A process for extracting long-equivalent wavelength interferometric information from a two-wavelength polychromatic or achromatic interferometer. The process comprises the steps of simultaneously recording a non-linear sum of two different frequency visible light interferograms on a high resolution film and then placing the developed film in an optical train for Fourier transformation, low pass spatial filtering and inverse transformation of the film image to produce low spatial frequency fringes corresponding to a long-equivalent wavelength interferogram. The recorded non-linear sum irradiance derived from the two-wavelength interferometer is obtained by controlling the exposure so that the average interferogram irradiance is set at either the noise level threshold or the saturation level threshold of the film.
Fig. 1
METHOD FOR EXTRACTING LONG-EQUIVALENT WAVELENGTH INF...
SUMMARY OF THE INVENTION

The present invention overcomes the aforementioned deficiencies of the multiplicative process by exploiting the information on a single interferogram produced simultaneously at two different wavelengths such as in the manner described in the disclosure of the parent application hereof. More specifically, the present invention comprises an information extraction process in which a non-linear recording of the sum interferogram as provided by a polychromatic interferometer on high resolution film, may be utilized to extract long-equivalent wavelength interferometric information. When the sum interferogram exposure is adjusted to fall in a non-linear portion of the high resolution recording film, a Fourier transform of the resulting record reveals both sum and difference spatial frequencies. The latter corresponds precisely to the long-equivalent wavelength interferometric information. Once this film is processed, it may be put into a conventional spatial filtering optical train which provides Fourier transformation, low pass spatial filtering and inverse transformation, the output of which comprises a filtered version of the original two-wavelength interferogram, but with only the difference frequency component present. This difference frequency component corresponds to the long-equivalent wavelength interferometric information desired. Thus, as a result of the unique process of the present invention, a non-linear recording of the sum interferogram can be processed in the same manner as a multiplicative interferogram to reveal the long-equivalent wavelength information of interest.

OBJECTS OF THE INVENTION

It is therefore a principal object of the present invention to provide a process for extracting long-equivalent wavelength interferometric information from a single sum interferogram derived from a two-wavelength interferometer.

It is an additional object of the present invention to provide a process for extracting long-equivalent wavelength interferometric information without requiring any form of multiplicative process that would require the use of two independent single frequency interferograms.

It is still an additional object of the present invention to provide an improved method for extracting long-equivalent wavelength interferometric information that is especially adapted for use with a polychromatic interferometer for measuring the topography of the human cornea.

It is still an additional object of the present invention to provide an improved method for use in topographically mapping a reflective surface wherein a dual wavelength sum fringe pattern is provided by a wavelength-independent interferometer.

It is still an additional object of the present invention to provide a method for extracting a non-ambiguous difference frequency fringe pattern from a wavelength-independent optical interferometer without using multiplicative processing.

BRIEF DESCRIPTION OF THE DRAWINGS

The aforementioned objects and advantages of the present invention, as well as additional objects and advantages thereof, will be more fully understood as a result of a detailed description of a preferred embodiment when taken in conjunction with the following drawings in which:

FIG. 1 is a block diagram of an aspheric testing scheme which includes the process of the present invention;

FIG. 2 is a graphical representation of the non-linear sum of interferometer fringe patterns used to explain a step in the process of the present invention; and

FIG. 3 is a graphical representation of a spatially-filtered, non-linearly processed sum interferogram which corresponds to a result produced by the process of the present invention.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT

Referring now to FIG. 1, it will be seen that the process of the present invention is designed to be used in conjunction with a polychromatic or achromatic interferometer such as for measuring the topography of an aspherical surface such as the cornea of the human eye. One polychromatic or achromatic interferometer is disclosed in detail in patent application Ser. No. 07/364,165 filed on June 12, 1989 of which the present invention is a continuation in part. The disclosure of the aforementioned parent application is incorporated herein by reference and should be considered a part of the disclosure of the present invention. However, it will be understood that the present invention is not limited for operation with the wavelength-independent interferometer disclosed in the parent application. The present invention comprises a process which can be used with other polychromatic or achromatic interferometers, or for that matter any interferometer capable of producing a sum interferogram generated using two different wavelength light sources from which it is desired to extract a long-equivalent wavelength interferogram.

