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MEASURER OF OPTICAL FIBER DISPERSION BASED ON TWO-WAVELENGTH LASER

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Summary: The recirculation method based on optoelectronic simultaneously recirculation on two different optical wavelengths was designed for dispersion measuring of an optical fibre. This allows to receive the information about dispersion of the given optical fiber, and also to measure the length of a tested fiber. The laser diode on the basis of unsymmetrical quantum well heterostructure, providing generation of sounding radiation on two various wavelengths, is used as source of radiation in this system.

1. Introduction

Optical fibre communication systems provide an opportunity of delivery to the considerable distances of the extremely high volume information with the great velocity Dispersion is one of main parameters determining information transmission capacity of fibre optical communication systems. The optical fiber represents a disperse medium. Information optical pulses are exposed to contortions when they are propagating on optical fiber. Presence of any kind of dispersion worsens amplitude - phase relations of light waves, reducing thus volume of the transmitted information [1]. Intermodal dispersion is present only at multimode fibers and is a major factor restricting their broadbandness. Origination of a chromatic dispersion is principal caused by non-monochromatic source of radiation, numerically characterized by linewidth of radiation. Expansion of a light impulse under propagation at optical fibre, caused by difference of group velocities of two component of principal mode is the reason of origination of polarization dispersion [1]. Because of restricted application of multimode fibers in the modern extended high-speed telecommunications, measuring of intermodal dispersion does not represent an essential interest, therefore the great importance represents the measuring of resulting chromatic dispersion.

2. System design

The recirculation method based on optoelectronic simultaneously recirculation on two different optical wavelengths was designed for chromatic dispersion measuring of an optical fibre. The difference of refraction indexes on these wavelengths in a optical fiber and, hence, the difference of optical delays radiation is determined from values of recirculation frequencies on two wavelengths [2]. This allows to receive the information about dispersion of the given optical fiber, and also to measure the length of a tested fiber.

The block-diagram of a two-frequency recirculation measurer is shown in Fig. 1. As the rangefinder transmitter, a semiconductor laser diode with an asymmetric quantum-well heterostructure is proposed to use. The structure of such a laser is described in Ref. [3] The active region of the laser diode contains two quantum wells of different width. The quantum wells, barrier, and cladding layers form a single optical waveguide for the lasing radiation at two different wavelengths. The lasing wavelength is switching by changing of the injection current. The duration of electrical pulses and, accordingly, of emitted light pulses at the different wavelengths can be made as low as 1 ns. The difference of the lasing wavelengths $\Delta\lambda = \lambda_1 - \lambda_2$ for the asymmetric quantum-well laser diodes achieve a value of 20 to 70 nm.

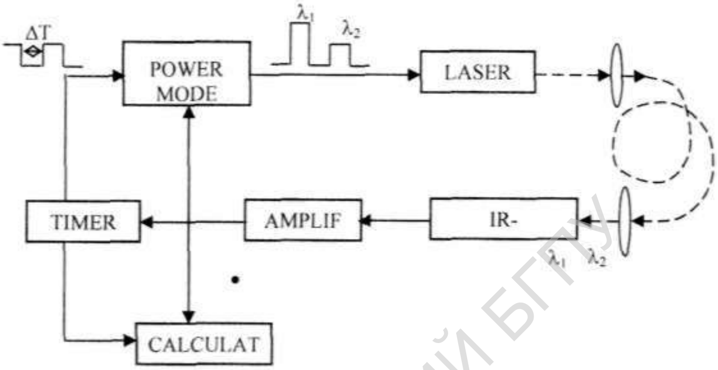

Fig. 1 Principle diagram of a two-frequency recirculation measurer of optical fibre dispersion.

The block TIMER forms two pulses followed in time after an interval ΔT_0. The block POWER MODE provides appropriate amplitudes of current pulses for lasing emission at the wavelengths λ_1 and λ_2. For recirculation sensing systems, a measured optical fibre plays a role of an optical delay line in the feedback loop. At the short-circuited optical feedback in the system, a process of recirculation is fixed. The frequency of the recirculation will be defined by the optical delay of radiation at optical fibre and by the constant electrical delay in functional blocks of the system. Using the described above mode of operation of the laser diode source, optical pulses at different wavelengths λ_1 and λ_2 are serially sent on a distance. Since the velocity of propagation of optical radiation in optical fibre depends on the wavelength λ and $\lambda_2 < \lambda_1$, the radiation delay in optical fibre at λ_2 will be greater than at λ_1. If the wavelength difference equals $\Delta\lambda = 20$ nm, the value of Δt is the order of 10^{-10} s at the length of a tested fiber $L \sim 100$ m. Obviously, measurements of such short time intervals a high degree of accuracy cause great complexities. However, in a recirculation mode there is accumulation of the temporal delay difference and for the number of recirculation periods N equal 10^3 to 10^4 the difference of the delays becomes $T = N\Delta t$ and makes up magnitudes of hundred nanoseconds. In the developed system, for measurement of Δt the number N of recirculation periods is defined where the difference of the delays equals $T = \Delta T_o$, i.e., $\Delta t = \Delta T_o/N$ After the number of recirculation periods becomes equal $N \geq \Delta T_o/\Delta t$, the recirculation process are stopped. The optical fibre dispersion D in ps/km*nm and the length of a tested fiber is calculated according the formula

$$D = \frac{\Delta t}{L\Delta\lambda} = \frac{\Delta T_0 n_1}{N(\tau_1 - t_e)c\Delta\lambda}, \qquad\qquad L = \frac{(\tau_1 - t_e)c}{n_1}, \qquad (1)$$

where, n_1 is the refraction index of tested fiber at the wavelength λ_1, t_e is the electrical delay time, τ_1 is the recirculation periods for the λ_1 radiation, N - number of recirculation periods for which the difference of optical delays becomes equal ΔT_0

3. Simulation results

Mathematical simulations of measurer are presented on fig.2-4.

