Gooch & Housego PLC

PCFM Open Day

Introduction

CEO: Mark Webster

Introduction

- Mark Webster – CEO - Brief re-cap of the recent interim results & an overview of the strategy and performance improvement plan
- Tour of the Ilminster facility
- Alex Warnock – COO – Operational Performance Improvement
- Andy Rowswell - General Manager (Ilminster & Glenrothes Sites) – The Role of Optics in A&D
- Lunch
- Murray Reed – CTO – New Product Development
- Andrew Robertson - Senior Vice President – Systems Technology Group (STG)
- Stratos Kehayas– VP Space Photonics – Space Photonics

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Highlights

Operational & Financial Highlights

- Strong performance from industrial laser & telecommunications products underpinned 13% increase in revenue to a record £38.9 million for the first six months of FY2015
- Adjusted profit before tax up 23.5% to £6.3m from £5.1m
- Investment in R&D up 10%
- Melbourne site closure completed and products transferred to other G&H sites
- Solid order book of £34.6 million, up 5.8% since the year end
- Initiatives to drive performance improvement programme across G&H launched
- Strong cash inflow supporting 15.4% increase in the interim dividend of 3.0p

"Gooch & Housego has performed well in the first six months of the financial year against a background of generally improving market conditions. We remain focused on delivering our financial goals and continued growth in FY15 and beyond." Mark Webster- CEO

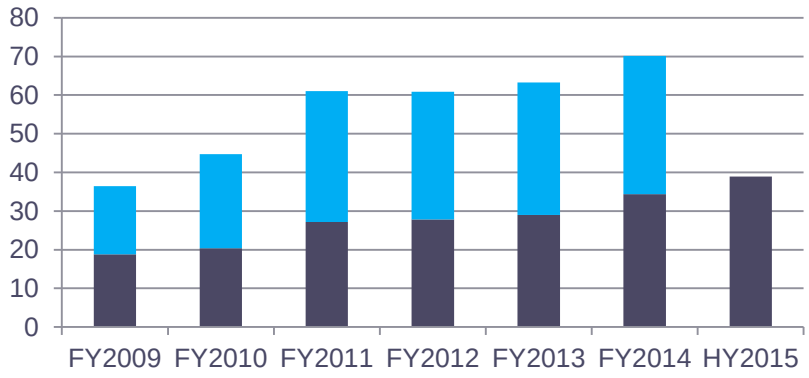
Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Highlights

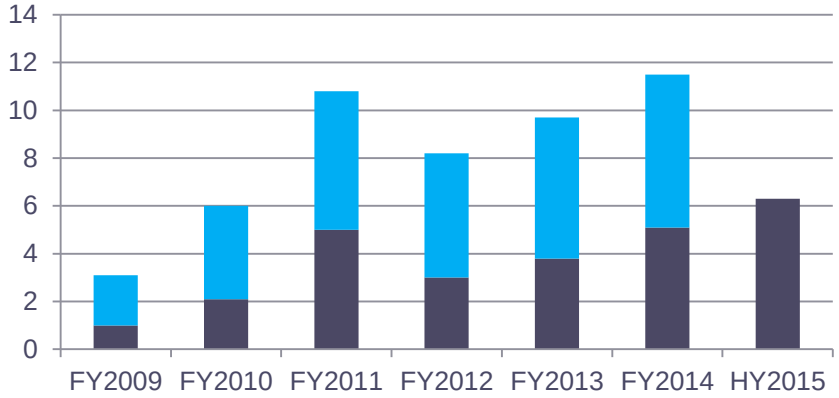
Results at a glance

Half Year Ended 31 March	HY 2015	HY 2014	Change
Revenue	**£38.9m**	**£34.4m**	13.1%
Adjusted profit before tax	**£6.3m**	**£5.1m**	23.5%
Adjusted basic earnings per share	**19.3p**	**15.9p**	21.4%
Interim dividend per share	**3.0p**	**2.6p**	15.4%
Net cash	**£11.9m**	**£2.3m**	£9.6m

Revenue £'m



Adjusted PBT £'m



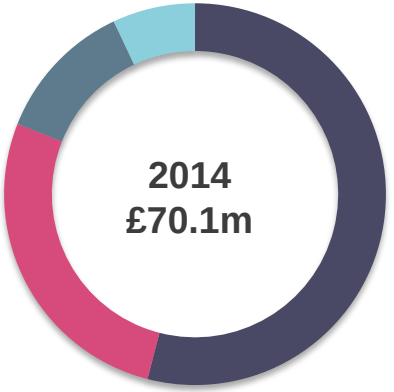
"The business has delivered sales growth and improving margins driven by a strong performance in our Industrial division" Andrew Boteler - CFO

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Strategy & Preparing for the Future

Diversification

The newer markets of Aerospace & Defence and Life Sciences, together with new application areas within our Industrial market, offer the potential for significant growth through their rapid adoption of photonic technologies

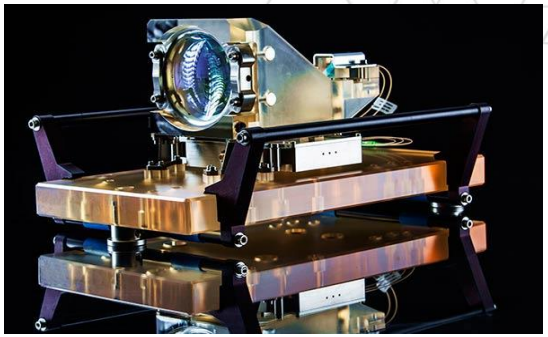


Six Year CAGR By Market

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Strategy & Preparing for the Future

Moving up the Value Chain



Diversify

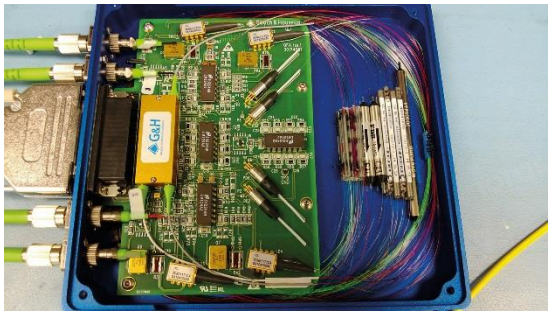
Exploit high-growth opportunities for photonics technology

- *Fibre Optic lasers*
- *Fibre Optic sensing*
- *Laser surgery*
- *A&D sub- systems and systems*
- *Medical Diagnostics*
- *Space/ Satellite communications*

- **Move up the value chain**

Leverage excellence in components to become a solutions provider

Optics + electronics + software + mechanics = *added value*
Materials => components => modules => systems



Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Strategy & Preparing for the Future

Performance Improvement Plan

Three key areas of focus:

1. ***Ensuring a consistent high level of operational excellence across all the sites***

   Small corporate group that lead, manage and set standards for supply chain management, quality assurance, compliance, process engineering, lean manufacturing and continuous manufacturing improvement

2. ***Develop deeper ties with key target customers***

   Grow presence in US and Far East, hire key Business Development skills / experience in A&D and Life Sciences. Greater focus on business development and moving up the value chain with key customers

3. ***Ensure there is a 'balanced' R&D portfolio that meets customers' strategic needs***

   Prioritise site based projects using rigorous technical, market and financial analysis. Continue to increase resource, in particular STG and focus on high return projects. Balance between short and medium term projects.

.

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Outlook

Gooch & Housego is well placed to deliver continued growth in FY15 and beyond, through our **twin strategies** of :

- Diversification and;
- Moving up the value chain.

These strategies will be supplemented by the **performance improvement programme** aimed at :

- Driving operational excellence;
- Developing deeper ties with key customers; and
- Ensuring we have a balanced R&D portfolio.

Finally, the business has the financial and management capacity to execute on **acquisition opportunities** should they arise.

Operational Performance Improvement

Alex Warnock – Chief Operating Officer

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Operations Vision

Key Objective:

Ensure a consistent and high level of operational excellence across all G&H sites setting standards for quality, manufacturing efficiency, process engineering, supply chain management, HSE & compliance.

We will achieve this by….

- Identifying and removing inefficiencies
- Regular and consistent communication
- Embedding a unified culture of continuous improvement across the G&H group
- Leveraging our collective strengths and harnessing the scalability that comes from the larger G&H entity
- Providing reliable and consistent data management/metrics/KPI's
- Driving the organisation to use the processes we already have and closing the gaps where we don't!
- Strengthening Vendor Quality Management activities

…. but without derailing the existing performance of our business

Operations Vision

Optimising the Structure

- **Site General Manager structure remains intact**
  - Will look to strengthen management team at sites with shared General Manager's

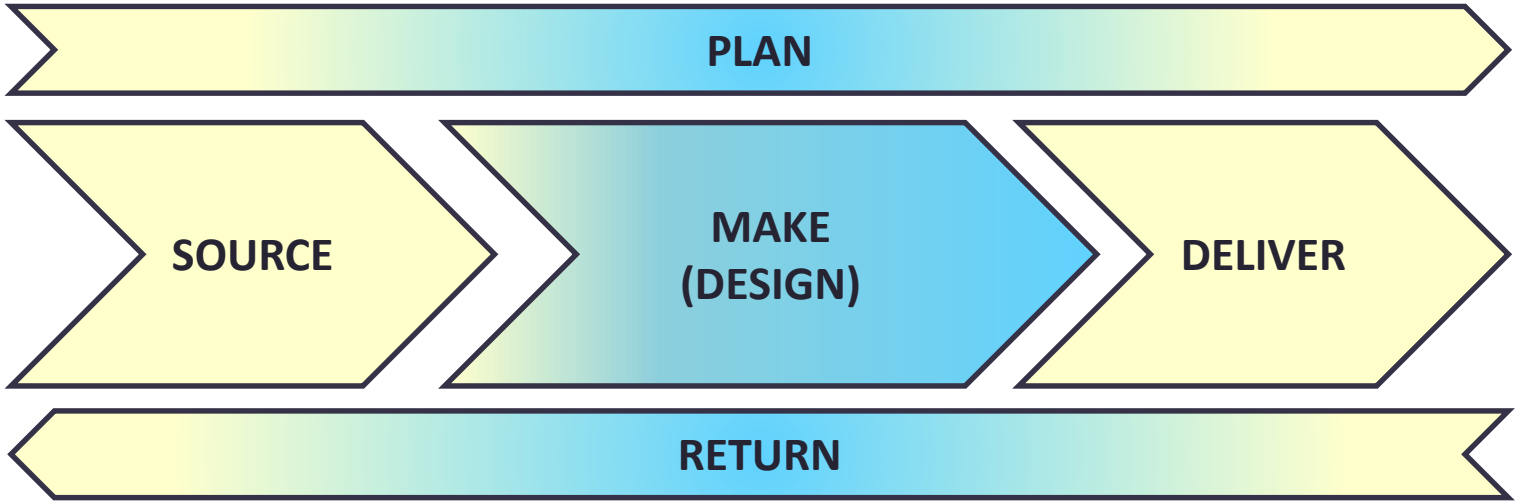
- **Formation of a group level Global Quality Organisation**
  - Based around 4 core functions – quality systems, compliance, process/tools and continuous improvement
  - Solid reporting line from Site Quality Managers to Senior VP Global Quality
  - Aim is to harmonise group quality ethos, systems, policies and procedures
  - QS responsibilities include: Accreditations; product verification; internal audit/CAPA process; supplier quality; product reliability; QMS management review and reporting; calibration; customer support/audits/questionnaires
  - Introduction of dedicated expertise in US/UK to manage compliance/export requirements
  - Formalise a function to drive group wide standardisation of process/tools

Operations Vision

Optimising the Structure (Cont'd)

Formation of a group level Global Supply Chain Organisation

- Initial emphasis on strategic sourcing, global procurement and demand planning
- Commodity Managers introduced as market/technology experts with responsibility for supplier selection and management, cost control and Inventory optimisation
- Introduction of a Demand Manager to implement a consistent planning process across sites, review demand loading and deploy consistent MRP implementation/practices
- Creation of a dedicated logistics function responsible for freight carrier management, import/export engineering and compliance



Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Operations Vision
Working Capital

- **Inventory Purchases must be viewed as Investments!**
- **Target inventory reduction via active management of Material, WIP and Finished Goods**
- **Development of an Inventory Policy**
- **Supported by ABC Classification Functionality available in ERP**
- **In practical terms**
  - Schedule lines for High $ items whenever possible
  - Use JIT, KanBan, VMI as often as possible with High $ parts

We need to think in terms of days of inventory being purchased and held…

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Operations Vision

Optimising the Structure (Cont'd)

- **Integrate the Business Systems function within Operations**

  A data driven culture is integral to our success - *"In God we trust. All others must bring data." W. Edwards Deming*

- **Increase Product Management capacity and improve functional alignment/communication with Sales/Business Development**

- **Develop "Best in Class" manufacturing sites to support the vision**

- **Embed a Continuous Improvement culture across all sites at all employee levels**

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Operations Vision

Driving towards a LEAN Enterprise

Techniques used to smooth, speed production

Techniques used to prevent or detect defects

Tools used to establish a base of operational stability and a culture of continuous improvement

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Operations Vision
Summary

7 months on…

We have already made good progress but still have a lot to do and have significant opportunities in front of us …

Key priorities for the coming year are…

1. Continue to drive growth across all sites
2. Strengthen our data provision and enhance KPI reporting
3. Extend the reach of LEAN across all G&H sites
4. Maintain tight cost controls
5. Further develop our people and capabilities

The Role of Optics in A&D

Andy Rowswell
GM Ilminster/Glenrothes

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Market Definition

•Worldwide defence and Security Tier 1 & 2 Primes and OEMs. G&H start from an established position in PO component supply.