The first step of the process of the present invention comprises the step of producing a simultaneous non-linear recording of the sum of two visible light interferograms on high resolution film. Although any high resolution film may be appropriate for use with the present invention, in a preferred embodiment of the invention, such film is preferably high resolution instant film such as Xerox Dry Micro-Film sold under the trademark XDM. This film is a high resolution selenium and thermoplastic-based material and has an extremely fine grain characteristic that constitutes a high resolution photoreceptor especially suitable for use in the invention. The term non-linear recording as used in the present invention, refers to a non-linear recording of the sum irradiance in which the average interferogram irradiance is set at either the noise ("fog") or saturation exposure level of the photo receptor or film. FIG. 2 shows the non-linear sum of interferometric patterns where the average irradiance has been set at the noise level of the film, meaning the interferogram has been underexposed on the film. The results obtained in the present invention by setting the average irradiance at the saturation level should be qualitatively identical. However, from a radiometric and clinical standpoint, the underexposure technique would be the most desirable way to introduce the necessary non-linearity to produce a clipped sum interferogram, the equivalent waveform of which is shown in FIG. 2 for a tilted plano surface.

Those having skill in the art to which the present invention pertains will understand that the Fourier
The invention pertains to the process of extracting long-equivalent wavelength interferometric information from a wavelength-independent sum interferometer, the method comprising the steps of:

1. A method for extracting long-equivalent wavelength interferometric information from a wavelength-independent sum interferometer, the method comprising the steps of:
   a) preparing a non-linear sum two-wavelength interferogram;
   b) placing the interferogram prepared in step a) in a Fourier transform, spatial filter, inverse Fourier transformation of the resulted image of such a record;
   c) detecting the output image of said optical train.

2. The method recited in claim 1 wherein step a) comprises the steps of:
   a) preparing a non-linear sum two-wavelength interferogram; and
   b) placing the interferogram prepared in step a) in a Fourier transform, spatial filter, inverse Fourier transform optical train; and
   c) detecting the output image of said optical train.

3. The method recited in claim 1 wherein step c) comprises the steps of:
   a) preparing a non-linear sum interferogram from said interferometric information on a high resolution film with the exposure adjusted to fall in a non-linear portion of said film; and
   b) detecting the optical inverse Fourier transform of said spatially filtered interferogram.

4. A method for use in topographically mapping a reflective surface; the method comprising the following steps:
   a) generating an interferometric fringe pattern from said surface with at least two distinct wavelengths of light reflected simultaneously from said surface; and
   b) preparing a non-linear sum interferogram from said fringe pattern;
   c) obtaining an optical Fourier transform of said interferogram; and
   d) spatially filtering out all frequency components of said Fourier transform except the components corresponding to the difference frequency between said two distinct wavelengths of light;
   e) obtaining an optical inverse Fourier transform of said spatially filtered Fourier transform.

5. The method recited in claim 4 wherein step b) comprises the steps of:
   a) generating a non-linear sum interferogram from said interferometric information from a polychromatic or achromatic interferometer; and
   b) detecting the optical inverse Fourier transform obtained in step e).

6. The method recited in claim 4 wherein step b) comprises the steps of:
   a) generating a non-linear sum interferogram from a high resolution film with the exposure thereof being such that the average irradiance of said pattern substantially coincides with the noise exposure level of said film; and
   b) detecting the optical inverse Fourier transform obtained in step e).

7. A method for extracting a non-ambiguous difference frequency fringe pattern from a two-wavelength optical interferometer; the method comprising the steps of:
   a) generating a non-linear sum interferogram from said interferometer;
b) placing the interferogram generated in step a) in a
Fourier transform, spatial filter, inverse transform
optical train wherein said spatial filter comprises a
pinhole having an aperture dimension for passing
only said difference frequency component.
8. The method recited in claim 7 wherein step a)
comprises the steps of exposing the optical output of
said interferometer on a film at an exposure level ad-
justed to a non-linear exposure portion of said film; and
developing said film.
9. The method recited in claim 8 wherein the average
of said adjusted exposure level corresponds to the noise
threshold of said film.
10. The method recited in claim 8 wherein the aver-
age of said adjusted exposure level corresponds to the
saturation threshold of said film.

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