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Monitoring the work of the test laboratory by participating in the proficiency testing program in the field of the laser performance measurements

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Abstract

Monitoring the validity result is the critical requirement of the international standard ISO/IEC 17025:2017 for test and calibration laboratories to provide objective evidence of their technical competence. Applying the interlaboratory comparison, using alternative instrumentation that has been calibrated, functional checks of measuring and testing equipment, and other methods for monitoring the validity of results is not enough to have confidence in the quality of test results. Modern standards in the field of quality for test and calibration laboratories require applying other forms for assessing the characteristics of the used test method. Particularly, it concerns the participation in interlaboratory comparisons.

One of the tools that could be used for monitoring the validity result is comparing laboratory test results with the results that are obtained by other laboratories, e.g. proficiency testing. This paper presents the result of a proficiency testing program for laser performance measurements that was organized by the International provider IFM Quality Services PTY Ltd. in 2021. The purpose of the paper is to demonstrate the results of the participation of the SE "Ukrmetrteststandard" in proficiency testing of measuring laser performance, to reveal the correlation of the results comparing with the previous years and different tasks and to assess the possible causes of outliers. Twenty-two laboratories that had been accredited by the ISO/IEC 17025 standard participated in the proficiency testing. The results were evaluated using the Z-score as the performance criterion.

Potential risks of proficiency testing with a small number of participants and possible causes of results outliers were assessed.

Keywords: laser safety; laser energy; proficiency testing; ISO/IEC 17025; IEC 60825-1.

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1. Introduction

Laser emission has many advantages that are necessary not only for scientific research, but also for everyday life: the emission propagates in a rather narrow direction creating in such a way a point image on the object to which it is directed at.

This narrow beam allows collecting high intensity in a small amount thus transmitting a large amount of energy with a single beam. In addition, due to the progress in the development of semiconductors, scientists have been able to create a semiconductor laser that is less expensive and can be very small comparing with the models designed using other technologies. Lasers are popular in many areas: cosmetology (hair removal), surgery (vision correction), measurement (laser rangefinders), construction (laser level), multimedia (laser disk reader), production (laser CNC), and art (laser shows). This list can be further continued but it is obvious that laser emitters can be found everywhere nowadays.

During laser application to the human body, the above-mentioned benefits are a source of potential hazard due to improper use and possible non-conformities at the development and manufacturer stages because laser application can lead to irreversible reactions in human bodies, such as burns, blindness, and serious injuries. Safety requirements for lasers were published by the International Electrotechnical Commission (IEC) and can be found some international standards and technical recommendations such as IEC 60601-2-22:2019 [1], IEC 60825-1:2014 [2], and IEC 60825-8:2006 [3]. These normative documents are the global approach for ensuring laser safety and providing informative guidance for manufacturers, professional clinicians, and administrators of laser facilities. Laser emission can pose photochemical, retinal, and thermal hazards to humans [2, 4]. As reported by Smalley (2011) [5], laser users should have operating knowledge of the technical material, including exposure limits, nominal ocular hazard area, optical density levels, maximum permissible exposure, classifications, etc. Taking into account the quality metrics of test laboratories that verify the compliance of laser devices with international standards becomes a critical stage for human safety insurance.

Proficiency testing (PT) is an important component to assess the work of laboratories using pre-established criteria by means of interlaboratory comparisons in accordance with ISO/IEC 17025 [6]. Nowadays several programs are conducted in different countries to demonstrate the conformity of the laboratory infrastructure, for example, the IFM Quality Services PTY Ltd. (IFMQS) programs for Test and Calibration Laboratories.

A satisfactory result in proficiency testing demonstrates that a laboratory is able to bear reliable results, which evidences its competency, owing to its methods, equipment, traceability, infrastructure, and personnel [7]. Moreover, unsatisfactory results permit laboratories to identify non-conformities and implement appropriate corrective actions to improve their quality. Even though proficiency testing is an important component to demonstrate competence, especially in legal metrology, it is not available for a range of measuring instruments, once they also include visual and safety aspects regarding consumer protection and fair competition, besides metrological aspects.

