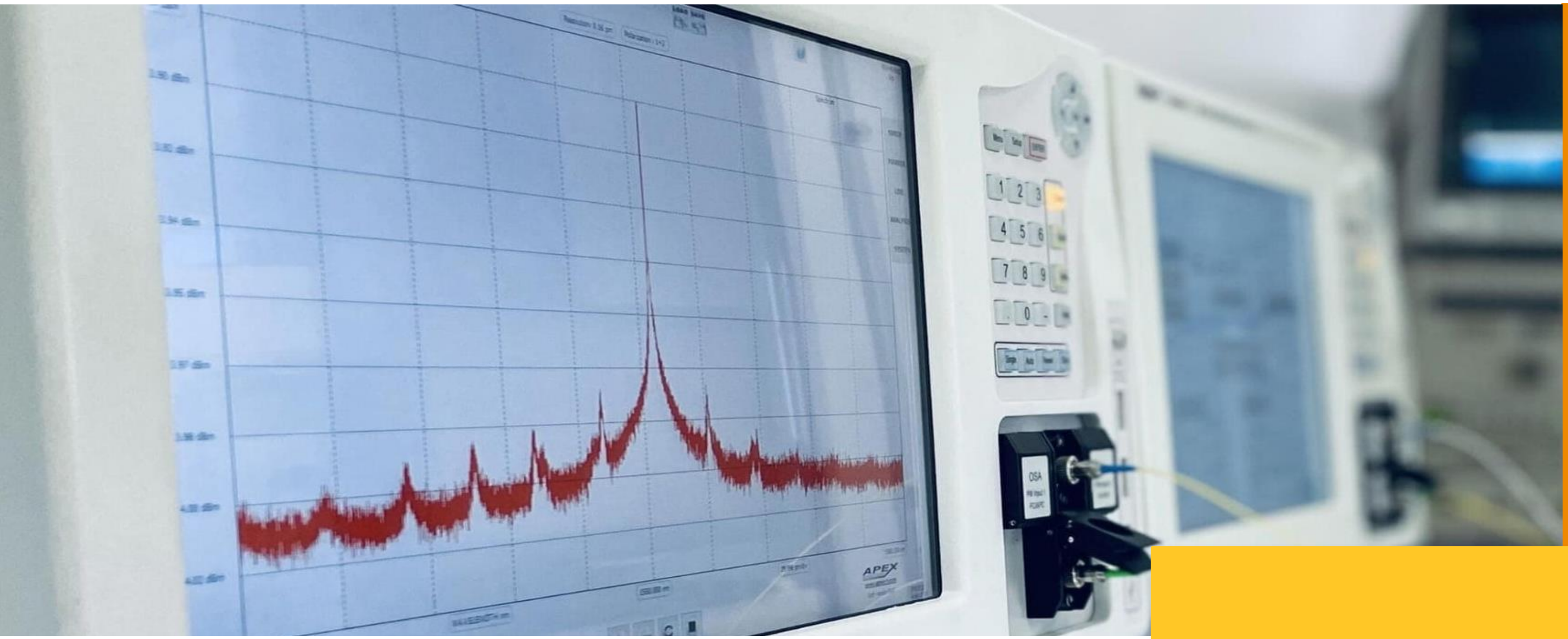


APEX TECHNOLOGIES

ANGELTECH PIC INTERNATIONAL CONFERENCE

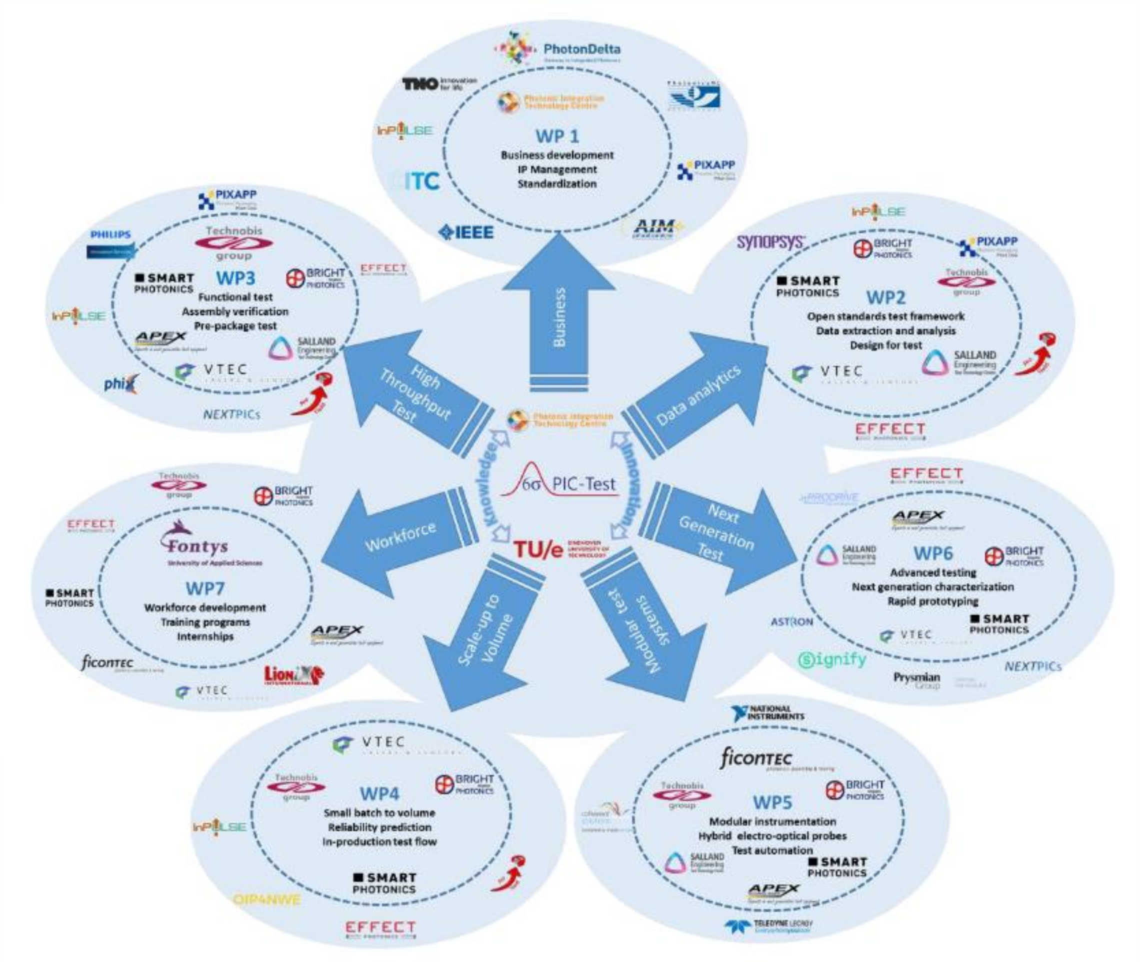
Advanced Photonic Integrated Circuit Testing: APEX Technologies' solution for High Precision Optical Instrumentation

TOMY MAREST, OPTICAL SENSING PROJECT LEADER

About APEX Technologies

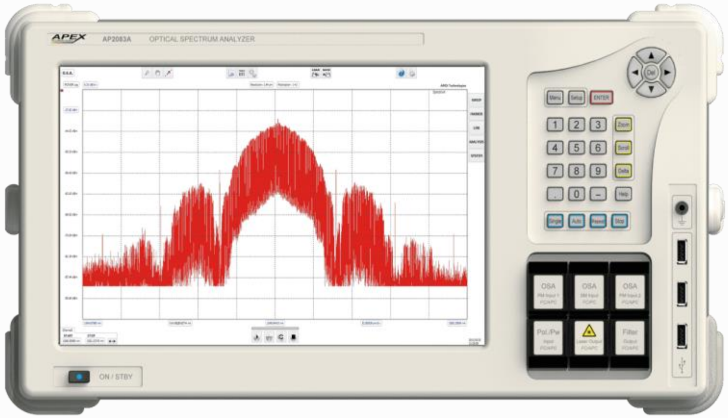
- Founded in 1998 in collaboration with France Telecom Scientists group.
- Located at French Optics Valley
- 500 equipment over more than 35 countries in the world since 2001
- 30 employee (50% working in R&D)
- Member of the PIC-Test program

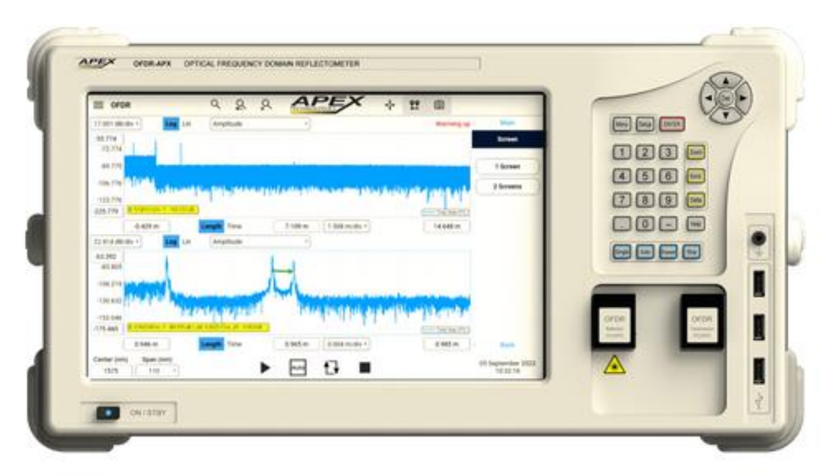
- **PIC-Test program** is a metrology program initiated by **Eindhoven University of Technology with industrial partners**
- It aims to **improve PIC production, quality while reducing costs**.
- This requires :
  - **High precision optical instrument**
  - **Test automation**



