Linear sweep of telecoms lasers for Optical Coherence Tomography (OCT) applications

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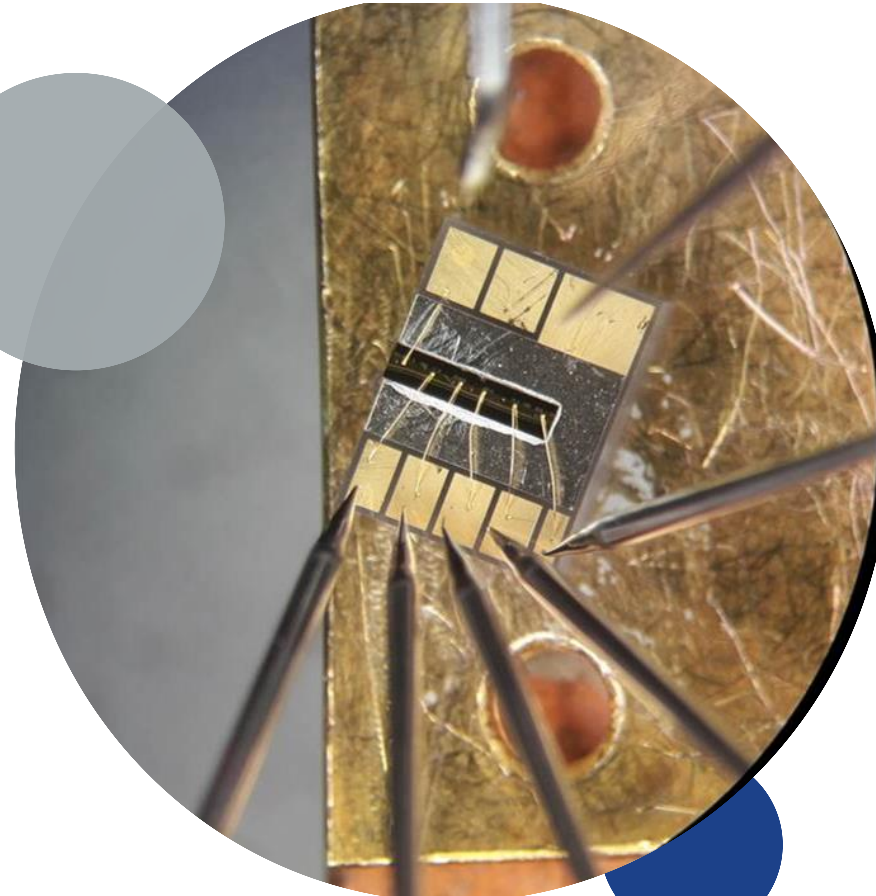

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Outline

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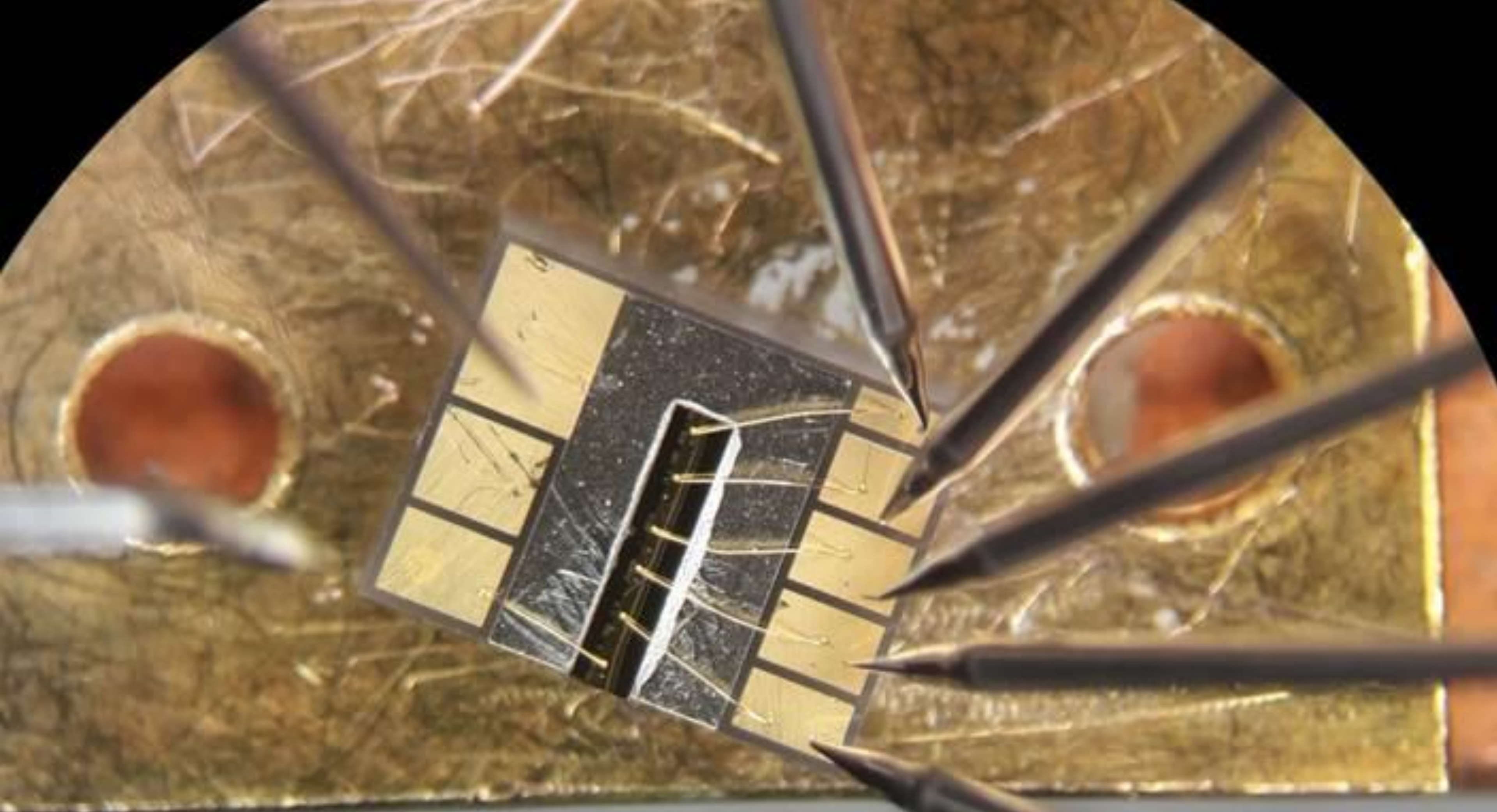
- Motivation and Main Learning
- Optical Coherence Tomography (OCT) basics
- Research Methods
- Results



Motivation and Main Learning

Control techniques of a telecoms multi-section tunable laser in order to perform Swept Source OCT.

OCT Basics – Medical case

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1

Patient with gastrointestinal discomfort

2

Clinician performs an endoscopy

3

Abnormal tissue is detected

4

A Biopsy is taken

5

Sample is sent to the lab

OCT Basics – Medical case

1


Patient with gastrointestinal discomfort

2


Clinician performs an endoscopy

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Abnormal tissue is detected

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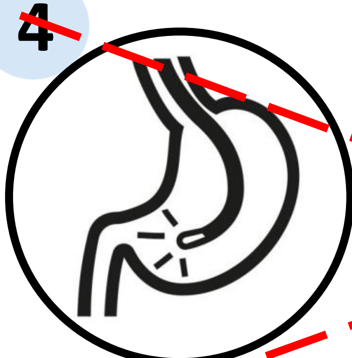
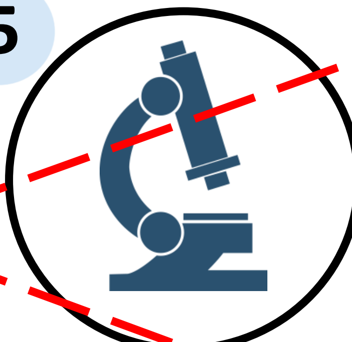
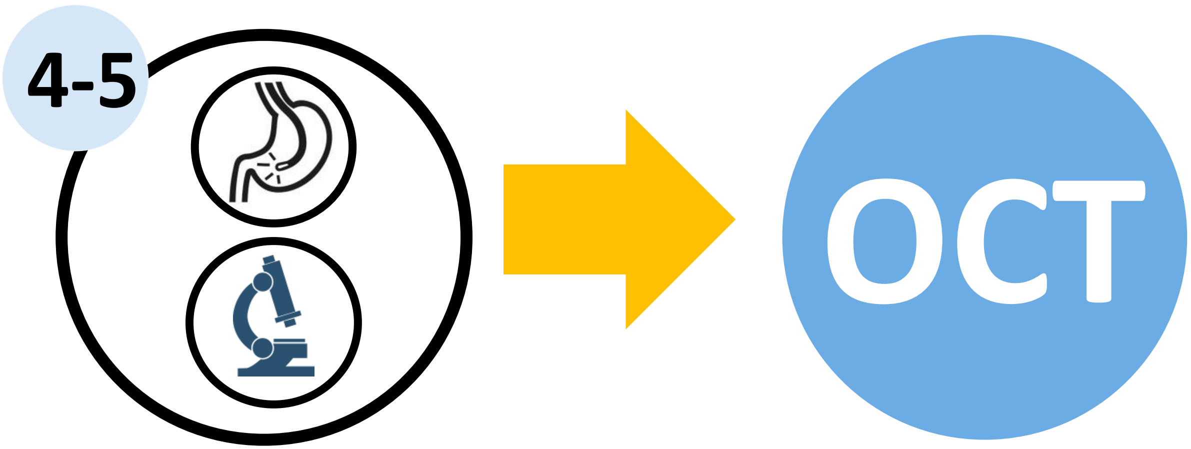


A Biopsy is taken

5


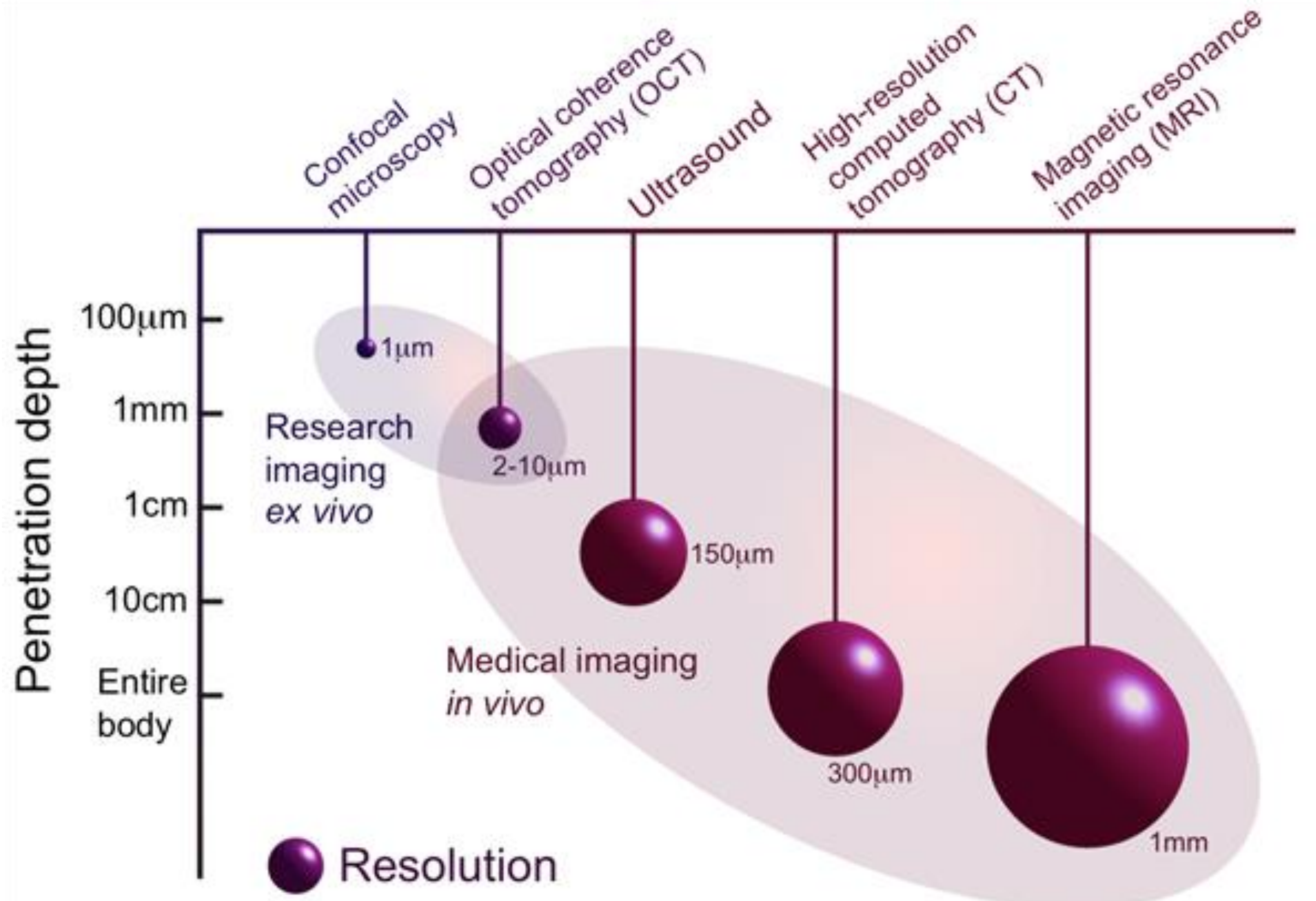
Sample is sent to the lab

OCT Basics – Medical case



- Is it possible to avoid taking a biopsy?
- Is there an optical technology that can generate an ‘optical biopsy’ as a 3D image with morphological data?

