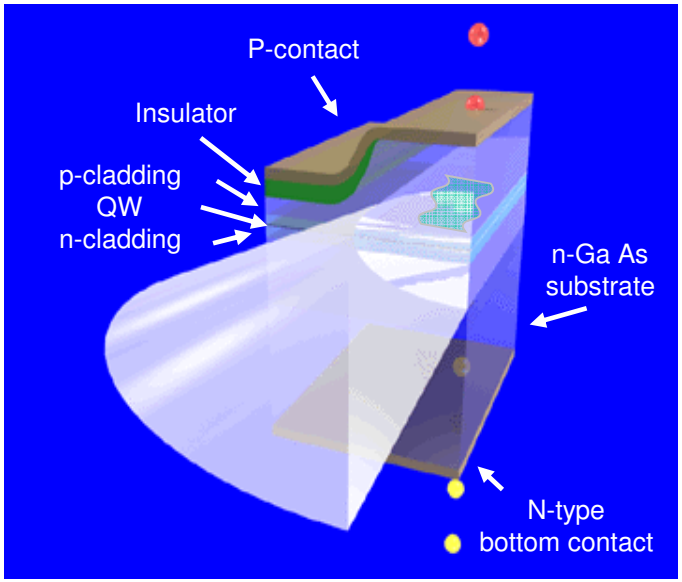


Laser diode development for Tm-pumping

- Development of 79x nm diodes with integrated functionality for direct pumping of 2 µm fibre lasers
  - Tm-doped fibre has high absorption at ~790 nm
- Development of epi-structure
  - Gain maximum adjusted to ~79x nm
- Chip development
  - Increased non-stabilised efficiency at 79x nm
  - Increased output power densities
  - Integrated Bragg grating for narrow wavelength stabilisation
- Integrated pump package development
  - Multiple single emitters integrated into a single package
  - Integrated laser diode protection mechanism against 1.7-2.0 µm radiation
  - Realisation of pump block.

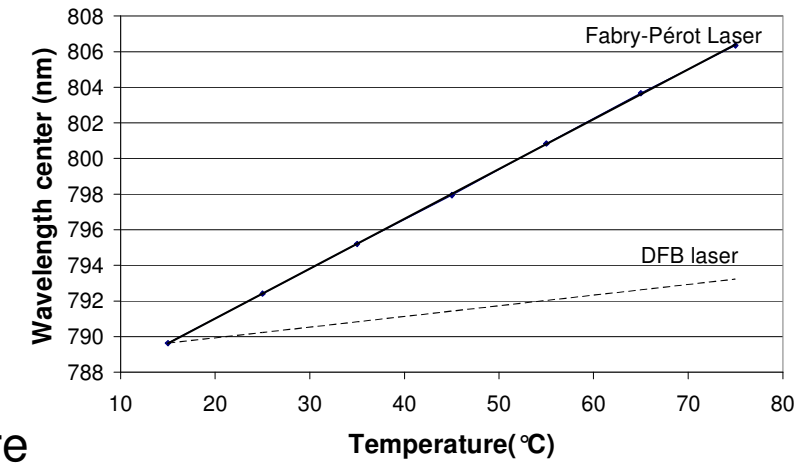


Absorption cross section Tm:YLF
(Koopmann et al, 2009)



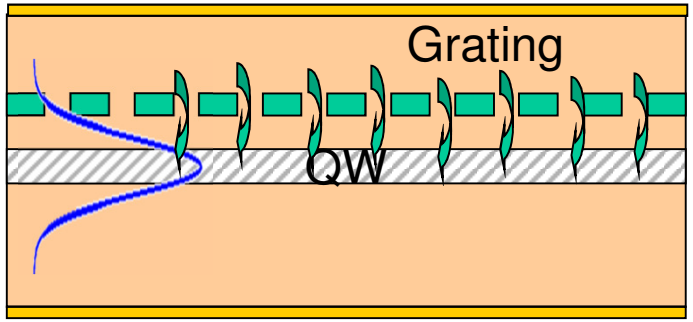
Diode laser wavelength stabilisation

- For pumping materials with narrow absorption bands and a wide operation regime, wavelength stabilisation is required



