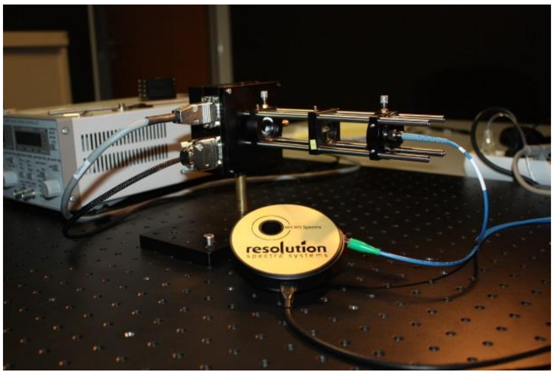
Educational Kit

Fourier Transform and Laser characterization

Based on SWIFTS technology Laser Spectrum Analyzer – MICRO Spectra

- ✓ Fourier Transform Spectroscopy
- ✓ Interferometry
- ✓ Laser Spectrum & Modes
- ✓ Laser diode & VCSEL
- ✓ Integrated Optics



This educational kit is to support the preparation of an educational experiment in the field of Fourier transform spectroscopy and LASER characterization.

A stand alone experiment dealing with Fourier transform spectroscopy, VCSEL laser sources is described based on the MICRO Spectra, an ultra-high resolution mini Laser Spectrum Analyzer using SWIFTS technology (SWIFTS : Stationary Wave Integrated Fourier Transform Spectrometer, French patents).

Other types of experiments such as optical coherence tomography, fibered bragg grating sensors, phase modulation, data processing in the Fourier domain, compressive sensing or laser source analysis are also presented.

Setup included

Opto-mechanics
- Mounting base (x1)
- Metric post holder (x1)
- Post (x1)
- Cage rods (x 4)
- XY Translating Lens Mount (x2)
- Plano-convexe lens
- FC/APC Fiber connector / SM1
- Iris mount
- Iris Diaphragm
- Fiber optical polarizer, FC/APC

Laser Spectrum Analyzer
- MICRO Spectra
- SpectraResolver software –Education version

Source
- Multimode VCSEL 850 nm (x3)

Controler
- Current driver (x1)
- TE-cooled diode mount

The use of a powermeter is recommended for the coupling step.

Educational approach around SWIFTS

SWIFTS technology (Stationary Wave Integrated Fourier Transform Spectrometer) used in the MICRO Spectra is a disruptive technology based on classical interferometry as it can be tackled with a Michelson system. The use of a MICRO Spectra provides the possibility to set up an experiment which extend the Michelson experiment: no need for fine mirror adjustment but rather a focus on laser source itself and/or the data analysis and processing based on Fourier mathematics.

Moreover, it can be very beneficial for students to put into perspective SWIFTS inside the spectroscopy domain. Indeed, as illustrated in the following figure, from a conceptual point of view, SWIFTS links Fourier Transform Spectrometer and grating spectrometers which are *in fine* interferometric systems.

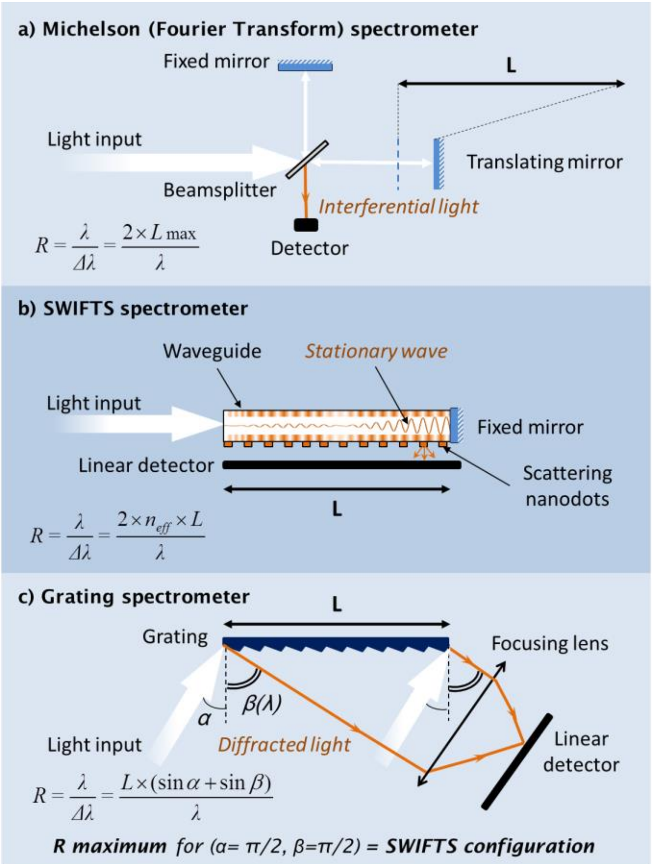


Figure : The SWIFTS principle is compared with grating spectrometers and Michelson (Fourier-transform) spectrometers.

(a) A Fourier-transform spectrometer is shown in a Michelson configuration.