Ukrainian Scientific and Technical Institute for Certification and Tests of Electrical Equipment UkrTEST of the SE “Ukrmetrteststandard” took part in a single-phase PT on lasers by the IFMQS in 2021.

Materials and methods

The PT for laser power measurements is based on IEC 60825-1 Ed. 3.0 (2014-05) [2] and IEC 60825-1 Ed. 2.0 (2007) [4]. To ensure compliance with the requirements of ISO/IEC 17043 [8] the provider set up the requirements regarding environmental conditions for measuring the laser power; the temperature has to be maintained in the range of 20 °C – 25 °C with relative humidity < 80% RH. The specified electrical input for a test sample is a direct current of 3.2 V. The sample is submitted personally by the IFMQS to each laboratory participating in the PT. Homogenous tests samples are submitted to the participants by the PT provider. The test sample represents a laser module with an extended laser beam source.

The PT provider assigned the participants to the following:

• Task 1: Measurement/confirmation of the peak emitted wavelength.

1.1. Measured Peak Wavelength (nanometer);

1.2. Measured Laser Module Body Temperature (Celsius degrees);

1.3. Reporting the observed current with the specified electrical input (mA).

• Task 2: Measurement of a maximum optical power according to IEC 60825-1 Ed. 2.0 Table 11 Condition 1 and IEC 60825-1 Ed. 3.0 Table 10 Condition 1: aperture stop with the diameter of 50 mm at the distance of 2000 mm.

2.1. Measured Power (W);

2.2. Measured Laser Module Body Temperature (Celsius degrees).

• Task 3: Measurement of a maximum optical power according to IEC 60825-1 Ed. 2.0 Table 11 Condition 2: aperture stop with the diameter of 7 mm at the distance of 70 mm.

3.1. Measured Power (W);

3.2. Measured Laser Module Body Temperature (Celsius degrees).

• Task 4: Measurement of a maximum optical power according to IEC 60825-1 Ed. 2.0 Table 11 Condition 3 and IEC 60825-1 Ed. 3.0 Table 10 Condition 3: aperture stop with the diameter of 7 mm at the distance of 100 mm.

4.1. Measured Power (W);

4.2. Measured Laser Module Body Temperature (Celsius degrees).

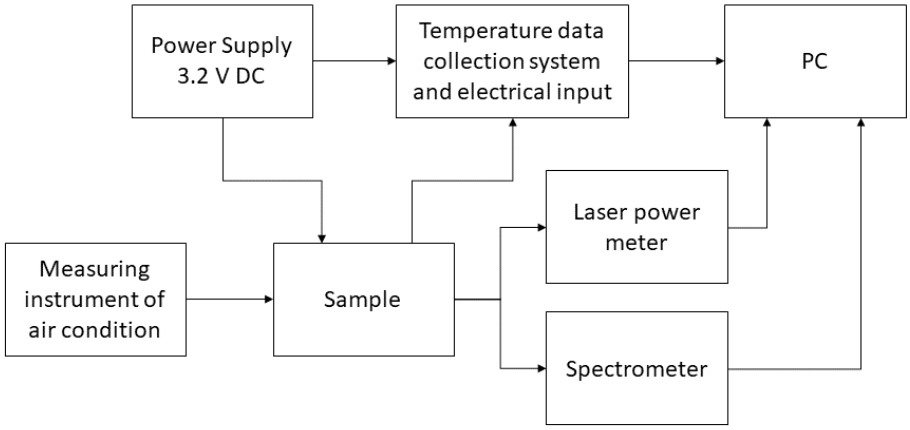


Fig. 1. The test set-up of the IFM test. Adapted from IEC 60825-1

- Task 5: Recording ambient temperature and relative humidity.

5.1. Ambient Temperature (Celsius degrees);

5.2. Ambient Relative Humidity (%).

To provide the required measurements the following test set-up was prepared, which is shown in Fig. 1.

