

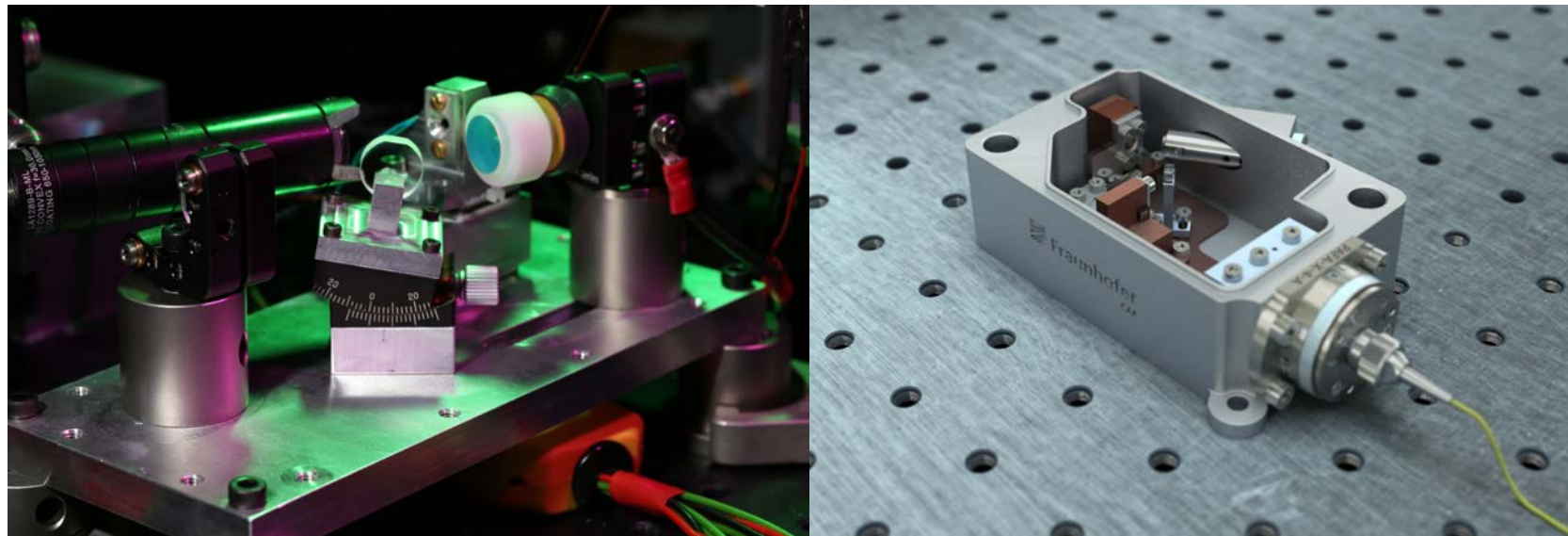
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# Laser Source Development at Fraunhofer CAP

Laser source development at Fraunhofer CAP for lidar, remote spectroscopy and space-based quantum technologies

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Lloyd J. McKnight and Fraunhofer CAP team



# Contents

- Fraunhofer UK
- Wind Lidar activities
- Stand-off spectroscopy
- Quantum technologies

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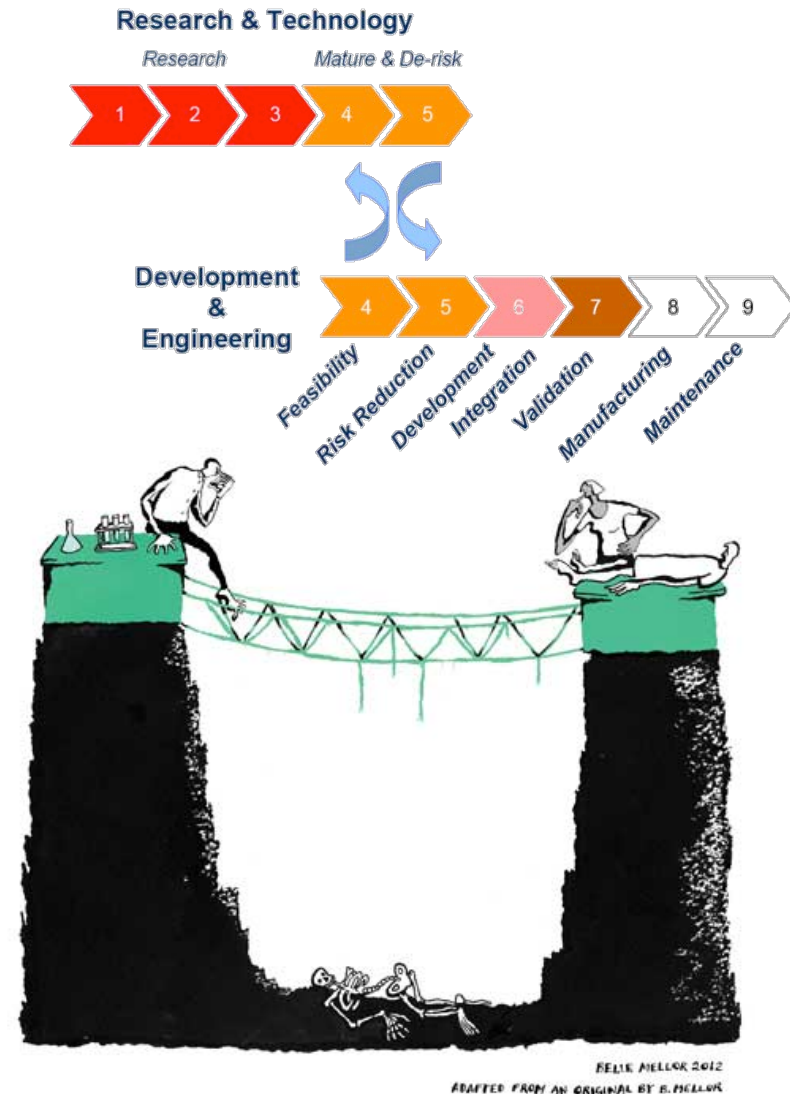
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Organisation overview

# FRAUNHOFER UK

# What are we?

- A not-for-profit research and technology organisation that exists to benefit the UK's economy
- Provide professional R&D services to industry: Bridging the “valley of death” TRL3 – TRL7
- Part of international (Europe's largest) research and technology provider network -> 70 Institutes and Centres worldwide
- Demand driven research combined with scientific excellence
- We are not an academic group – although we draw on academic expertise



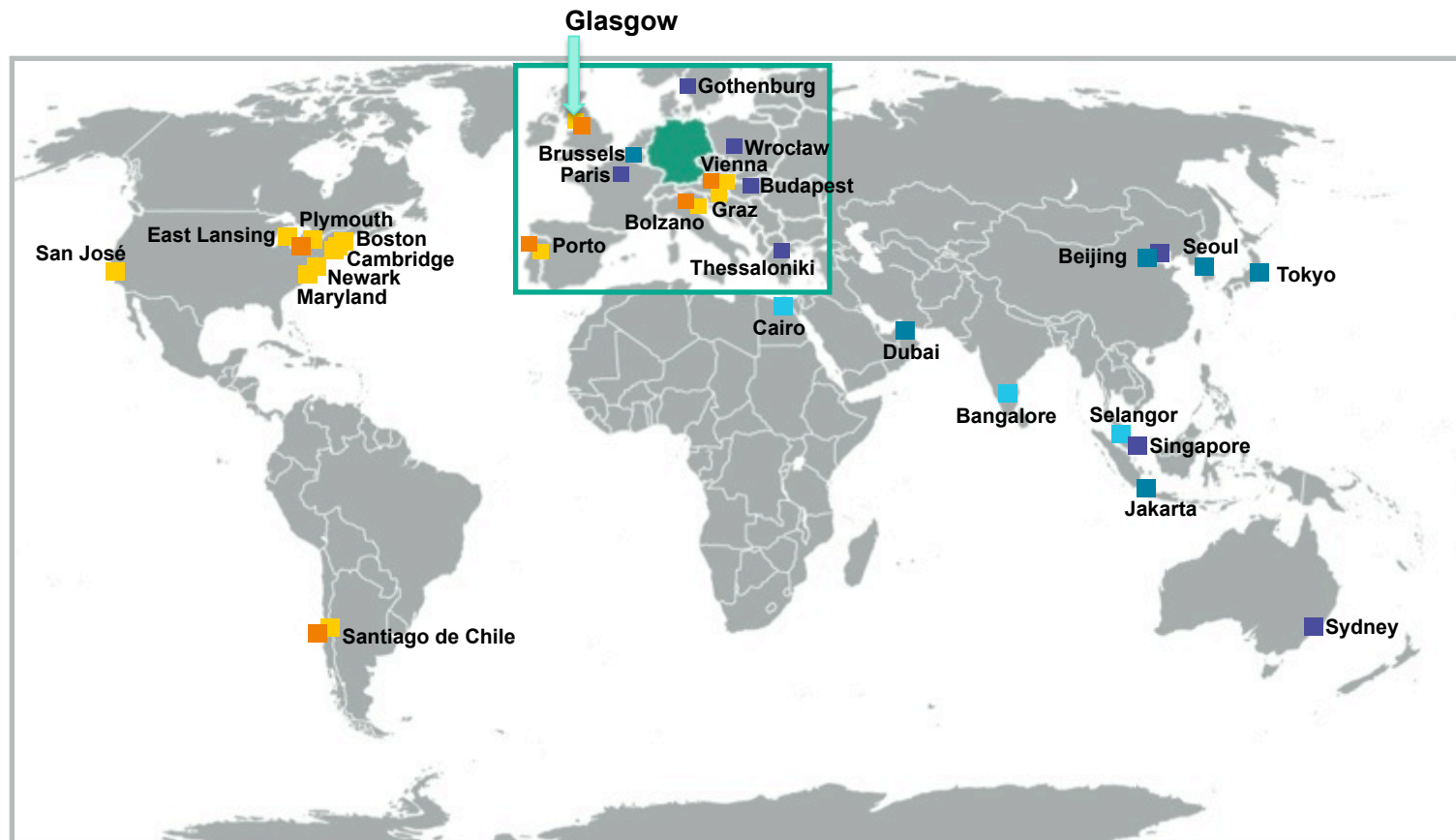
# The Fraunhofer-Gesellschaft in Germany



- >60 Institutes
- more than 22,000 employees
- ~€2 billion budget
- 7 Groups:
  - Information and Communication Technology
  - Life Sciences
  - Microelectronics
  - Light & Surfaces
  - Production
  - Materials and Components
  - Defense and Security



# Fraunhofer worldwide



- Subsidiary
- Center
- Project Center / Strategic Cooperation
- Representative Office
- Senior Advisor



# Fraunhofer in the UK

- Hauser Report: 'The Current and Future Role of Technology and Innovation Centres in the UK' (March 2010)
- 2009 - Lord Drayson wrote to Fraunhofer inviting discussion on ways it could interact better with UK universities
- 2012 – Fraunhofer UK established



**BBC** Sign in News Sport Weather iPlayer TV Rad

## NEWS SCOTLAND BUSINESS

Home World UK England N.Ireland Scotland Wales Business Politics Health Education SciEnvi

Scotland Politics Scotland Business Edinburgh, Fife & East Glasgow & West Highlands & Islands ME, C

30 May 2012 Last updated at 01:17

### Glasgow to host Fraunhofer laser research hub

Europe's largest contract research organisation is to create a hub for laser research and technology in Glasgow.

The move by Fraunhofer-Gesellschaft is a strategic collaboration with the University of Strathclyde

The Fraunhofer Centre for Applied Photonics will cover a variety of sectors including security, healthcare, energy and transport.

The centre for applied photonics will be based at Strathclyde's Technology and Innovation Centre

