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# DWDM DEMULTIPLEXING WITH 25-GHZ CHANNEL SPACING FOR 60-GHZ BAND RADIO-ON-FIBER SYSTEMS

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**Abstract** *We experimentally demonstrate demultiplexing using an arrayed-waveguide grating for a DWDM mm-wave fiber-radio system by optical frequency interleaving. No noticeable power penalty was observed after 25-km SMF transmission when the channel separation was 25 GHz.*

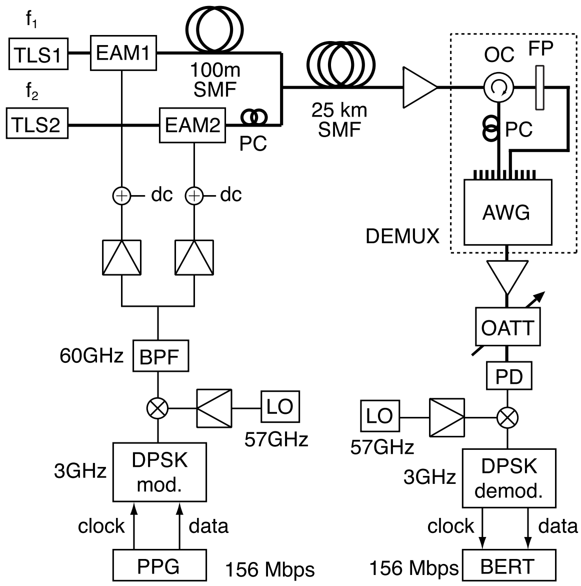
## Introduction

For future radio communication, millimeter-wave (mm-wave) fiber-radio system is very attractive to realize broadband radio-access services, because it will resolve the scarcity of microwave frequency resource problem. In mm-wave fiber-radio systems, a central station (CS) should be connected with a huge number of base stations (BS's) to cover each service area as in a microwave cellular system because of the large transmission loss in free space. Therefore, applying dense wavelength division multiplexing (DWDM) to the system will be a strong candidate in order to support all of BS's for future fiber-optic access network infrastructure. There have been several reports on such DWDM fiber-radio systems [1]-[3]. To increase the spectral efficiency of the system, the concept of optical frequency interleaving was first proposed by Schaffer et al. by simultaneous upconversion scheme with an electro-optic modulator [4]. Recently, a simple method to increase the spectral efficiency by optical frequency interleaving was proposed in which the modulation format could be either optical double side band (DSB) or optical single side band (SSB) [5]-[8].

In this paper, we experimentally demonstrate a demultiplexing (DEMUX) scheme for the DWDM fiber-radio system using an arrayed-waveguide grating (AWG), which was proposed in [6] and [8]. In the experiment, 25-GHz separated 2-channel optical DSB signals modulated by a 60-GHz mm-wave carrying a 156 Mbps data are optically multiplexed by frequency interleaving. After transmission in 25-km standard single mode fiber (SMF) and DEMUX, we observe no noticeable power penalty in the received data.

## Experimental setup

Fig. 1 shows experimental setup. Two CW lights from tunable laser sources (TLS1 and TLS2) whose optical frequencies are depicted by $f_1$ and $f_2$ are intensity modulated by electro-absorption modulators (EAM1 and EAM2) independently with a 60-GHz mm-wave carrying a 156-Mbps differential phase shift keying (DPSK) data of channels 1 and 2. The channel spacing $f_1 - f_2$ was set to be 25 GHz. A 100-m long SMF after EAM1 is used to decrease the correlation between the data. The multiplexed optical signal is transmitted through 25-km long SMF. The DEMUX operation is achieved as follows. The transmitted signal is fed to a Fabry-Perot etalon (FP) through an optical circulator (OC). The free spectral range of the FP is adjusted to equal to the channel separation. The reflectivities of the both surfaces of the FP used in the experiment are 80 %. The FP is tuned in order to separate carriers (transmission) and sidebands (reflection) from the multiplexed optical signals. The AWG [9] is designed to filter only the desired frequency components (carrier and one of the sidebands) out of the input signals. This can be done by properly adjusting the separation of the input waveguides at the interface between the input channel waveguide and the slab waveguide regions. In this experiment, we use a commercially available AWG (24 input and one output waveguides) with 25-GHz channel spacing, although the ideal input channel spacing of the AWG (2 input and N output waveguides, N: total channel number) is 60 GHz. The demultiplexed optical signal is detected by a




TLS: tunable laser source, EAM: electro-absorption modulator, PC: polarization controller, SMF: standard single-mode fiber, OC: optical circulator, FP: Fabry-Perot etalon, AWG: arrayed waveguide grating, OATT: optical variable attenuator, PD: photo diode

Fig. 1 Experimental setup. The demultiplexing (DEMUX) scheme is shown as the dashed box.

photodiode (PD). The bit-error rate (BER) of the decoded 156 Mbps data is measured as a function of the received optical power, which is measured at the input of the PD.

