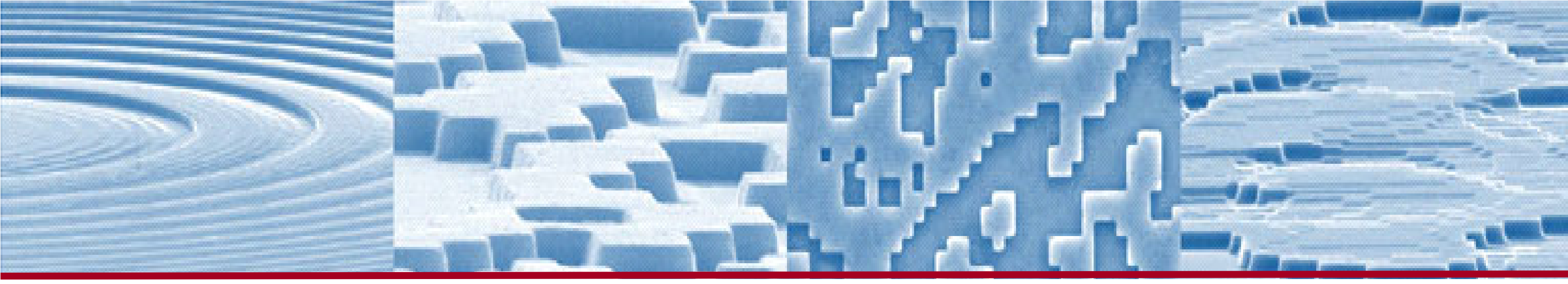
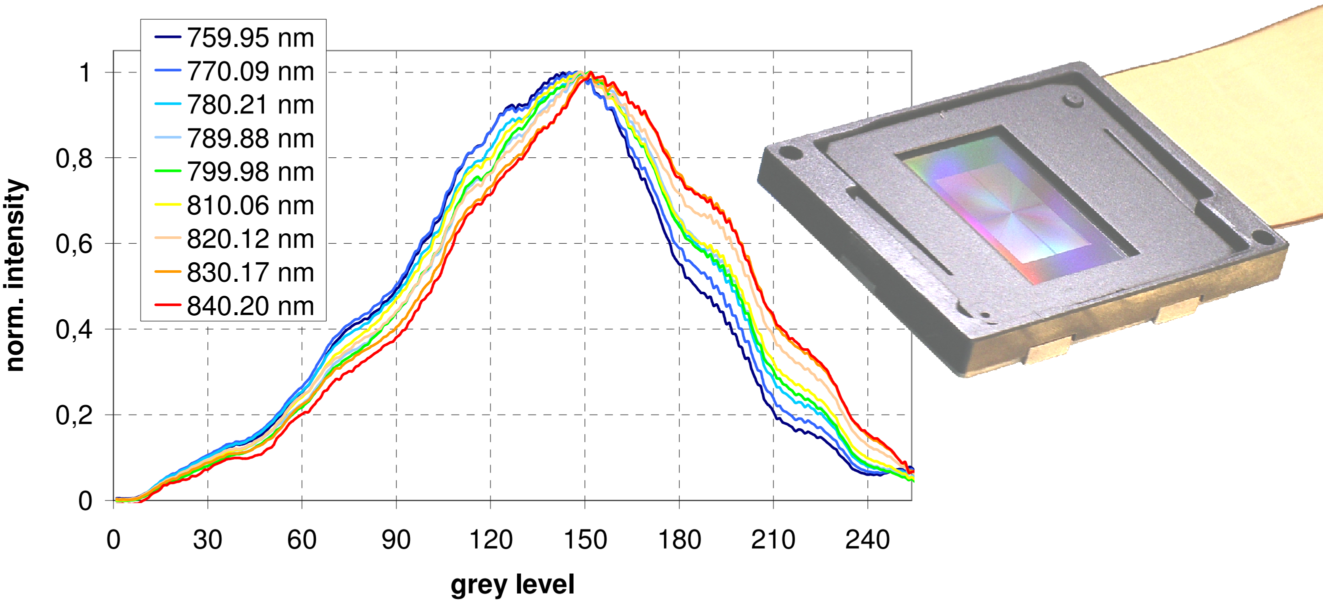


