ISLA project newsletter #6

August 2015

ISLA is a project supported by the European Commission under the Seventh Framework Programme (FP7).

Welcome to the final ISLA project newsletter!

The ISLA project finished at the end of June 2015. Over the last three and a half years the project has had a major impact on the development of components for 2 µm fibre lasers. This final newsletter summarises the main advances made in the project:

- Thulium fibres with 70% slope efficiency at >100 W output
- Holmium fibres with 75% slope efficiency
- Amplitude modulators and tuneable filters
- Fibre-coupled isolators, pump combiners and low loss taps
- Wavelength-flattened couplers
- Fibre-coupled silicon pulse pickers
- Graphene-based modelockers
- 793 nm diodes >38 W in 105 µm fibre with 0.15 NA demonstrated
- Wavelength stabilised 793 nm diodes with 60% power conversion efficiency

There is also a summary of the excellent ISLA workshop (26-Jun-2015) and "Stop Press!" news of an ISLA session at Photonics West next year!

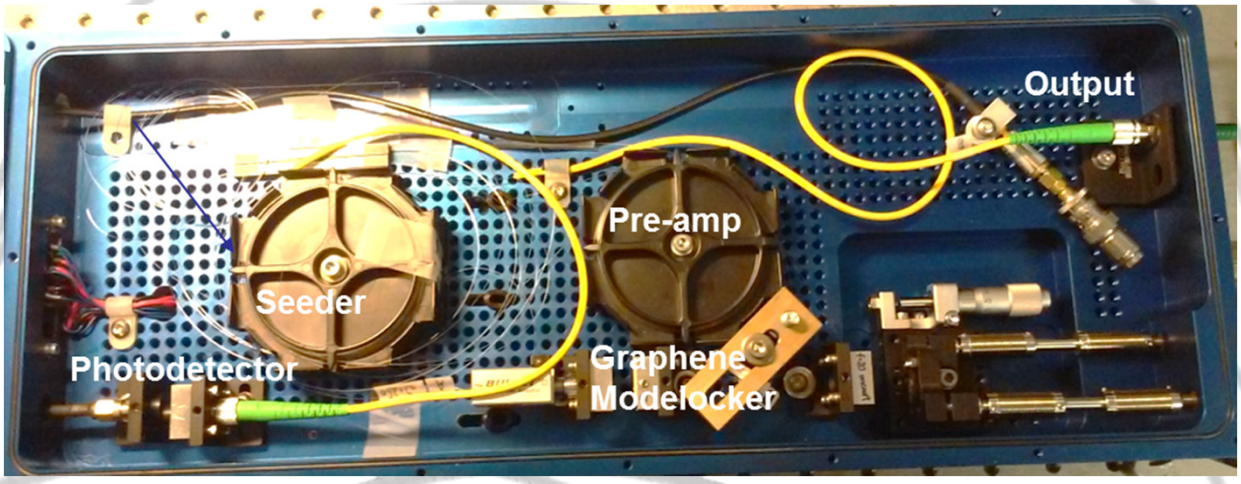


Photo of the ISLA 2 µm ps-laser during the development phase

Consortium

Gooch & Housego

TRINITY COLLEGE DUBLIN
COLÁISTE NA TRÍONÓIDE, BAILE ÁTHA CLIATH

rofin

UNIVERSITY OF Southampton
Optoelectronics Research Centre

II-VI LASER ENTERPRISE

JDSU

VIVID COMPONENTS

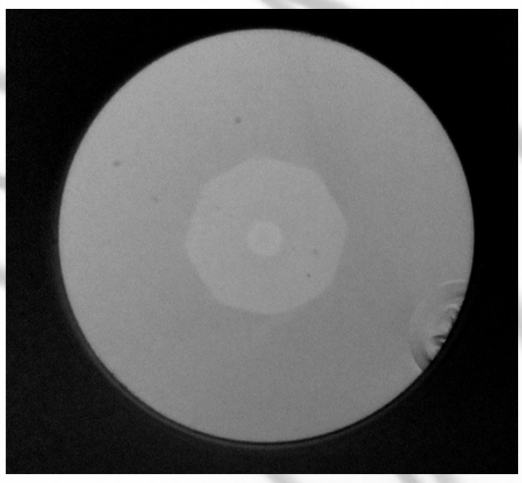
Coordinator Andrew Robertson arobertson@goochandhousego.com
Admin Bruce Napier bruce@vividcomponents.co.uk

