Crystal-Grating technology for wavelength measurement

Eliezer Manor and David Vaknin
Specrys ltd, Weizmann Science Park, POB 4126, Ness Ziona 70400, Israel
Phone: +972-(8)-9300665, Fax: +972-(8)-9300667, Email: shirat@netvision.net.il

Abstract
Specrys ltd, a privately owned Israeli company, developed a novel method for fast, accurate and simple measurement of optical wavelength. The method uses birefringence crystals which serve as optical encoders and decoders , enabling accurate measurement with one element detector for each wavelength. Possible applications are described.

Introduction
Traditional methods for wavelength and spectroscopic measurements require arrays with large amounts of detectors and complex optical setups. The accuracy of such traditional devices is directly dependent on the number of optical detectors located on the focal plane and on the focal length of the optical element. Therefore such devices are sensitive to mechanical stability and to ambient conditions. The novel method utilizes the effect of double refraction cased by birefringence crystals to light rays when passing through them.

The method
The phase shift generated between the ordinary and extraordinary beams travelling through a birefringence crystal depends on the parameters of the crystal, as well as on the incident angle of the light beam entering the crystal. Therefore, the phase shift between the two 90º polarized beams constutues the encoding information of the incident angle between the beam and the crystal.
The measuring device consists of an optical bench, on which several optical elements and one or more detectors are mounted. The incident beam is disperssed by a grating, similar to the ones used in regular spectrometers, mounted on the optical bench, directing it in an angular direction relative to its wavelength. The disperssed beam is then passing the birefringence crystal, rigidly mounted on the same optical bench. The outgoing beam from the crystal consists of the two perpendicularly polarized beams, with a phaseshift between them. This phaseshift contains the information of the incident angle and therefore of the wavelength. The two perpendiculary polarized beams with the phaseshift generated between them by the birefringence crystal, are afterwards converted optically in an intensity waveform, when the beam coming out of the birefringes crystal passes through an elasto-optically resonant crystal. The waveform itself contains the information of the wavelength. The sampling time is determined by the resonant frequency of the elasto-optic crystal.
The optical intensity waveform light beam is focused on <u>one</u> element detector, which transforms the light in an electronic waveform signal. The waveform, not its geometrical location on the focal plane, contains the information of the optical wavelength. The waveform is analyzed (the harmonics). The wavelength is derived from the relationships between the intensities of the harmonics. <u>Using this way, the measurement of the wavelength is made in the time domain, rather than in the space domain, as traditionally made so far.</u>
A beam of light containing several discrete peaks of wavelengths, is been measured similarly, using several detectors (as the number of the peaks), mounted on the focal plane and electronically processed in parallel.
The above describes the layout of a device measuring one or several discrete optical wavelengths.

Technology Status
Several devices were built in order demonstrate and prove the technology, as well as a few applications. The specific units, already built, proof the feasibility of the technology, as well as applications using up tp 128 channels for different wavelengths, which are measured simultaneously. The accuracy achieved is better than 1 picometer and the measuremt is been done in less than 1 millisecond.

Applications
There are quite many applications while being able to carry out accurate and fast dicrete optical wavelength measurements of one or many channels, with a simple, compact and rugged device, in real time – parallel or in series.
The 2 main categories of these measurements are of the following natures: (1) Measurement of discrete spectrum peaks, such as of a Raman spectrum, and (2) Measurement of wavelength shift generated by optical sensors, such as FBG (Fiber Bragg Grating). These 2 measurements are related to applications such as materials (and traces) identification and mechanical stress/ vibrations analysis.
Materials identification is applicable in different industrial branches (such as food industry, drug industry, chemical industry, etc), as well as for homeland security (detection of explosives' traces). The mechanical stress & vibrations analysis might be suitable for homeland security (such as intrusion detection) and SHM (Structural Health Monitoring) for applications such as buildings, bridges, towers and aicraft fuselages (real-time measurement, when the FBG sensors are embedded in composite materials).

Conclusions

The novel Cystal-Grating technology and its applications were proven, tested and measured.

References

1. US Patent No. US 7,515,262 B2, dated Apr. 7, 2009, PCT filed: Jan. 21, 2004