OCT Basics – Comparison of OCT

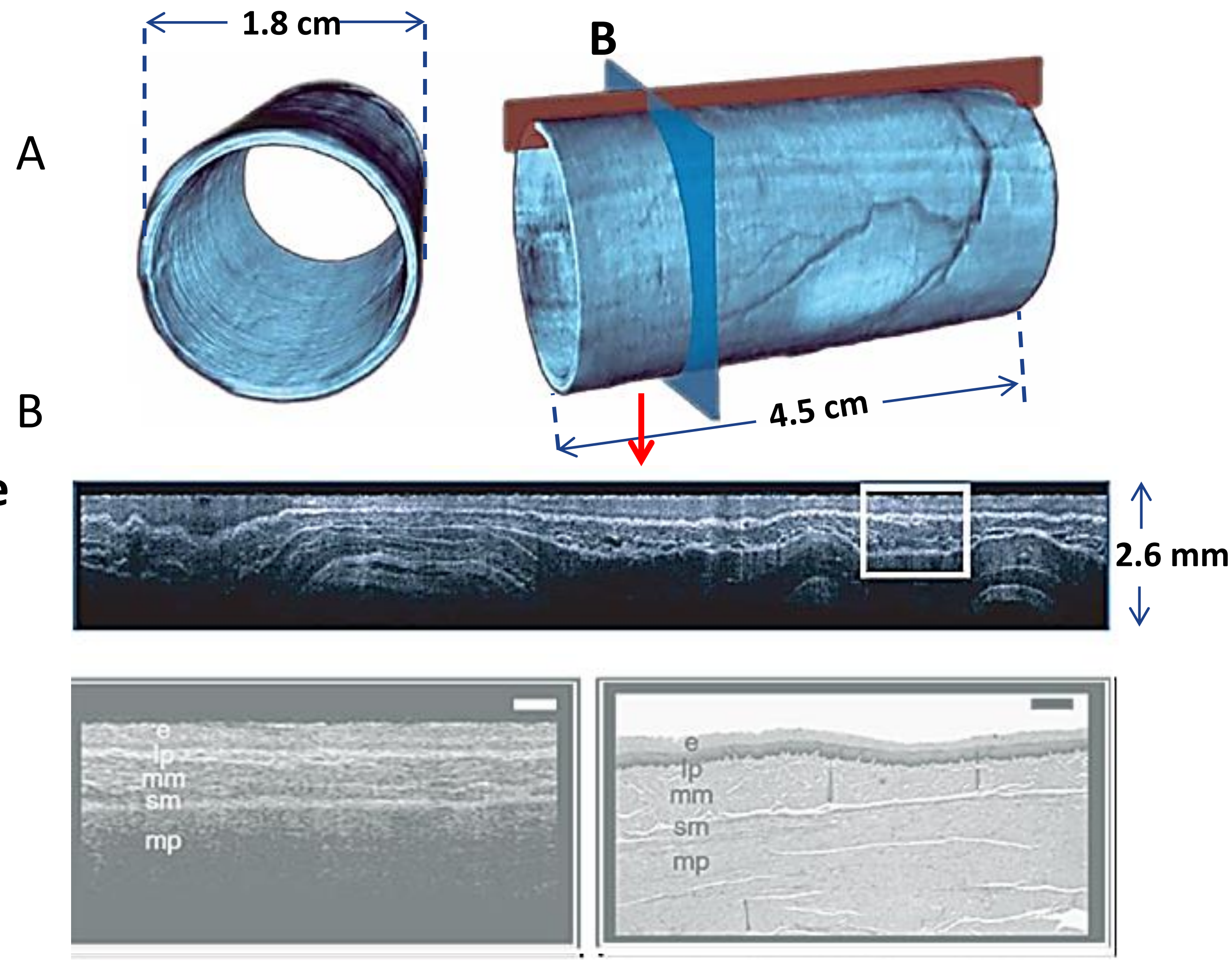


Optical + Biomedical Engineering Laboratory. The University of Western Australia

OCT Basics – OCT images

A - 3D cylinder of Porcine esophagus. Dimensions measured with the **morphological** OCT capabilities.

B - Unwrapped **transverse section** showing layered structure

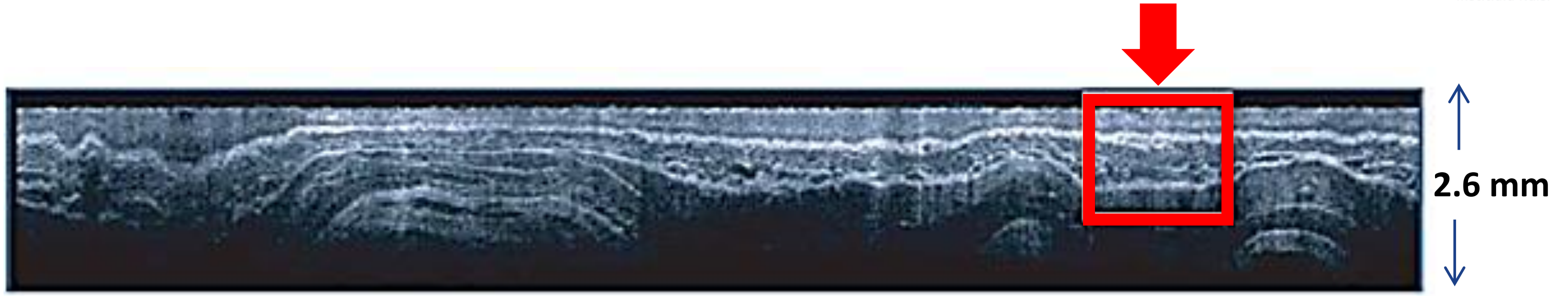


Comprehensive OCT image of a Porcine esophagus

1. S. Yun, E. Bouma, et.al. "Comprehensive volumetric optical microscopy in vivo". Nature medicine Vol. 12 (2006)

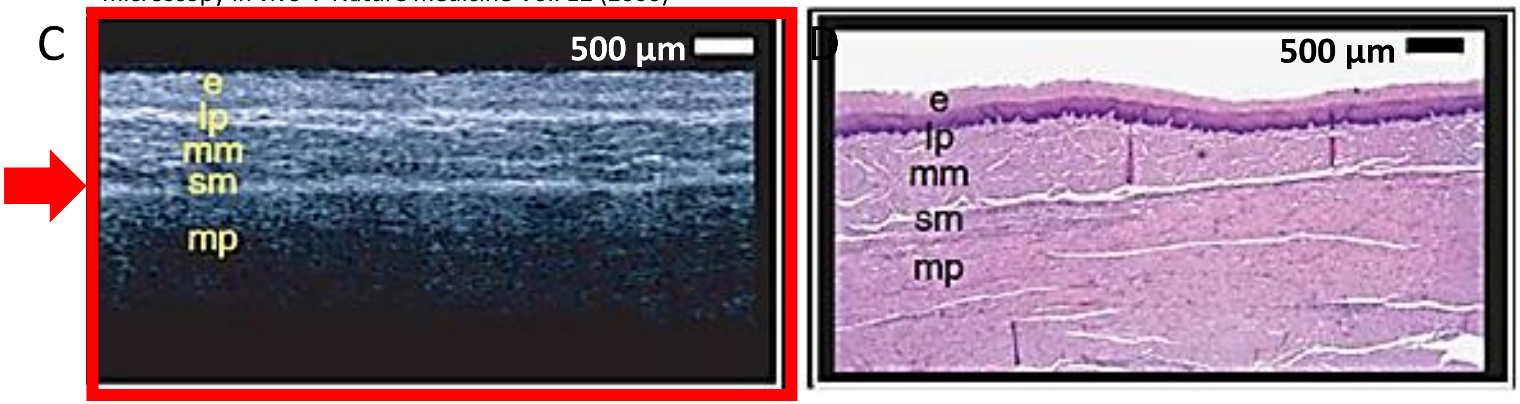
OCT Basics – OCT images

B



1. S. Yun, E. Bouma, et.al. "Comprehensive volumetric optical microscopy in vivo". Nature medicine Vol. 12 (2006)

C



C - Magnified version of 'B' showing the inner sub layers of the esophageal wall. e- squamous epithelium, lp – lamina propria, mm – muscularis mucosa, sm – submucosa, mp – muscularis propria

D - Corresponding histology section of B

OCT Basics - What is OCT?