The provider provided a semiconductor laser module as a sample. The Hygrometer Testo 608-H1 was used to control the ambient conditions under which the measurements are carried out. To provide the required electrical input according to the task, the KEYSIGHT 3631A power supply was used, which supplied 3.2 V of a direct current to the sample. The KEYSIGHT 34972A data acquisition system was used to control the electrical input during the test and to measure the observed current. It was also used to measure the sample body temperature using a separate module with thermocouples. For this, the temperature distribution on the laser module body was previously evaluated using the *testo* 925. The results that were provided to the IFMQS were measured at the point of maximum heating of the sample body. The OceanView HR4000CG-UV-NIR spectrometer was used to measure the peak wavelength of the laser module. To measure the maximum power of the laser emission in accordance with Tasks 2–4, the Ophir StarBright laser power and energy meter was used together with laser photodiode power sensors. In addition, aperture stops were used, the diameter of which was controlled using a caliper. The distance between the sample and the aperture stop was controlled using a measuring tape. Data from the data acquisition system, spectrometer, laser power, and energy meter were collected on a personal computer.

Results and Discussion

The circulation of the samples among the laboratories started in January and ended in April 2021. In general, the participants performed all tasks correctly.

There was a correlation between the results of laser power measurements reported for Tasks 3 and 4. This correlation was also noted in previous PT in 2020 and 2019. Both tasks had the same aperture stop with the diameter of 7 mm while distances varied by 30 mm, which is shown in Fig. 2. Therefore, they are likely to correlate due to the similar conditions.

The laser power measurement distance for Task 2 was 2000 mm, which was much larger than 70 mm (Task 3) and 100 mm (Task 4). Task 2 also required a larger aperture stop with the diameter of 50 mm comparing to 7 mm. No statistical correlation was found between Tasks 2 and 3, and Tasks 2 and 4, which is shown in Fig. 3.