Ground-breaking Tm and Ho-doped silica fibres

UNIVERSITY OF Southampton
Optoelectronics Research Centre

Over the course of the ISLA project, fibre fabrication effort at the ORC has developed high efficiency Tm and Ho fibres for operation within the 2 µm spectral region. This has led to the demonstration of slope efficiencies of up to 70% for 793 nm pumped Tm fibre w.r.t. absorbed pump power. This high efficiency Tm fibre has been utilised to pump holmium doped fibre produced within the ORC.

Recent work has focused on the development of holmium fibre for double-clad pumping. Investigations into the material choice for cladding materials in the 2 µm region has led to fabrication of all-glass structures for pump guidance utilising a fluorine-doped glass. In addition to minimising pump loss due to cladding material attenuation, remarkable advances on the reduction of OH impurities in the cladding glass have been accomplished.



Fibre end section of a triple-clad Ho-doped fibre produced at the ORC.

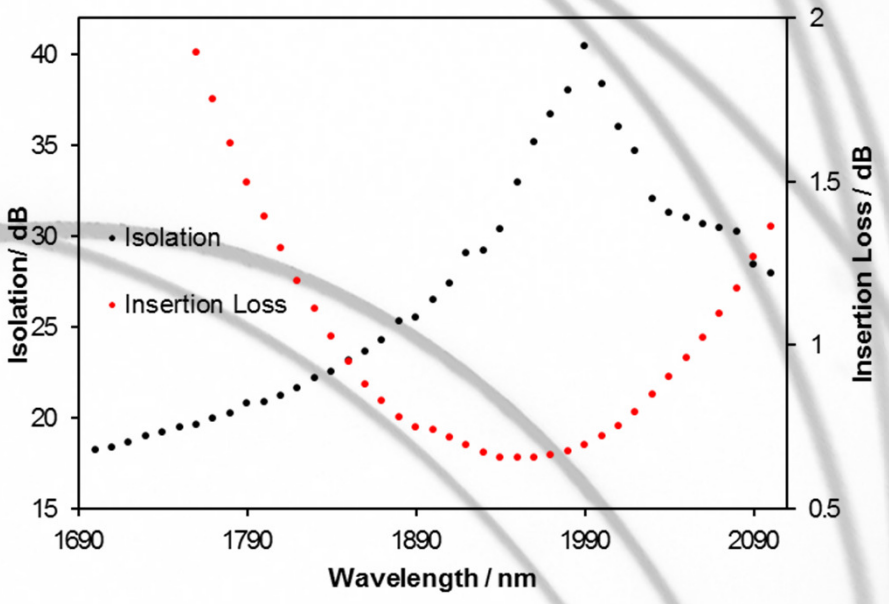
The ORC has also developed a cladding shaping technique using a CO_2 laser to directly process the outer cladding geometry of the preform. In addition to being much faster, the resultant surface quality is much higher than results with traditional mechanical machining methods. This has allowed further processing of the preform to a triple-clad structure without the requirement to fire polish. Removal of this fire polishing step significantly reduces the OH incorporated into the pump cladding of the fibre. This has yielded fibre with a reduced OH contamination in the pump cladding than was previously possible, resulting in reduced loss to 2 µm pump radiation.

