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DESIGN AND CONSTRUCTION OF A WDM TRANSCEIVER WITH VHGT USING HYBRID INTEGRATION TECHNOLOGY

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Abstract:
We report about design and construction of WDM bidirectional transceiver module (TRx) for the passive optical network (PON) of a fiber to the home FTTH topology. The TRx uses a microoptics hybrid integration technology with volume holographic Bragg grating triplex filter (VHGT) and a collimation lenses for wavelength multiplexing/ demultiplexing. Our optical WDM transceiver TRx has been constructed using system of a four micromodules in the new circle topology. The optical micromodul with VHGT filter, two optoelectronic receivers' micromodules for receiving download information (internet and digital TV signals) and optoelectronic transmitter micromodul for transmitting of a upload information.

INTRODUCTION

The microoptical lightwave circuit (MLC) and planar lightwave circuit (PLC) hybrid integration technology enables us to construct component by combining MLC or PLC with passive function (fiber, planar waveguides, collimation lenses, optical gratings atc.) and active optoelectronic devices (laser diodes, semiconductor optical amplifiers, photodiodes atc.) hybridized on a MLC or PLC [1], [2]. WDM type triplex transceiver TRx is useful for a subscriber part of the passive optical network PON for a fiber to the home FTTH topology. An optical TRx transmits a 1310 nm radiation upload and receives a 1490 nm download internet data as well as a 1550 nm download digital video signals for wavelength division multiplexing WDM cable TV application. The TRx uses a microoptics or planar lightwave hybrid integration technology. For wavelength multiplexing/ demultiplexing (MUX/DEMUX) were used TFF (thin-film filters), optical mirrors and prisms [3].
Our optical WDM transceiver TRx has been constructed using system of a four micromodules in the new circle topology. The triplex optical MUX/DEMUX micromodule was composed of volume holographic Bragg grating triplex filter (VHGT) from Ondax Ltd. This transmission type grating filter has high diffraction efficiency and very low insertion loses and optical crosstalk [4]. The optoelectronic part of TRx is crate of a two microwave OE (optoelectronics) receiver micromodules with bandwidth of 2.5 GHz with design after [5]. The OE transmitter micromodule uses Fabry-Perot laser diode with a injection microwave modulator and optical power feed back control electronics.

DESIGN AND MEASURE RESULTS OF THE MICROMODULES

The triplex optical micromodule

The triplex optical MUX/DEMUX micromodule was composed of VHGT filter made by BK7 glass made by Ondax Ltd. with collimating cylindrical microlens 2,2 mm in radius and optical multimode fiber 50/125 μm. The end of the fiber was fixed in a metallic tube. A VHGT filters are ideal microoptical beam distribution element having high diffraction efficiency and very low insertion loses and optical crosstalk. The volume holographic transmission gratings are an extremely accurate and temperature-stable means of filtering a narrow band optical spectrum.
We measured the diffraction angles as first step, to determine geometry of location of the receiving and transmitting micromodule θ_{diff} = 18.4° for λ_1 = 1490 nm and θ_{diff}= 19.1° for λ_2 =1550 nm and determine Bragg constants of the VHGT after (1),
.

$$\Lambda = \frac{\lambda_B}{2\sin(\frac{\theta_{\text{diff}}}{2})} \tag{1}$$

where Λ is the Bragg constant, λ_B is the Bragg wavelength and θ_{diff} is the Bragg diffraction angle of a grating. The Bragg constant $\Lambda = 4.66$ μm for λ_1 = 1490 nm and $\Lambda = 4.671$ μm for λ_2 =1550 nm was calculated after (1).

The diffraction efficiency given by (2) was calculated η = 99.8% for wavelength 1490 and η =□97.4% for 1550 nm. The results of the measuring are shown in Fig. 1,2 and Tab. 1. For measuring was used ten axis micromanipulator and Beam Profiler BP104-IR.

$$\eta_B = \sin^2\left(\frac{\pi \Delta n d}{\lambda_B \cos \alpha_n}\right) \qquad (2)$$

where α_n is the Bragg-matched incident angle in the medium, Δn is grating strength refraction index modulation, d is thickness of the grating

