New colorless 10Gbps remote modulator for multiwavelength access

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A dramatic cost reduction of wavelength-specified sources is expected for customer interfaces in next-generation high-bandwidth networks.

Fiber-to-the-home (FTTH) technology provides residences with high-speed broadband access to digital services and the Internet. FTTH networks have now established their economic competitiveness by providing significantly reduced operating expenses and enhanced revenue opportunities for carriers. With the offer of novel high-bandwidth services such as triple play (voice, video, and data transmission on the same platform) and high-definition video, a new market situation is rapidly emerging. For the first time, there exists a possibility to connect customers to these services at the required speed and at a fair cost. This represents a strong driving force for the further deployment of standard passive optical networks (PONs) and the design of next-generation access technology.

The most promising new architectures are based on wavelength-division multiplexing (WDM). They can provide some increase in speed with virtual point-to-point connections. To increase the number of customers, WDM and time-division multiplexing (TDM) systems will have to provide speeds up to 10Gbps per wavelength. However, the cost of classical WDM components, such as WDM and tunable lasers, represents an important drawback. This can be overcome by the ‘colorless concept,’ in which wavelength complexities such as channel generation and wavelength control are kept in the carrier’s central office for large cost sharing, while the optical network unit (ONU) on customer premises relies on wavelength agnostic remote modulation (i.e. identical components regardless of the working wavelength). These ONUs will allow device mass production and reduce maintenance and replacement costs. Moreover, inexpensive, compatible FTTH colorless components may also lower the cost of WDM access devices, such as the reconfigurable optical multiplexers used to add and remove wavelengths and their traffic at nodes in a WDM network. These developments could also lead to some hardware convergence in network segments in metro-access areas.

Our work focuses on the design of components for a possible PON overlay scenario consisting of the use of a coarse WDM architecture based on 10Gbps ‘colored’ ONU diplexers as a first step, followed by a WDM architecture with fully colorless 10Gbps ONU components. The first demonstrations of colorless ONU components were made using reflective semiconductor optical amplifiers (R-SOA), which offer data rates up to 2.5Gbps but require a trade-off between the gain and bandwidth that limits their speed. Injection-locked Fabry–Pérot lasers operating at 1.25Gbps may lead to higher speeds, but their high locking power limits the splitting ratio and increases system cost.

To solve speed scalability and distance impairment issues, we recently demonstrated a new 10Gbps monolithically integrated amplified reflective electroabsorption modulator (R-EAM-SOA) that separates the modulation and amplification functions. The device showed promising performance as a remote colorless...
Figure 2. Reflection gain spectra for different modulator bias, also showing the static extinction ratio.

Figure 3. 10Gbps transmitted power spectra for an error rate fixed at $10^{-9}$ at different temperatures. Inserts: Examples of recorded eyes. BER: Bit error rate. dBm: Decibels below 1mW.

data source (see Figure 1).\textsuperscript{5,6} But the presence of an aluminum-containing material required use of a shallow-ridge waveguide structure with high thermal resistance, which prevented operation over a large spectral range with insertion gain.

More recently, we developed an AlGaInAs/InP (aluminum gallium indium arsenide/indium phosphide) quantum well (QW) structure with enhanced excitonic confinement leading to diodes with a sharp absorption edge even at high electric field.\textsuperscript{7} This property significantly improves the working spectral range, corresponding to a high extinction ratio. Using such QW structures, we designed and fabricated new reflective amplified EAMs working at 10Gbps over a 40nm spectral range up to 60° C. Further improvement of the R-EAM-SOA was achieved by selecting a semi-insulating buried heterostructure for its good thermal and modal properties. Design flexibility was added with the development of a selective area growth (SAG) technique suitable for aluminum-containing materials. Using SAG, we engineered integrated functions by positively detuning the SOA gap wavelength with respect to the EAM absorption edge. This enhances the reflection gain in the working wavelength range, typically located ~40–50nm above the absorption edge.\textsuperscript{8,9} The component shows an insertion gain up to 10dB and lossless operation over 50nm (see Figure 2). It operates at 10Gbps over 80nm at 20° C, does not incur thermal penalties up to 90° C, and can link 10km standard fiber up to 60° C (see Figure 3). This performance redefines the state of the art for 10Gbps colorless components.

We still need to improve the polarization dependence and output power of the component, but the present level of sophistication makes the device close to practical application in 10Gbps wavelength agnostic networks. Colorless reflective components are very attractive for cost and flexibility reasons. But wide use of this technology may rely on providing a simple solution to single fiber two-way transmission on the same wavelength, which presently suffers from Rayleigh backscattering penalties.

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Christophe Kazmierski contributed to pioneering work on long-wavelength lasers at the Central Research Laboratory of Thomson-CSF. He also headed the Laser Department of France Télécom R&D, working on laser-based photonic circuits. At the Alcatel-Thales III-V Laboratory, he is focused on 40–100Gbps electroadsoption modulator-based sources. He has authored over 250 papers and 14 patents in the field of III-V semiconductors. He has also served on program committees at international semiconductor laser and microwave photonics conferences.

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