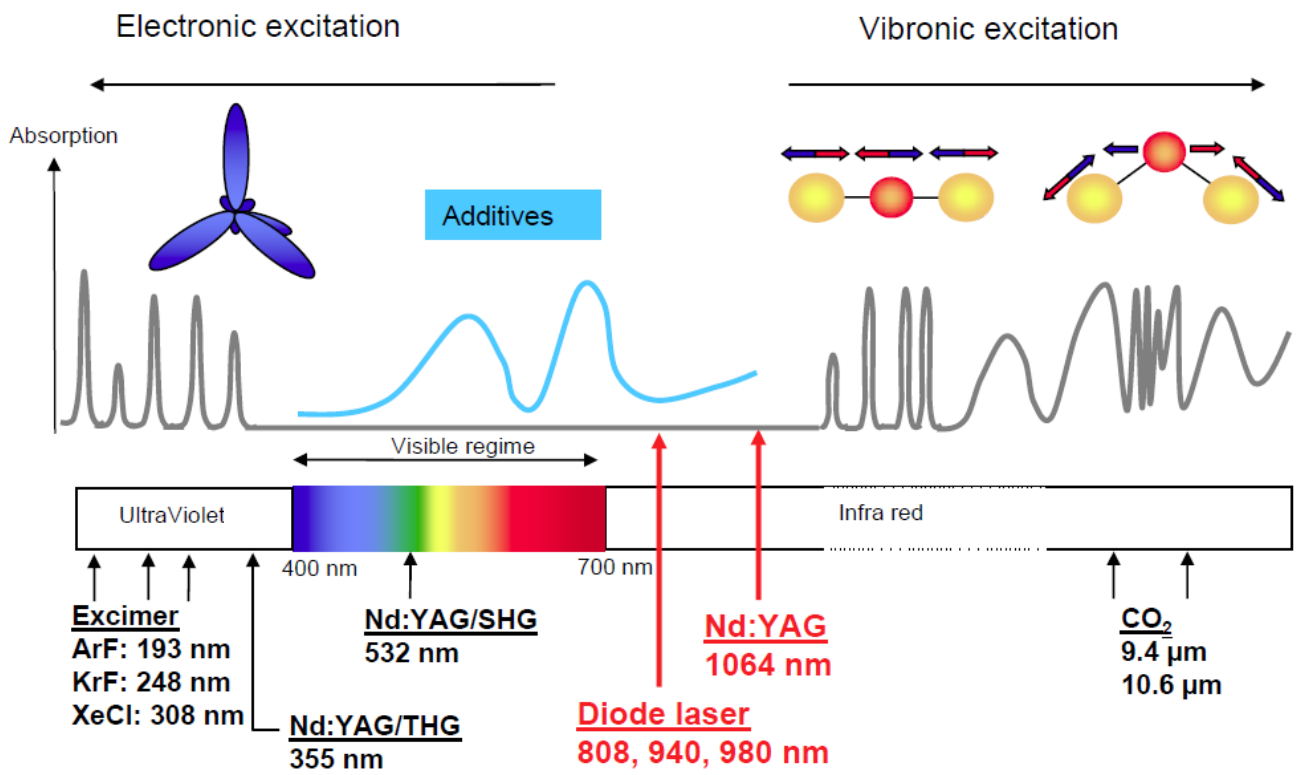
- Fabry-Pérot laser diode
  - Centre wavelength shifts with temperature
  - dλ/dT ~0.3 nm/ ℃

- Cost efficient approach
  - Introduction of distributed feedback by internal longitudinal gratings (DFB laser)
  - Reduced wavelength shift with temperature
  - dλ/dT ~0.06 nm/ ℃.



Demo: transparent plastic cutting 1

- Most plastics do not absorb laser radiation in the region extending from UV to near-IR
- Laser welding (conversion of laser radiation into heat) requires material manipulation
  - Polymer sensitisation required
    - Addition of dyes
    - Another absorbing layer
- At around 1.7 µm the intrinsic absorptivity of plastic increases due to vibronic excitation.



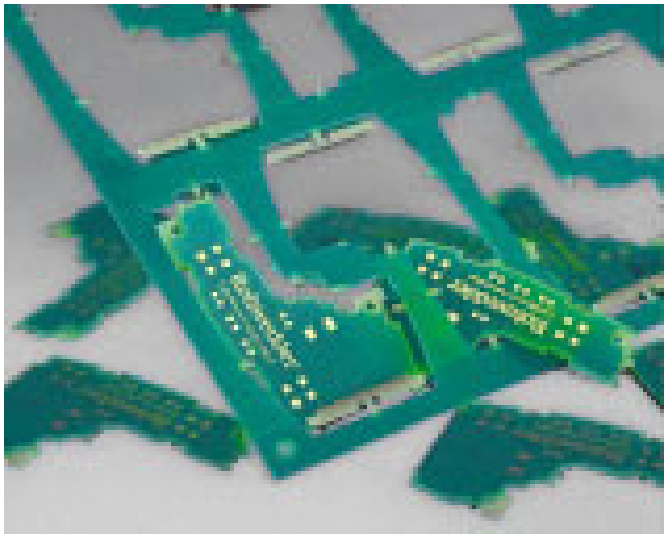
Demo: transparent plastic cutting 2

- Plastic technology is continually developing new polymers and composite materials
  - Highly dynamic application field requiring steady research in laser technology.