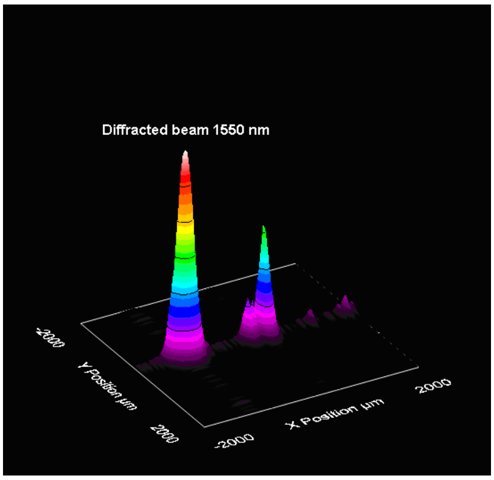

Fig. 1: The diffracted beam for the wavelength λ_1 =1550 nm

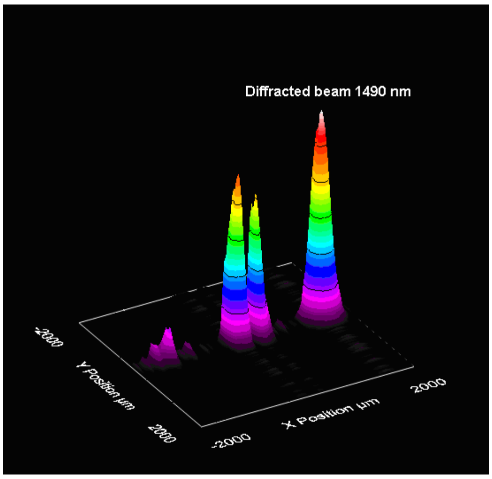

Fig. 2: The diffracted beam for the wavelength λ_2 =1490 nm

Table 1: The diffraction efficiency of the VHGT

λ_t [nm]	η_B [%]
1490	73.36
1550	74.42

It was founded that the measured diffract efficiency η =73.6 % for wavelength 1550 nm was different from the theoretical computed value η =□97.4 %. This phenomenon comes from a grating system imper-fection and a material optical dissipation.

The minimal optical crosstalk of the optical beam for both wavelength was very important requirement to the reach good BER. The optical crosstalk was given by (3), (4)

$$A_\lambda = \frac{P_{1\lambda}}{P_{2\lambda}} [\%] \qquad (3)$$

$$a_\lambda = 10 \log \frac{P_{1\lambda}}{P_{2\lambda}} [dB] \qquad (4)$$

where P□λ□ is optical diffracted power , $P_{2\lambda}$□ is optical power diffracted to direction opposite wavelength. For BER = 10^{-9} it was needed a_λ □> 11 dB. The results of the measuring is shown in Fig. 3,4 and Tab.2

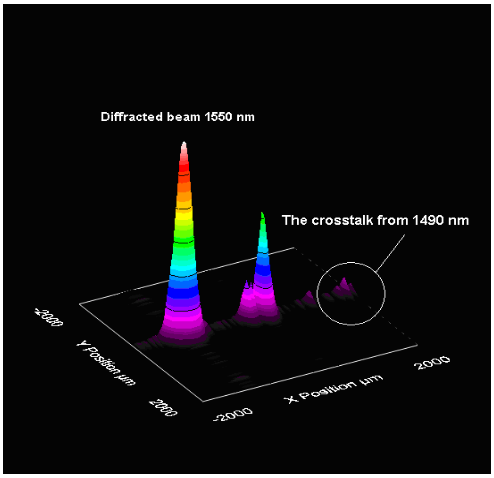

Fig. 3: The optical crosstalk for the wavelength λ_1=1550 nm

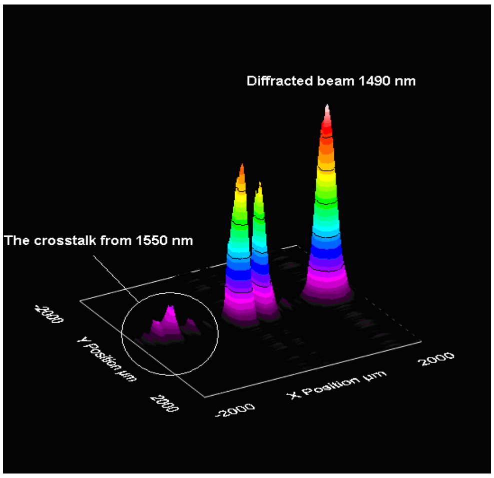

Fig. 4: The optical crosstalk for the wavelength λ_2=1490 nm

Table 2: The diffracted efficiency of the VHGT

λ_t [nm]	A_λ [%]	a_λ [dB]
1490	4,95	13,05

1550	4,70	13,28

The optoelectronic receiver micromodule

Our work was concentrated on design and construction of a microwave hybrid optoelectronic receiver micromodule [5], where the PIN photodiode was connected by microstripe line to input of the HBT amplifier. The all parts are placed on the composite material substrate.

