1.3 µm Monolithic Integrated Optoelectronic Receiver using InGaAs MSM Photodiode and AlGaAs/GaAs HEMTs grown on GaAs

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Abstract: *The first 1.3 µm monolithic integrated optoelectronic receiver using an InGaAs MSM photodiode and AlGaAs/GaAs HEMTs grown on a GaAs substrate has been fabricated. At each differential output the transimpedance is 26.8 kΩ. The bandwidth of 430 MHz implies suitability for transmission rates up to 622 Mbit/s.*

Introduction: Fiber optical links with extremely high data rates are required in long haul telecommunication systems as well as in computer local area networks, and board-to-board and chip-to-chip interconnections. Short distance interconnections can operate at 0.85 µm wavelength [1-2]. For data transmission over longer distances transmitters and receivers for a wavelength of either 1.3 µm or 1.55 µm are required. Recent advances in heteroepitaxial growth of lattice mismatched materials have made possible the fabrication of long wavelength InGaAs photodetectors on GaAs substrates. We report on the first 1.3 µm monolithic integrated photoreceiver using an InGaAs MSM photodiode and AlGaAs/GaAs HEMTs.

Design and Fabrication: The photoreceiver was fabricated using our standard process for enhancement and depletion AlGaAs/GaAs HEMTs with 0.3 µm gate lengths [3-4]. The following mean values for the enhancement and depletion HEMT parameters, respectively, were obtained: threshold voltage: 0.05 and -0.7 V, transconductance: 470 and 350 mS/mm, source resistance: both types 0.6 Ω mm, transit frequency: 50 and 42 GHz. This standard process now includes InGaAs MSM photodiodes.

Fig. 1 shows a schematic cross section of an InGaAs MSM photodiode integrated with an AlGaAs/GaAs HEMT. The vertical structure is grown on the semi-insulating GaAs-substrate by MBE [3]. The photodiode layers are on top of the AlGaAs/GaAs HEMT layers ($In_{0.45}Ga_{0.55}As$: $T_{growth} = 500$ °C). Definition of the photodiode mesa is done by a non-selective wet etch process followed by a selective reactive ion etch process. The latter stops as soon as the AlGaAs etch stop layer is reached. The photodiode fingers are defined by electron-beam lithography and formed by evaporation and subsequent lift-off of Ti/Pt/Au Schottky metal [4]. Airbridges connect the photodiode to the electronic circuit. As shown in Figures 2 and 3 the photoreceiver consists of an MSM photodiode, a transimpedance amplifier, a second amplifier stage, and a two-stage differential amplifier.

Device and Circuit Performance: Fig. 4 shows the measured current-voltage characteristics of a photodiode. The DC responsivities are 0.08 A/W for 6 V bias and 0.16 A/W for 10 V bias. Within the total voltage range the dark current is less than 1 µA for a photodiode with an active area of 25x25 µm^2.
All photoreceiver measurements were performed on-wafer using CASCADE probes. The integrated photodiode was irradiated by 1.3 µm light from a calibrated laser diode via a single mode fiber. The measured transimpedance at each photoreceiver output is 26.8 kΩ. Maximum output voltage swing is 0.85 V and the power dissipation is 250 mW. Fig. 5 shows the relative response versus frequency. The -3 dB bandwidth for sinusoidal modulated light lies at 430 MHz. The response to pulse-modulated optical signals was tested by means of an ANRITSU pulse pattern generator. Eye diagrams of the two output voltages show (Fig. 6) that the photoreceiver operates successfully at a data rate of 622 Mbit/s.

References:

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[3] Köhler, K. et al., Inst. Phys. Conf. Ser., 1990, **112**, pp. 521-526
[4] Hülsmann, A. et al., Jpn. J. Appl. Phys., 1990, **29**, (10), pp. 2317-2320