# Who we are



Martin Dawson



John-Mark Hopkins



David Stothard



Henry Bookey



Alex Lagatsky



Christopher Carson



Loyd McKnight



Brynmor Jones



Gerald Bonner



Peter Schlosser



Matt Warden



Simon Sorensen



John Macarthur



Anne-Marie Haughey



Alan Kemp



David Armstrong



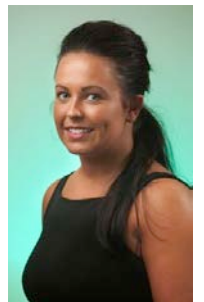
Paul McCartney



Mark Scullion



Ewan Mulhern



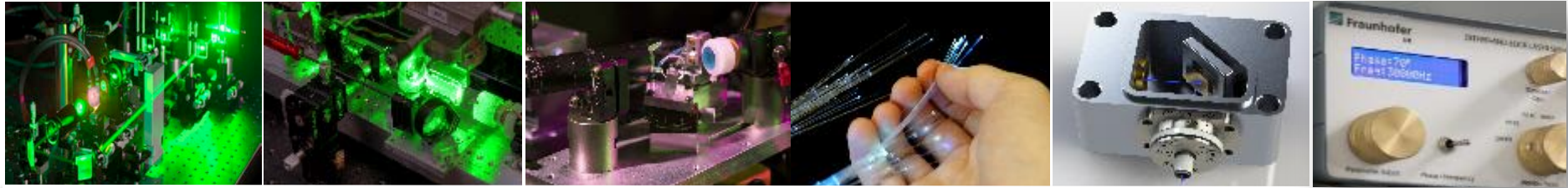
Lisa Flanagan



Joanna Wiles



# Research – Engineering - Design

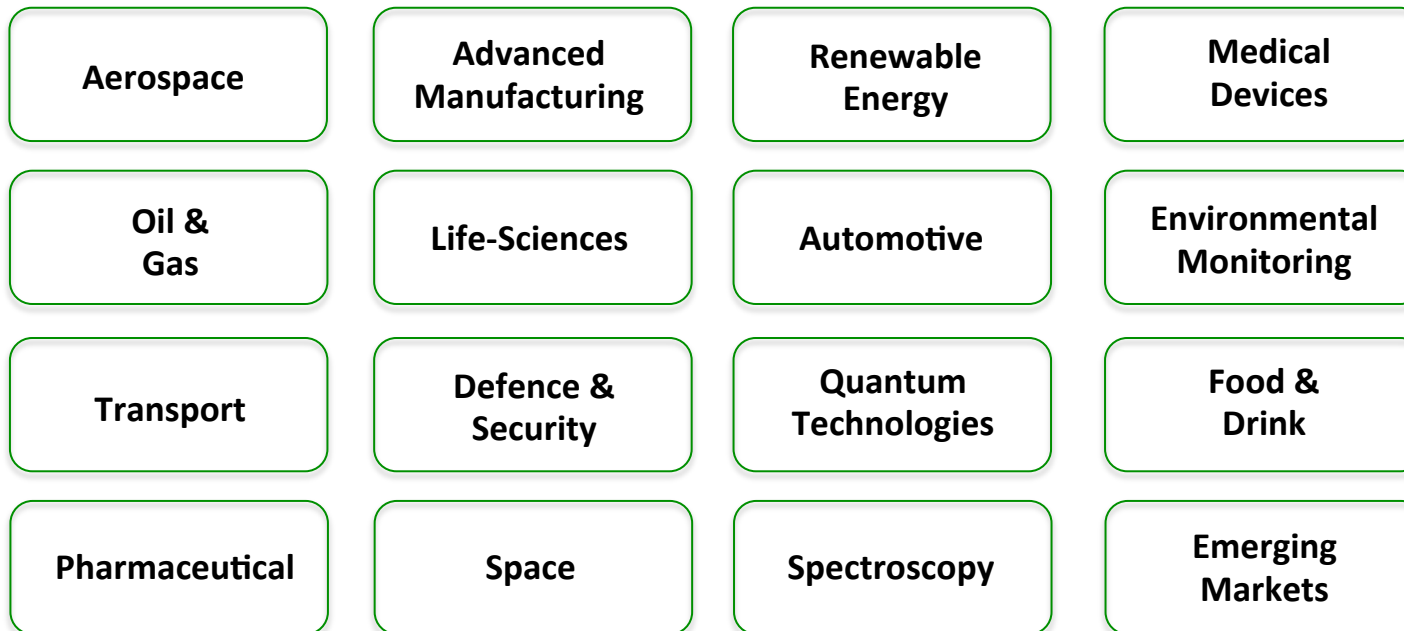


SOLID-STATE LASERS	MID-INFRARED LASERS	SEMICONDUCTOR DISK LASERS	INTEGRATED OPTICS	MODEL, DESIGN, PROTOTYPE	INSTRUMENTATION
<p>Fraunhofer Centre for Applied Photonics designs, develops and prototypes laser systems for real-world applications in compact and robust packages that deliver excellent performance.</p>	<p>With many competing technical routes to generating challenging infrared wavelengths, Fraunhofer CAP's expertise (across multiple platforms) allows us to choose the best methods for your applications.</p>	<p>Achieve the exact wavelength required for your application, with very high quality beam and Watt-level outputs across a very broad spectral range - UV to mid-IR - with semiconductor disk lasers.</p>	<p>Fibre lasers, distributed fibre optic sensors, waveguide lasers &amp; devices, single-substrate component and functionality integration, including microfluidics and the application of such for a spectrum of use scenarios.</p>	<p>The optical, thermal, mechanical and electronic performance of systems are rigorously modelled and designed within agreed parameters to ensure the best possible outcomes - particularly for higher risk projects.</p>	<p>The incorporation of detectors, electronics, rugged opto-mechanical designs, signal processing and interfacing with laser and optics technical expertise, to produce practical instrumentation, measurement and detection systems.</p>

# Translating Themes of Interest into Market Segments



- **Emerging and Enabling Technologies.**
  - **Infrastructure Systems.**
  - **Health and Life sciences.**
  - **Manufacturing and Materials.**



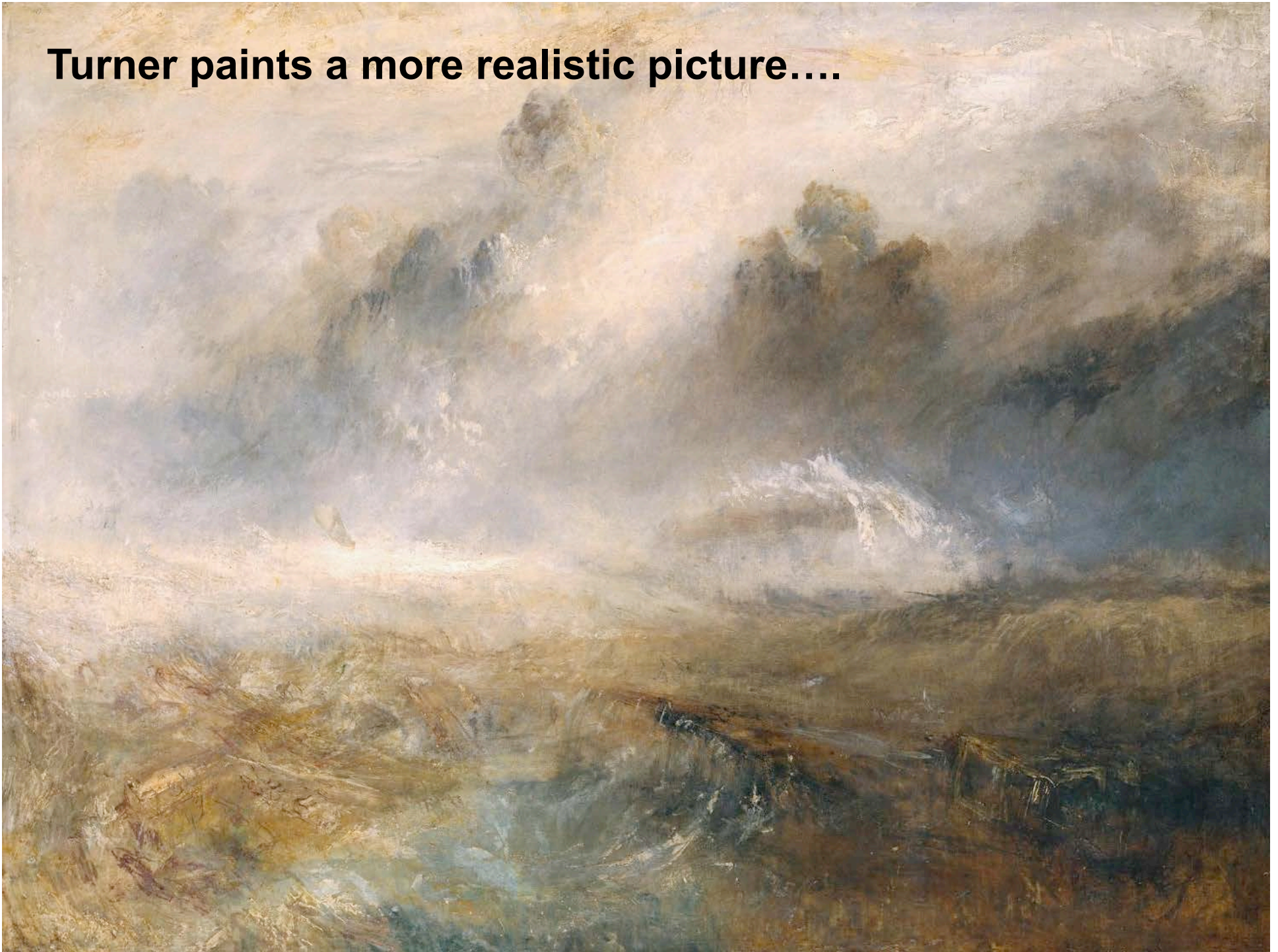
# WIND SPEED LIDAR

# The offshore environment?



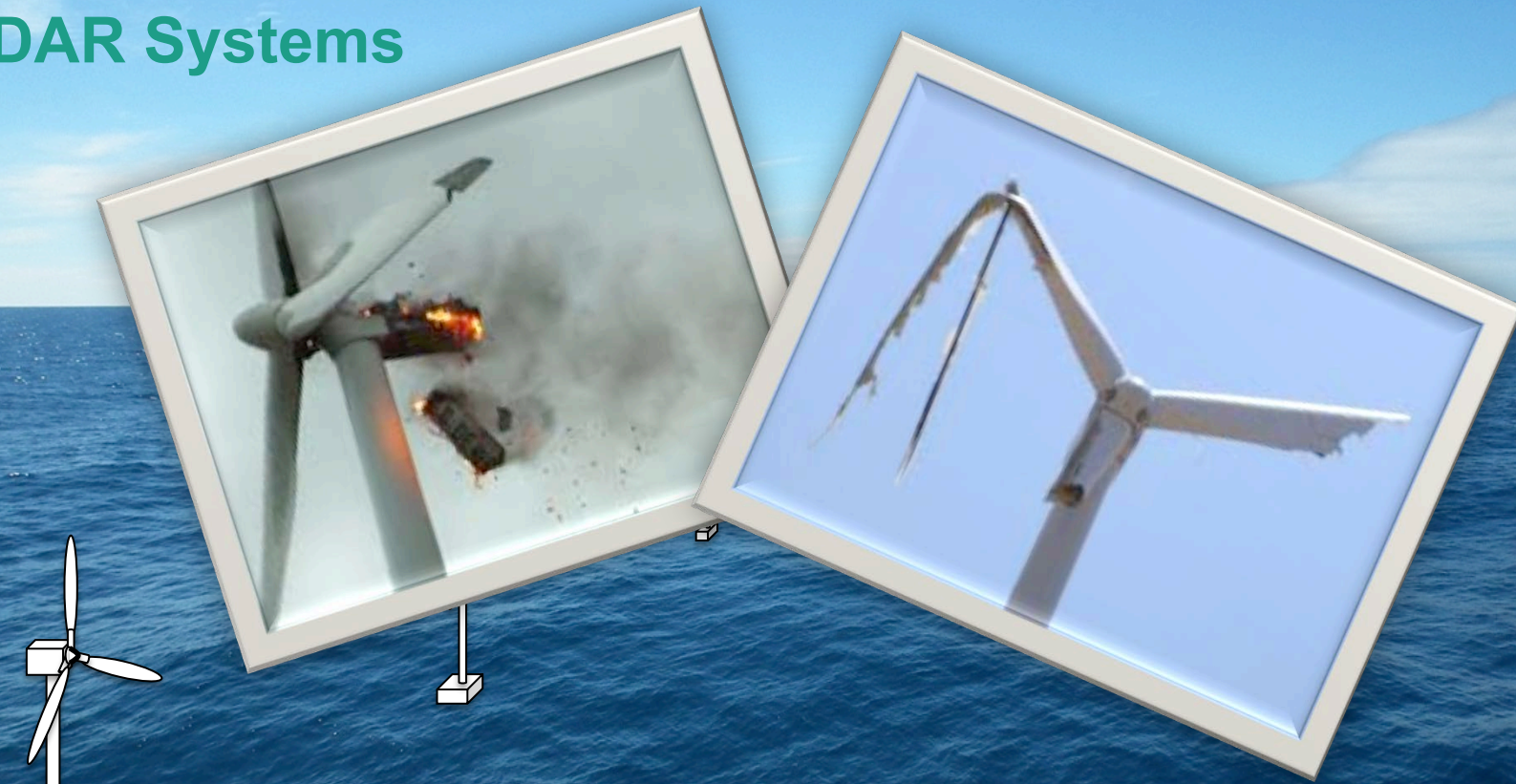


**Turner paints a more realistic picture....**





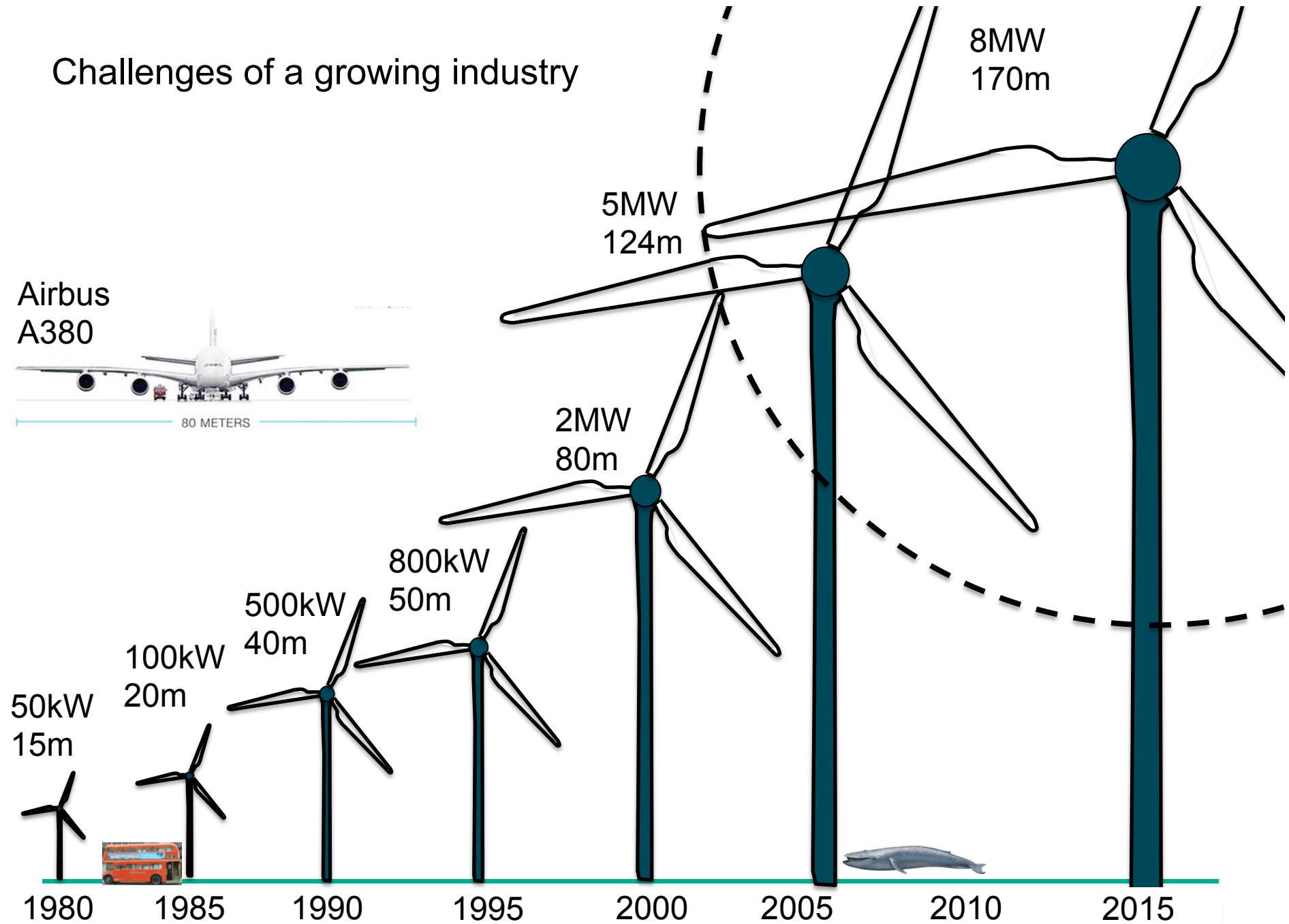
# Wind Energy Harvesting LIDAR Systems



As Offshore Wind Turbines get larger  
Wind speed can vary significantly across the rotor disc

- Reduced energy extraction
- Uneven blade loading
- Gust damage to assets
- Increased O&M costs

