Cut-back Measurements

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I. Introduction

This document is a lab report, describing the experimental results of the cut-back measurements technique implemented for the characterization of Si_3Ni_4 waveguides.

II. Theoretical Backround

A. Loss Mechanisms

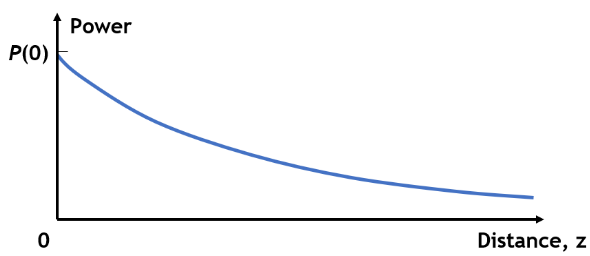
Loss can be attributed to three reasons: scattering, absorption, and radiation. Scattering loss is usually important in glass or dielectric waveguides, while absorption loss is most important in semiconductor guides. Radiation loss becomes important when the guides are bent through a curve.

B. Propagation Loss

When the origin of the loss is uniformly spread over the waveguide length, the guided optical power will decrease exponentially with the propagation distance.

$$P\left(z\right) = P\left(0\right)e^{-a_p z} \tag{1}$$

where α_p is called the power attenuation coefficient.



C. Characterization of optical waveguides

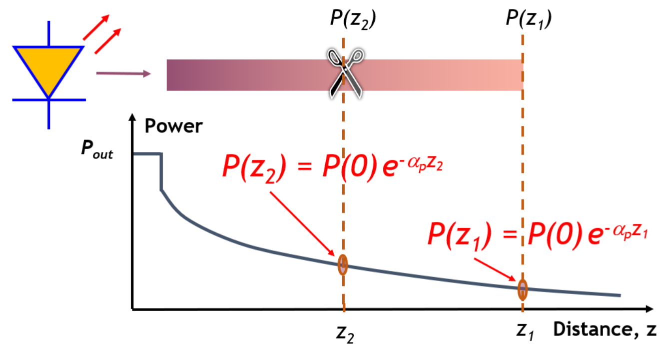
Determining the performance of a passive optical waveguide circuit often consists of measuring the power transmission of the components.

D. Cut-back Measurements

Cut-back Measurements is a non destructive technique for determining certain optical fiber transmission characteristics, such as attenuation. Attenuation coefficient is calculated by:

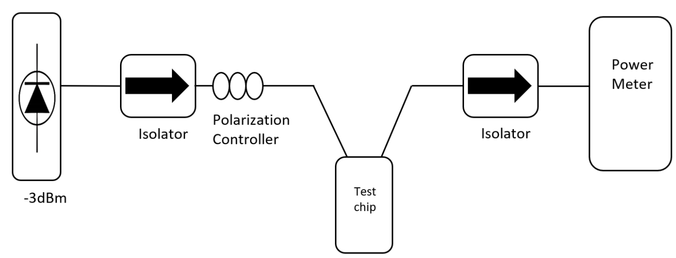
$$a_p = -\frac{1}{z_1 - z_2} \cdot \ln \frac{P\left(z_1\right)}{P\left(z_2\right)} \tag{2}$$

Dimensional analysis of a_p confirms that it is measured in dB/cm. The main advantage of this method, is that it makes it easy to **eliminate the coupling efficiency**.



III. Experimental Set-up

A light beam from a tunable laser is focused on the one facet of the chip using an optical fiber. Polarization of the beam can be controlled by polarization control wheels at the input. The laser spot can be aligned to the waveguides using a micro translation stage which is often actuated piezo-electrically. Part of the laser light will is coupled into the waveguides.



