A method for detecting sub-wavelength features by means of a multimode waveguide and a mode splitting photonic IC

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A new method is presented to read optical disks. Light is focussed on and picked up from the disk by a multimodal waveguide. Experimental results of a photonic IC controlling these waveguide modes are presented.

Introduction

Optical data storage tries to cope with the strong need for exchangeable super high-density, high-data rate storage memories that can be easily copied and can be produced at low cost. In this search for higher information density, the classical diffraction limit forms an important barrier. In this paper we propose a method to improve the resolution without making the spot size on the disk smaller than the wavelength. The idea is to reconstruct the bit pattern from the complete field profile (including amplitude and phase) of the intermediate-field response of light reflecting on the disk. This field is measured by picking it up into the different modes of a multimodal waveguide.

A multimodal waveguide used to detect the bit patterns

Our approach is to detect the complete far field by a multimodal waveguide that is moved along the tracks of bit patterns on the disk. Fig.1 shows a schematic version of our scanning waveguide approach. Through the multimodal waveguide light is focused on the disk, using one of the modes of the waveguide or a linear combination of the modes. This light reflects on the disk and couples back into the different modes of the waveguide. To control those different modes in the waveguide we use a photonic IC, which excites and detects the different order modes in the multimodal waveguide from and to monomodal input and output waveguides. This way we can measure the reflection matrix formed by the mode to mode coupling from the waveguide to the disk and back. Each cell of this matrix gives the fraction that is reflected from light sent through mode i and coupled back into mode j. If we can detect this matrix while the waveguide is moving along the tracks of bumps and holes on the disk, we get a response curve for each of the cells.

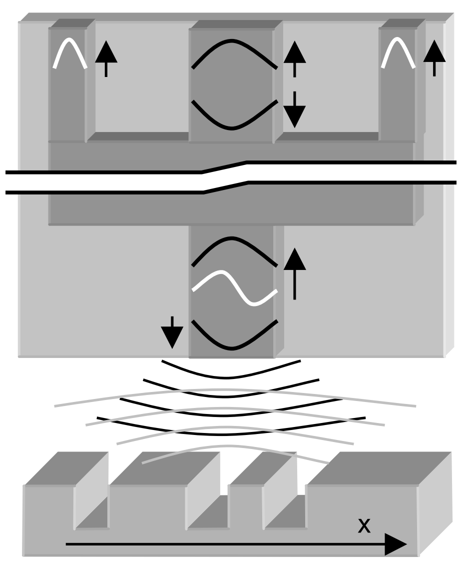

Figure 1: Shematic view of the PIC, waveguide and disk.

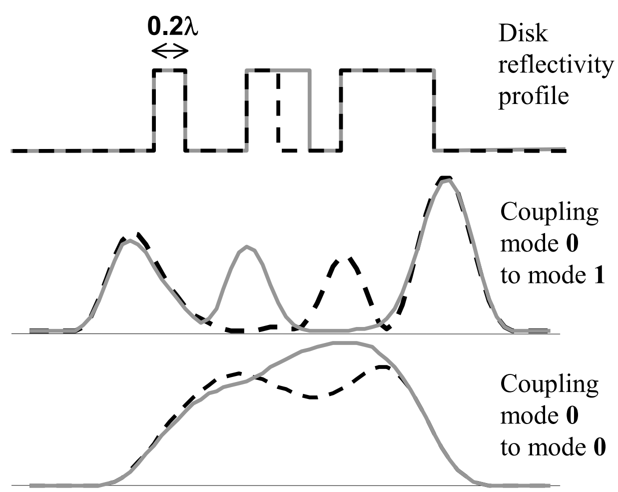

Figure 2a: Two bit pattern with bit length 0.2 λ
Figure 2b: Mode-to-mode coupling coefficients when scanning along the bit pattern

On fig. 2a two bit patterns are shown as a change in reflectivity of the disk. The length of the bits is 0.2 λ. The bit patterns in black dashed line and in gray continuous line have only one bit in difference. On fig. 2b is shown how the mode-to-mode coupling is changing when the waveguide is moved along those two bit patterns. While there is no obvious connection between the bit patterns and the response curves, it must be clear that if the two different bit patterns generate response curves are significantly different the bit pattern can be deduced. The mode-to-mode coupling coefficients were calculated with the simulation tool CAMFR[1]. This program is rigorously vectorial but can only handle two-dimensional components. Therefor our simulations are based on two-dimensional models of waveguide and disk. The simulation results are independent of the wavelength, but to show a proof of principle a wavelength of 980 nm was used for the design of waveguide and photonic IC. The air gap in our simulations is one wavelength. At this distance most evanescent waves are already lost, but propagation has not yet fully shaped the distribution.