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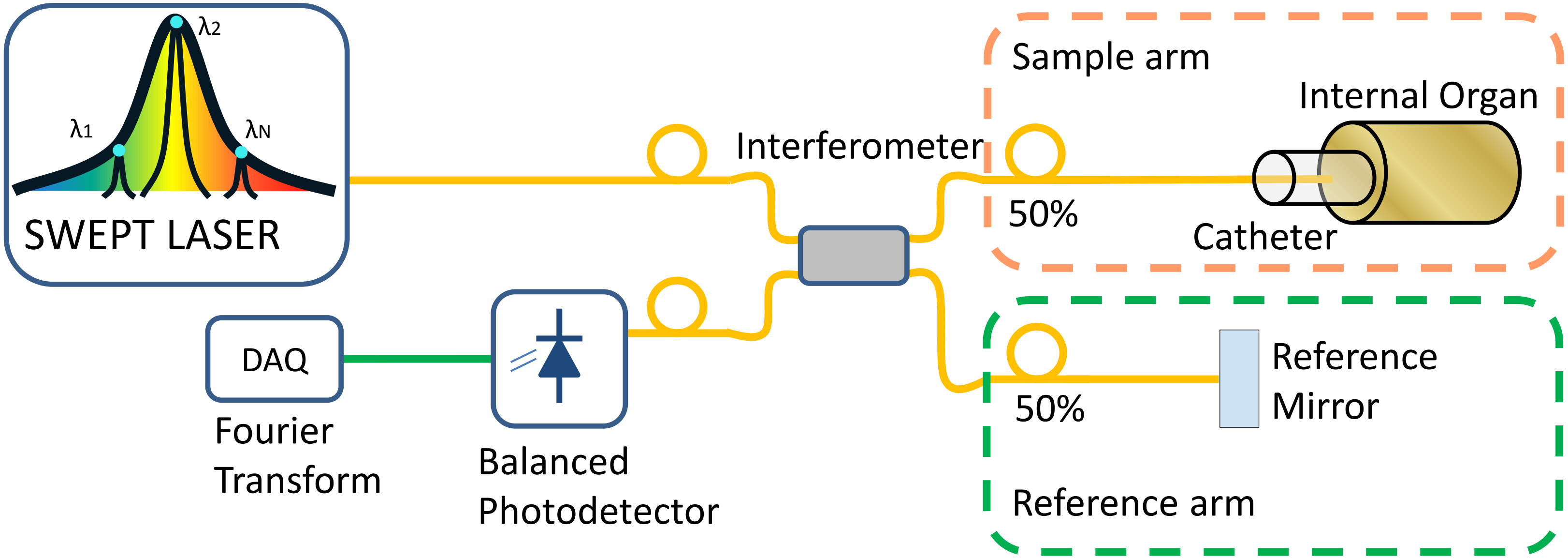
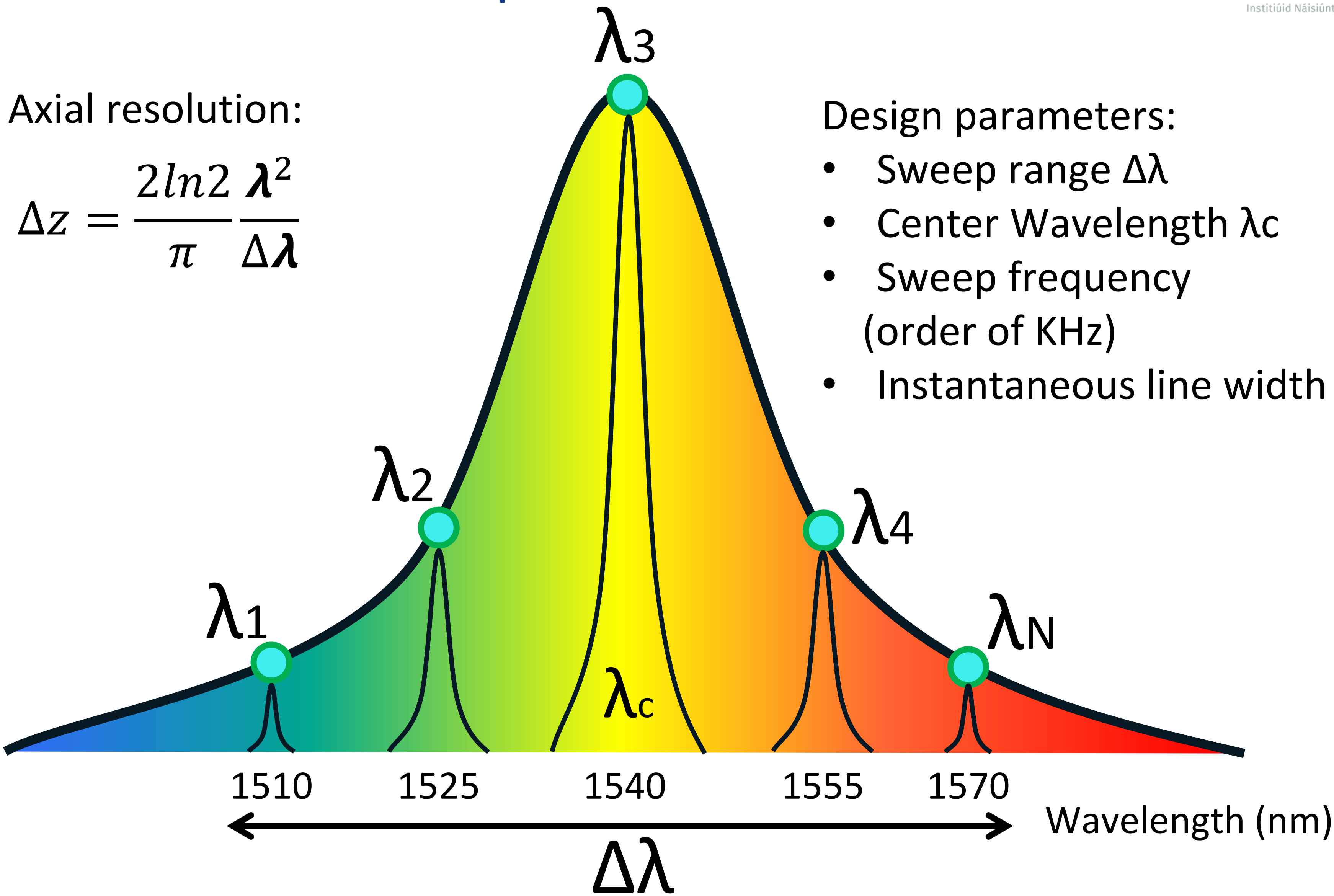


- Low coherence interferometry technique, where interference occurs when the path lengths are matched to within the coherence length
- Axial resolution decoupled from lateral resolution

OCT Basics - Swept Source

Axial resolution:

$$\Delta z = \frac{2ln2}{\pi}\frac{\boldsymbol{\lambda}^2}{\Delta\boldsymbol{\lambda}}$$



Design parameters:

- Sweep range Δλ
- Center Wavelength λc
- Sweep frequency (order of KHz)
- Instantaneous line width

How to design a swept source?

Tunable Telecommunication Lasers

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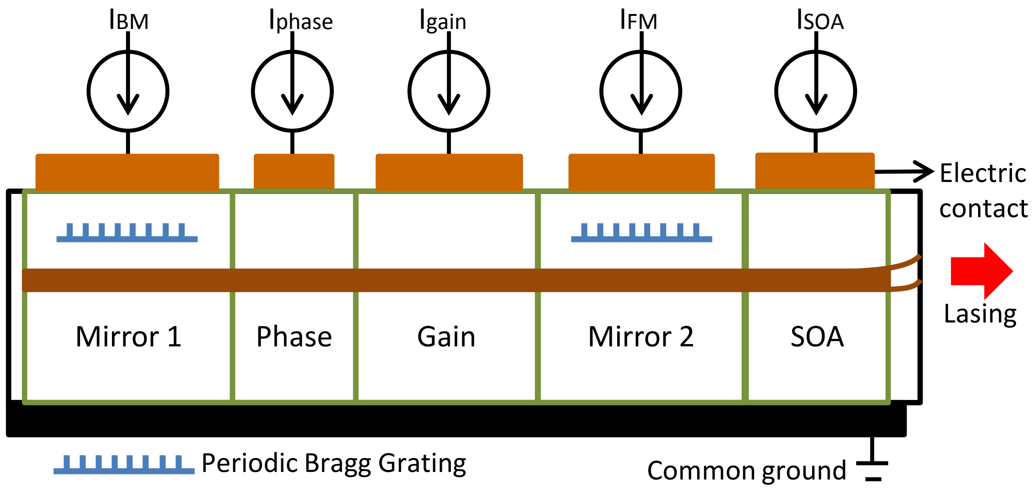
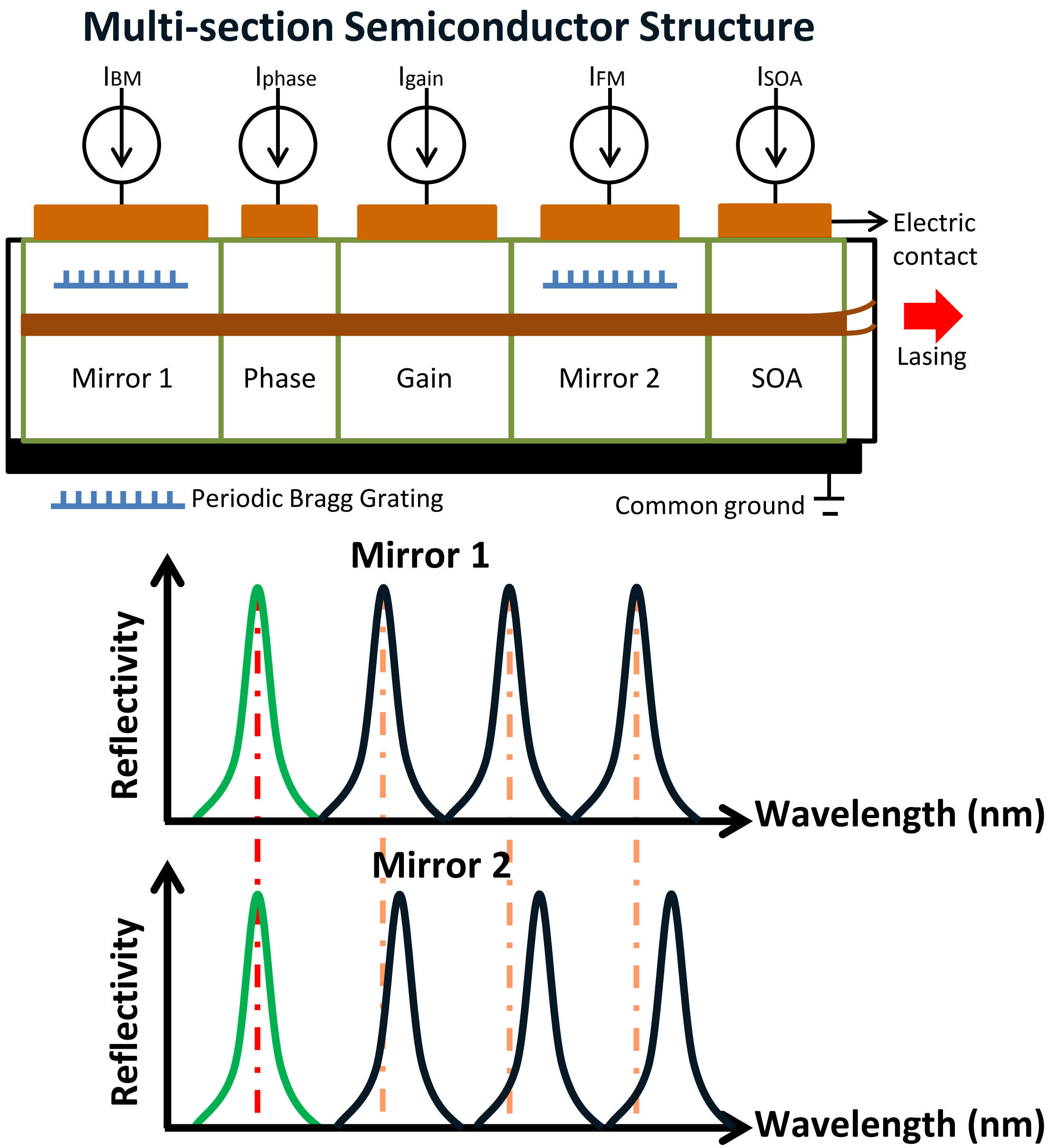
Multi-section Semiconductor Structure



- 5 section laser: 2 Vernier Mirrors , Phase, Gain, Semiconductor Optical Amplifier (SOA)
- Fast wavelength tuning speed (≈ 5 ns)
- All-electronically tunable laser without mechanical parts (Vernier tuning)

