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# An overview study on the TL and OSL dosimetry patent processes over time

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## ABSTRACT

**Since its discovery, ionizing radiation has been used in many different applications. Materials and methods have been developed to measure and quantify radiation doses. Thermoluminescence (TL) and Optically Stimulated Luminescence (OSL) are two techniques used for radiation dosimetry. Both TL and OSL are primarily applied in several areas, such as dating of ancient materials, equipment quality control and individual monitoring. One of the parameters to measure the knowledge and development of a technology is the number of patents related to the field. In this work, we established a methodology for patent search on the World Intellectual Property Organization (WIPO) database aiming to review the development of TL and OSL dosimetry over time. We concluded that along with the OSL technique development, the TL technique should continue to be explored in radiation dosimetry.**

***Keywords:*** **dosimetry, thermoluminescence, optically stimulated luminescence, patent, intellectual property.**

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## 1. INTRODUCTION

The use of ionizing radiation in medicine followed the discovery of x-rays by Roentgen in 1895 [1]. Presently, gamma and x-rays, electrons, and heavy charged particles are largely used in medicine for several applications. Often, ionizing radiation for imaging is a major tool for disease diagnoses. In addition, ionizing radiation frequently brings substantial advantages for disease treatments compared to conventional invasive methods. Also, the application of radioactivity in several areas, such as energy, services and healthcare, is concerned about the undesirable effects of ionizing radiation although the benefits of its application [2].

Skin erythema was the first severe damage, a well-known radiation effect. The first recommendations about radiation protection were based on a limit of 0.01 skin erythema dose (SED) per month, in 1924. In the subsequent year, Sievert proposed 0.1 SED per year, it was estimated that 1 SED would correspond to 6 Sv. External dosimetry started in the 1920s with film dosimeters [3]. In June 1960, the International Labour Conference adopted the Radiation Protection Convention, 1960 (No. 115), and its accompanying Recommendation (No. 114). This applies to all activities involving the exposure of workers to ionizing radiations in the course of their work. Convention No. 114 says that appropriate monitoring of workers and places of work shall be carried out to measure the exposure of workers to ionizing radiation and radioactive substances, to ascertain that the applicable levels are respected [4].

The dosimetry of ionizing radiation is essential for radiation protection, equipment commissioning, and quality assurance. Worldwide, occupational and environmental dose assessment programs and various protocols for equipment quality control are based on passive solid-state dosimeters [5–8]. The most established passive dosimetric systems apply thermoluminescence (TL) or optically stimulated luminescence (OSL) techniques [9-11].

The TL and OSL dosimeters are composed of radiation-sensitive detector materials that emit light with an intensity proportional to the radiation dose previously absorbed by the material when subjected to an external stimulus, thermal (TL) or optical (OSL) [10,12].

First TL studies date to the late 1940s and LiF soon emerged as a TL detector. Since then, the TL technique has been successfully used for various dosimetric applications with several well-known and characterized suitable materials. OSL technique has been known for more than 70 years

[13]. It was first developed and established for retrospective dosimetry, known as OSL dating [14]. However, in the early 2000s, it has caught the attention of the radiation dosimetry research community after the study of the OSL properties of a developed material, $Al_2O_3$:C, for TL measurements [15–17]. Today, the OSL technique using $Al_2O_3$:C detectors is popular and well-established for personal, environmental and medical dosimetry [18].

The OSL technique has various advantages over the TL technique [10,19,20]. The use of light (from a LED, laser, or lamp), instead of heating, to read the detector, overcomes the problems related to the temperature dependence of the luminescence efficiency (thermal quenching) and changes in the sensitivity of the material [21]. The optical readout also allows the use of detectors made with plastic, such as the Luxel™ (aluminum oxide powder with plastic matrix). This detector is thin (~ 0.3 mm) and can be used in different sizes and shapes (small detectors of 2 mm diameter or strips for dose profile measurement in computed tomography). The optical readout is also doubtless easier to control than the detector heating. Moreover, the readout can be faster using OSL, because one can stimulate only the initial intensity of the OSL. In addition to the fast readout, the stimulation of a small portion of the OSL signal allows multiple readouts of the detectors. Another advantage associated with the OSL technique is the detector reader. The OSL reader is relatively simple compared to a TL reader and can be small and portable, allowing fast readout on-site [22].

However, the main disadvantage of the OSL dosimetry is the small number of well-characterized and suitable materials commercially available. For that reason, several researchers are studying the production of new dosimetric materials exploring the OSL technique [23–28].