HEO 1080P
APPLICATION NOTE

HDTV Phase Panel Developer Kit For FS-Laser Applications



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Introduction

In the last few years femtosecond (fs) lasers have evolved to become widely used tools in scientific and industrial applications.
In cooperation with the Max Born Institute in Berlin [3], HOLOEYE performed measurements for the phase modulator HEO 1080P using a Ti:Sapphire fs- Laser with a centre wavelength of 800nm, repetition rate of 1KHz and a pulse duration of 28fs. Some measurements at 400nm after SHG have also been done and will be shown in this document. The measurements include the determination of the phase modulation as a function of the wavelength and laser power, dispersion measurements and the determination of the damage threshold for one fs-laser source.

Device adjustments

Prior to fs-laser experiments the SLM was calibrated in order to get a linear phase response of 2π at 780nm. This is possible since the gray level to voltage look up table (GVLUT also known as “gamma”) is freely editable. This was essential for the interpretation of some of the following measurements. Figure 1 shows a graph with the uncorrected default and the linearised phase response at 780nm. Here a 780nm laser diode, a two beam interference setup (see figure 2) and the measurement program “PhaseCam” were used. This software as well as a description of the measurement procedure can be downloaded from the HOLOEYE web page http://www.holoeye.com/download_area.html .

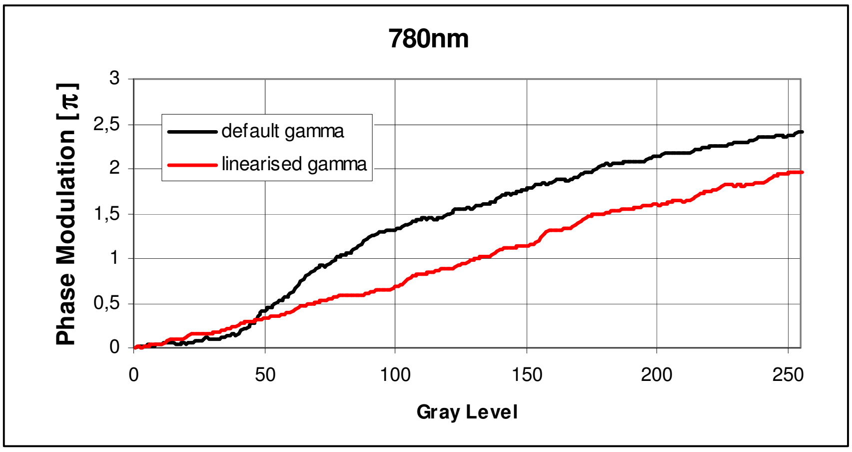

FIG 1: Uncorrected and corrected phase

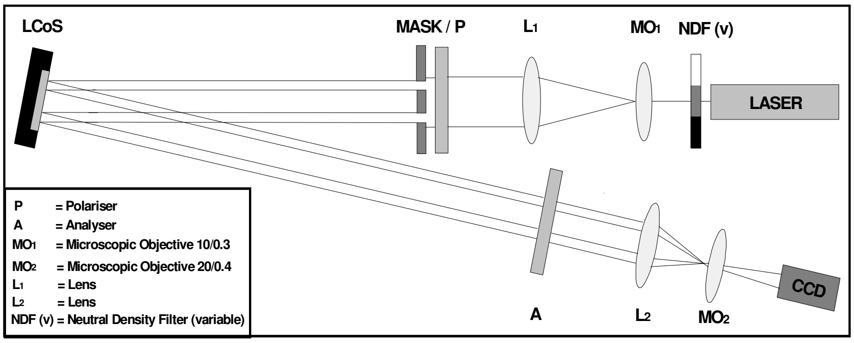

FIG 2: Two beam interference setup

Phase modulation as a function of the wavelength

Another convenient method to determine roughly the phase modulation depth are intensity measurements of diffraction orders as a function of the addressed groove gray level (GL) for an addressed binary diffraction grating [1]. This method was chosen here because of its simplicity concerning the optical setup (see figure 3) and evaluation compared to the above interference setup. This method doesn't give as complete results in terms of phase modulation