Our solutions

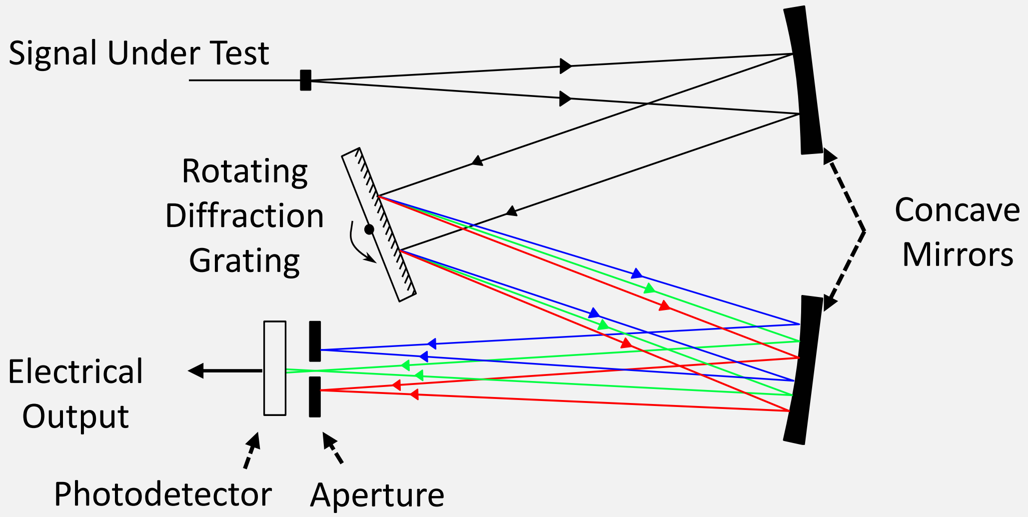
- We propose a variety of instrument such as:
  - A high precision **Optical Spectrum Analyzer – OSA** (wavelength, bandwidth, and laser power…)
  - A high precision **Optical Frequency domain Reflectometer - OFDR** (insertion loss, reflection loss, waveguide properties with high spatial resolution)
  - Those devices work thanks to an integrated **mode-hope free continuous tunable laser - TLS** (can be purchased separately as a benchtop unit that can be connected to OSA and OFDR)





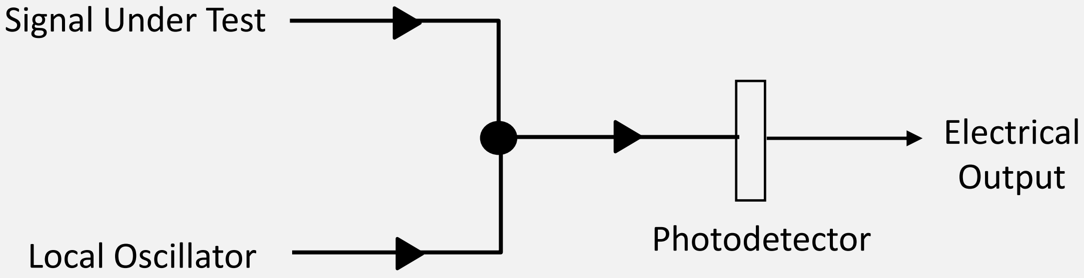
Optical Spectrum Analyzer - OSA

Grating Based OSA



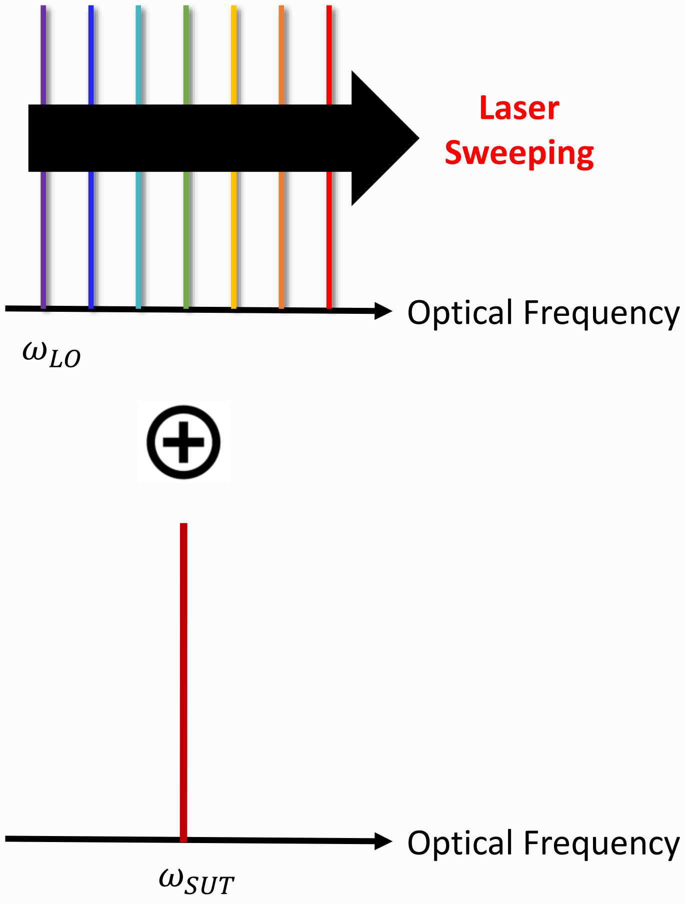
Low resolution (typ. 2500 MHz – 20 pm @ 1550 nm)

Interferometric Based OSA

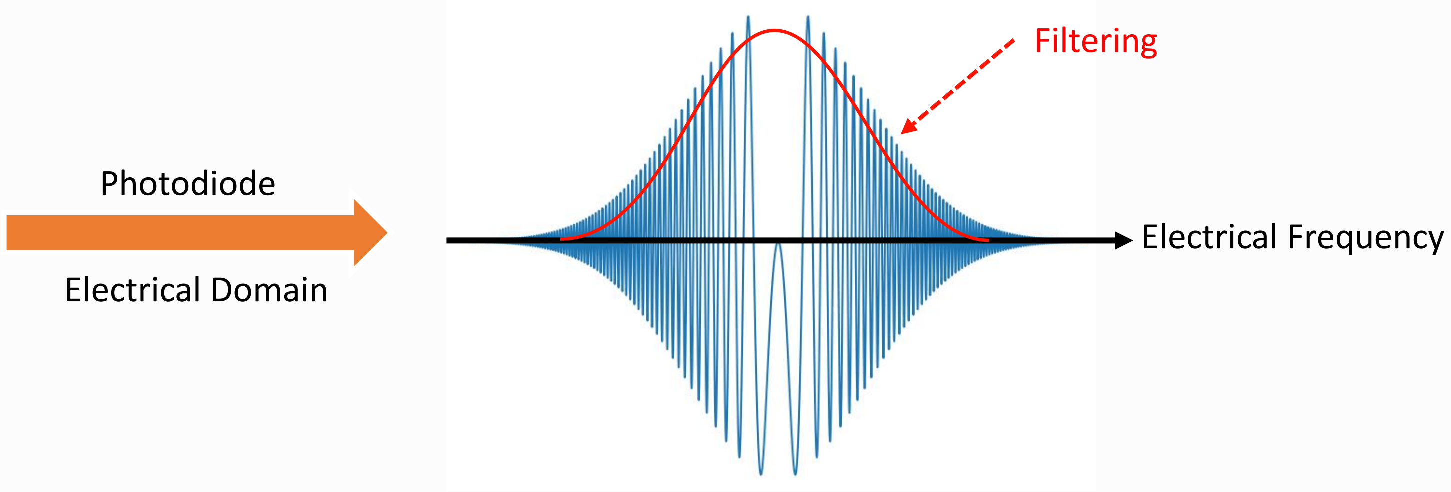


High resolution (typ. 5 MHz – 0.04 pm @ 1550 nm)

How does it work ?



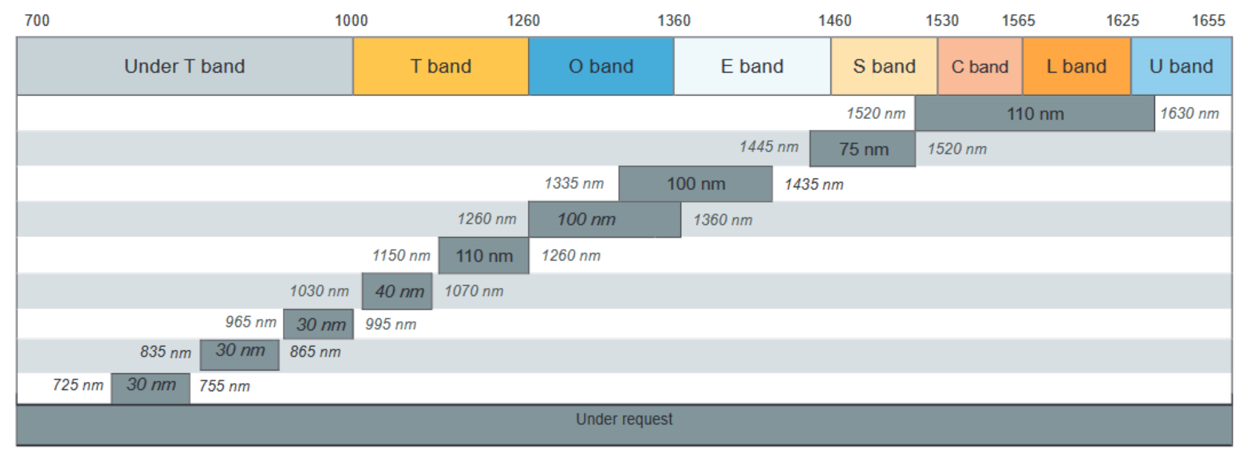
- Our design include polarization diversity to ensure polarization independent spectrum measurement