For more info contact Andy Clarkson: wac@orc.soton.ac.uk

Fibre-in fibre-out optical isolators at 2 µm

Gooch & Housego

G&H (Torquay) has already reported on its prototype isolator development based on Faraday rotator materials earlier in the ISLA project. This technology has now been extended to fibre-in fibre-out (FIFO) devices. PM and non-PM isolators were manufactured and had insertion losses of <1 dB, isolation of up to 40 dB and return loss >40 dB. The PM isolators had a polarisation extinction ratio (PER) of >23 dB. The performance with temperature has also been tested and the power handling of the isolators is currently being investigated.

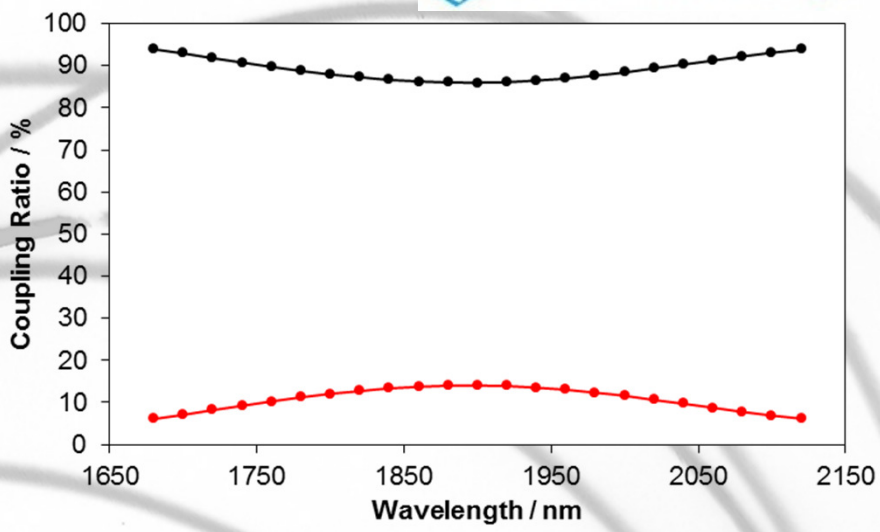


Graph showing the insertion loss and isolation of a FIFO isolator developed at G&H in the ISLA project.

For more info contact Gary Stevens: gstevens@goochandhousego.com

Ultra-wideband fused couplers at 2 µm

As reported in previous newsletters, G&H (Torquay) has developed a range of world-leading fused fibre components at 2 µm. In response to industry requirements, couplers with an extremely flat coupling response over the operating wavelength of thulium and holmium fibres have been developed. For example the 50:50 coupler split ratio varies by only ±12%, and the 90:10 by <±4% from 1700-2100 nm.



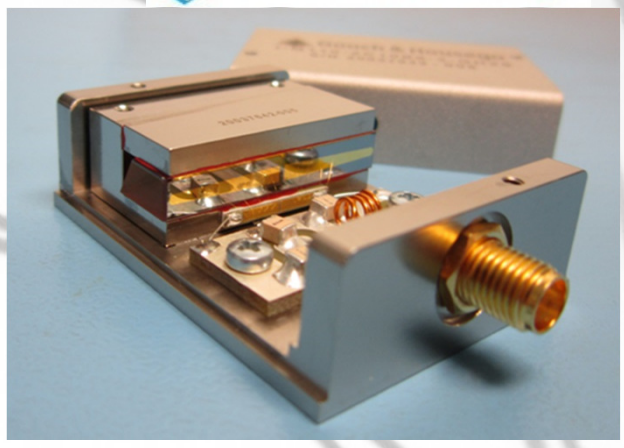
The coupling response of a 90:10 splitter, showing that the coupling ratio varies by only ±4% between 1680 and 2120 nm.