In addition to new materials and portable reading systems for OSL dosimetry, studies in the literature have proposed using artificial intelligence in individual monitoring [29] and to estimate fading of OSL and TL signals [30]. New potential applications of the OSL technique reported in the literature include dose measurements in treatments, such as radiotherapy with patient motion, using passive systems [31] and real-time measurements [32].

Intellectual products are intangible goods, which can be protected by Intellectual Property. Technical creations, such as inventions, models, industrial designs, among others, can be protected by Industrial Property. Specifically, technical inventions are subject to patent, provided they meet certain requirements, such as: having an inventive act, being a solution to a technical problem, being industrially manufacturable or useful and, above all, being new in the state of the art. With a 'patent document', the inventor can exclusively exploit his invention economically. On the other hand, technological knowledge becomes public information, which can be consulted in a patent database. In practice, the dissemination of knowledge through patents can drive the development of new technological solutions. In this sense, the study of patents in a given technical area could be an indicator of the technological development (in that area) in a country or the advances in a field.

The World Intellectual Property Organization (WIPO) is a global forum for intellectual property services, policies, information and cooperation. It was funded by United Nations in 1967, with 193 member states, owing to lead the development of a balanced and effective international intellectual property system that enables innovation and creativity for the benefit of all [33]. The WIPO has a database with global intellectual property filings for patents, trademarks and designs.

In this study, we established a methodology for patent search on the WIPO database aiming to review the development of TL and OSL dosimetry over time, and we also discussed the advances in radiation protection and other applications that require dosimetry.

## 2. MATERIALS AND METHODS

A patent process search was conducted on the WIPO database. The keywords used for the search were “dosimetry”, “thermoluminescence” and “optically stimulated luminescence”, which could appear anywhere in the patent text. We did not restrict the results to a specific period, so the search returns all the results with an entrance in the database up to May 2022.

The extraction of data was made directly in the WIPO database, which returns a spreadsheet in xls format. As we collected a large number of data, we used Python language for data analyses. Python is a high-level, general-purpose programming language that allows quicker work and integrates the systems more effectively [34]. The developed code using python allows reading, quantifying, and performing the analyses of the patent process registered for each area “dosimetry”, “thermoluminescence” or “optically stimulated luminescence” and cross-reference between them.

## 3. RESULTS AND DISCUSSION

The search of patent processes in the WIPO database returns all the patent processes related to “dosimetry”, “thermoluminescence” and “optically stimulated luminescence” in the period from

1950 to May 2022 from several countries and organizations. The keywords used could be in the patent document title as well as anywhere in the text. WIPO database brings EP and WO listed in the category *organizations*, with the countries. Those abbreviations refer to EPO (European Patent Office) and a short for WIPO. The countries which appeared in the referred search and respective acronyms are: United States of America (US), Australia (AU), Canada (CA), India (IN), United Kingdom (GB), China (CN), Russia (RU), Israel (IL) and Japan (JP).

Table 1 presents the number of the patent processes returned for each keyword or combination of keywords.

**Table 1:** Number of patent processes from WIPO database for keywords searched.

| Keywords | Number of the patent processes |
|---|---|
| dosimetry | 17,268 |
| thermoluminescence | 3,030 |
| optically stimulated luminescence | 547 |
| dosimetry AND thermoluminescence | 3,028 |
| dosimetry AND optically stimulated luminescence | 547 |
| dosimetry AND thermoluminescence AND optically stimulated luminescence | 257 |

Comparing the results of the search with “thermoluminescence” and “optically stimulated luminescence” keywords, it was noteworthy the higher number of the patent processes with “thermoluminescence”. One of the reasons is because the TL technique is older than the OSL technique and it has a long history of successful application in several fields of dosimetry (occupational, environment, clinical and retrospective) and dating [21].

Figure 1 shows the top 7 countries and their respective order of magnitude number of patents for the keyword “dosimetry”.

The data from WIPO showed that the major part of patents in dosimetry is from the US (United States of America), in fact about 50%. The other fraction is from countries or offices (EP or WO) located in developed nations (Figure 1).

Figure 2 shows the number of patent processes related to “dosimetry” over time.