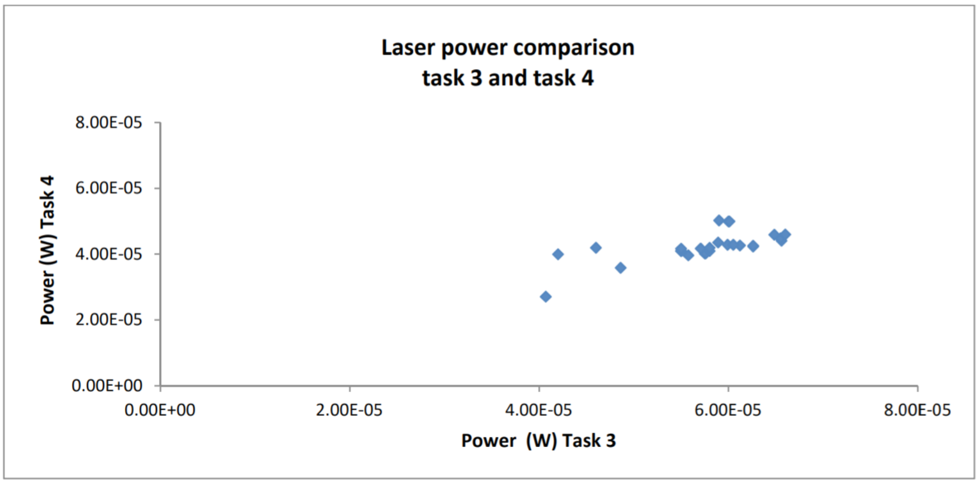


Fig. 2. Comparison of laser power for Tasks 3 and 4

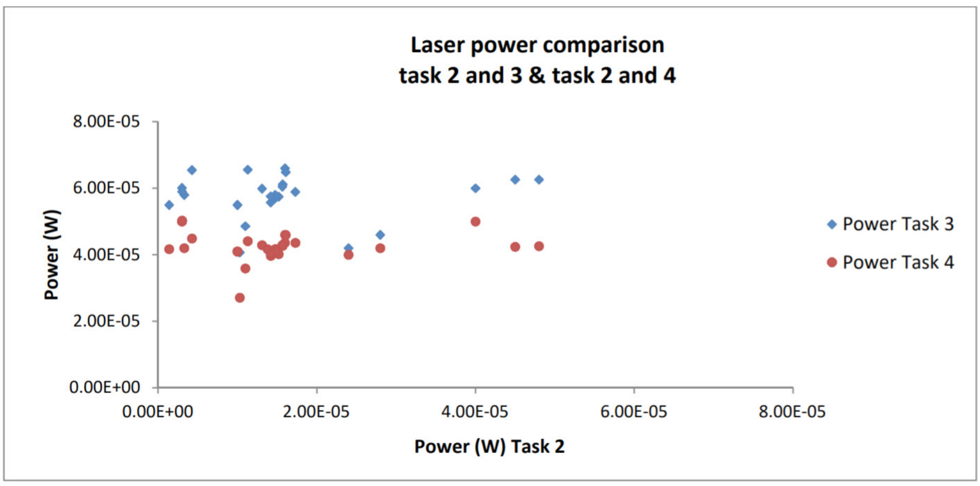


Fig. 3. Comparison of laser power for Tasks 2 and 3 and Tasks 2 and 4

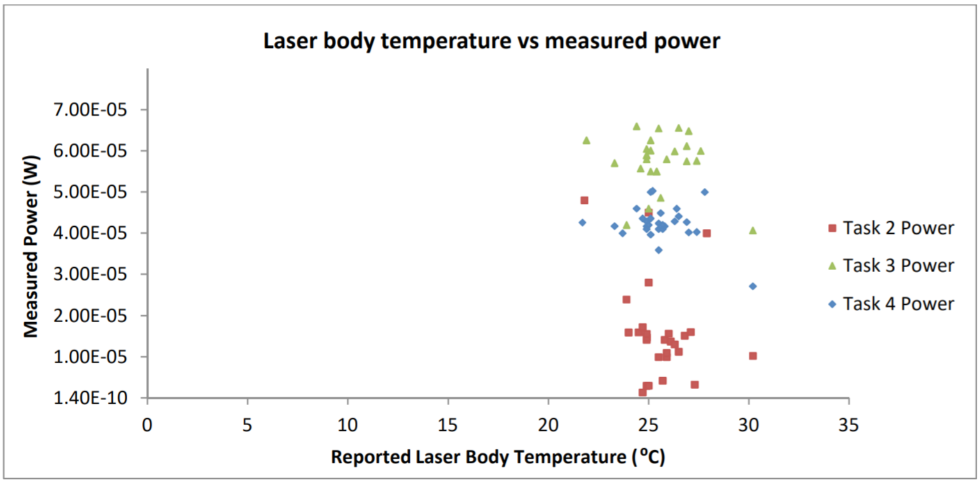


Fig. 4. Comparison of the laser body temperature and measured laser powers for Tasks 2, 3 and 4

Fig. 4 demonstrates the relation between the laser body temperature and measured laser power for Task 2, Task 3, and Task 4. The reported laser body temperature and laser powers were evaluated and no significant variations were observed.

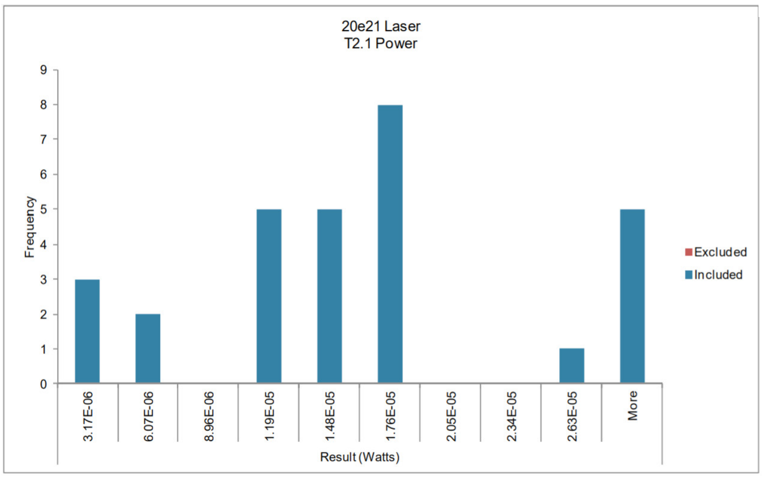
The result of the measurements according to Tasks 2, 3, 4 is shown in Fig. 5—7.