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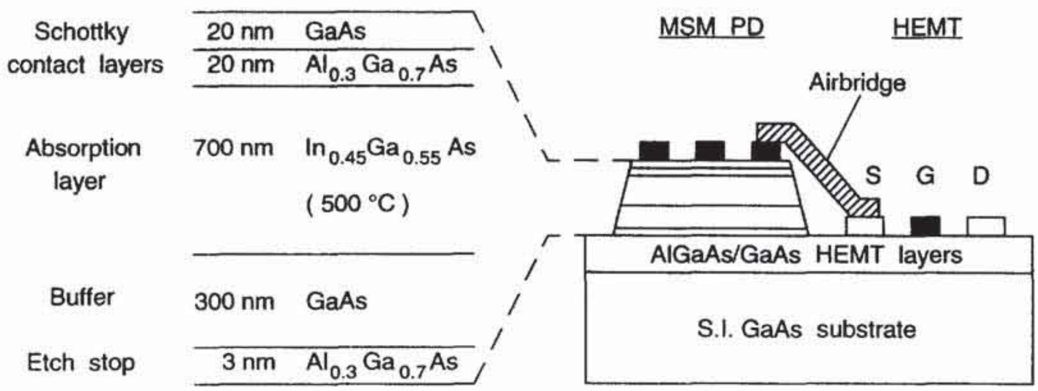

Fig. 1. Schematic cross section of an InGaAs MSM photodiode integrated with an AlGaAs/GaAs HEMT.

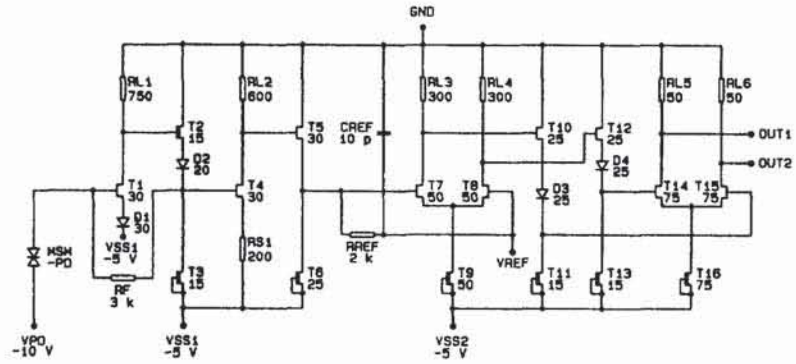

Fig. 2. Circuit diagram of the photoreceiver. T1: enhancement transistor with 30 µm gate width, T2: depletion transistor with 15 µm gate width, D1: 30 µm wide diode, RF: 3.0 kΩ NiCr thin film resistor, CREF: 10 pF MIM capacitor. RL5 and RL6 are off-chip resistors. The layout also includes blocking capacitors for the supply voltages.

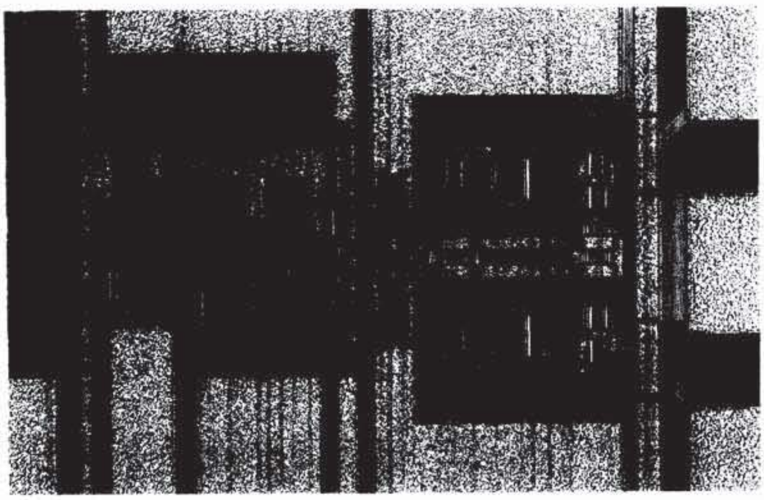

Fig. 3. Photograph of a fabricated photoreceiver. The depicted chip area measures 525x350 µm^2. The MSM photodiode has an active area of 25x25 µm^2. Anti-reflection coating was not used.

