Development of an opto-electronic channel for scintillation fiber detectors

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Abstract

The characteristics of an opto-electronic channel (for analog signal transmission) and its separate units: transmitting unit, based on a semiconductor laser, and a photoreceiving unit, containing a high-speed photodiode and two microwave gain stages are presented. The total rise time of the channel does not exceed 120 ps.

The characteristics of an 8-channel circuit, processing the signals of radiation detectors, based on solid-state electron multipliers, are also adduced.

I. INTRODUCTION

In order to transmit analog signals from various detectors to registering equipment in the course of carrying out experimental physics measurements, optical fiber links are used more and more often. That is connected with the successful development of optical fiber technology and advantages of optical fiber links in providing a wide frequency band for analog signal transmission over distances from hundreds of meters to several kilometers and a noise immunity of transmission in an environment of strong electromagnetic fields. The application of optical fiber transmission links provides a subnanosecond time resolution of channels.

In the publication [1] an optical fiber link for transmitting analog signals at a bandwidth of 1GHz was described. A further development of optical fiber links is reflected in the given report. The designed optical fiber link with a bandwidth of 3GHz, containing a wide-band transmitting module, a segment of a single-mode optical fiber, 100m long, and a high-speed photoreceiving unit, is presented.

II. TRANSMITTING MODULE

The transmitting unit is built with a high-speed semiconductor (GaAlAs/GaAs) laser POM-22 with a wave-length of 1.3mcm and has a frequency modulation band not less than 6GHz in the small signal mode. It is well known, that the transient of a semiconductor laser has a relaxation character with a sharply expressed first spike of transient. The shape of the transient depends on how much does the bias current exceed the threshold one and on the amplitude of the modulation current pulse. In order to ensure the linearity of converting electric pulses into light ones with minimal spikes on the transient, those parameters should be selected experimentally for a specific type of laser. For the laser used, having a threshold current of Ip=20mA and a maximal output power of Pmax=5mW, the optimal bias parameters are a working point with P=0.15 Pmax and a pulse pumping current within 20mA. Thereby the duration of transient is ensured to be within 70ps at a spike within 15%. Fig.1 shows the design of the transmitting module together with the PCB of laser mode control. The control PCB contains a supply voltage stabilizer and a feedback circuit with a photocurrent amplifier, intended to set the working point of the semiconductor laser.

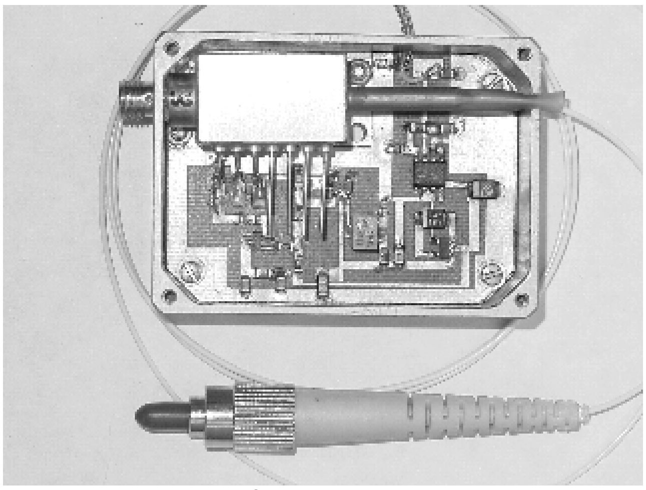

Fig.1. Design of the transmitting module.

The semiconductor laser is mounted in a hermetic housing with an input microwave connector of the SMA type and an output optical cable with an FC connector

III. RECEIVING MODULE AND OPTICAL TRANSMISSION LINE

The structure of the receiving module (fig.2) contains a fast InGaAs pin photodiode of the PROM-0112 type, having the diameter of sensitive pad equal to 40mcm, and two microwave gain stages. In the capacity of the photocurrent amplifier and power amplifier there were used the Gali series chip-amplifiers of “Mini-Circuits” with a bandwidth up to 8GHz. The total gain of the two stages makes up 36dB. The use of Gali chip amplifiers allows to create preamp circuits with various gains and bandwidths of several gigahertz. The

