The problem is considered of creating a uniform structure for the various categories of a standard for the unit of average laser radiation power. The approach is based on directly synthesizing the structure of a standard instrument. As an example, a computer modeling is carried out of a combination which is typical for many types of measurement, namely a measurement transducer and a voltmeter, and this was applied to the case of measuring average laser radiation power.

Key words: measurement transducer, voltmeter, standard deviation, average power, laser radiation, distribution function.

A modern standard instrument (especially one for measuring quantities which characterize different radiations) as well as being a single-valued or multiple-valued measure preserving the unit, contains a combination of mutually coupled measurement transducers, technical and computational devices, and elements enabling the required metrological characteristics to be obtained and enabling the processing of the measurement information to be automated. The most typical component parts of standard instruments in these fields of measurement are:

• a radiation source intended for metrological use;
• standard measurement transducers for converting the input physical quantities to output electrical quantities and analog and digital measurement information signals which are proportional to them;
• devices for processing, recording, and documenting the latter and also, as necessary, for displaying them in the form of experimental results which are accessible to an operator.

It is evident that the most important metrological characteristics of any standard instrument, namely the errors (uncertainties) of reproducing a unit and of transferring its size, are influenced not only by the conditions of performing the measurements and by external factors, but also above all by the choice of the structural scheme of the instrument and of the algorithm and program for processing the information and controlling the entire system.

There hence follows the first conclusion concerning the necessity for a directed synthesis of the structure of the instrument, the provision of algorithms, and the software, and this requires the characteristics and parameters of both the component parts and the instrument as a whole to be considered, taken into account, and optimized. The optimality criterion can be chosen to be the normalized minimum values of the above-mentioned errors (uncertainties).

It is well known by metrologists that when reproducing a unit and transferring its size it is first of all necessary to strive to minimize the systematic error. Experience over a decade has shown that one effective way of eliminating systematic errors when transferring the size of a unit is to unify the structural schemes of the secondary and working standards controlling the checking scheme.
Hence follows the second conclusion concerning the expediency of developing, as part of the considered checking scheme, a single type of structure of the standard instruments of different categories. This makes it possible not only to eliminate systematic error in transferring the size of the unit and to minimize its uneliminated residual part, but also to solve the problem of a directed synthesis of the structure of the instrument and the algorithms and software for processing the information and also for controlling all the processes occurring.

Thus, the quite universal metrological problem is posed, for a given checking scheme, of developing and implementing a structural scheme of a standard instrument of any category not only and not so much on the basis of previous metrological experience as on the basis of synthesizing it for a specified error (uncertainty) of reproducing the unit and transferring its size, utilizing information concerning the metrological characteristics forming part of the measurement transducers and the technical devices.

Each of the measurement transducers possesses its own inherent metrological characteristics including its accuracy characteristics. This means that the errors of the transducer are not only the confidence intervals and probabilities but also the distribution laws and the correlation dependences. When synthesizing the structural scheme of a standard instrument, the very complex problem arises of composing its principal components ensuring optimization of the parameters of the measurement process.

Of course, the solution of such a problem in a general form first requires a detailed examination of the approaches to solving the simplest problems with a minimum number of components. One can then increase the list of parameters and the number of components of a typical structure, adding the optimization of the algorithms and software.

By way of an example, a computer modeling is performed below of a combination of a measurement transducer and a digital voltmeter which is typical for many forms of measurement, and this is applied to measuring the average power of laser radiation.

Up to the present time, accumulated experimental experience has been utilized when creating standards of the units of average laser radiation power. The present work represents an attempt to construct a standard with previously specified metrological characteristics on the basis of a mathematical modeling of the measurement process. This approach is all the more timely since in recent years, according to the recommendations of the International Committee on Weights and Measures, when measuring various quantities a characteristic such as the measurement accuracy is replaced by another quantity, namely the uncertainty of measurements which is characterized by a variance $\sigma^2$. It is also recommended that use be made of another quantity $u$, defined as the standard deviation [1], as the characteristic of the results of measurements.

The standard of the unit of average power of laser radiation in several of the countries which are leading in this measurement field takes the form of a high-precision measurement transducer. This forms part of a measuring system [2] constituting a standard instrument for reproducing the unit and transferring its size. In Russia, this is a measuring instrument which includes an apparatus for transferring the size of the unit and includes a laser radiation source, distributing and focusing optics, and an apparatus for making average power measurements. The latter consists of a measurement transducer for converting the average laser radiation power into an analog electrical signal and a secondary device (a voltmeter, multimeter, etc.) designed to measure the output signals when reproducing the unit of average power and transferring its size [3]. Thus, both in the leading foreign countries and in Russia the principal metrological characteristics of the standard are determined by a combination of a measurement transducer and a digital voltmeter which takes the form of a very simple optical radiometer.

It is for this reason that in Russia the measurement process is modeled using this instrument as a component of the standards of various categories of the checking scheme for instruments measuring the average power of laser radiation. The standard deviation is calculated below for such a radiometer on the basis of the proposed model for very varied situations. The result obtained can be subsequently used in order to select the measurement transducer and the digital voltmeter when solving a specific metrological problem.

Let us assume that laser radiation of power $P_0$, constant in time, is incident on a measurement transducer. Each of the elements of the radiometer converts the input quantity with a certain spread of values, known from experiment, which is characterized by a root-mean-square deviation. From the given value of the root-mean-square deviation (which is different for different transducers), we construct probability density distribution functions of three types: uniform (rectangular), triangular, and normal. We normalize to unity the average value for the digital voltmeter. We perform similar normalization of