Modeling optoelectronic converting structures using the ZEMAX software package

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Abstract. The paper is devoted to the study of the possibility of constructing a digital conversion on new optoelectronic principles that will expand the frequency range of the conversion, as well as increase the bit conversion, thereby improving accuracy. The basic configuration options of radiating elements in digital-to-analog conversion systems are considered. Simulation was carried out using the ZEMAX software package. The dependence of the conversion of an input digital signal into an analog signal at a photodetector is investigated.

1. Introduction
An optoelectronic digital-to-analog converter consists of emitters whose luminous flux powers form a geometric progression with a denominator 2 [1, 2]. In this work, an eight-bit optoelectronic converter is modeled, therefore there are eight emitters. Each of the light sources is fed with a logical signal corresponding to a certain bit of the input register. The most powerful is fed the value of the most significant bit, the weakest - the least significant bit. The light from the switched on emitters is reflected from the mirror and is directed to the photodetector, which converts the total luminous flux into an analog electrical signal proportional to it [3, 4].

2. Modeling of optoelectronic converting structures (variant 1)
Several optical circuits were simulated. One of the versions is shown schematically in Figure 1. The radius of curvature of the mirror is equal to twice the distance from the light emitters to the mirror.

Fig. 1. The design of the optoelectronic converter (variant 1).
In order to optimize the thermal regime, the emitters are arranged in terms of power as shown in Figure 2. Here the value "x" is the power of the "weakest" emitter.

![Fig. 2. Mutual arrangement of emitters.](image)

The optical system has the form shown in Figure 3 and Figure 4.

![Fig. 3. Projection of an inconsistent system in Zemax.](image)

![Fig. 4. Three-dimensional model of an optoelectronic converter in Zemax.](image)

By means of Zemax the readings of the photodetector were taken with various combinations of the emitters switched on (the “off” of the emitter was modeled by setting the number of its analyzed beams to zero).

The graph of the dependence of the detector reading on the decimal value at the input of the converter is shown in Figure 5.

![Fig. 5. Dependence of the total radiation power recorded by the detector on the input digital signal.](image)
Figure 5 shows that the detector readings linearly depend on the digital value at the input of the converter with an approximation confidence $R^2 = 0.9993$. This suggests that the simulated system successfully copes with the function of the digital-to-analog converter. The output signal is linear to the input signal.

3. **Modeling of optoelectronic converting structures (variant 2)**

The next was considered the optical scheme of the optoelectronic converter in the performance, schematically (not to scale) shown in Figure 6.

![Fig. 6. The design of the optoelectronic converter (variant 1).](image)

In order to optimize the thermal regime, the emitters are located in terms of power as shown in Figure 7.

![Fig. 7. Mutual arrangement of emitters.](image)

The optical layout is shown in Figure 8 and Figure 9.

![Fig. 8. Projection of an inconsistent system in Zemax.](image)
By means of Zemax, readings of the photodetector were taken with various combinations of the included emitters. The graph of the dependence of the detector reading on the decimal value is shown in Figure 10.

Figure 10 shows that the detector readings are strictly linearly dependent on the digital value at the input of the optoelectronic converter with an approximation reliability $R^2 > 0.9999$. This suggests that the simulated system successfully copes with the function of the digital-to-analog converter. The output signal is linear to the digital input value.

4. **Modeling of optoelectronic converting structures (variant 3)**

The next one to model the optoelectronic converter was the version that is schematically shown in isometric view in Figure 11.

The optical system has the form shown in Figure 12 and Figure 13.
Then the readings of the photodetector were taken by means of Zemax. The graph of the dependence of the detector reading on the decimal value is shown in Figure 14.

Figure 16 shows that the detector readings are linearly dependent on the digital value at the input of the optoelectronic converter with an approximation confidence $R^2 = 0.9999$. This suggests that the simulated system successfully copes with the function of the digital-to-analog converter.

5. Conclusions
Three of the possible designs for an eight-bit optoelectronic converter were modeled with Zemax. As a result of modeling the optical system of an optoelectronic digital-to-analog converter, it was obtained that the readings of the detector linearly depend on the digital value at the input of the optoelectronic converter with an approximation reliability of $R^2 = 0.99$, which indicates that the simulated systems
successfully cope with the function of the digital-to-analog converter. The modeled optoelectronic converters have small dimensions, they can be made of a hybrid or integrated microcircuit, and the dimensions are not the limit for this design and, if necessary, can be reduced if you choose emitters with a smaller opening angle of signal conversion without reducing the bit width, it is possible to use optoelectronic DAC and ADC.

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