Construction of a Fourier Transform Optical Spectral Analyzer

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Abstract

Fourier transform optical spectral analyzers are interferometers that permit to determine the spectral content of a stationary optical signal by means of the Fourier transform of the temporal auto correlation function of the analytical signal. This method of obtaining the spectral content of optical radiation is specially appropriate for weak signals and for signals in the far infra red region, where the signal to noise ratio puts limits to the resolution of conventional spectral analyzers. In this work the construction of a "homemade" Fourier transform optical spectral analyzer is described.

Introduction

An Optical Spectral Analyzer (OSA) is an instrument that determines the spectral content of an optical light flux. The conventional OSA systems use diffraction gratings in order to separate wave lengths and spatially resolved electro-optic detectors to register the energy flux corresponding to small wavelength-bins. Ideally the wavelength-bins should be infinitely narrow to have a perfect resolution. In practice the possibility to approach the ideal case is limited by the signal to noise ratio of the detectors. Mathematically speaking, the ideal case corresponds to a representation of the spectral content in terms of a delta function basis in frequency function space, and this basis is difficult to realize experimentally. The Fourier Transform OSA uses a different bases in function space and then transforms back to the delta bases mathematically [1]. The basic element of this system is a precision Michelson interferometer. The output intensity of the interferometer is registered as a function of optical path length difference of the interferometer arms. The spectral content of the incident light is obtained calculating the Fourier transform of this function. As the interferometer output contains many frequencies the output intensity is not small so that the signal to noise ratio is not a critical parameter. Although this type of OSA is well known and commercially available it is interesting to construct one. First of all the commercial Fourier Transform OSAs are expensive instruments and secondly the construction permits to get a deep insight into the critical difficulties of the method. In the present work a tentative construction is described.

Experimental Setup

The heart of our Fourier Transform OSA is a Michelson interferometer. The compensation of optical path length corresponding to the beam splitter is obtained cutting a beam splitter in half and using the two halves in a modified Michelson arrangement, where the light comes and goes on different ways in the interferometer arms, as shown in fig.1.

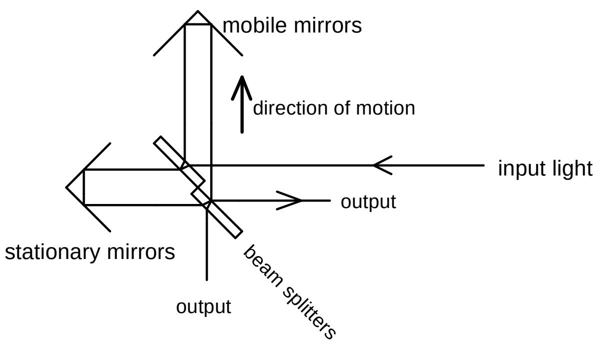

Fig. 1 Modified Michelson Interferometer with variable path length in one of the interferometer arms.

One of the interferometer arms has a variable length. To permit this variation of path length the two 90 degree mirrors, which terminate the interferometer arm, are mounted on a slide that can be pulled by a clockwork on a precision rail. The output light intensity has to be registered as a function of the mirror displacement. It is not necessary to move the mirrors with a high precision step motor or micrometer screw. The exact mirror position can simply be measured interferometrically with the help of a He-Ne laser. Nevertheless, the precision of translation is in fact one of the main problems of the construction. It is essential that the translation be a pure translation, without any rotation. If there were any rotations involved, different parts of the mirror surface would travel different distances and this way the optical path lengths of different parts of the incoming light would be different too.

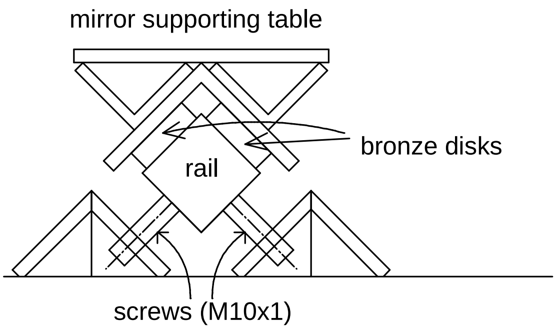

Fig. 2 Precision rail with mirror supporting slide.

The translator of our interferometer was constructed in the following way: a precision machined bar of steel, with quadratic section 38mm x 38 mm, rests on two rows of screws in such an orientation that the diagonals of the square point in vertical and horizontal directions, compare fig 2. This bar acts as a rail. Four bronze disks were carefully cleaned and pressed on the clean surface of the rail. Then the borders of the disks were glued to the rail with hot glue. With the 4 disks in place the mirror supporting table was glued with two component glue to the discs. At the end the hot glue was broken off. The rail supporting screws can be adjusted such as to distribute the forces uniformly avoiding small deformations of the rail.

The absence of rotations was tested in the following way: A He-Ne laser beam was duplicated with the help of a glass plate with enhanced surface parallelism and the two beams (9 mm distance between them) were sent into the interferometer. Two output signals were registered and shown on the x and y axis of an oscilloscope. When the slide is being pulled there should appear a stationary ellipses on the screen, indicating that the two probing beams suffer exactly the same changes of optical path length and their interference oscillations keep a stationary relative phase. In first experiments with 3 cm mirror displacements small deformations of the ellipsis were observed indicating a phase change of the order of π in about 10^5 oscillations. At the moment we are trying to minimize this error further. During these tests light intensities were registered simply by photo-transistors. Later, during the real use of the instrument, the interferometric measurement of the mirror position can still be performed with a simple photo-transistor, but the light measurement of the output light shall be done with calibrated detectors.

The mechanical setup may be used both for visible and for infra-red radiation. However the beam splitters have to be special for each spectral range.

First tests of the interferometer using it as a Fourier Transform OSA are planned in the near future.

Conclusions

A precision translator was built and it was tested that the translation is rotation free with precision of the order 10^{-5}. We believe that the real error is smaller than this value. The first tests were carried out without careful alignment of the measuring optics. The measurement of the translation error and the error itself shall be improved. Thereafter it is planned to test the instrument for real OSA applications.

Acknowledgements

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References

[1]Sumner P. Davis, Mark C. Abrams, James W. Brault: Fourier Transform Spectrometery Academic Press (2001)