A photonic IC to split off the modes

To detect the evolution of the mode-to-mode coupling matrix a photonic IC is needed. It is hard to detect all elements of this matrix, but it may be sufficient only to detect some of them. As mentioned above a low crosstalk for the splitting of the different modes is very important. A component that splits off zeroth and first order mode has been designed and fabricated. The principle of the mode splitter is based on restricted interference in a multimode interferometer[2][3]. As is shown on fig. 3, the splitter replicates the zeroth order mode at the central output waveguide and splits the first order mode up into two zero order modes at the two outer output waveguides. The components were fabricated out of a GaAs/AlGaAs-wafer with an etch depth of 180nm. The components were measured extensively. Experimental crosstalk levels down to –20dB were detected. The component also proved to be relatively intolerant to small fabrication inaccuracies.

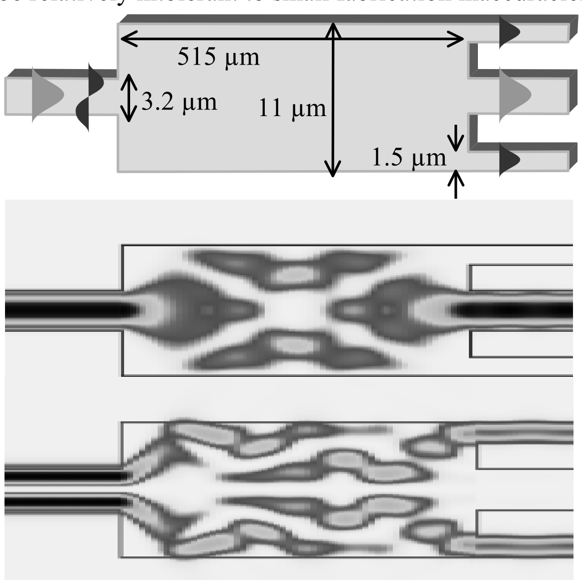

Figure 3a: Mode splitter dimensions
Figure 3b: Optical fields inside the splitter for mode 0 and mode 1

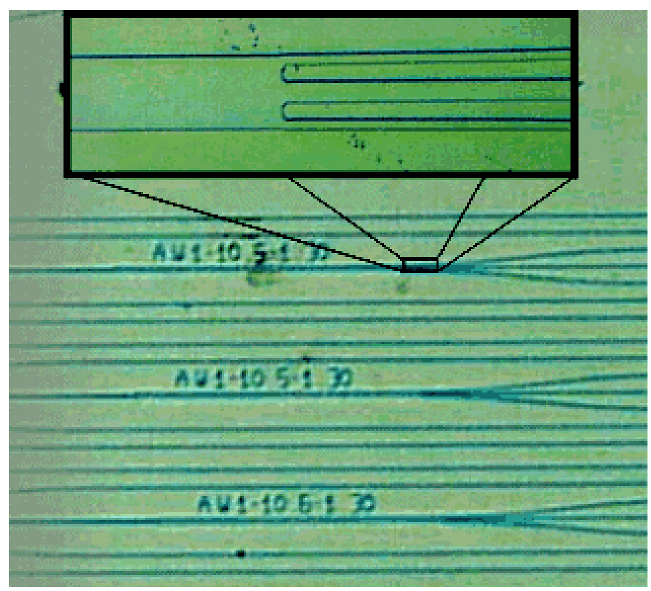

Figure 4: Detail of components

Acknowledgments

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References

[1] http://camfr.sourceforge.net

[2] L.B. Soldano, E.C.M. Pennings, "Optical multi-mode interference devices based on self-imaging: principles and applications", IEEE Journal of Lightwave Technology, vol. 13, pp. 615-627, April 1995.

[3] J. Leuthold, R. Hess, J. Eckner, P.A. Besse and H. Melchior, "Spatial mode filters realized with multimode interference couplers", Optics Letters, vol. 21, pp. 836-838, 1996.