# Tomographic measurement of stress in optical fiber preforms with microstructured core

Florian Just, Christian Segel, Hartmut Bartelt

*Institute of Photonic Technology, Jena*

mailto:florian.just@ipht-jena.de

We present results of photoelastic computer tomography measurements of the axial residual stress profile in fiber preforms. A polarimetric method for measuring the stress profile of samples with arbitrary cross section is used to conclude on the birefringence properties of the investigated samples.

## 1 Introduction

All silica-based fibers consist of a basic structure of core and cladding. To realize light guidance in the fiber it is necessary to generate a difference in the refractive index between the core and the cladding. This index step is adjusted by the composition of several sections with different doping compositions in the preform. During the preparation process thermal stresses are frozen into the preform due to the difference of the coefficients of thermal expansion (CTE) of the regions.

Induced stress can significantly influence the optical and mechanical properties of optical fibers. For example, stress can modify the refractive index profile and thus influence light propagation in optical fibers. Moreover, using the specific generation of high stresses, it is possible to obtain polarization maintaining in optical fibers. Likewise, highly doped preforms can crack during preparation caused by the frozen in stresses. On the other hand, highly doped fibers or even preforms can crack during preparation caused by the frozen in stresses.

Therefore it is of great interest to measure the residual stress caused by composition differences. This is possible by investigating the thermal stress in fiber preforms. In preforms without axial symmetric stress distribution it is moreover necessary to use tomographic principles to measure the 2-dimensional stress distribution of the cross section.

## 2 Experimental Setup

The setup we used to measure the residual stress distribution is shown in Fig. 1. A diode laser ($\lambda$=644 nm) is used as light source. The beam passes the sample (P), which is immersed in a cuvette with index-matching liquid, transversal to the preform axis. The cuvette is placed between two polarizers (P-rot and A). These elements are arranged under an angle of 90° relative to each other. In this way a beam not influenced by the sample will be completely absorbed in the setup. Due to the stress induced phase shift of the sample, a part of the light passes the analyzer. Using the rotatable polarizer we are compensating the retardation of the beam by analyzing the minimum of the transmitted light intensity on the detector. Using this angle, it is possible to calculate the phase shift of the beam at this specific point in the sample. The spatial resolution of the measurement setup is approximately 10 µm [1].

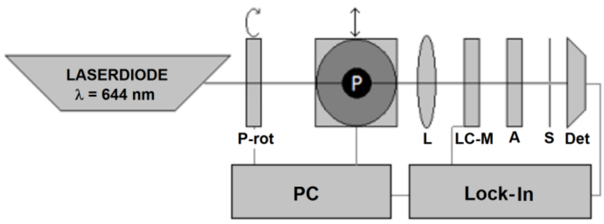


***Fig. 1*** *Measurement setup*

For tomographic measurements it is necessary to measure a large number of these line scans under different angles. With these projections it is possible to calculate the residual stress distribution of the cross section using an inverse Radon-transformation [2]. The induced index changes and finally the stress birefringence can then be calculated by the equations for the stress optic effect [3].

## 3 Experimental Results

The results of the polarimetric computer tomography are shown in Fig. 2. To determine the stress distribution of the preform we used a number of 72 projections, whereby each projection is composed of about 600 measuring points. The preform and core diameter were 5mm and 650µm, respectively.

The microstructured core is constructed of various elements with different compositions. They are doped in such a way that the refractive index of the elements is almost identical ($\Delta n \approx 5*10^{-4}$). The cladding of the preform consists of pure silica glass. The resolution of the measurement is sufficiently high to image the pure silica sections

DGaO Proceedings 2011 – http://www.dgao-proceedings.de – ISSN: 1614-8436 – urn:nbn:de:0287-2011-A029-6

between the stress elements of the core. They have a width of about 20µm. One single element of the core has a diameter of about 140µm.