•Initially targeting customers located in the UK and Europe with planned market sector expansion into the US.

•Products and applications include Fixed Mag, Switchable and Zoom modules for integration into numerous Land / Air / Sea systems including target designation and range-finding, imaging and surveillance.

•Market Size Estimate ~$5BN (*Frost & Sullivan)*

•The accessible PO / Integrated module market has been assessed as £800M

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Accessible Market

MANPAD TARGETING SYSTEMS

Aerospace & defence

- Target designation
- Laser Range Finding
- Fast-Jet HUD Displays
- Helicopter HUD Displays
- Hand-held Equipment
- Surveillance
- Threat detection
- Imaging

FAST - JET
OPTICS & MODULES

PORTABLE EQUIPMENT

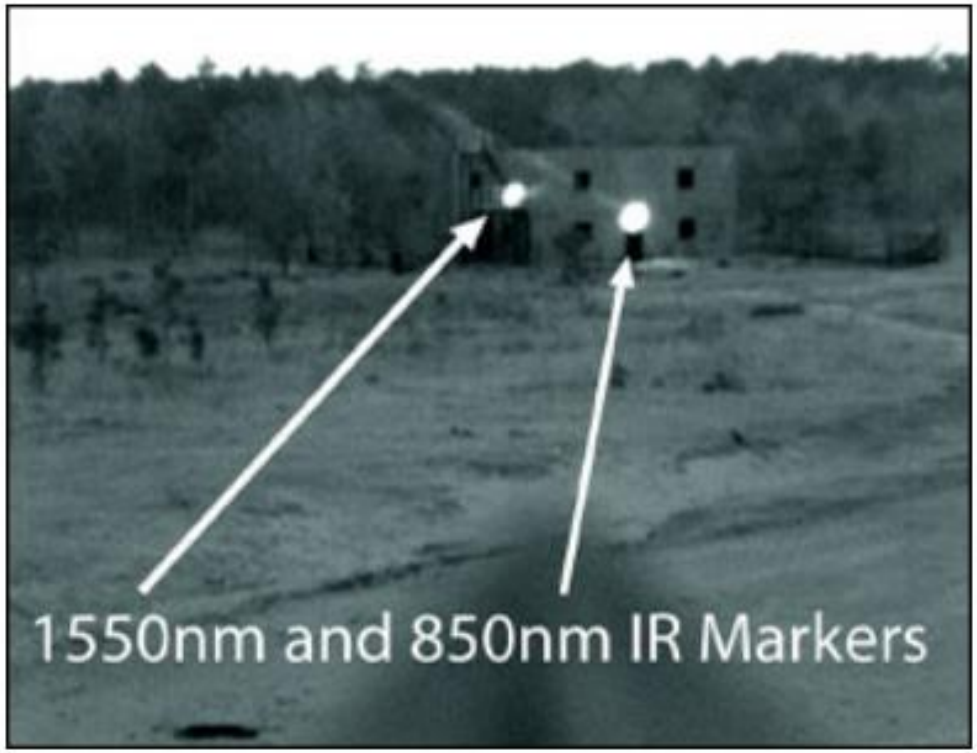
ATTACK HELICOPTER
OPTICS & MODULES

TARGETING POD OPTICS & MODULES

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Defence & Security

Laser beacon detection



EYESAFE LASER TARGETING

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

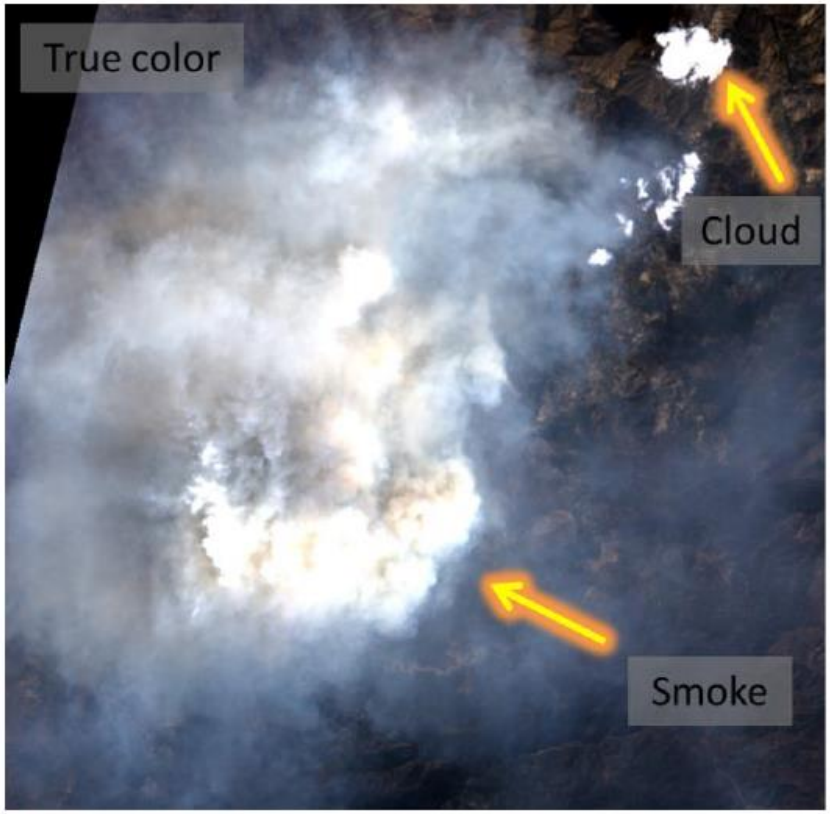
Defence & Security

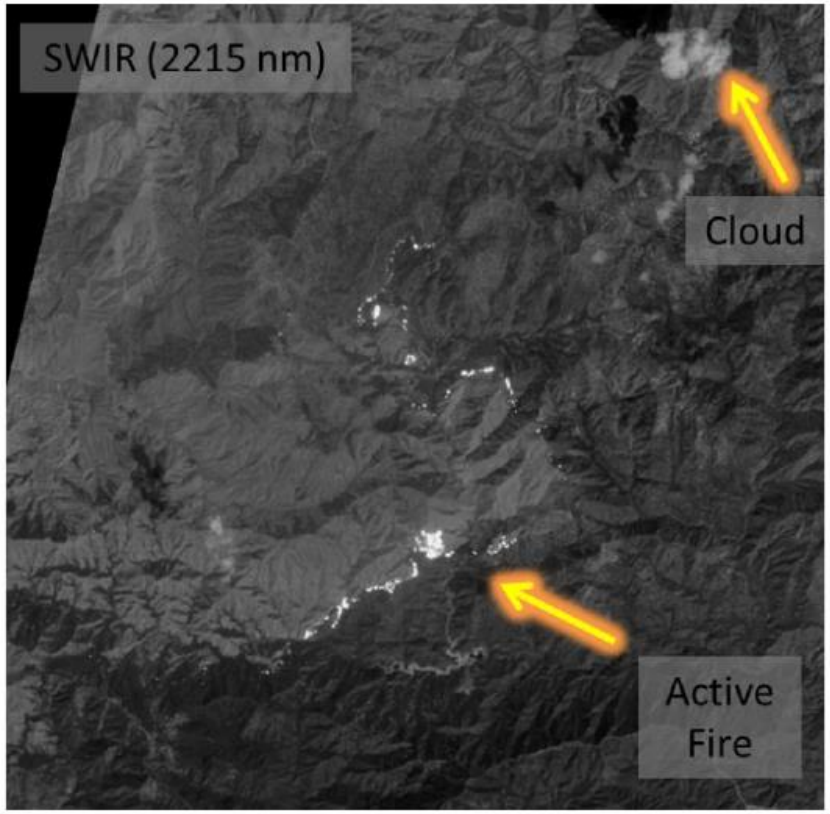
Surveillance

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Defence & Security

Intelligence & Surveillance





Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Development Plan

Established Capability

This program of work will incorporate and evolve current capabilities including the manufacture of precision optical components and sub-assemblies in the Visible and IR wavelength range(s).

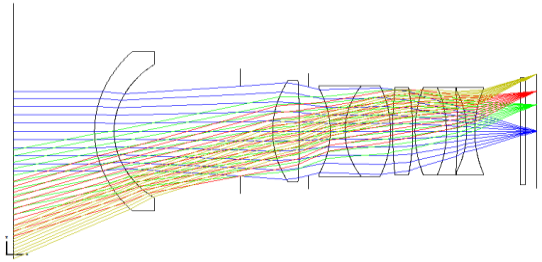
Move up the value chain

Leverage excellence in components to become a solutions provider

Optics + electronics + software + mechanics = *added value*

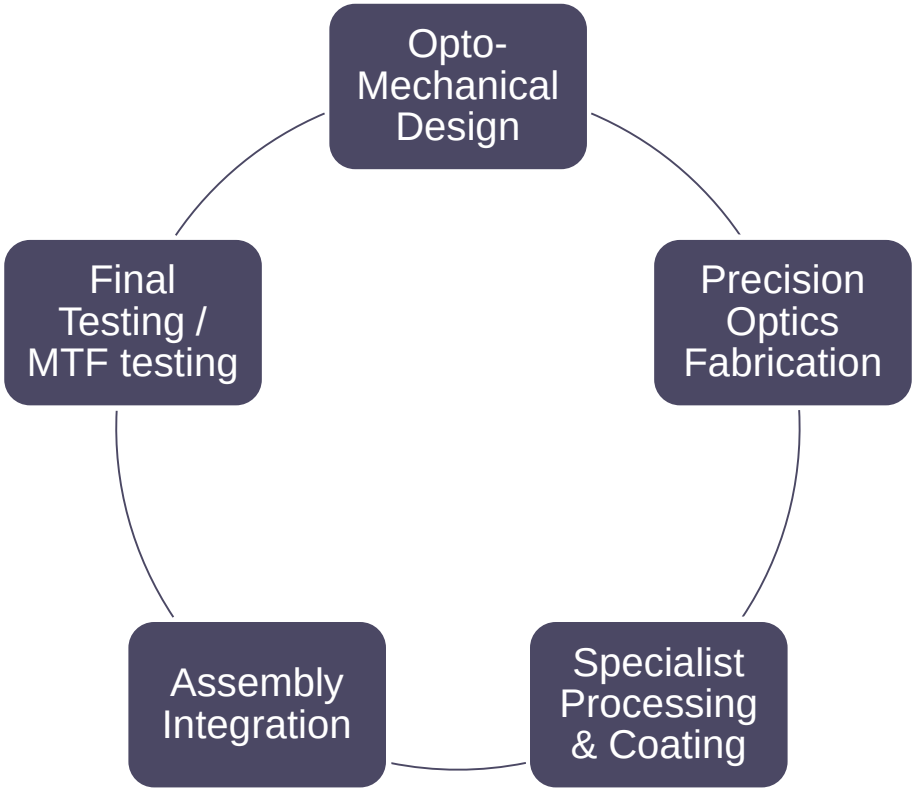
Materials => components => modules

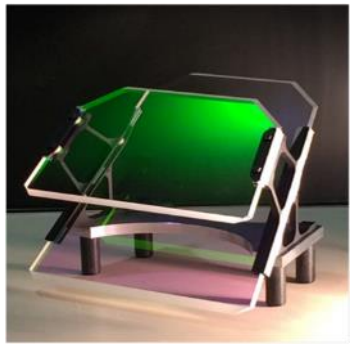
‘Our strategy’ is to become a fully integrated producer of high Precision Modules for the defence & Security sector.



Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Development Plan – Continued





Develop and expand Assembly/Integration capabilities

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Market Entry Point(s)

- Where do we start in offering a product(s) ?

  1. Design-to-manufacture of added value VIS to LWIR Lens Modules

- SWIR Wavelengths excel in:
  - Defence & Security applications
  - Imaging penetration through smoke
  - Imaging penetration through fog / water vapour
  - Imaging in low-light / moon light
  - Imaging of laser lines for confirmed targeting

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Market Entry Point(s)

- Where do we start in offering a product(s) ?

  2. HUD avionic display modules – emerging fast-jet and helicopter programs

- Strong prime customer base in the UK, EU and US
- HUD requirements include:
  - Defence fast-jet applications
  - Defence helicopter applications
  - Pilot aid to view information – reduced pilot workload
  - Avionic combiner assemblies – symbology projection
  - Mechanical design and flat optics a speciality at ILM

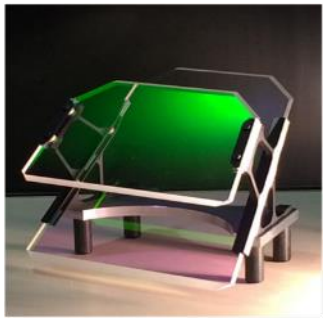
Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Timeline and Current Position

- Complete UK design-to-manufacture combining G&H companies; Ilminster and Glenrothes.

- Design-to-Manufacture of PO Lens Module
  - Phase 1 - Tested hardware will be available FY16

- HUD avionic combiner assemblies
  - Phase 1 - Qualification hardware targeted for FY17



Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

New Product Development

Murray Reed CTO

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

New Product R&D is Critical to G&H's Growth

G&H's Business

- Optics and photonics technology
- Components and subsystems
- For medium to high volume OEMs
- High value customization for every customer

New Product Development

- Innovates our technology and IP
- Enables new applications and new customers
- Secures the relationship with our customers
- Drives cost reduction and maintains our margins

2012 R&D spend
£4.3m = 7.1% of revenue

2013 R&D spend
£4.9m = 7.4% of revenue

2014 R&D spend
£5.7m = 7.8% of revenue

H1 2015 R&D spend
£3.2m = 8.2% of revenue

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

FY'15 Goal: Focus on Strategic New Products

New Products that

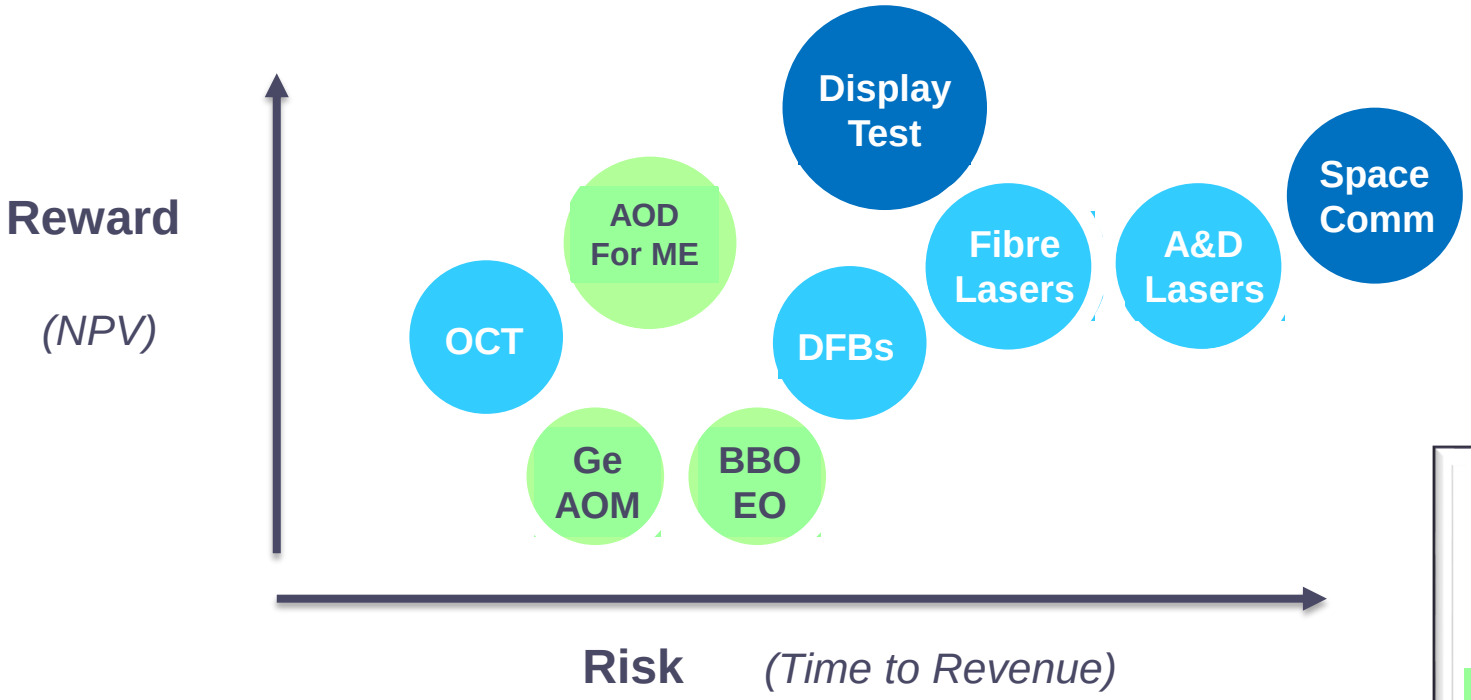
- Deliver high growth over the next 5 years
- Extend well beyond our existing customers and products
- Extend across our sites to lever more of our capabilities
- Develop systems and move us up the value chain

Add up to an R&D Portfolio that Balances

- Short term (1-3 years) and long term (3-5 years)
- Low risk (existing technology) and higher risk (new technology)
- Fast return (current applications) and
  longer investment (developing applications)

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

G&H's Nine Major R&D Programmes



Major R&D Programmes Require

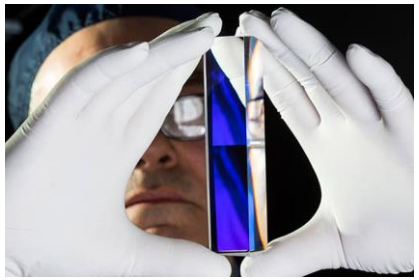
- Stand Alone Budgets and Resource Plans
- Dedicated R&D Leaders and Teams
- Critical Milestone Schedules and Delivery

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Moving Up the Value Chain

The Key Drivers for G&H

- The differentiation of our components
- Our customers lack of photonic expertise
- Our ability to provide vertical integration
- Our ability to offer design engineering services



G&H's Key Targets

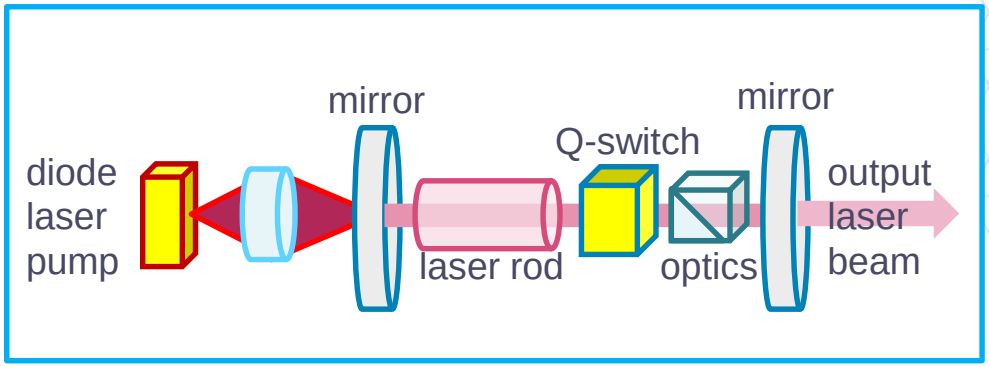
- AO and EO systems
- OCT imaging
- Aero & Defence lasers
- Fibre lasers
- Satellite communications

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Why Fibre Lasers are a Disruptive Technology

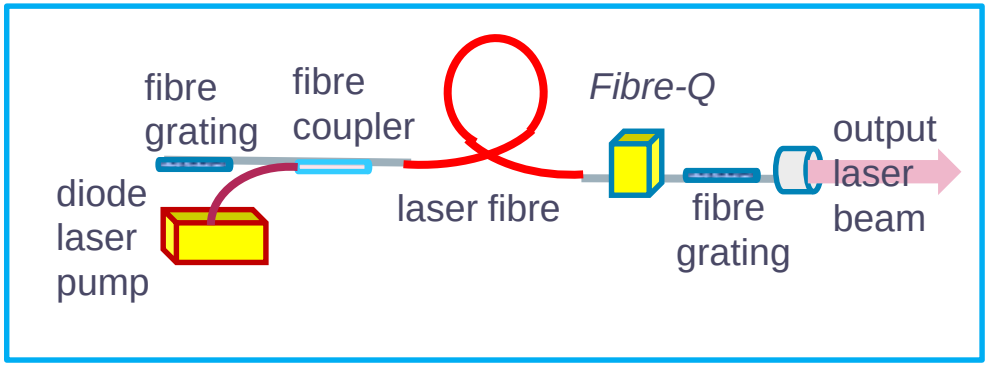
Solid State Lasers

- Laser crystals and glasses
- Discrete optics
- Laser beams in the air
- Mechanical assembly



Fibre Lasers

- Telecom technology
- Integrated fibre-optics
- Sealed guided laser path
- Fused fibre assembly



Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Fibre Lasers have Multiple Critical Advantages

High Reliability

- Integrated, stable and sealed optical path

Small Size

- Modular compact designs

Excellent Performance

- High beam quality and small focus area
- High power (>10kW) scaling
- Constant focus position over entire power range

Low Cost

- Integrated assembly with minimal mechanics
- High efficiency (>30% vs <10% for conventional)
- Low service requirements

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Fibre Lasers already Dominate Many Applications

Marking

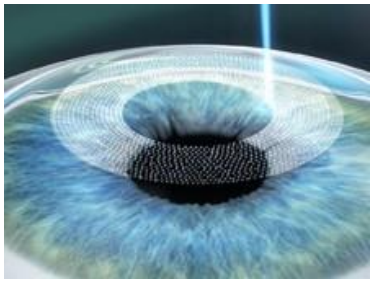
- Metals
- Plastics

Machining

- Metal cutting , drilling, welding
- Micromachining, scribing

Medical Therapy

- Eye Surgery



defence

- *LIDAR*
- *Directed Energy*

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

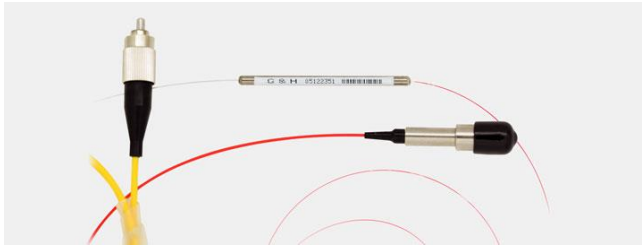
G&H makes a Wide Range of Fibre Laser Components

