Miniaturized bulk-optical Mach-Zehnder filter for optical code division multiplexing

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Introduction

With the increase in voice and data communications over the recent years, the need for bandwidth is growing with an exponential rate. Multiplexing techniques for multiple use of existing fiber transmission lines are the preferred way to satisfy this need. Optical code division multiplexing (CDM) has been demonstrated to be an interesting transmission technique for access and metro networks, where reduction of implementation and maintenance cost is a vital issue /1/. In the framework of the german KomNet field trial a CDM system applying periodic spectral encoding of directly driven LEDs operating at 155.52Mbit/s per channel was demonstrated /2/. For encoding fiber Mach-Zehnder filters with free spectral ranges of FSR = 10-20GHz working in the wavelength region of 1550±35 nm were used. The optical decoding filters at the receivers are miniaturized bulk-optical Mach-Zehnder interferometers (MZI) with their FSR matched to the respective encoding filter FSR at the transmitter. The development and manufacturing of these MZI decoding filters will be described in this paper.

Optics design

From the system specifications, the required parameter of the MZI are derived: The FSR of the MZI must match the transmitter FSR to better than 10^{-5} which is guaranteed by adjusting the optical path difference by a piezo actuator. The minimum required contrast of the interferometer is 20dB even for random polarization of the incoming light. The basic design of the MZI is sketched in Fig. 1.
Design calculations with ray tracing (ZEMAX) and the free space wave propagation software package GLAD (Fig. 2) showed, that the most critical parameter of the optical elements are polarization dependent phase retardations of the beam splitters and the piezo-actuated reflecting prism. Thermal behavior and adjustment tolerances turned out to be less critical because active FSR fine-tuning is provided during operation.

Components

Standard reflecting prisms operating with total internal reflection (TIR) cause large phase retardances between the p- and s-components of the incoming light. To suppress depolarization during reflection on the legs of the prism, a special coating of this element is necessary to replace TIR. The coating designed and fabricated by the company mso jena guaranteed a reflection of more than 99% at a retardance of the reflected beam below 1° over the whole wavelength range (Fig. 3).
All other optical components are selected commercially available miniature non-polarizing beam splitters, aspheres and right angle prisms. Because manufacturers do not specify the retardance of the non-polarizing beam splitters extensive measurements of polarization behavior of these elements were carried out. The utilized beam splitters showed orientation dependent retardation and a beam splitting ratio requiring proper orientation and combination of elements for each module to satisfy the design constraints. The customized piezo-drive including tilt adjustment screws for the first beam splitter and the reflecting prism was supplied by the company piezosystem jena.

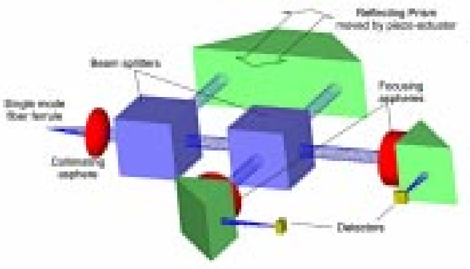

Fig. 1:
Schematic design of the Mach-Zehnder interferometer

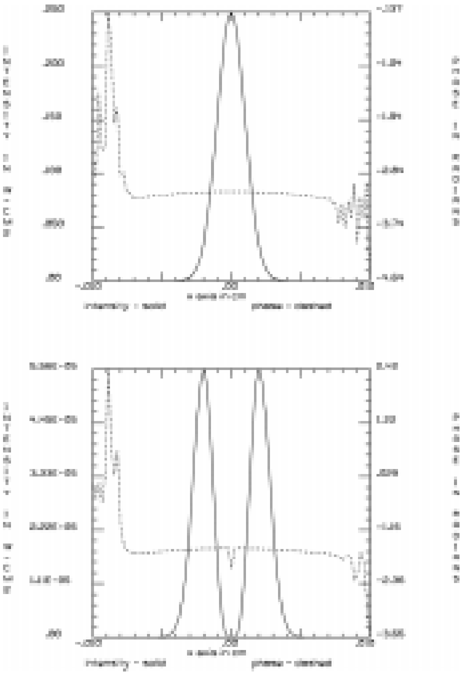

Fig. 2:
Point spread function for constructive and destructive interference, respectively, calculated with GLAD