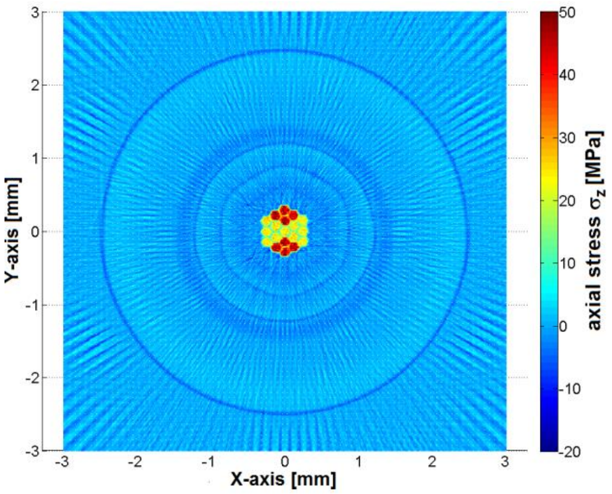


***Fig. 2*** *2-D axial stress distribution of the preform*

We find that the stress in the core is highly asymmetric. In the cladding only minor residual stresses are induced. Especially the borders of the different silica layers can be seen there. The stress in the region with the higher CTE is approximately 50 MPa. The results of the stress induced refractive index difference and the birefringence were calculated from the stress values. They can be seen in Fig. 3 and Fig. 4, respectively.

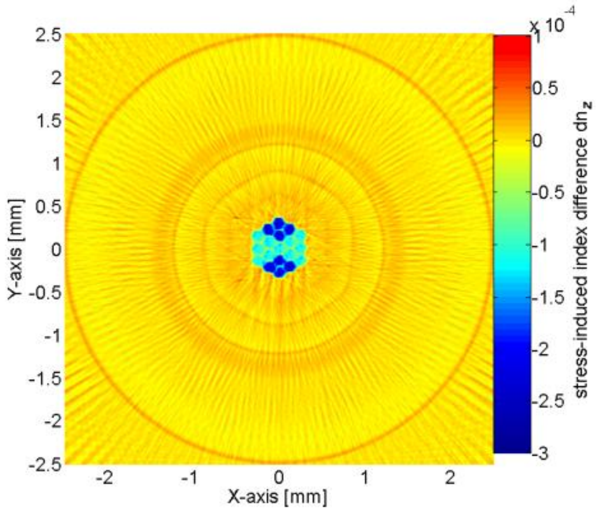


***Fig. 3*** *Refractive index difference distribution*

It can be observed, that the method is able to measure the very complex distribution of birefringence with a high spatial resolution as well as a high resolution in birefringence. We observe the highest value of birefringence in the central element of the structure with $\Delta n \approx 10^{-4}$.

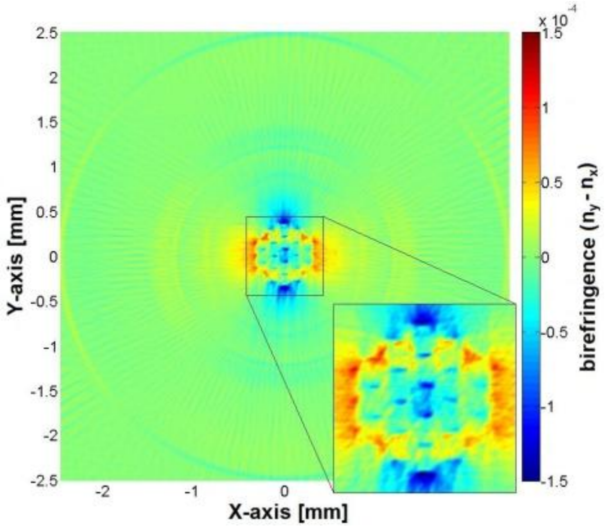


***Fig. 4*** *Induced stress birefringence distribution*

## 4 Conclusion

We presented a nondestructive measurement method for the thermal stress and the induced stress birefringence. The residual stress distribution of a fiber preform with a non-axisymmetric structure was measured successfully. It was shown that it is possible to investigate several stress sections with a high resolution. Also the influence on refractive index and birefringence caused by the stress distribution was calculated.

## Acknowledgement

Funding by the Thuringian Ministry of Education, Science and Culture (EFRE program) and the Federal Ministry of Education and Research (INLAS program) is gratefully acknowledged.

## References

[1] F. Just, H.-R. Müller, S. Unger, J. Kirchhof, V. Reichel und H. Bartelt: „Ytterbium-Doping Related Stresses in Preforms for High-Power Fiber Lasers“ in *Journal of Lightwave Technology*, vol. 27 (2009)

[2] T. Abe, Y Misunge und H. Koga: „Photoelastic computer tomography: a novel measurement method for axial residual stress profile in optical fibers “ in *J. Opt. Soc. Amer. A.*, vol. 3 (1986), pp. 133-138

[3] G. W. Scherer: „Stress-induced index profile distortion in optical waveguides“ in *Applied Optics,* vol. 19 (1980)