# Challenges of a growing industry

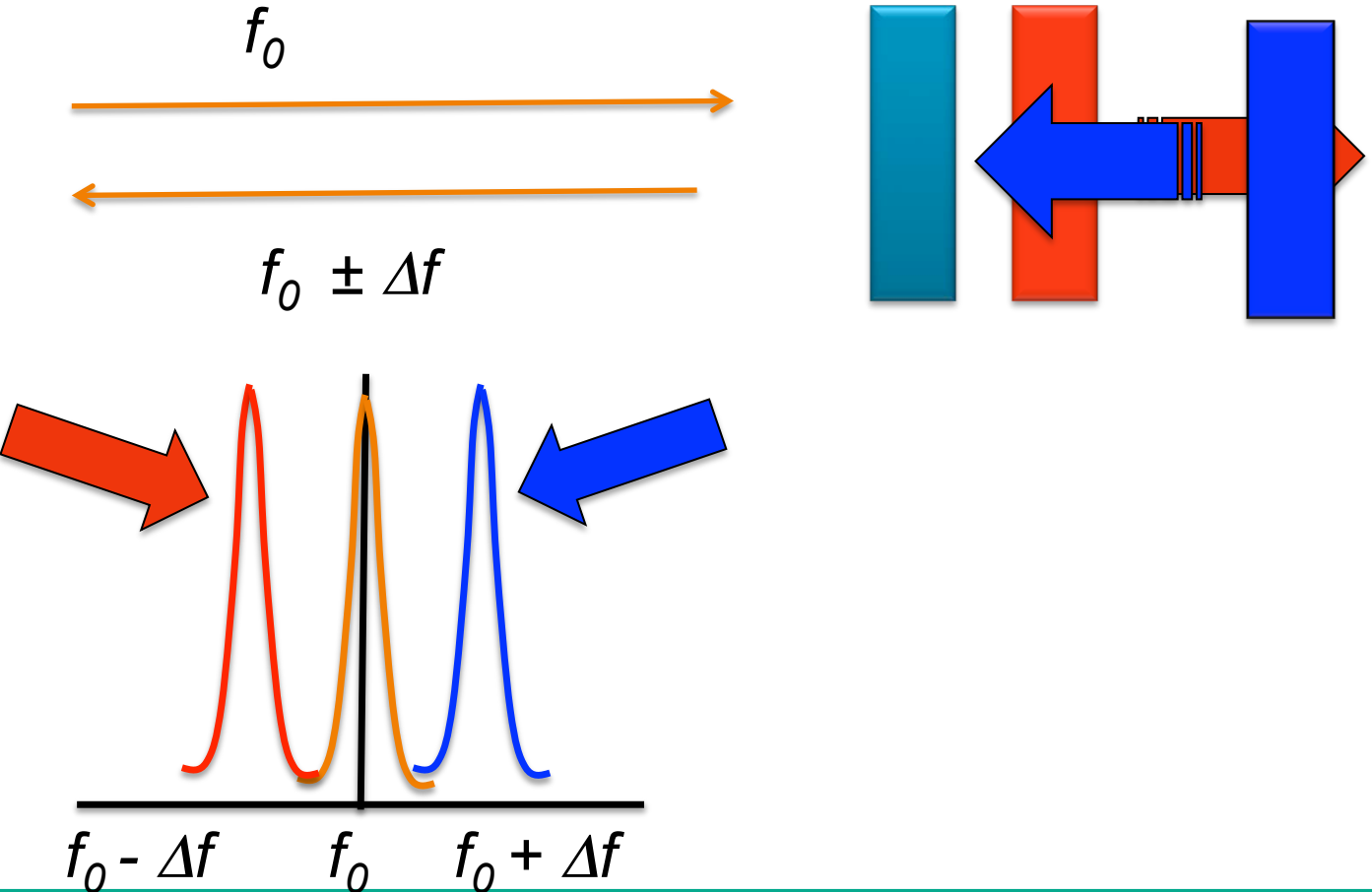


© Fraunhofer

(EWEA 2007)