Tunable Telecommunication Lasers



Tunable Telecommunication Lasers

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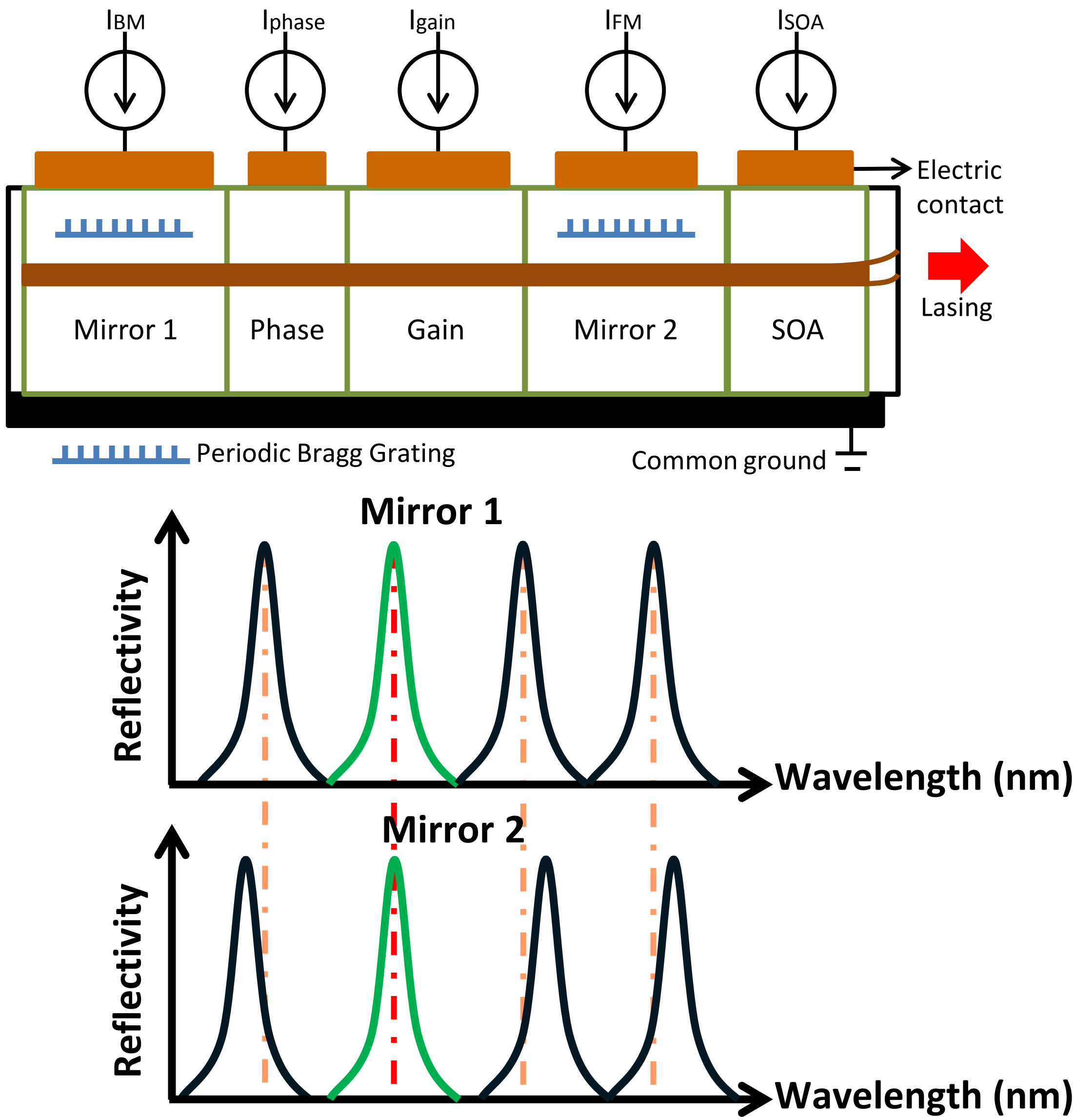
Multi-section Semiconductor Structure



Tunable Telecommunication Lasers

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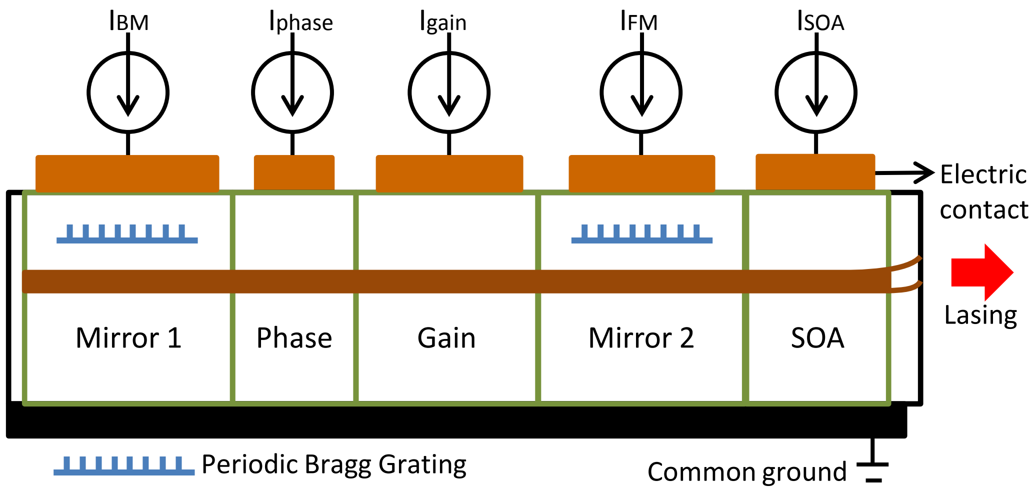
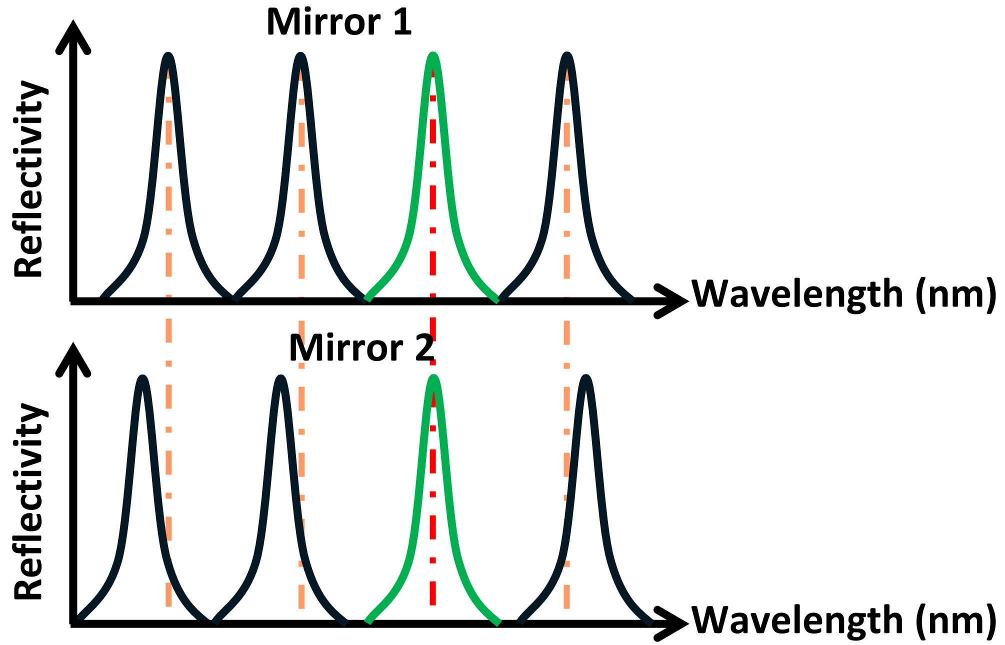
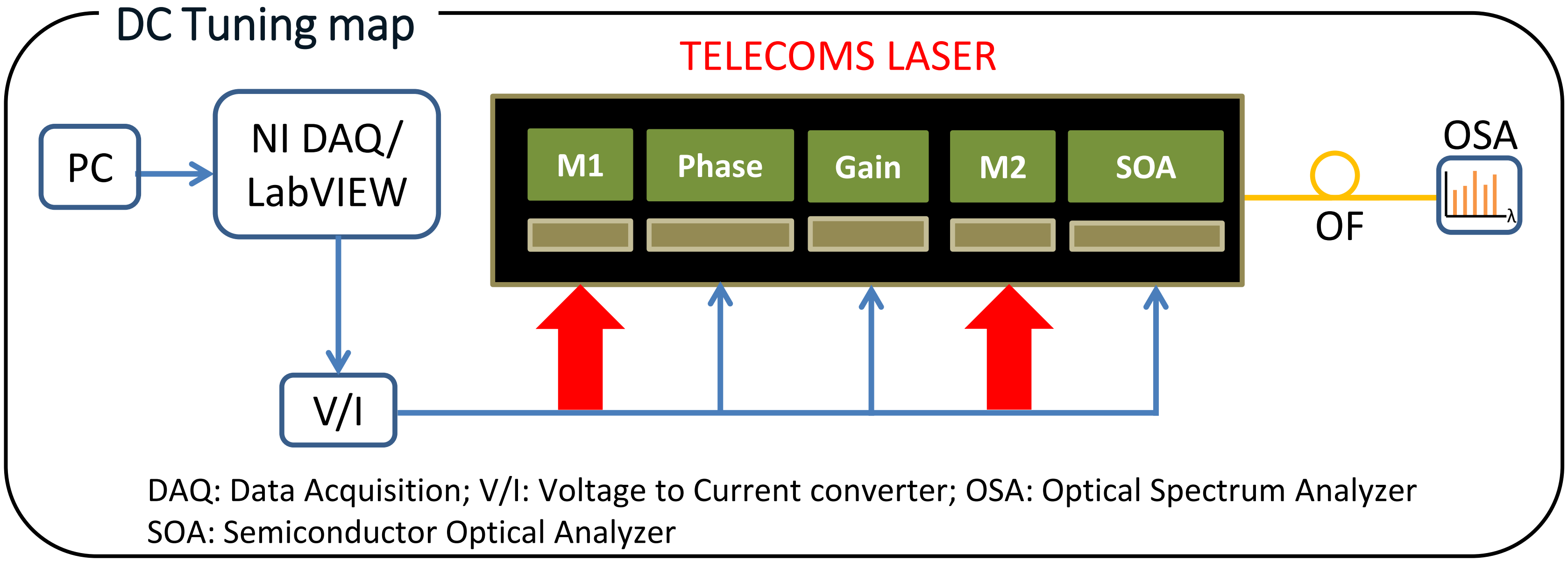
Multi-section Semiconductor Structure