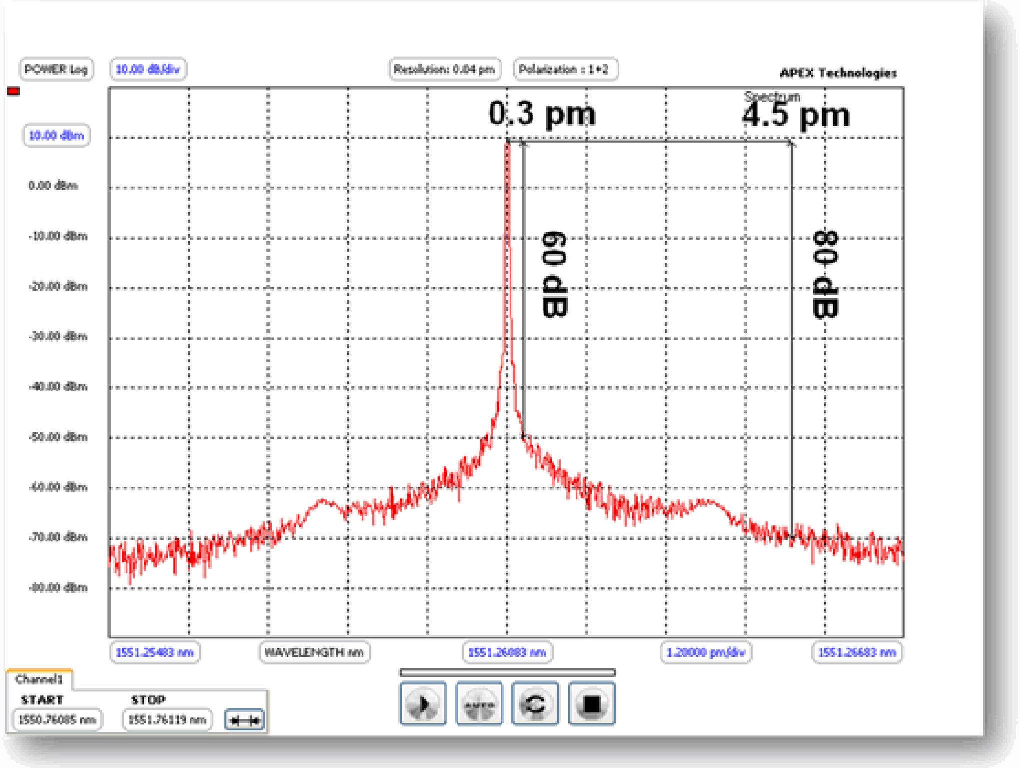


- The shape of the filter and its width sets the OSA resolution

- Highest resolution on the market : 5 MHz (0.04 pm) with +/- 2 pm absolute accuracy
- High Close in dynamic : @ +/- 0.3 pm from the peak, dynamic > 60 dB
- High Spurious Free Dynamic Range : 55 dB
- Sensitivity : -80 dBm

Thanks to **our integrated tunable laser source**, the device can work in multiple optical band **(from 850 nm to 1630 nm)**



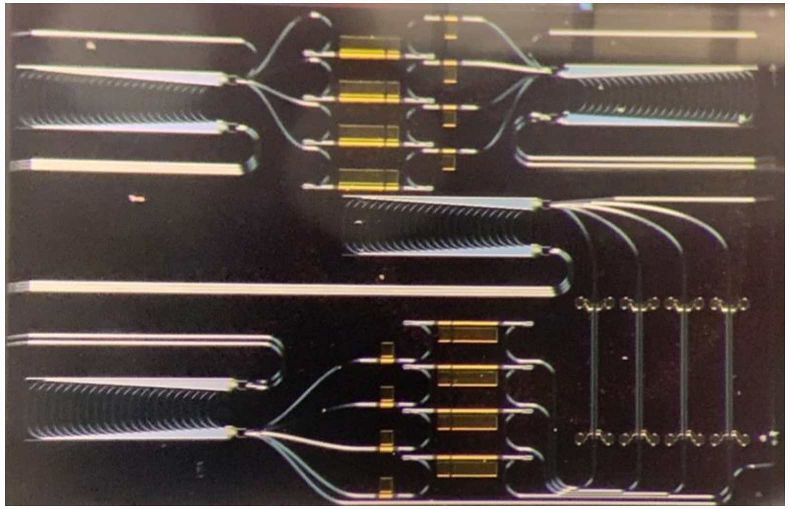


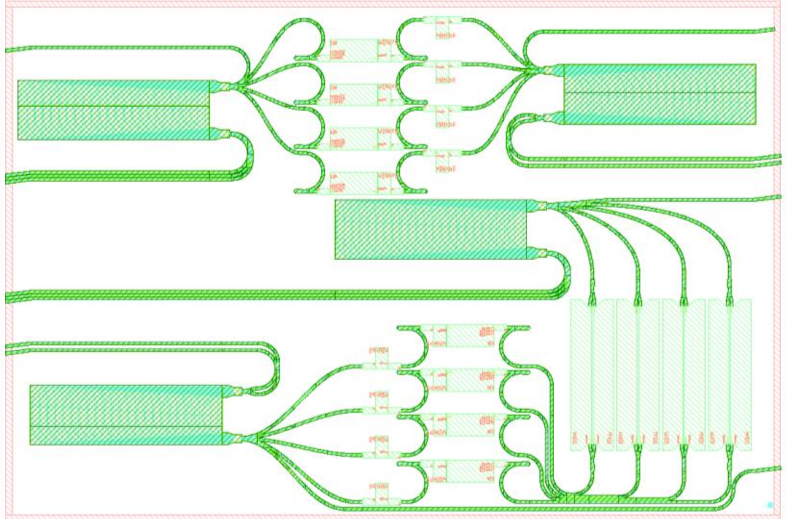
OSA - measurements

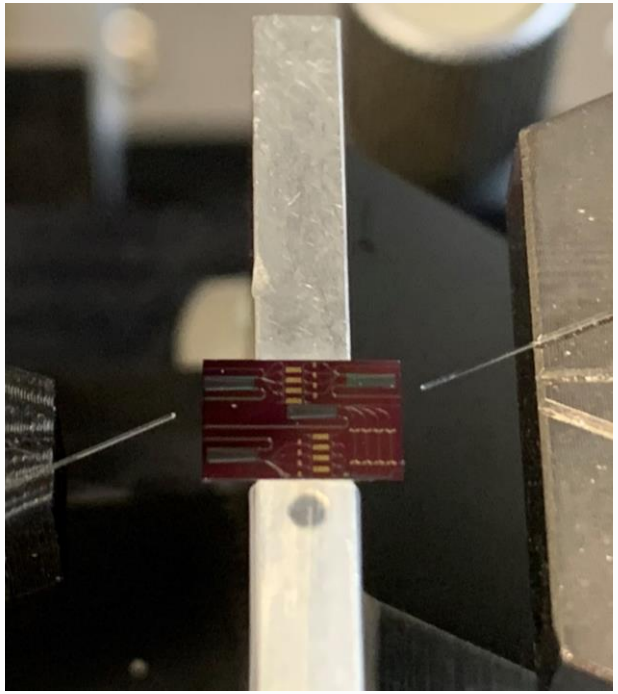
PIC with an array waveguide grating (AWG) as part of a multi-wavelength laser structure [1].

The AWG channels are spaced 0.8 nano-meters apart at λ = 1550 nm.

The chip was manually aligned, and the spectra of each channel was superimposed on a single graph.





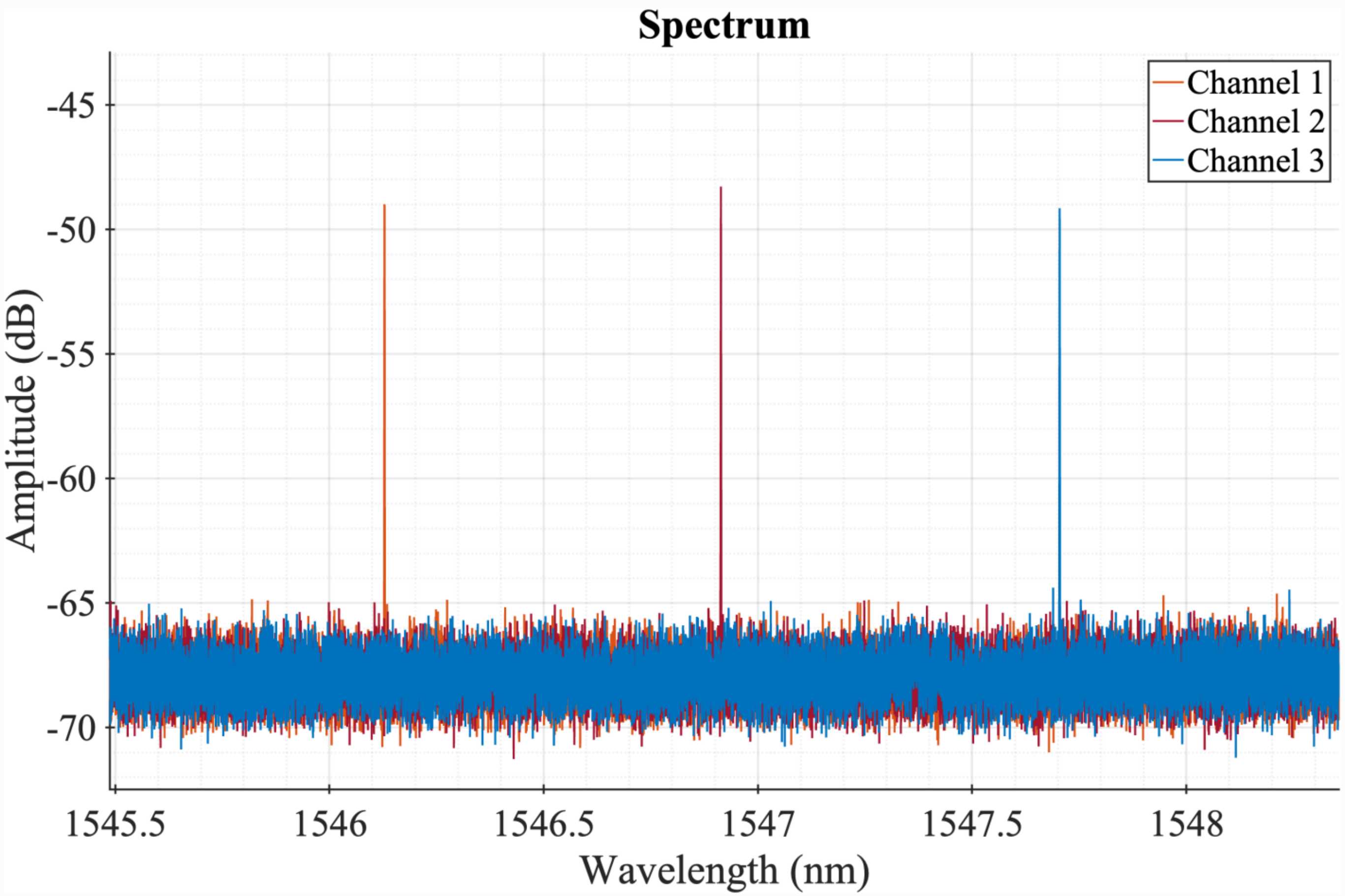


[1] J. Zhao, P. J. Williams, M. K. Smit and X. J. M. Leijtens, "Monolithic integrated filtered-feedback multi-wavelength laser," OFC/NFOEC, Los Angeles, CA, USA, 2012, pp. 1-3.