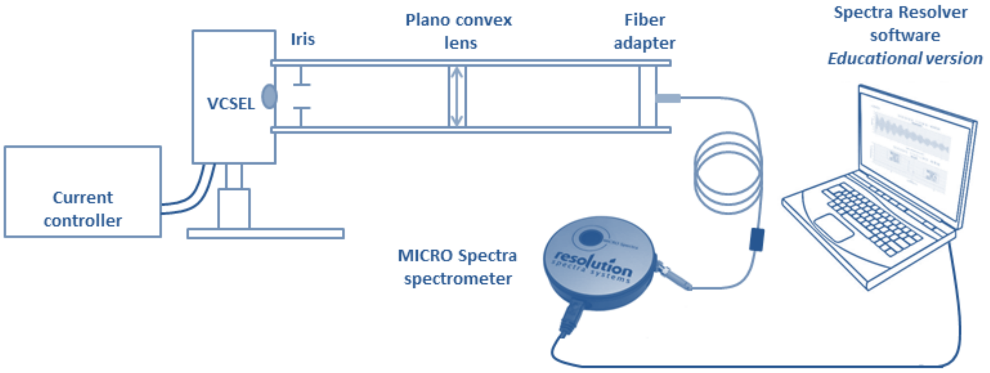
(b) A SWIFTS spectrometer is like a simplified Michelson interferometer in which the scanning mirror and the detector are replaced by the nanodetectors.

(c) A grating spectrometer is an interferometric system that creates an optical path difference (OPD) equal to L x (sinα+sinβ) between the rays reaching the two sides of the grating. For a given grating width L, the resolving power of the grating is maximum for two angles that correspond to the SWIFTS configuration (incident and diffracted light are aligned).

The MICRO Spectra can take advantage of the SWIFTS technology to develop different types of experiments such as: measurement of an Optical Path Difference, Coherence Tomography signals, frequencies in the Fourier domain or a temporal auto-correlation.

Finaly, this Educational experiment can provide an interesting view on the History of Science: SWIFTS is a modern implementation of the coloured photographic plates for which Gabriel LIPPMANN have been awarded the Nobel Prize in 1908.

Example of setup



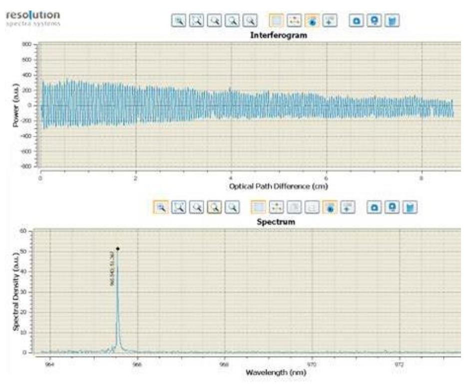
Content of the *turnkey* Experiment kit

Different approaches are possible depending on the students' knowledges, as well as their grade level. Among the different choices :

- The experiment can be mostly focused on laser and use the MICRO Spectra as a analysis tool or it can be focused on the optical detection in the Fourier domain,
- The experiment can be based on an intuitive approach of the Fourier transform and limited to the use of *SpectraResolver* software or/and based on analytical calculation in order to process a spectrum, using for instance FFT algorithm (Fast Fourier Transform),
- The delivered multimode VCSEL can be used or/and otheravailable sources such as tunable laser, fibered or not.

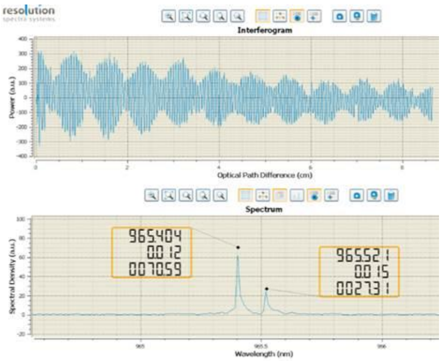
The Educational kit includes a guide for students, which includes these different approaches.

Example of results with the turnkey experiment kit



Singlemode tunable laser

A VCSEL or a laser diode spectrum can be measured with the MICRO Spectra. In the SpectraResolver software, the undersampled Fourier function of the laser can be observed. An explanation of SWIFTS principle consisting on a static interferometer provides the understanding to measure the absolute wavelength of the laser. A slight shift of the wavelength due to a change of the laser drive current or temperature can be measured with the change of the Fourier pattern period.



Dual and multimode laser

When used at the edge of its operating range, the chosen laser diode or VCSEL can be dual-mode. This type of regime can be identified when the Fourier patern is a low frequency function modulated by a high frequency sinusoid. The periods of these two patterns gives access to the absolute wavelengths of the two laser modes. The laser cavity dimension can be extrapolated from this result. Furthermore, the unstability of a VCSEL can be easily observed shifting from single mode regime to hightly multimode emission when tuning drive current or temperature.

Domains which can be addressed with the MICRO Spectra

The MICRO Spectra can be used to imagine different experiments in the following domains :

- ✓ **Data processing in the Fourier domain** with the raw data of the MICRO Spectra. It illustrates a very classical approach in spectroscopy (high and low frequency removal etc.)
- ✓ **Characteriation of laser sources.** The MICRO Spectra can be used to characterize many types of laser sources (Solid state lasers, semiconductor lasers, laser diodes…).
- ✓ **Compressive Sensing.** SWIFTS is intrinsically using Compressive Sensing which is the use of undersampled information.
- ✓ **Optical Coherent Tomography (OCT).** The MICRO Spectra coupled with a (fibered) Mach-Zehnder interferometer illuminated by a SLED source can provide OCT information directly in the spatial domain.
- ✓ **Bragg sensor.** The MICRO Spectra can be used as an fiber Bragg Grating sensor interrogator. It can be also an intersating approach to measure different kinds of spectra in the Fourier domain (use of different FWHM).
- ✓ **Phase modulation and Stationary wave.** The MICRO Spectra can be coupled with aphase modulator in order to finely shift the stationary wave and scan the optical fringes.

Example of related training course :

- **Master of Science (MS, MSc) in Optics / Photonics / Physics / Optical Sciences**

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