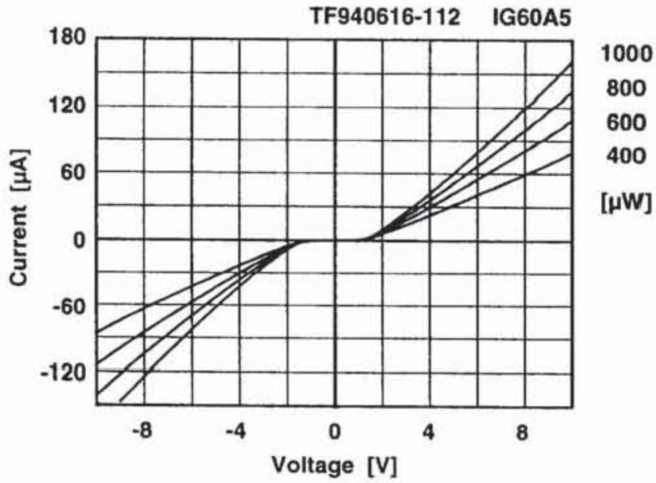

Fig. 4. Measured current-voltage characteristics of an MSM photodiode for different intensities of the 1.3 μm laser diode irradiation. The MSM photodiode has 0.75 μm wide fingers with 1.0 μm wide spacing.

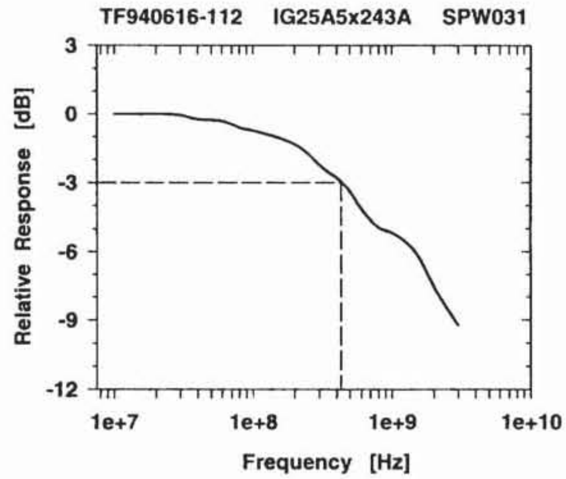

Fig. 5. Measured frequency response of the photoreceiver. The -3 dB bandwidth lies at 430 MHz. The photoreceiver bandwidth is limited by the integrated photodiode.

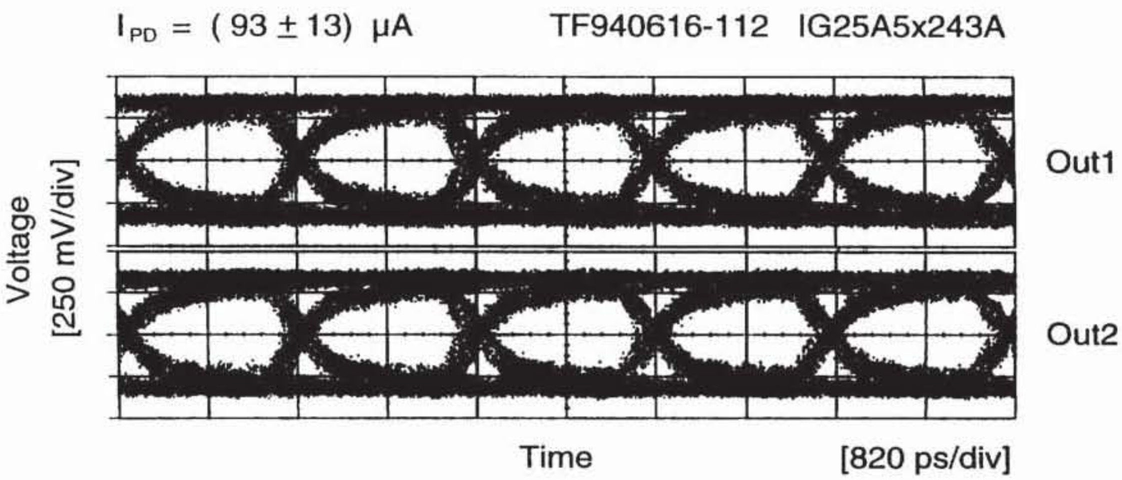

Fig. 6. Eye diagrams of the photoreceiver output voltages for 622 Mbit/s pseudorandom optical pulse input.