OSA - measurements

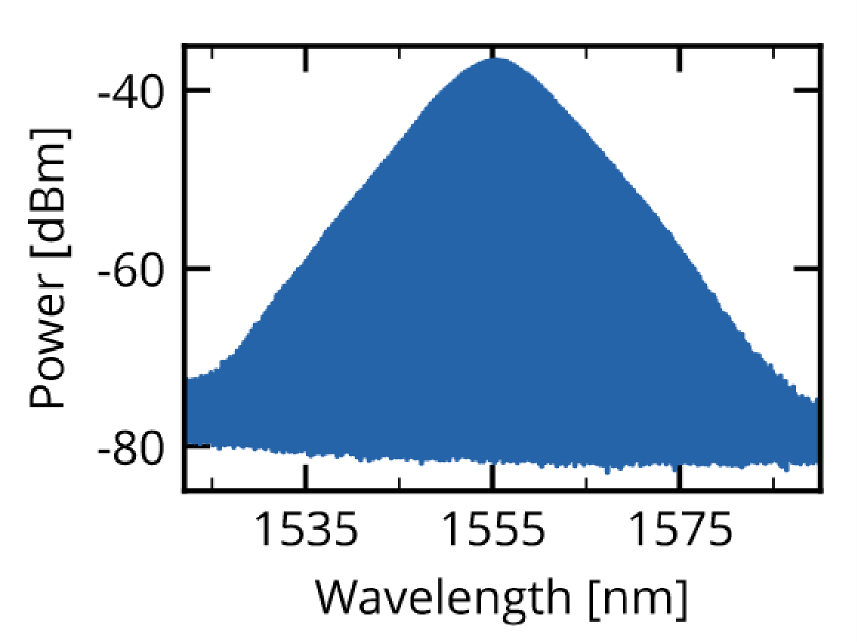
The spectrum obtained by the OSA clearly shows the spacing between the channels.

Although the losses in the AWG were high, including reflections from the angled faucets, and manual alignment tolerances, the high responsivity of the photo-detector in the OSA was able to detect the weak signal.

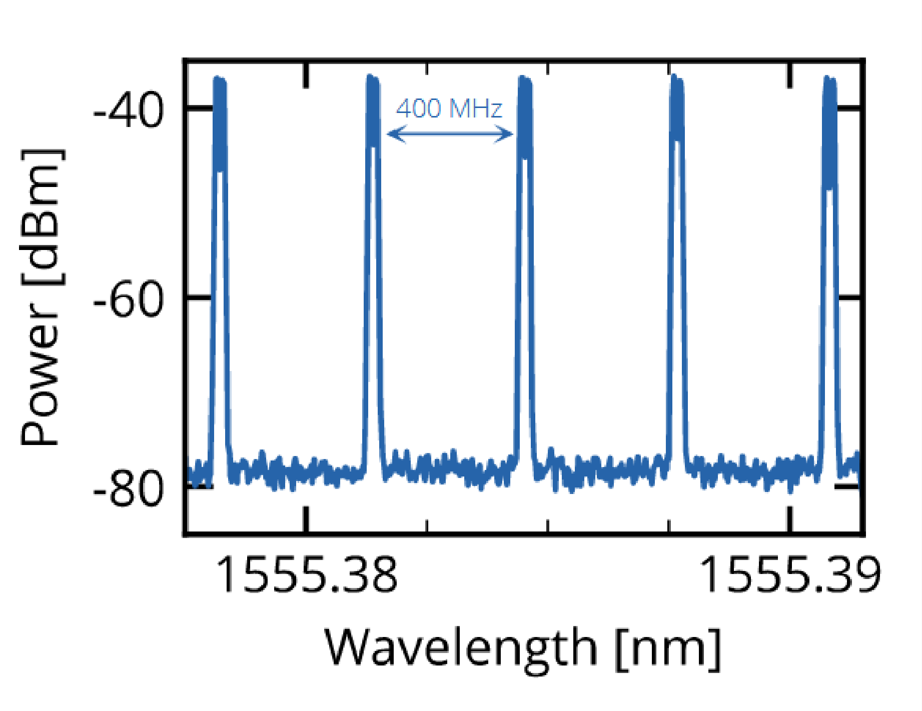


Example Menhir Photonics

Here is an example on an Optical frequency comb from Menhir Photonics (MENHIR-1550 OFC) with 400 MHz spacing



Close up

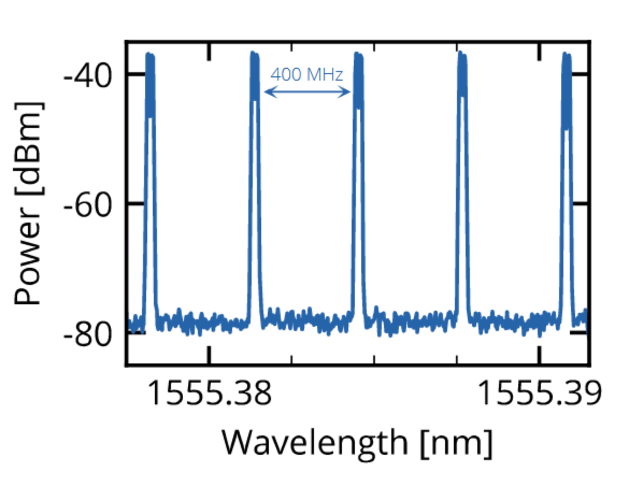


Menhir Photonics

https://www.photonics.com/White_Papers/Coherent_Optical_Comb_Characterization/wpp2286

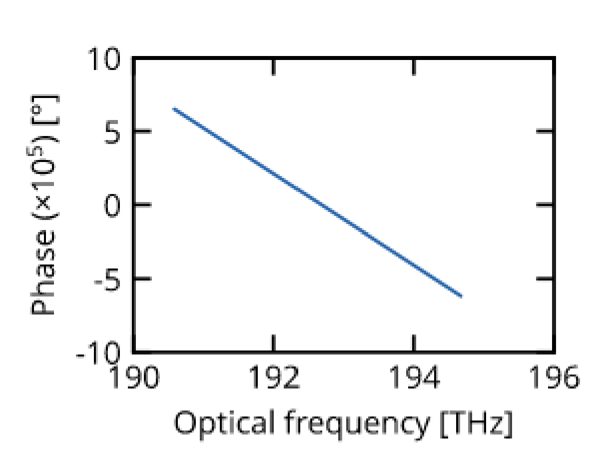
Example Menhir Photonics

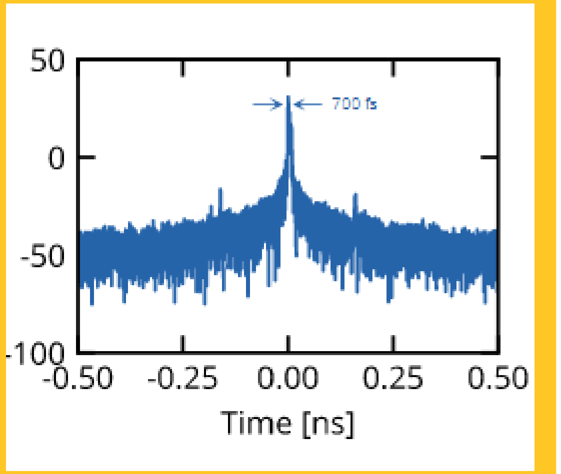
We can even retrieve the pulse profile in the time domain → **Optical Complex Spectrum Analyzer (OCSA)**



OSA measurement

Inverse Fourier transform



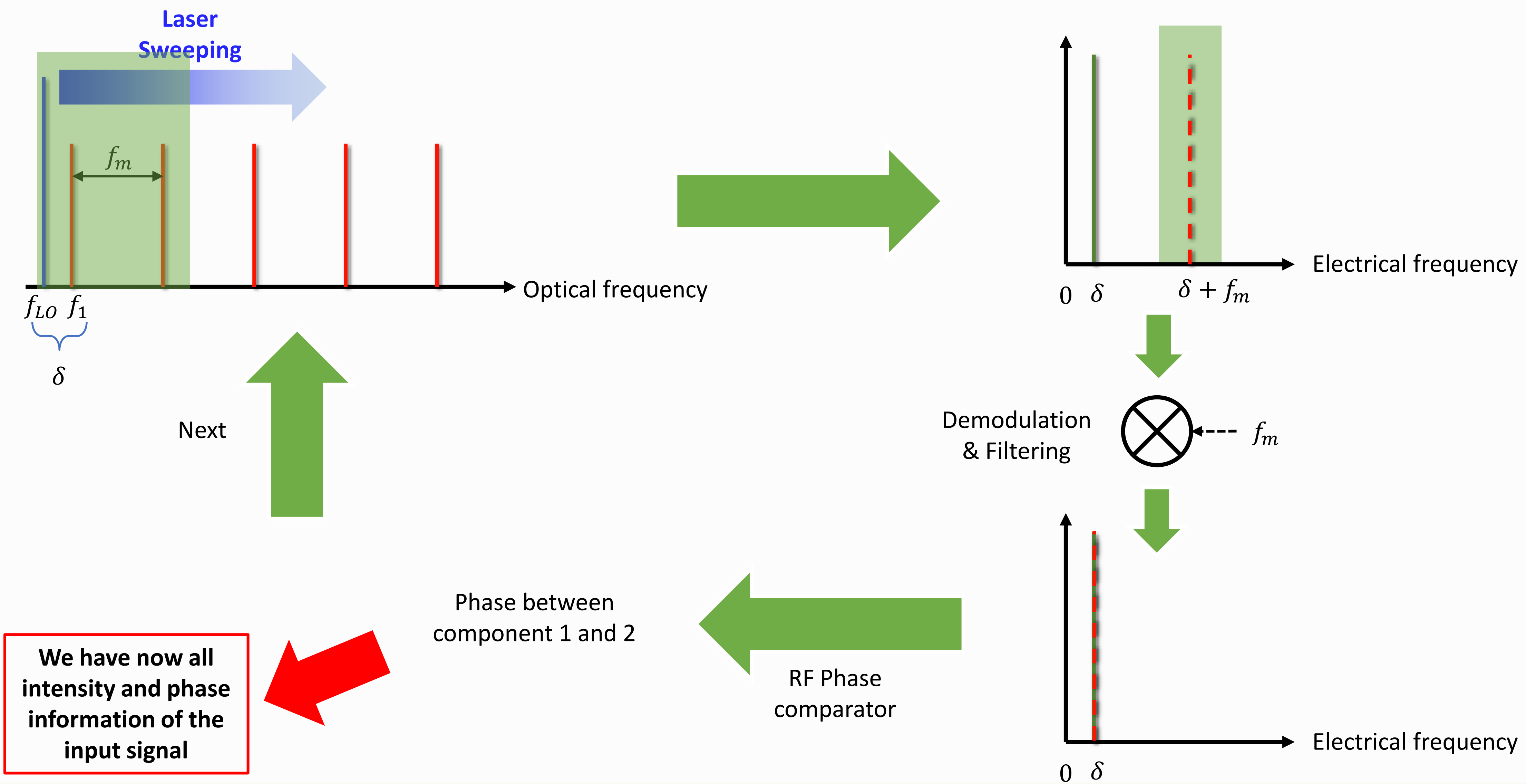


OCSA measurement

Menhir Photonics

https://www.photonics.com/White_Papers/Coherent_Optical_Comb_Characterization/wpp2286