**Results**

Fig. 2 (a)-(d) show the measured optical spectra of the fiber-radio signals at (a) OC input, (b) transmission of FP, (c) reflection of FP, and (d) AWG output, respectively. Separation of carriers and sidebands can be seen from Fig. 2 (b) and (c) as indicated by arrows. In the experiment we filtered the carrier and the lower sideband of the desired channel with the AWG as shown in Fig. 2 (d). The carrier and the sideband of the undesired channel are suppressed by 13 dB and 34 dB of the desired carrier and the sideband, respectively. This is because that we used an AWG with 25-GHz channel spacing.

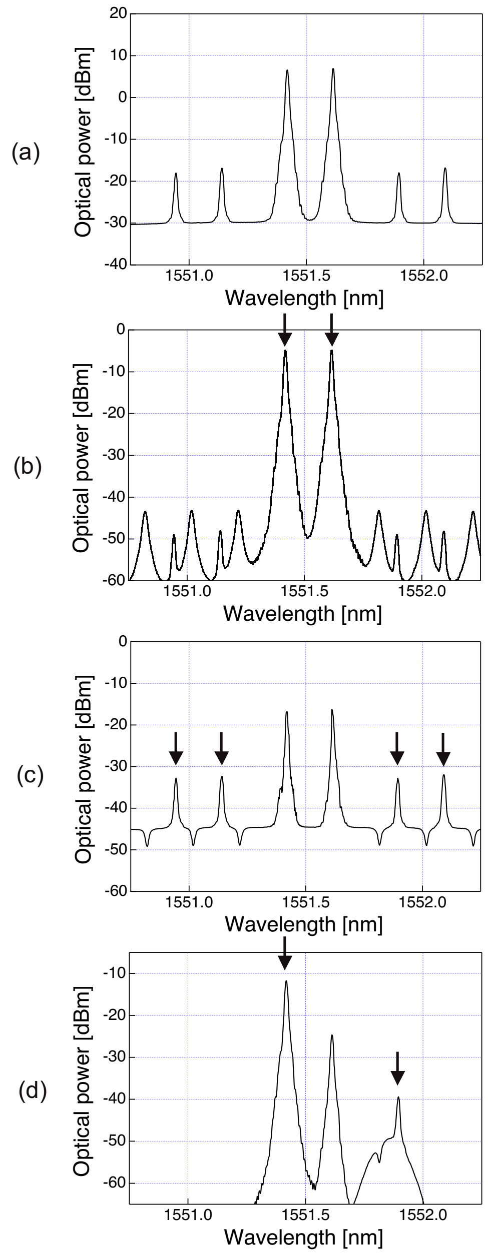



Fig. 2 Measure optical spectra of the fiber-radio signals at (a) OC input, (b) transmission of FP, (c) reflection of FP, and (d) AWG output, respectively.

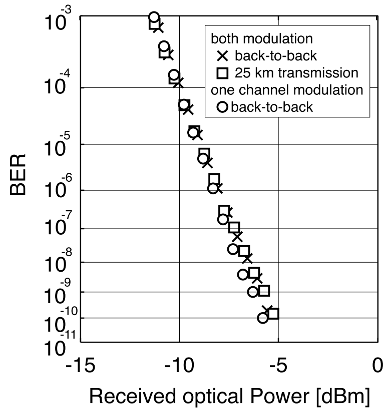



Fig. 3 Measured BER of channel 1 versus the received optical power.

Fig. 3 shows the measured BER of channel 1 versus the received optical power. ○ indicates the back-to-back BER when only the desired channel was optically modulated. × also indicates the back-to-back BER but when both channels were modulated. □ indicates the BER after 25-km SMF transmission when both channels were modulated. No BER floor (> $10^{-11}$) was observed for all cases. No noticeable power penalty was observed even after SMF transmission because we filtered and used only one of the sidebands for detection. We obtained nearly the same results for channel 2.

**Conclusions**

We have successfully demonstrated demultiplexing using an AWG for a DWDM mm-wave fiber-radio system by optical frequency interleaving. No noticeable power penalty was observed due to 25-km SMF transmission and interchannel interference when the channel separation was 25 GHz. Future works include demultiplexing of multi-channel optical signals.

**References**

1 K. Kitayama, IEEE/OSA J. Lightwave Technol., 16 (1998), page 969.
2 K. Kojucharow et al., IEEE MTT-S International Microwave Symposium (2000), WE4C-7.
3 A. Narasimha et al., Electron. Lett., 36 (2000), page 1135.
4 C. G. Schaffer et al., MWP2000, WE2.4.
5 C. Lim et al., Electron. Lett., 37 (2001), page 1043.
6 H. Toda et al., MWP2001, Tu-3.3.
7 C. Lim et al., 2001 LEOS Annual Meeting, MG4.
8 H. Toda et al., MOC'01, C2.
9 K. Okamoto et al., IEICE Trans. Electron., E81-C (1998), page 1176.