High Resolution Interference Microscopy:
3D measurement of focused light at 405nm applied to optical disc

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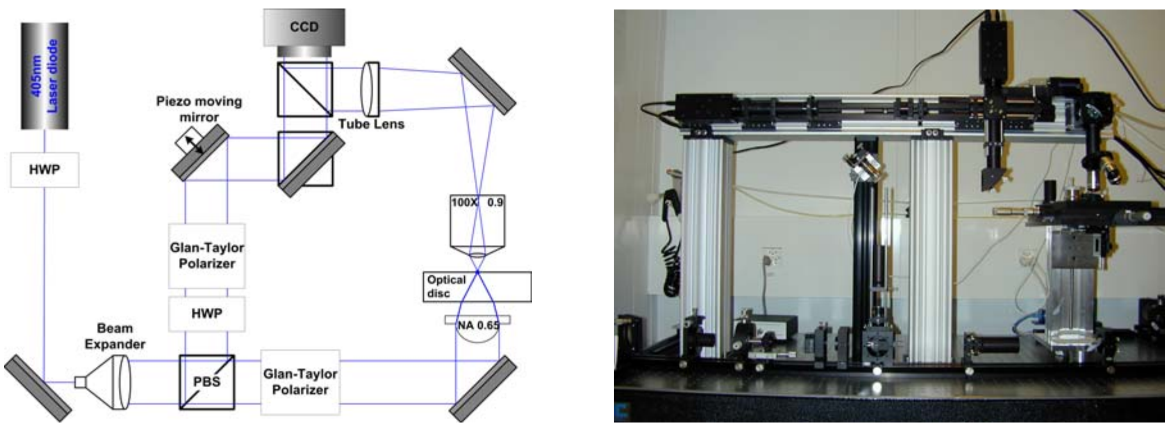
1. Introduction

High capacity data storage on DVD and optical discs is based on focused light beams. The characterization of light fields within the focus point is a very difficult task, which requires a high-resolution method like scanning near field optical microscopy (SNOM). However, SNOM measurements are slow and cannot be used for dynamic processes. Therefore, we employ a measurement technique based on High Resolution Interference Microscopy (HRIM) to investigate focused light fields used for high-density optical storage. HRIM allows the characterization of amplitude and phase of electromagnetic wave-fields in the far-field with very high spatial accuracy. An experimental tool working in transmission with a resolution of 20nm in the object plane and a He Ne laser at wavelength of 633nm was presented in our previous work [1]. Because the focused spot size in the optical disc is usually defined as $\lambda/(2NA)$, high density optical data storage systems require a light source with shorter wavelength and a focusing objective lens with high numerical aperture (NA). In order to characterize the today's optical storage systems, one has to work at 405nm wavelengths. We are building a micro-interferometric system, which employs a blue laser diode. Compared to previous measurements, we increased the resolution by using immersion techniques and high numerical aperture objectives.

2. Experimental setup

The experimental setup of HRIM is employing the Mach-Zehnder interferometer shown in Fig. 1(a). A photograph of the actual instrument is shown in Fig. 1(b). The light source is a monomode polarizing laser diode (λ = 405nm). A polarizing beam splitter (PBS) splits the wave-field into a reference and an object arm with an adjustable energy ratio by half wave plates (HWP) and Glan-Taylor polarizers. This permits to optimize the contrast of the interference fringes for an easier automatic phase determination. In the object arm, the expanded plane wave illuminates the system under investigation, i.e. a pickup lens, which focuses the incoming light through the optical disc. They are mounted on a precision piezo stage, which allows scanning in propagation (z) direction. The scan range is 500µm and an accuracy of 1nm is specified. The emerging light field is observed by a standard microscope setup. The observing objective basically limits the angular spectrum transmitted by the measurement optical system. A high NA ensures generally a high resolution of amplitude fields. In order to achieve it, an objective with high numerical aperture such as 100X / NA 0.9 and an oil immersion objective of 100X / NA 1.4 were used. In the reference arm a piezo-electrically driven mirror is mounted to change the optic path lengths. The phase distribution of the wave-field is obtained by measuring the interference fringes at different piezo positions and employing a classical 5-frame algorithm. In this scheme, 5 frames of the 2-D intensity pattern are recorded, each frame being shifted in phase by adding an additional phase of λ / 4 [2].