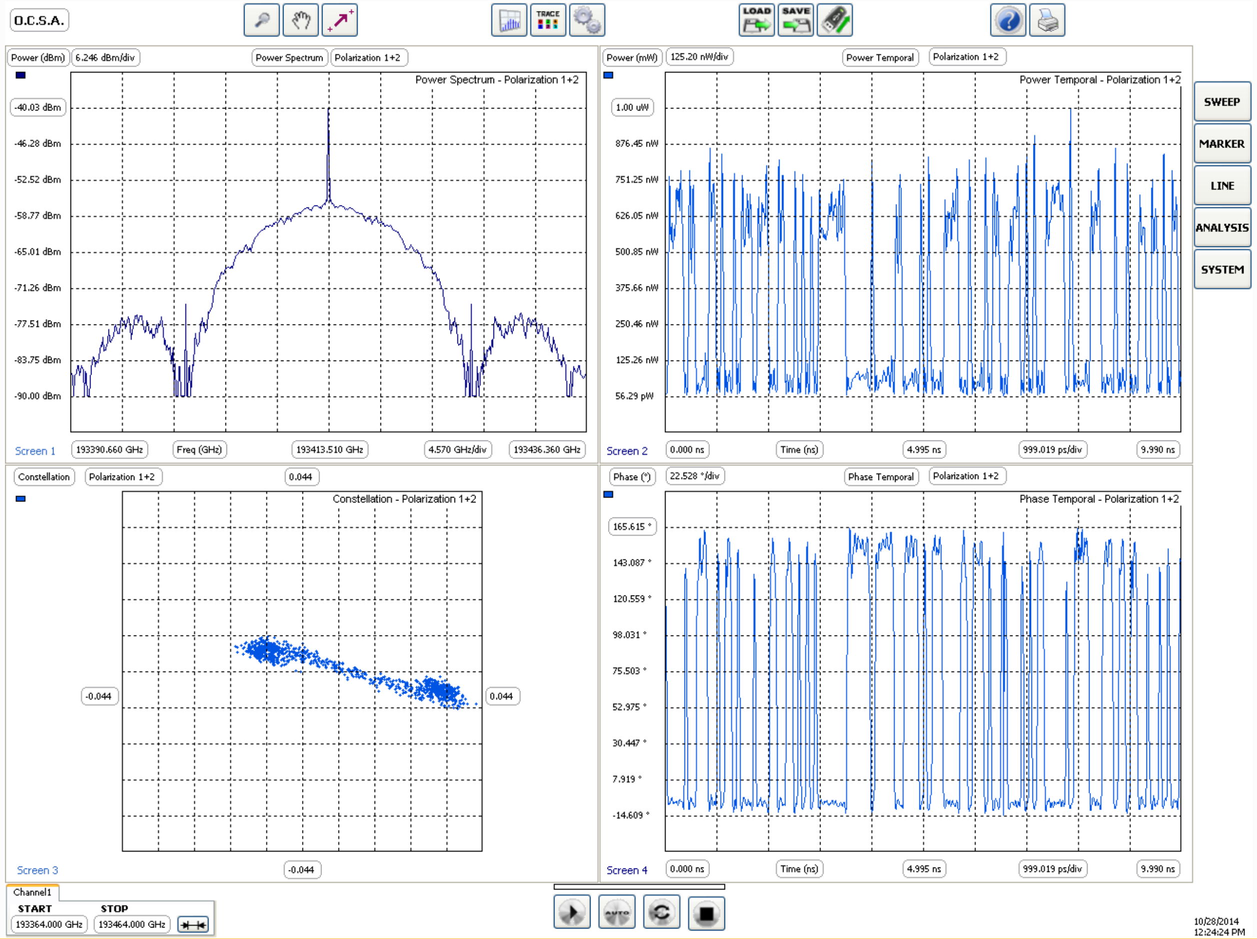
How does it work ?



Optical Complex Spectrum Analyzer - OCSA

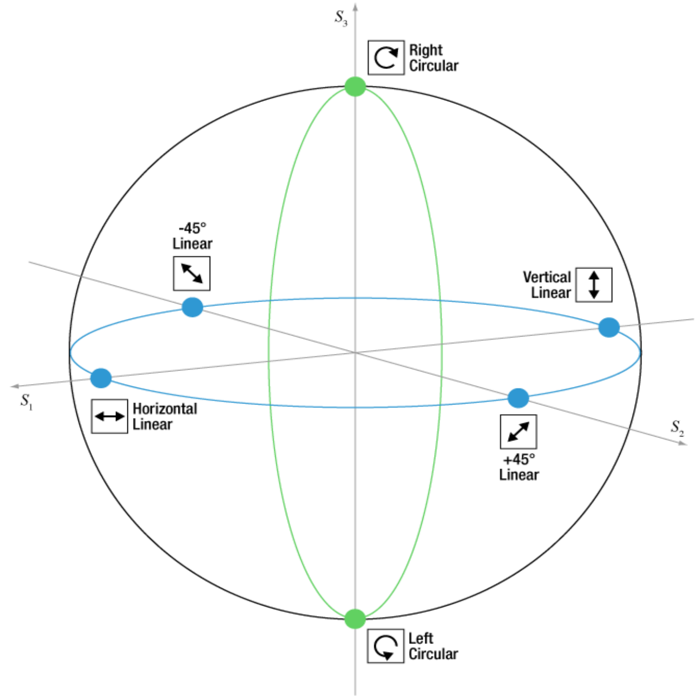
- In the case of modulated signals (70 MHz to 900 MHz), **OSA measurement can be completed with phase information** with our Optical Complex Spectrum Analyzer

- It allows measurement of :
  - Optical Phase
  - Chirp
  - Pulse shape in time domain,
  - Eye diagram and constellation
  - Group delay



Polarimeter

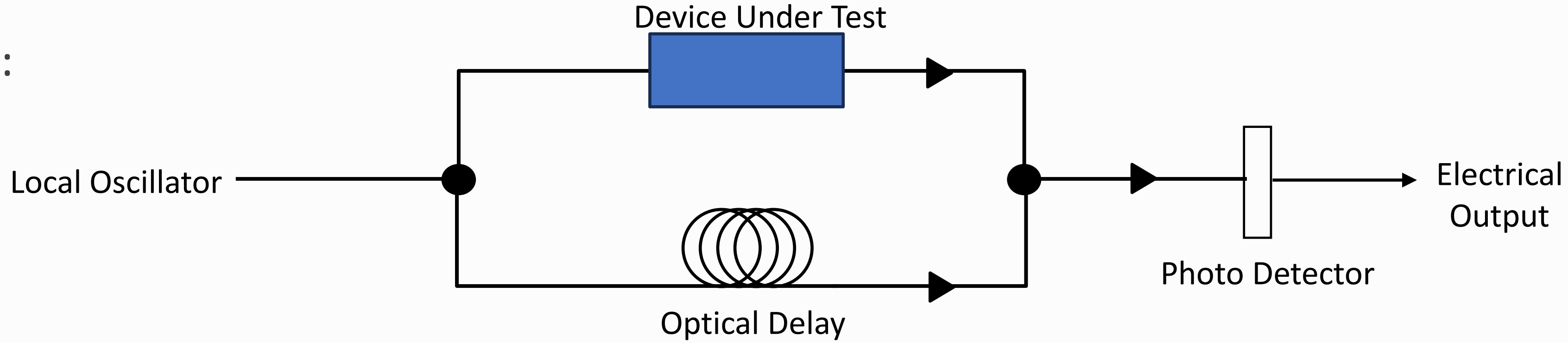
- All those measurement can completed by **polarimeter option**
- Based on the measurement of the four Stokes parameters
- If you are optimizing polarization into your device you can have a **real-time measurement of the state and the degree of polarization** displayed on Poincaré sphere, Jones graph or as a Stokes oscilloscope
- Also available as a benchtop unit, module and component