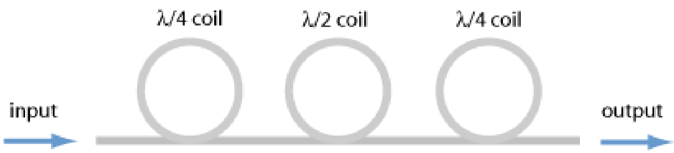
After transmission through the waveguide light is coupled out through the left facet and collected using an objective lens of which the focus is aligned with the left facet.

A. Tunable Semiconductor Laser

The **santec TSL-550** was used. It is a high performance tunable laser with a wide tuning range and an output combining high power and high signal-to-noise ratio.

B. Polarization Controller

Polarization Controller is a device which allows one to control the state of polarization of light within fibers.

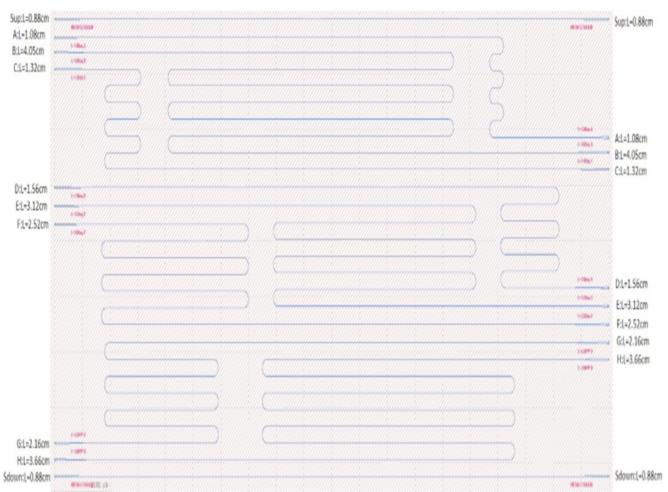


C. Lithographic Mask

The Lithographic Mask employed, includes a wide range of bended waveguides of different lengths.

Waveguide	A	B	C	D
Length (cm)	1.08	4.05	1.32	1.56
Waveguide	E	F	G	H
Length (cm)	3.12	2.52	2.16	3.66

The aforementioned waveguides are depicted in the image below.



IV. Experimental Procedure

P_{out} was measured for each one of the 8 waveguides of length ranging from 1.08cm to 4.05cm and for wavelengths ranging from 1500 to 1580 nm. The extraction of the optical losses for the waveguides was carried out for TM polarization, using the corresponding 37° inclination coupler.

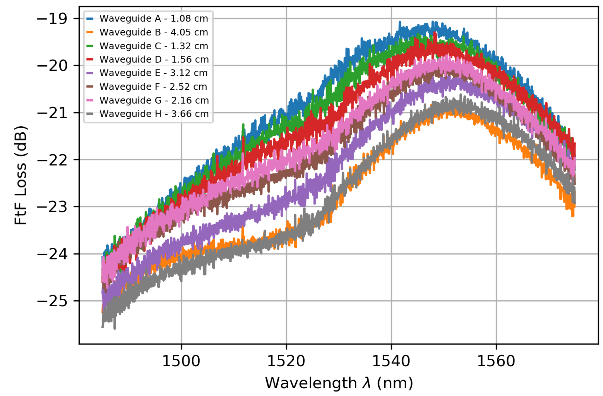
V. Experimental Results

A. Ftf Loss

Fiber-to-fiber losses were computed according to:

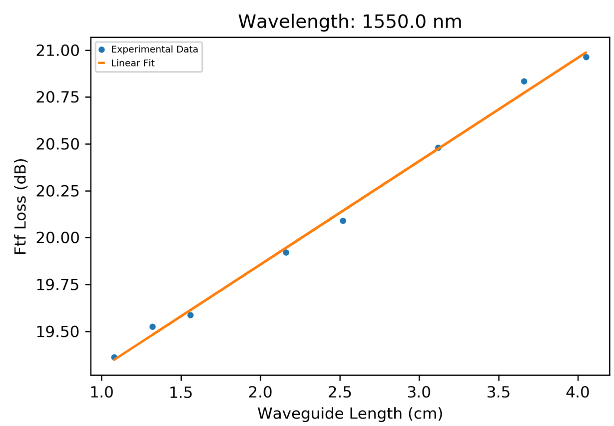
$$Ftf\ Loss = P_{out} - P_{in} - 2dB \tag{3}$$

where $2dB$ is the attenuation introduced by the second isolator. In the following figure, one can see how fiber-to-fiber losses variate with respect to the beam wavelength for all waveguides employed.



