Imaging of the field distribution in integrated optical waveguides

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A near-field optical microscope with a shear force height feedback system has been developed to measure the field distribution in integrated optical devices. The microscope has been applied on real devices.

Introduction

The aim of the project is to study the electro-magnetic fields in integrated optical waveguide structures in amplitude, phase, polarization and time, with a spatial resolution of $\lambda/50$. A near-field optical microscope with a shear force height feedback system has been developed to image the amplitude of the optical field distribution. With this microscope it is possible to measure simultaneously the optical field distribution in a waveguide and its topography [1].

Experimental

Piezoelectric bimorph plates have been used for a large area scanner with a range of 250 x 150 x 4 μm^3 for the x, y and z direction, respectively. The whole scanner can be translated in the x and y direction over 6 mm. The sensitivity of the scanner in the z-direction is 0.5 nm. The scanner is built on a tripod system for the coarse approaching of the fiber probe to the waveguide structure. A tuning fork shear-force feedback system has been implemented as distance control mechanism for the microscope which can also be used for the fine approach [2].

The fiber probe scans over the waveguide surface at a distance of a few nm, while the waveguide is fixed. The evanescent wave of the light inside the waveguide is coupled into the fiber probe, due to the frustrated total internal reflection (figure 1a) and is collected with a photo-multiplier tube. The setup for amplitude imaging is shown in figure 1b.

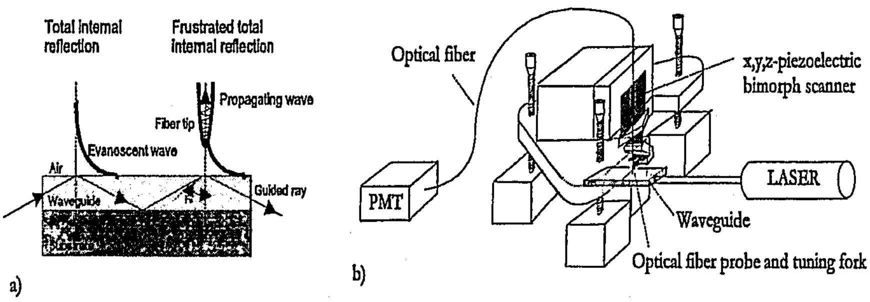

Fig. 1: a) Frustrated total internal reflection, b) Near-field optical microscope for amplitude imaging of the field distribution in integrated optical waveguides.

Results

The topography and the propagation of the light in a Si_3N_4 Mach-Zehnder interferometer is shown in figure 2 and 3. A comparison is made between measurement and simulation in figure 2. The field distribution for different incouple angles is shown in figure 3.

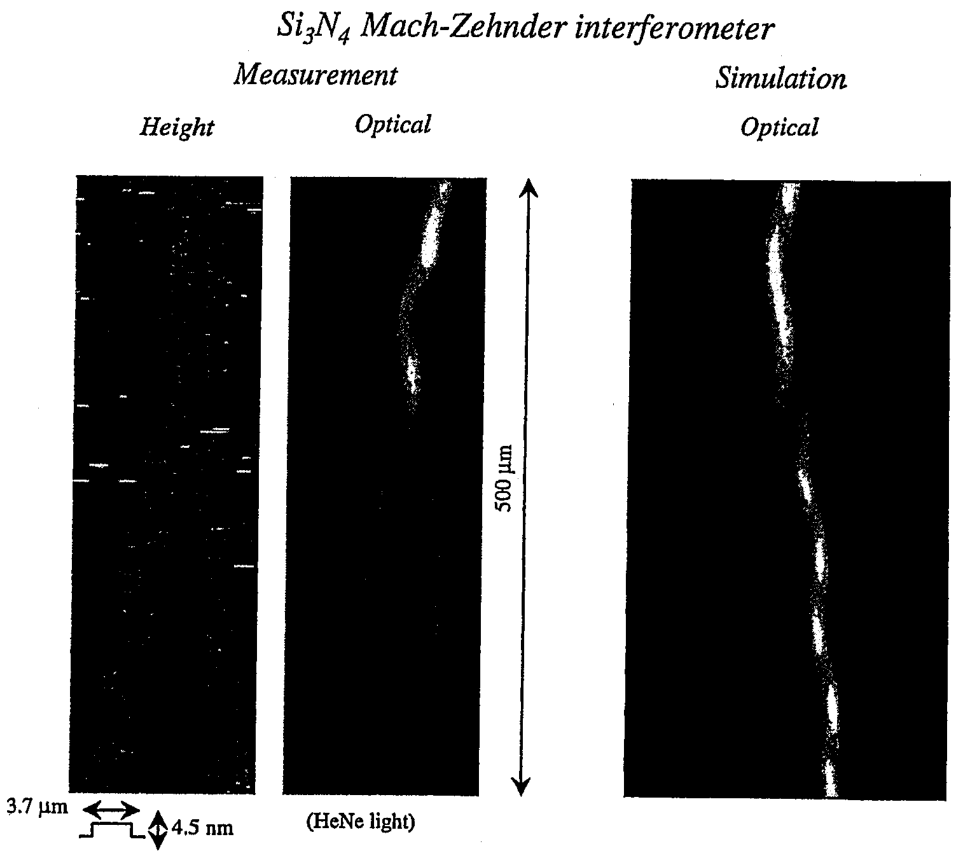

Fig. 2: The measured and the simulated propagation of the light in a Si_3N_4 Mach-Zehnder interferometer. The scan range is 20 µm x 500 µm. The height of the structure is 4.5 nm. The measured topography is shown in the left image and the measured propagation of the light is shown in the center image. The right image shows the simulated propagation of the light obtained with a "Finite difference beam propagation method" (FDBPM) [3,4].