The theoretical analysis describes the microstrip connection between the PIN photodiode and the input of the HBT amplifier by the small signal equivalent circuit. For frequency response analysis we used the small signal equivalent circuit of the OE receiver input Fig.5

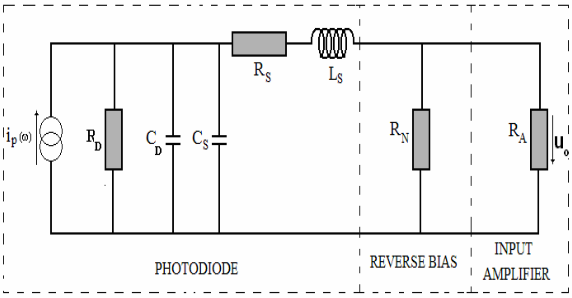

Fig. 5: The small signal equivalent circuit of the PIN photodiode with SMD assembly and input of the HBT amplifier

where

$i_p(\omega)$ - PIN photodiode photocurrent source

C_D - capacitance of depletion layer 0.5 pF

C_S - stray capacitance 1 pF

R_s - series resistance 10 Ω

R_D - dynamic resistance of the PIN photodiode 1 kΩ

L - inductance generated by the photodiode SMD carrier

R_N - thin film resistor for reverse bias voltage 2 kΩ

R_A - input impedance 50 Ω of the ideal amplifier

The PIN photodiode (C30606ECER from Judson Technologies) chip connection to the microstrip waveguide is composed from compensation inductance made by gold microstrip on the alumina carrier L_1 and gold wire connection L_2. For calculation frequency response limit it was counted inductance L given by (5).

$$L = L_1 + L_2 \qquad (5)$$

For the cutoff angle frequency ω_T of the module complex transition Z_T impedance characteristic (6) was derived

$$|Z_T| = \frac{R_D R_P}{\left[(R_D+R_S+R_P-\omega^2 L C_D R_D)^2+\omega^2(L+R_D R_S C_D+R_D R_P C_D)^2\right]^{1/2}} \qquad (6)$$

The cut off angle frequency ω_T was derived as root of the transcendent equation (7)

$$|Z_T(\omega_T)| = |Z_T(0)| / 2^{1/2} \qquad (7)$$

where $|Z_T(0)|$ is module of the impedance for ω = 0, R_P is parallel R_A and R_N combination.

The limit frequency f_T received by solve equation (7) was f_T = 2.78 GHz. The module $|Z_T(0)|$ = 46.07 Ω, C_T = 1.5 pF and L = 4.5 nH. The small signal equivalent circuit presented in the Fig.5 was implemented for simulation in Win Mide program. The capacity of depletion layer C_D was a function of reverse bias voltage and for 5 V is catalog value 0.50 pF. C_s is stray capacity signal connection PIN photodiode SMD assembly. For good high frequency response it is essential to be C_D and C_s kept as low as possible. After that it is necessary to reduce R_A or to provide high-frequency equalization. The inductance and capacity generated by the photodiode SMD carrier was simulated to analyze its influence on the device. The measured and simulated results at the frequency range 0.1 – 3.5 GHz is shown in the Fig. 6.

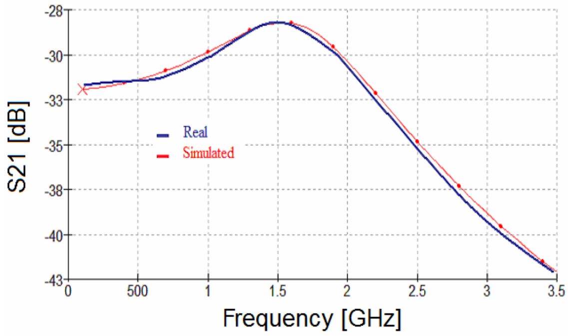

Fig. 6: The measured and simulated S_{21} modulation characteristic of the OE receiver micromodule for R_s = 10 Ω, L_S = 4.8 nH, $C_{eq} = C_D // C_s$ =1.5.pF