For more info contact Gary Stevens:
gstevens@goochandhousego.com

Acousto-optic devices for 2 µm

Narrow resolution AOTF

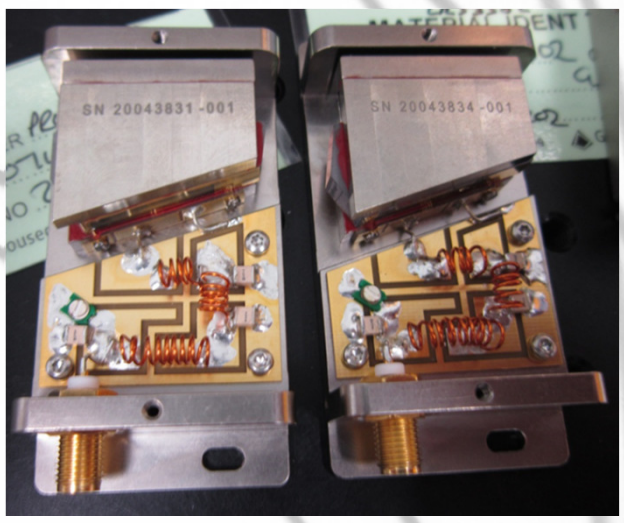
During the ISLA project, Gooch & Housego (UK), based in Ilminster, has successfully developed a number of AO devices specifically for operation in the 2 µm region. These components include new types of modulators and novel tuneable filters:



General-purpose AOM in TeO_2

- General-purpose AO modulator based on TeO_2
  - Good overall performance
- AO modulator (AOM) based on chalcogenide glass
  - Low drive power
  - Little or no polarisation dependence
- Narrow resolution AO tuneable filter (AOTF)
  - <1.5 nm @ 2 µm
  - Low drive power (400 mW)
- Zero frequency shift AOTF
  - Based on patented double pass method.

More information, including some product datasheets, is available from the Gooch and Housego website:
www.goochandhousego.com



Zero frequency shift AOTF

For more info contact G&H (UK): sales@goochandhousego.com

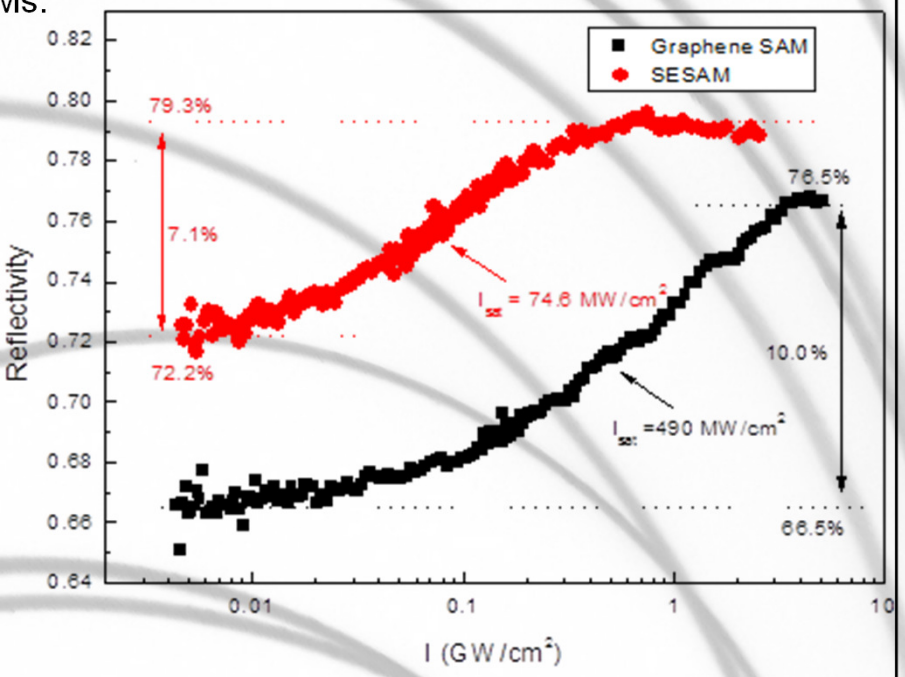
Graphene saturable absorber mirrors for 2 µm

TRINITY COLLEGE DUBLIN
COLÁISTE NA TRÍONÓIDE, BAILE ÁTHA CLIATH

Within the frame of ISLA, the TCD group has developed graphene saturable absorber mirrors (SAMs) for application as passive mode-lockers to generate 2 µm ultrashort pulses. The experimental results show that the graphene SAM performance is comparable with traditional commercial SESAMs (semiconductor saturable absorber mirrors), but with much easier fabrication, lower cost and broader operating wavelength.