**Figure 1:** *Total number of the patent processes with the keyword "dosimetry" up to May/2022 for the top 7 patent offices*

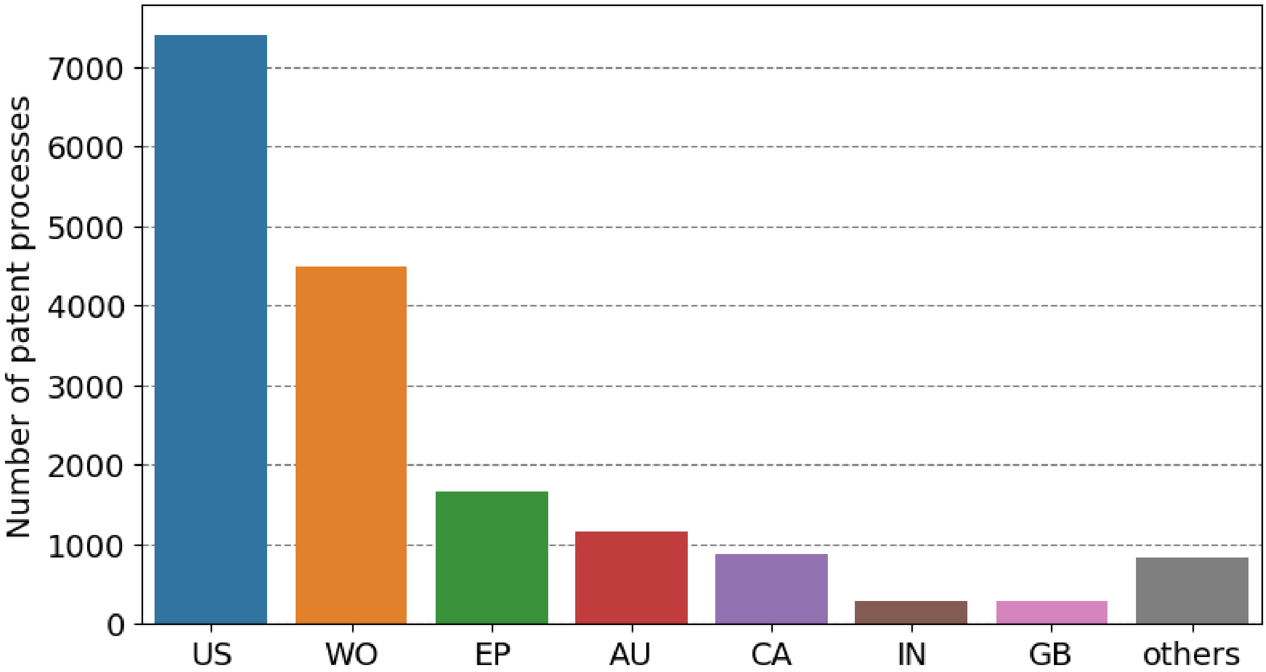
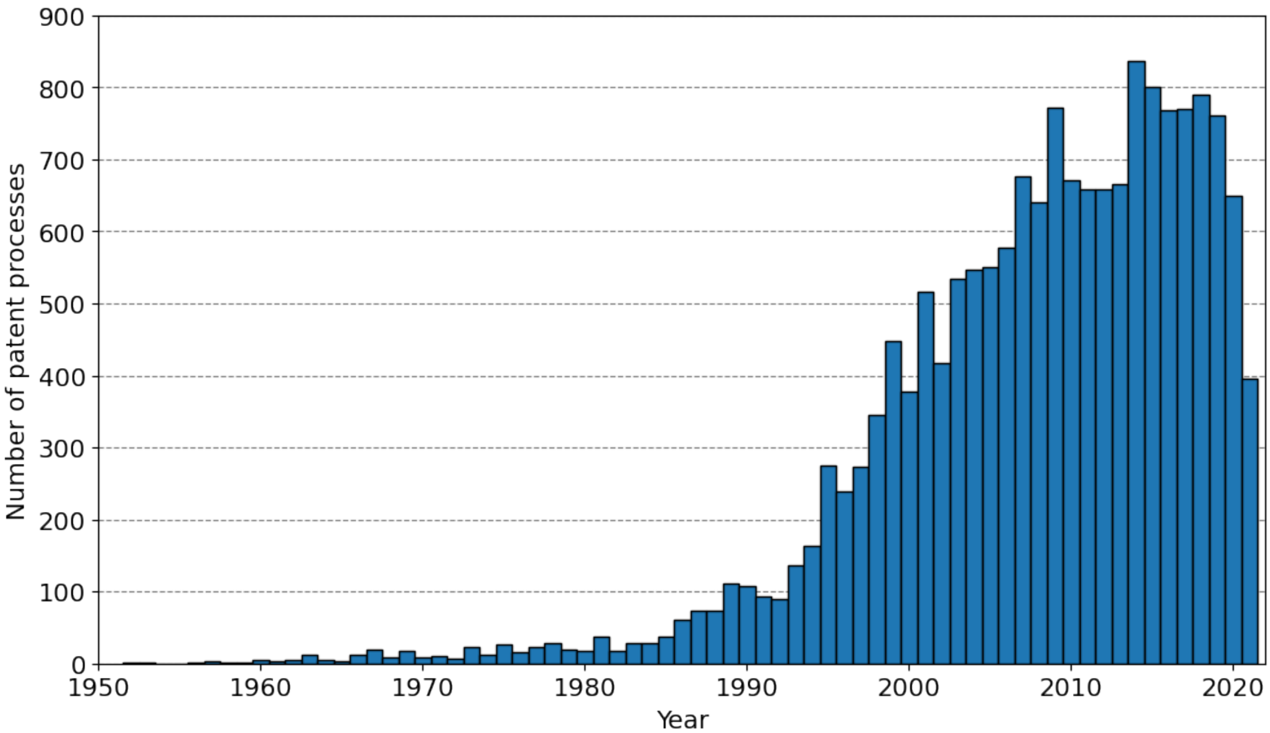



