Single-Shot FT-Spectrometer "Tilt" with two-beam interferometer

TLB
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In these miniature spectroscopes according to the invention, the use of a novel anamorphic mirror optics in combination with field of view discriminators leads to a compact optical arrangement and avoids interfering influences in the interferogram. This makes it possible to measure moving objects such as fire storms.

- Hyperspectral single-shot sensor with imaging
- Single-shot approach allows the use of comparatively inexpensive light sources
- Handheld or drone assisted operation possible: High robustness in field use and long-term stability
- Cost advantages through simple optical design
- (Possibility of integrating of an autofocus system for precise object detection)

Fields of application

- Examination of the skin (skin cancer screening)
- Examination of partially exposed tissue, e.g. during tumor operations
- Inspection of the interior of the eye, e.g. retina
- Analysis of food, especially on unsteady running conveyor belts, also
- bulk products like cereals and pulses
- Fluorescence light analysis of objects and scenes in UV incident light
- Measurement in moving objects such as erupting volcanoes or
- firestorms during flyover of forest fires
- Identification of plastics in moving objects by means of the spectrum,
- e.g. for waste sorting on a conveyor belt
- Measurements using hand-held units and manual scan of objects

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US 11,530,982 granted
US 11,566,998 B2 granted
EP 3760990 B1 (GB/FR/DE) granted

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Service
Technologie-Lizenz-Büro GmbH has been entrusted with exploiting this technology and assisting companies in obtaining licenses.

- (forensics in criminology, medicine, hygiene, archaeology, botany,
- mineralogy)
- Thermal imaging in the near and far range
- Airport scanner

Background

A wide range of industries have a demand for spectrally and spatially resolved sample analysis and determination, be it of gas compositions, liquids, solids, or specific material components. In medical research and development, in emissions control and hazardous materials detection, Fourier Transform Infrared spectroscopy (FT-IR spectroscopy) is indispensable when it comes to the analysis, detection and identification of samples.

Problem

Particularly when used in mobile devices, e.g. hand-held devices or devices installed in drones or helicopters, conventional methods do not allow for conclusive results when the sample or spectrometer is moved unsteadily. A high light efficiency, short exposure times and a high wavenumber accuracy of the spatially resolved spectrum is required, which needs to be measured with a highly robust device in terms of shock and vibrations. A further requirement is that the devices should be small, with only short optical paths within the interferometer and contain as few optical components as possible.

Solution

Scientists at the Universität Stuttgart have now developed two new methods for spatially-resolved single-shot FT spectroscopy that can be used to obtain hyperspectral image information of moving objects or turbulent scenes in harsh environments.
In both mini spectroscopes without moving components, the use of a new type of anamorphic mirror optics in combination with image field discriminators create a compact optical setup and reduces disturbances in the interferogram. With both methods, the mirror groups - according to the invention - can be designed monolithically and are thus comparatively small and compact. This ultimately enables the construction of new types of mobile measuring devices.

Single-Shot FT-Spectrometer "Tilt" with two-beam interferometer

This method utilizes two-beam interferometers with two image-field discriminators at each of the coherent images. Two-beam interferometers that could be used are Michelson-type, Mach-Zehnder and cyclic two-beam interferometers. After an image field discrimination, only a narrow partial image remains for detection. From the two coherent partial images, an interferogram can be obtained in single-shot mode for each measuring spot of the image. Thus, many interferograms - one for each measuring spot - can be recorded simultaneously. After the Fourier transformation of the interferograms, they provide a hyperspectral partial image. The hyperspectral overall image is obtained by adding the hyperspectral partial images that were taken at differenttimes.

In both the Michelson type and Mach-Zehnder interferometer, a retroreflector consisting of two mirrors is placed in each interferometer arm. Each arm is assigned an image field discriminator. The retroreflector causes a constant lateral shear of the partial beams, that leads to a tilt of the light beam on the detector which is always constant, i.e. invariant under shearing. In contrast, the cyclical two-beam interferometer uses only one retroreflector consisting of two mirrors in the rotating beam path. In each of the two beam paths, it is assigned one image field discriminator, which is located inside the
retroreflector. This means that when using these interferometer types, image field discrimination actually takes place directly in or on the retroreflector, i.e. inside the interferometer - which is unprecedented. This approach has great strengths regarding image field discrimination of laterally extended objects. Even with faint objects, a good signal-to-noise ratio can be achieved using the well-known light throughput advantage of FT spectroscopy. Due to the tilt invariance of the retroreflectors under displacement, a misalignment of the spectrometer is nearly impossible, even if there are vibrations.

“Shear” single-shot FT spectrometer with Michelson type interferometer

This method generates a lateral shear that is invariant with transversedisplacement by using a Michelson type interferometer in combination with aspecial retroreflector as the end reflector, implemented as a triple angle mirrorgroup where each of the three mirrors is perpendicular to a common reference plane. This means that a high wavenumber accuracy can be permanently achieved, which enables measurements with high spectral resolution. When the retroreflector is realized as a monolithic triple-angled mirror group, in which the three plane mirror surfaces are each arranged perpendicular to a common reference plane, the image field discriminators need not be located in the interferometer. In this case, it is sufficient to place a single image field discriminator in front of the Michelson type interferometer. For the examination of stand-alone point light sources, an image field discriminator is not even necessary.
 In summary, a new imaging FT spectroscopy instrument can be created for the robust generation of spatial interferograms - with permanently high wavenumber accuracy and without any moving components in the interferometer.

Literature and links

Hahn R et al.: Single-shot low coherence pointwise measuring interferometer with potential for in-line inspection; Meas. Sci. Technol. (2017) 025009 (13pp); doi:10.1088/1361-6501/aa52f1