The SAMs were fabricated by transferring a vacuum filtrated graphene film onto silver coated mirrors. Graphene was exfoliated from graphite by liquid phase exfoliation (LPE) with high power ultrasonic excitation. Next the graphene nanoflakes were deposited as films and transferred onto a silver mirror to produce graphene SAMs.

The SAMs were characterised at 2 µm using the I-scan technique and compared with commercial state-of-art SESAMs. The graphene components exhibited a modulation depth of 10%, non-saturable loss of ~24% and a saturated intensity of 490 MW/cm². This compared favourably with the commercial product, particularly the modulation depth which was only ~7% for the SESAM.



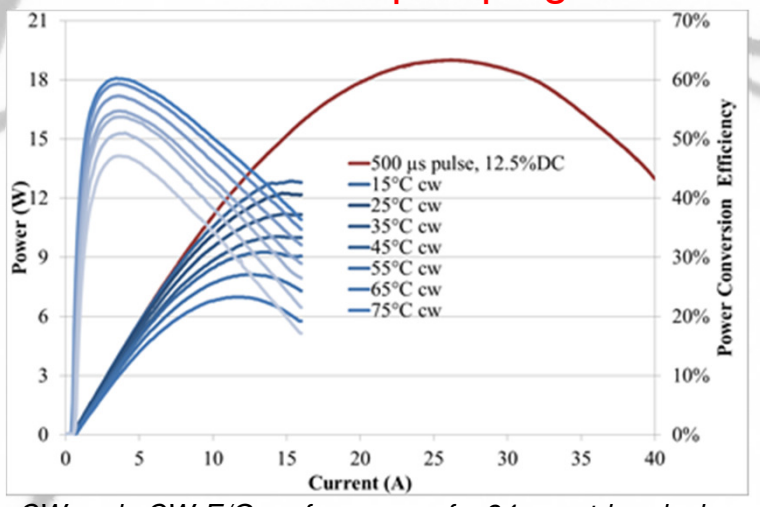
Nonlinear optical responses of graphene SAM and SESAM

This data implies that the graphene SAMs are able to reach the performance of SESAMs, despite the fact that the SAMs are much lower cost. There are still several options to improve the graphene SAM performance, including anti-reflective coatings to reduce loss and protective coatings to enhance the damage threshold.

For more info contact Werner Blau: wblau@tcd.ie

79x nm diodes for pumping Tm lasers

II-VI LASER ENTERPRISE



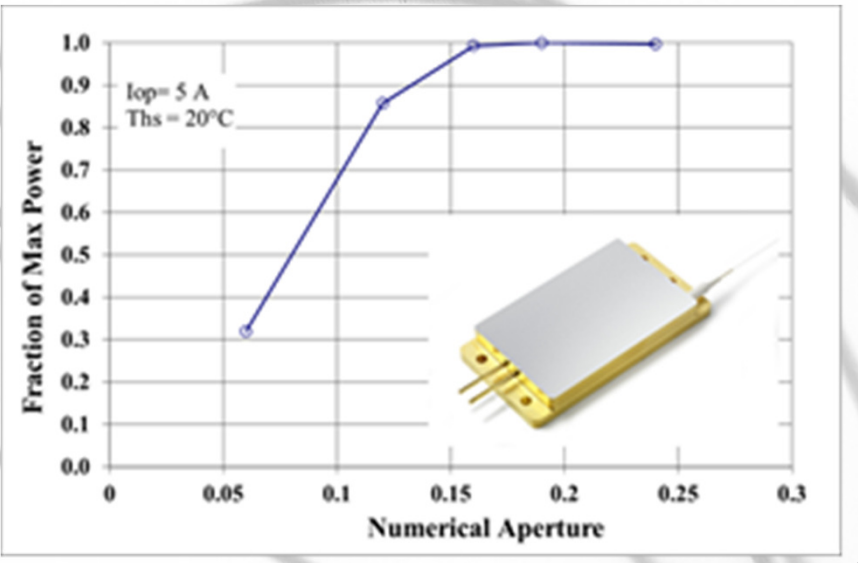
CW and qCW-E/O performance of a 94 µm stripe device