B. Ftf Loss - Waveguide Length

For different wavelengths, the relationship between Fiber-to-fiber Loss and Waveguide Length was modeled linearly. **Fiber-to-fiber losses increase linearly as the length of the waveguide increases.**



Above, one can see the linear fit for the case of 1550 nm. The slope of the line is equal to the losses per unit of length, that is the attenuation coefficient a_p. In the table below, one can see the variations of a_p with respect to the beam wavelength.

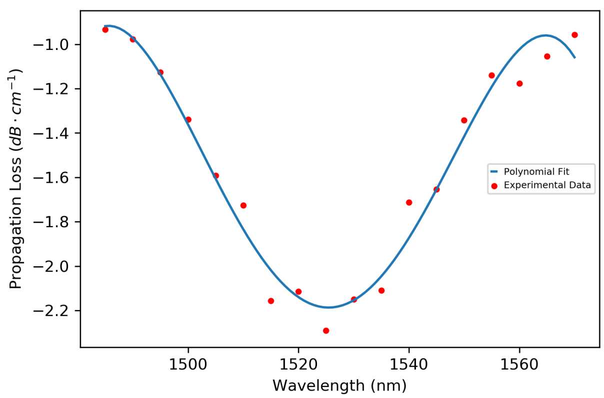
Wavelength (nm)	1485	1490	1495	1500	1505	1510
$a_p\ (dB/cm)$	0.384	0.402	0.463	0.550	0.654	0.709
Wavelength (nm)	1515	1520	1525	1530	1535	1540
$a_p\ (dB/cm)$	0.886	0.869	0.941	0.883	0.867	0.704
Wavelength (nm)	1545	1550	1555	1560	1565	1570
$a_p\ (dB/cm)$	0.680	0.551	0.468	0.483	0.433	0.394

C. Propagation Loss

Propagation Loss was computed according to:

$$Propagation\ Loss = f\left(x\right) \cdot L_i \tag{4}$$

where L_i is the waveguide length. The relation between the propagation loss and the wavelength of the beam was modeled with a 4th-order polynomial regression.

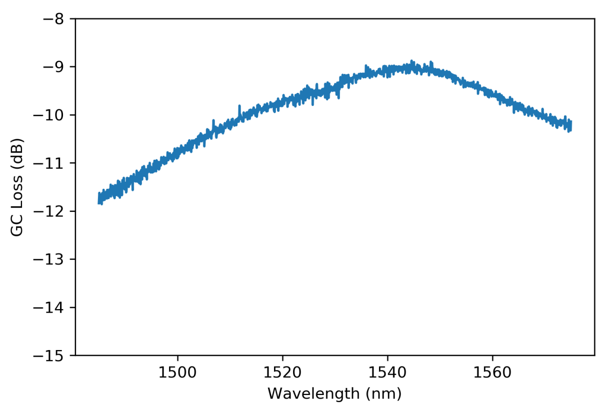


D. Grating Couple Loss

The losses that each grating coupler induces for wavelengths from 1500 to 1580 nm, were computed according to equation

$$GC\ Loss = \frac{\text{Ftf Loss} - \text{Propagation Loss}}{2} \tag{5}$$

One can see that **they depend mildly on the wavelength of the laser, with a peak at around 1550 nm**. The graph below is for waveguide D.



References

[1] Dries Van Thourhout, B. Noble, Erik Stijns and Heidi Ottevaere, "Microphotonics"