shape but this was not necessary since we were just looking for π and 2π values. In theory the intensity of the first diffraction orders have minimal intensity for phase differences of groove and ridge of $n*\pi$; with n = even number and maximal intensity of $m*\pi$ with m = odd number, the 0^{th} order vice versa. In figure 4 one can see such a measurement for a binary grating with a grating period of 4 SLM pixels for different wavelengths.

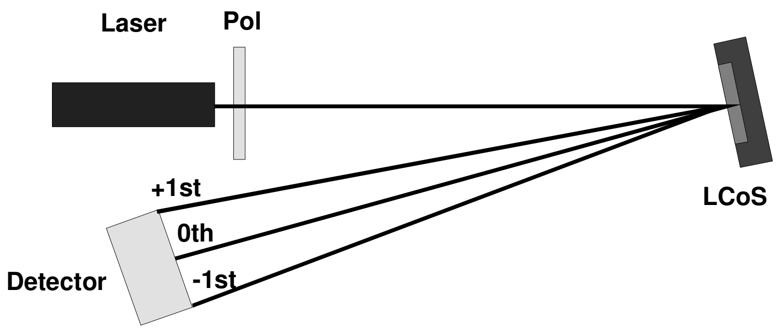

FIG 3: Sketch of diffraction setup

This was done using a fs laser with a centre wavelength of 800nm and a temporal autocorrelation width of 48fs ± 3fs. Due to the usage of at least 2 dielectric mirrors, the pulse duration after Sekans Hyperbolicus Fit of the autocorrelations and deconvolution is longer than 28fs. Since the pulse duration in the measurement setup couldn't be measured, just an estimation of the pulse duration to smaller than 90fs is possible. The repetition rate is 1 kHz. Due to the digital addressing scheme of the investigated LCoS based spatial light modulator that leads to a superimposed slight phase fluctuation [2] a beat frequency between laser, SLM and detector occurs. An averaging or a triggering between laser and SLM is recommended. For our tests each measurement result is averaged over 10 single measurements.
In figure 3 and 4 we show 2 results of such a diffraction measurement method for 800nm and 400nm centre wavelength.

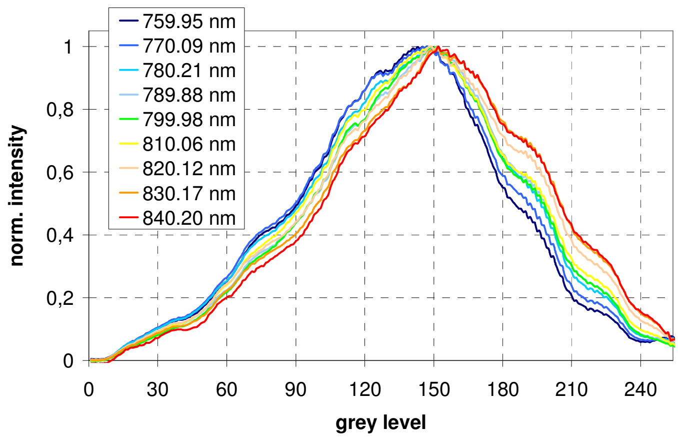

FIG 3: Intensity of the $+1^{st}$ diffraction order as a function of the wavelength; ridge GL = 0

Figure 3 illustrates that the SLM behaves as expected since the phase modulation at ~780nm is about 2π (+1st diffraction order rises to a maximum and back to a minimum) and the phase shift is higher for shorter wave lengths.
This procedure has been repeated with frequency doubled pulses. The result is shown in the graph below. Here the same GVLUT as for the 800nm measurement was used. Due to the $1/\lambda$ dependence of the phase modulation one can expect a much higher phase modulation at 400nm than for 800nm. A gamma curve that yields a 2π phase shift at 800nm leads here to a 5π phase shift.