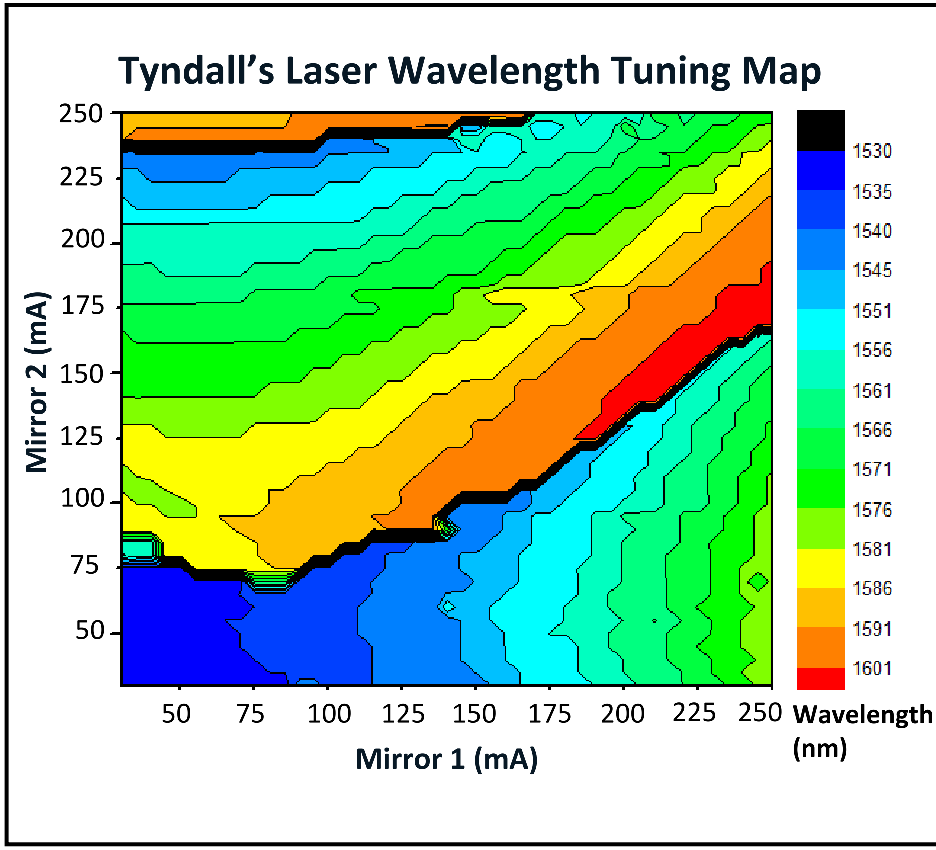


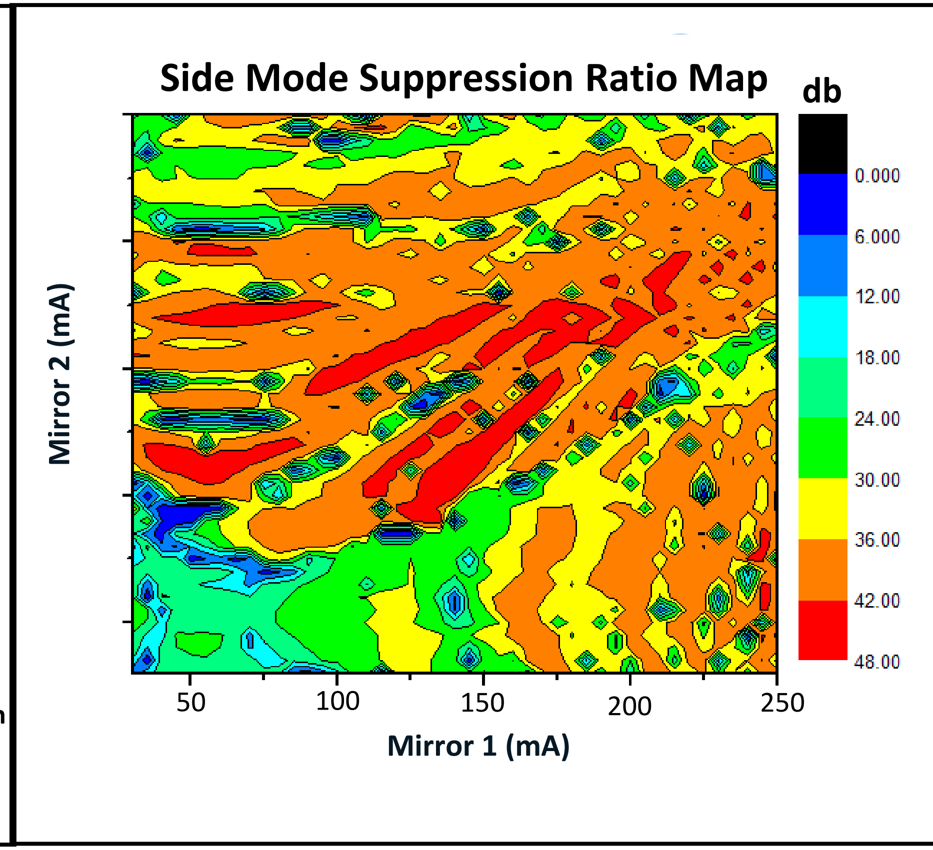
Experimental Setup



- Setup to obtain a *DC TUNING MAP*
- M1 and M2 are tuned while phase, gain and the Semiconductor Optical Aanalyzer (SOA) have a fixed bias

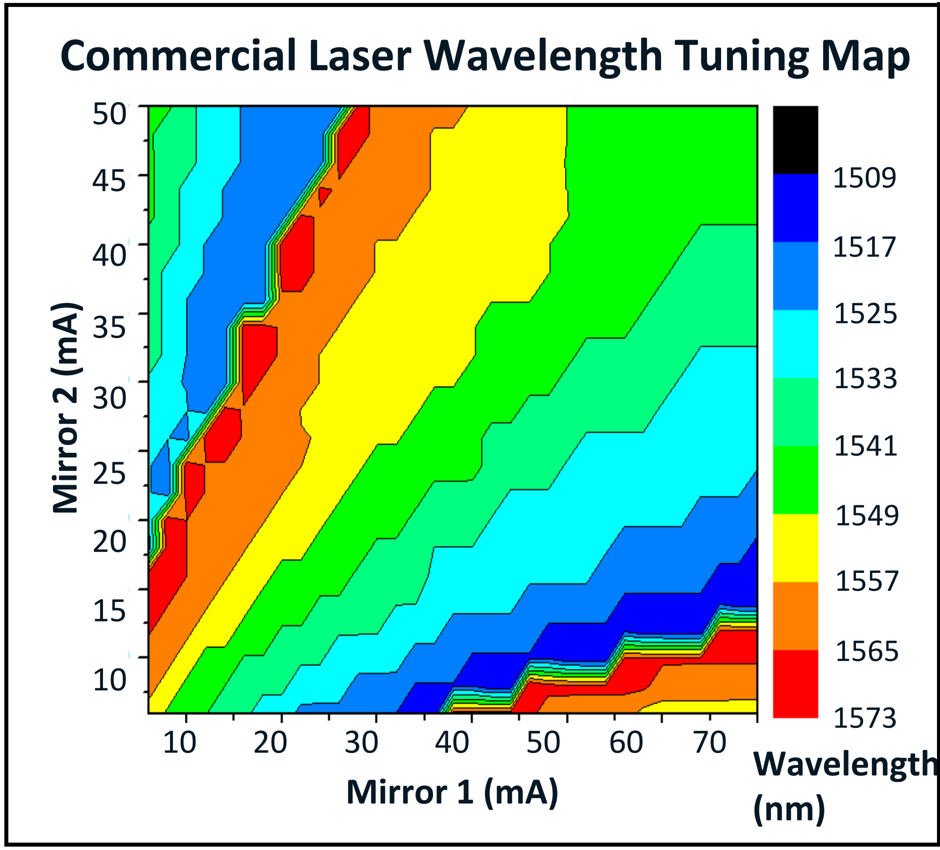
RESULTS
DC MODE

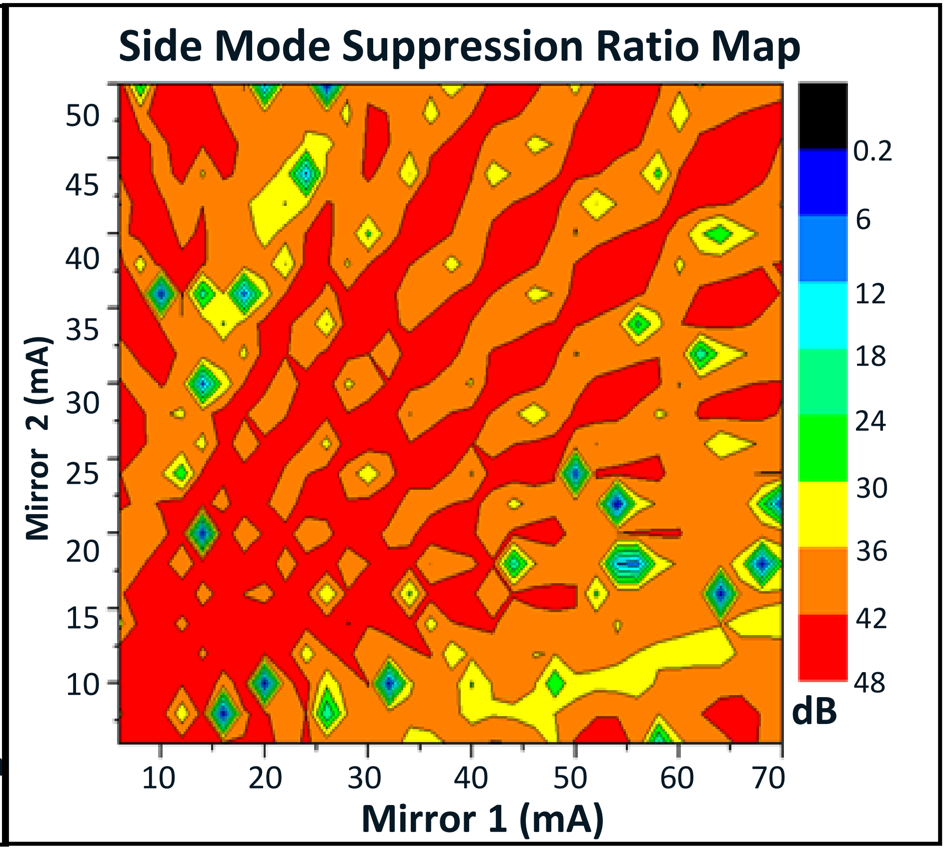




RESULTS – HOME MADE LASER DC TUNING MAPS

- Good wavelength coverage from 1535-1600 nm (65 nm)
- Acceptable single mode operation
- Tuning paths can be identified



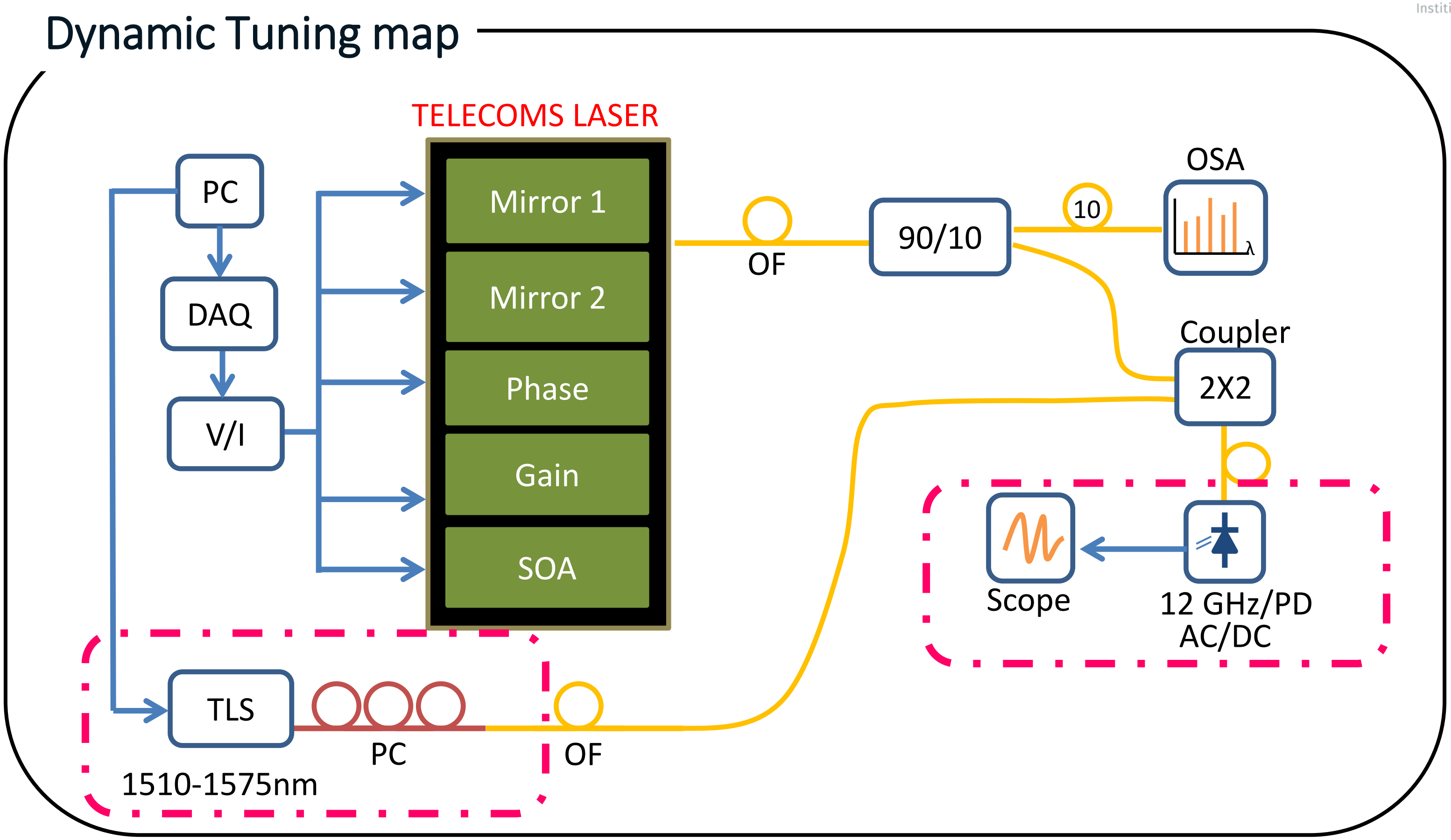


RESULTS – COMMERCIAL LASER TUNING MAPS

- Good wavelength coverage from 1510-1570 nm (60 nm)
- Very good SMSR ratio – single mode operation
- Mode-hopping between the borders of the tuning paths