The simulation and measurement of S_{21} modulation characteristic reveal that the limit frequency f_T of the OE receiver was 2.5 GHz. The bandwidth of the OE receiver is limited by the capacity depletion layer C_D of the photodiode and C_S stray capacity of the contact spots. The inductance distributed along the signal way between PIN photodiode and input of the HBT amplifier shift the bandwidth of the OE receiver micromodule from 1.91 GHz to 2.5 GHz with reasonable ripple 3 dB.

DESIGN OF MICROOPTICAL WDM TRANSCEIVER TRx

The WDM transceiver TRx has been constructed using system of a four micromodules in the new circle topology set on the alumina or composite substrate. The fundamental layout of the hybrid integrated microoptical WDM transceiver is given on Fig. 7.

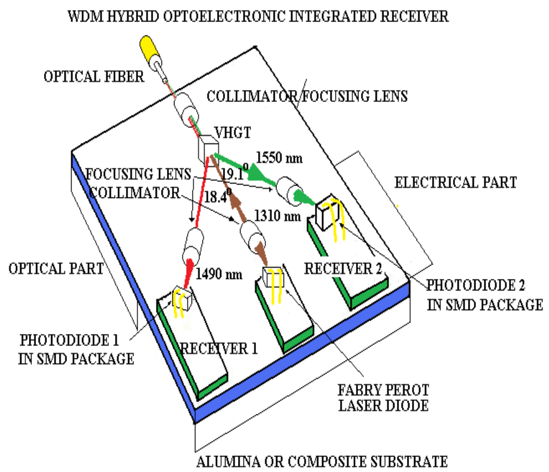

Fig. 7: WDM type triplex transceiver TRx

The triplex optical micromodule was composed of VHGT filter with collimating cylindrical microlens and optical multimode fiber. This transmission type grating filter has high diffraction efficiency, see Tab. 1, very low insertion losses 0.14 to 0.29 dB and optical crosstalk after Tab.2. The optoelectronic part of TRx crate a two OE receiver micromodules with decollimation lenses. The hybrid microwave OE receivers uses InGaAs PIN photodiodes and HBT microwave amplifier made by thin layer hybrid integration technology. The optical beams were coupled on the PIN photodiodes active surface by decollimating lens. The optoelectronic transmitter micromodule for λ_3=1310 nm upstream radiation uses Fabry-Perot InGaAsP laser diode fix on metallic submount with a microwave modulator and optical average power feed back control electronics. The feed back control was realized by ADN 2830A integrated circuit from Advance Semiconductor. The optical microisolator and collimation lens separate laser diode from nondiffracted radiation of the VHGT downstream beams.

CONCLUSIONS

In the paper we report about design and construction of a WDM bidirectional transceiver module TRx, which was design and constructed for subscribe part passive optical networks with fiber to the home topology (PON-FTTH). The TRx uses a microoptics hybrid integration technology, with volume holographic Bragg grating triplex filter (VHGT) for three wavelength MUX/DEMUX function.

Our optical WDM transceiver TRx has been constructed using system of a four micromodules in the new circle topology. The triplex optical micromodule is composed of VHGT filter with collimating cylindrical microlens and multimode optical fiber. The diffraction angles, efficiencies and insert losses of the triplex VHGT filter were verified by the beam analyzing system Beam Profiler BP 104-IR from Thor Labs. The diffraction angle was 18.4 and 19.1 degrees for wavelength 1490 and 1550 nm. The measured diffraction efficiency was 73.36 % and 74.42 % with insert losses below 0.3 dB. The next two optoelectronic receiver micromodules include collimation lenses and hybrid microwave OE receivers. The optoelectronics receivers were made by thin layer hybrid integration technology. The optoelectronic transmitter micro-module uses Fabry-Perot InGaAsP laser diode with optical microisolator, microwave modulator and optical power feed back control electronics.

Alternatively we design a optical WDM transceiver TRx made by the polymer PLC (planar lightwave circuit) hybrid integration technology with a epoxy novolak polymer NANO^{TM} SU-8 2000 monomode ridge waveguides and graded planar optical interference filters.

ACKNOWLEDGMENTS

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