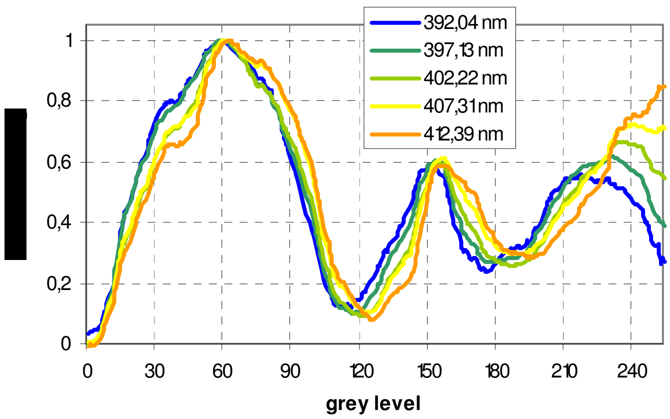

FIG 4: Intensity of the +1st diffraction order as a function of the wavelength; ridge GL = 0

Dependence of the modulation on the laser power

Measurements have been performed to evaluate the influence of high pulse peak powers to the phase modulation behaviour of the tested SLM. The phase modulation has been measured with the above procedure for 5 different average laser powers. The graph below shows the results and it can be seen that no change of the phase modulation properties occurred for laser powers up to 270mW. The $1/e^2$ radius of the laser beam was 2.6mm. Taking into account the repetition rate of 1 kHz, this result means that pulse peak powers of up to $20GW/cm^2$ can be modulated without any degradation of the display and change in the performance.

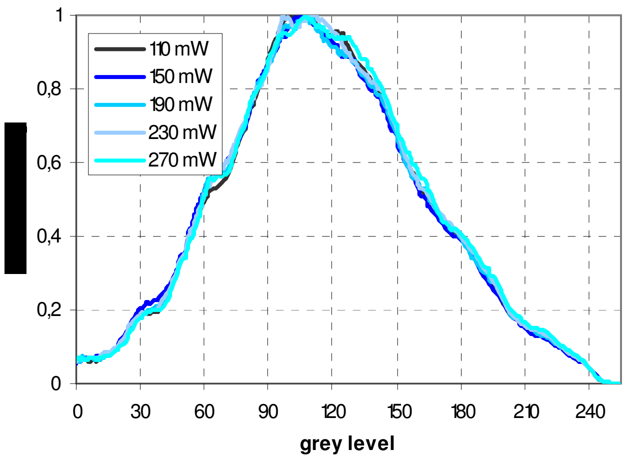

FIG 5: Phase modulation at 800nm as a function of the average laser power; ridge GL = 255

Dispersion measurements

Here we show the influences of the used micro display to the pulse duration of the used laser. The graph below shows the autocorrelation of the pulse after reflection on a metal mirror. This is taken as reference.

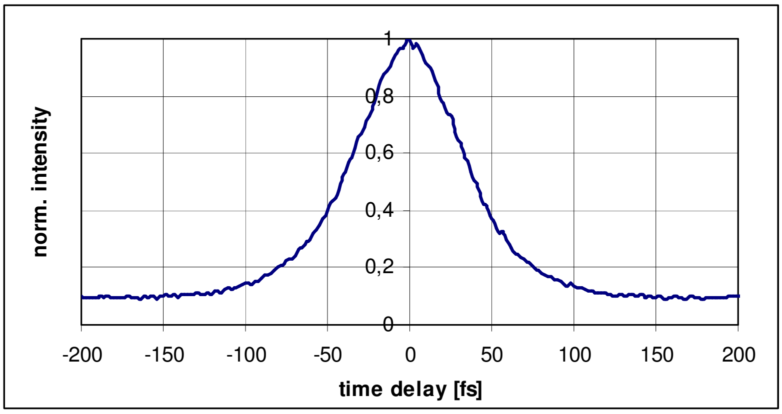

FIG. 6: Autocorrelation of a pulse after reflection on metal mirror

The graph in figure 6 shows a comparison between the laser pulse autocorrelations after reflection on the metal mirror and after reflective micro display of the HEO 1080P (in switched-off state).