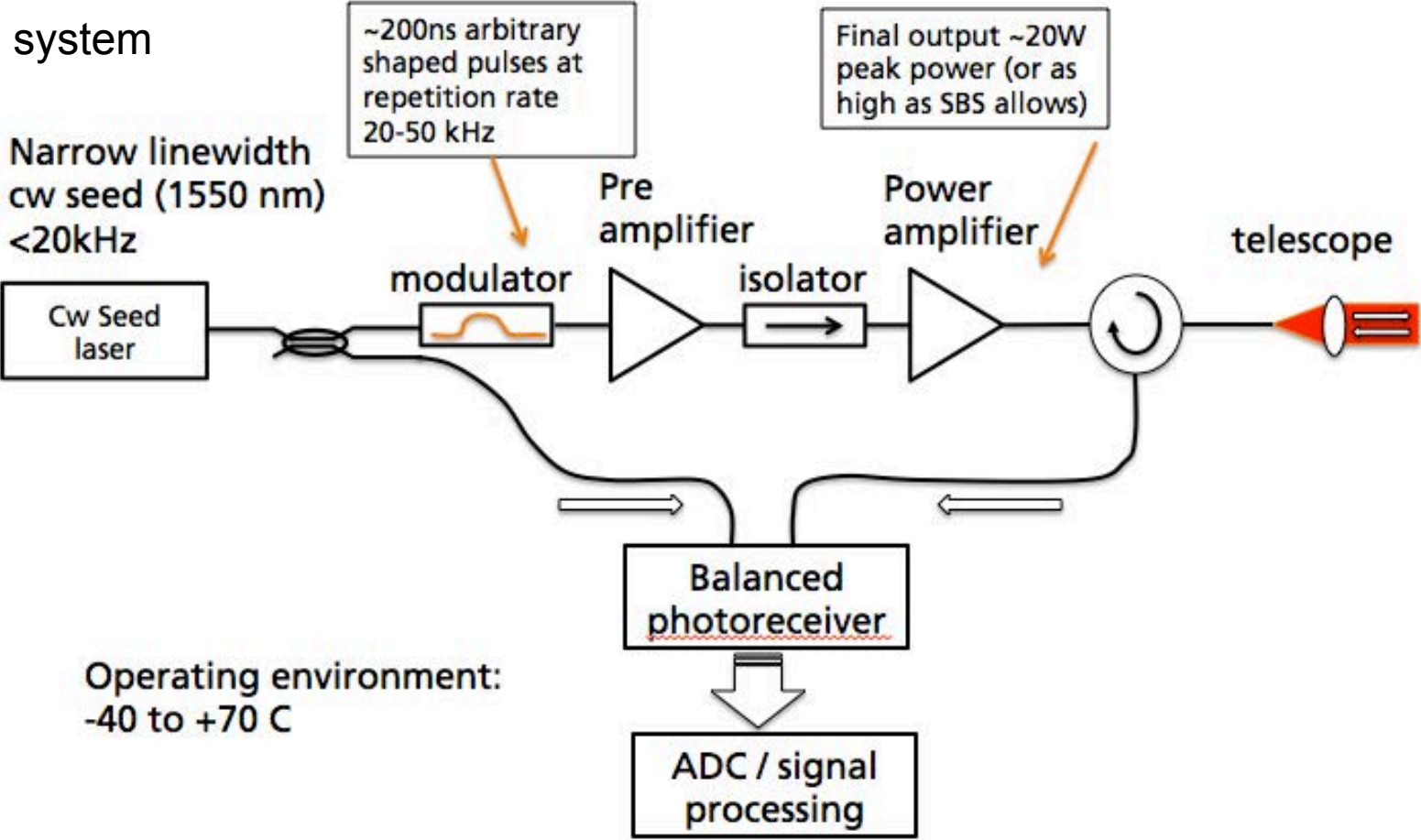


# Doppler measurements



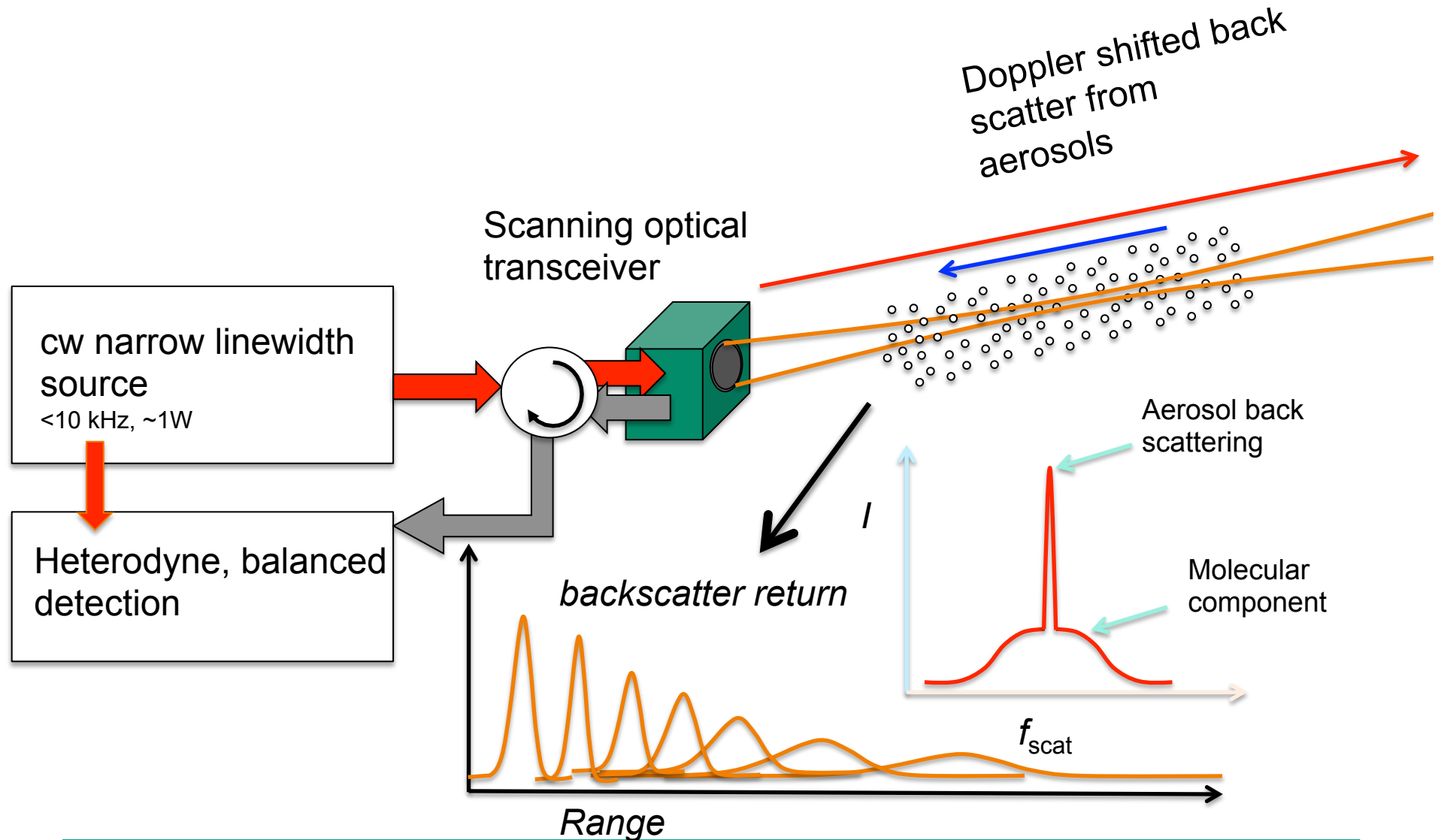
# Wind Energy Harvesting LIDAR Systems

A typical system



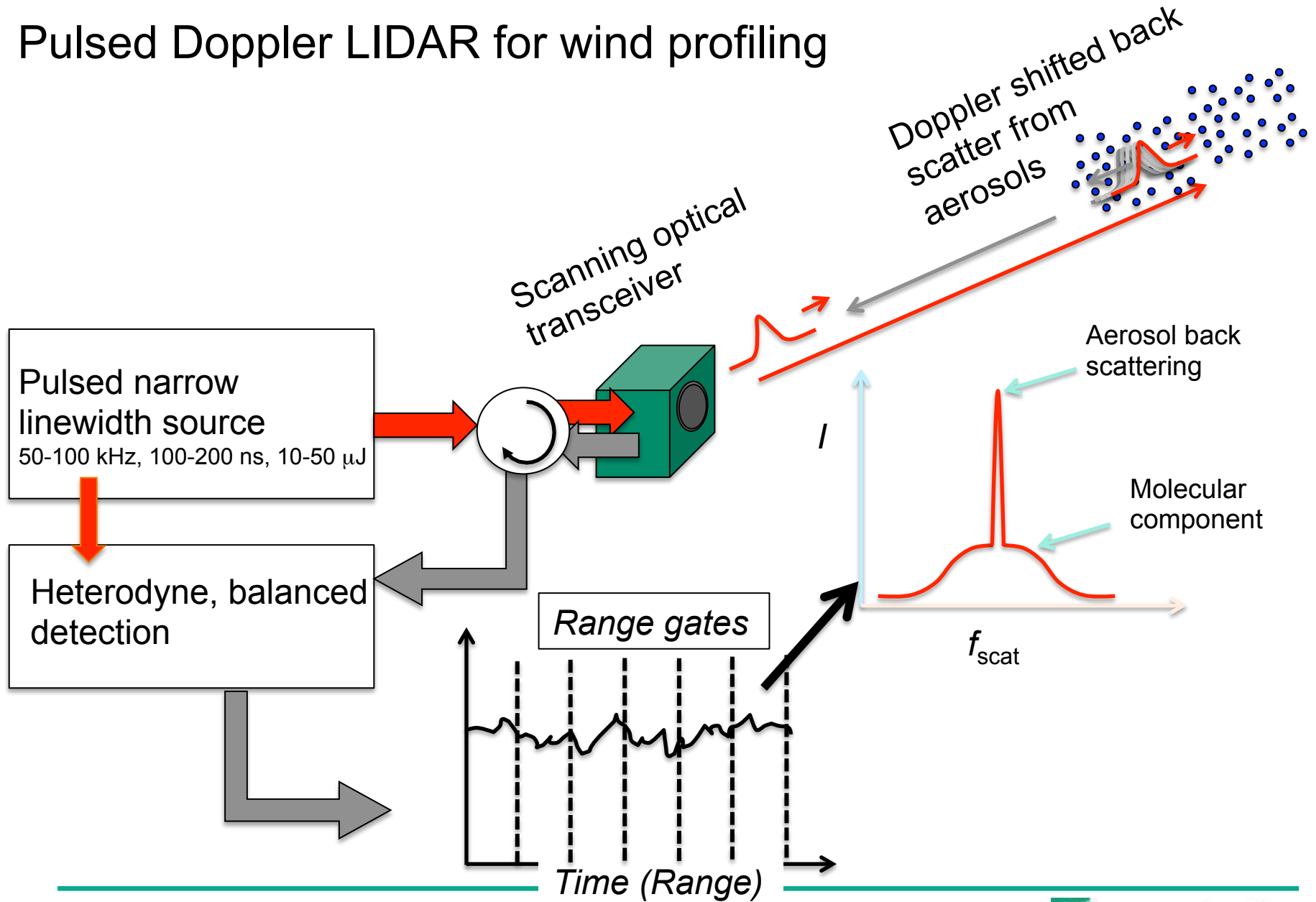


# cw Doppler LIDAR for wind profiling

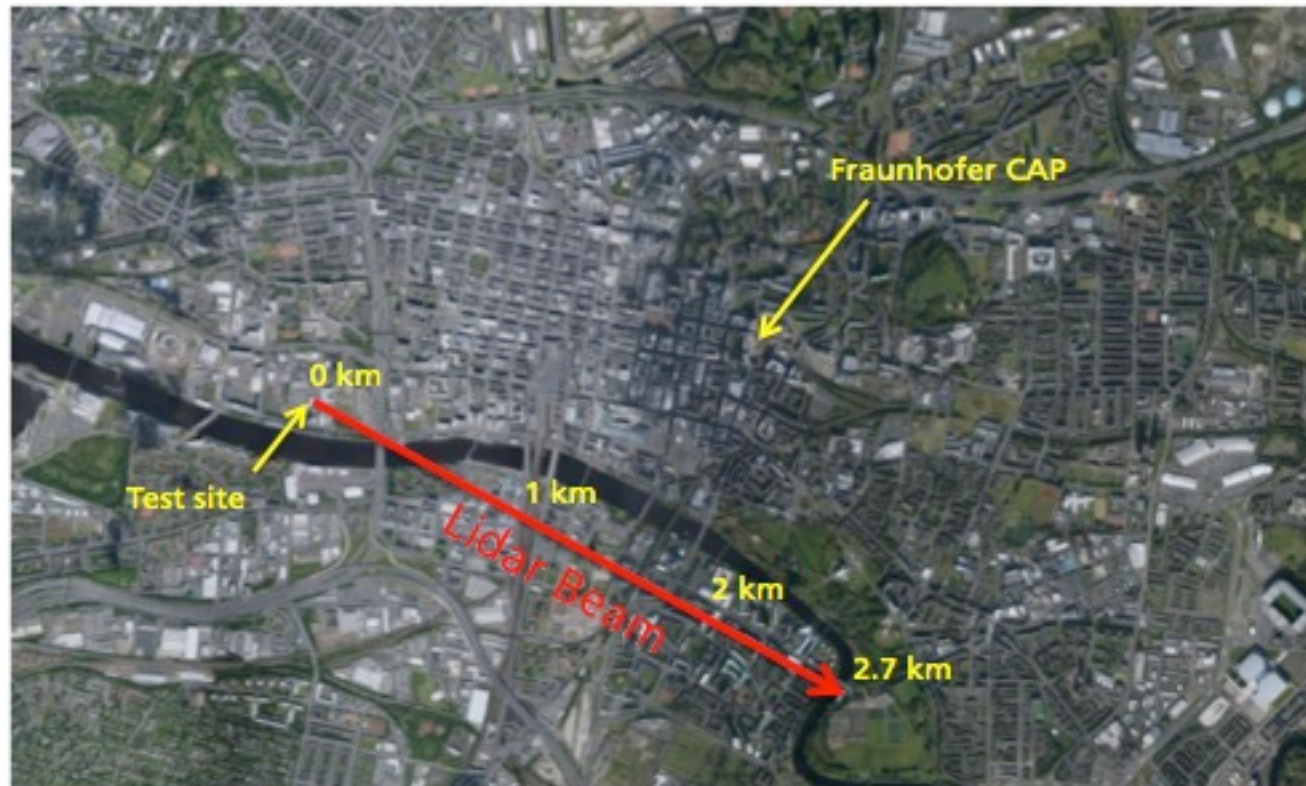




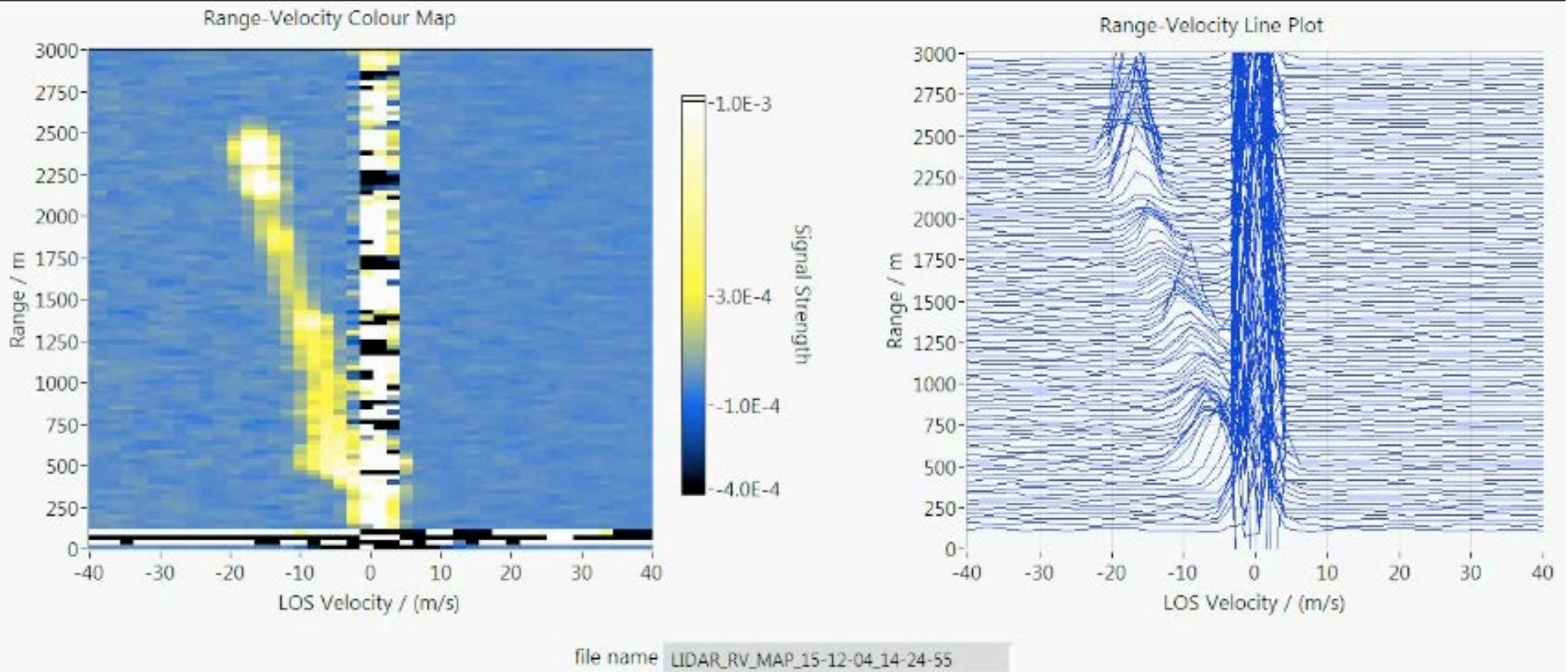
# Pulsed Doppler LIDAR for wind profiling



# On-sky measurements



## Pulsed Doppler measurements out to 3 km

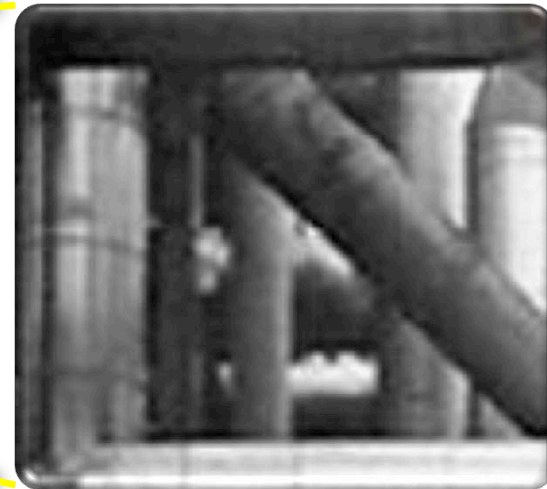
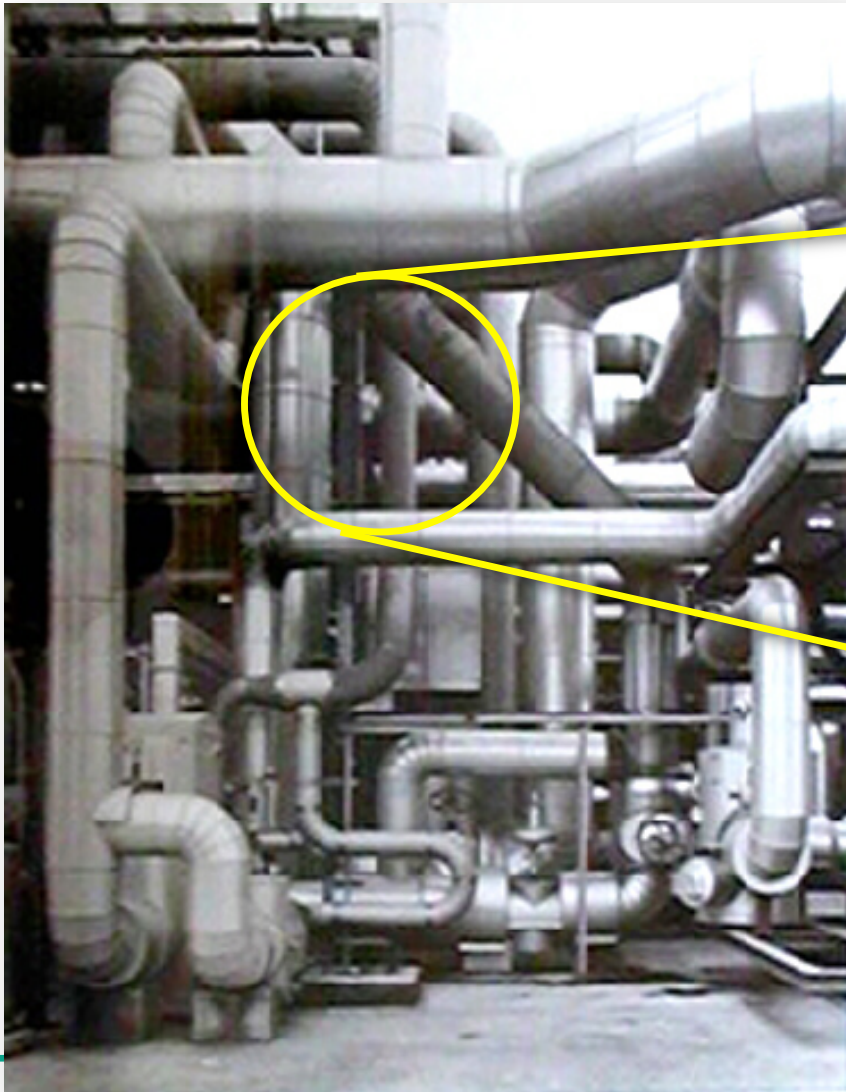