96% of the participants reported acceptable results for peak wavelength. Approximately 83% of the participants reported acceptable results for Task 2 and Task 3. 90% of the participants reported acceptable results for Task 4.

As a result, 318 individual test results were obtained. Of these results, 116 were scored. Out of the total, 14 results were assessed as outliers.

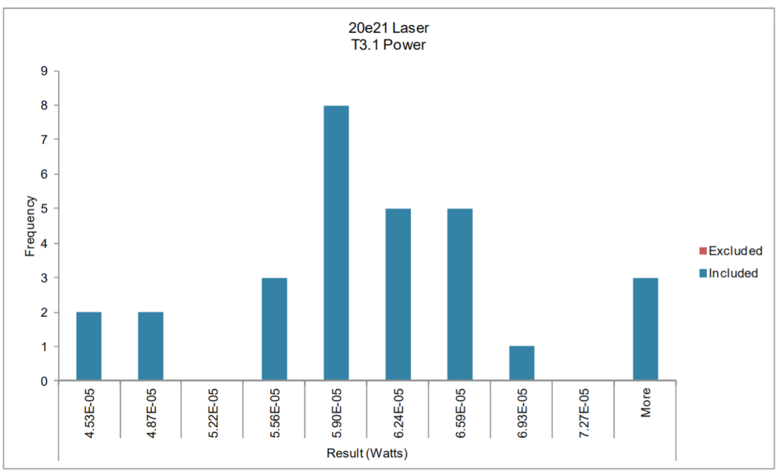
Conclusions

The method, which is used for evaluating results and discussed in this paper, can lead to a false-positive result. This is possible because the provider does not



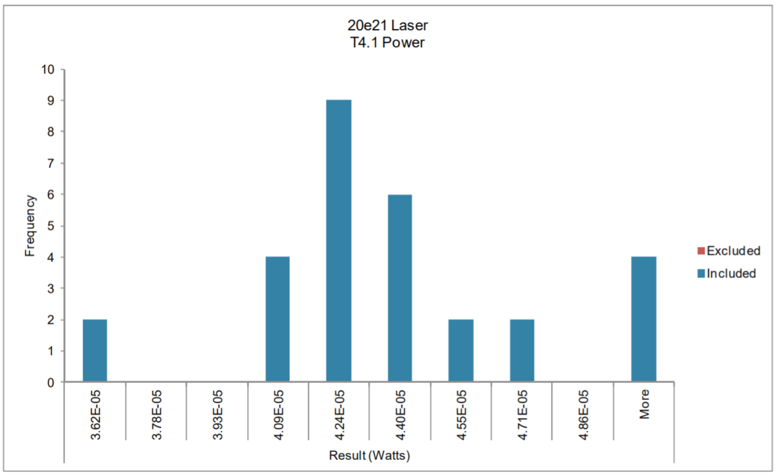
20e21 Laser T2.1 Power (Watts)	
Number of Results Received	29
Number of Results Analysed	29
Quartile 1	1.03E-05
Quartile 3	1.61E-05
IQR	5.79E-06
NIQR	4.29E-06
Median	1.48E-05
Acceptable High: Median + (3*NIQR)	2.76E-05
Acceptable Low: Median - (3*NIQR)	1.87E-06
Statistically Acceptable Range	2.58E-05

Fig. 5. Measured laser power according to Task 2



20e21 Laser T3.1 Power (Watts)	
Number of Results Received	29
Number of Results Analysed	29
Quartile 1	5.58E-05
Quartile 3	6.26E-05
IQR	6.85E-06
NIQR	5.08E-06
Median	5.90E-05
Acceptable High: Median + (3*NIQR)	7.42E-05
Acceptable Low: Median - (3*NIQR)	4.38E-05
Statistically Acceptable Range	3.05E-05

Fig. 6. Measured laser power according to Task 3



20e21 Laser T4.1 Power (Watts)	
Number of Results Received	29
Number of Results Analysed	29
Quartile 1	4.10E-05
Quartile 3	4.41E-05
IQR	3.10E-06
NIQR	2.30E-06
Median	4.24E-05
Acceptable High: Median + (3*NIQR)	4.93E-05
Acceptable Low: Median - (3*NIQR)	3.55E-05
Statistically Acceptable Range	1.38E-05

Fig. 7. Measured laser power according to Task 4

provide the results from the reference laboratory. In this regard, with a limited number of program participants, there is a nonzero probability of accepting a false result as a correct one, and the scattering will be estimated from the wrong result. This is possible when measuring the low powers of laser emission at the edge of the resolution of receivers.