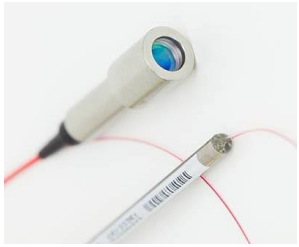
AO Modulators

***Fibre-Q* Fiber Coupled AOMs**

Fused Fibre Components

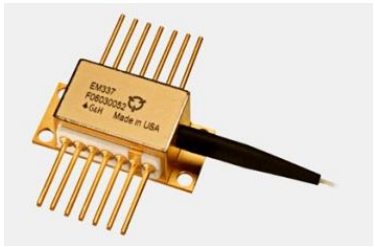
- SM Wavelength Couplers
- MM Beam Couplers
- Power Splitters





Fibre Coupled Components

- Collimators
- Semiconductor Pump Lasers
- DFB Seed lasers
- SHG Wavelength Convertors



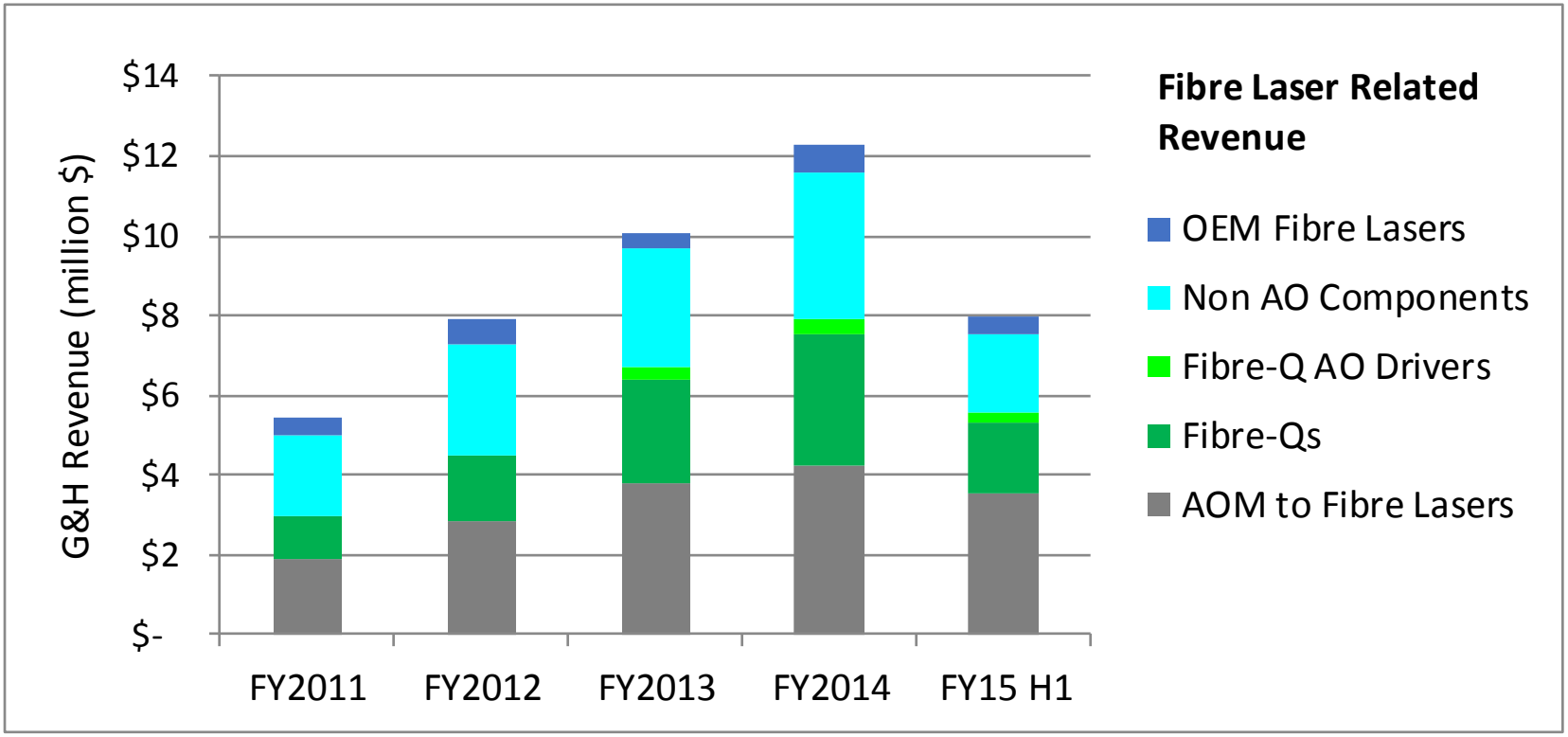
OEM Fibre Lasers

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Fibre Lasers are Helping to Drive G&H Growth

The Market is Mature and Diversifying

- We sell to all of the major fiber laser manufacturers
- Demand is worldwide and growing fastest in China

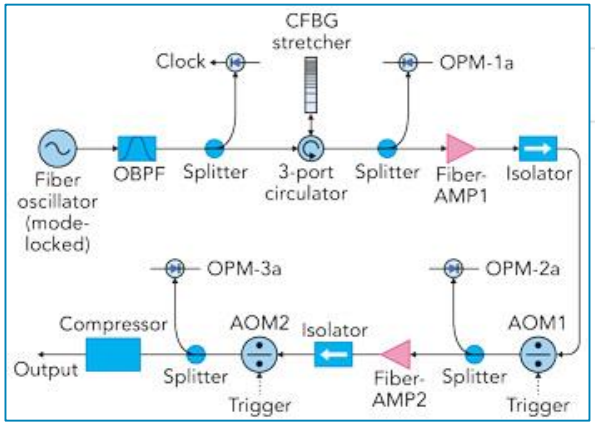


Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

New Fibre Laser Products in Development

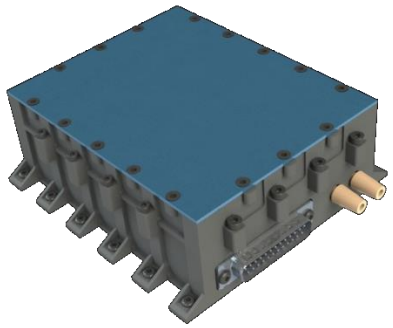
More Fibre Laser AOMs

- Higher speed *Fibre-Q*
- *Fibre-Q* for visible light
- Low cost *Fibre-Q*
- Modular *Fibre-Q* Driver



New OEM Fibre Lasers

- Low power femtosecond Seed Oscillators
- High Power picosecond Amplifiers
- High Power Narrow-Linewidth 780nm Laser
  - ***"FreezeRay"*** UK Innovate Funded Program
  - Pump a Quantum Cold Atom Trap
  - Deliver a laser to e2V for a High Precision Quantum Technology (QT) Positioning, Navigation, & Timing system



Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Conclusion

Photonics Technology is Maturing

- Guided-wave fibre and integrated-circuits are replacing discrete “free-space” optics
- Semiconductor and fibre lasers are replacing gas tube and bulk solid-state lasers
- Photonics systems are becoming more reliable, more efficient, more compact, more powerful, faster and lower cost.

G&H is developing New Photonics Components and Systems to Enable Multiple New Applications

- Microelectronics manufacturing, high resolution flat panels, remote sensing, quantum technology, 3-D medical imaging (e.g. OCT) and high bandwidth communication (e.g. Space Communication).

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

STG update and emerging OCT Applications

Dr Andrew Robertson – Senior Vice President

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Systems Technology Group (STG)

Aims of the STG

- To lead organic growth of system and sub-assembly business
- Respond to customer needs beyond the capability of any individual site
- Designing system level products that can be transferred into site manufacturing and ramped to high volume

Implementation

- Corporate team offering full system design services
- System modelling to prototype manufacturing
- Use design expertise from senior experts at all sites
- Identify skills gap and recruit (e.g. electronics, mechanical, space)

Focus

- Optical Coherence Tomography
- Optical Satellite Communications
- Fibre Lasers
- Electronics

STG Update

Increased Headcount (July 13 – 4, July 14 – 11, July 15 – 21)

- Now 21 people
- 9 Optical Engineers (all PhDs)
- 4 Electrical Engineers
- 2 Mechanical Engineers
- 1 Software Engineer
- 5 Support
- Recruiting 2 more for FY15

Mezzanine laboratory for satellite communications

New Facilities

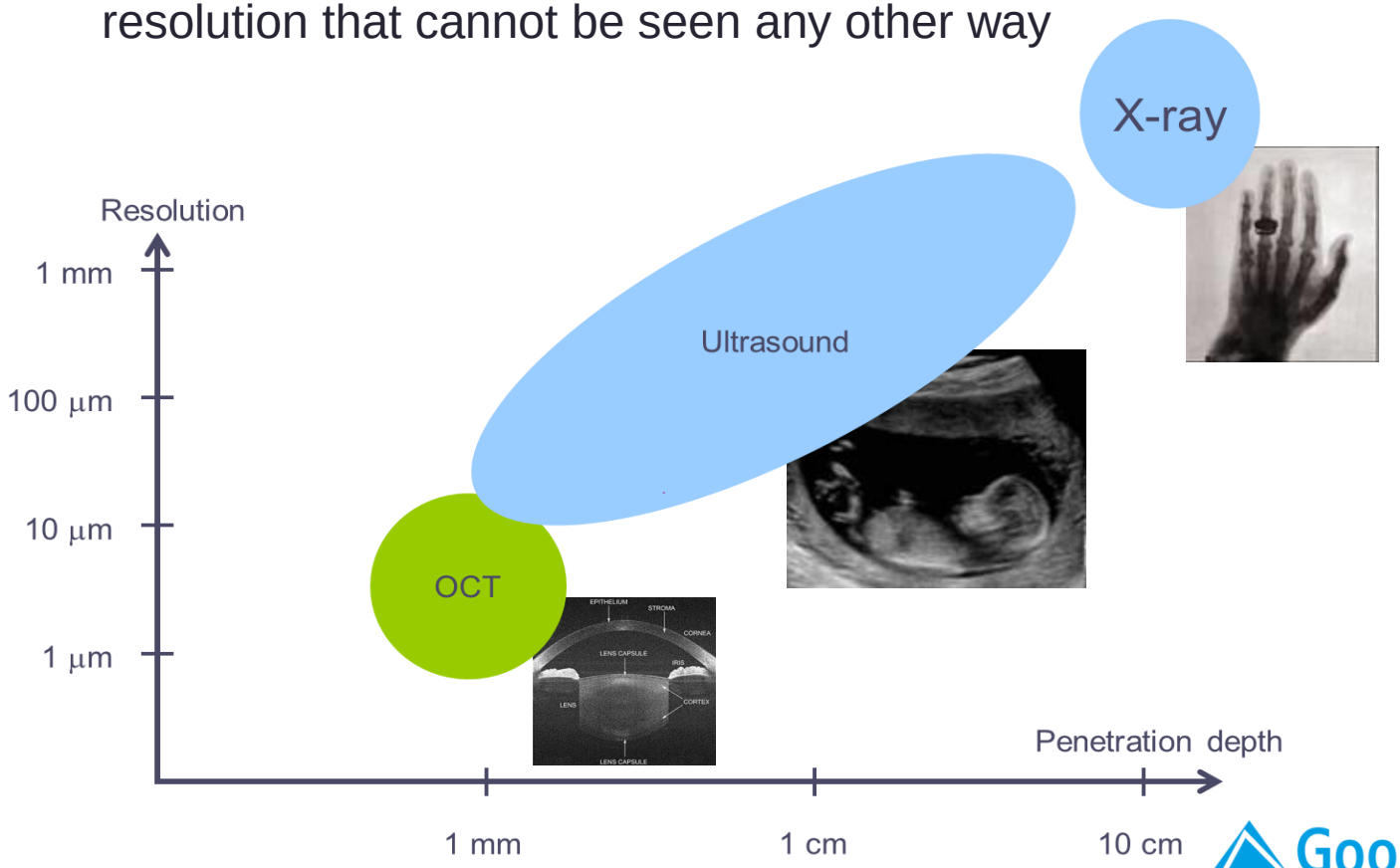
- New Office space in Torquay Mezzanine
- New laboratory space in Mezzanine
- Further expansion of Mezzanine