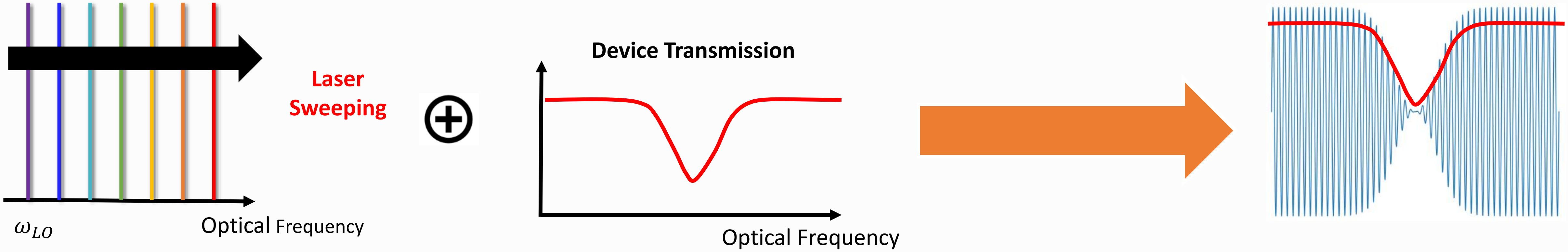


Optical component analysis capability

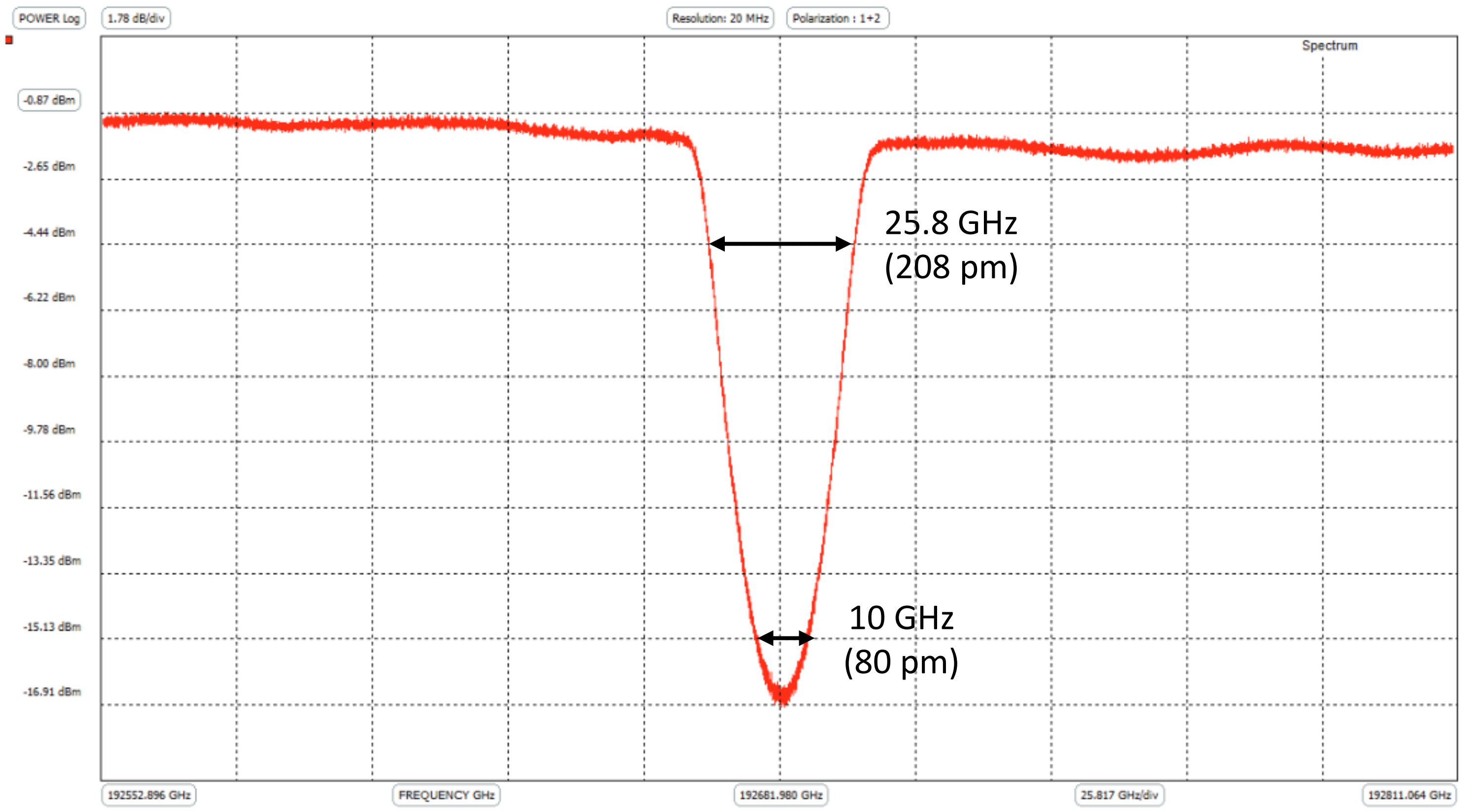
- **The OSA can be turned in an optical component analyzer** to measure the transmission of a device with high resolution (8fm) and 63dB dynamic in a single sweep.
- Useful to characterize micro-ring resonators for exemple

How it works :





Here is an example on a Fiber Bragg Grating filter centered around 1556 nm



Reflectometer

- New materials, designs, fabrication techniques and evaluating device performance and reliability investigation
- **Reflectometer can be used**
- They can detect changes in the optical properties of waveguides and structures such as
  - Bends
  - Cracks
  - Variations in refractive index

- They measure the **optical reflections and losses along the waveguide through Rayleight backscattering**
- Different technologies allows difference maximal length and **spatial resolution**

Usual reflectometer

Time Domain Reflectometry

- Use light pulses
- Very long device length (<100 km)
- Low resolution (10 cm for best cases)
- Dead Zone

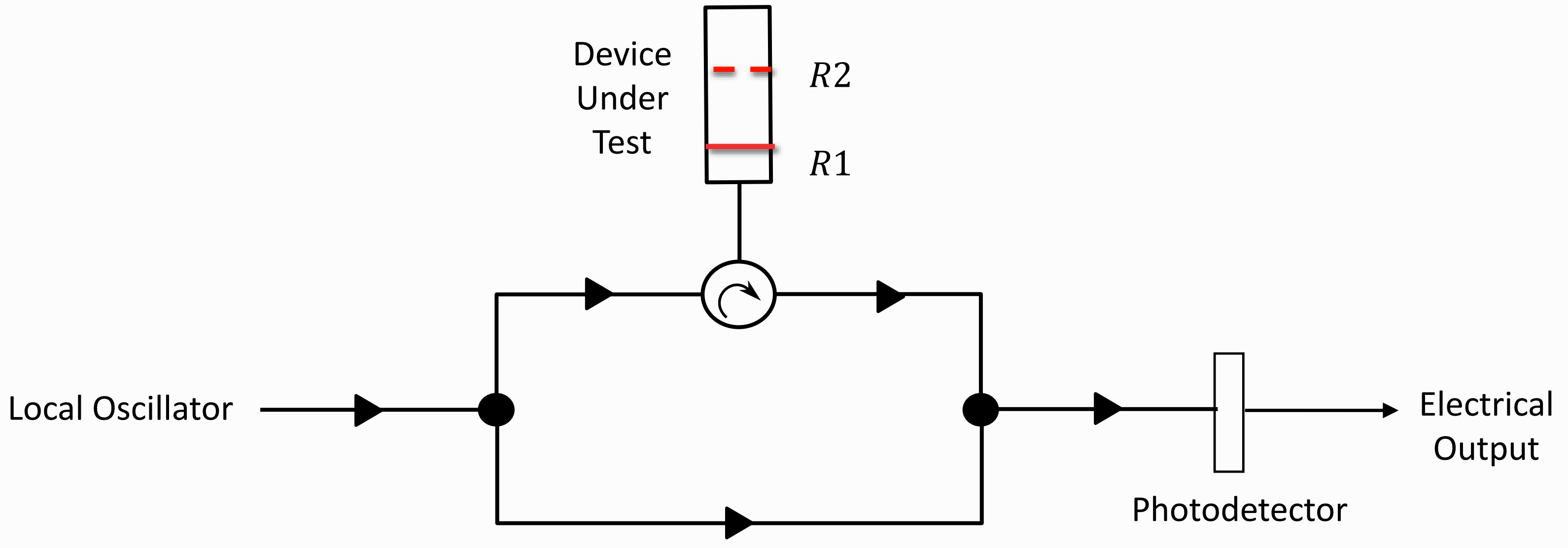
Low Coherence Reflectometry

- Use low coherence source and optical delay line
- Very short device length (< 10 m)
- Intermediate resolution (100 µm)
- Limited by Optical delay line
- No Dead Zone

Frequency Domain Reflectometry

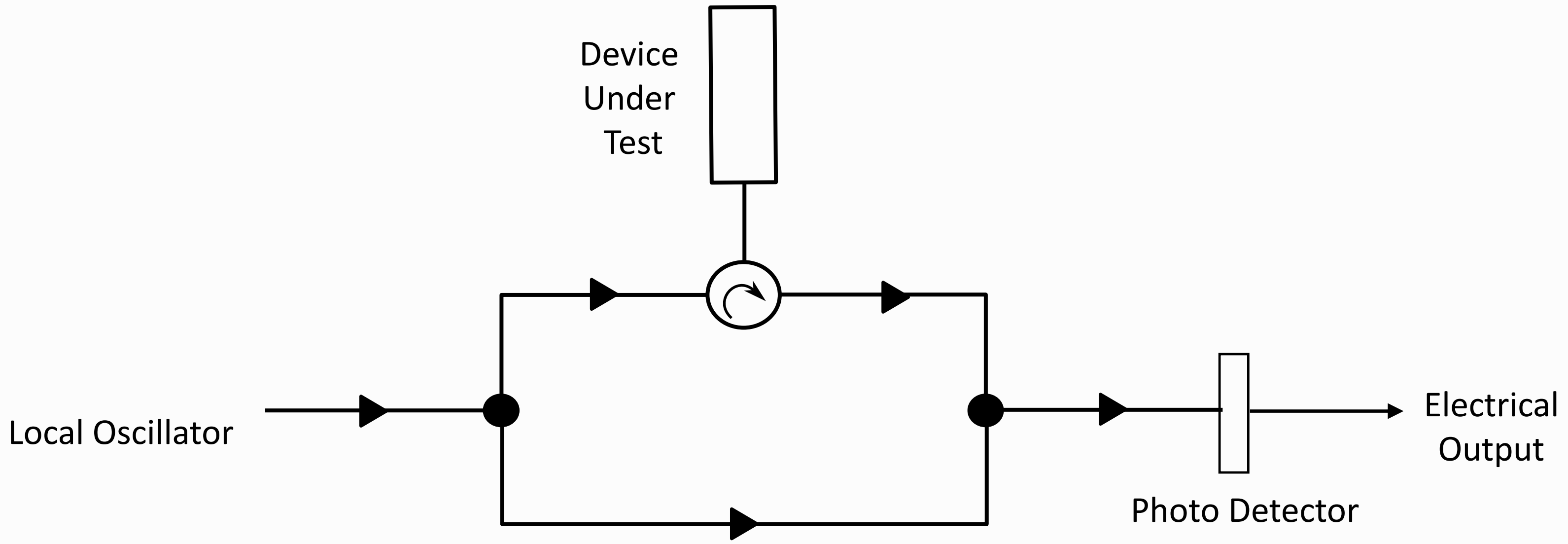
- **Use coherent source and analyze interference**
- **Intermediate device length (cm to 350 m)**
- **High resolution (8 µm)**
- **No Dead Zone**

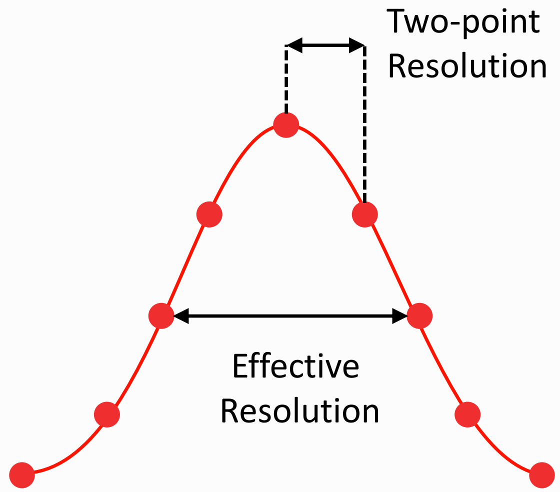
How it works ?


