Monochromatic spectrum reconstruction by geometric phase-shifting interferometry

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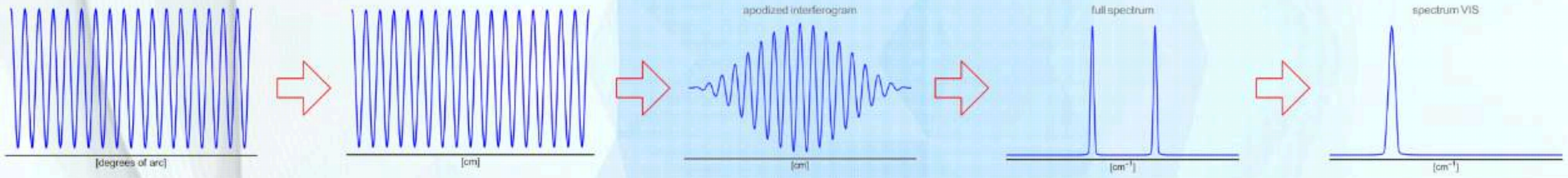
Interferometry, Fourier-transform and single-pixel detection are well established mathematical and scientific methods for various precision measurements and characterizations. A successful combination of the three is found in Fourier-transform spectroscopy; a method that works by scanning the interferogram of incident radiation – recorded, either, at constant time intervals (time domain) or constant spatial increments (spatial domain) – and applying the Fourier transformation to obtain the spectrum (in temporal or spatial frequencies, respectively). Usually, the scanning is achieved by moving one of the mirrors in the interferometer, hence by controlling the dynamic phase difference. In the present work, a different approach based on controlling the geometric phase is proposed. A polarising interferometer is designed and tested with this idea, and the monochromatic spectrum of light from several LEDs, with various central wavelength, is reconstructed with this method.

METHOD

Applying the Fourier-transform spectroscopy method to data from a polarizing phase-shifting interferometer.

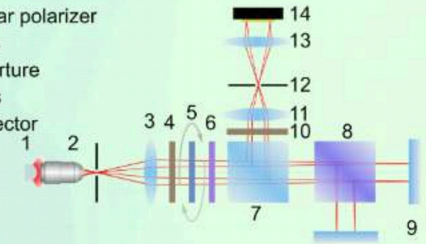


$\Delta rot = N\,\varphi\ (degrees\ of\ arc) \quad \varphi = 90°$ — Total rotation of the HWP as a function of the number of fringes, where φ is the angle for one fringe count.

$OPD_e = 2\,d = N\,\lambda\ (cm)$ — The *equivalent* OPD in terms of the counted number of fringes. (Artifact)

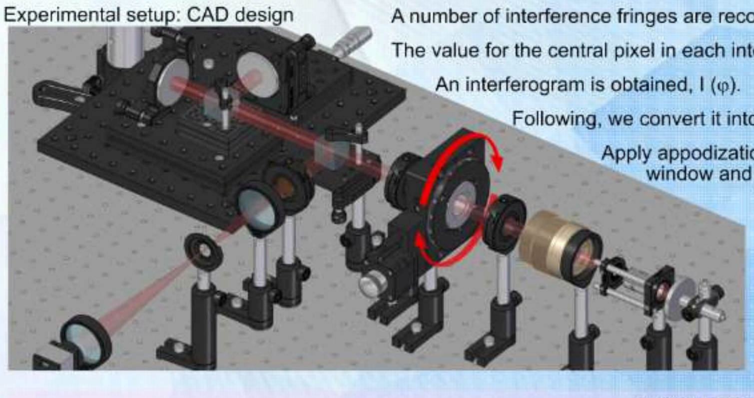
$\Delta rot = \frac{OPD_e}{\lambda}\,\varphi\ (degrees\ of\ arc)$ — Total rotation as a function of the equivalent OPD.

1 LED source
2 beam expander
3 collimating lens
4 linear polarizer
5 rotating HWP
6 fixed QWP
7 BSC
8 PBSC
9 mirrors
10 linear polarizer
11 lens
12 aperture
13 lens
14 detector

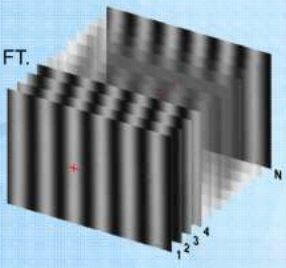


EXPERIMENTAL

Experimental setup: CAD design



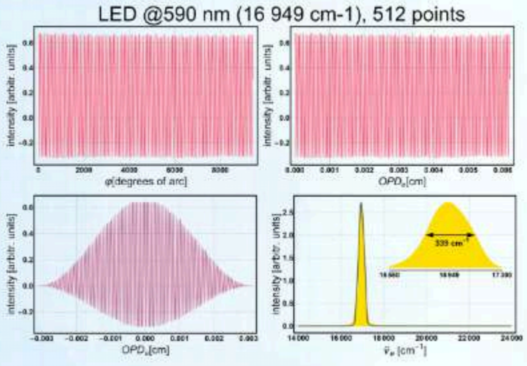
A number of interference fringes are recorded = *N*pts.
The value for the central pixel in each interference image is extracted.
An interferogram is obtained, I (φ).
Following, we convert it into I (x).
Apply appodization window and perform FT.