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Optical Coherence Tomography (OCT)

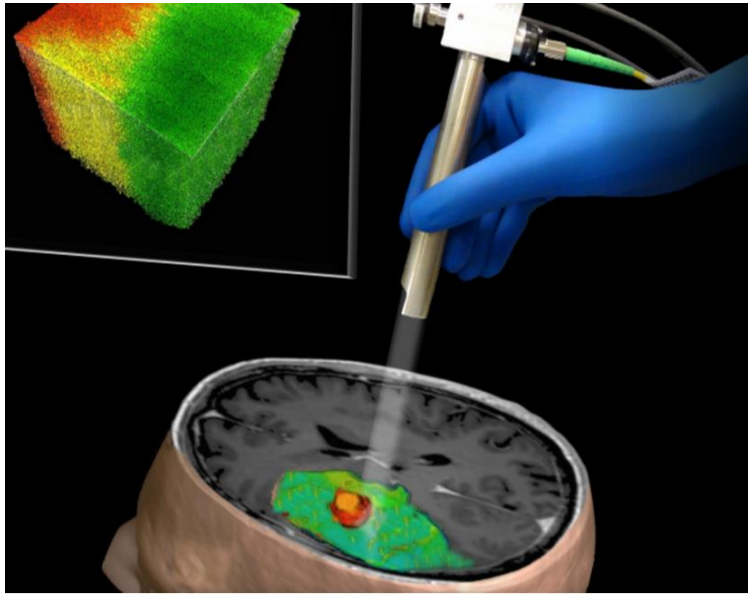
Key biomedical optical imaging technology

- Developed commercially in last 10 years
- Non-invasive, non-contact, completely safe
- Able to image living tissue “in-situ” in high resolution that cannot be seen any other way



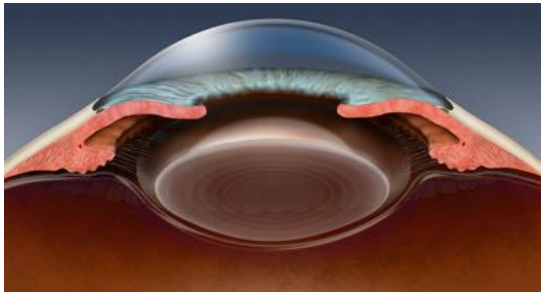
Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

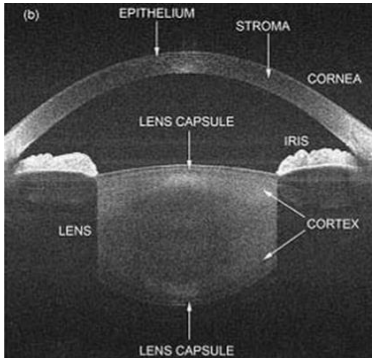
Optical Coherence Tomography (OCT)
How it works

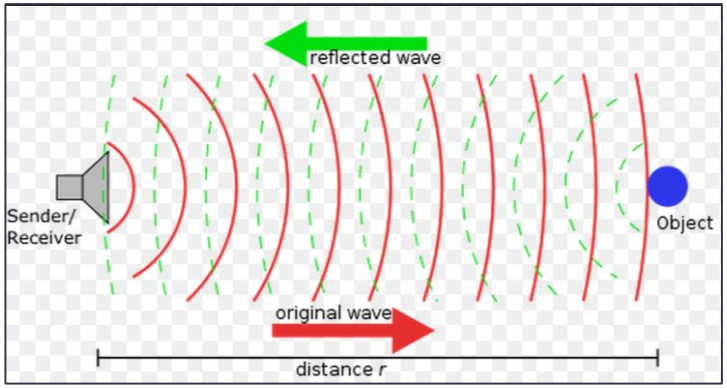


OCT uses optical waves (light)

- Light source transmits
- Light waves bounce off target
- Reflected echoes received
- 3D Image created
- Resolution is millionth of metre







Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

OCT Markets

Recent market report estimates current total *biomedical market* is $500M rising to $1B by 2019 with 12% CAGR

Largest application is ophthalmic OCT for imaging the retina. Current snapshot of market

- Retinal Imaging – 75%
- Cardiovascular – 15%
- Guided surgery, gastroenterology, dermatology – 10%

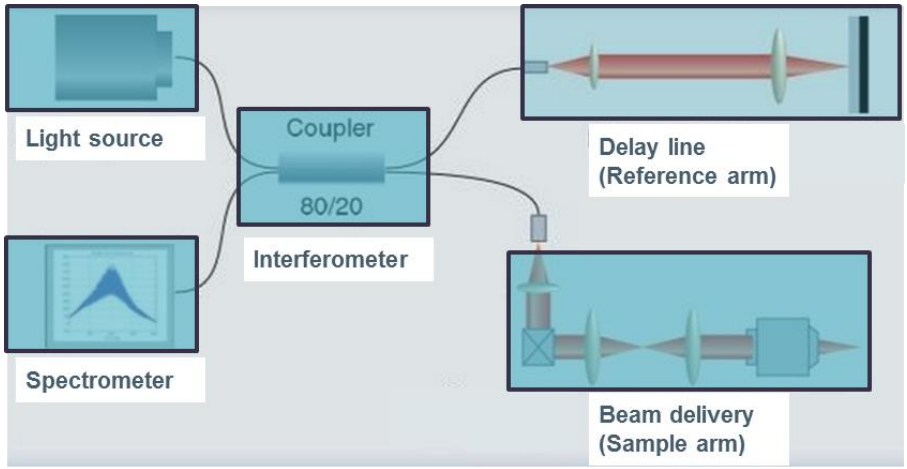
Active R&D activity in non-biomedical applications, some of which could lead rapidly to volume requirements

- Quality control of flat panel displays
- Semiconductor test

Non-biomedical applications predicted to breakthrough to high volume over next five years

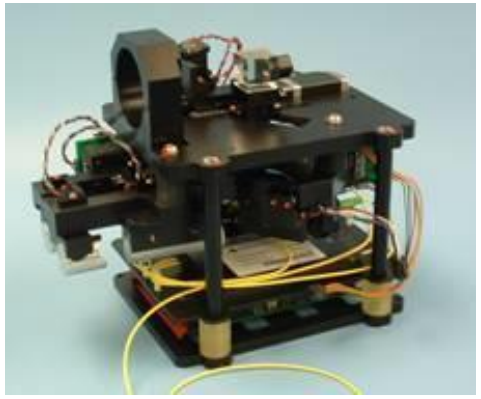
Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

OCT Optical Hardware



OCT Optical Hardware

- $100M TAM, $50M SAM
- Optical Head contains 5 key modules
- G&H supply
  - Interferometer
  - Spectrometer
  - Delay Line
- Currently supply 4 out of top 6 ophthalmic OCT companies



OCT – Optical Head

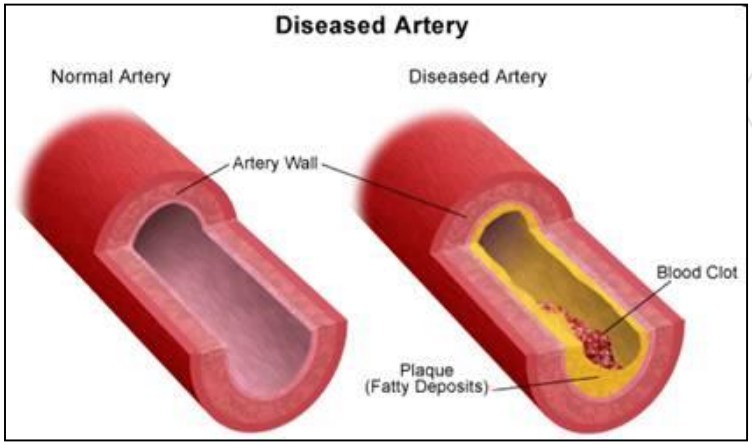
OCT – Retinal Imager

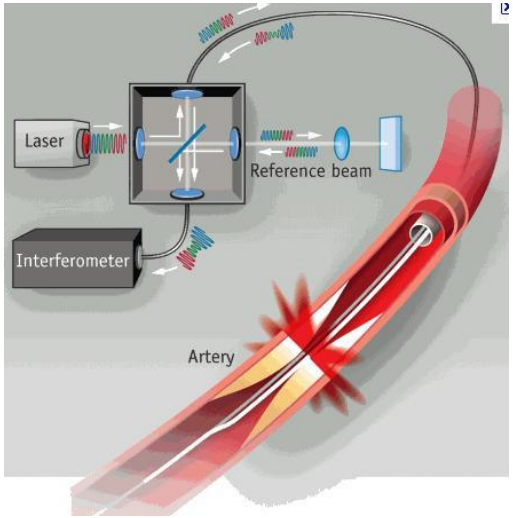
Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Emerging OCT - Cardiology

Intravascular imaging

- Assessment of diseased artery
- Positioning of stents
- Post-operative monitoring of stent

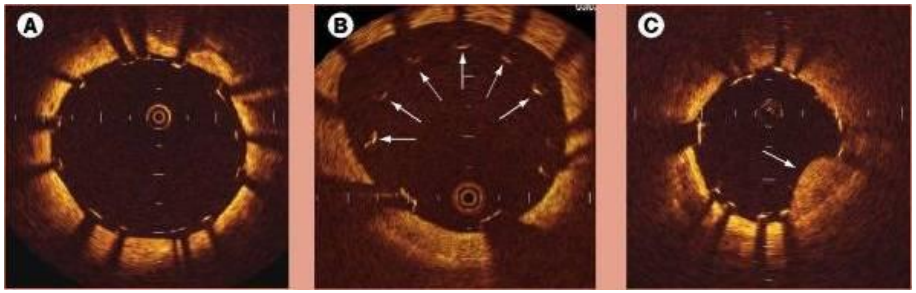




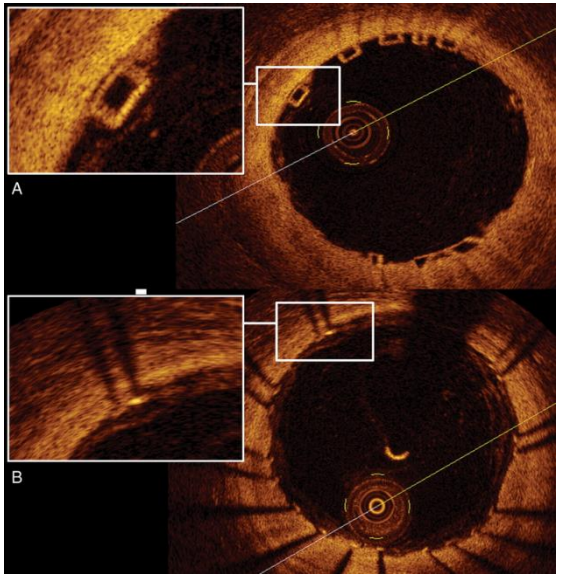
Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Cardiology OCT images