Device
Under
Test
$R2$
$R1$
Local Oscillator
Electrical
Output
Photodetector


Laser
Sweeping
Optical Frequency
ω_{LO}
2 reflections
R1 and R2
$R2$
$R1$
Electrical frequency
f_1
f_2

How it works ?

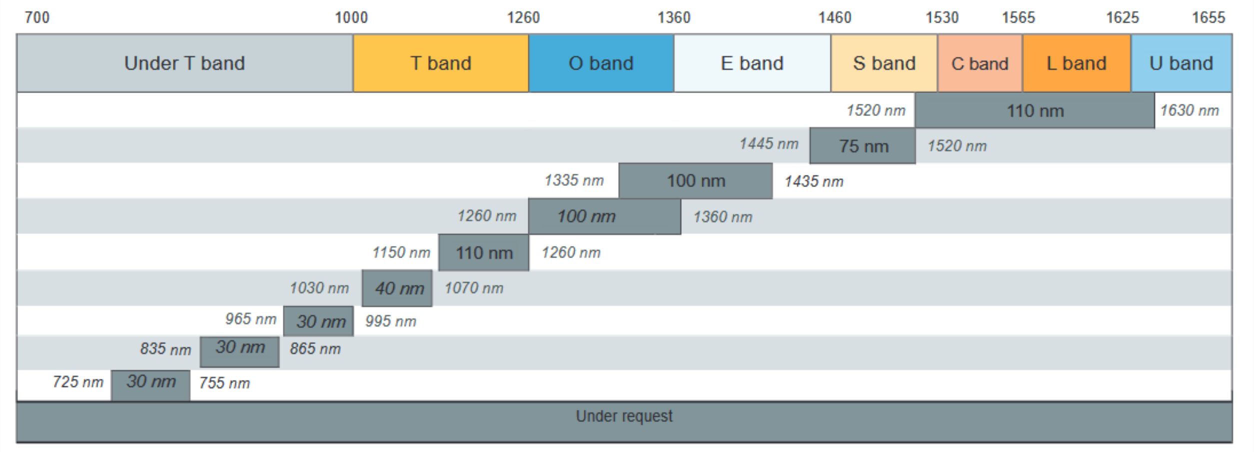




- **Two point spatial resolution** is **proportional to the wavelength span** of the laser source (Fourier)
- **The effective resolution** (minimum width of a beating) is set by the **laser linewdith**

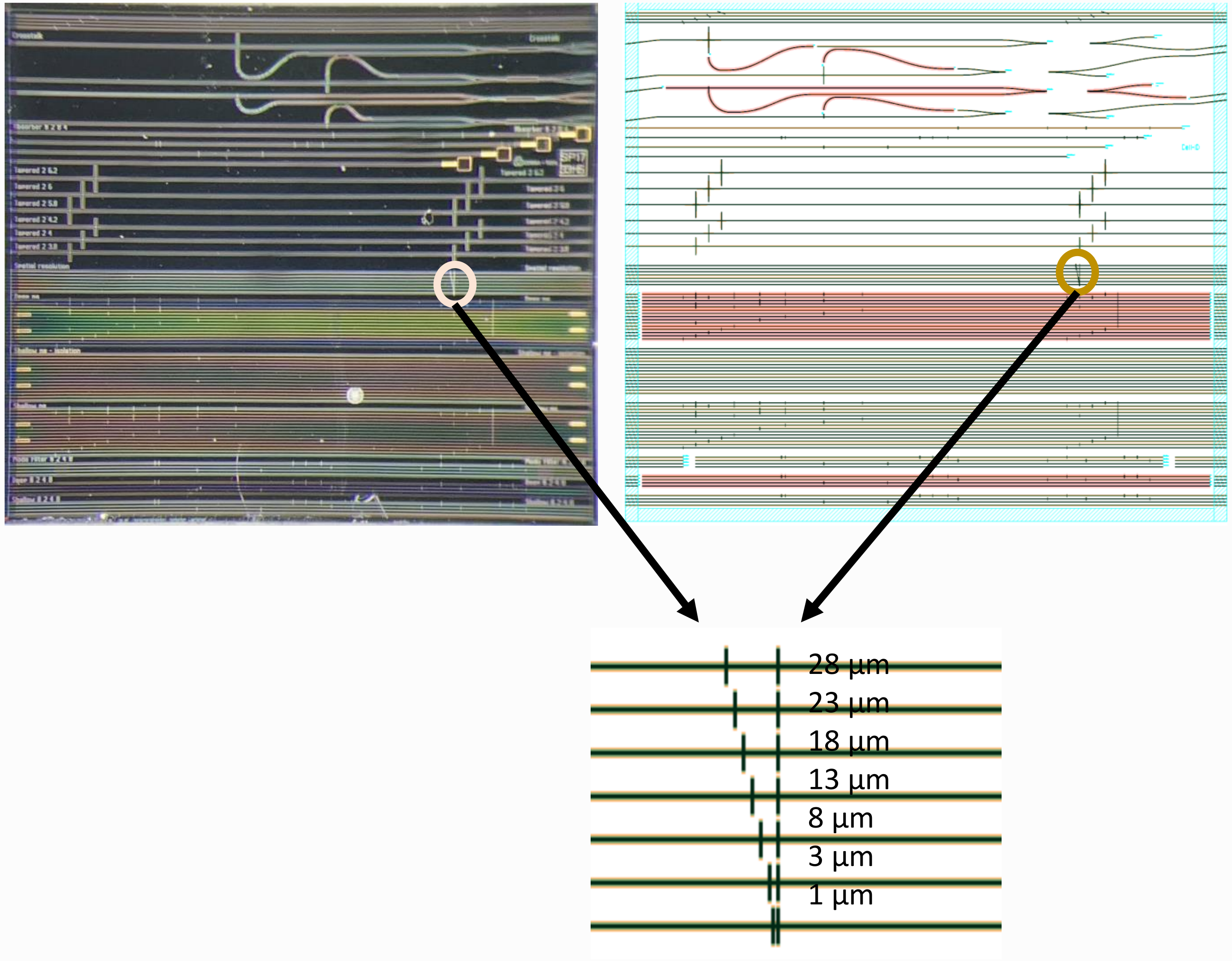
- Two-point resolution : <8 µm (in SMF28 – Equivalent of 3.4 µm in PIC)
- High sensitivity: -135 dB
- Highest available dynamic : 120 dB allowing efficient high reflectivity measurement
- The speed of the device (0,5 Hz) for the highest resolution allows fast optimization

Thanks to **our integrated tunable laser source**, the device can work in multiple optical band **(from 850 nm to 1630 nm)**

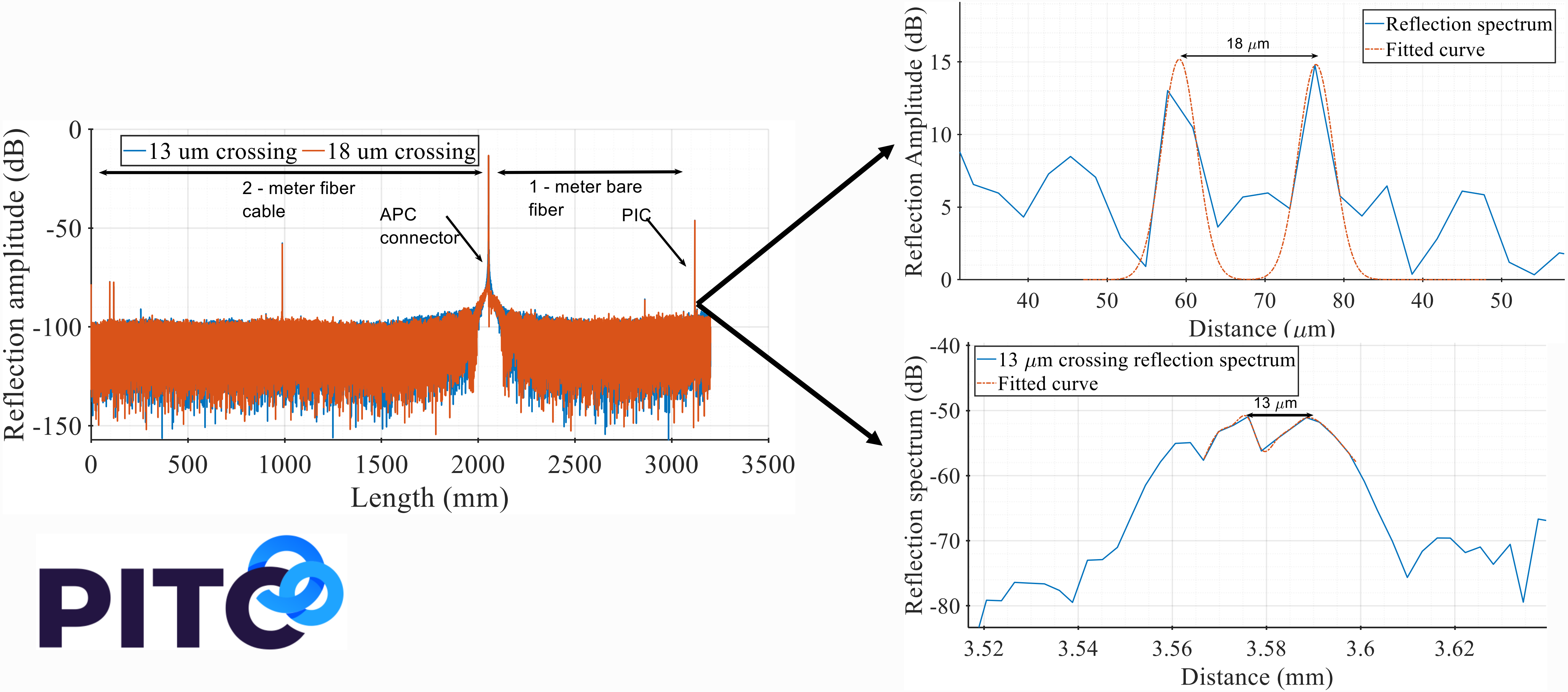


OFDR measurement for PIC example

- PIC with multiple waveguide crossings with multiple widths.
- Manual alignment using lensed fibers.
- Setup used a 2-meter long APC fiber patch cord, which is connected through a connector to a 1-meter long bare fiber.