OPO and QCL technology

# STAND-OFF SPECTROSCOPY

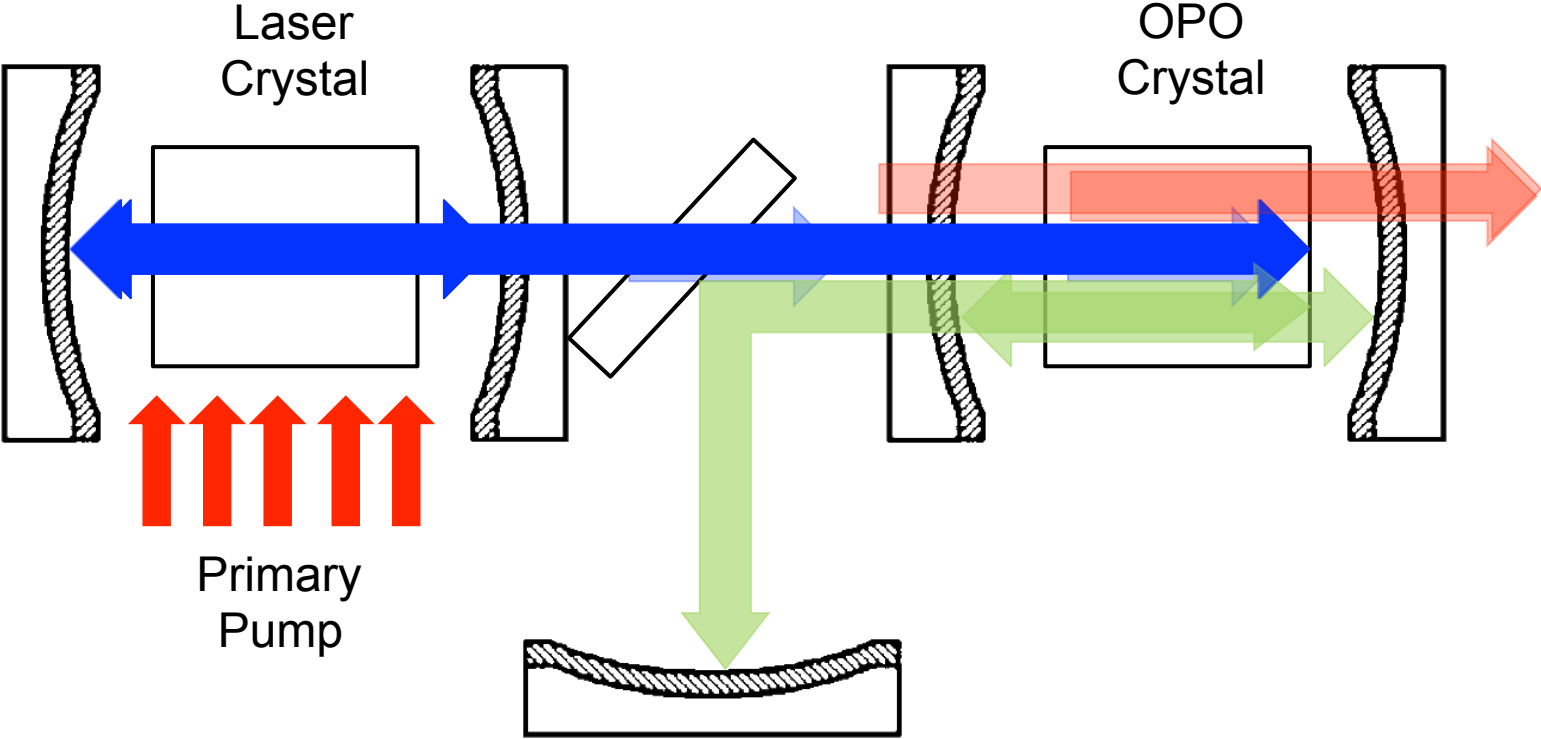


# The importance of mid- to deep-IR laser sources





# Optical Parametric Oscillators – *Intracavity Pumping*

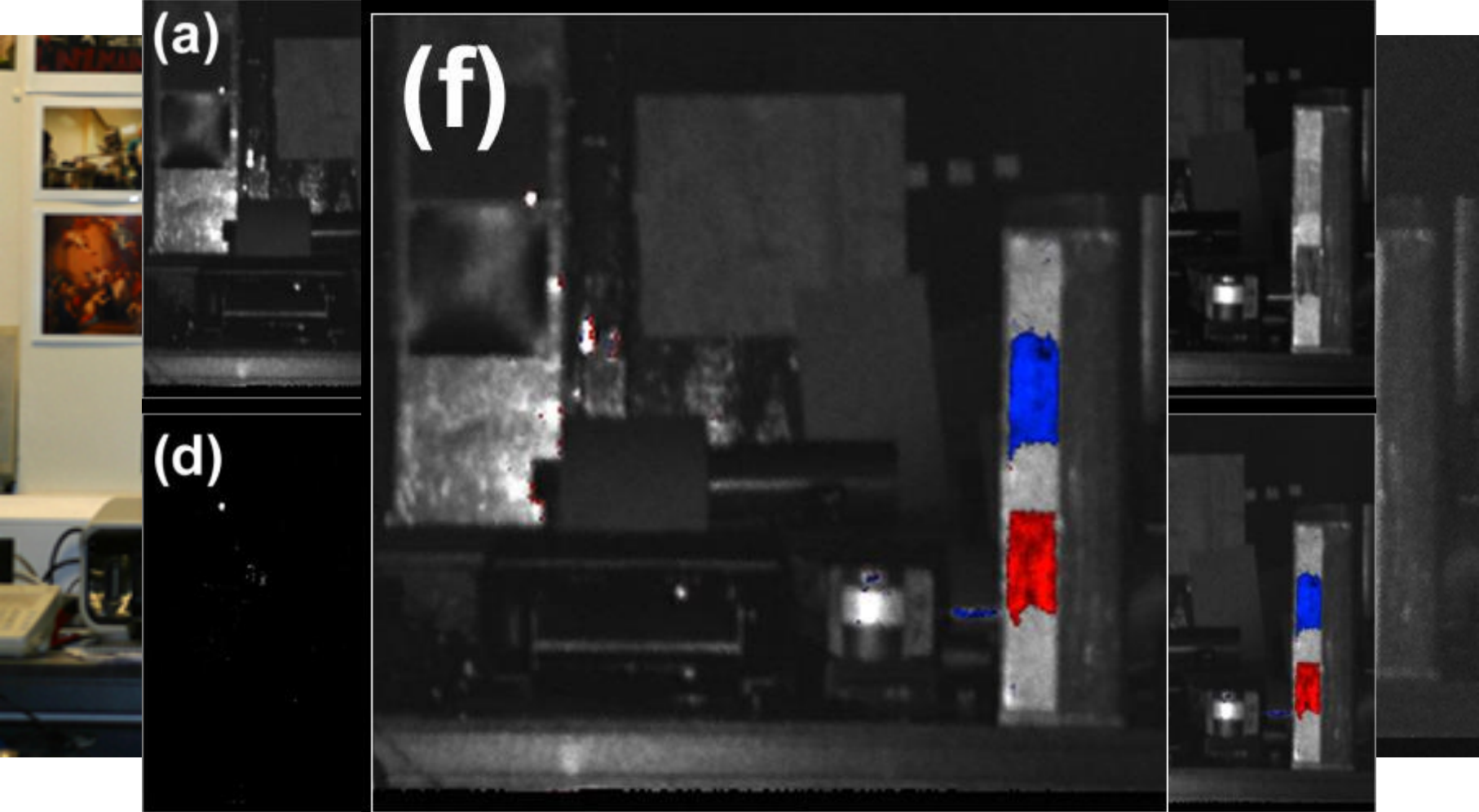


## ICOPOs: Miniature by design

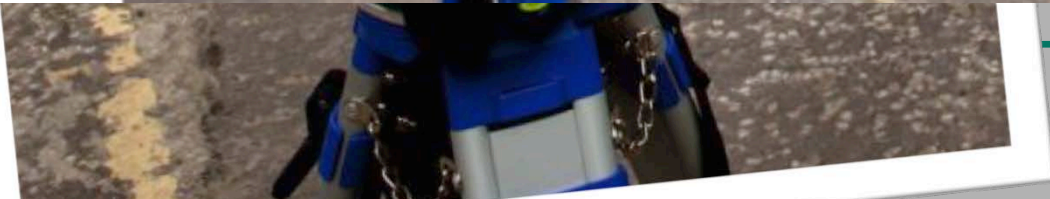
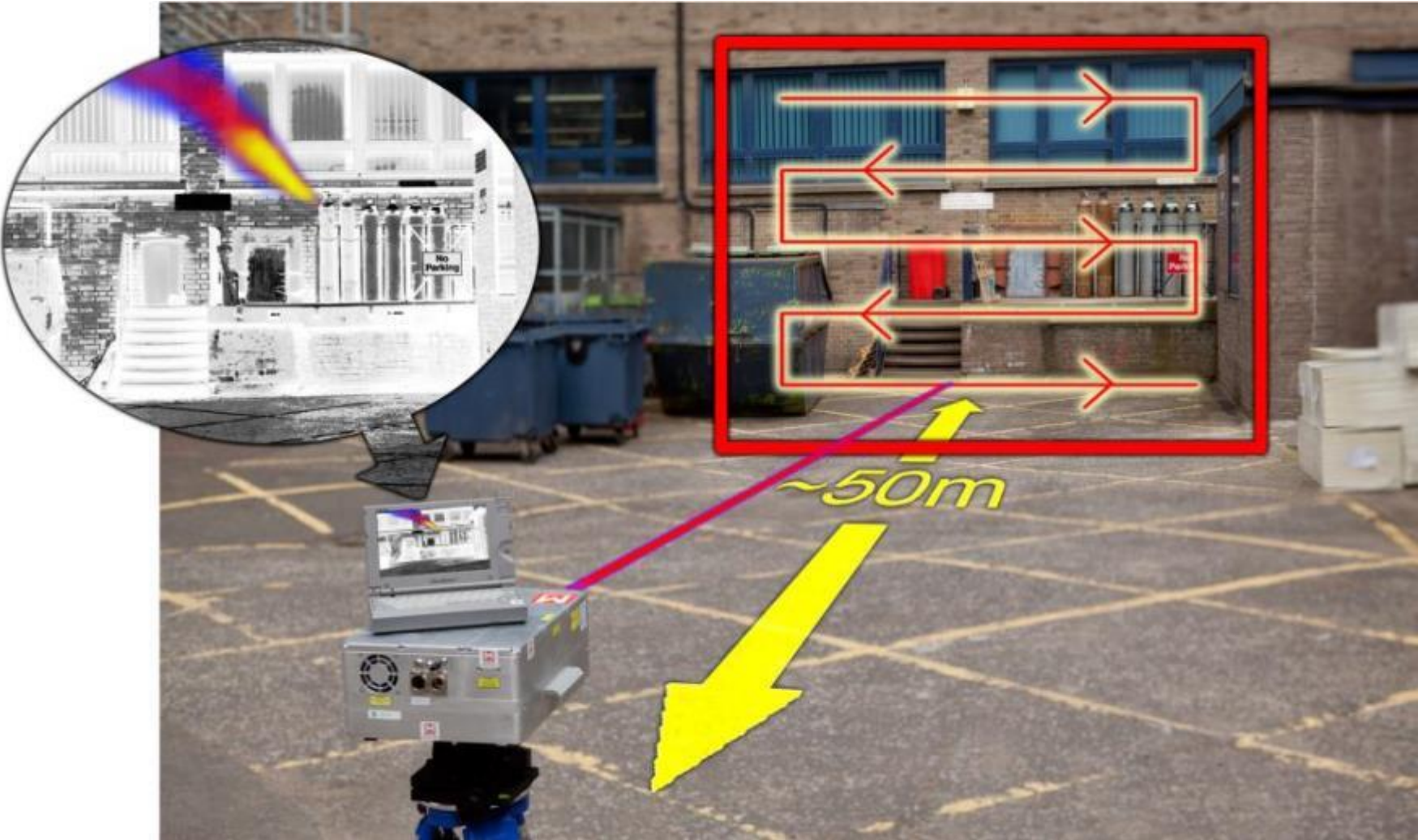
**1.3 – 4.7  $\mu\text{m}$**