3D image of Stent within artery



Effectiveness of Stent



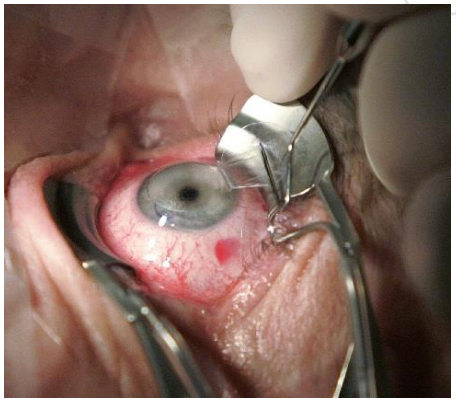
Development of bioabsorbable Stent

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

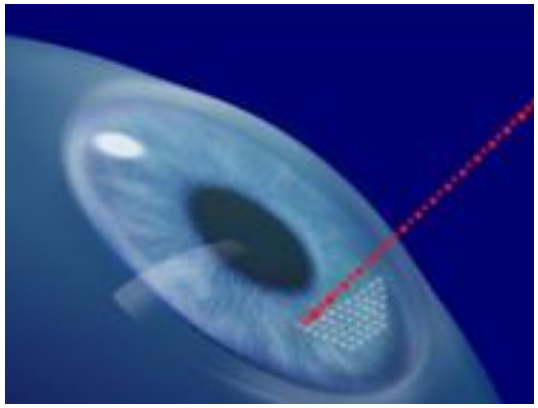
Emerging OCT – Guided Eye Surgery

LASIK and cataract surgery rapidly adopting OCT

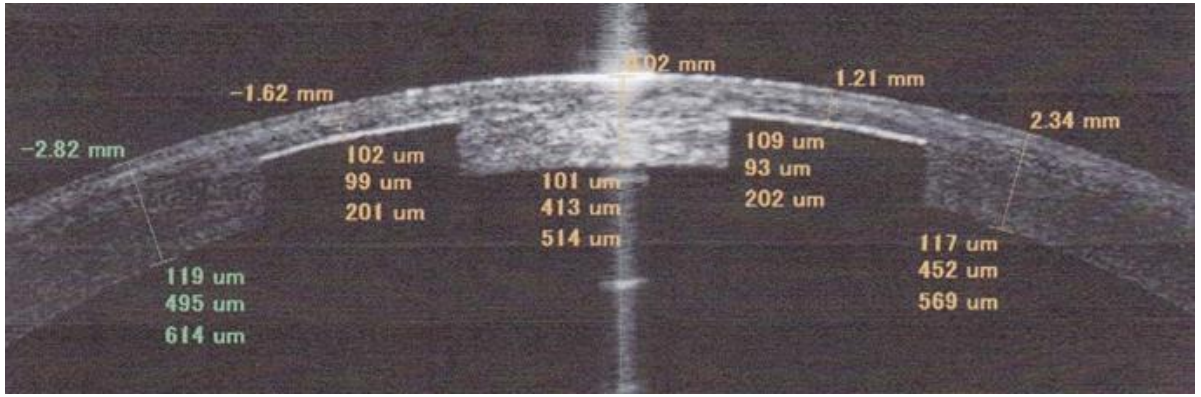
- OCT measurement of front of the eye guides femtosecond lasers to make precise incisions
- Removes dependence on surgeon skill & experience
- Removes need for surgical scalpel reducing risk of infection
- Procedure takes only 20 minutes



Traditional flap removal



OCT guided LASIK flap removal



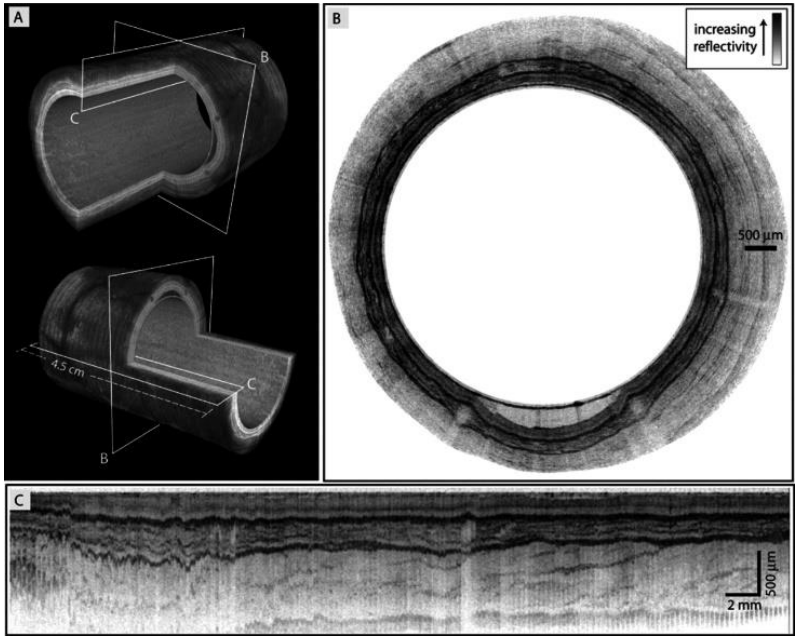
OCT image provides guidance to lasers and provides measurement

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Emerging OCT – Gastroenterology

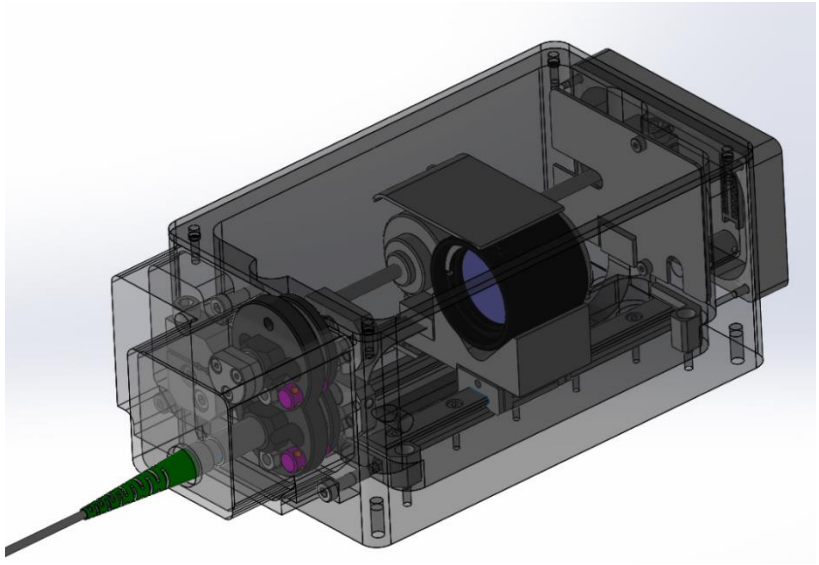
Imaging of the lining of the oesophagus

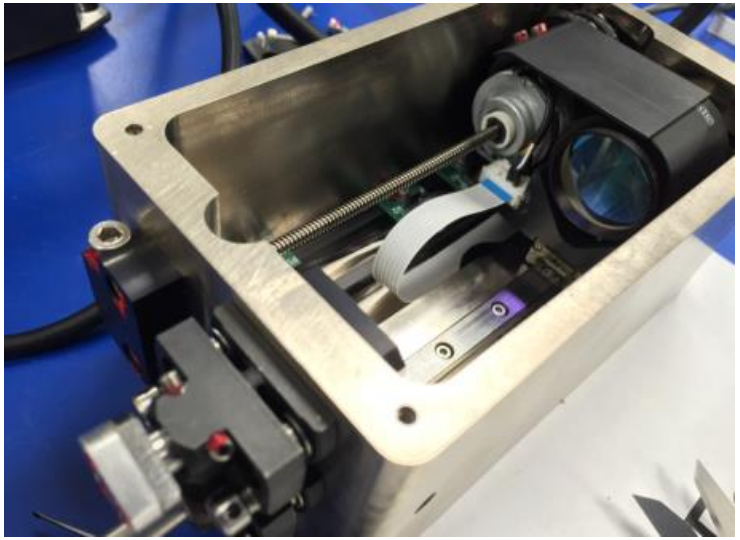
- Goal is to identify Barrett's Oesophagus
- Considered to be premalignant condition to cancer
- 5-15% heartburn referrals have Barrett's oesophagus
- Normal screening is down throat endoscopic procedure plus biopsy



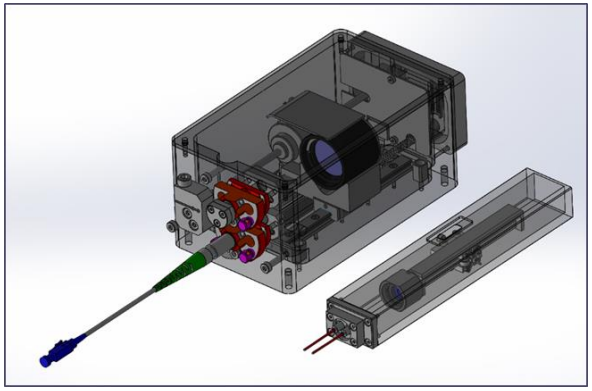
Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

New OCT Products – Delay Line





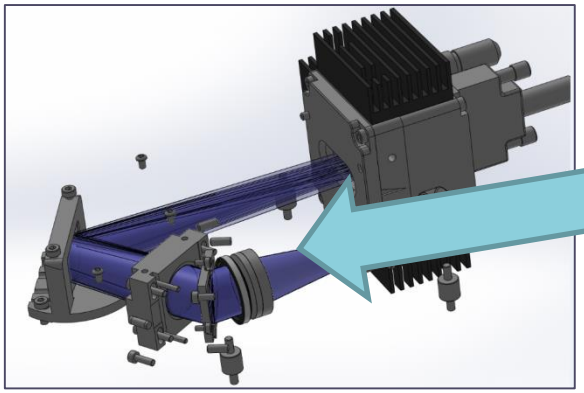
Second Generation OCT Optical Delay Line Production Units



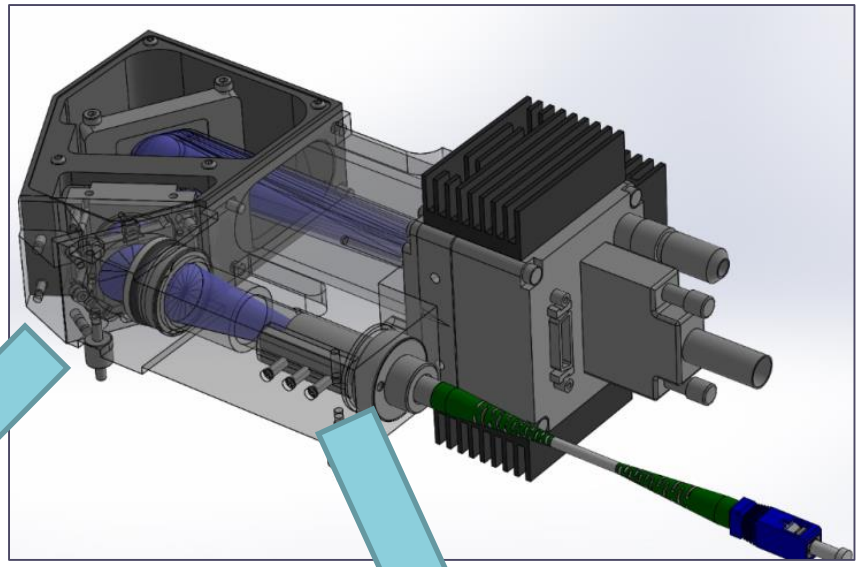
Miniature
Delay Line Concept

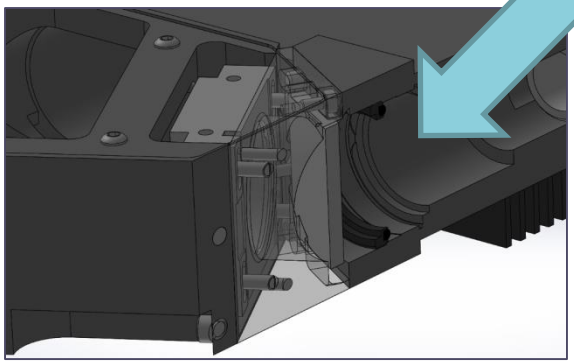
Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