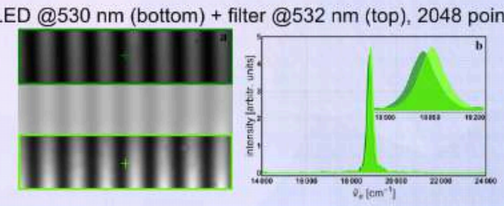
Measurement parameters

*N*pts	*Res* (cm⁻¹)	*OPDe* (cm)	δrot (°)	*N*	Δrot (°)	δx_e (nm)
512	150.4	0.00664	18.5	105	9453.5	130
1024	92.4	0.01082	15	171	15390	105.8
2048	69.3	0.01442	10	228	20520	70.5
4096	38.5	0.02595	9	410	36900	63.4
8192	28.9	0.03461	6	547	49230	42.3
16384	17.3	0.05765	5	911	81990	35.2

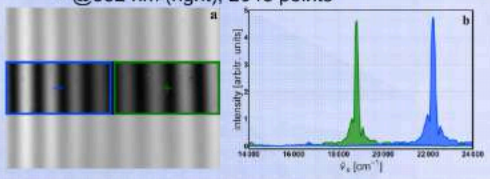
LED @590 nm (16 949 cm-1), 512 points



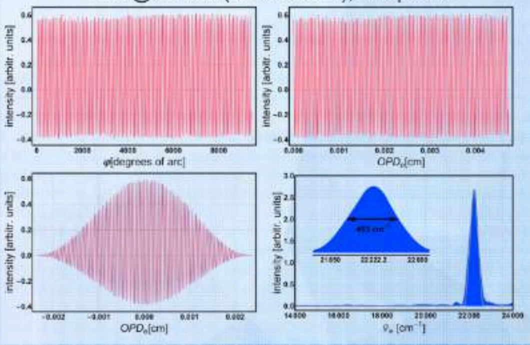
LED @530 nm (bottom) + filter @532 nm (top), 2048 points



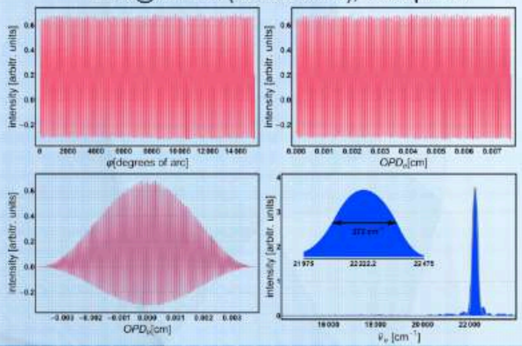
"white" LED and 2 filters: @450 nm (left) + @532 nm (right), 2048 points



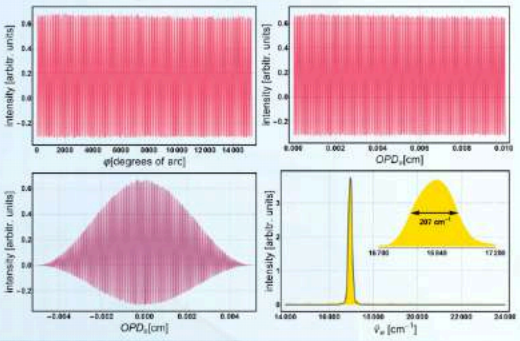
LED @450 nm (22 222 cm-1), 512 points



LED @450 nm (22 222 cm-1), 1024 points



LED @590 nm (16 949 cm-1), 1024 points



CONCLUSIONS

- Geometric phase can be used as a phase shifter mechanism for light measurement using Fourier-transform spectroscopy.
- Only monochromatic radiation can be measured due to the achromatic nature of the geometric phase.
- It is possible to measure multiple wavelengths at once by assuring spatially separated sources and a CCD as detector.
- The main advantage is controling rotations of degrees of arc instead of translations on the order of tens of nanometers.
- The amount of this rotation motion is considerably larger and, in consequence, easier to control with less noise involved.

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