It is suggested that the results of participants' outliers may be caused due to incorrect placement of measuring instruments during power measurements. The axis of the energy propagation of the laser beam must be exactly parallel to the axis of the receiver of the laser power meter. It can be achieved by different methods, which must be applied in accordance with the laboratory test procedure under ISO/IEC 17025.

Therefore, the participation of a reference laboratory can be considered the best result in assessing the competence of the laboratory.

Контроль роботи випробувальної лабораторії шляхом участі в програмі перевірки кваліфікації в галузі вимірювань характеристик лазера

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Анотація

Моніторинг результату валідності є важливою вимогою міжнародного стандарту ISO/IEC 17025:2017 щодо надання об’єктивних доказів технічної компетентності для випробувальних та калібрувальних лабораторій. Застосування внутрішньолабораторного порівняння, використання альтернативних відкаліброваних приладів, функціональних перевірок вимірювального обладнання та інших методів, які використовуються для моніторингу достовірності результатів, недостатньо для гарантії якості результатів випробувань.

Одним з інструментів, які можна використовувати для моніторингу результату валідності, є порівняння результатів лабораторного випробування із результатами, отриманими іншими лабораторіями – перевірка кваліфікації. Метою участі в перевірці кваліфікації є підтвердження компетентності випробувальної лабораторії та оцінка правильності використовуваних лабораторією методів. Надано результати програми перевірки кваліфікації для вимірювання характеристик лазера, що була організована міжнародним провайдером IFM Quality Services PTY Ltd. у 2021 році. Мета статті – продемонструвати результати участі ДП “Укрметртестстандарт” у перевірці кваліфікації в галузі вимірювань характеристик лазера, знайти співвідношення результатів у порівнянні з попередніми роками й різними завданнями та оцінити можливі причини відхилень. Двадцять дві лабораторії, акредитовані за стандартом ISO/IEC 17025, брали участь у перевірці кваліфікації. Оцінку результатів проводили з використанням Z-оцінки як критерію ефективності учасників. Проведено аналіз результатів вимірювань потужності лазера усіх лабораторій за методами міжнародних стандартів серії IEC 60825-1, які брали участь у перевірці кваліфікації у 2021 році.

Було оцінено потенційні ризики перевірки кваліфікації з невеликою кількістю учасників і можливі причини відхилень результатів.

Ключові слова: лазерна безпека; енергія лазера; перевірка кваліфікації; ISO/IEC 17025; IEC 60825-1.

Контроль работы испытательной лаборатории путем участия в программе проверки квалификации в области измерений характеристик лазера

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Аннотация

Мониторинг результата валидности является важным требованием международного стандарта ISO/IEC 17025:2017 о предоставлении объективных доказательств технической компетентности испытательных и калибровочных лабораторий.

Одним из инструментов, который можно использовать для контроля валидности, является сравнение результатов лабораторных испытаний с результатами, полученными в других лабораториях – проверка квалификации. В статье представлены результаты программы проверки квалификации по измерению характеристик лазера, организованной международным провайдером IFM Quality Services PTY Ltd. в 2021 году. Цель статьи – продемонстрировать результаты участия в проверке квалификации, провести соотношение результатов по сравнению с предыдущими годами и разными задачами, оценить возможные причины отклонений. Оценка результатов проводилась с использованием Z-оценки в качестве критерия результативности участников. Были оценены потенциальные риски проверки квалификации с небольшим количеством участников и возможные причины отклонения результатов.

Ключевые слова: лазерная безопасность; энергия лазера; проверка квалификации; ISO/IEC 17025; IEC 60825-1.

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