Low-Loss S-, C- and L-band Differential Phase Shift Keying Demodulator

Yannick Keith Lize[1,2,3], Mathieu Faucher[1], Érick Jarry[1], Patrick Ouellette[1], Alexandre Wetter[1], Raman Kashyap[2], Alan E. Willner[3]
ITF Laboratories, 400 Montpellier, Montréal, Canada, e-mail: ylize@itflabs.com
Engineering Physics Department, École Polytechnique de Montréal, Montréal, Canada, e-mail: yannick.lize@polymtl.ca
Viterbi School of Engineering, University of Southern California, Los Angeles, CA.

Abstract: We developed an all-fiber delay-line interferometer DPSK demodulator for the S, C and L band with low insertion loss, low-birefringence and greater than 20dB of extinction ratio from 1460nm to 1640nm in a single device.

OCIS codes: 060.2340, 060.5060

1. Introduction

Differential phase shift keying (DPSK) in its diverse flavours is arguably becoming a format of choice in the deployment of next generation optical communication systems. The benefits of using DPSK, return-to-zero (RZ) DPSK and carrier-suppressed-return-to-zero (CSRZ)-DPSK as an alternative to intensity modulation to improve receiver sensitivity and tolerance to certain nonlinear effects have been demonstrated [1-3].

A DPSK receiver requires an optical delay-line interferometer (DLI) [4] followed by a balanced receiver to take advantage of the reduced 3dB OSNR requirement. Although several techniques can be used to implement the DLI, a fused fiber solution illustrated in Fig. 1, offers optimal optical performance from the point of view of insertion loss, extinction ratio, port imbalance, ambient vibration tolerances, tunability and bandwidth [4]. Wideband operation of DLI is of great interest since it would allow a single component to be used for any of the ITU-defined transmission window, namely of the S-band (short) 1460-1530nm, the C-band (common) 1530-1575nm, and the L-band (long) 1575-1625nm. A wideband device does not only provide significant inventory cost reduction but it may also be necessary for future, dynamically reconfigurable, networks utilizing the full low-loss window of silica fibers.

In this paper we present an all-fiber ultra wideband DPSK demodulator capable of operating over 180nm of bandwidth. The demodulator provides less very low insertion loss, birefringence, and polarization dependent loss while having better than 20dB of extinction ratio from 1460-1640nm.

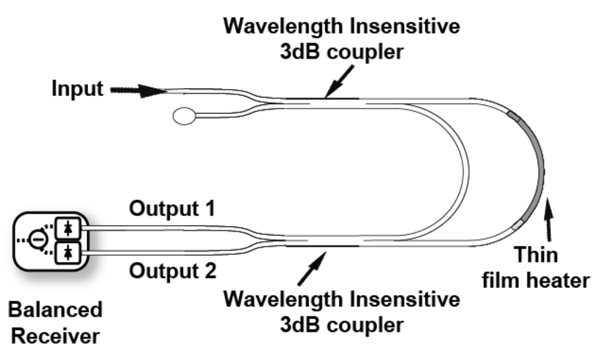

Fig. 1. Schematic of the ITF Labs DPSK demodulator using wavelength insensitive couplers (WIC). The wide bandwidth of the WICs allow for S,C and L band.

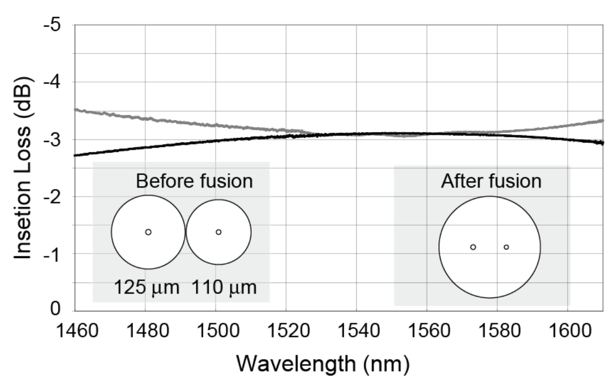

Fig. 2. Typical measured wavelength independent couplers (WIC) using asymmetric fibers and group velocity equalization to obtain flat response close 180nm of bandwidth.

2. Theory

In a free-space Mach-Zehnder interferometer beam splitters are used to separate the light along the two paths and to recombine them for interference. Ideally a 50/50 splitting ratio would provide infinite extinction ratio if no polarization effects are present. Free-space beam splitters can be wavelength dependent which restricts the bandwidth where adequate extinction ratio is obtained. In the all-fiber implementation, fiber couplers act as beam splitters. Although fiber couplers are usually wavelength sensitive, we developed and demonstrated a wavelength-independent coupler (WIC) [5] as shown in Fig.2. The optical properties of fused tapered components are determined by their geometry, i.e., their transverse and longitudinal index profiles. In our method, we use the inherent characteristic of asymmetric couplers to provide incomplete power transfers from one output of the coupler to the other, allowing for the realization of a prescribed splitting ratio. Concurrently, group velocity equalization flattens the spectral response of the components for wideband coupling [5].

Table 1. Measured Parameters for two typical devices at 12GHz and 43GHz showing extinction ratio to higher than 20dB with low losses and all specifications stable across 180nm of bandwidth.

