Electro-Optical Imaging Fourier-Transform Spectrometer

Size, weight, and vibration are reduced by eliminating moving parts.

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An electro-optical (E-O) imaging Fourier-transform spectrometer (IFTS), now under development, is a prototype of improved imaging spectrometers to be used for hyperspectral imaging, especially in the infrared spectral region. Unlike both imaging and non-imaging traditional Fourier-transform spectrometers, the E-O IFTS does not contain any moving parts. Elimination of the moving parts and the associated actuator mechanisms and supporting structures would increase reliability while enabling reductions in size and mass, relative to traditional Fourier-transform spectrometers that offer equivalent capabilities. Elimination of moving parts would also eliminate the vibrations caused by the motions of those parts.

Figure 1 schematically depicts a traditional Fourier-transform spectrometer, wherein a critical time delay is varied by translating one the mirrors of a Michelson interferometer. The time-dependent optical output is a periodic representation of the input spectrum. Data characterizing the input spectrum are generated through fast-Fourier-transform (FFT) post-processing of the output in conjunction with the varying time delay.

In the E-O IFTS, the Michelson interferometer optics and the bulky, slow translation mechanism are replaced with a solid-state time-delay/interferometer assembly. Included in the assembly (see Figure 2) are an input polarizer, an input passive quarter-wave plate (phase shifter), a series of $N$ liquid-crystal-based electro-optical achromatic half-wave switches $(S_1, S_2, \ldots S_N)$ interspersed with a series of $(N + 1)$ passive birefringent wave retarders $(\Gamma_1, \Gamma_2, \ldots \Gamma_N)$, and an output polarizer.

The assembly can be regarded as consisting largely of a series of overlapping building blocks, each consisting of two of the passive wave retarders and the achromatic half-wave switch between them. By electro-optically rotating the orientation of the switch to an angle of either 0° or 45° with respect to the input polarization, one can cause the total retardation of the waves passing through the unit to be either the difference or the sum, respectively, of the retardations introduced by the individual retarders. Each retarder following the first one is made twice as thick as (to introduce twice the retardation of) the one preceding it. Hence, by means of binary actuation of the switches among all combinations of sums and differences, it is possible to obtain $2^N$ different retardation values in increments of the smallest such value and thereby to obtain an arithmetic progression of small time-delay steps.

This work was done by Tien-Hsin Chao and Hanying Zhou of Caltech for NASA’s Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to: Innovative Technology Assets Management JPL
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