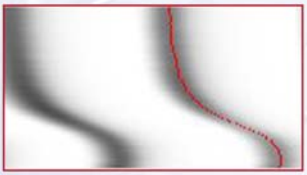
Phase Cam

Phase & Amplitude Measurement



Operating Instruction

HOLOEYE **Pioneers in Photonic Technology**

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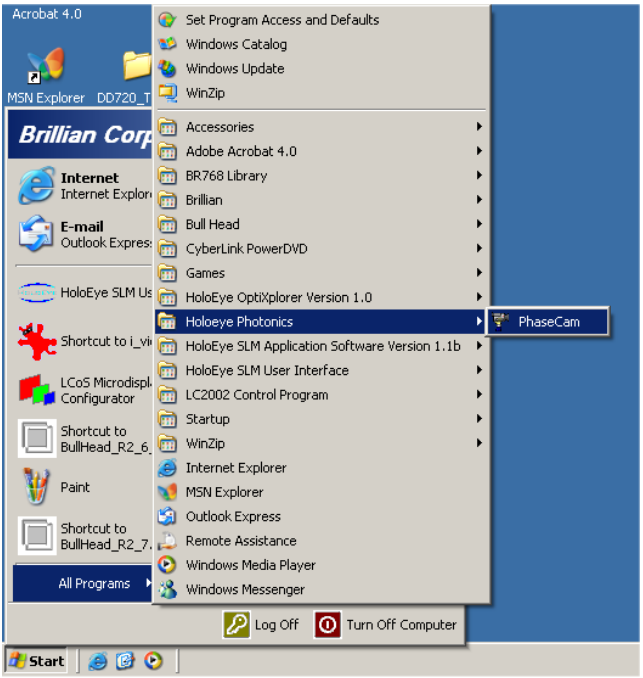
1 Introduction

The phase modulation that can be achieved with a spatial light modulator for a coherent light source can be measured with different methods such as measuring the intensity distribution of diffraction orders created by a changeable binary grating or using a Mach-Zehnder interferometer for transmissive displays and a Michelson interferometer for reflective displays.
The method which will be shown here is also based on two beam interference and can be used for transmissive as well as for reflective displays. Another advantage compared to the Mach-Zehnder and Michelson interferometers is that no beam splitting element is necessary what can influence the measurement.
Here the display will be illuminated by two coherent and collimated laser beams by using of a double hole mask (hole diameter approx. 2mm, distance approx. 7mm). Both beams are separately guided to an appropriate display half. The left one will be addressed with a constant gray level whereas the other half will be addressed with changing gray levels from 0 to 255. A lens behind the display let both beams interfere with each other and a microscope objective images the expanded interference pattern onto a CCD camera. A phase shift as a function of the addressed gray level will appear as a shift in the interference pattern and will be evaluated by the supplied software.
It often is also important to know the amplitude modulation for a certain phase modulation. This can be determined by a slightly modified set up. One beam has to be blocked and the CCD camera has to be replaced by a photo detector. The software has to be driven in amplitude mode. Here the whole display will be addressed with homogeneous gray level.

2 Installation

For installing the measurement program “PhaseCam” execute SETUP.EXE, located in the folder “PhaseCam”. The program requests for all informations required for the installation process.
After the installation has been successfully completed, the program can be started from the Windows Start menu as shown below.



3 Measurement set up

3.1 Transmissive spatial light modulator

The un-polarised laser beam is guided through a variable neutral density filter to adjust the intensity detected by the CCD camera. The beam is then expanded by a microscope objective and collimated by a lens. A mirror reflects this beam under a small angle (~6°) in order to illuminate the whole display aperture of a transmissive spatial light modulator (e.g. LC 2002). A linear polariser in front of the SLM sets the incoming polarisation state. If the used laser is already polarised, a $\lambda/2$ wave plate would be necessary instead of the polariser to set the incoming polarisation state. A double hole mask (hole Ø~3mm, distance ~7mm) creates two beams (one for each display half) which will be guided through the analyser behind the SLM and combined by a lens. The interference pattern of the two beams will then be imaged onto the CCD chip by using a second microscope objective. The shift of the interference pattern of a pre selected camera line will be evaluated by the software "Phase Cam". Thereby an intensity minimum of the interference pattern (defined by the user) is the starting point of the measurement. This minimum will be detected by the software and its movement, as a function of the addressed gray level, is a measure for the phase shift.
The complete set-up can be seen in figure 1.