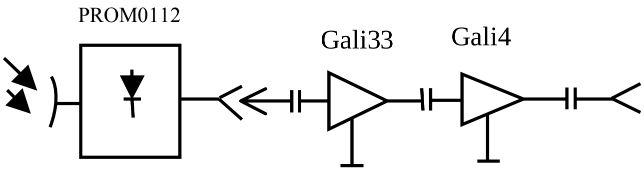

Figure 2. Structure of the receiving module

photoreceiver circuit is implemented as a microstrip PCB, using caseless elements and placed in a shielded housing, shown in fig.3. The optical output of the transmitting module

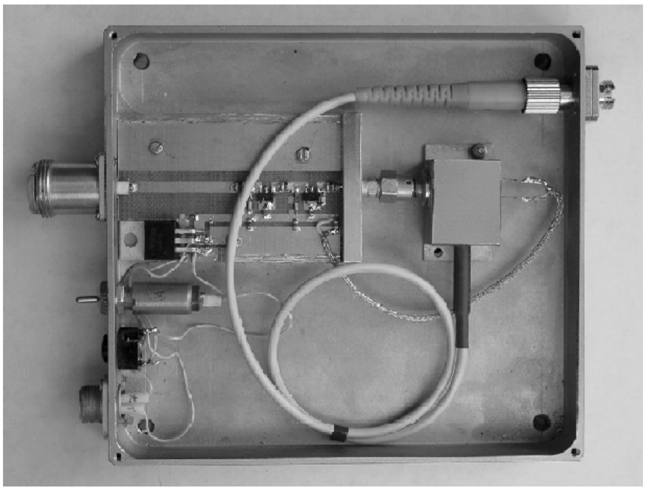

Figure 3. Design of the receiving module

and optical input of the photoreceiver module are terminated by segments of “Pigtail” single-mode optical fiber, having FC/APC optical connectors. The reflection factor of that type of connector is as low, as – (55…70)dB, what allows to reduce the level of modulation noises of the semiconductor laser and the whole system of measurement.

In the capacity of a transmission line there was used a standard single-mode optical cable with a 9/125mcm cross-section, terminated by FC/APC connectors. The optical fiber channel provides a transfer factor of approximately unity at a maximal output amplitude up to 1.5V and non-linear distortions within 10%. Fig.4 shows the transfer characteristic of the designed optical fiber channel. The total rise time of the channel does not exceed 120 ps.

IV. Development of the electronic part of scintillation fiber detector

In [2] one of the versions of the scintillation fiber detector, using solid-state electron multipliers (SSEM) for converting light bursts into electric signals, was described in detail. In [3] the authors of SSEM call it also SiPM.

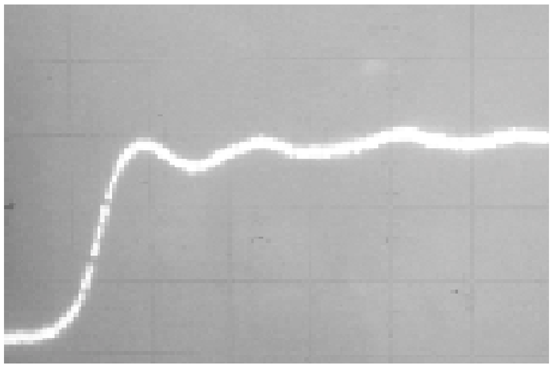

Figure 4. Transient of the optical fiber channel: 0.5V/div; 500ps/div.

The structure of the electronic part was extended by adding a new eight-channel unit, normalizing the output pulse duration and converting the ECL levels to the NIM ones, what is necessary for a further digital processing. Thereat the monoflop section, built with the Russian ECL ICs 100TM131 and 100LM101, normalizes duration, adjusted continuously from 5 to 20 ns. After passing a buffer amplifier, that pulse appears at the link`s output connector in the form of a negative pulse of the NIM standard.

The further improvement of the structure of the channel`s electronic part is linked with the development of an analog-digital Bi-CMOS ASIC. The structure of that ASIC contains a low-noise preamplifier, followed by both the timing and amplitude parts of channel, arranged in parallel. The output of the amplitude part uses analog multiplexing. In the timing one the logic signals after a high-speed comparator are expected to be used as timing marks (for instance, to determine the particle`s time of flight).

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V. References

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