**Figure 2:** *Number of patent processes per year with the keyword "dosimetry" up to 2021.*

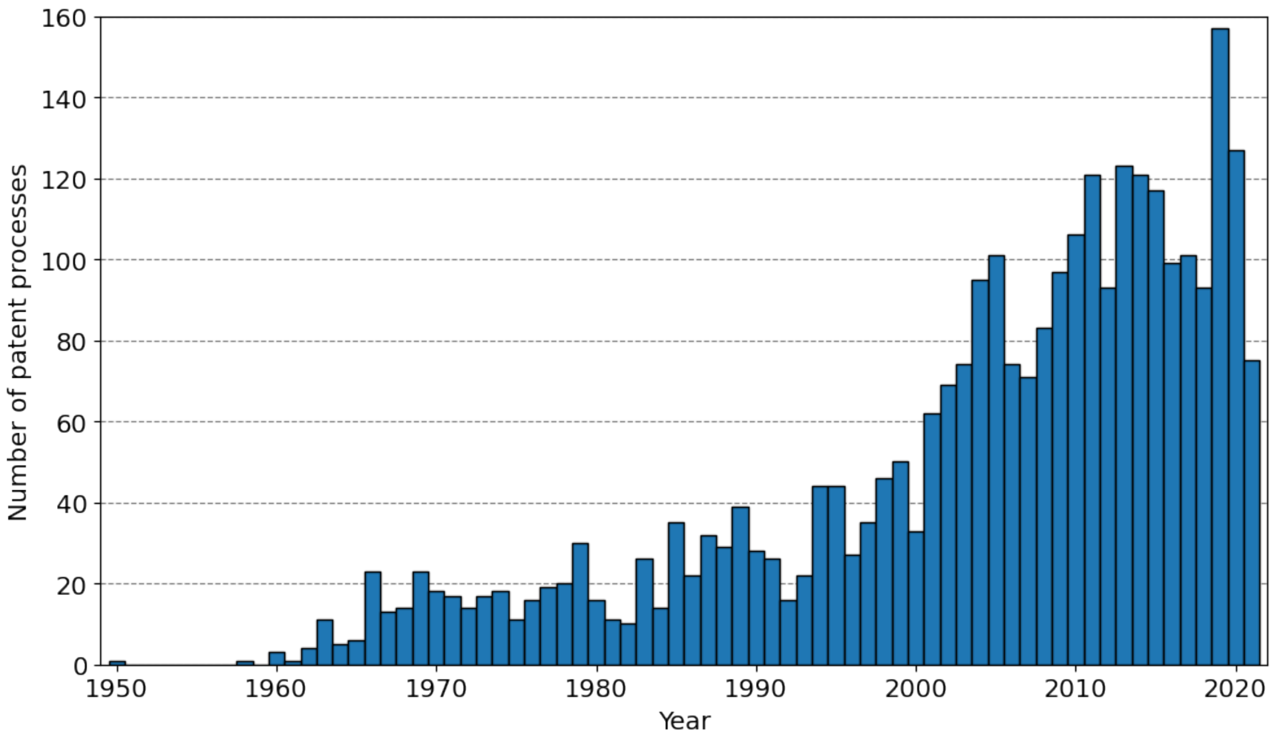


Using the patent processes over time as an indicator of the development of dosimetry, observing Figure 2, a small growth in the number of patents up to the 1970s is followed by a discrete increase between the 1970s and 1980s. We infer that this is given the international publications of the International Commission on Radiation Protection (ICRP) [35] requirements due to hazard biological effects of ionizing radiation.