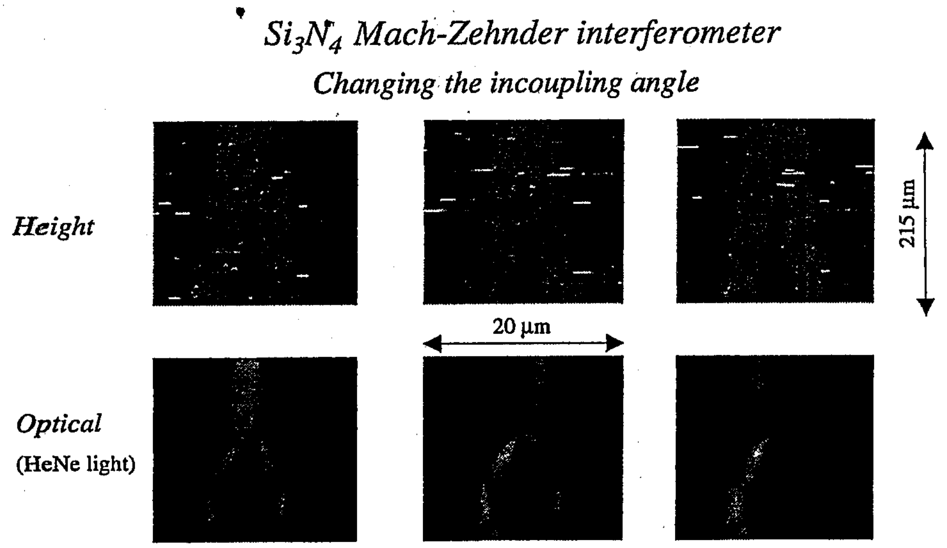

Fig. 3: Light propagation in a Si_3N_4 Mach-Zehnder interferometer for different incouple angles of the light. The scan range is 20 µm x 215 µm. The height of the structure is 4.5 nm. The topography is shown in the top images and the propagation of the light is shown in the bottom images.

The topography and the propagation of the light in a SiON channel waveguide is shown in figure 4.

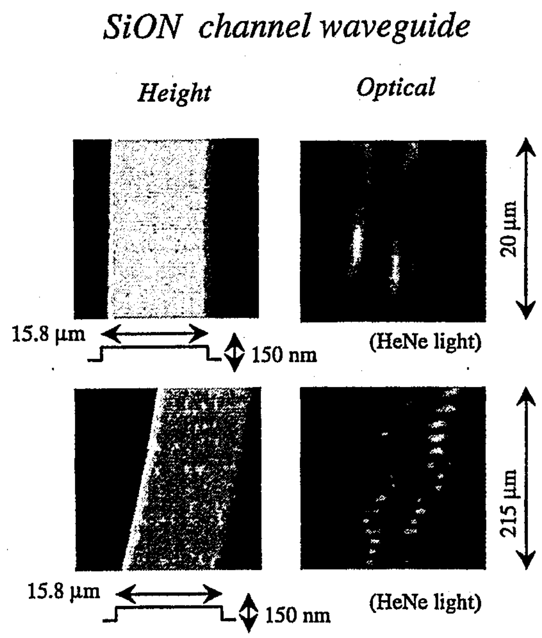

Fig. 4: Light propagation in a SiON channel waveguide. The scan range is 20 µm x 20 µm for the top images and 20 µm x 215 µm for the bottom images . The height of the structure is 150 nm. The topography is shown in the left images and the propagation of the light is shown in the right images.

Conclusions

A near-field optical microscope has been developed to image the amplitude of the optical field distribution in integrated optical waveguide structures. The developed scanner has a scan range of 250 x 150 x 4 μm^3 for the x, y and z direction, respectively. The whole scanner can be translated in the x and y direction over 6 mm. The sensitivity of the scanner in the z-direction is 0.5 nm. The amplitude of the optical field distribution in a SiON channel waveguide and a Si_3N_4 Mach-Zehnder interferometer has been measured simultaneously with the topography. The measured optical field distribution is comparable with the simulated optical field distribution for the Si_3N_4 Mach-Zehnder interferometer.

Future outlook

A position feedback control system will be implemented to compensate for the nonlinearity of the scanner. To obtain phase images the microscope will be integrated in one branch of a Mach-Zehnder interferometer. Phase maps of splitters, converters, (de)multiplexers can be recorded in that way. Furthermore, time maps will show the temporal evolution of ultrafast pulses through the waveguide.

Acknowledgements

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References

[1] E.G. Borgonjen, M.H.P. Moers, A.G.T. Ruiter, N.F. van Hulst, Probing field distribution on waveguide structures with an atomic force / photon scanning tunneling microscope, "Near-Field Optics" (eds. M.Paesler &P. Moyer), *SPIE 2535, 125-131, 1995.*

[2] A.G.T. Ruiter, J.A. Veerman, K.O. van der Werf, N.F. van Hulst, Dynamic with a shear force height feedback system of tuning fork shear-force feedback, *Appl. Phys. Lett.*, 71 (1), 28-30, 1997.

[3] H.J.W.M. Hoekstra, G.J.M. Krijnen, P.V. Lambeck, *IEEE J. Lightw. Techn.,* 10, 1352, 1993.

[4] T.H. Hoekstra, H.J. van Weerden, P.V. Lambeck, Th. J.A. Popma, *IEEE Photonics Technol. Lett.*, 6, 83, 1994.