tuning from a single device  
**without component change**

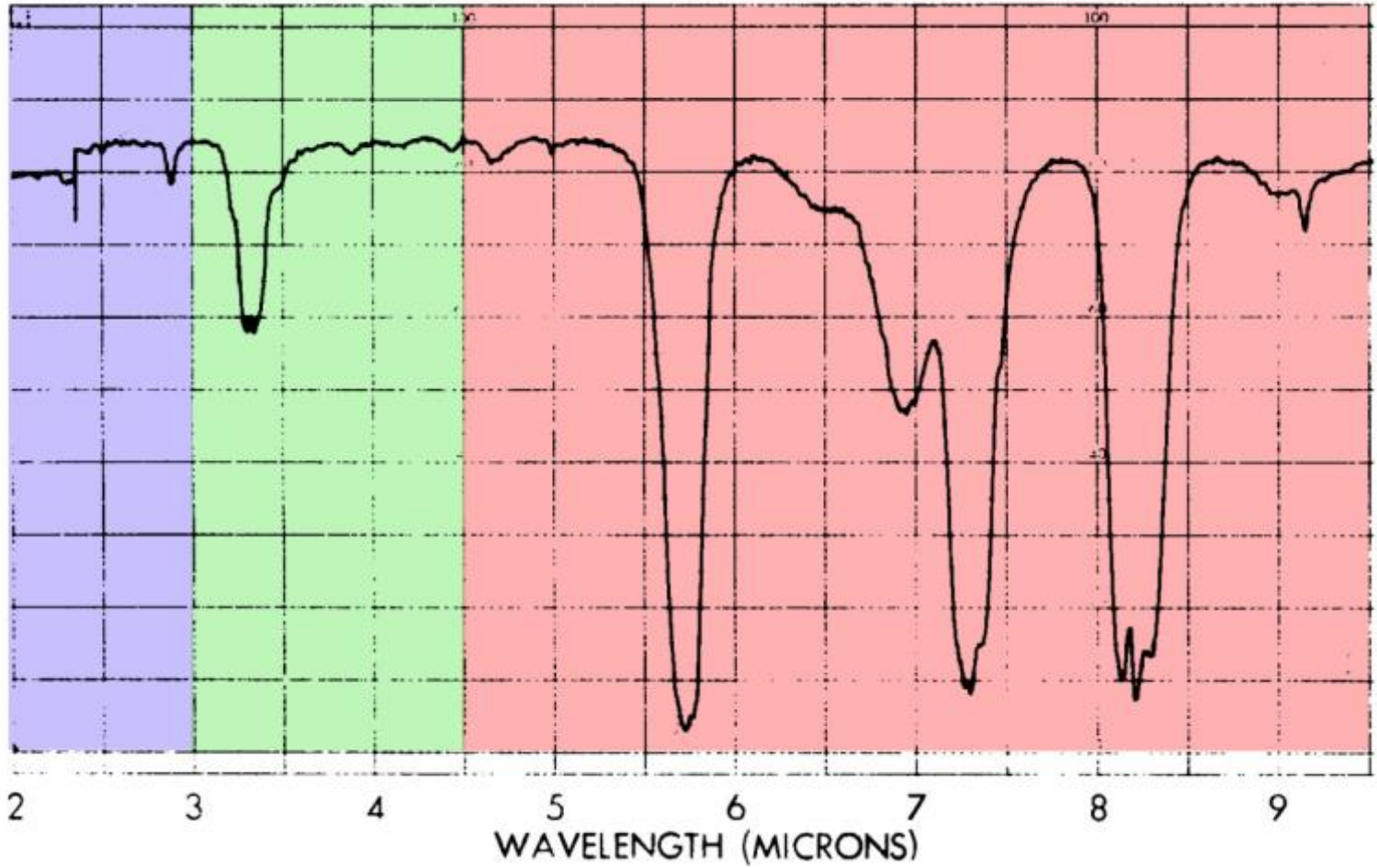
# Chemical contamination detection



# Technology refinement

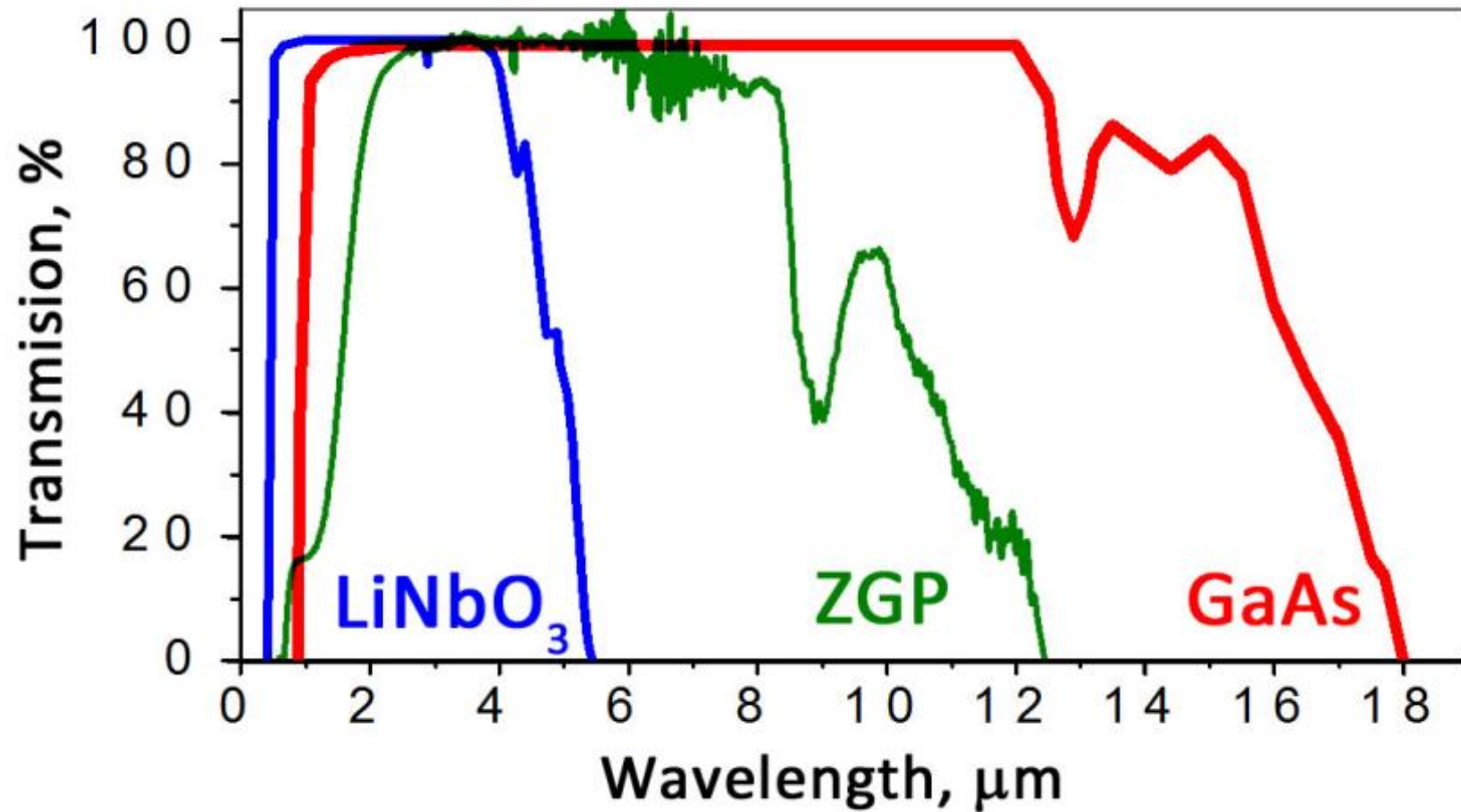


# Penetrating to deeper-IR wavelengths

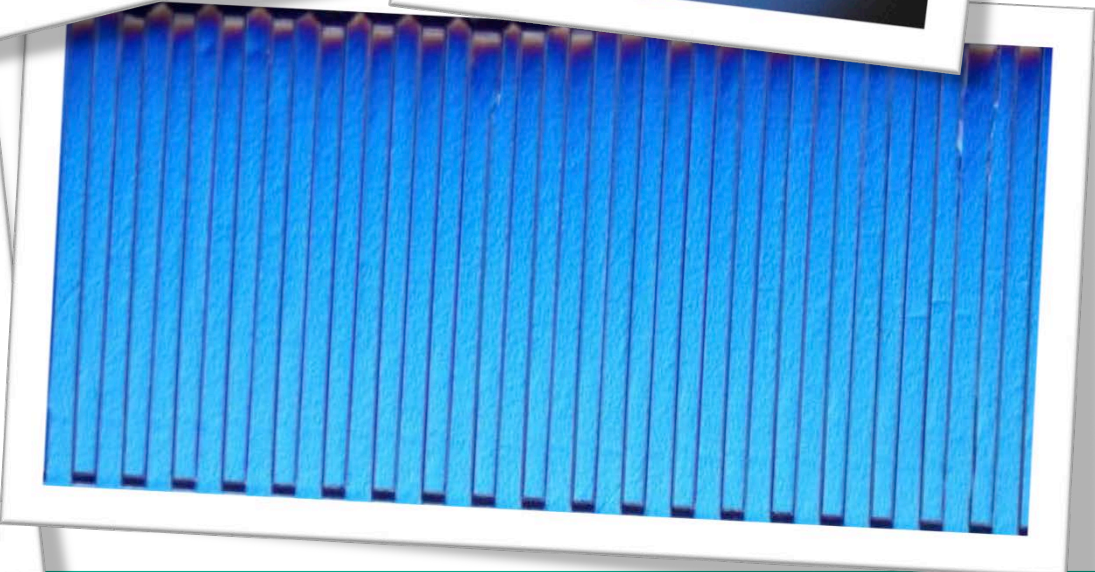
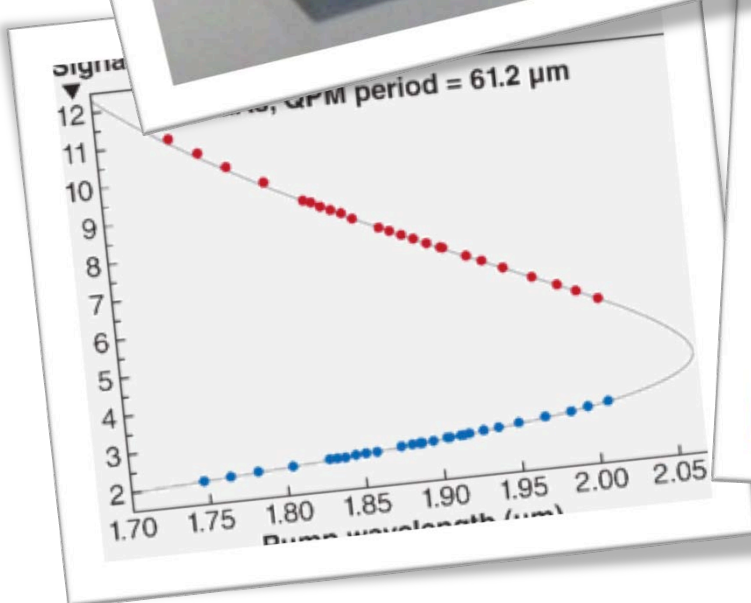
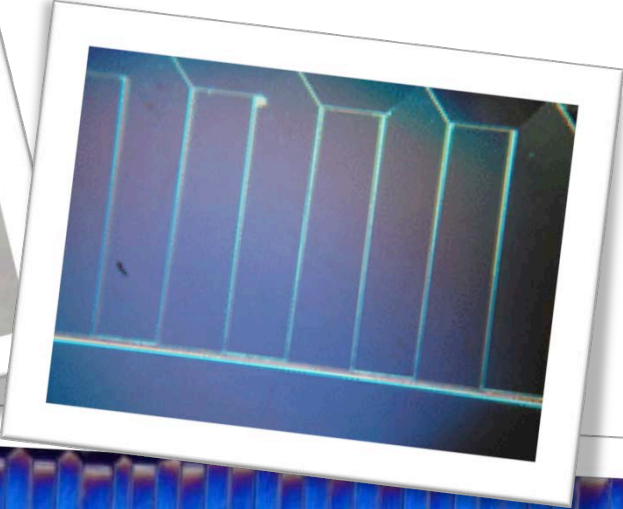
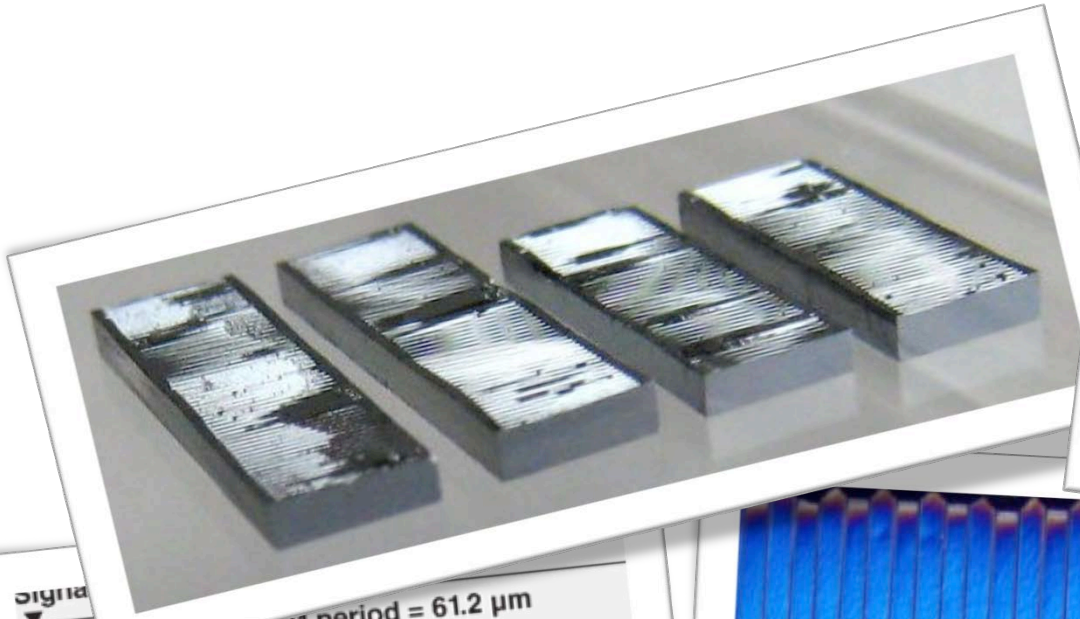




# Pushing out to the fingerprint region



# Pushing out to the fingerprint region



***Compact High Performance Quantum Cascade Laser Sensors***  
**2015-2018**

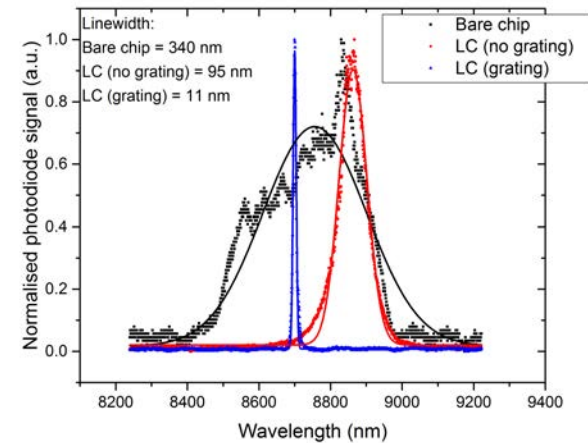
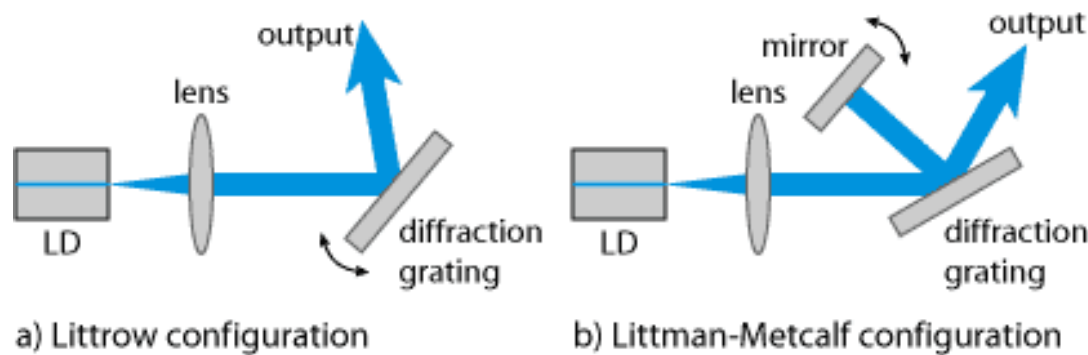
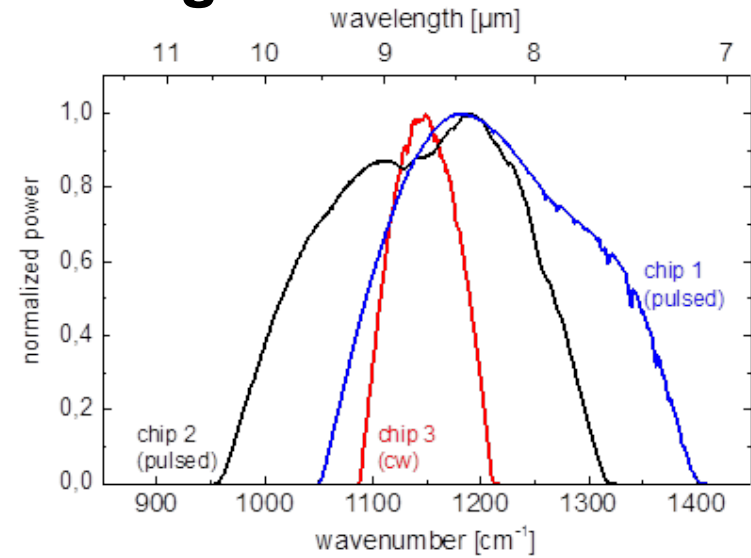
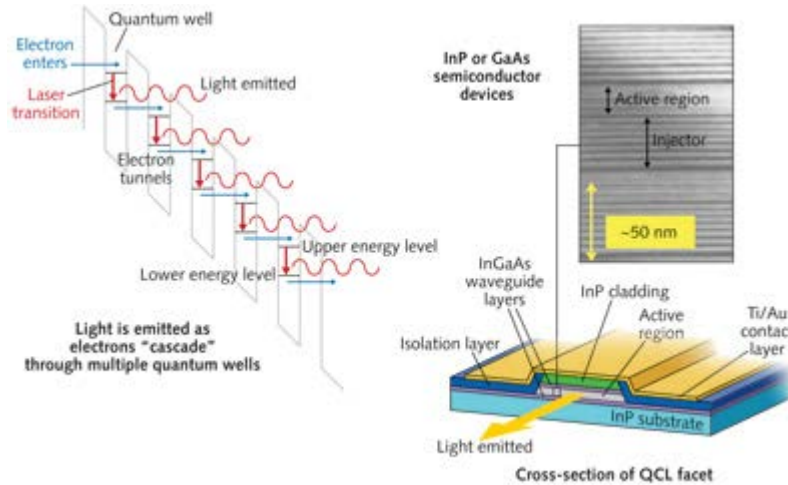
**Real-time Stand-off explosive detection using  
QCLs for security applications**

**Fraunhofer Centre for Applied Photonics  
Fraunhofer IAF  
Fraunhofer IPMS  
M Squared Lasers  
VIGO Systems  
Bundeskriminalamt**



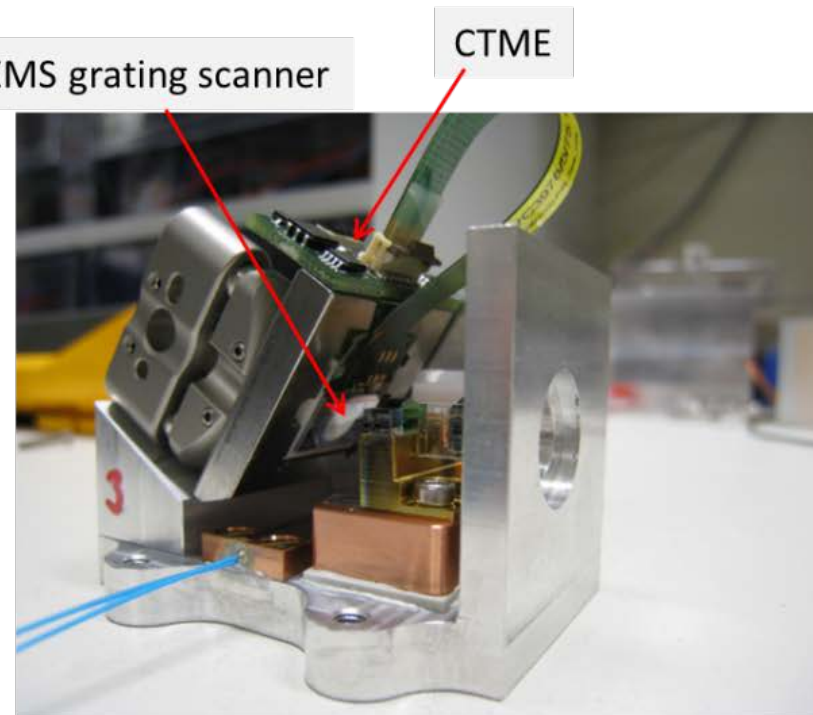
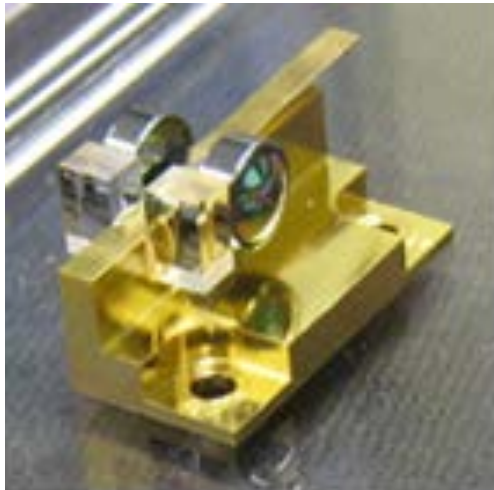
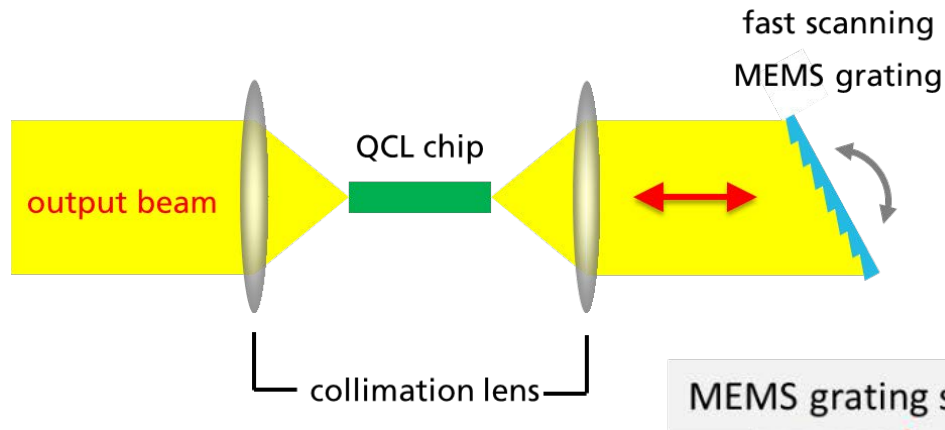
This project has received funding from the *European Union's Horizon 2020 research and innovation programme* under grant agreement No 645535