Wavelength (nm)	*1460*		*1510*		*1530*		*1550*		*1580*		*1610*		*1640*	
Free Spectral Range (GHz)	12.0	43.0	12.0	43.0	12.0	43.0	12.0	43.0	12.0	43.0	12.0	43.0	12.0	43.0
Insertion loss	.25	0.5	.19	.5	.22	.5	.26	.5	.23	.5	.25	.5	.29	.6
Extinction Ratio	20.8	20.5	31.4	31.4	40.0	32.9	39.0	33.6	32.8	32.8	41.8	32.2	20.6	32.6
Polarization dependent f(GHz)	0.03	.53	.05	.40	.06	.42	.05	.43	.03	.42	.04	.49	.04	.46
Polarization dependent Loss	.02	0.05	.01	.04	.02	.02	.01	.06	.02	.05	.01	.08	.01	.1

3. Experimental Results

As illustrated in Fig.1, the DPSK demodulator is comprised of two 3dB WIC with a specified delay between them. The phase of the interferometer is controlled using a heater directly deposited on the optical fiber to compensate for temperature drifts and accommodate for laser aging over the lifetime of the system. Results for two typical demodulators with FSR of 12GHz and 43GHz DPSK are presented in Tab.1. FSR and loss are very stable from 1460nm to 1640nm while the minimum extinction ratio is kept higher than 20dB across the band. An extinction ratio of is more than 15 dB in our design, is enough to ensure that the signal is demodulated without penalty [6] since the interferometer provides port imbalance of less than 0.1dB. Fig. 3 illustrates the measured transmission spectra for the two ports of the 12GHz and 43GHz demodulators with greater than 20dB of extinction around 1460nm and

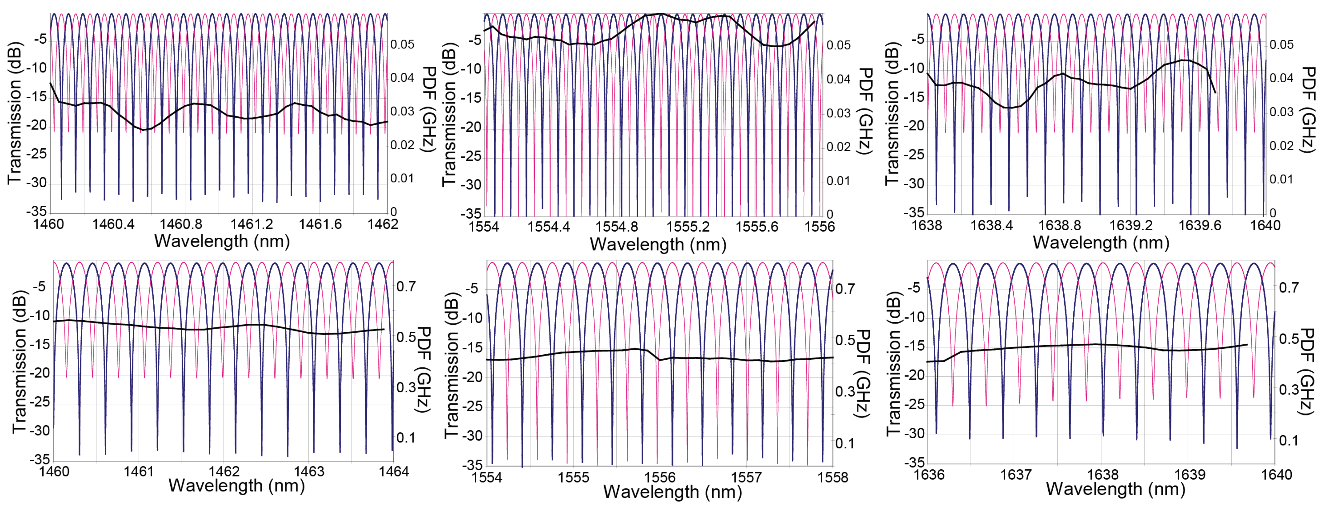

Fig. 3. Transmission spectra for a typical 12 GHz (top) and 43GHz (bottom) DPSK demodulator at around 1460nm, 1555nm and 1640nm. Extinction ratio in kept higher than 20dB over 180nm of bandwidth. Insertion loss and polarization dependent frequency shift (PDF) are low without much variation across the band.

1640nm.

4. Conclusion

We have developed an ultra-wideband DPSK demodulator for the S, C and L band which can operate over 180nm of bandwidth. The device not only provides significant inventory cost reduction but may also be necessary for future dynamically reconfigurable networks. The device has low loss and extinction ratio higher than 20dB.

5. References

[1] A. H. Gnauck and P. J. Winzer, "Optical phase-shift-keyed transmission", *J. Lightwave Technol.*, 23, (2005), pp. 115-130.
[2] V.S. Grigoryan, P.S. Cho,, I Shpantzer. ," Nonlinear Penalty Reduction of RZ-DBPSK Versus RZ-OOK Modulation Format in Fiber Communications", in Proc. ECOC'02, Copenhagen, Denmark, (2006).
[3] X. Liu, "Nonlinear effects in phase shift keyed transmission," in Proc. OFC'04, Los Angeles, CA (2004).
[4] F. Séguin, F. Gonthier, "Tuneable all-fiber, delay-line interferometer for DPSK demodulation", Optical Fiber Communication Conference, Technical Digest. OFC/NFOEC Volume 5, pp248 – 250 (2005)
[5] N. Godbout, S. Lacroix, F. Gonthier, in Proc. ECOC'06, Cannes, France (2006).
[6] Winzer, and H. Kim, ''Degradations in Balanced DPSK Receivers'' *IEEE Photon. Technol. Lett.*, 15,(2003), pp. 1282-1284.