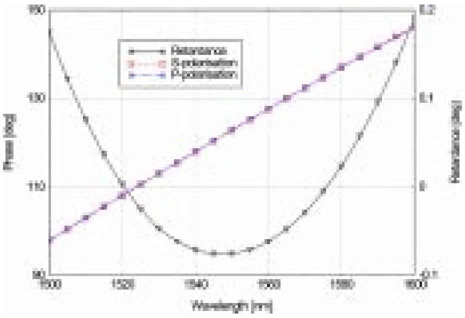

Fig. 3:
Phase behavior of the non-polarizing reflection coating

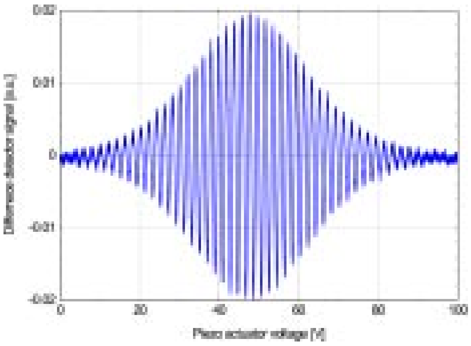

Fig. 5:
Typical transmission curve of the interferometer in dependence from piezo actuator voltage

Assembly

The proper distance of the reflecting prism to achieve the required FSR and the pointing and parallelism of the interfering beams are the most critical parameters to be maintained during assembly. Both are disturbed mainly by wedge errors of the beam splitters. The beam splitters and the reflection prism are positioned onto the housing of the piezo-drive by means of precision alignment elements equipped with a vacuum gripper.
To assess the state of adjustment, each filter was assembled with either a fiber-coupled DFB laser diode or the signal from the transmitter LED with the matched filter applied. After the optimum position was found, the elements were attached onto the piezo housing with UV-curing glue.
To optimize differential detector operation of the two photodiodes an adjustable knife edge obscuration is applied to equalize the electrical output of both diodes.

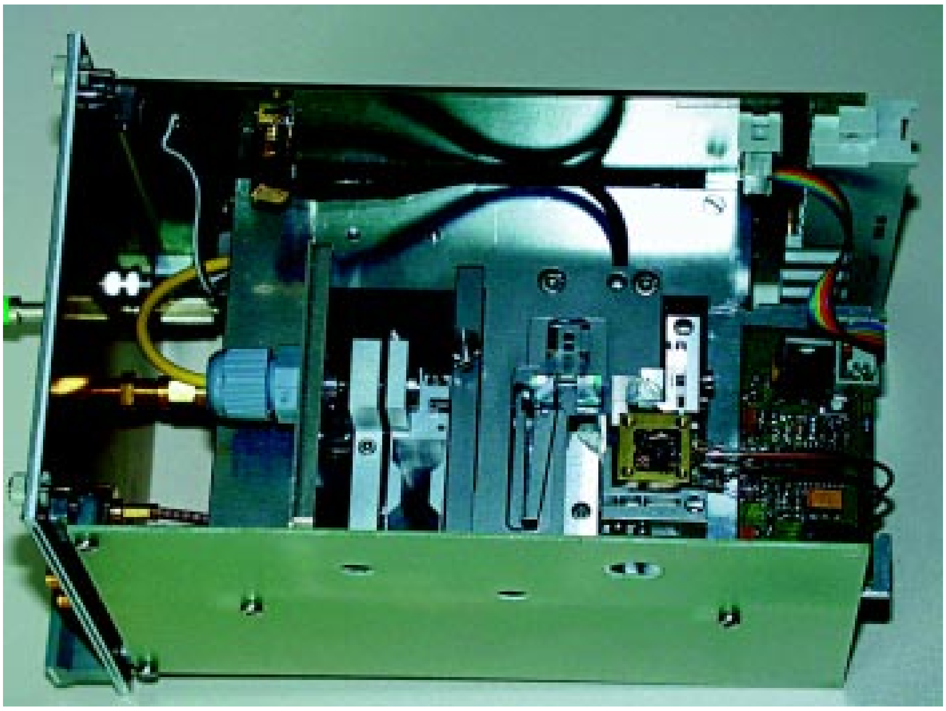

Fig. 4:
Mach-Zehnder filter (cover removed) integrated into receiver module

Results

For the specified FSR range of 10-20GHz a total of 10 matched filters (Fig. 4) with frequency spacing of about 1 Ghz were manufactured with typical responses as sketched in Fig 5. The prototypes showed sufficient mechanical and thermal stability. In agreement with the design calculations and the characterization of the utilized elements, the contrast of the interferometers and the dependence of the filter response curves from the state of polarization are well within the specification.

Acknowledgement

This work was funded under contract 01 BP 813/1 by the German Ministry of Education, Science, Research and Technology. We like to thank Dr. Pfeiffer from Alcatel SEL AG, Dr. Goering and Mr. Martin from company piezosystem jena and Mr. Schallenberg from company mso jena for support and fruitful discussions during the project.

References

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/2/ Haisch, H., Pfeiffer, Th., "Photonic technologies in hybrid access systems", Int. Topical Workshop on contemporary photonic technologies, paper WB-1, Tokyo 2000