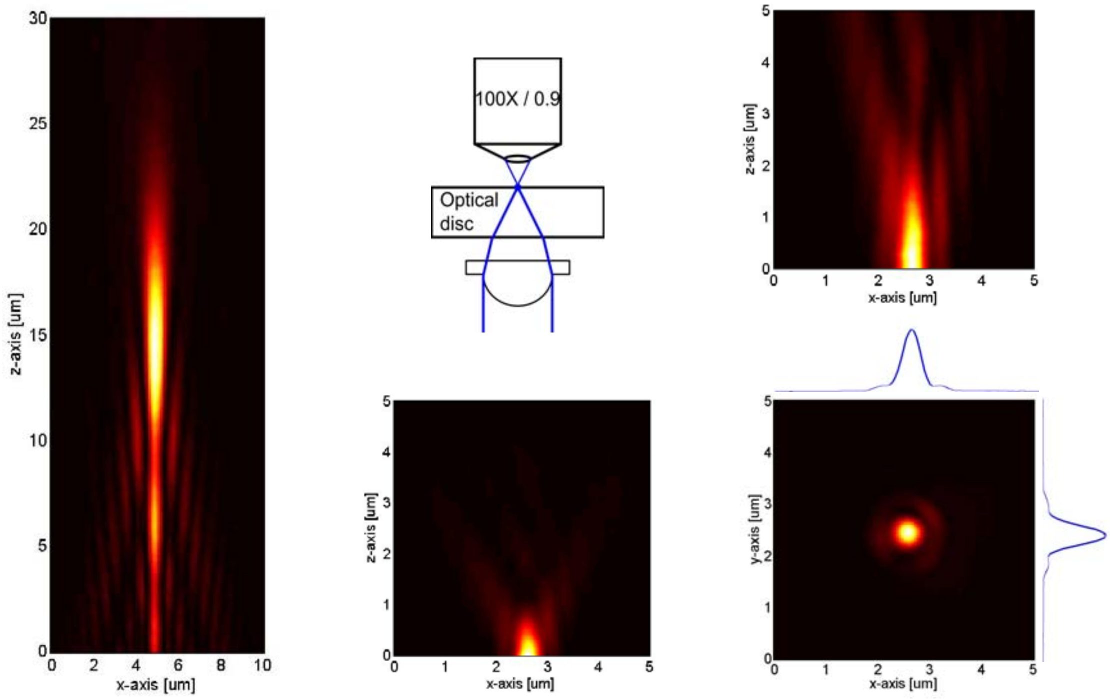
(a) (b)

Fig. 1. Experimental setup of 405nm HRIM: (a) schematic picture and (b) photograph.

With the HRIM one can measure phase and intensity distributions in planes with a field of view smaller than 1 mm in diameter. Three-dimensional measurements can be done by scanning the sample (and illumination) with a piezo stage. Different cross-sections (x-y, x-z, y-z) can be observed by taking slices through the completed 3D data map. The resolution of intensity fields is limited by diffraction, but the phase maps can be recorded at higher resolution [1].

3. Measurement results and conclusion

We have investigated light fields emerging from a standard DVD pickup lens with NA of 0.65. This lens has a correction for 600µm thick polycarbonate cover. The measured intensity distribution in free space (without disc) is shown in Fig. 2(a). The propagation direction is from the bottom to the top of the image. The plane z = 0 indicates the starting plane of the measurement with no relation to the actual position of the lens. The expected strong intensity modulation from the focus towards the lens is clearly seen in Fig. 2(a). To observe the focused light field under real working conditions a polycarbonate disc with 600µm thickness is placed in front of the lens and hold by an alignment system that is mounted on the main stage containing a z-axis piezo actuator and a three axis alignment stage. A schematic of the geometry is given in Fig. 2(b). The intensity distribution emerging from the top of the disc is shown in lower part of Fig. 2(b). Compared to Fig. 2(a) the spot size is reduced because the lens is corrected for a cover layer of 600µm. Figure 2(c) shows the intensity distribution and profiles of a focal spot when an oil immersion objective lens is used. Higher resolution is reached. The theoretical spot diameter is calculated to be 760nm and the measured diameter is approximately 900nm. The difference between the calculation and the measurement is caused by the limited resolution of microscope objectives. This study shows the applicability of HRIM to study light fields propagating under various conditions. Most interesting situations are when the Super Resolution Near-Field Structure (Super-RENS) disc with its non-linear effect is studied and when phase fields are observed.



(a) (b) (c)

Fig. 2. Measured intensity images: (a) in free space, (b) geometry of measurement with disk and intensity distribution after the disc (objective 100X / NA 0.9), (c) scanned with an immersion objective (100X / NA 1.4).

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References

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