Wernli (2016) described the history of radiological protection in eras. From 1990 to today, according to the author, we are in the era of regulations, standardization and commerce. This era is characterized by vast developments in dosimetry techniques and numerical dosimetry, but also paperwork and legislation with the dosimetric market concentration on a few key companies [3]. As shown in Figure 2, the dosimetry patent processes had exponential growth starting in 1990.

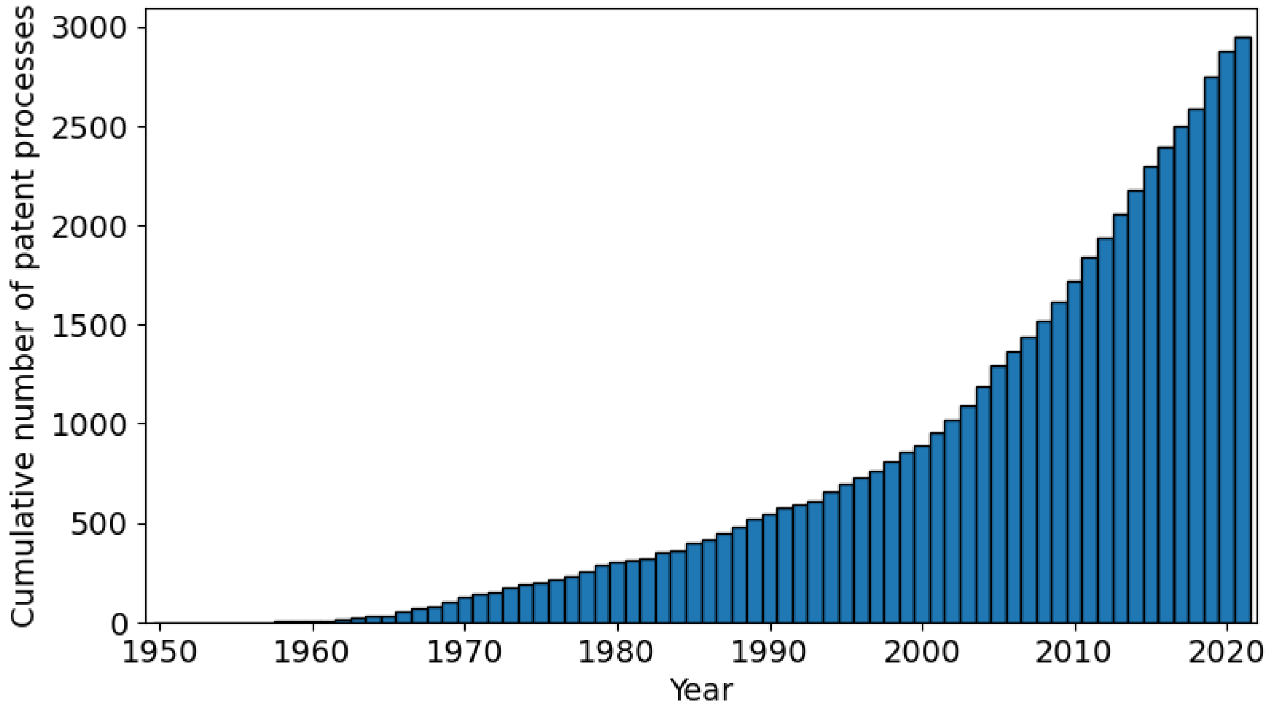
Figures 3 and 5 present the number of patents over time (up to 2021) related to TL and OSL, respectively.

**Figure 3:** *Number of patent processes per year with the keyword "TL" up to 2021.*




Despite the fact that the TL technique has been explored for various decades, Figure 4 shows that the technology is still growing as the cumulative number of patents has not reached a plateau yet.

**Figure 4:** *Cumulative number of the patent processes with the keyword "TL" up to 2021.*




Although the OSL technique presents several advantages over the TL technique, results showed a slowdown in the number of patent processes related to OSL. The large number of patents reported was over the 2000s. This period matched with the development of Luxel (Landauer Inc.) based on Al2O3:C [10,12].

A list of the countries with the higher number of patents since 2015 is shown in Table 2. As previously mentioned, even in the last 7 years, the top 5 countries/offices with the higher number of patent processes presented more TL than OSL patents.

Figures 6, 7 and 8 present the top 7 countries in the number of patent processes related to the search of keywords related to TL, OSL and "TL+OSL".