- 2 µm fibre lasers will enable plastic material processing
  - No costly additives necessary
  - No CO_2 lasers (emitting at 10 µm).

- The advantages of fibre lasers can be fully utilised, resulting in best process conditions
  - High power & beam quality
  - High efficiency and smallest size
  - Fibre beam delivery.

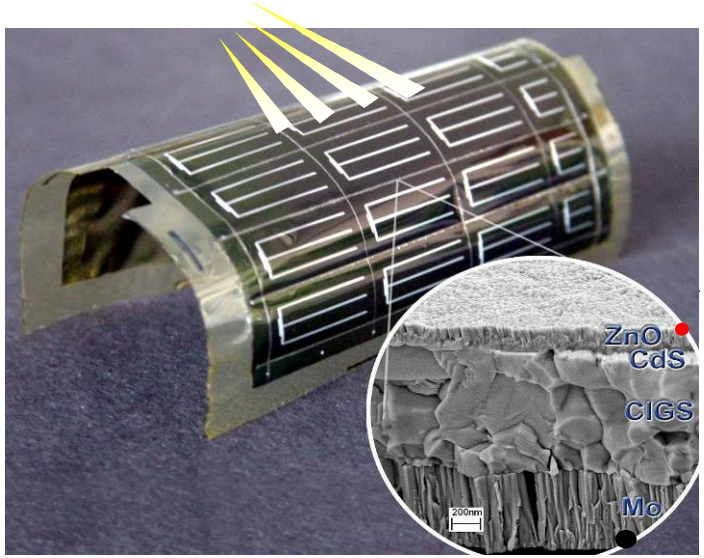
Separating PMMA windows for mobile phones



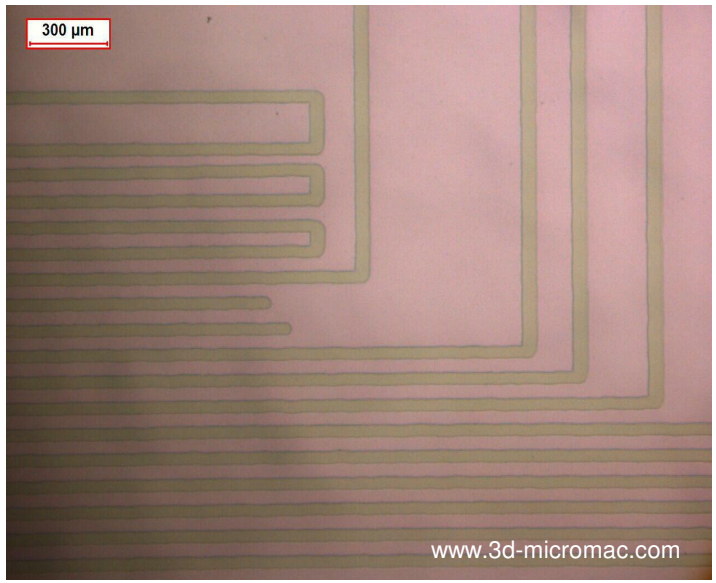
Quick and precise cutting of fiber optic reinforced synthetic resin plates with a CO_2 laser

Demo: PV cell scribing

- Solar cell manufacture is one of the largest markets for photonics
  - Includes various materials, including ITO, flexible substrates and organic thin films
  - Multifunctional layers and heterostructures
- Huge areas with fine line scribing requires extremely fast scribe rates
  - Several metres per second with high quality cutting/ scribing!
  - Round the clock production
- 2 µm lasers offer eye-safe high power solutions
  - Higher absorption in many relevant solar materials than existing solutions.



ETH Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich



Project details

- ISLA is funded under the European Commission's Seventh Framework Programme

• Programme acronym	FP7-ICT (http://cordis.europa.eu/fp7/ict/home_en.html)
• Programme type	Seventh Framework Programme
• Sub-programme area	Core and disruptive photonic technologies (b), (e)
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• End date	30-Sep-2014
• Duration	36 months

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