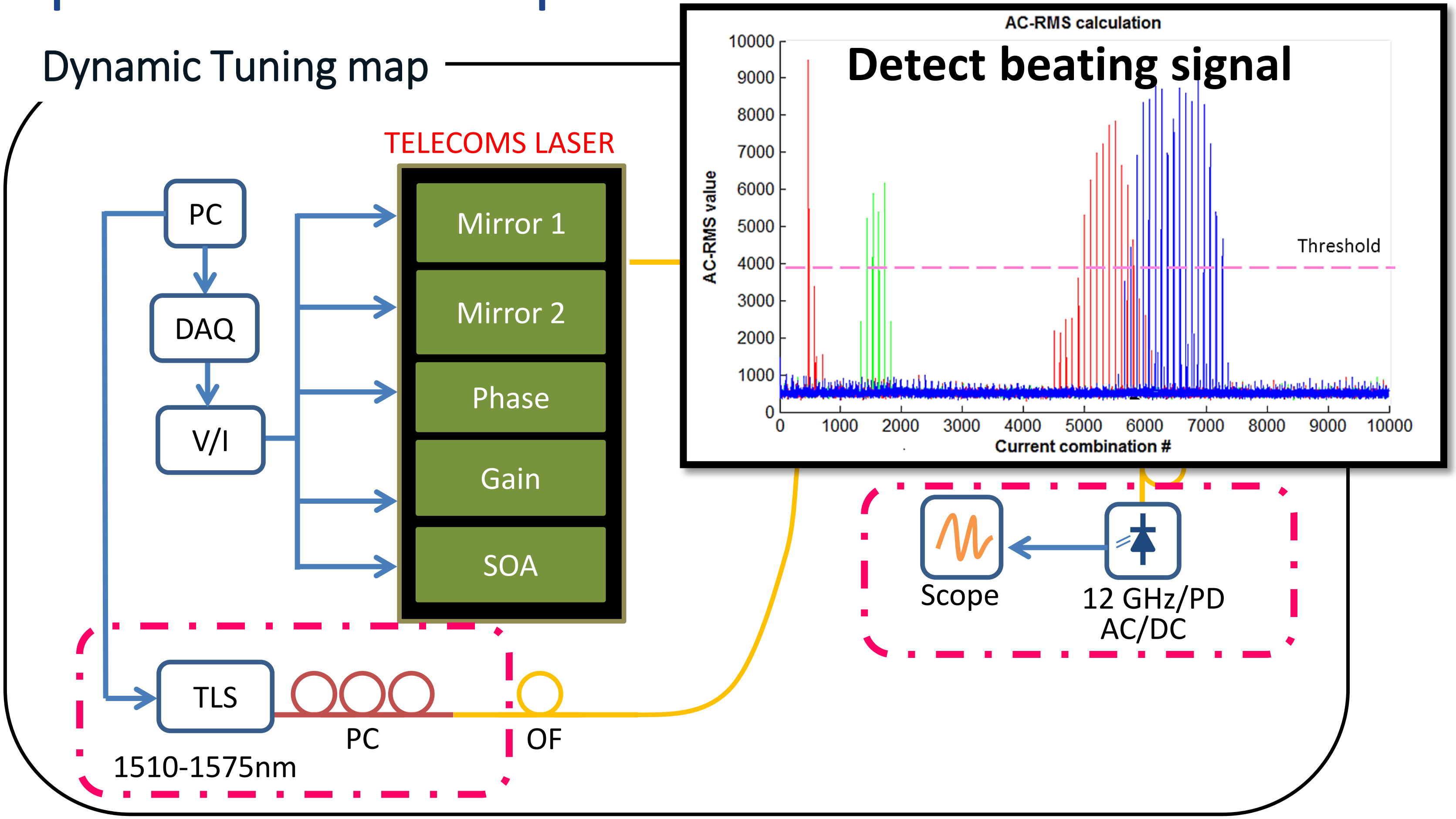
RESULTS
DYNAMIC MODE

Experimental Setup



- Setup to obtain a ***Dynamic Tuning Map***
- Add an external Tunable Laser Source (TLS), combine it with the Telecoms Laser and measure a beating signal

Experimental Setup



- Setup to obtain a ***Dynamic Tuning Map***
- Add an external Tunable Laser Source (TLS), combine it with the Telecoms Laser and measure a beating signal

Results – Dynamic Tuning Map Commercial Laser

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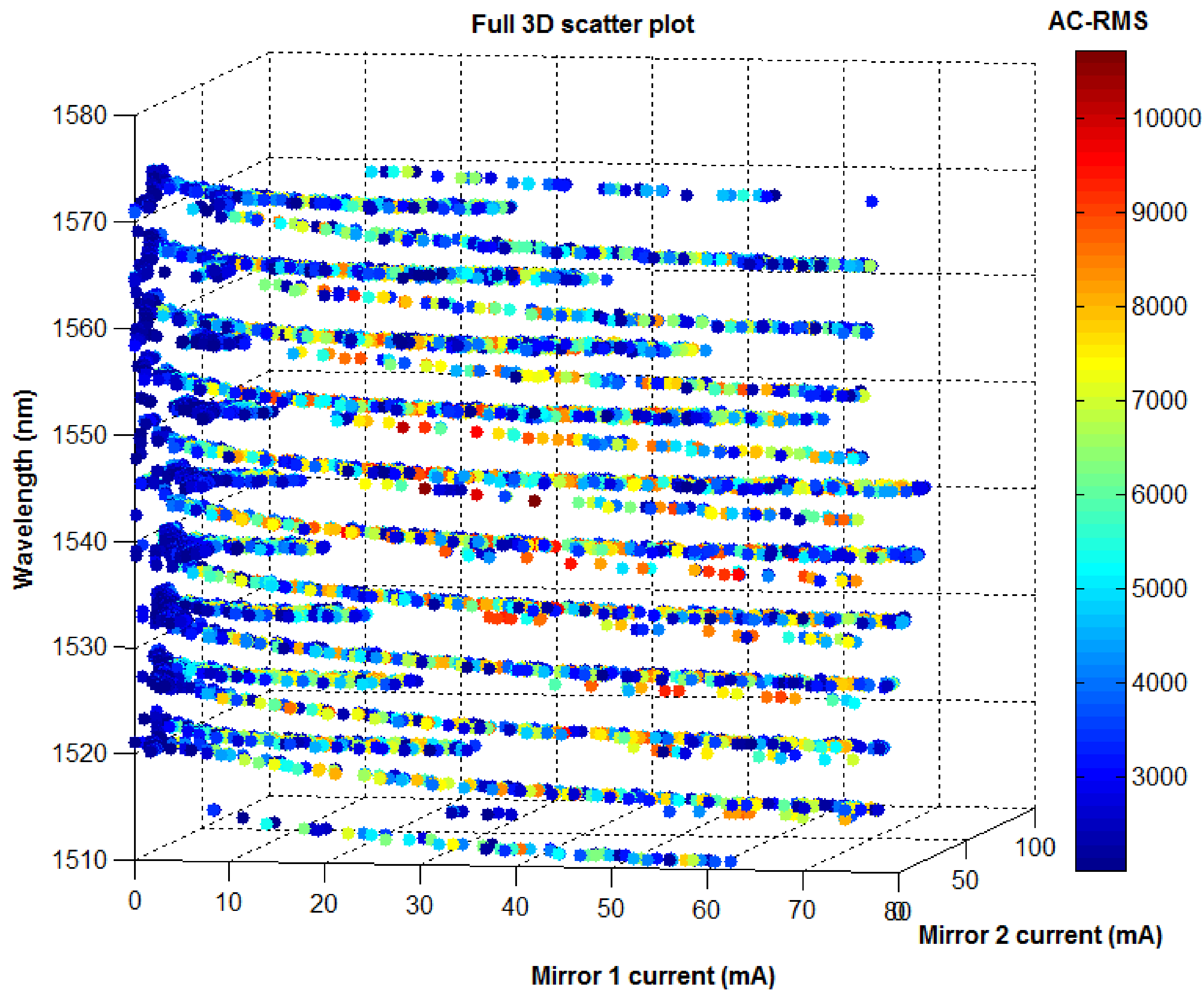
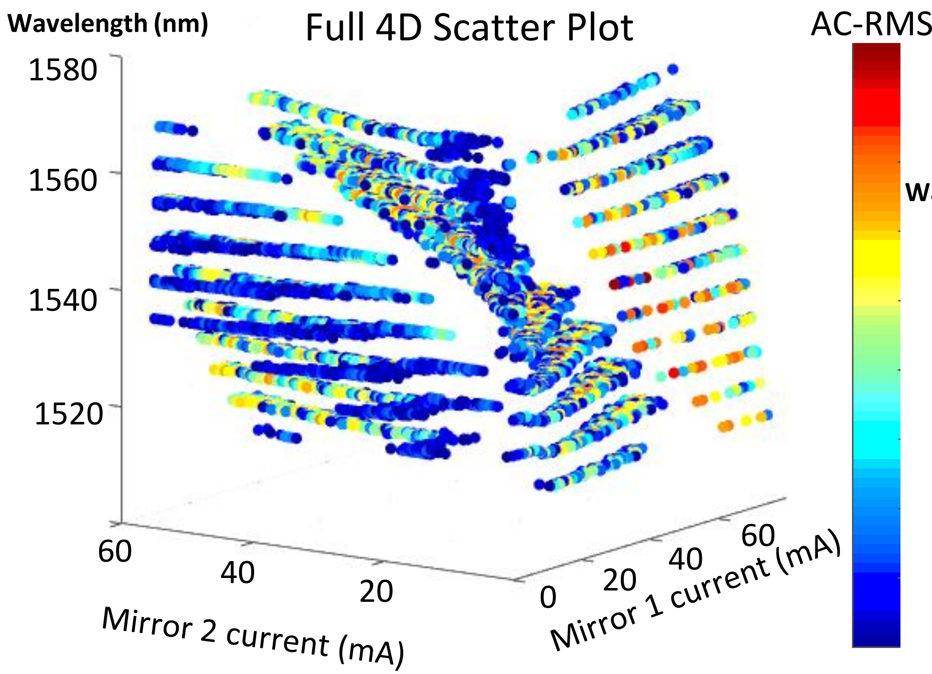
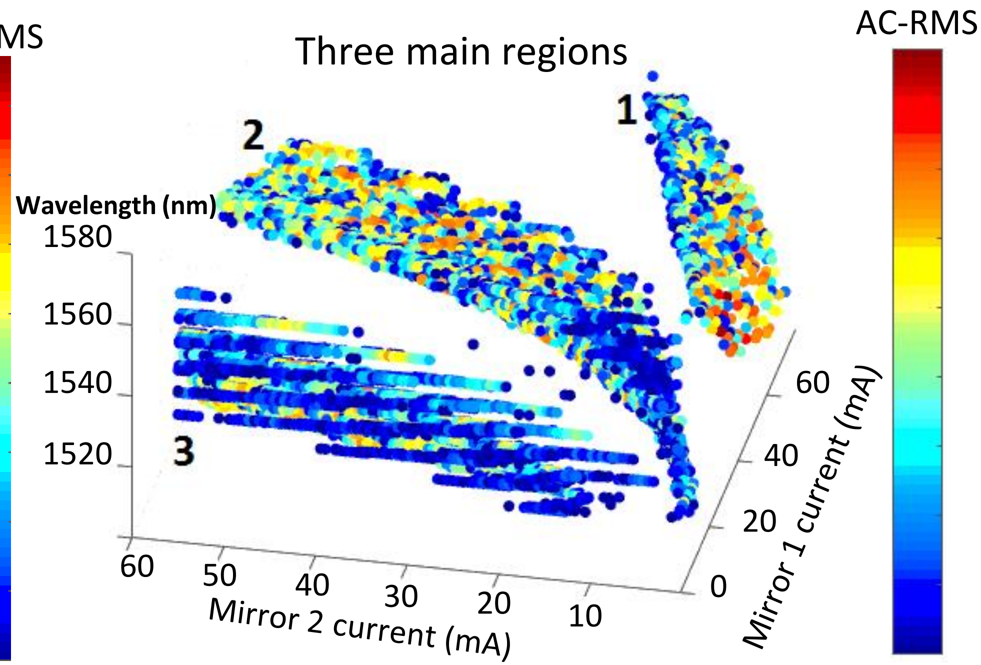
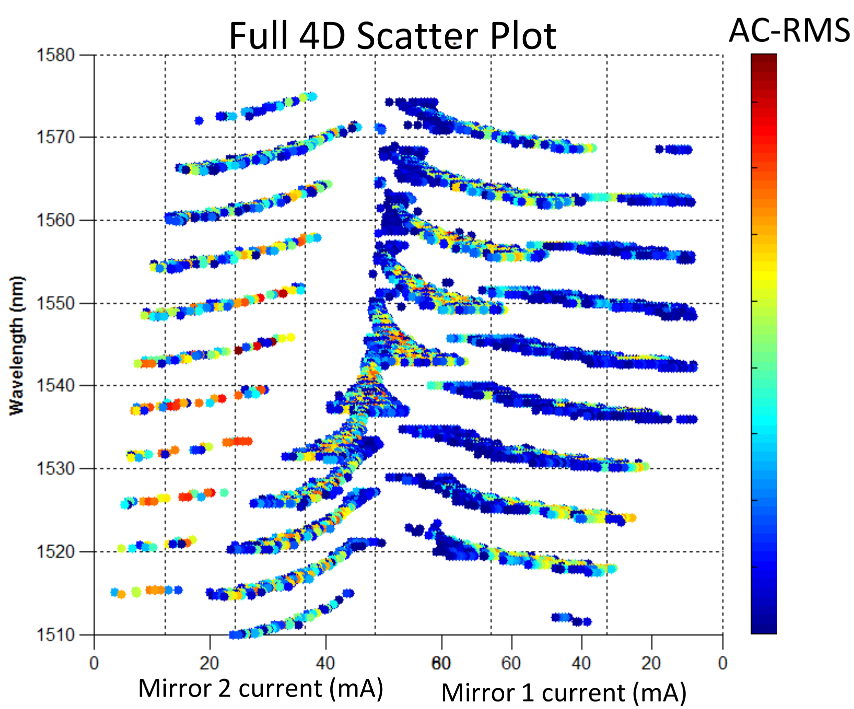
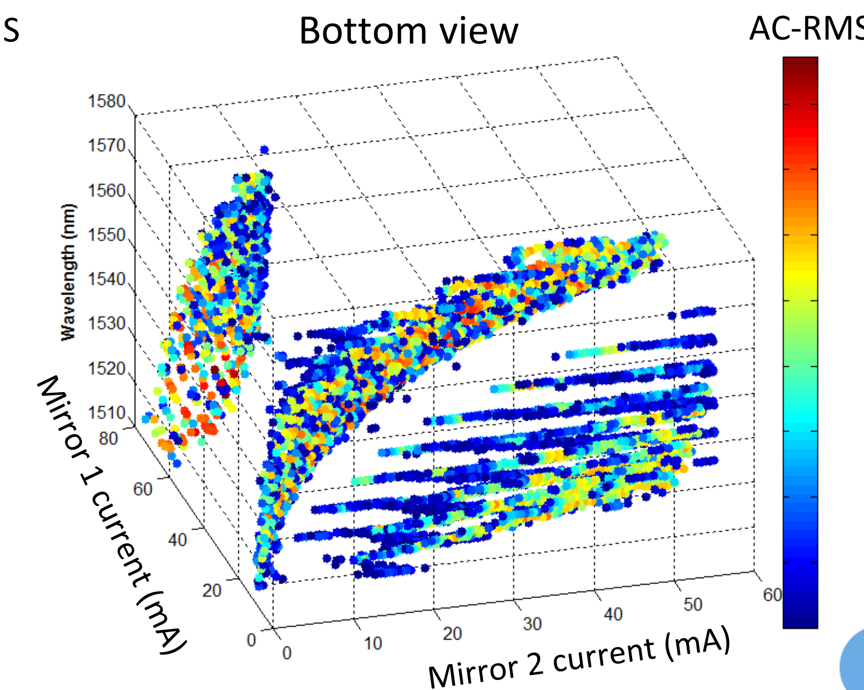
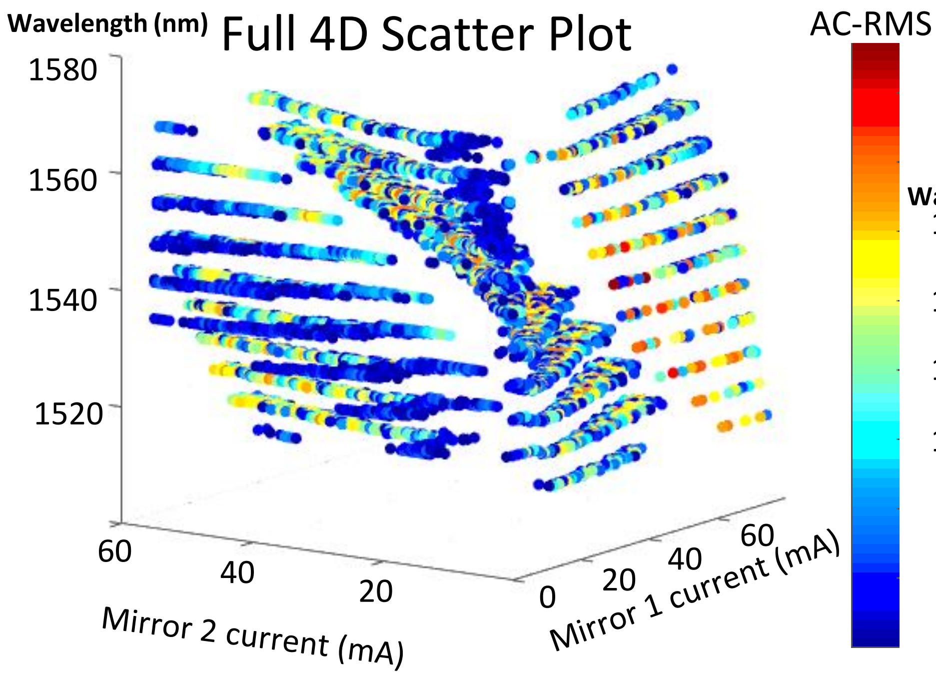