**Figure 5:** *Number of patent processes per year with the keyword "OSL" up to 2021.*

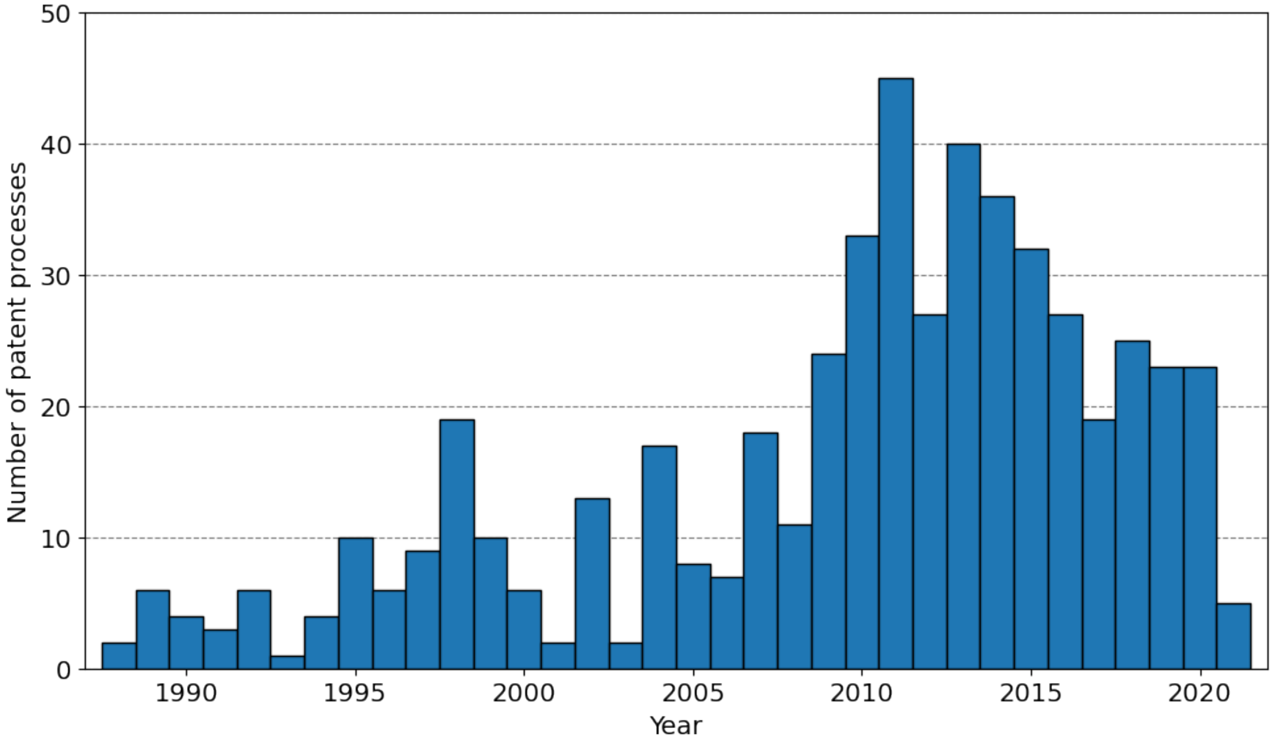



**Table 2:** List of countries and offices with the higher number of patents in "dosimetry", "thermoluminescence" (TL) and "optically stimulated luminescence" (OSL). Number of patent processes registered in each country since 2015.

| | Number of patents since 2015 | | |
|---|---|---|---|
| **Country/Office** | **Dosimetry** | **TL** | **OSL** |
| US | 2,290 | 346 | 68 |
| WO | 1,586 | 130 | 40 |
| AU | 401 | 36 | 5 |
| EP | 300 | 45 | 18 |
| IN | 119 | 27 | 5 |

**Figure 6:** *Total number of the patent processes with the keyword "TL", up to May/2022, for the top 7 countries and others.*