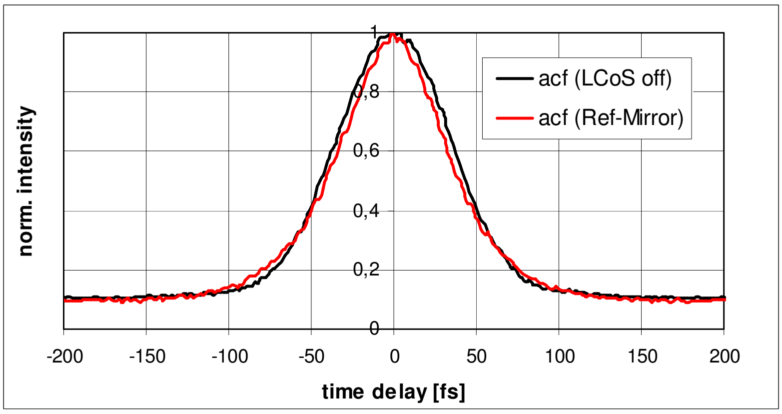

FIG. 6: Autocorrelation of the pulse after reflection on a metal mirror and the LCoS micro display

The comparison between the autocorrelation of the reflected pulses from the reference mirror and the SLM in switched-off state shows that the influences of the micro display to the pulse duration and the pulse form are marginal.

Since the device under test changes its birefringence as a function of the applied voltage it is also necessary to investigate dispersion effects as a function of the voltage dependent orientation of the LC molecules. The following graphs shows pulse durations after (Sekans Hyperbolikus) deconvolution for different addressed gray levels. It can be seen that the pulse duration keeps stable for intermediate gray levels but will be changed by some fs compared to the pulse duration in switched-off state.

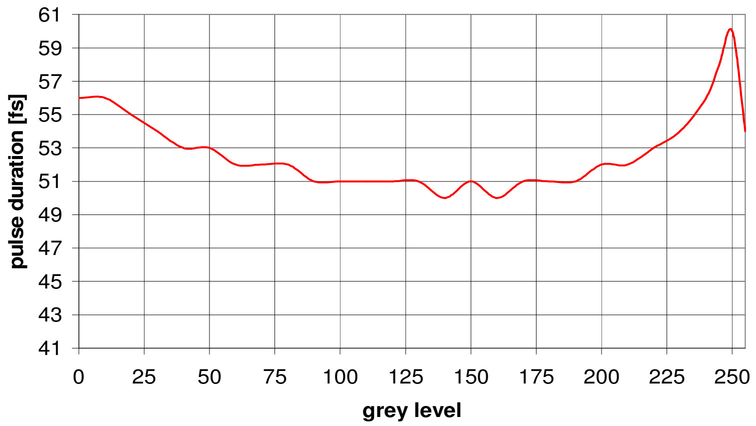

FIG 7: Pulse duration as a function of the addressed gray level.

Damage threshold

For applications where high intensities have to be modulated, knowledge about the damage threshold of the used elements is required.
In our experiment the fs laser with 200mW average power a repetition rate of 1 kHz (200µJ per pulse) and pulse duration of 94fs was focused with a lens. The display was then moved along the optical axis towards the focal plane until a significant damage of the LCoS display occurred. Taking the beam diameter into account, the damage threshold was determined to be approximately 0,25 TW/cm².

Conclusion

We have shown that our phase only SLM can be used with fs Laser sources at 800nm and 400nm. It has been demonstrated that even high pulse power of up to 0,25 TW/cm² can be modulated without any change in the optical performance. But one has to keep in mind that due to the birefringent nature of such an element a phase level dependent change of the pulse duration and pulse form will occur. Another important fact that should be taken into account is the need of a triggering to achieve optimal performance. This is caused by the digital addressing scheme of this device. A Vsync impulse can be taken from the driver unit of the presented SLM [5] that can be used for triggering with external sources.

References

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