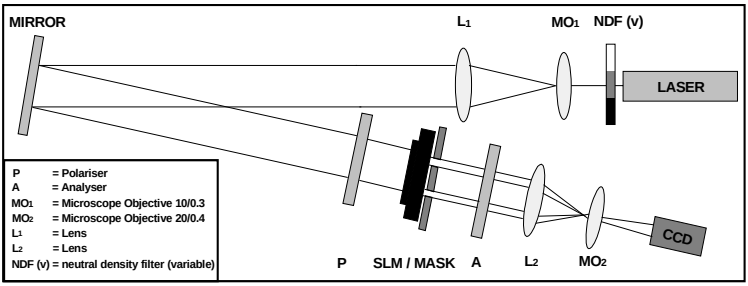


FIG. 1: Set-up for a transmissive SLM

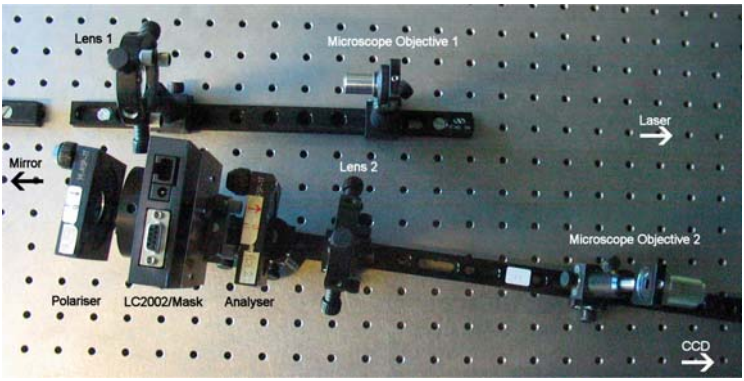


FIG. 2: Photo of translusive setup

3.2 Reflective spatial light modulator

To measure the phase shift of a reflective SLM (e.g. LC-R 2500 and HEO 1080P) the above set-up has to be adapted. The polariser respectively the $\lambda/2$ wave plate has to be placed behind the collimating lens. The mask creates two beams which illuminate the LCoS panel that replaces the mirror of the transmissive configuration. The two beams will then be reflected under a small angle (~6°), analysed by the analyser and combined by the lens. The CCD camera detects the interference pattern as described above.

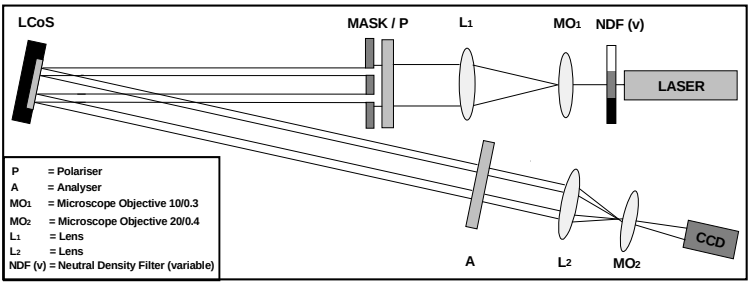


FIG. 3: Set-up for a reflective LCoS - Display

4 Software Functions/Buttons

Figure 4 shows the user interface of the software. It can be seen that it is basically divided into two parts. The part on the left hand side is used to set the measurement properties. On the right part the camera image will appear. The control part consists of 6 category groups which will be explained in this section.

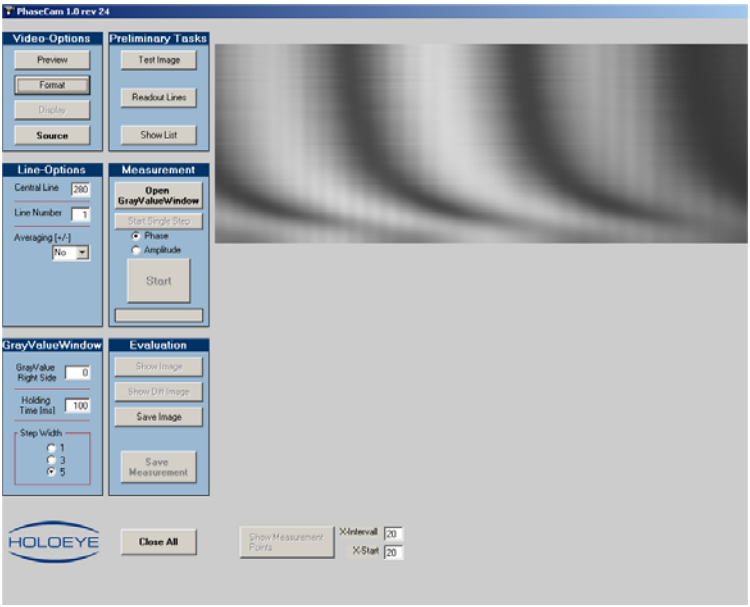


FIG. 4: User interface

4.1 Video Options

- Preview

  This function displays the live stream of the used camera (web cam, CCD).