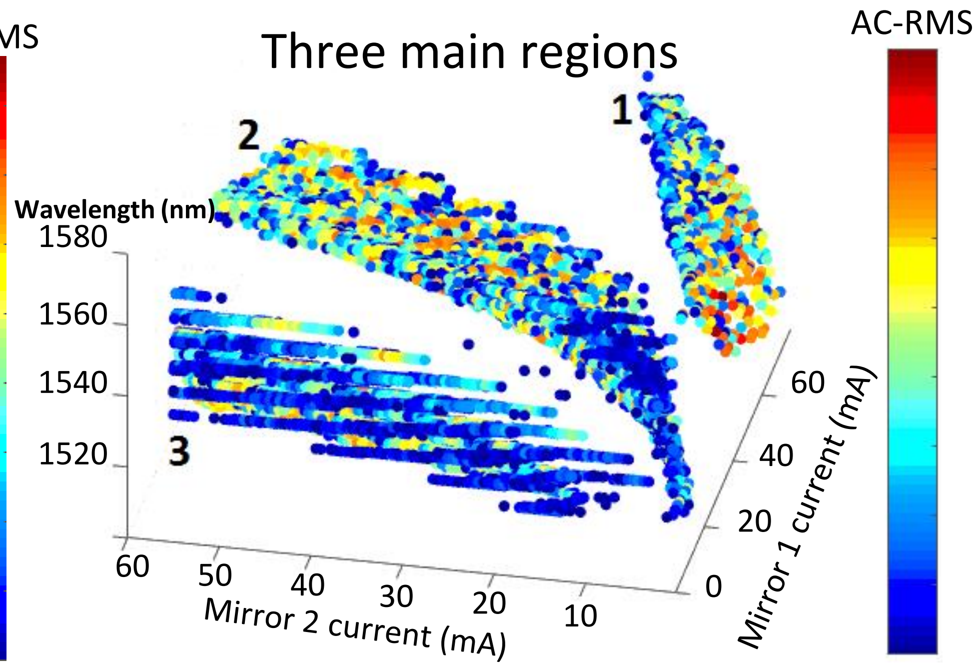

Full 4D Scatter Plot
Wavelength (nm)
AC-RMS
1580
1560
1540
1520
60
40
20
0
Mirror 2 current (mA)
20
40
60
Mirror 1 current (mA)


Three main regions
AC-RMS
1
2
3
Wavelength (nm)
1580
1560
1540
1520
60
50
40
30
20
10
Mirror 2 current (mA)
0
20
40
60
Mirror 1 current (mA)


Full 4D Scatter Plot
AC-RMS
Wavelength (nm)
1580
1570
1560
1550
1540
1530
1520
1510
0
20
40
60
Mirror 2 current (mA)
60
40
20
0
Mirror 1 current (mA)


Bottom view
AC-RMS
Wavelength (nm)
1580
1570
1560
1550
1540
1530
1520
1510
80
60
40
20
0
Mirror 1 current (mA)
0
10
20
30
40
50
60
Mirror 2 current (mA)

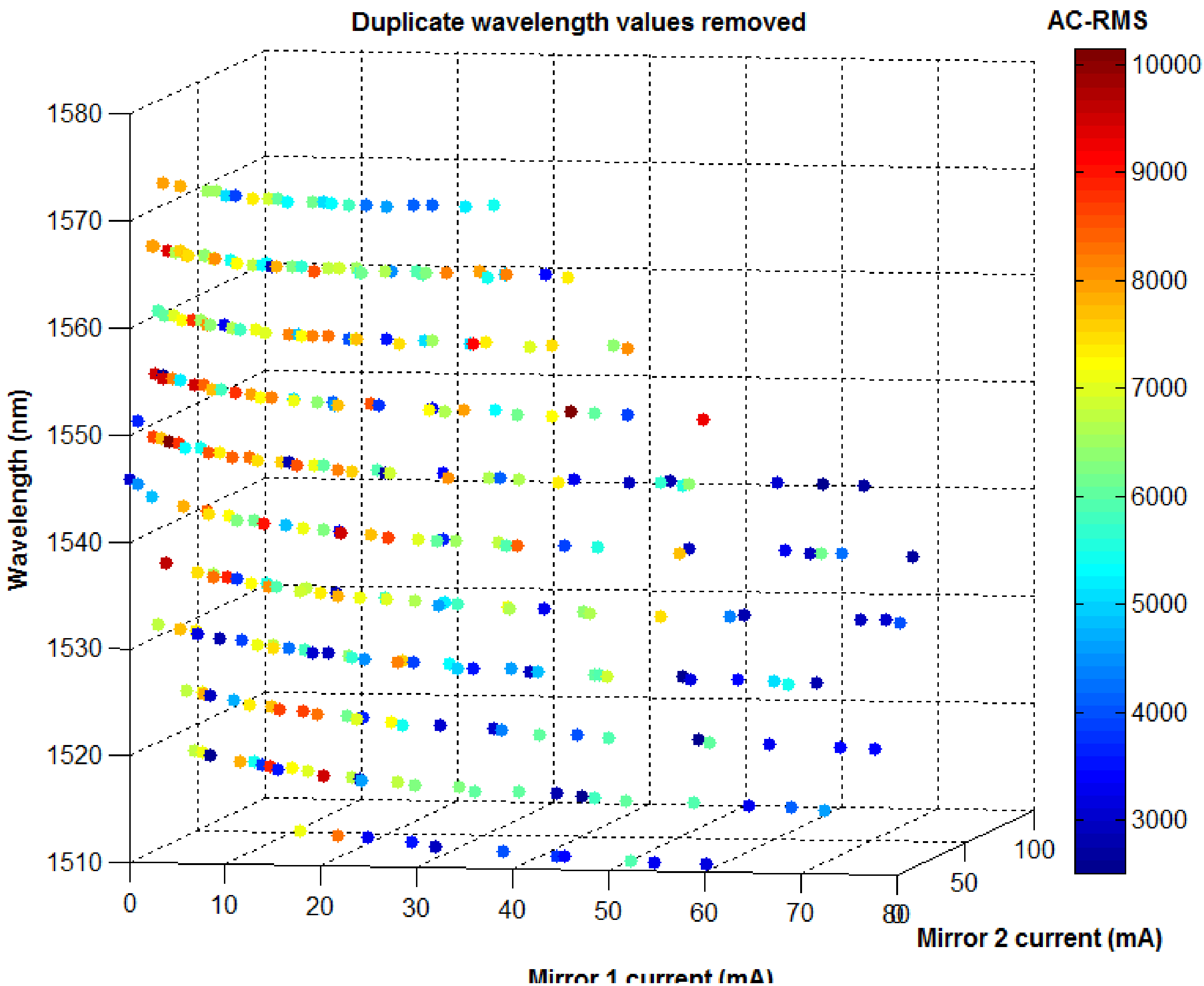




RESULTS DYNAMIC TUNING MAPS

- 4D graphical representation (≈ 3000 points)
- Three main regions
- What points shall be chosen?