New OCT Products – Spectrometer

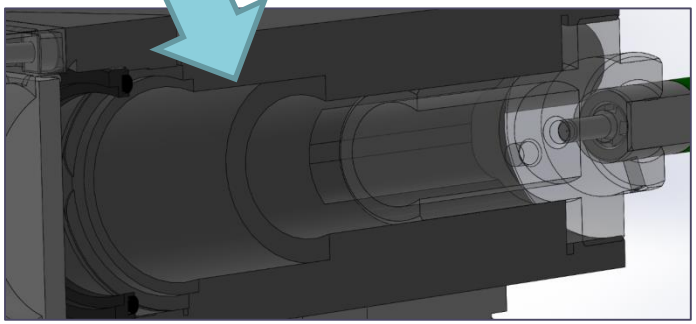


Separation of degrees of adjustment to avoid crosstalk





Mounting of grating and focussing lens - material selection for thermal stability



Fibre input – kinematic mounting to ensure pointing stability

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

STG OCT highlights over last 12 months

1x design-in of G&H spectrometer product

- Ophthalmic (retinal imaging)
- First 60 prototypes ordered
- 250 per year

2x design-in of G&H delay line product

- Gastroenterology - first production units shipped
- Laser guided surgery – first prototypes shipped

Negotiating first development contract with cardiovascular customer

- Delay lines
- Interferometer

In each case, customers are market leaders

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

G&H OCT Strategy

Consolidation of business with existing customers

- Ensure we keep all existing business
- Win new design-ins

Target key players in emerging OCT applications

- Win development contracts
- Design in existing products

Develop new products

- Key development programs
    - Delay lines
    - Spectrometers
- Identify further new products

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Space Photonics

1st July 2015

Stratos Kehayas, VP Space Photonics

Vision

- **Implementation of G&H Strategic Objectives**
- **(A) Address and lead new markets**
  - R&D and technology transfer of innovative new products **in satellite communications**
  - **System-oriented R&D** focusing on new product line creation
- **(B) Moving up the value chain**
  - **Functional integration of G&H components** into high value sub-systems
  - Satellite manufacturers ask for a **'one-stop-shop'** partner
  - **'Site-agnostic approach'** for achieving synergies and economies of scale in space photonics across G&H

To become the leading supplier of space photonics systems

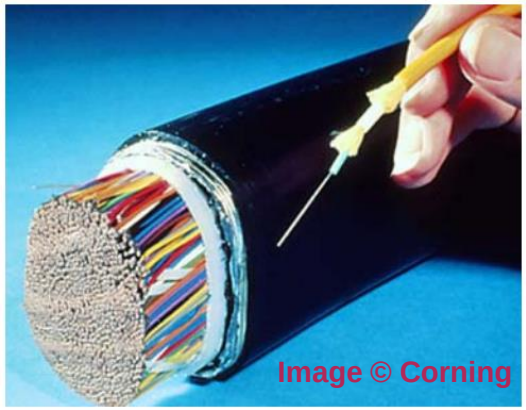
Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

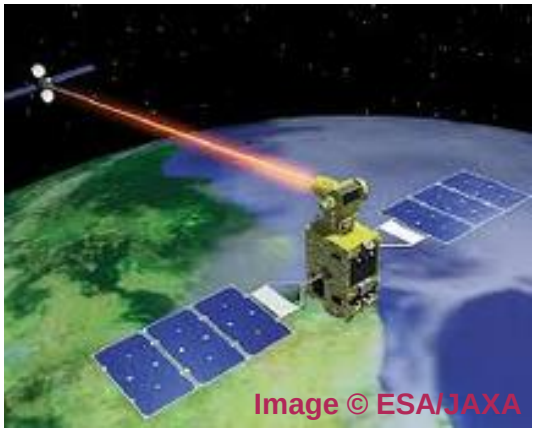
Space photonics & laser-comms

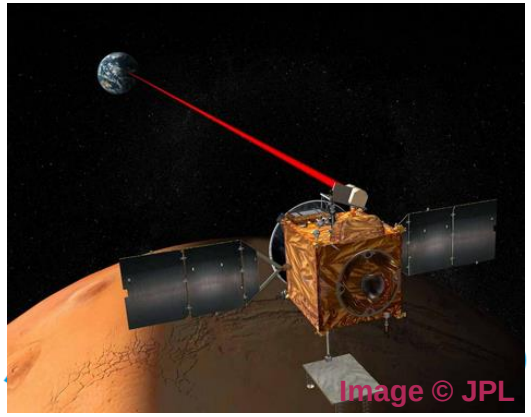
- **WHY?**
  - No Electromagnetic interference (EMI)
  - Low power consumption
  - Small volume / Lightweight systems
  - High capacity / future-proof
  - Secure communication links
- **WHERE?**
  - Satellite to Satellite (ISLs)
  - Satellite to ground
  - UAV to Satellite/Ground
  - Deep space

⬇

- **Taking hi-res photos of Mars surface will need:**
  - 9 years with current technology – 5Mb/s
  - 9 weeks with laser links – 250Mb/s ((JPL-DOT)



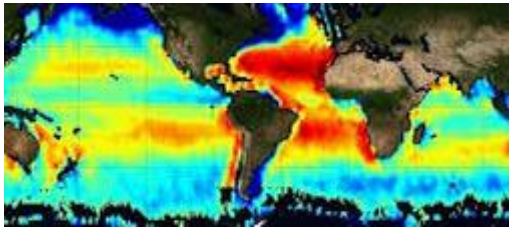


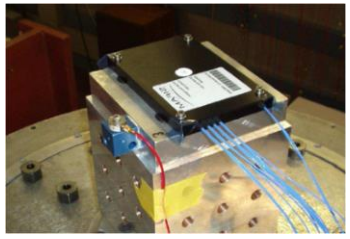


Fiber-optics technology for space: Starting point

2010: World's first fibre coupler modules to fly in mission critical payload (SMOS satellite) *built by G&H*

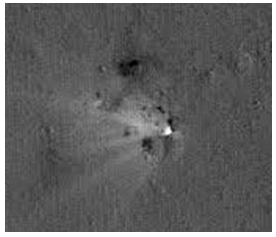
In operation. Zero failures





2013: World's first couplers, DFBs and pump lasers for laser-comms (LADEE satellite) *built by G&H*

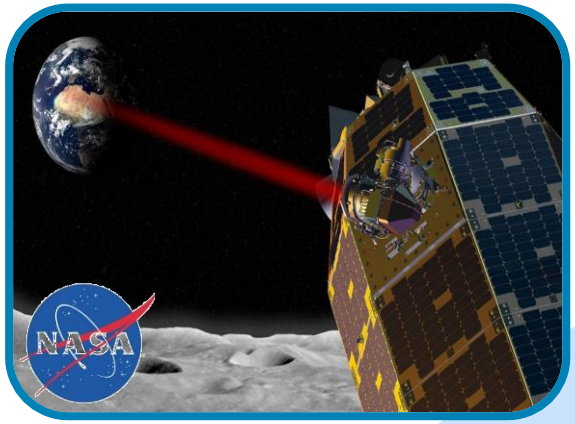
Successful laser link established



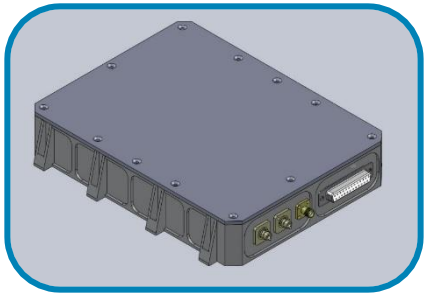
…The *laser* has landed

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

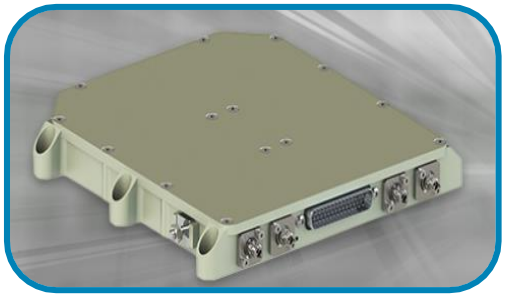
Laser-comm Roadmap



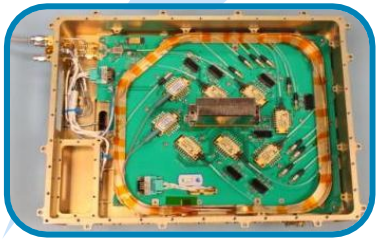
2020
- **Units**
- Laser modems
- *Inter-satellite*
- *Deep space*



2017
- **Sub-units**
- Amplifiers
- *Satellite to Ground*

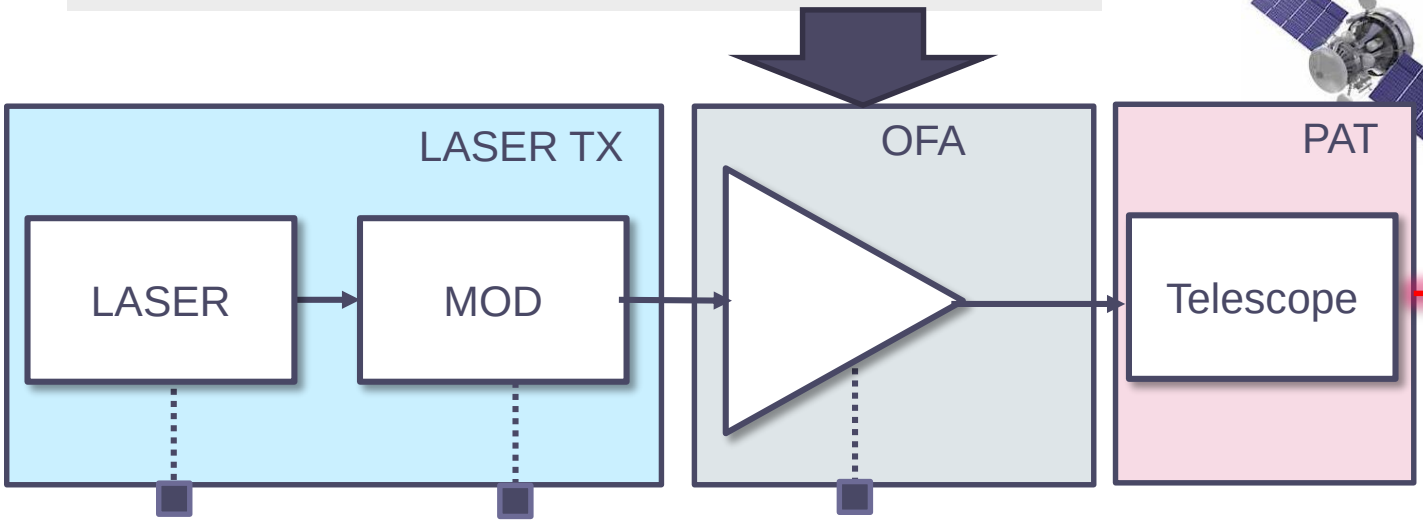


2013
- **Components**
- Lasers
- Fused passives
- *Lunar link*



Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Laser communications ‘101’



Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

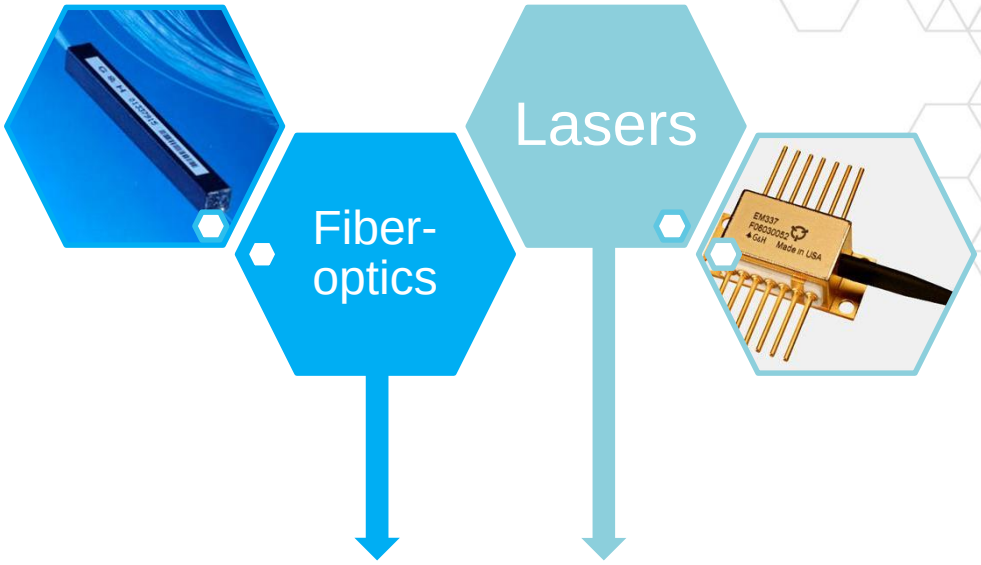
Our 1st 'mission': the Amplifier

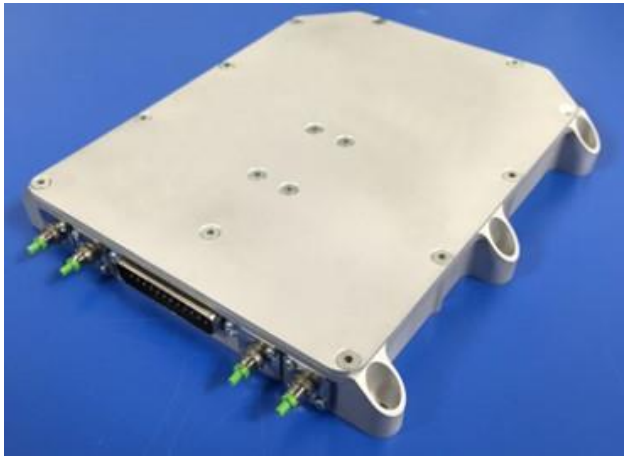
WHY?

- Critical components of an Amplifier manufactured by G&H
  - Fiber-optics (G&H Torquay)
  - Optoelectronics (G&H Boston)
- Vertical integration (traceability, reliability, supply chain control)

USPs

- Space heritage of components
- System design capabilities
- Module manufacturing expertise

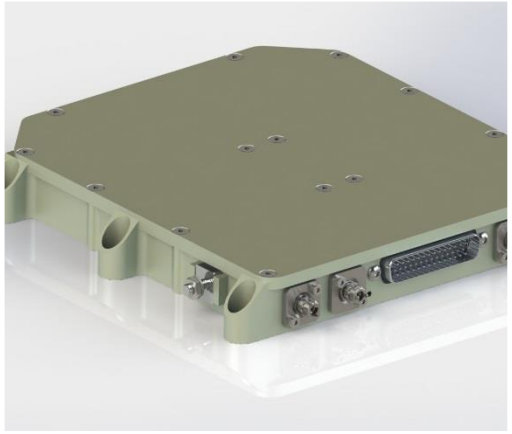




Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

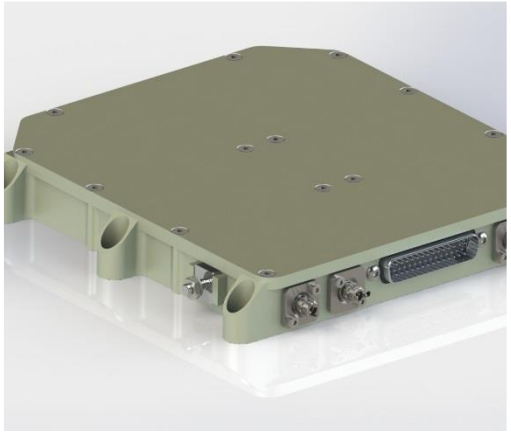
Target product lines

PEGASUS



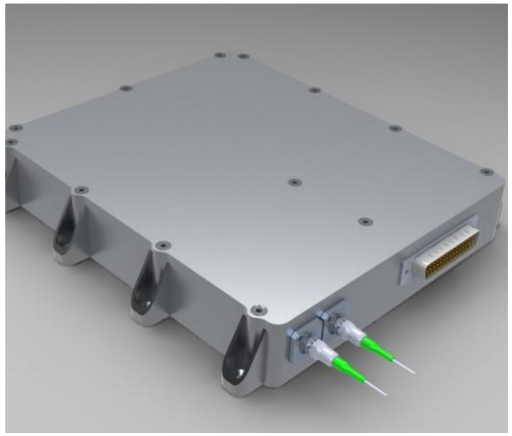
- **Pre-amplifiers**
- High gain
- Inter-satellite links

HYDRA



- **Mid-power**
- Satellite to Ground laser links

CENTAURUS



- **High-power**
- Inter-satellite links
- Deep space probes

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Running development contracts – mapping to product lines

1) HYDRA Series

- ESA
- For Optel-u terminal by RUAG
- In qualification stage

2) CENTAURUS-35

- ESA
- High-power booster amplifiers
- Deep space / inter-satellite links

3) CENTAURUS-40

- ESA
- High-power booster amplifiers
- Feeder links
- Qualification of models

4) PEGASUS Series

- ESA
- High-gain pre-amplifiers
- Earth Observation / inter-satellite links
- Qualification of models

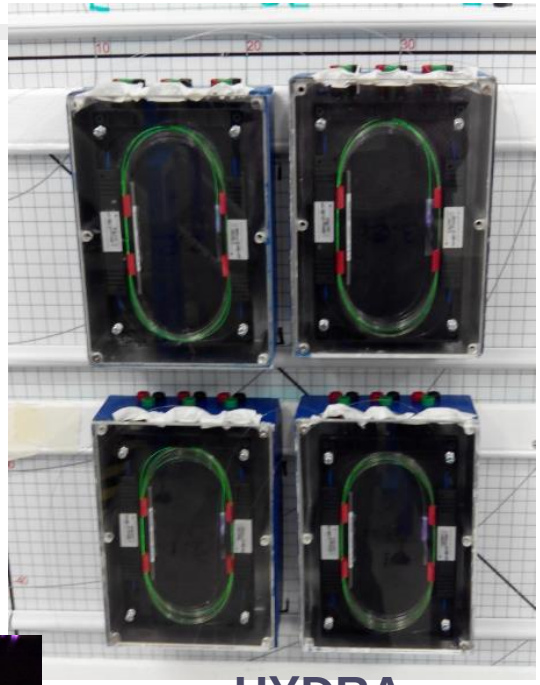
5) Active & passive components

- ESA & EU
- Component space assessment
- Isolators, Pump combiners
- Pump Lasers, DFBs, HSDs

€ 2 million funding secured
to support R&D program (2014 – 2017)

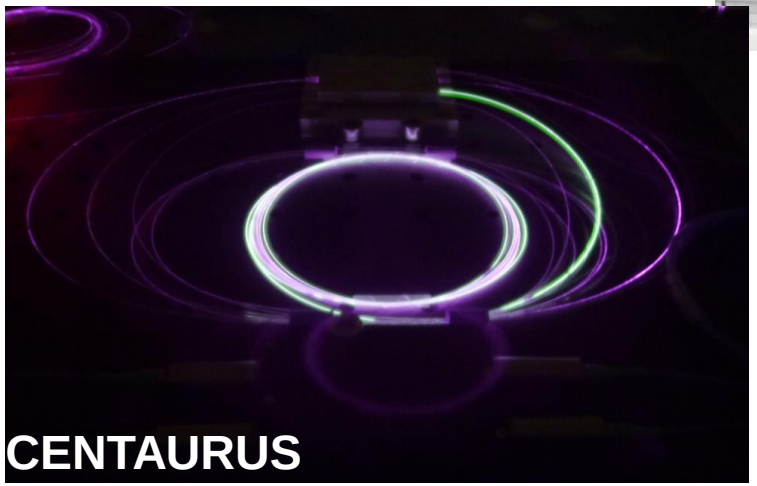
Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

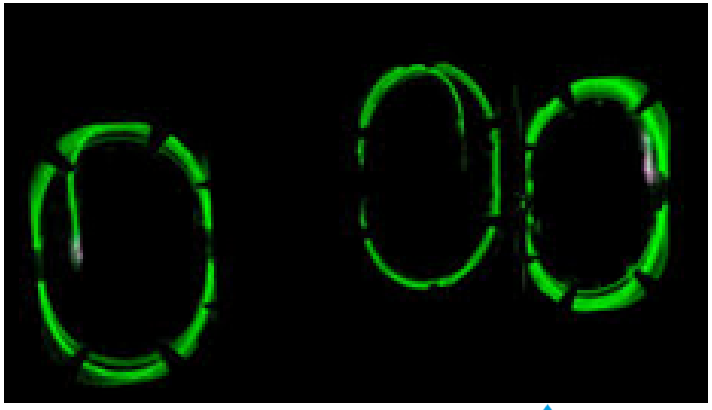
A lot of amplifiers being built and tested!



HYDRA

PEGASUS



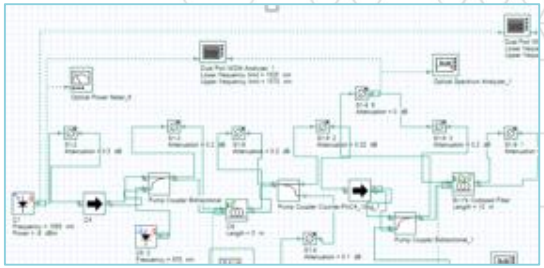


Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES

Moving up the value chain = new capabilities required

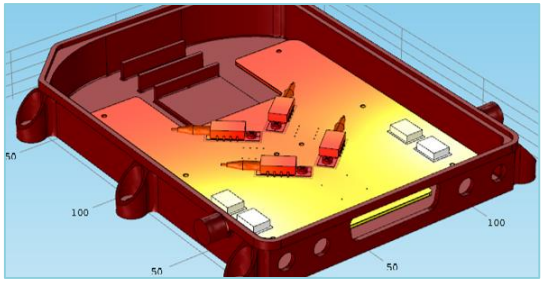
Optical Circuit modelling

- Accurate simulation of amplifier performance
- Allows for customization to end-users (built to spec)



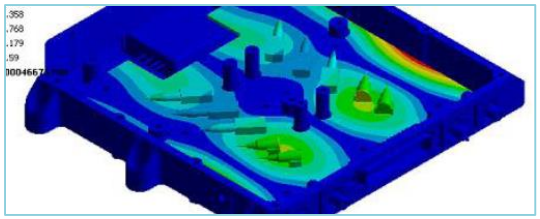
Thermal modelling

- Thermal behavior of module in thermal vacuum
- Required for estimating performance in space



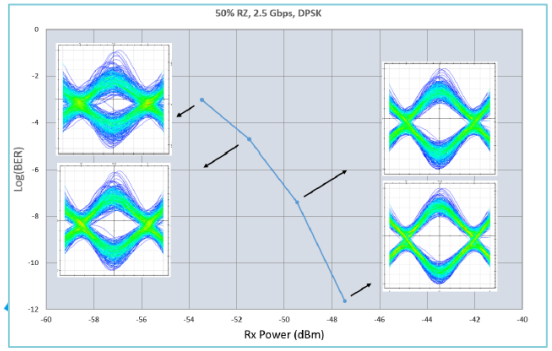
Mechanical modelling

- Stress analysis of module
- Required to prove survival during launch



System modelling

- Estimation of amplifier performance in transmission link
- Provides clients with insight on how our amplifiers operate in their system



Come fly with me

	Prototype	Qualify	Fly
HYDRA			
PEGASUS			
CENTAURUS			

2014 | 2016 | 2018 | 2020

Gooch & Housego
ENABLING PHOTONIC TECHNOLOGIES