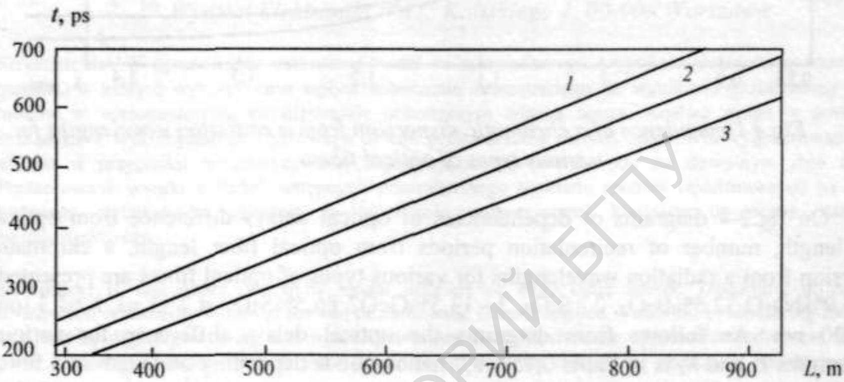

Fig. 2. Dependence of optical delays differenceΔt from optical fiber length L.

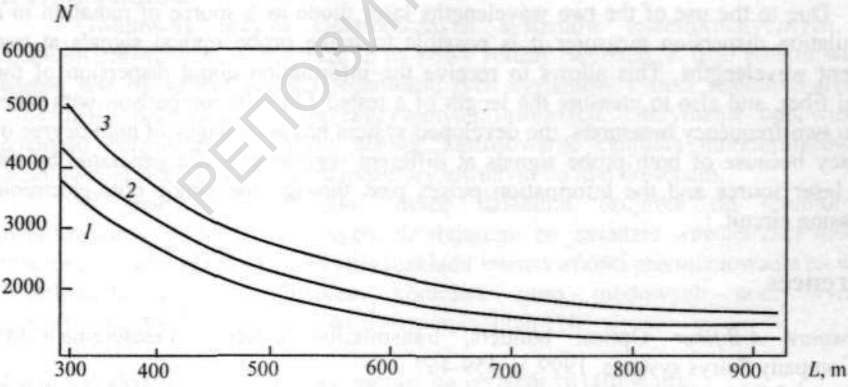

Fig. 3. Dependence of number of recirculation periods N from optical fiber length L.

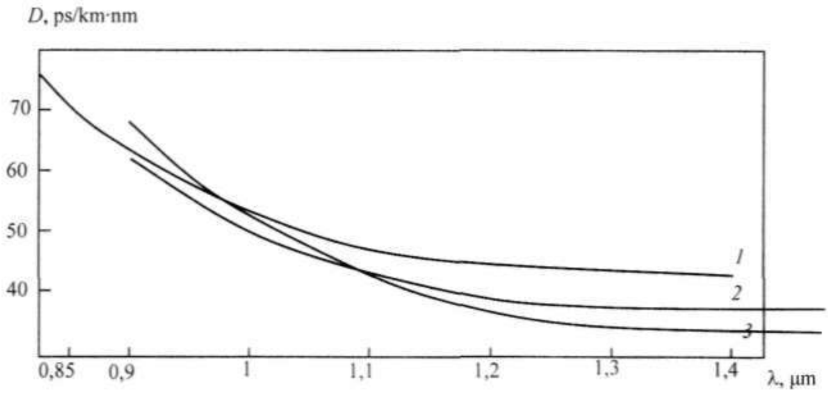

Fig.4 Dependence of a chromatic dispersion from a radiation wavelengths for various types of optical fibers.

On fig.2-4 diagrams of dependencies of optical delays difference from optical fiber length, number of recirculation periods from optical fiber length, a chromatic dispersion from a radiation wavelengths for various types of optical fibers are presented: 1 - 16,9%Na_2O 32,5%B_2O_3, 2 - SiO_2, 3 - 13,5%GeO2 86,5%SiO_2 at T=1 μs, λ =1,3 μm, Δλ =20 nm. As follows from diagrams the optical delays difference for various wavelengths λ_1 and λ_2 is in limits 0,15…0,7 nanoseconds depending on length of a fibre. Thus for measuring such short time intervals it is necessary about 10^3…10^4 recirculation periods.

Due to the use of the two wavelengths laser diode as a source of radiation in a recirculation dispersion measurer it is possible to make probe optical signals at two different wavelengths. This allows to receive the information about dispersion of the optical fiber, and also to measure the length of a tested fiber. In comparison with other known two-frequency measurers, the developed system has advantages of high degree of accuracy because of both probe signals at different wavelengths are generated by the same laser source and the information pulses pass through the single opto-electronic processing circuit.

References

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[3] *Ikeda S., Shimizu A.* Evidence of the wavelength switching caused by a blocked carrier transport in an asymmetric dual quantum well laser // Appl. Phys. Lett. 1991. Vol.59, No.5. P.504-506.