# Spectral coverage and line narrowing

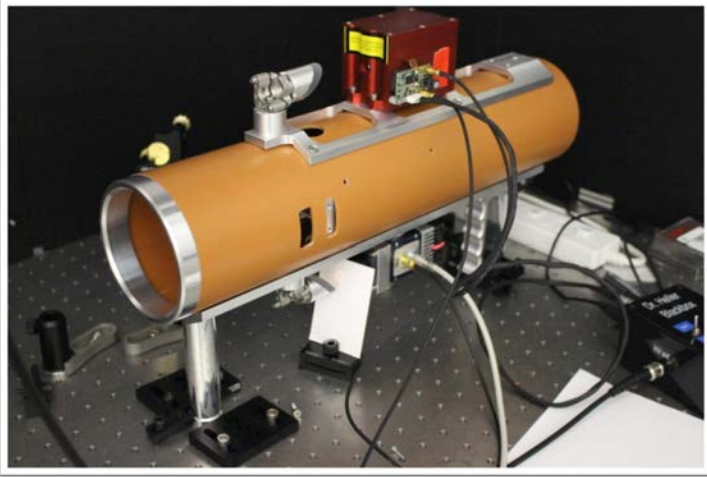
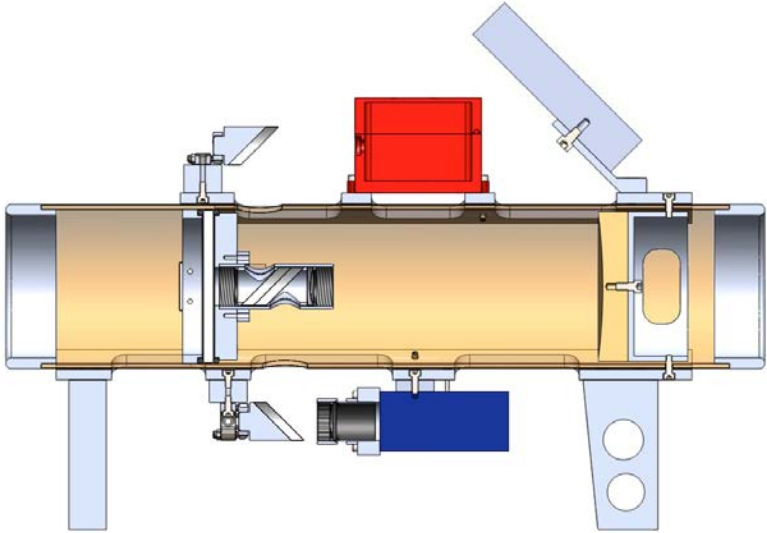
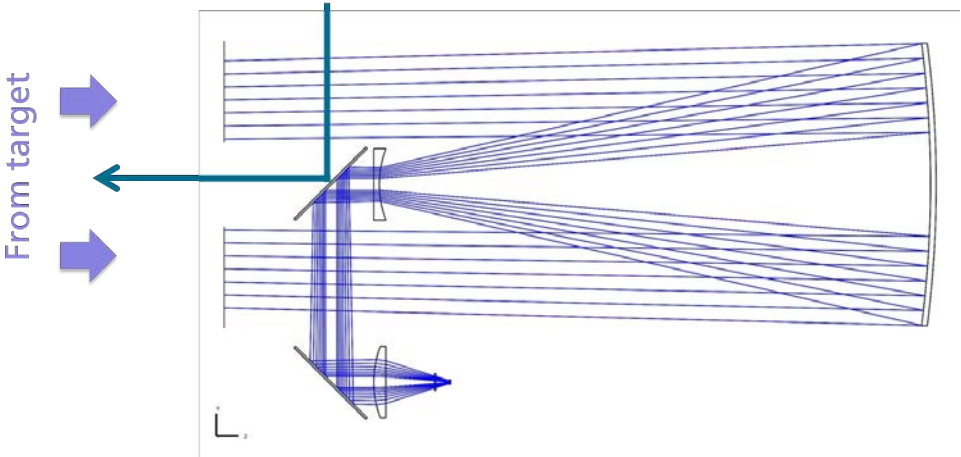




# Rapid-scan EC-QCL with MOEMS-Grating



# Optical and Mechanical Design and Fabrication



# QUANTUM TECHNOLOGIES

# Clocks and Interferometers

- Earth observation
- Science
- Navigation
- Telecommunication

## Optical clocks

- Navigation
- Timestamping and clock distribution
- Science

## Gravity

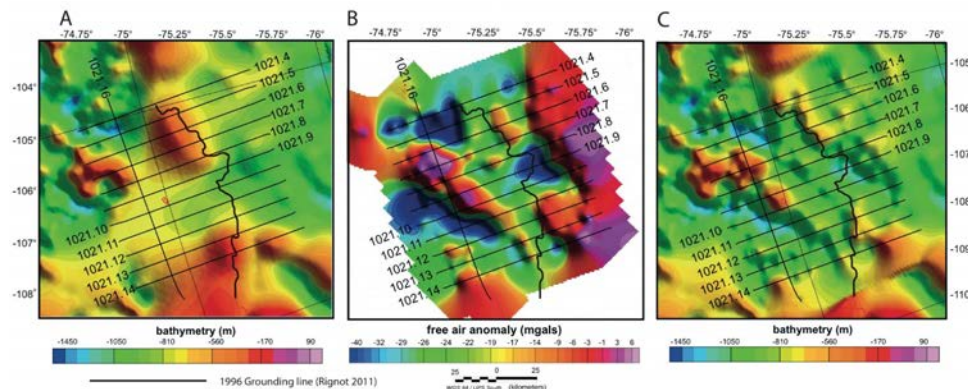
- Oil & gas exploration
- Navigation
- Precision metrology
- Geodesy
- Seismology

## Magnetic

- Geo-magnetic studies

## Internal and rotation

- Navigation





# Optical clock – ingredients

Similar to their mechanical counterparts, optical clocks rely on two fundamental principles

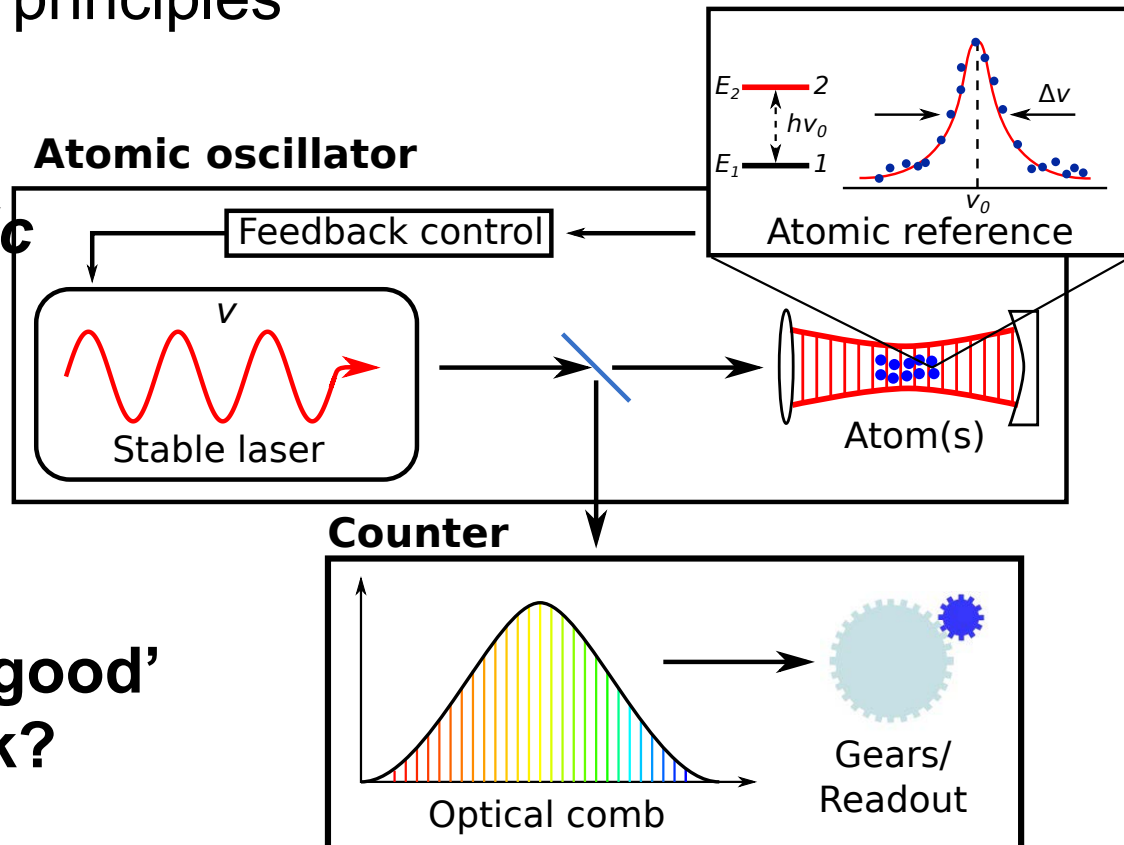
1. Periodic event  
(oscillator)

– **Optical atomic transition**

2. Counter

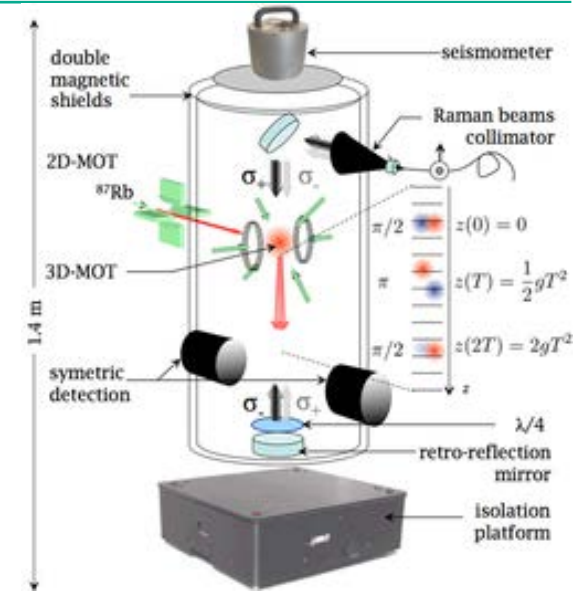
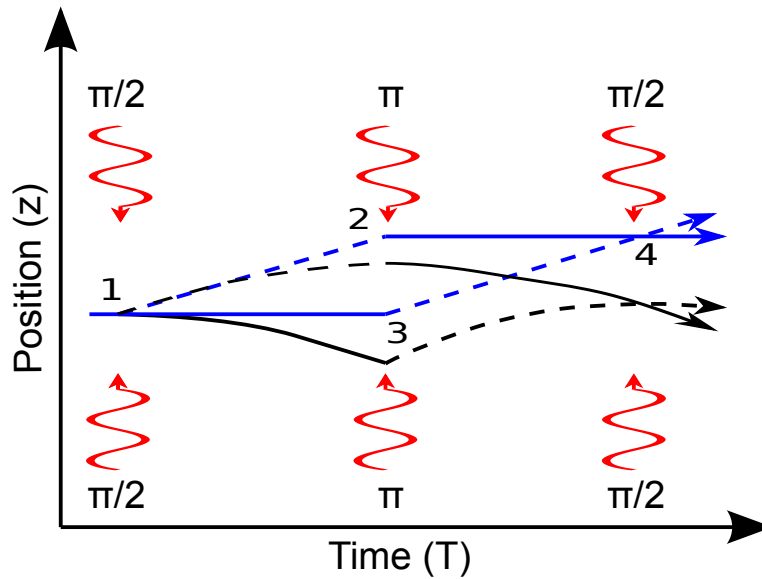
– **Frequency comb**

What makes a ‘good’ optical clock?