Within ISLA, II-VI Laser Enterprise (formerly Oclaro Switzerland) has developed pump laser diodes at 79x nm optimised for pumping thulium (Tm) doped double-clad fibres.

High power conversion efficiency in excess of 60% was demonstrated. For high power applications, such as thulium fibre laser pumping, an output power of more than 12.5 W in CW operation for 94 µm wide broad-area single-emitters and 19.5 W qCW operation has been achieved.

Wavelength stabilisation of these laser diodes was accomplished by using a distributed feedback grating (DFB). 60% power conversion efficiency was also achieved in these stabilised devices. Locking has been obtained over the full current range between 1 A and 6 A tested so far, with some margin for temperature variation

For efficient fibre laser pumping the laser diodes were integrated in a multi-emitter platform, achieving 38 W out of a 105 µm fiber within 0.15 NA.

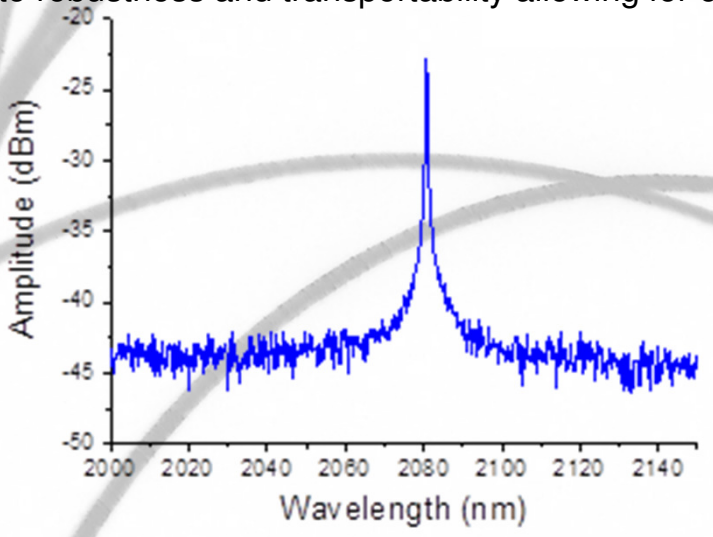


Right: NA filling of the output fibre at 5 A operating current.

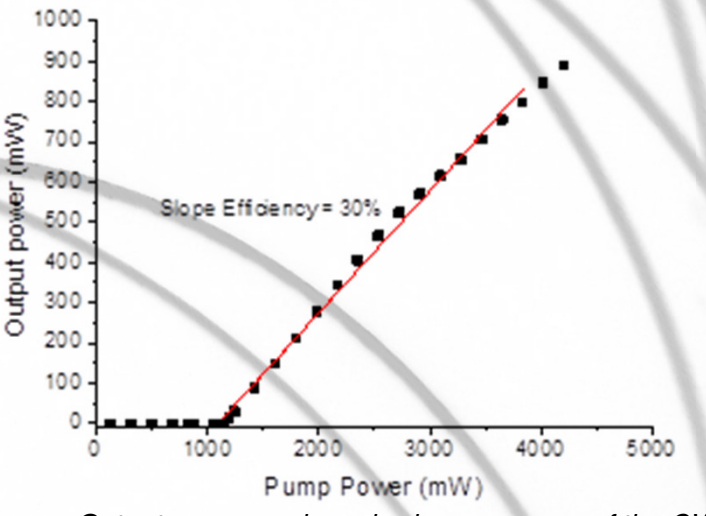
For more info contact Susanne Pawlik:
Susanne.Pawlik@II-VI.com