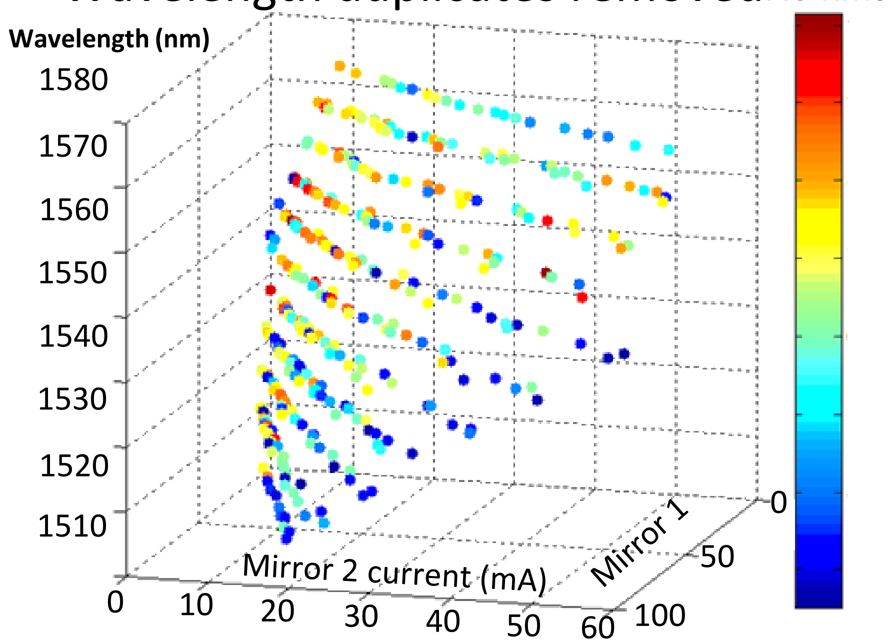
Results – Wavelength duplicates removed



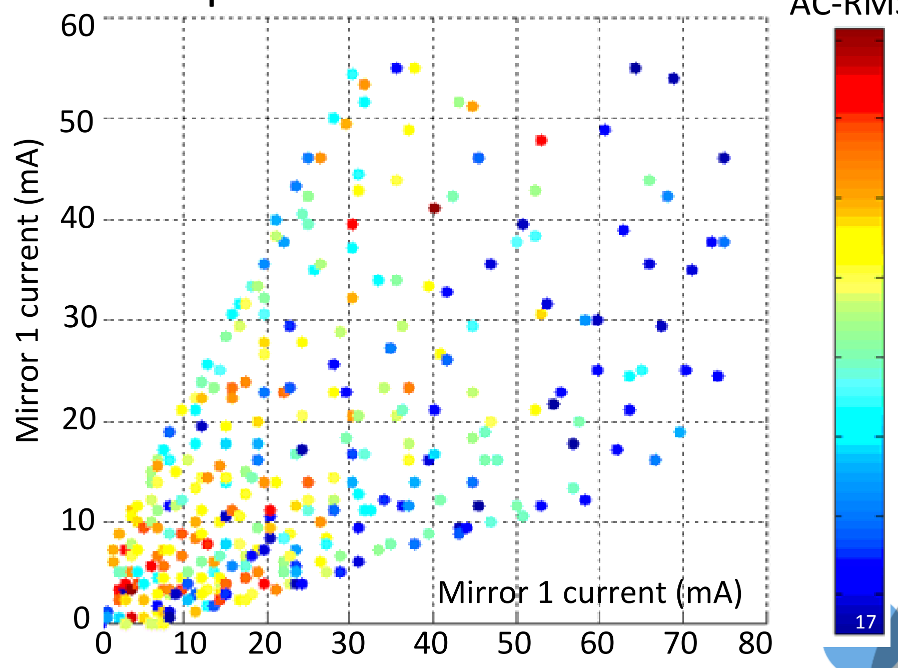
RESULTS DYNAMIC TUNING MAPS

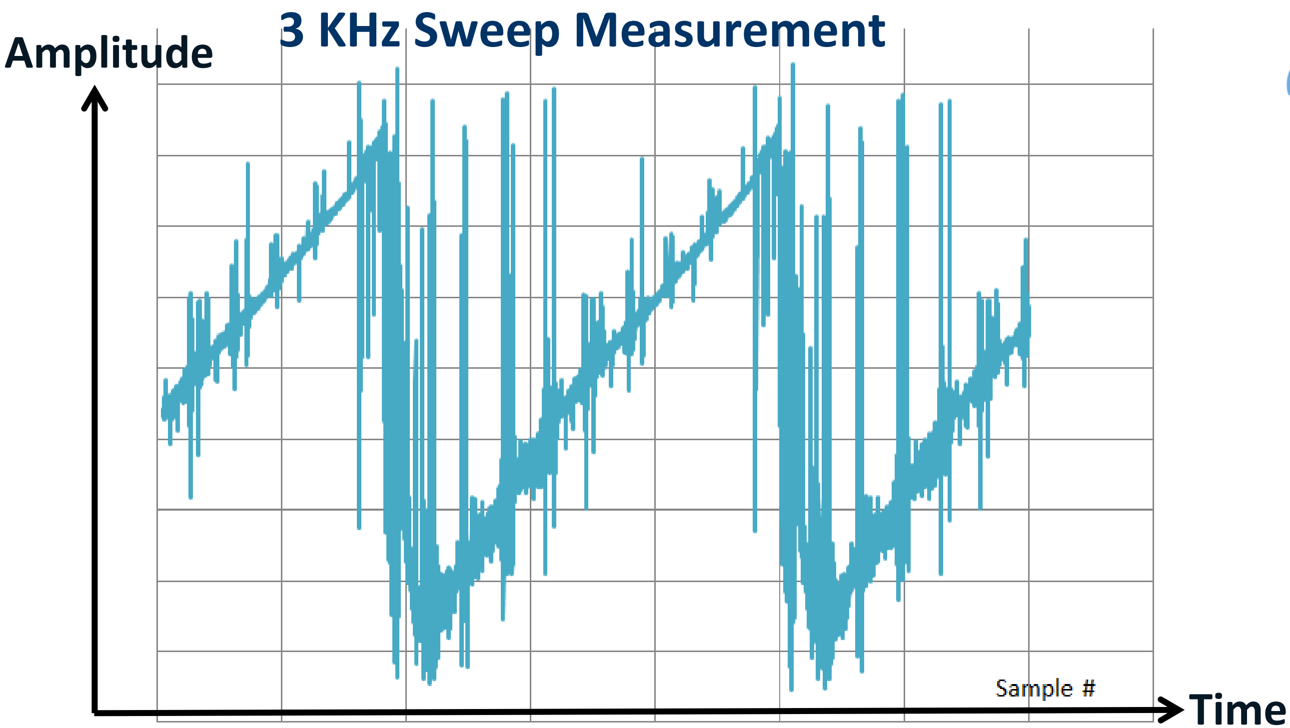
- Remove wavelength duplicates and end up with ≈ 300 points
- Obtain a ‘tuning dictionary’ and perform a linear sweep
- Many current combinations found in the down left corner

Wavelength duplicates removed



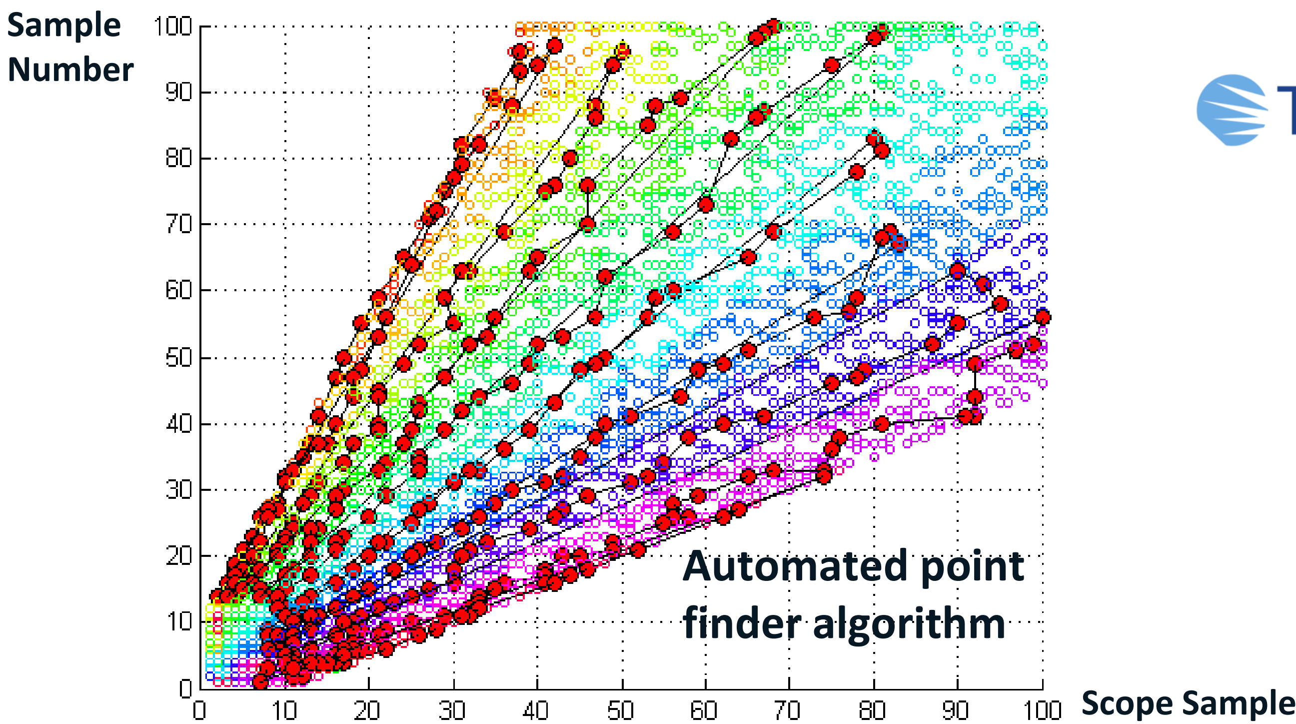
Map of current combinations





RESULTS DYNAMIC TUNING MAPS

- 3 KHZ Sweep Measurement follows linear trend but high noise transition are present (mode hops)



RESULTS DYNAMIC TUNING MAPS

- Proposed algorithm for automated point finder

Conclusion/Future Work

- Telecoms laser are suitable to be the core laser of a swept laser
- The proposed setup can be automatically obtain and measure the tuning maps
- Acceptable swept ranges of ≈ 60 nm were obtained
- A methodology to find the ideal sweep map is proposed
- Low-noise driven electronics are required to avoid mode hoping

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Funded under Horizon 2020

the EU's research and innovation programme, PICCOLO aims to boost early detection and reduce diagnostic time of colorectal cancer

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