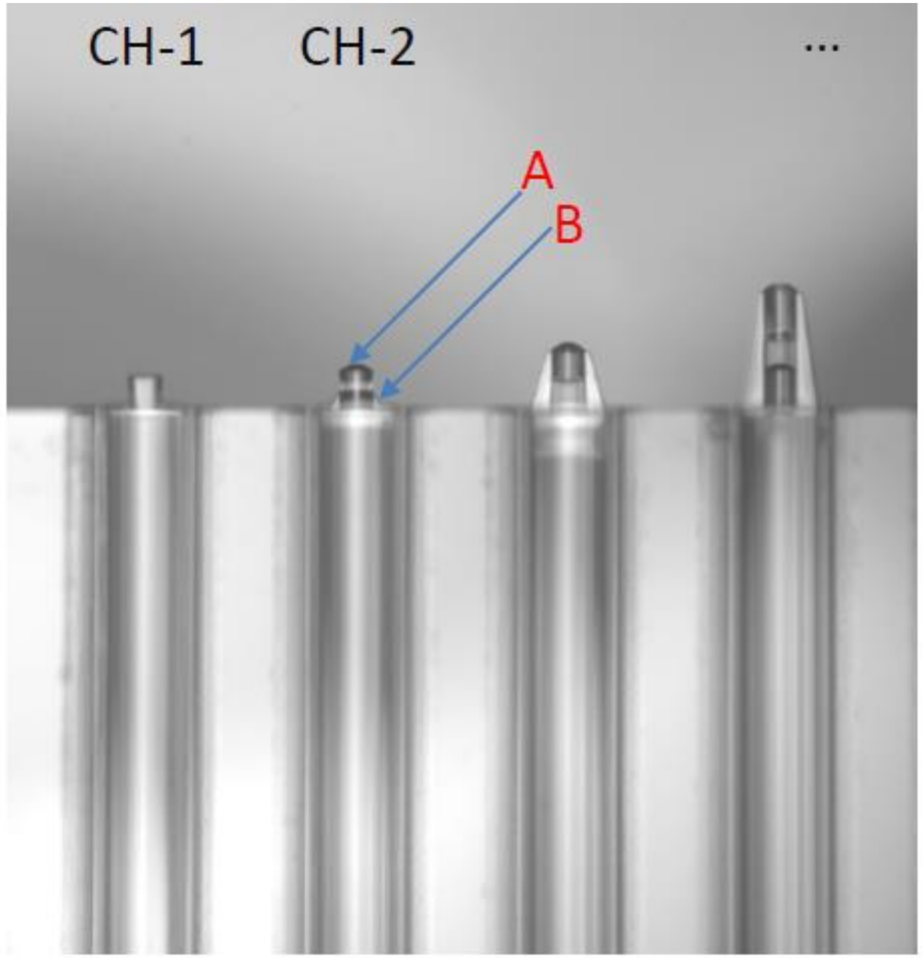
OFDR measurement for PIC example



Example – Sample from Vanguard Automation

Examples with samples from Vanguard Automation :

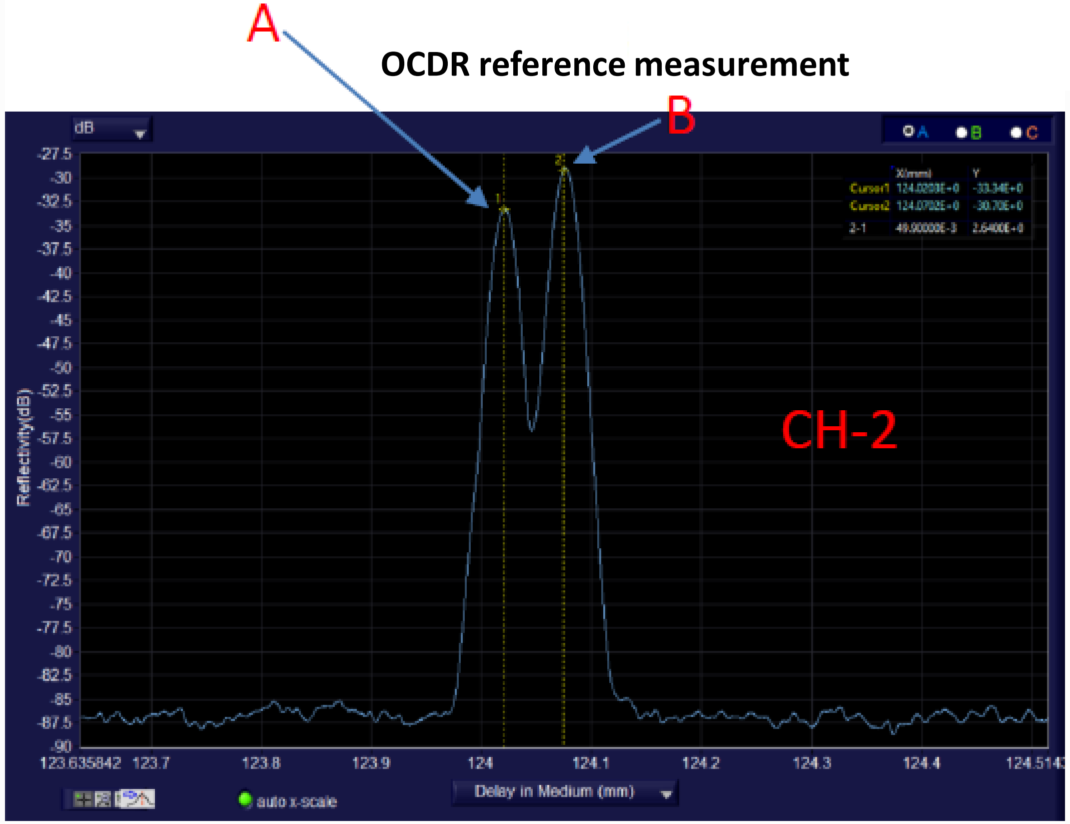
- CH-1 : 40 µm thick square block
- **CH-2 : lens (2 reflections points separated by 50 µm)**
- CH-3 : lens with air gap
- CH-4 : stacked lens with airgap



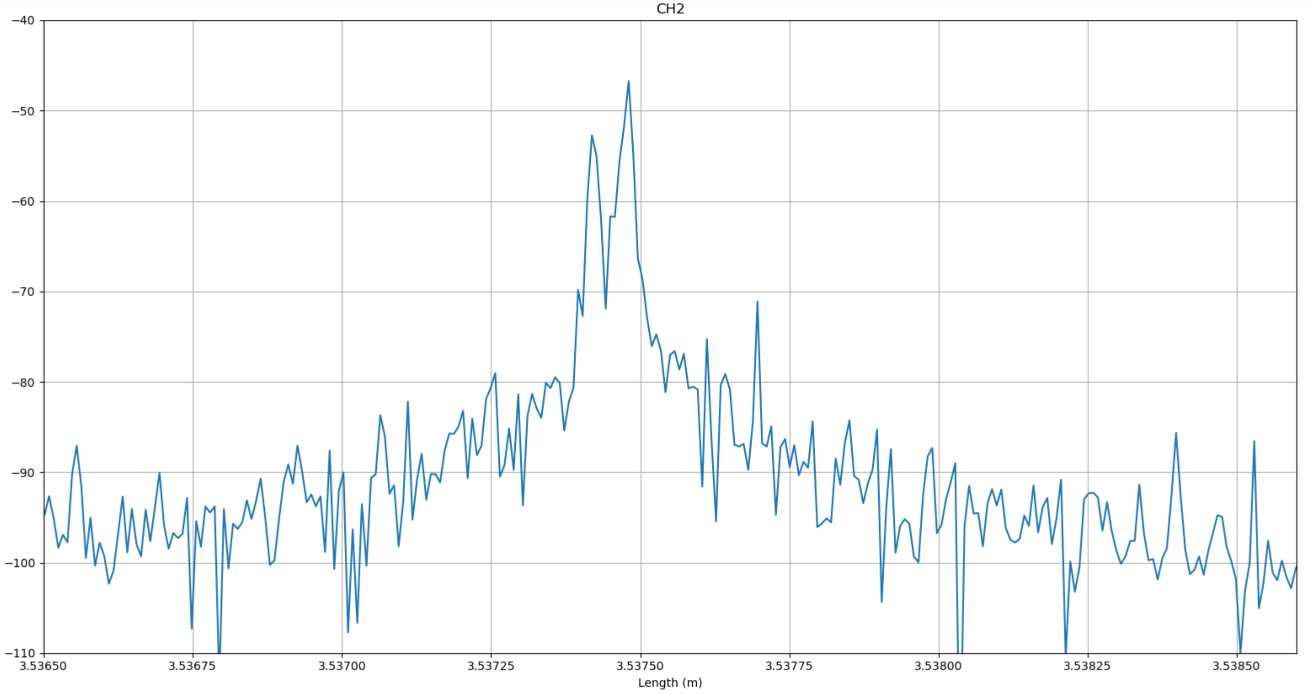
Example – Sample from Vanguard Automation

If we look at the CH2 we retrieve the 2 reflections points which are separated by 50 µm distance

OCDR reference measurement



APEX Technologies OFDR



vanguard AUTOMATION

Thanks for your attention

TOMY MAREST