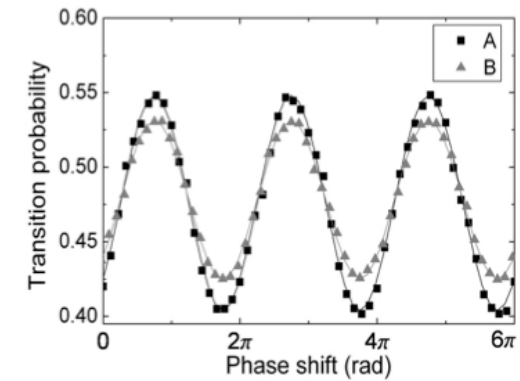


# Gravimeter

- Atom itself propagates & interferes
- Light acts as the beamsplitter & mirror



LNE-SYRTE, Paris, interferometer



**Single Frequency  
Lasers**

**Frequency Combs**

**Pulsed lasers**

**Beam delivery**

**Locking systems**

**Synchronisation  
systems**

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# Existing Fraunhofer UK QT activities

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European Space Agency (2 Projects)

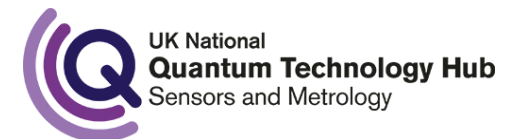
- Lasers for strontium cooling and manipulation
- 422 nm, 461 nm, 689 nm, 813 nm

Innovate UK (7 Projects, more expected)

- Lasers and systems for optical clocks
- Quantum Key distribution
- Magnetometers and Inertial Sensors

Quantum Technology Hub

- Technology demonstrators
- Component support



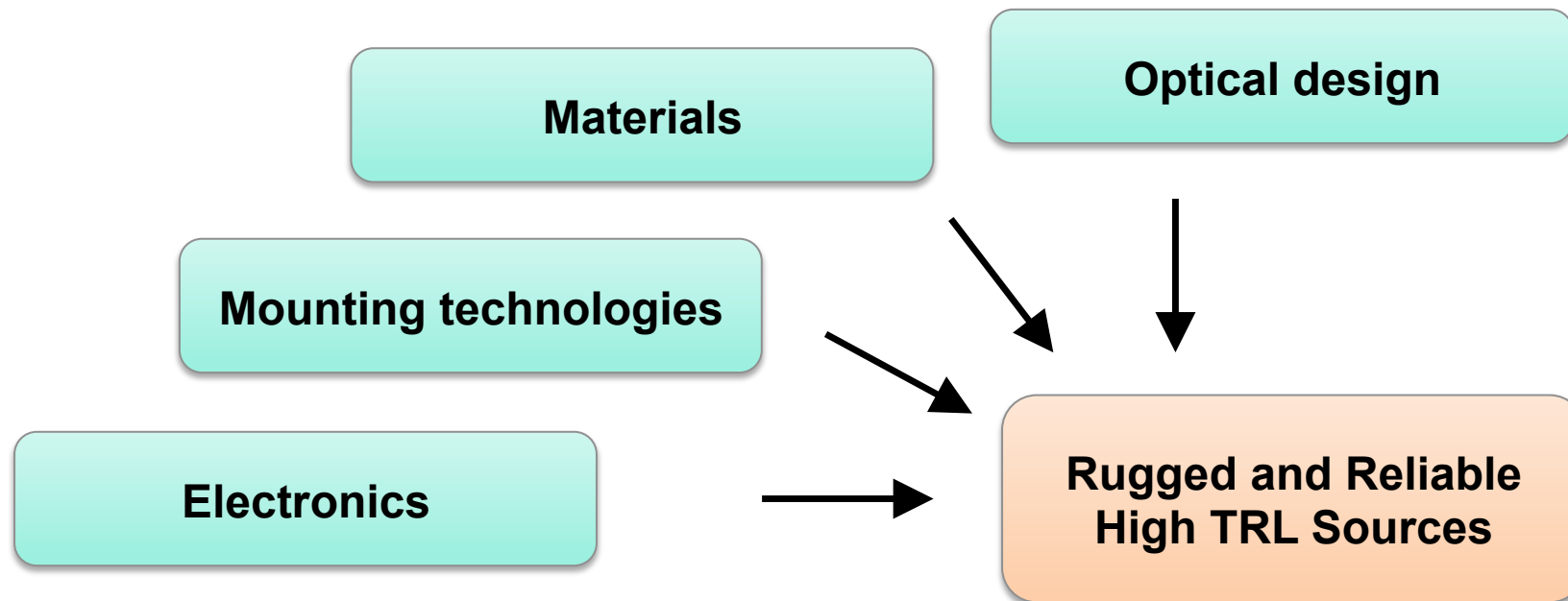


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# Technology out of the lab environment

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- High reliability
- Compact
- Vibration insensitive
- Power Efficient



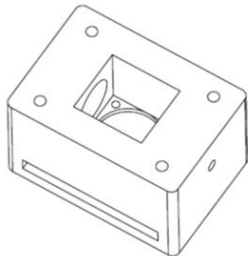
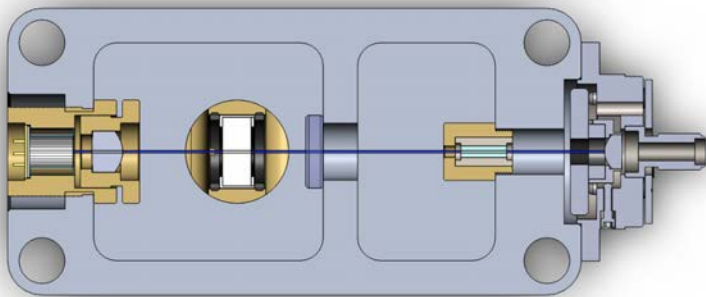
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# Diode: Rugged high-performance ECDLs

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Application: Optical clocks: cooling, pumping and clock lasers

- Many ECDL designs and solutions are not tolerant to vibrations
- We are designing compact and rugged solutions
- Working with diode manufacturers to offer unique wavelength solutions



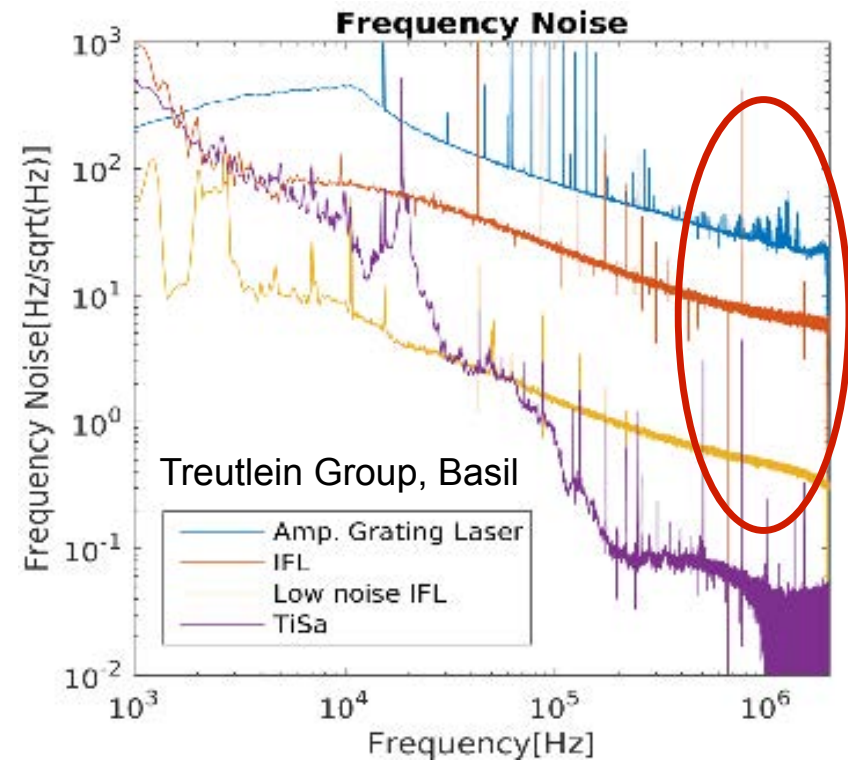
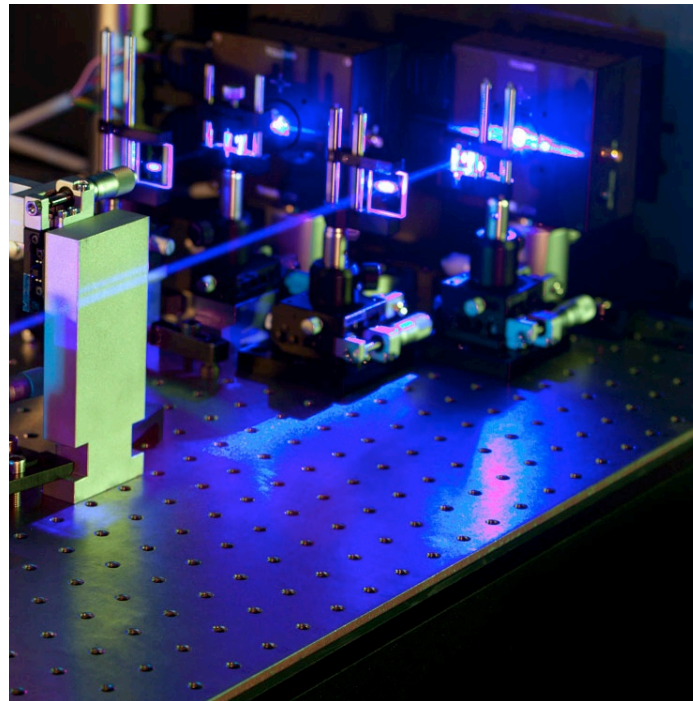
- Comparison of Stabilisation Techniques:

- Grating
  - Interference Filter
  - Etalon
  - Prism
- Environmental Testing
  - Key Performance Targets

# Solid-State: Spectral purity low-noise

Application: Optical clocks, Trapping lasers and cooling lasers

- Diode-pumped solid-state lasers have excellent properties
- High frequency noise low compared to diodes



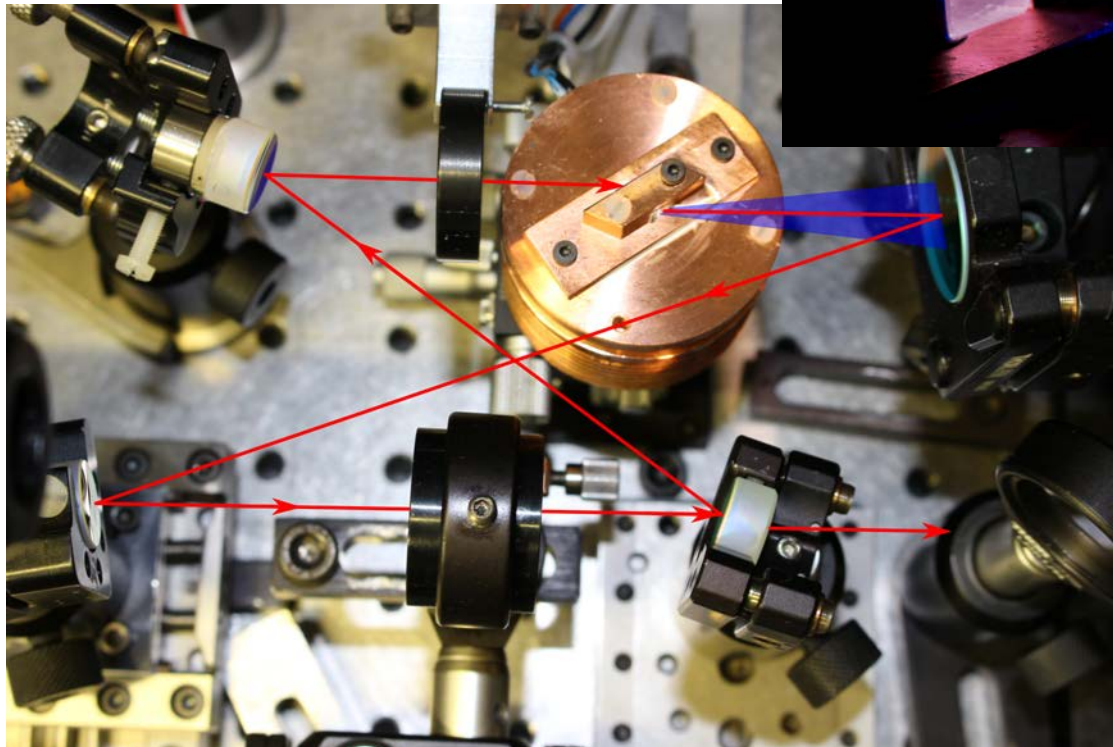
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# Solid-State: Spectral purity low-noise

---

Application: Optical clocks, Trapping lasers and cooling lasers

- High power from simple 'dirty' electronics
- High spectral quality (no background ASE)

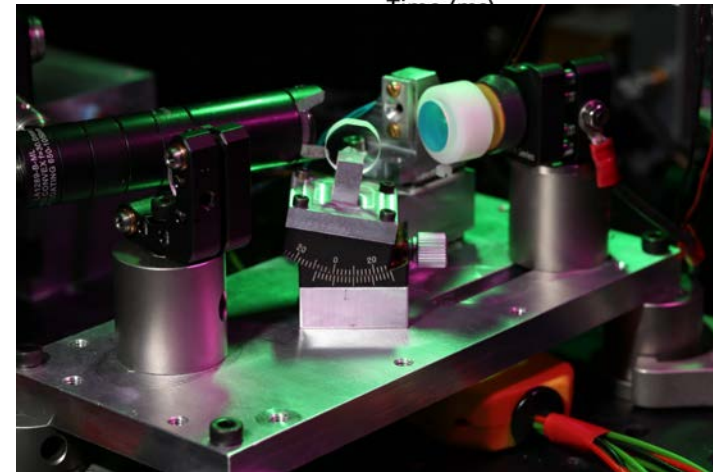
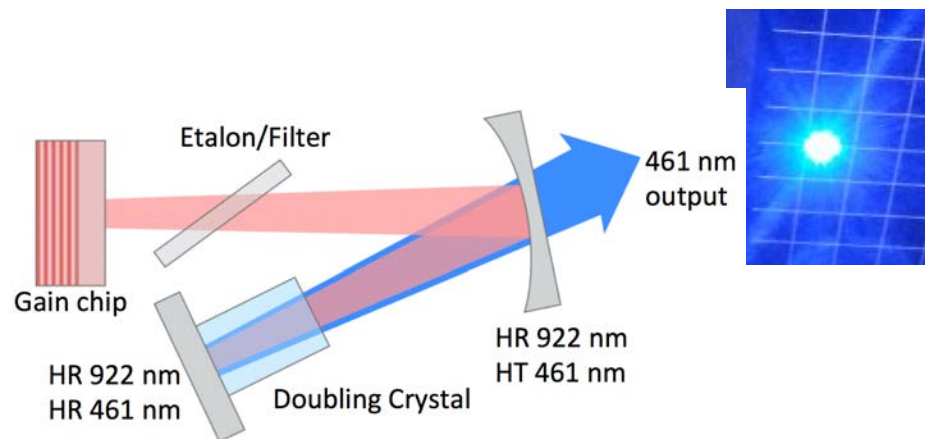
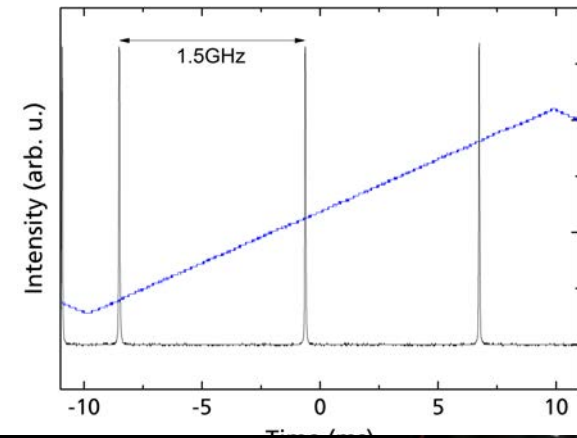


- Reduction in SWaP
- Reliable performance
- Meet target specifications

# Semiconductor Disk Lasers

Application: Optical clocks, Trapping lasers and cooling lasers

- SDLs offer excellent beam quality.
- Can select wavelength by design.
- Developing compact units suitable for vibration-heavy environments





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# Summary

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- Wind Lidar activities
- Stand-off spectroscopy
- Quantum technologies

Opportunity to collaborate in many areas where Fraunhofer CAP have unique technologies and skills.

# Thank you!