Progress on 2 µm ps pulsed laser

The building of ISLA Demo Laser 3, a SM ps-pulse master oscillator power amplifier (MOPA), is underway. Unfortunately it was not possible to complete the integration within the project timescale, but the work continues using components from the ISLA partners. A CW oscillator has been implemented to verify the functionality of the ISLA components. The oscillator was pumped with a 4 W multimode pump diode from II-VI Laser Enterprise. The laser threshold occurred at a launched pump power of 1 W. The emission wavelength was 2080 nm, defined by the Bragg wavelength of the chirped fibre Bragg grating which served also as the output coupler. The laser slope efficiency was 30% and the maximum output power was 950 mW, limited by the available power of the pump diode. The ISLA team is currently focused on achieving mode-locking of the oscillator and integrating it with an industrial grade housing which also accommodates the fibre-coupled AOM (from G&H), the pulse stretcher and pre-amplifiers stages. Integration is one key to robustness and transportability allowing for efficient demo activities.



Optical spectrum analyser trace of the CW oscillator showing operation at 2.08 µm



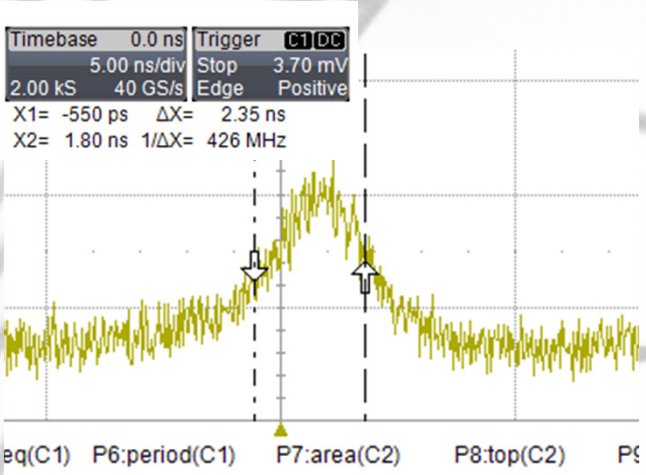
Output power vs. launched pump power of the CW oscillator. The measured slope efficiency is 30%.