- Format

  This opens a dialog window where the screen resolution can be selected. If USB 1.1 is used the resolution will be limited to 320*240 pixel. This button as well as the "Display" button is inactive if the camera does not provide this function.

- Source

  If the source button is pressed the user can control basic settings of the camera (e.g. brightness, contrast…) to get an optimal interference pattern.

4.2 Preliminary Tasks

- Test image

  With that function a stable test image will be recorded by the CCD camera and displayed on the right side of the user interface. This image is used for selecting the measurement line (see section 4.3).

- Readout Lines

  If the "test image" and the measurement line have been selected, the location of the minima and maxima as well as the period of the interference pattern can be determined. These values will appear on the lower right part of the user interface (see figure 4).
  The column where the software starts to search for a minimum can now be selected in the small window "X-Start". "X-Interval" is the number of columns which are used by the program to search for a minimum around the "X-Start" value.

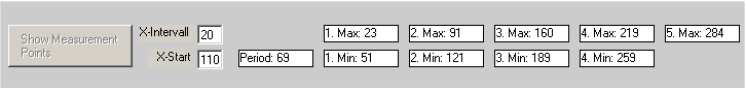


FIG. 4: Min., max and period of the measurement line

- Show List

  This button lists the intensity distribution of the selected measurement line in a table.

4.3 Line Options

- Central Line

  By pressing the right mouse button inside of the „test image“ the measurement line will be selected. The selected line should have maximal interference contrast. The effective line number can be seen in the small window right beside “central line”.

- Line number

  Here the user can set the amount of measurement lines around the central line.

- Averaging [+/-]

  This function can be used to avoid saturation of the camera by averaging a certain amount of columns of the measurement line. This option also smoothes the interference pattern (see figure 5).

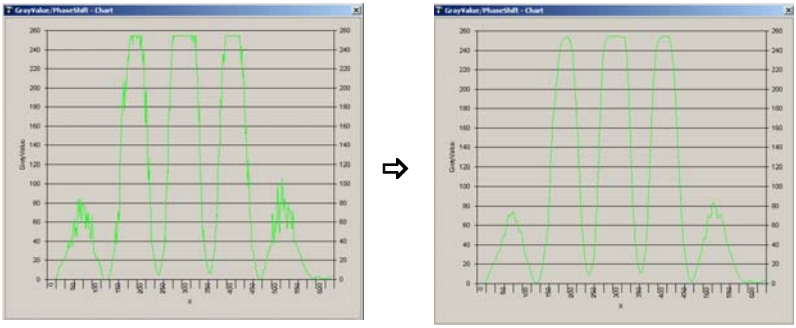


FIG. 5: Averaging

4.4 Gray Value Window

- Gray Value Right Side

  This function enables the selection of the reference gray value.

- Holding Time [ms]

  This function sets the holding time between two following gray levels. The minimum time unit is 100ms and is limited by Windows.

- Increment

  Here one can choose the gray level increment of the measurement. Increasing the increment shortens the measurement time but on the other hand reduces the accuracy.

4.5 Measurement

- Open Gray Value Window

  This opens the gray value window which will be addressed onto the panel.

- Start Single Step

  The user can increment the gray level of the active display half manually.

- Phase/Amplitude

  This option changes the mode of addressing. If phase mode is activated both display halves will be addressed independently.
  If amplitude mode is active the display will be addressed with homogeneous gray level. All buttons which are only necessary for the evaluation of the interference pattern will be blocked.

- Start

  This starts the automatic measurement.

4.6 Evaluation

- Show Image

  If the measurement is finished, all lines per gray level will be displayed below each other (see figure 6). The measurement points are already shown in this graph.

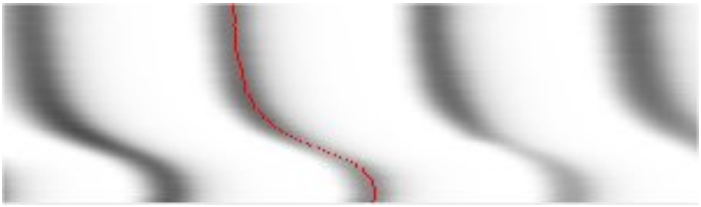


FIG. 6: Measurement image

- Show Diff Image

  A two colored image of the upper image will be displayed (see figure 7).

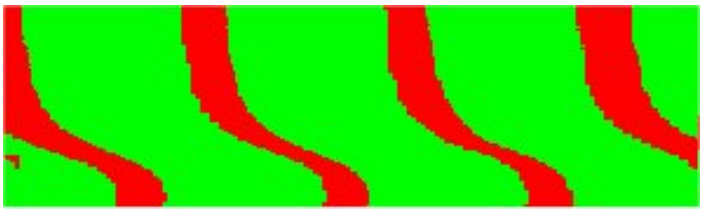


FIG. 7: Differential image

- Save Image

  This function saves the shown measurement image.