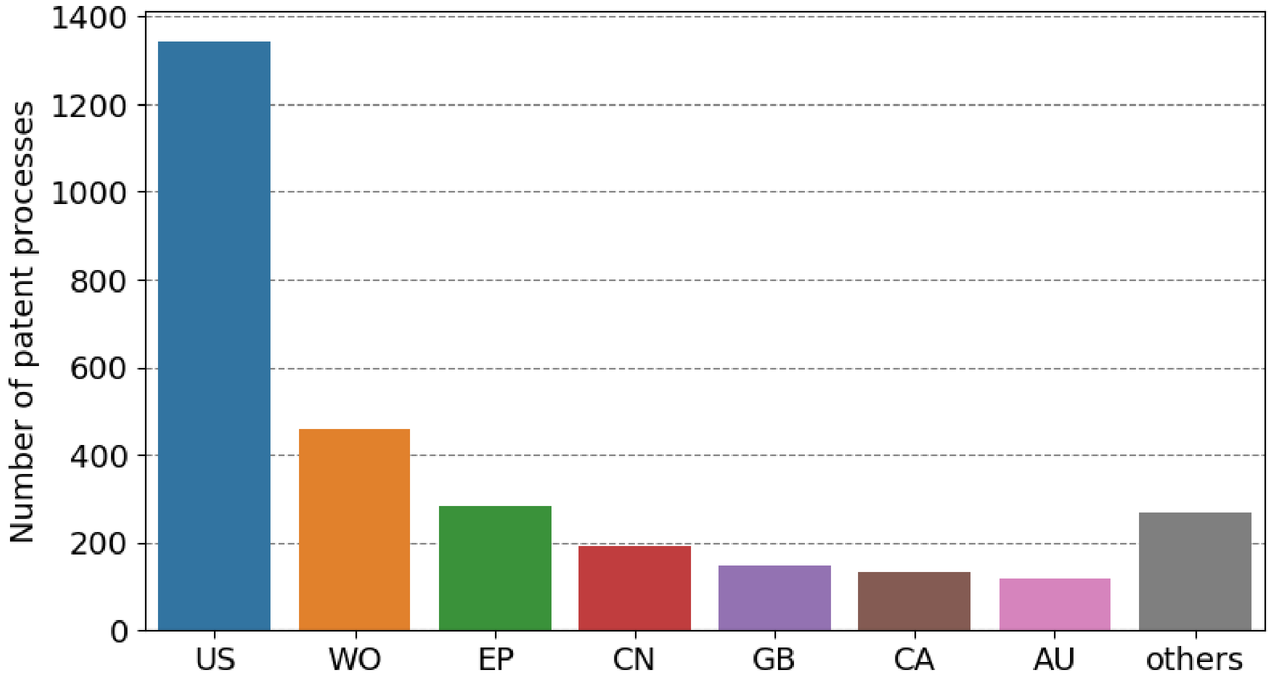



**Figure 7:** *Total number of patent processes with the keyword "OSL", up to May/2022, for the top 7 countries and others.*