For more info contact Peter Hofmann: Peter.Hofmann@jdsu.com

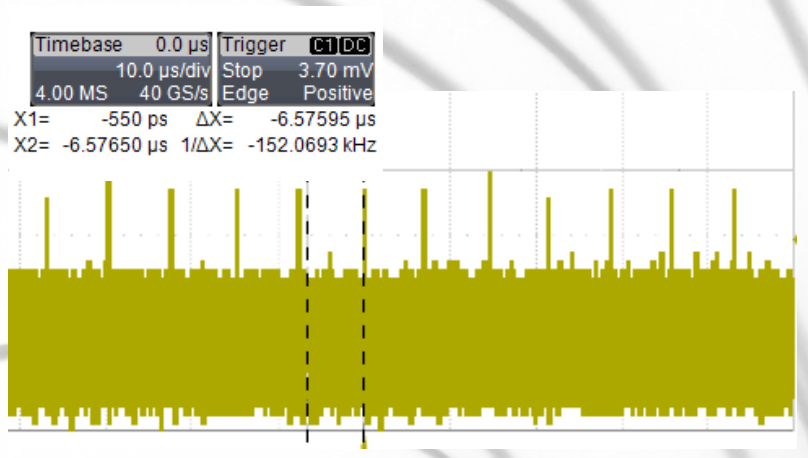
Progress on 2 µm ns pulsed laser

ISLA Demo Laser 2 targeted a ns-pulsed 2 µm laser. Laser pulses with a length of 2.5 ns at a repetition rate of 150 kHz have been generated from a passively Q-switched microchip laser. This laser consists of a Tm:YAP crystal and a SESAM Q-switch carefully matched to allow lasing only in a narrow spectral range around 1950 nm. At a resonator length of only 2.5 mm, this enables the generation of regular pulse trains with high repetition rate and short pulse duration.

This solid-state microchip laser can then serve as a seeder for a Tm fibre amplifier using the components developed within the ISLA project, boosting its output power from less than 100 mW to the 10 W range.



OSA trace showing individual ~2.5 ns pulses



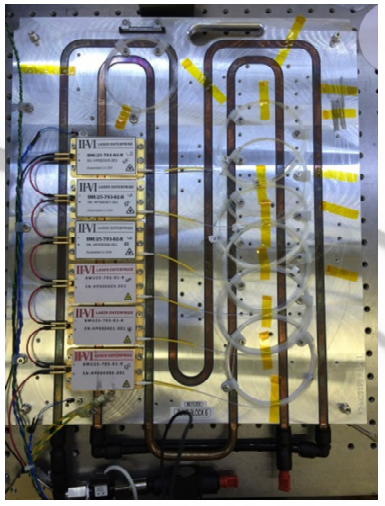
OSA trace showing individual ~150 kHz pulse train

For more info contact Sina Riecke: S.Riecke@rofin.de

Progress on 2 µm 500 W CW laser

The building of ISLA Demo Laser 1 is also in progress. All the ISLA components, from G&H, ORC and II-VI are in place and the assembly and integration is underway at ORC Southampton, but unfortunately it was not possible to demonstrate the laser before the end of the project.

However, the work on ISLA will continue and the laser will be completed in the next few weeks. It will remain at Southampton for the rest of 2015, and will be used in a series of key Tm and Ho laser experiments. In 2016 the laser will be shipped to the Rofin facility in Hamburg for installation in the state-of-the-art Applications Laboratory. A six month period of testing in an industrial environment will begin, and it is planned to include a number of ISLA Advisory Group partners in this demonstration work.



Images of the ISLA CW laser being assembled at ORC from components developed and produced in the ISLA project.

For more info contact Peter Shardlow: peter.shardlow@soton.ac.uk

ISLA workshop (Munich; 26-Jun-2015)

A workshop was held on FRI 26-Jun-2015 at the Räter Park Hotel (Munich, Germany) to present the results of the ISLA project. This full-day event consisted of a set of seven technical presentations from the ISLA consortium summarising the outcomes from the project, and a set of seven presentations from guest speakers on applications for 2 µm lasers. The topics ranged from medical lasers for surgery to verification of oil paintings using OCT. The fully booked event was held the day following the Laser World of Photonics exhibition in Munich to maximise the number and quality of attendees.

The workshop was a big success: the quality of presentations from both ISLA partners and guests was outstanding. Many visitors commented that it was a particularly useful and interesting day. Slides from the workshop are available from the project public website:
http://isla-project.eu/outputs/isla-workshop/
[For confidentiality reasons, some of the guest presenters' slides are not available.]

Left: Peter Shardlow (Southampton ORC) presenting on ISLA Tm and Ho fibres.

Right: Lasse Leick (NKT Photonics) presenting on pump sources for mid-IR supercontinuum sources.

Below: The ISLA workshop audience

ISLA at Photonics West 2016

ISLA has been invited to have a dedicated session at Photonics West 2016! It will be part of LASE conference LA105 "Component and packaging for laser systems" and will consist of four presentations on ISLA results. We hope to see you there!

Photonics West