- Save Measurement

  This saves the measurement values in a .txt file including the period of the interference pattern and the position of the measured line for each addressed gray level.

5 Measurement schedule

5.1 Adjustment

It is recommended to have a look at the *"Preview"* before starting the measurement to make sure that everything is correctly adjusted, that the interference pattern looks reasonably and that the camera is not saturated. The image below shows an example.

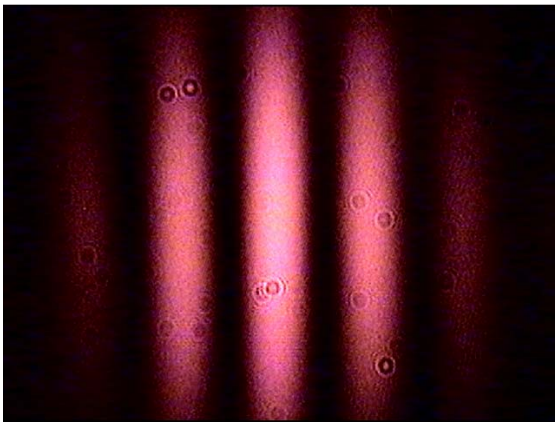


FIG. 8: Interference pattern detected by a camera

5.2 Declaration of the measurement line

After proper adjustment press the *"test image"* button. A stable image will be recorded and displayed. This image is used for selecting the measurement line by pressing the right mouse button inside of that image. This line should have a sinusoidal intensity distribution. Afterwards press "*readout lines"* to determine the intensity distribution of the measurement line. The minima and maxima as well as the period of the interference pattern will appear in the lower right corner of the software window.

5.3 Open Gray Value Window

If the measurement line is given, open the gray window, move it onto the display and enlarge it to full screen with the middle of the three options in the right upper edge of that window. It might be more convenient to open that window before the adjustment to create an interference pattern like it is present when the measurement starts.

5.4 Increment

Before starting the measurement the increment has to be chosen. This option changes the time and the resolution of one measurement. This is of course always a compromise since fast measurements have low resolution and slow measurements have high resolution. For gamma correction an increment of one is necessary!

5.5 Measurement

The “Start” button starts the measurement and gray level from 0 to 255 will be addressed onto the active half of the gray level window successively.

FIG. 9: 3 examples of addressed gray level pattern

6 Evaluation

6.1 Show image

If one presses this button when the measurement is finished an image will appear at the position of the former live image in which the selected measurement line for each addressed gray level is drawn one below the other. This image gives the first impression of the measurement and shows clearly if and how the interference pattern is shifted.
A convenient function for the first rough determination of the total phase shift is implemented. If the user moves the cursor into the shown image and presses the right mouse button, a bar will appear at the position of the cursor. If the user holds the button and moves the cursor, a second bar appears and the distance in pixel will be shown just above the image (see figure 10). If the start and the end value are chosen for both bars one can see how far the interference pattern was shifted during the measurements. By taking the period of the interference pattern into account (see 4.2) the phase shift can easily be calculated.

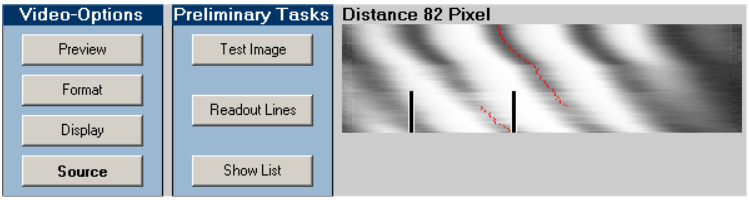


FIG. 10: Metering bars

6.2 Show measurement points

If this button is pressed after the above explained image is shown, the measurement points (values with min intensity) will appear as red points. If the distribution of these points has no big jumps and irregularities (which can be introduced by vibrations or air flow) the measurement will be evaluable. It is

possible that the measurement points “jump” to the next minimum [mod 2π]. This can be corrected in a spreadsheet program like Excel afterwards by adding or subtracting one period. Now one can save the measurement as a .txt file that includes the period and position values for each addressed gray level. The phase modulation as a function of the addressed gray level can be calculated by using e.g. Excel. The 1st value has to be subtracted from each measurement value in order to set the start point (gray level 0) to zero. Dividing each value by half the period (π) will lead to a phase shift of multiples of π.

6.3 Save Measurement

The measurement will be saved as a .txt file with the indication of the period. The evaluation can then be done with a spreadsheet program (see 6.2)

6.4 Save image (optional)

The image of the shifted interference pattern can be saved to ease the documentation.

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