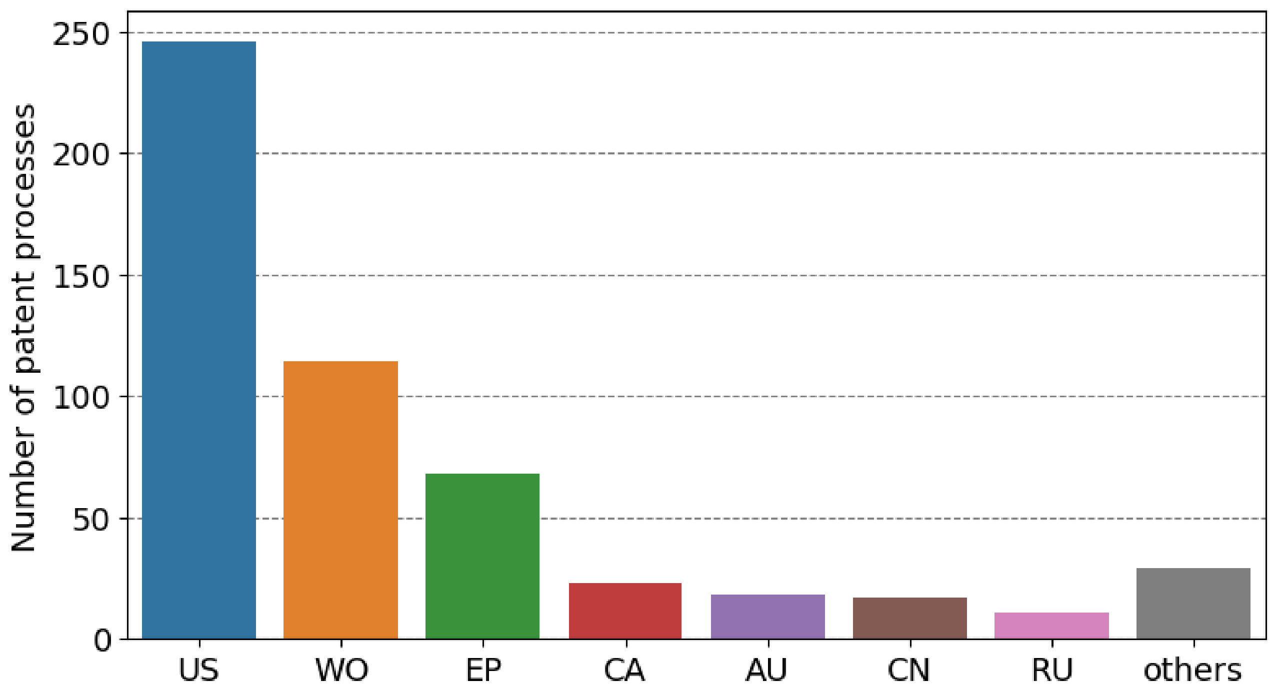
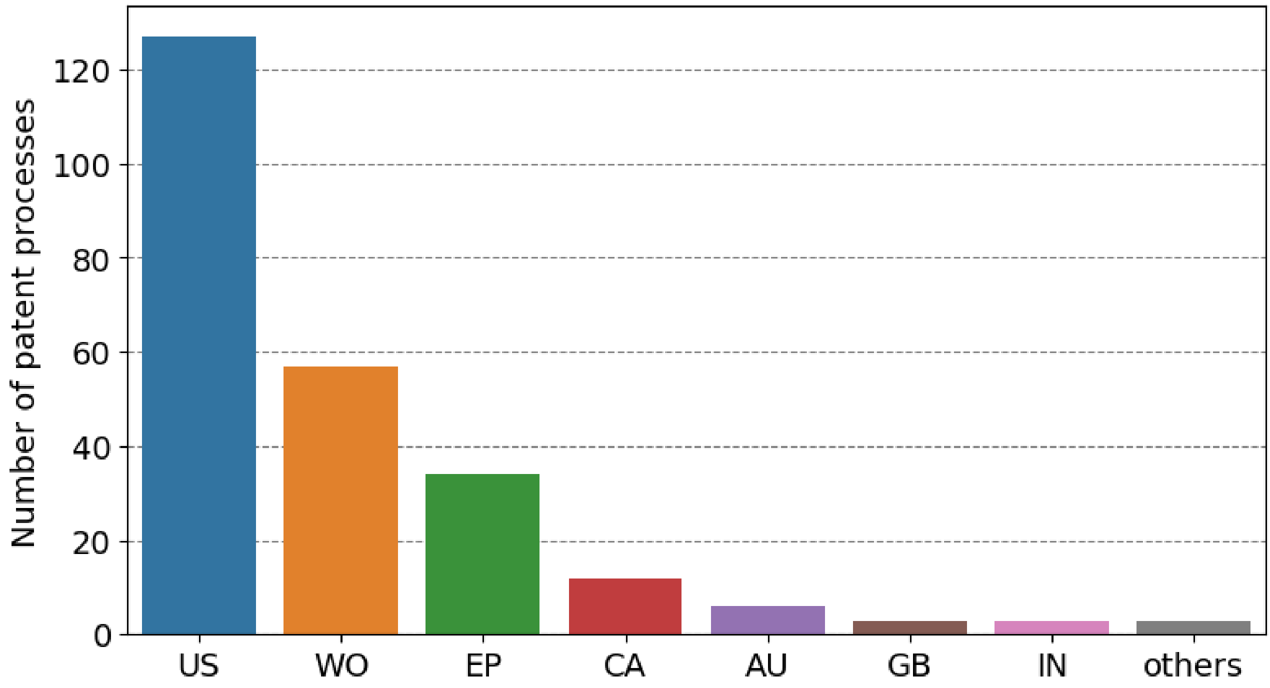


**Figure 8:** *Total number of the patent processes with both keywords "TL" and "OSL", up to May/2022, for the top 7 countries.*




Comparing the results from Table 1 with the data presented in Figures 6, 7 and 8, we observed that even in the combined searches with the terms related to TL and OSL dosimetry, approximately 50% of the results for OSL dosimetry are connected to TL technique.

## 4. CONCLUSION

The cumulative number of patent processes over time can be used as an indicator of development and evolution of the technology. Through the WIPO database, we link dosimetry patent data with the evolution of radiation protection and international recommendations from the ILO and ICRP. Furthermore, we found that although the OSL technique has several advantages over the TL technique, the latter is still under development, as the number of patents continues to grow. Another highlight is that about 50% of the OSL-related search results match the combined search including dosimetry, TL and OSL. Thus, we concluded that along with the OSL technique development, the TL technique will continue to be explored in the area of radiation dosimetry, although this technique has already consolidated its hold on the radiation detection market.

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