Electrically Variable Optical Attenuator using All-Fiber Sagnac Loop Interferometer

Michael Fokine, Helio Carvalho, Paula M. P. Gouvêa, Danays M. González, I. C. S. Carvalho
Physics Dept., PUC-RIO

Maria Cristina R. Carvalho
CETUC, PUC-RIO

Oleksandr Tarasenko, Walter Margulis
ACREO-Sweden

Rua Marquês de São Vicente, 225 Gávea.
22452-970 Rio de Janeiro - RJ

michael@fokine.net

Abstract

In this work a variable optical attenuator, based on the all-fiber Sagnac loop interferometer is examined. The intensity of the transmitted signal at the output of the interferometer is controlled by changing the polarization state of the light in the loop of the interferometer. Three different means of controlling the state of polarization of the light in the loop are tested, including mechanical polarization control as well as electrical polarization control by using the fibers with internal electrodes.

Introduction

As high-speed optical telecommunication systems continue to advance to higher capacities, the need for more functional optical components and devices increase. One important component is the variable optical attenuator (VOA). There has been a strong demand for Variable Optical Attenuators (VOAs) in e.g. DWDM networks due to their variable attenuation range [1] and possibility to tailor their wavelength characteristics. Typical applications are e.g. to balance the signal intensities in WDM networks, optimizing gain in erbium doped amplifiers, or to protect devices and systems from damage due to high intensities.

Today, there are several types of commercial VOAs, such as microelectromechanical systems (MEMS) [2], liquid crystals based devices [3]. These systems however, increase the use of fiber-to-bulk coupling that require additional points where the light needs to be coupled out of or into the fiber. The key advantages for using all-fiber VOA’s are high stability, potentially high speed devices, simplicity in design and low loss. An important technique for controlling the transmitted signal in a fiber loop reflector or Sagnac loop interferometer has been previously shown by Mortimore [4], presenting an interesting result on how to control the transmitted signal by inducing birefringence.

In this work we explore a VOA based on the Sagnac loop interferometer in which the intensity of the transmitted signal at the output of the interferometer can be controlled by controlling the polarization state, or birefringence, in the loop of the interferometer [5]. Three different methods of controlling the state of polarization of the light in the loop are examined; (a) a mechanical fiber polarization controller, to characterize the fundamental behavior of the VOA Sagnac loop Interferometer, (b) a fiber based Kerr phase modulator, and (c) thermally poled fiber. The latter two methods are based on fibers containing electrodes positioned along the core of the fiber, enabling electrical control of the VOA with fast response as well as providing all-fiber solutions.

Experimental Setup

The experimental setup consists of a Sagnac loop Interferometer configuration as shown in figure 1. The fiber Sagnac interferometer is made by combining the two output ports of a 3 dB coupler, at a wavelength of 1550 nm, to form the loop. The type of polarization controller under study is then placed inside the loop. A laser at 1550 nm is launched into port 1, while the intensity of the signal is monitored at port 2 using an InGaAs photodetector and an oscilloscope. The 1550 nm laser is modulated using a function generator, which was also used to trigger the oscilloscope. The intensity of the laser was approximately -10 dBm, avoiding any non-linear effects from the light in the interferometer.
The mechanical polarization controller was a Newport F-Pol-PC device. This device works on the principle of a mechanical fiber squeezer mechanism, which is rotated about the fiber. This allows conversion of any input polarization to any desired output polarization. The Kerr phase modulator and the poled fiber device are based on metal-electrode filled two-hole fibers. The metal electrodes are inserted into the holes of the fiber by a temperature-pressure process described in detail elsewhere [6]. For the Kerr phase modulator a low-temperature alloy of Bi-Sn was used and typical fiber-electrode lengths of 1-2 meters [7]. For the poled fiber device, either lead (Pb) or Au-Sn alloy was used. In this case the length of the fiber-electrode is much shorter, typically 10-15 cm. Thermal poling of electrode containing fiber is described in detail by Myrén et. al. [8]

Results and Discussions

Figure 1 shows the output response of the Sagnac loop interferometer as a function of the angular variation of the mechanical polarization controller at a set value of applied pressure to the fiber squeezer. The function of the rotation of the mechanical polarizer corresponds approximately to a corresponding rotation of a half wave plate, showing a maxima or minima every 45 degrees. As can be seen, the rotation of the mechanical polarizer results in very repeatable results with minima very close to zero, representing a signal extinction ratio of more than 99%, indicating the potential as a wide dynamic range device. As for long term operation, this device shows very good stability, an intrinsic property of the Sagnac loop interferometer. Further, a comparison between the different means of polarization control will be presented including details on the overall electrical and optical performance of the different devices.

Figure 2: Typical response of the output from the Sagnac loop interferometer when altering the polarization of the light in the loop using the mechanical polarization controller.
Conclusions
Variable optical attenuators, based on the all-fiber Sagnac loop interferometer are examined. The intensity of the transmitted signal at the output of the interferometer is controlled by changing the polarization state of the light in the loop of the interferometer by using various methods of controlling the state of polarization of the light in the loop. The different methods include mechanical polarization control as well as electrical polarization control by using the fibers with internal electrodes.

The rotation of the polarization based on the mechanical polarizer resulted in a reproducible, stable and wide dynamic device with an extinction ratio of more than 99%. The development of a VOA Sagnac loop Interferometer is further investigated when different means of polarization control are considered based on Kerr phase modulator and thermally poled fibers.

Acknowledgements
Michael Fokine acknowledges the financial support from CNPq

References